Kotlin Language Documentation 2.2.0

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Kotlin Docs

Get started with Kotlin

Kotlin is a modern but already mature programming language designed to make developers happier. It's concise, safe, interoperable with Java and other languages, and provides many ways to reuse code between multiple platforms for productive programming.

To start, why not take our tour of Kotlin? This tour covers the fundamentals of the Kotlin programming language and can be completed entirely within your browser.

Start the Kotlin tour

Install Kotlin

Kotlin is included in each IntelliJ IDEA and Android Studio release. Download and install one of these IDEs to start using Kotlin.

Choose your Kotlin use case

Console

Here you'll learn how to develop a console application and create unit tests with Kotlin.

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To start using Kotlin for Android development, read Google's recommendation for getting started with Kotlin on Android.

Data analysis

From building data pipelines to productionizing machine learning models, Kotlin is a great choice for working with data and getting the most out of it.

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3. Follow Kotlin for Data Analysis on Twitter:KotlinForData.

Join the Kotlin community

Stay in the loop with the latest updates across the Kotlin ecosystem and share your experience.

- Join us on:
    - Slack: get an invite.
    - StackOverflow: subscribe to the "kotlin" tag.
- Follow Kotlin on Youtube, Twitter, Bluesky, and Reddit.
- Subscribe to Kotlin news.

If you encounter any difficulties or problems, report an issue in our issue tracker.

Is anything missing?

If anything is missing or seems confusing on this page, please share your feedback.

Welcome to our tour of Kotlin!

These tours can be completed entirely within your browser. There is no installation required.

Quickly learn the essentials of the Kotlin programming language through our tours, which will take you from beginner to intermediate level. Each chapter contains:

- Theory to introduce key concepts of the language with examples.
- Practice with exercises to test your understanding of what you have learned.
- Solutions for your reference.

Start with our beginner tour to grasp the fundamentals:

Start the beginner's Kotlin tour

Beginner tour contents

- Variables
- Basic types
- Collections
- Control flow
- Functions
- Classes
- Null safety

If you're ready to take your understanding of Kotlin to the next level, take our intermediate tour:

Start the intermediate Kotlin tour

Intermediate tour contents

Hello world

Here is a simple program that prints "Hello, world!":

```kotlin
fun main() {
    println("Hello, world!")
    // Hello, world!
}
```

In Kotlin:

- fun is used to declare a function
- The main() function is where your program starts from
- The body of a function is written within curly braces {}
- println() and print() functions print their arguments to standard output

A function is a set of instructions that performs a specific task. Once you create a function, you can use it whenever you need to perform that task, without having to write the instructions all over again. Functions are discussed in more detail in a couple of chapters. Until then, all examples use the main() function.

Variables

All programs need to be able to store data, and variables help you to do just that. In Kotlin, you can declare:

- Read-only variables with val
- Mutable variables with var

You can't change a read-only variable once you have given it a value.

To assign a value, use the assignment operator =.

For example:

```kotlin
fun main() {
    val popcorn = 5    // There are 5 boxes of popcorn
    val hotdog = 7     // There are 7 hotdogs
    var customers = 10 // There are 10 customers in the queue

    // Some customers leave the queue
    customers = 8
    println(customers)
    // 8
}
```

Variables can be declared outside the main() function at the beginning of your program. Variables declared in this way are said to be declared at top level.

As customers is a mutable variable, its value can be reassigned after declaration.

We recommend that you declare all variables as read-only (val) by default. Declare mutable variables (var) only if necessary.

String templates

It's useful to know how to print the contents of variables to standard output. You can do this with string templates. You can use template expressions to access data stored in variables and other objects, and convert them into strings. A string value is a sequence of characters in double quotes ". Template expressions always start with a dollar sign $.

To evaluate a piece of code in a template expression, place the code within curly braces {} after the dollar sign $.

For example:

```kotlin
fun main() {
    val customers = 10
    println("There are $customers customers")
    // There are 10 customers

    println("There are ${customers + 1} customers")
    // There are 11 customers
}
```

For more information, see String templates.

You will notice that there aren't any types declared for variables. Kotlin has inferred the type itself: Int. This tour explains the different Kotlin basic types and how to declare them in the next chapter.

Practice

Exercise

Complete the code to make the program print "Mary is 20 years old" to standard output:

```kotlin
fun main() {
    val name = "Mary"
    val age = 20
    // Write your code here
}
```

```kotlin
fun main() {
    val name = "Mary"
    val age = 20
    println("$name is $age years old")
}
```

Next step

Basic types

Basic types

Every variable and data structure in Kotlin has a type. Types are important because they tell the compiler what you are allowed to do with that variable or data structure. In other words, what functions and properties it has.

In the last chapter, Kotlin was able to tell in the previous example that customers has type Int. Kotlin's ability to infer the type is called type inference. customers is assigned an integer value. From this, Kotlin infers that customers has a numerical type Int. As a result, the compiler knows that you can perform arithmetic operations with customers:

```kotlin
fun main() {
    var customers = 10

    // Some customers leave the queue
    customers = 8

    customers = customers + 3 // Example of addition: 11
    customers += 7            // Example of addition: 18
    customers -= 3            // Example of subtraction: 15
    customers *= 2            // Example of multiplication: 30
    customers /= 3            // Example of division: 10

    println(customers) // 10
}
```

> +=, -=, *=, /=, and %= are augmented assignment operators. For more information, see Augmented assignments.

In total, Kotlin has the following basic types:

Category	Basic types	Example code
Integers	Byte, Short, Int, Long	val year: Int = 2020
Unsigned integers	UByte, UShort, UInt, ULong	val score: UInt = 100u
Floating-point numbers	Float, Double	val currentTemp: Float = 24.5f, val price: Double = 19.99
Booleans	Boolean	val isEnabled: Boolean = true
Characters	Char	val separator: Char = ','
Strings	String	val message: String = "Hello, world!"

For more information on basic types and their properties, see Basic types.

With this knowledge, you can declare variables and initialize them later. Kotlin can manage this as long as variables are initialized before the first read.

To declare a variable without initializing it, specify its type with :. For example:

```kotlin
fun main() {
    // Variable declared without initialization
    val d: Int
    // Variable initialized
    d = 3

    // Variable explicitly typed and initialized
    val e: String = "hello"

    // Variables can be read because they have been initialized
    println(d) // 3
    println(e) // hello
}
```

If you don't initialize a variable before it is read, you see an error:

```kotlin
fun main() {
    // Variable declared without initialization
    val d: Int

    // Triggers an error
    println(d)
    // Variable 'd' must be initialized
}
```

Now that you know how to declare basic types, it's time to learn about collections.

Practice

Exercise

Explicitly declare the correct type for each variable:

```kotlin
fun main() {
    val a: Int = 1000
    val b = "log message"
    val c = 3.14
    val d = 100_000_000_000_000
    val e = false
    val f = '\n'
}
```

```kotlin
fun main() {
    val a: Int = 1000
    val b: String = "log message"
    val c: Double = 3.14
    val d: Long = 100_000_000_000_000
    val e: Boolean = false
    val f: Char = '\n'
}
```

Next step

Collections

Collections

When programming, it is useful to be able to group data into structures for later processing. Kotlin provides collections for exactly this purpose.

Kotlin has the following collections for grouping items:

Collection type	Description
Lists	Ordered collections of items
Sets	Unique unordered collections of items
Maps	Sets of key-value pairs where keys are unique and map to only one value

Each collection type can be mutable or read only.

List

Lists store items in the order that they are added, and allow for duplicate items.

To create a read-only list (List), use the listOf() function.

To create a mutable list (MutableList), use the mutableListOf() function.

When creating lists, Kotlin can infer the type of items stored. To declare the type explicitly, add the type within angled brackets <> after the list declaration:

```
fun main() {
    // Read only list
    val readOnlyShapes = listOf("triangle", "square", "circle")
    println(readOnlyShapes)
    // [triangle, square, circle]

    // Mutable list with explicit type declaration
    val shapes: MutableList<String> = mutableListOf("triangle", "square", "circle")
    println(shapes)
    // [triangle, square, circle]
}
```

To prevent unwanted modifications, you can create a read-only view of a mutable list by assigning it to a List:

```
val shapes: MutableList<String> = mutableListOf("triangle", "square", "circle")
    val shapesLocked: List<String> = shapes
```

This is also called casting.

Lists are ordered so to access an item in a list, use the indexed access operator []:

```
fun main() {
    val readOnlyShapes = listOf("triangle", "square", "circle")
    println("The first item in the list is: ${readOnlyShapes[0]}")
    // The first item in the list is: triangle
}
```

To get the first or last item in a list, use .first() and .last() functions respectively:

```
fun main() {
    val readOnlyShapes = listOf("triangle", "square", "circle")
    println("The first item in the list is: ${readOnlyShapes.first()}")
    // The first item in the list is: triangle
}
```

.first() and .last() functions are examples of extension functions. To call an extension function on an object, write the function name after the object appended with a period .

Extension functions are covered in detail in the intermediate tour. For now, you only need to know how to call them.

To get the number of items in a list, use the .count() function:

```
fun main() {
    val readOnlyShapes = listOf("triangle", "square", "circle")
    println("This list has ${readOnlyShapes.count()} items")
    // This list has 3 items
}
```

To check that an item is in a list, use the in operator:

```
fun main() {
    val readOnlyShapes = listOf("triangle", "square", "circle")
    println("circle" in readOnlyShapes)
    // true
}
```

To add or remove items from a mutable list, use .add() and .remove() functions respectively:

```
fun main() {
    val shapes: MutableList<String> = mutableListOf("triangle", "square", "circle")
    // Add "pentagon" to the list
    shapes.add("pentagon")
    println(shapes)
    // [triangle, square, circle, pentagon]

    // Remove the first "pentagon" from the list
    shapes.remove("pentagon")
    println(shapes)
    // [triangle, square, circle]
}
```

Set

Whereas lists are ordered and allow duplicate items, sets are unordered and only store unique items.

To create a read-only set (Set), use the setOf() function.

To create a mutable set (MutableSet), use the mutableSetOf() function.

When creating sets, Kotlin can infer the type of items stored. To declare the type explicitly, add the type within angled brackets <> after the set declaration:

```
fun main() {
    // Read-only set
    val readOnlyFruit = setOf("apple", "banana", "cherry", "cherry")
    // Mutable set with explicit type declaration
    val fruit: MutableSet<String> = mutableSetOf("apple", "banana", "cherry", "cherry")

    println(readOnlyFruit)
    // [apple, banana, cherry]
}
```

You can see in the previous example that because sets only contain unique elements, the duplicate "cherry" item is dropped.

To prevent unwanted modifications, you can create a read-only view of a mutable set by assigning it to a Set:

```
val fruit: MutableSet<String> = mutableSetOf("apple", "banana", "cherry", "cherry")
    val fruitLocked: Set<String> = fruit
```

As sets are unordered, you can't access an item at a particular index.

To get the number of items in a set, use the .count() function:

```
fun main() {
    val readOnlyFruit = setOf("apple", "banana", "cherry", "cherry")
    println("This set has ${readOnlyFruit.count()} items")
    // This set has 3 items
}
```

To check that an item is in a set, use the in operator:

```
fun main() {
    val readOnlyFruit = setOf("apple", "banana", "cherry", "cherry")
    println("banana" in readOnlyFruit)
    // true
}
```

To add or remove items from a mutable set, use .add() and .remove() functions respectively:

```
fun main() {
    val fruit: MutableSet<String> = mutableSetOf("apple", "banana", "cherry", "cherry")
    fruit.add("dragonfruit")    // Add "dragonfruit" to the set
    println(fruit)              // [apple, banana, cherry, dragonfruit]

    fruit.remove("dragonfruit") // Remove "dragonfruit" from the set
    println(fruit)              // [apple, banana, cherry]
}
```

Map

Maps store items as key-value pairs. You access the value by referencing the key. You can imagine a map like a food menu. You can find the price (value), by finding the food (key) you want to eat. Maps are useful if you want to look up a value without using a numbered index, like in a list.

- Every key in a map must be unique so that Kotlin can understand which value you want to get.
- You can have duplicate values in a map.

To create a read-only map (Map), use the mapOf() function.

To create a mutable map (MutableMap), use the mutableMapOf() function.

When creating maps, Kotlin can infer the type of items stored. To declare the type explicitly, add the types of the keys and values within angled brackets <> after the map declaration. For example: MutableMap<String, Int>. The keys have type String and the values have type Int.

The easiest way to create maps is to use to between each key and its related value:

```
fun main() {
    // Read-only map
    val readOnlyJuiceMenu = mapOf("apple" to 100, "kiwi" to 190, "orange" to 100)
    println(readOnlyJuiceMenu)
    // {apple=100, kiwi=190, orange=100}

    // Mutable map with explicit type declaration
    val juiceMenu: MutableMap<String, Int> = mutableMapOf("apple" to 100, "kiwi" to 190, "orange" to 100)
    println(juiceMenu)
    // {apple=100, kiwi=190, orange=100}
}
```

To prevent unwanted modifications, you can create a read-only view of a mutable map by assigning it to a Map:

```
val juiceMenu: MutableMap<String, Int> = mutableMapOf("apple" to 100, "kiwi" to 190, "orange" to 100)
    val juiceMenuLocked: Map<String, Int> = juiceMenu
```

To access a value in a map, use the indexed access operator [] with its key:

```
fun main() {
    // Read-only map
    val readOnlyJuiceMenu = mapOf("apple" to 100, "kiwi" to 190, "orange" to 100)
    println("The value of apple juice is: ${readOnlyJuiceMenu["apple"]}")
    // The value of apple juice is: 100
}
```

If you try to access a key-value pair with a key that doesn't exist in a map, you see a null value:

```
fun main() {
    // Read-only map
    val readOnlyJuiceMenu = mapOf("apple" to 100, "kiwi" to 190, "orange" to 100)
    println("The value of pineapple juice is: ${readOnlyJuiceMenu["pineapple"]}")
    // The value of pineapple juice is: null
}
```

This tour explains null values later in the Null safety chapter.

You can also use the indexed access operator [] to add items to a mutable map:

```
fun main() {
    val juiceMenu: MutableMap<String, Int> = mutableMapOf("apple" to 100, "kiwi" to 190, "orange" to 100)
    juiceMenu["coconut"] = 150 // Add key "coconut" with value 150 to the map
    println(juiceMenu)
    // {apple=100, kiwi=190, orange=100, coconut=150}
}
```

To remove items from a mutable map, use the .remove() function:

```
fun main() {
    val juiceMenu: MutableMap<String, Int> = mutableMapOf("apple" to 100, "kiwi" to 190, "orange" to 100)
    juiceMenu.remove("orange")    // Remove key "orange" from the map
    println(juiceMenu)
    // {apple=100, kiwi=190}
}
```

To get the number of items in a map, use the .count() function:

```
fun main() {
    // Read-only map
    val readOnlyJuiceMenu = mapOf("apple" to 100, "kiwi" to 190, "orange" to 100)
    println("This map has ${readOnlyJuiceMenu.count()} key-value pairs")
    // This map has 3 key-value pairs
}
```

To check if a specific key is already included in a map, use the .containsKey() function:

```
fun main() {
    val readOnlyJuiceMenu = mapOf("apple" to 100, "kiwi" to 190, "orange" to 100)
    println(readOnlyJuiceMenu.containsKey("kiwi"))
    // true
}
```

To obtain a collection of the keys or values of a map, use the keys and values properties respectively:

```
fun main() {
    val readOnlyJuiceMenu = mapOf("apple" to 100, "kiwi" to 190, "orange" to 100)
    println(readOnlyJuiceMenu.keys)
    // [apple, kiwi, orange]
    println(readOnlyJuiceMenu.values)
    // [100, 190, 100]
}
```

keys and values are examples of properties of an object. To access the property of an object, write the property name after the object appended with a period .

Properties are discussed in more detail in the Classes chapter. At this point in the tour, you only need to know how to access them.

To check that a key or value is in a map, use the in operator:

```
fun main() {
    val readOnlyJuiceMenu = mapOf("apple" to 100, "kiwi" to 190, "orange" to 100)
    println("orange" in readOnlyJuiceMenu.keys)
    // true

    // Alternatively, you don't need to use the keys property
    println("orange" in readOnlyJuiceMenu)
    // true

    println(200 in readOnlyJuiceMenu.values)
    // false
}
```

For more information on what you can do with collections, see Collections.

Now that you know about basic types and how to manage collections, it's time to explore the control flow that you can use in your programs.

Practice

Exercise 1

You have a list of “green” numbers and a list of “red” numbers. Complete the code to print how many numbers there are in total.

```
fun main() {
    val greenNumbers = listOf(1, 4, 23)
    val redNumbers = listOf(17, 2)
    // Write your code here
}
```

```
fun main() {
    val greenNumbers = listOf(1, 4, 23)
    val redNumbers = listOf(17, 2)
    val totalCount = greenNumbers.count() + redNumbers.count()
    println(totalCount)
}
```

Exercise 2

You have a set of protocols supported by your server. A user requests to use a particular protocol. Complete the program to check whether the requested protocol is supported or not (isSupported must be a Boolean value).

```
fun main() {
    val SUPPORTED = setOf("HTTP", "HTTPS", "FTP")
    val requested = "smtp"
    val isSupported = // Write your code here
    println("Support for $requested: $isSupported")
}
```

Hint
Make sure that you check the requested protocol in upper case. You can use the .uppercase() function to help you with this.

```
fun main() {
    val SUPPORTED = setOf("HTTP", "HTTPS", "FTP")
    val requested = "smtp"
    val isSupported = requested.uppercase() in SUPPORTED
    println("Support for $requested: $isSupported")
}
```

Exercise 3

Define a map that relates integer numbers from 1 to 3 to their corresponding spelling. Use this map to spell the given number.

```
fun main() {
    val number2word = // Write your code here
    val n = 2
    println("$n is spelt as '${<Write your code here >}'")
}
```

```
fun main() {
    val number2word = mapOf(1 to "one", 2 to "two", 3 to "three")
    val n = 2
    println("$n is spelt as '${number2word[n]}'")
}
```

Next step

Control flow

Control flow

Like other programming languages, Kotlin is capable of making decisions based on whether a piece of code is evaluated to be true. Such pieces of code are called conditional expressions. Kotlin is also able to create and iterate through loops.

Conditional expressions

Kotlin provides if and when for checking conditional expressions.

If you have to choose between if and when, we recommend using when because it:

- Makes your code easier to read.
- Makes it easier to add another branch.
- Leads to fewer mistakes in your code.

If

To use if, add the conditional expression within parentheses () and the action to take if the result is true within curly braces {}:

```
fun main() {
    val d: Int
    val check = true

    if (check) {
        d = 1
    } else {
        d = 2
    }

    println(d)
    // 1
}
```

There is no ternary operator condition ? then : else in Kotlin. Instead, if can be used as an expression. If there is only one line of code per action, the curly braces {} are optional:

```
fun main() {
    val a = 1
    val b = 2

    println(if (a > b) a else b) // Returns a value: 2
}
```

When

Use when when you have a conditional expression with multiple branches.

To use when:

- Place the value you want to evaluate within parentheses ().
- Place the branches within curly braces {}.
- Use -> in each branch to separate each check from the action to take if the check is successful.

when can be used either as a statement or as an expression. A statement doesn't return anything but performs actions instead.

Here is an example of using when as a statement:

```kotlin
fun main() {
    val obj = "Hello"

    when (obj) {
        // Checks whether obj equals to "1"
        "1" -> println("One")
        // Checks whether obj equals to "Hello"
        "Hello" -> println("Greeting")
        // Default statement
        else -> println("Unknown")
    }
    // Greeting
}
```

Note that all branch conditions are checked sequentially until one of them is satisfied. So only the first suitable branch is executed.

An expression returns a value that can be used later in your code.

Here is an example of using when as an expression. The when expression is assigned immediately to a variable which is later used with the println() function:

```kotlin
fun main() {
//sampleStart
    val obj = "Hello"

    val result = when (obj) {
        // If obj equals "1", sets result to "one"
        "1" -> "One"
        // If obj equals "Hello", sets result to "Greeting"
        "Hello" -> "Greeting"
        // Sets result to "Unknown" if no previous condition is satisfied
        else -> "Unknown"
    }
    println(result)
    // Greeting
}
```

The examples of when that you've seen so far both had a subject: obj. But when can also be used without a subject.

This example uses a when expression without a subject to check a chain of Boolean expressions:

```kotlin
fun main() {
    val trafficLightState = "Red" // This can be "Green", "Yellow", or "Red"

    val trafficAction = when {
        trafficLightState == "Green" -> "Go"
        trafficLightState == "Yellow" -> "Slow down"
        trafficLightState == "Red" -> "Stop"
        else -> "Malfunction"
    }

    println(trafficAction)
    // Stop
}
```

However, you can have the same code but with trafficLightState as the subject:

```
fun main() {
    val trafficLightState = "Red" // This can be "Green", "Yellow", or "Red"

    val trafficAction = when (trafficLightState) {
        "Green" -> "Go"
        "Yellow" -> "Slow down"
        "Red" -> "Stop"
        else -> "Malfunction"
    }

    println(trafficAction)
    // Stop
}
```

Using when with a subject makes your code easier to read and maintain. When you use a subject with a when expression, it also helps Kotlin check that all possible cases are covered. Otherwise, if you don't use a subject with a when expression, you need to provide an else branch.

Conditional expressions practice

Exercise 1

Create a simple game where you win if throwing two dice results in the same number. Use if to print You win :) if the dice match or You lose :(otherwise.

> In this exercise, you import a package so that you can use the Random.nextInt() function to give you a random Int. For more information about importing packages, see Packages and imports.

Hint
Use the equality operator (==) to compare the dice results.

```
import kotlin.random.Random

fun main() {
    val firstResult = Random.nextInt(6)
    val secondResult = Random.nextInt(6)
    // Write your code here
}
```

```
import kotlin.random.Random

fun main() {
    val firstResult = Random.nextInt(6)
    val secondResult = Random.nextInt(6)
    if (firstResult == secondResult)
        println("You win :)")
    else
        println("You lose :(")
}
```

Exercise 2

Using a when expression, update the following program so that it prints the corresponding actions when you input the names of game console buttons.

Button	Action
A	Yes

Button	Action
B	No
X	Menu
Y	Nothing
Other	There is no such button

```kotlin
fun main() {
    val button = "A"

    println(
        // Write your code here
    )
}
```

```kotlin
fun main() {
    val button = "A"

    println(
        when (button) {
            "A" -> "Yes"
            "B" -> "No"
            "X" -> "Menu"
            "Y" -> "Nothing"
            else -> "There is no such button"
        }
    )
}
```

Ranges

Before talking about loops, it's useful to know how to construct ranges for loops to iterate over.

The most common way to create a range in Kotlin is to use the .. operator. For example, 1..4 is equivalent to 1, 2, 3, 4.

To declare a range that doesn't include the end value, use the ..< operator. For example, 1..<4 is equivalent to 1, 2, 3.

To declare a range in reverse order, use downTo. For example, 4 downTo 1 is equivalent to 4, 3, 2, 1.

To declare a range that increments in a step that isn't 1, use step and your desired increment value. For example, 1..5 step 2 is equivalent to 1, 3, 5.

You can also do the same with Char ranges:

- 'a'..'d' is equivalent to 'a', 'b', 'c', 'd'
- 'z' downTo 's' step 2 is equivalent to 'z', 'x', 'v', 't'

Loops

The two most common loop structures in programming are for and while. Use for to iterate over a range of values and perform an action. Use while to continue an action until a particular condition is satisfied.

For

Using your new knowledge of ranges, you can create a for loop that iterates over numbers 1 to 5 and prints the number each time.

Place the iterator and range within parentheses () with keyword in. Add the action you want to complete within curly braces {}:

```
fun main() {
    for (number in 1..5) {
        // number is the iterator and 1..5 is the range
        print(number)
    }
    // 12345
}
```

Collections can also be iterated over by loops:

```
fun main() {
    val cakes = listOf("carrot", "cheese", "chocolate")

    for (cake in cakes) {
        println("Yummy, it's a $cake cake!")
    }
    // Yummy, it's a carrot cake!
    // Yummy, it's a cheese cake!
    // Yummy, it's a chocolate cake!
}
```

While

while can be used in two ways:

- To execute a code block while a conditional expression is true. (while)
- To execute the code block first and then check the conditional expression. (do-while)

In the first use case (while):

- Declare the conditional expression for your while loop to continue within parentheses ().
- Add the action you want to complete within curly braces {}.

> The following examples use the increment operator ++ to increment the value of the cakesEaten variable.

```
fun main() {
    var cakesEaten = 0
    while (cakesEaten < 3) {
        println("Eat a cake")
        cakesEaten++
    }
    // Eat a cake
    // Eat a cake
    // Eat a cake
}
```

In the second use case (do-while):

- Declare the conditional expression for your while loop to continue within parentheses ().
- Define the action you want to complete within curly braces {} with the keyword do.

```
fun main() {
    var cakesEaten = 0
    var cakesBaked = 0
    while (cakesEaten < 3) {
        println("Eat a cake")
        cakesEaten++
    }
    do {
        println("Bake a cake")
        cakesBaked++
    } while (cakesBaked < cakesEaten)
    // Eat a cake
    // Eat a cake
    // Eat a cake
    // Bake a cake
    // Bake a cake
    // Bake a cake
}
```

For more information and examples of conditional expressions and loops, see Conditions and loops.

Now that you know the fundamentals of Kotlin control flow, it's time to learn how to write your own functions.

Loops practice

Exercise 1

You have a program that counts pizza slices until there’s a whole pizza with 8 slices. Refactor this program in two ways:

- Use a while loop.
- Use a do-while loop.

```kotlin
fun main() {
    var pizzaSlices = 0
    // Start refactoring here
    pizzaSlices++
    println("There's only $pizzaSlices slice/s of pizza :(")
    pizzaSlices++
    println("There's only $pizzaSlices slice/s of pizza :(")
    pizzaSlices++
    println("There's only $pizzaSlices slice/s of pizza :(")
    pizzaSlices++
    println("There's only $pizzaSlices slice/s of pizza :(")
    pizzaSlices++
    println("There's only $pizzaSlices slice/s of pizza :(")
    pizzaSlices++
    println("There's only $pizzaSlices slice/s of pizza :(")
    pizzaSlices++
    println("There's only $pizzaSlices slice/s of pizza :(")
    pizzaSlices++
    // End refactoring here
    println("There are $pizzaSlices slices of pizza. Hooray! We have a whole pizza! :D")
}
```

```kotlin
fun main() {
    var pizzaSlices = 0
    while ( pizzaSlices < 7 ) {
        pizzaSlices++
        println("There's only $pizzaSlices slice/s of pizza :(")
    }
    pizzaSlices++
    println("There are $pizzaSlices slices of pizza. Hooray! We have a whole pizza! :D")
}
```

```kotlin
fun main() {
    var pizzaSlices = 0
    pizzaSlices++
    do {
        println("There's only $pizzaSlices slice/s of pizza :(")
        pizzaSlices++
    } while ( pizzaSlices < 8 )
    println("There are $pizzaSlices slices of pizza. Hooray! We have a whole pizza! :D")
}
```

Exercise 2

Write a program that simulates the Fizz buzz game. Your task is to print numbers from 1 to 100 incrementally, replacing any number divisible by three with the word "fizz", and any number divisible by five with the word "buzz". Any number divisible by both 3 and 5 must be replaced with the word "fizzbuzz".

Hint 1
Use a for loop to count numbers and a when expression to decide what to print at each step.

Hint 2
Use the modulo operator (%) to return the remainder of a number being divided. Use the equality operator (==) to check if the remainder equals zero.

```
fun main() {
    // Write your code here
}
```

```
fun main() {
    for (number in 1..100) {
        println(
            when {
                number % 15 == 0 -> "fizzbuzz"
                number % 3 == 0 -> "fizz"
                number % 5 == 0 -> "buzz"
                else -> "$number"
            }
        )
    }
}
```

Exercise 3

You have a list of words. Use for and if to print only the words that start with the letter l.

Hint
Use the .startsWith() function for String type.

```
fun main() {
    val words = listOf("dinosaur", "limousine", "magazine", "language")
    // Write your code here
}
```

```
fun main() {
    val words = listOf("dinosaur", "limousine", "magazine", "language")
    for (w in words) {
        if (w.startsWith("l"))
            println(w)
    }
}
```

Next step

Functions

Functions

You can declare your own functions in Kotlin using the fun keyword.

```
fun hello() {
    return println("Hello, world!")
}

fun main() {
    hello()
    // Hello, world!
}
```

In Kotlin:

- Function parameters are written within parentheses ().
- Each parameter must have a type, and multiple parameters must be separated by commas ,.
- The return type is written after the function's parentheses (), separated by a colon :.
- The body of a function is written within curly braces {}.
- The return keyword is used to exit or return something from a function.

> If a function doesn't return anything useful, the return type and return keyword can be omitted. Learn more about this in Functions without return.

In the following example:

- x and y are function parameters.
- x and y have type Int.
- The function's return type is Int.
- The function returns a sum of x and y when called.

```kotlin
fun sum(x: Int, y: Int): Int {
    return x + y
}

fun main() {
    println(sum(1, 2))
    // 3
}
```

> We recommend in our coding conventions that you name functions starting with a lowercase letter and use camel case with no underscores.

Named arguments

For concise code, when calling your function, you don't have to include parameter names. However, including parameter names does make your code easier to read. This is called using named arguments. If you do include parameter names, then you can write the parameters in any order.

> In the following example, string templates ($) are used to access the parameter values, convert them to String type, and then concatenate them into a string for printing.

```kotlin
fun printMessageWithPrefix(message: String, prefix: String) {
    println("[$prefix] $message")
}

fun main() {
    // Uses named arguments with swapped parameter order
    printMessageWithPrefix(prefix = "Log", message = "Hello")
    // [Log] Hello
}
```

Default parameter values

You can define default values for your function parameters. Any parameter with a default value can be omitted when calling your function. To declare a default value, use the assignment operator = after the type:

```kotlin
fun printMessageWithPrefix(message: String, prefix: String = "Info") {
    println("[$prefix] $message")
}
```

```kotlin
fun main() {
    // Function called with both parameters
    printMessageWithPrefix("Hello", "Log")
    // [Log] Hello

    // Function called only with message parameter
    printMessageWithPrefix("Hello")
    // [Info] Hello

    printMessageWithPrefix(prefix = "Log", message = "Hello")
    // [Log] Hello
}
```

You can skip specific parameters with default values, rather than omitting them all. However, after the first skipped parameter, you must name all subsequent parameters.

Functions without return

If your function doesn't return a useful value then its return type is Unit. Unit is a type with only one value – Unit. You don't have to declare that Unit is returned explicitly in your function body. This means that you don't have to use the return keyword or declare a return type:

```kotlin
fun printMessage(message: String) {
    println(message)
    // `return Unit` or `return` is optional
}

fun main() {
    printMessage("Hello")
    // Hello
}
```

Single-expression functions

To make your code more concise, you can use single-expression functions. For example, the sum() function can be shortened:

```kotlin
fun sum(x: Int, y: Int): Int {
    return x + y
}

fun main() {
    println(sum(1, 2))
    // 3
}
```

You can remove the curly braces {} and declare the function body using the assignment operator =. When you use the assignment operator =, Kotlin uses type inference, so you can also omit the return type. The sum() function then becomes one line:

```kotlin
fun sum(x: Int, y: Int) = x + y

fun main() {
    println(sum(1, 2))
    // 3
}
```

However, if you want your code to be quickly understood by other developers, it's a good idea to explicitly define the return type even when using the assignment operator =.

If you use {} curly braces to declare your function body, you must declare the return type unless it is the Unit type.

Early returns in functions

To stop the code in your function from being processed further than a certain point, use the return keyword. This example uses if to return from a function early if the conditional expression is found to be true:

```kotlin
// A list of registered usernames
val registeredUsernames = mutableListOf("john_doe", "jane_smith")

// A list of registered emails
val registeredEmails = mutableListOf("john@example.com", "jane@example.com")

fun registerUser(username: String, email: String): String {
    // Early return if the username is already taken
    if (username in registeredUsernames) {
        return "Username already taken. Please choose a different username."
    }

    // Early return if the email is already registered
    if (email in registeredEmails) {
        return "Email already registered. Please use a different email."
    }

    // Proceed with the registration if the username and email are not taken
    registeredUsernames.add(username)
    registeredEmails.add(email)

    return "User registered successfully: $username"
}

fun main() {
    println(registerUser("john_doe", "newjohn@example.com"))
    // Username already taken. Please choose a different username.
    println(registerUser("new_user", "newuser@example.com"))
    // User registered successfully: new_user
}
```

Functions practice

Exercise 1

Write a function called circleArea that takes the radius of a circle in integer format as a parameter and outputs the area of that circle.

In this exercise, you import a package so that you can access the value of pi via PI. For more information about importing packages, see Packages and imports.

```kotlin
import kotlin.math.PI

// Write your code here

fun main() {
    println(circleArea(2))
}
```

```kotlin
import kotlin.math.PI

fun circleArea(radius: Int): Double {
    return PI * radius * radius
}

fun main() {
    println(circleArea(2)) // 12.566370614359172
}
```

Exercise 2

Rewrite the circleArea function from the previous exercise as a single-expression function.

```kotlin
import kotlin.math.PI

// Write your code here

fun main() {
    println(circleArea(2))
}
```

```kotlin
import kotlin.math.PI

fun circleArea(radius: Int): Double = PI * radius * radius

fun main() {
    println(circleArea(2)) // 12.566370614359172
}
```

Exercise 3

You have a function that translates a time interval given in hours, minutes, and seconds into seconds. In most cases, you need to pass only one or two function parameters while the rest are equal to 0. Improve the function and the code that calls it by using default parameter values and named arguments so that the code is easier to read.

```kotlin
fun intervalInSeconds(hours: Int, minutes: Int, seconds: Int) =
    ((hours * 60) + minutes) * 60 + seconds

fun main() {
    println(intervalInSeconds(1, 20, 15))
    println(intervalInSeconds(0, 1, 25))
    println(intervalInSeconds(2, 0, 0))
    println(intervalInSeconds(0, 10, 0))
    println(intervalInSeconds(1, 0, 1))
}
```

```kotlin
fun intervalInSeconds(hours: Int = 0, minutes: Int = 0, seconds: Int = 0) =
    ((hours * 60) + minutes) * 60 + seconds

fun main() {
    println(intervalInSeconds(1, 20, 15))
    println(intervalInSeconds(minutes = 1, seconds = 25))
    println(intervalInSeconds(hours = 2))
    println(intervalInSeconds(minutes = 10))
    println(intervalInSeconds(hours = 1, seconds = 1))
}
```

Lambda expressions

Kotlin allows you to write even more concise code for functions by using lambda expressions.

For example, the following uppercaseString() function:

```kotlin
fun uppercaseString(text: String): String {
    return text.uppercase()
}
fun main() {
    println(uppercaseString("hello"))
    // HELLO
}
```

Can also be written as a lambda expression:

```kotlin
fun main() {
    val upperCaseString = { text: String -> text.uppercase() }
    println(upperCaseString("hello"))
    // HELLO
}
```

Lambda expressions can be hard to understand at first glance so let's break it down. Lambda expressions are written within curly braces {}.

Within the lambda expression, you write:

- The parameters followed by an ->.
- The function body after the ->.

In the previous example:

- text is a function parameter.
- text has type String.
- The function returns the result of the .uppercase() function called on text.
- The entire lambda expression is assigned to the upperCaseString variable with the assignment operator =.
- The lambda expression is called by using the variable upperCaseString like a function and the string "hello" as a parameter.
- The println() function prints the result.

> If you declare a lambda without parameters, then there is no need to use ->. For example:
>
> ```
> { println("Log message") }
> ```

Lambda expressions can be used in a number of ways. You can:

- Pass a lambda expression as a parameter to another function
- Return a lambda expression from a function
- Invoke a lambda expression on its own

Pass to another function

A great example of when it is useful to pass a lambda expression to a function, is using the .filter() function on collections:

```
fun main() {
        val numbers = listOf(1, -2, 3, -4, 5, -6)

    val positives = numbers.filter ({ x -> x > 0 })

    val isNegative = { x: Int -> x < 0 }
    val negatives = numbers.filter(isNegative)

    println(positives)
    // [1, 3, 5]
    println(negatives)
    // [-2, -4, -6]
    //sampleEnd
}
```

The .filter() function accepts a lambda expression as a predicate:

- { x -> x > 0 } takes each element of the list and returns only those that are positive.
- { x -> x < 0 } takes each element of the list and returns only those that are negative.

This example demonstrates two ways of passing a lambda expression to a function:

- For positive numbers, the example adds the lambda expression directly in the .filter() function.
- For negative numbers, the example assigns the lambda expression to the isNegative variable. Then the isNegative variable is used as a function parameter in the .filter() function. In this case, you have to specify the type of function parameters (x) in the lambda expression.

If a lambda expression is the only function parameter, you can drop the function parentheses ():

```
val positives = numbers.filter { x -> x > 0 }
```

This is an example of a trailing lambda, which is discussed in more detail at the end of this chapter.

Another good example, is using the .map() function to transform items in a collection:

```
fun main() {
        val numbers = listOf(1, -2, 3, -4, 5, -6)
    val doubled = numbers.map { x -> x * 2 }

    val isTripled = { x: Int -> x * 3 }
    val tripled = numbers.map(isTripled)

    println(doubled)
    // [2, -4, 6, -8, 10, -12]
    println(tripled)
    // [3, -6, 9, -12, 15, -18]
    //sampleEnd
}
```

The .map() function accepts a lambda expression as a transform function:

- { x -> x * 2 } takes each element of the list and returns that element multiplied by 2.
- { x -> x * 3 } takes each element of the list and returns that element multiplied by 3.

Function types

Before you can return a lambda expression from a function, you first need to understand function types.

You have already learned about basic types but functions themselves also have a type. Kotlin's type inference can infer a function's type from the parameter type. But there may be times when you need to explicitly specify the function type. The compiler needs the function type so that it knows what is and isn't allowed for that function.

The syntax for a function type has:

- Each parameter's type written within parentheses () and separated by commas ,.
- The return type written after ->.

For example: (String) -> String or (Int, Int) -> Int.

This is what a lambda expression looks like if a function type for upperCaseString() is defined:

```
val upperCaseString: (String) -> String = { text -> text.uppercase() }

fun main() {
    println(upperCaseString("hello"))
    // HELLO
}
```

If your lambda expression has no parameters then the parentheses () are left empty. For example: () -> Unit

You must declare parameter and return types either in the lambda expression or as a function type. Otherwise, the compiler won't be able to know what type your lambda expression is.

For example, the following won't work:

val upperCaseString = { str -> str.uppercase() }

Return from a function

Lambda expressions can be returned from a function. So that the compiler understands what type the lambda expression returned is, you must declare a function type.

In the following example, the toSeconds() function has function type (Int) -> Int because it always returns a lambda expression that takes a parameter of type Int and returns an Int value.

This example uses a when expression to determine which lambda expression is returned when toSeconds() is called:

```kotlin
fun toSeconds(time: String): (Int) -> Int = when (time) {
    "hour" -> { value -> value * 60 * 60 }
    "minute" -> { value -> value * 60 }
    "second" -> { value -> value }
    else -> { value -> value }
}

fun main() {
    val timesInMinutes = listOf(2, 10, 15, 1)
    val min2sec = toSeconds("minute")
    val totalTimeInSeconds = timesInMinutes.map(min2sec).sum()
    println("Total time is $totalTimeInSeconds secs")
    // Total time is 1680 secs
}
```

Invoke separately

Lambda expressions can be invoked on their own by adding parentheses () after the curly braces {} and including any parameters within the parentheses:

```kotlin
fun main() {
        println({ text: String -> text.uppercase() }("hello"))
    // HELLO
    //sampleEnd
}
```

Trailing lambdas

As you have already seen, if a lambda expression is the only function parameter, you can drop the function parentheses (). If a lambda expression is passed as the last parameter of a function, then the expression can be written outside the function parentheses (). In both cases, this syntax is called a trailing lambda.

For example, the .fold() function accepts an initial value and an operation:

```kotlin
fun main() {
        // The initial value is zero.
    // The operation sums the initial value with every item in the list cumulatively.
    println(listOf(1, 2, 3).fold(0, { x, item -> x + item })) // 6

    // Alternatively, in the form of a trailing lambda
    println(listOf(1, 2, 3).fold(0) { x, item -> x + item })  // 6
    //sampleEnd
}
```

For more information on lambda expressions, see Lambda expressions and anonymous functions.

The next step in our tour is to learn about classes in Kotlin.

Lambda expressions practice

Exercise 1

You have a list of actions supported by a web service, a common prefix for all requests, and an ID of a particular resource. To request an action title over the resource with ID: 5, you need to create the following URL: https://example.com/book-info/5/title. Use a lambda expression to create a list of URLs from the list of actions.

```kotlin
fun main() {
    val actions = listOf("title", "year", "author")
    val prefix = "https://example.com/book-info"
    val id = 5
    val urls = // Write your code here
    println(urls)
}
```

```
fun main() {
    val actions = listOf("title", "year", "author")
    val prefix = "https://example.com/book-info"
    val id = 5
    val urls = actions.map { action -> "$prefix/$id/$action" }
    println(urls)
}
```

Exercise 2

Write a function that takes an Int value and an action (a function with type () -> Unit) which then repeats the action the given number of times. Then use this function to print “Hello” 5 times.

```
fun repeatN(n: Int, action: () -> Unit) {
    // Write your code here
}

fun main() {
    // Write your code here
}
```

```
fun repeatN(n: Int, action: () -> Unit) {
    for (i in 1..n) {
        action()
    }
}

fun main() {
    repeatN(5) {
        println("Hello")
    }
}
```

Next step

Classes

Classes

Kotlin supports object-oriented programming with classes and objects. Objects are useful for storing data in your program. Classes allow you to declare a set of characteristics for an object. When you create objects from a class, you can save time and effort because you don't have to declare these characteristics every time.

To declare a class, use the class keyword:

```
class Customer
```

Properties

Characteristics of a class's object can be declared in properties. You can declare properties for a class:

- Within parentheses () after the class name.

```
class Contact(val id: Int, var email: String)
```

- Within the class body defined by curly braces {}.

```
class Contact(val id: Int, var email: String) {
    val category: String = ""
}
```

We recommend that you declare properties as read-only (val) unless they need to be changed after an instance of the class is created.

You can declare properties without val or var within parentheses but these properties are not accessible after an instance has been created.

- The content contained within parentheses () is called the class header.
- You can use a trailing comma when declaring class properties.

Just like with function parameters, class properties can have default values:

```
class Contact(val id: Int, var email: String = "example@gmail.com") {
    val category: String = "work"
}
```

Create instance

To create an object from a class, you declare a class instance using a constructor.

By default, Kotlin automatically creates a constructor with the parameters declared in the class header.

For example:

```
class Contact(val id: Int, var email: String)

fun main() {
    val contact = Contact(1, "mary@gmail.com")
}
```

In the example:

- Contact is a class.
- contact is an instance of the Contact class.
- id and email are properties.
- id and email are used with the default constructor to create contact.

Kotlin classes can have many constructors, including ones that you define yourself. To learn more about how to declare multiple constructors, see Constructors.

Access properties

To access a property of an instance, write the name of the property after the instance name appended with a period .:

```
class Contact(val id: Int, var email: String)

fun main() {
    val contact = Contact(1, "mary@gmail.com")

    // Prints the value of the property: email
    println(contact.email)
    // mary@gmail.com

    // Updates the value of the property: email
    contact.email = "jane@gmail.com"

    // Prints the new value of the property: email
    println(contact.email)
    // jane@gmail.com
}
```

To concatenate the value of a property as part of a string, you can use string templates ($). For example:

```
println("Their email address is: ${contact.email}")
```

Member functions

In addition to declaring properties as part of an object's characteristics, you can also define an object's behavior with member functions.

In Kotlin, member functions must be declared within the class body. To call a member function on an instance, write the function name after the instance name appended with a period .. For example:

```
class Contact(val id: Int, var email: String) {
    fun printId() {
        println(id)
    }
}

fun main() {
    val contact = Contact(1, "mary@gmail.com")
    // Calls member function printId()
    contact.printId()
    // 1
}
```

Data classes

Kotlin has data classes which are particularly useful for storing data. Data classes have the same functionality as classes, but they come automatically with additional member functions. These member functions allow you to easily print the instance to readable output, compare instances of a class, copy instances, and more. As these functions are automatically available, you don't have to spend time writing the same boilerplate code for each of your classes.

To declare a data class, use the keyword data:

```
data class User(val name: String, val id: Int)
```

The most useful predefined member functions of data classes are:

Function	Description
toString()	Prints a readable string of the class instance and its properties.
equals() or ==	Compares instances of a class.
copy()	Creates a class instance by copying another, potentially with some different properties.

See the following sections for examples of how to use each function:

- Print as string
- Compare instances
- Copy instance

Print as string

To print a readable string of a class instance, you can explicitly call the toString() function, or use print functions (println() and print()) which automatically call toString() for you:

```kotlin
data class User(val name: String, val id: Int)

fun main() {
        val user = User("Alex", 1)

    // Automatically uses toString() function so that output is easy to read
    println(user)
    // User(name=Alex, id=1)
    //sampleEnd
}
```

This is particularly useful when debugging or creating logs.

Compare instances

To compare data class instances, use the equality operator ==:

```kotlin
data class User(val name: String, val id: Int)

fun main() {
        val user = User("Alex", 1)
    val secondUser = User("Alex", 1)
    val thirdUser = User("Max", 2)

    // Compares user to second user
    println("user == secondUser: ${user == secondUser}")
    // user == secondUser: true

    // Compares user to third user
    println("user == thirdUser: ${user == thirdUser}")
    // user == thirdUser: false
    //sampleEnd
}
```

Copy instance

To create an exact copy of a data class instance, call the copy() function on the instance.

To create a copy of a data class instance and change some properties, call the copy() function on the instance and add replacement values for properties as function parameters.

For example:

```kotlin
data class User(val name: String, val id: Int)

fun main() {
        val user = User("Alex", 1)

    // Creates an exact copy of user
    println(user.copy())
    // User(name=Alex, id=1)

    // Creates a copy of user with name: "Max"
    println(user.copy("Max"))
    // User(name=Max, id=1)

    // Creates a copy of user with id: 3
    println(user.copy(id = 3))
    // User(name=Alex, id=3)
    //sampleEnd
}
```

Creating a copy of an instance is safer than modifying the original instance because any code that relies on the original instance isn't affected by the copy and what you do with it.

For more information about data classes, see Data classes.

The last chapter of this tour is about Kotlin's null safety.

Practice

Exercise 1

Define a data class Employee with two properties: one for a name, and another for a salary. Make sure that the property for salary is mutable, otherwise you won't get a salary boost at the end of the year! The main function demonstrates how you can use this data class.

```
// Write your code here

fun main() {
    val emp = Employee("Mary", 20)
    println(emp)
    emp.salary += 10
    println(emp)
}
```

```
data class Employee(val name: String, var salary: Int)

fun main() {
    val emp = Employee("Mary", 20)
    println(emp)
    emp.salary += 10
    println(emp)
}
```

Exercise 2

Declare the additional data classes that are needed for this code to compile.

```
data class Person(val name: Name, val address: Address, val ownsAPet: Boolean = true)
// Write your code here
// data class Name(...)

fun main() {
    val person = Person(
        Name("John", "Smith"),
        Address("123 Fake Street", City("Springfield", "US")),
        ownsAPet = false
    )
}
```

```
data class Person(val name: Name, val address: Address, val ownsAPet: Boolean = true)
data class Name(val first: String, val last: String)
data class Address(val street: String, val city: City)
data class City(val name: String, val countryCode: String)

fun main() {
    val person = Person(
        Name("John", "Smith"),
        Address("123 Fake Street", City("Springfield", "US")),
        ownsAPet = false
    )
}
```

Exercise 3

To test your code, you need a generator that can create random employees. Define a RandomEmployeeGenerator class with a fixed list of potential names (inside the class body). Configure the class with a minimum and maximum salary (inside the class header). In the class body, define the generateEmployee() function. Once again, the main function demonstrates how you can use this class.

In this exercise, you import a package so that you can use the Random.nextInt() function. For more information about importing packages, see Packages and imports.

Hint 1
Lists have an extension function called .random() that returns a random item within a list.

Hint 2
Random.nextInt(from = ..., until = ...) gives you a random Int number within specified limits.

```
import kotlin.random.Random

data class Employee(val name: String, var salary: Int)

// Write your code here

fun main() {
    val empGen = RandomEmployeeGenerator(10, 30)
    println(empGen.generateEmployee())
    println(empGen.generateEmployee())
    println(empGen.generateEmployee())
    empGen.minSalary = 50
    empGen.maxSalary = 100
    println(empGen.generateEmployee())
}
```

```
import kotlin.random.Random

data class Employee(val name: String, var salary: Int)

class RandomEmployeeGenerator(var minSalary: Int, var maxSalary: Int) {
    val names = listOf("John", "Mary", "Ann", "Paul", "Jack", "Elizabeth")
    fun generateEmployee() =
        Employee(names.random(),
            Random.nextInt(from = minSalary, until = maxSalary))
}

fun main() {
    val empGen = RandomEmployeeGenerator(10, 30)
    println(empGen.generateEmployee())
    println(empGen.generateEmployee())
    println(empGen.generateEmployee())
    empGen.minSalary = 50
    empGen.maxSalary = 100
    println(empGen.generateEmployee())
}
```

Next step

Null safety

Null safety

In Kotlin, it's possible to have a null value. Kotlin uses null values when something is missing or not yet set. You've already seen an example of Kotlin returning a null value in the Collections chapter when you tried to access a key-value pair with a key that doesn't exist in the map. Although it's useful to use null values in this way, you might run into problems if your code isn't prepared to handle them.

To help prevent issues with null values in your programs, Kotlin has null safety in place. Null safety detects potential problems with null values at compile time, rather than at run time.

Null safety is a combination of features that allow you to:

- Explicitly declare when null values are allowed in your program.
- Check for null values.
- Use safe calls to properties or functions that may contain null values.

* Declare actions to take if null values are detected.

Nullable types

Kotlin supports nullable types which allows the possibility for the declared type to have null values. By default, a type is not allowed to accept null values. Nullable types are declared by explicitly adding ? after the type declaration.

For example:

```
fun main() {
    // neverNull has String type
    var neverNull: String = "This can't be null"

    // Throws a compiler error
    neverNull = null

    // nullable has nullable String type
    var nullable: String? = "You can keep a null here"

    // This is OK
    nullable = null

    // By default, null values aren't accepted
    var inferredNonNull = "The compiler assumes non-nullable"

    // Throws a compiler error
    inferredNonNull = null

    // notNull doesn't accept null values
    fun strLength(notNull: String): Int {
        return notNull.length
    }

    println(strLength(neverNull)) // 18
    println(strLength(nullable))  // Throws a compiler error
}
```

length is a property of the String class that contains the number of characters within a string.

Check for null values

You can check for the presence of null values within conditional expressions. In the following example, the describeString() function has an if statement that checks whether maybeString is not null and if its length is greater than zero:

```
fun describeString(maybeString: String?): String {
    if (maybeString != null && maybeString.length > 0) {
        return "String of length ${maybeString.length}"
    } else {
        return "Empty or null string"
    }
}

fun main() {
    val nullString: String? = null
    println(describeString(nullString))
    // Empty or null string
}
```

Use safe calls

To safely access properties of an object that might contain a null value, use the safe call operator ?.. The safe call operator returns null if either the object or one of its accessed properties is null. This is useful if you want to avoid the presence of null values triggering errors in your code.

In the following example, the lengthString() function uses a safe call to return either the length of the string or null:

```
fun lengthString(maybeString: String?): Int? = maybeString?.length
```

```kotlin
fun main() {
    val nullString: String? = null
    println(lengthString(nullString))
    // null
}
```

Safe calls can be chained so that if any property of an object contains a null value, then null is returned without an error being thrown. For example:

```kotlin
person.company?.address?.country
```

The safe call operator can also be used to safely call an extension or member function. In this case, a null check is performed before the function is called. If the check detects a null value, then the call is skipped and null is returned.

In the following example, nullString is null so the invocation of .uppercase() is skipped and null is returned:

```kotlin
fun main() {
    val nullString: String? = null
    println(nullString?.uppercase())
    // null
}
```

Use Elvis operator

You can provide a default value to return if a null value is detected by using the Elvis operator ?:.

Write on the left-hand side of the Elvis operator what should be checked for a null value. Write on the right-hand side of the Elvis operator what should be returned if a null value is detected.

In the following example, nullString is null so the safe call to access the length property returns a null value. As a result, the Elvis operator returns 0:

```kotlin
fun main() {
    val nullString: String? = null
    println(nullString?.length ?: 0)
    // 0
}
```

For more information about null safety in Kotlin, see Null safety.

Practice

Exercise

You have the employeeById function that gives you access to a database of employees of a company. Unfortunately, this function returns a value of the Employee? type, so the result can be null. Your goal is to write a function that returns the salary of an employee when their id is provided, or 0 if the employee is missing from the database.

```kotlin
data class Employee (val name: String, var salary: Int)

fun employeeById(id: Int) = when(id) {
    1 -> Employee("Mary", 20)
    2 -> null
    3 -> Employee("John", 21)
    4 -> Employee("Ann", 23)
    else -> null
}

fun salaryById(id: Int) = // Write your code here

fun main() {
    println((1..5).sumOf { id -> salaryById(id) })
}
```

```kotlin
data class Employee (val name: String, var salary: Int)

fun employeeById(id: Int) = when(id) {
    1 -> Employee("Mary", 20)
    2 -> null
    3 -> Employee("John", 21)
    4 -> Employee("Ann", 23)
    else -> null
}

fun salaryById(id: Int) = employeeById(id)?.salary ?: 0

fun main() {
    println((1..5).sumOf { id -> salaryById(id) })
}
```

What's next?

Congratulations! Now that you have completed the beginner tour, take your understanding of Kotlin to the next level with our intermediate tour:

Start the intermediate Kotlin tour

Intermediate: Extension functions

In this chapter, you'll explore special Kotlin functions that make your code more concise and readable. Learn how they can help you use efficient design patterns to take your projects to the next level.

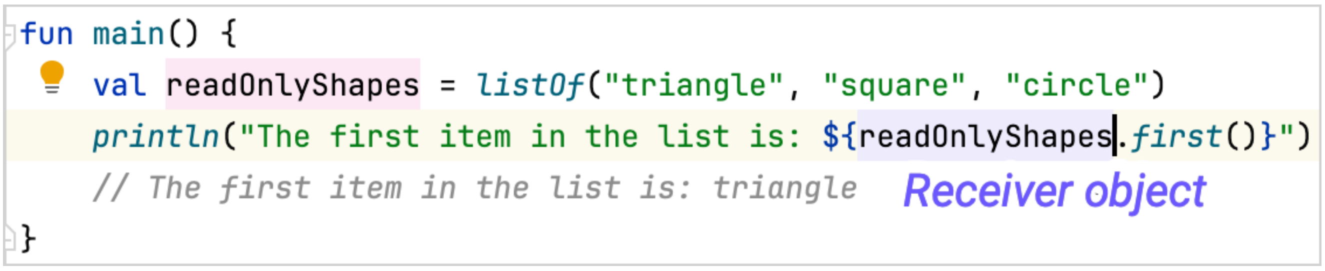
Extension functions

In software development, you often need to modify the behavior of a program without altering the original source code. For example, in your project, you might want to add extra functionality to a class from a third-party library.

Extension functions allow you to extend a class with additional functionality. You call extension functions the same way you call member functions of a class.

Before introducing the syntax for extension functions, you need to understand the terms receiver type and receiver object.

The receiver object is what the function is called on. In other words, the receiver is where or with whom the information is shared.



```kotlin
fun main() {
    val readOnlyShapes = listOf("triangle", "square", "circle")
    println("The first item in the list is: ${readOnlyShapes.first()}")
    // The first item in the list is: triangle
}
```

An example of sender and receiver

In this example, the main() function calls the .first() function. The .first() function is called on the readOnlyShapes variable, so the readOnlyShapes variable is the receiver.

The receiver object has a type so that the compiler understands when the function can be used.

This example uses the .first() function from the standard library to return the first element in a list. To create your own extension function, write the name of the class that you want to extend followed by a . and the name of your function. Continue with the rest of the function declaration, including its arguments and return type.

For example:

```
fun String.bold(): String = "<b>$this</b>"

fun main() {
    // "hello" is the receiver object
    println("hello".bold())
    // <b>hello</b>
}
```

In this example:

- String is the extended class, also known as the receiver type.
- bold is the name of the extension function.
- The .bold() extension function's return type is String.
- "hello", an instance of String, is the receiver object.
- The receiver object is accessed inside the body by the keyword: this.
- A string template ($) is used to access the value of this.
- The .bold() extension function takes a string and returns it in a <b> HTML element for bold text.

Extension-oriented design

You can define extension functions anywhere, which enables you to create extension-oriented designs. These designs separate core functionality from useful but non-essential features, making your code easier to read and maintain.

A good example is the HttpClient class from the Ktor library, which helps perform network requests. The core of its functionality is a single function request(), which takes all the information needed for an HTTP request:

```
class HttpClient {
    fun request(method: String, url: String, headers: Map<String, String>): HttpResponse {
        // Network code
    }
}
```

In practice, the most popular HTTP requests are GET or POST requests. It makes sense for the library to provide shorter names for these common use cases. However, these don't require writing new network code, only a specific request call. In other words, they are perfect candidates to be defined as separate .get() and .post() extension functions:

```
fun HttpClient.get(url: String): HttpResponse = request("GET", url, emptyMap())
fun HttpClient.post(url: String): HttpResponse = request("POST", url, emptyMap())
```

These .get() and .post() functions call the request() function with the correct HTTP method, so you don't have to. They streamline your code and make it easier to understand:

```
class HttpClient {
    fun request(method: String, url: String, headers: Map<String, String>): HttpResponse {
        println("Requesting $method to $url with headers: $headers")
        return HttpResponse("Response from $url")
    }
}

fun HttpClient.get(url: String): HttpResponse = request("GET", url, emptyMap())

fun main() {
    val client = HttpClient()

    // Making a GET request using request() directly
    val getResponseWithMember = client.request("GET", "https://example.com", emptyMap())

    // Making a GET request using the get() extension function
    val getResponseWithExtension = client.get("https://example.com")
}
```

This extension-oriented approach is widely used in Kotlin's standard library and other libraries. For example, the String class has many extension functions to help you work with strings.

For more information about extension functions, see Extensions.

Practice

Exercise 1

Write an extension function called isPositive that takes an integer and checks whether it is positive.

```
fun Int.// Write your code here

fun main() {
    println(1.isPositive())
    // true
}
```

```
fun Int.isPositive(): Boolean = this > 0

fun main() {
    println(1.isPositive())
    // true
}
```

Exercise 2

Write an extension function called toLowercaseString that takes a string and returns a lowercase version.

Hint
Use the .lowercase() function for the String type.

```
fun // Write your code here

fun main() {
    println("Hello World!".toLowercaseString())
    // hello world!
}
```

```
fun String.toLowercaseString(): String = this.lowercase()

fun main() {
    println("Hello World!".toLowercaseString())
    // hello world!
}
```

Next step

Intermediate: Scope functions

Intermediate: Scope functions

In this chapter, you'll build on your understanding of extension functions to learn how to use scope functions to write more idiomatic code.

Scope functions

In programming, a scope is the area in which your variable or object is recognized. The most commonly referred to scopes are the global scope and the local scope:

- Global scope – a variable or object that is accessible from anywhere in the program.
- Local scope – a variable or object that is only accessible within the block or function where it is defined.

In Kotlin, there are also scope functions that allow you to create a temporary scope around an object and execute some code.

Scope functions make your code more concise because you don't have to refer to the name of your object within the temporary scope. Depending on the scope function, you can access the object either by referencing it via the keyword this or using it as an argument via the keyword it.

Kotlin has five scope functions in total: let, apply, run, also, and with.

Each scope function takes a lambda expression and returns either the object or the result of the lambda expression. In this tour, we explain each scope function and how to use it.

> You can also watch the Back to the Stdlib: Making the Most of Kotlin's Standard Library talk on scope functions by Sebastian Aigner, Kotlin developer advocate.

Let

Use the let scope function when you want to perform null checks in your code and later perform further actions with the returned object.

Consider the example:

```
fun sendNotification(recipientAddress: String): String {
    println("Yo $recipientAddress!")
    return "Notification sent!"
}

fun getNextAddress(): String {
    return "sebastian@jetbrains.com"
}

fun main() {
    val address: String? = getNextAddress()
    sendNotification(address)
}
```

The example has two functions:

- sendNotification(), which has a function parameter recipientAddress and returns a string.
- getNextAddress(), which has no function parameters and returns a string.

The example creates a variable address that has a nullable String type. But this becomes a problem when you call the sendNotification() function because this function doesn't expect that address could be a null value. The compiler reports an error as a result:

```
Type mismatch: inferred type is String? but String was expected
```

From the beginner tour, you already know that you can perform a null check with an if condition or use the Elvis operator ?:. But what if you want to use the returned object later in your code? You could achieve this with an if condition and an else branch:

```
fun sendNotification(recipientAddress: String): String {
    println("Yo $recipientAddress!")
    return "Notification sent!"
}

fun getNextAddress(): String {
    return "sebastian@jetbrains.com"
}

fun main() {
        val address: String? = getNextAddress()
    val confirm = if(address != null) {
        sendNotification(address)
    } else { null }
    //sampleEnd
}
```

However, a more concise approach is to use the let scope function:

```
fun sendNotification(recipientAddress: String): String {
    println("Yo $recipientAddress!")
    return "Notification sent!"
}

fun getNextAddress(): String {
    return "sebastian@jetbrains.com"
}

fun main() {
        val address: String? = getNextAddress()
    val confirm = address?.let {
        sendNotification(it)
    }
    //sampleEnd
}
```

The example:

- Creates a variable called confirm.
- Uses a safe call for the let scope function on the address variable.
- Creates a temporary scope within the let scope function.
- Passes the sendNotification() function as a lambda expression into the let scope function.
- Refers to the address variable via it, using the temporary scope.
- Assigns the result to the confirm variable.

With this approach, your code can handle the address variable potentially being a null value, and you can use the confirm variable later in your code.

Apply

Use the apply scope function to initialize objects, like a class instance, at the time of creation rather than later on in your code. This approach makes your code easier to read and manage.

Consider the example:

```
class Client() {
    var token: String? = null
    fun connect() = println("connected!")
    fun authenticate() = println("authenticated!")
    fun getData(): String = "Mock data"
}

val client = Client()

fun main() {
    client.token = "asdf"
    client.connect()
    // connected!
    client.authenticate()
    // authenticated!
    client.getData()
}
```

The example has a Client class that contains one property called token and three member functions: connect(), authenticate(), and getData().

The example creates client as an instance of the Client class before initializing its token property and calling its member functions in the main() function.

Although this example is compact, in the real world, it can be a while before you can configure and use the class instance (and its member functions) after you've created it. However, if you use the apply scope function you can create, configure and use member functions on your class instance all in the same place in your code:

```
class Client() {
  var token: String? = null
  fun connect() = println("connected!")
  fun authenticate() = println("authenticated!")
  fun getData(): String = "Mock data"
}
val client = Client().apply {
  token = "asdf"
  connect()
  authenticate()
}

fun main() {
  client.getData()
  // connected!
  // authenticated!
}
```

The example:

- Creates client as an instance of the Client class.
- Uses the apply scope function on the client instance.
- Creates a temporary scope within the apply scope function so that you don't have to explicitly refer to the client instance when accessing its properties or functions.
- Passes a lambda expression to the apply scope function that updates the token property and calls the connect() and authenticate() functions.
- Calls the getData() member function on the client instance in the main() function.

As you can see, this strategy is convenient when you are working with large pieces of code.

Run

Similar to apply, you can use the run scope function to initialize an object, but it's better to use run to initialize an object at a specific moment in your code and immediately compute a result.

Let's continue the previous example for the apply function, but this time, you want the connect() and authenticate() functions to be grouped so that they are called on every request.

For example:

```
class Client() {
    var token: String? = null
    fun connect() = println("connected!")
    fun authenticate() = println("authenticated!")
    fun getData(): String = "Mock data"
}

val client: Client = Client().apply {
    token = "asdf"
}

fun main() {
    val result: String = client.run {
        connect()
        // connected!
        authenticate()
        // authenticated!
        getData()
    }
}
```

The example:

- Creates client as an instance of the Client class.
- Uses the apply scope function on the client instance.
- Creates a temporary scope within the apply scope function so that you don't have to explicitly refer to the client instance when accessing its properties or functions.
- Passes a lambda expression to the apply scope function that updates the token property.

The main() function:

- Creates a result variable with type String.
- Uses the run scope function on the client instance.
- Creates a temporary scope within the run scope function so that you don't have to explicitly refer to the client instance when accessing its properties or functions.
- Passes a lambda expression to the run scope function that calls the connect(), authenticate(), and getData() functions.
- Assigns the result to the result variable.

Now you can use the returned result further in your code.

Also

Use the also scope function to complete an additional action with an object and then return the object to continue using it in your code, like writing a log.

Consider the example:

```
fun main() {
    val medals: List<String> = listOf("Gold", "Silver", "Bronze")
    val reversedLongUppercaseMedals: List<String> =
        medals
            .map { it.uppercase() }
            .filter { it.length > 4 }
            .reversed()
    println(reversedLongUppercaseMedals)
    // [BRONZE, SILVER]
}
```

The example:

- Creates the medals variable that contains a list of strings.
- Creates the reversedLongUpperCaseMedals variable that has the List<String> type.
- Uses the .map() extension function on the medals variable.
- Passes a lambda expression to the .map() function that refers to medals via the it keyword and calls the .uppercase() extension function on it.
- Uses the .filter() extension function on the medals variable.
- Passes a lambda expression as a predicate to the .filter() function that refers to medals via the it keyword and checks if the length of the list contained in the medals variable is longer than 4 items.
- Uses the .reversed() extension function on the medals variable.
- Assigns the result to the reversedLongUpperCaseMedals variable.
- Prints the list contained in the reversedLongUpperCaseMedals variable.

It would be useful to add some logging in between the function calls to see what is happening to the medals variable. The also function helps with that:

```
fun main() {
    val medals: List<String> = listOf("Gold", "Silver", "Bronze")
    val reversedLongUppercaseMedals: List<String> =
        medals
            .map { it.uppercase() }
            .also { println(it) }
            // [GOLD, SILVER, BRONZE]
            .filter { it.length > 4 }
            .also { println(it) }
            // [SILVER, BRONZE]
            .reversed()
    println(reversedLongUppercaseMedals)
    // [BRONZE, SILVER]
}
```

Now the example:

- Uses the also scope function on the medals variable.

- Creates a temporary scope within the also scope function so that you don't have to explicitly refer to the medals variable when using it as a function parameter.
- Passes a lambda expression to the also scope function that calls the println() function using the medals variable as a function parameter via the it keyword.

Since the also function returns the object, it is useful for not only logging but debugging, chaining multiple operations, and performing other side-effect operations that don't affect the main flow of your code.

With

Unlike the other scope functions, with is not an extension function, so the syntax is different. You pass the receiver object to with as an argument.

Use the with scope function when you want to call multiple functions on an object.

Consider this example:

```kotlin
class Canvas {
    fun rect(x: Int, y: Int, w: Int, h: Int): Unit = println("$x, $y, $w, $h")
    fun circ(x: Int, y: Int, rad: Int): Unit = println("$x, $y, $rad")
    fun text(x: Int, y: Int, str: String): Unit = println("$x, $y, $str")
}

fun main() {
    val mainMonitorPrimaryBufferBackedCanvas = Canvas()

    mainMonitorPrimaryBufferBackedCanvas.text(10, 10, "Foo")
    mainMonitorPrimaryBufferBackedCanvas.rect(20, 30, 100, 50)
    mainMonitorPrimaryBufferBackedCanvas.circ(40, 60, 25)
    mainMonitorPrimaryBufferBackedCanvas.text(15, 45, "Hello")
    mainMonitorPrimaryBufferBackedCanvas.rect(70, 80, 150, 100)
    mainMonitorPrimaryBufferBackedCanvas.circ(90, 110, 40)
    mainMonitorPrimaryBufferBackedCanvas.text(35, 55, "World")
    mainMonitorPrimaryBufferBackedCanvas.rect(120, 140, 200, 75)
    mainMonitorPrimaryBufferBackedCanvas.circ(160, 180, 55)
    mainMonitorPrimaryBufferBackedCanvas.text(50, 70, "Kotlin")
}
```

The example creates a Canvas class that has three member functions: rect(), circ(), and text(). Each of these member functions prints a statement constructed from the function parameters that you provide.

The example creates mainMonitorPrimaryBufferBackedCanvas as an instance of the Canvas class before calling a sequence of member functions on the instance with different function parameters.

You can see that this code is hard to read. If you use the with function, the code is streamlined:

```kotlin
class Canvas {
    fun rect(x: Int, y: Int, w: Int, h: Int): Unit = println("$x, $y, $w, $h")
    fun circ(x: Int, y: Int, rad: Int): Unit = println("$x, $y, $rad")
    fun text(x: Int, y: Int, str: String): Unit = println("$x, $y, $str")
}

fun main() {
        val mainMonitorSecondaryBufferBackedCanvas = Canvas()
    with(mainMonitorSecondaryBufferBackedCanvas) {
        text(10, 10, "Foo")
        rect(20, 30, 100, 50)
        circ(40, 60, 25)
        text(15, 45, "Hello")
        rect(70, 80, 150, 100)
        circ(90, 110, 40)
        text(35, 55, "World")
        rect(120, 140, 200, 75)
        circ(160, 180, 55)
        text(50, 70, "Kotlin")
    }
    //sampleEnd
}
```

This example:

- Uses the with scope function with the mainMonitorSecondaryBufferBackedCanvas instance as the receiver object.
- Creates a temporary scope within the with scope function so that you don't have to explicitly refer to the mainMonitorSecondaryBufferBackedCanvas instance when calling its member functions.

- Passes a lambda expression to the with scope function that calls a sequence of member functions with different function parameters.

Now that this code is much easier to read, you are less likely to make mistakes.

Use case overview

This section has covered the different scope functions available in Kotlin and their main use cases for making your code more idiomatic. You can use this table as a quick reference. It's important to note that you don't need a complete understanding of how these functions work in order to use them in your code.

Function	Access to x via	Return value	Use case
let	it	Lambda result	Perform null checks in your code and later perform further actions with the returned object.
apply	this	x	Initialize objects at the time of creation.
run	this	Lambda result	Initialize objects at the time of creation AND compute a result.
also	it	x	Complete additional actions before returning the object.
with	this	Lambda result	Call multiple functions on an object.

For more information about scope functions, see Scope functions.

Practice

Exercise 1

Rewrite the .getPriceInEuros() function as a single-expression function that uses safe call operators ?. and the let scope function.

Hint
Use safe call operators ?. to safely access the priceInDollars property from the getProductInfo() function. Then, use the let scope function to convert the value of priceInDollars into euros.

```kotlin
data class ProductInfo(val priceInDollars: Double?)

class Product {
    fun getProductInfo(): ProductInfo? {
        return ProductInfo(100.0)
    }
}

// Rewrite this function
fun Product.getPriceInEuros(): Double? {
    val info = getProductInfo()
    if (info == null) return null
    val price = info.priceInDollars
    if (price == null) return null
    return convertToEuros(price)
}

fun convertToEuros(dollars: Double): Double {
    return dollars * 0.85
}

fun main() {
    val product = Product()
    val priceInEuros = product.getPriceInEuros()

    if (priceInEuros != null) {
        println("Price in Euros: €$priceInEuros")
        // Price in Euros: €85.0
    } else {
        println("Price information is not available.")
    }
}
```

```kotlin
data class ProductInfo(val priceInDollars: Double?)

class Product {
    fun getProductInfo(): ProductInfo? {
        return ProductInfo(100.0)
    }
}

fun Product.getPriceInEuros() = getProductInfo()?.priceInDollars?.let { convertToEuros(it) }

fun convertToEuros(dollars: Double): Double {
    return dollars * 0.85
}

fun main() {
    val product = Product()
    val priceInEuros = product.getPriceInEuros()

    if (priceInEuros != null) {
        println("Price in Euros: €$priceInEuros")
        // Price in Euros: €85.0
    } else {
        println("Price information is not available.")
    }
}
```

Exercise 2

You have an updateEmail() function that updates the email address of a user. Use the apply scope function to update the email address and then the also scope function to print a log message: Updating email for user with ID: ${it.id}.

```kotlin
data class User(val id: Int, var email: String)

fun updateEmail(user: User, newEmail: String): User = // Write your code here

fun main() {
    val user = User(1, "old_email@example.com")
    val updatedUser = updateEmail(user, "new_email@example.com")
    // Updating email for user with ID: 1

    println("Updated User: $updatedUser")
    // Updated User: User(id=1, email=new_email@example.com)
}
```

```kotlin
data class User(val id: Int, var email: String)

fun updateEmail(user: User, newEmail: String): User = user.apply {
    this.email = newEmail
}.also { println("Updating email for user with ID: ${it.id}") }

fun main() {
    val user = User(1, "old_email@example.com")
    val updatedUser = updateEmail(user, "new_email@example.com")
    // Updating email for user with ID: 1

    println("Updated User: $updatedUser")
    // Updated User: User(id=1, email=new_email@example.com)
}
```

Next step

Intermediate: Lambda expressions with receiver

Intermediate: Lambda expressions with receiver

In this chapter, you'll learn how to use receiver objects with another type of function, lambda expressions, and how they can help you create a domain-specific language.

Lambda expressions with receiver

In the beginner tour, you learned how to use lambda expressions. Lambda expressions can also have a receiver. In this case, lambda expressions can access any member functions or properties of the receiver object without having to explicitly specify the receiver object each time. Without these additional references, your code is easier to read and maintain.

> Lambda expressions with receiver are also known as function literals with receiver.

The syntax for a lambda expression with receiver is different when you define the function type. First, write the receiver object that you want to extend. Next, put a . and then complete the rest of your function type definition. For example:

```
MutableList<Int>.() -> Unit
```

This function type has:

- MutableList<Int> as the receiver type.
- No function parameters within the parentheses ().
- No return value: Unit.

Consider this example that extends the StringBuilder class:

```
fun main() {
    // Lambda expression with receiver definition
    fun StringBuilder.appendText() { append("Hello!") }

    // Use the lambda expression with receiver
    val stringBuilder = StringBuilder()
    stringBuilder.appendText()
    println(stringBuilder.toString())
    // Hello!
}
```

In this example:

- The StringBuilder class is the receiver type.
- The function type of the lambda expression has no function parameters () and has no return value Unit.
- The lambda expression calls the append() member function from the StringBuilder class and uses the string "Hello!" as the function parameter.
- An instance of the StringBuilder class is created.
- The lambda expression assigned to appendText is called on the stringBuilder instance.
- The stringBuilder instance is converted to string with the toString() function and printed via the println() function.

Lambda expressions with receiver are helpful when you want to create a domain-specific language (DSL). Since you have access to the receiver object's member functions and properties without explicitly referencing the receiver, your code becomes leaner.

To demonstrate this, consider an example that configures items in a menu. Let's begin with a MenuItem class and a Menu class that contains a function to add items to the menu called item(), as well as a list of all menu items items:

```
class MenuItem(val name: String)

class Menu(val name: String) {
    val items = mutableListOf<MenuItem>()

    fun item(name: String) {
        items.add(MenuItem(name))
    }
}
```

Let's use a lambda expression with receiver passed as a function parameter (init) to the menu() function that builds a menu as a starting point. You'll notice that the code follows a similar approach to the previous example with the StringBuilder class:

```
fun menu(name: String, init: Menu.() -> Unit): Menu {
    // Creates an instance of the Menu class
    val menu = Menu(name)
    // Calls the lambda expression with receiver init() on the class instance
    menu.init()
    return menu
}
```

Now you can use the DSL to configure a menu and create a printMenu() function to print the menu structure to the console:

```
class MenuItem(val name: String)

class Menu(val name: String) {
    val items = mutableListOf<MenuItem>()

    fun item(name: String) {
        items.add(MenuItem(name))
    }
}

fun menu(name: String, init: Menu.() -> Unit): Menu {
    val menu = Menu(name)
    menu.init()
    return menu
}

fun printMenu(menu: Menu) {
    println("Menu: ${menu.name}")
    menu.items.forEach { println("  Item: ${it.name}") }
}

// Use the DSL
fun main() {
    // Create the menu
    val mainMenu = menu("Main Menu") {
        // Add items to the menu
        item("Home")
        item("Settings")
        item("Exit")
    }

    // Print the menu
    printMenu(mainMenu)
    // Menu: Main Menu
    // Item: Home
    // Item: Settings
    // Item: Exit
}
```

As you can see, using a lambda expression with receiver greatly simplifies the code needed to create your menu. Lambda expressions are not only useful for setup and creation but also for configuration. They are commonly used in building DSLs for APIs, UI frameworks, and configuration builders to produce streamlined code, allowing you to focus more easily on the underlying code structure and logic.

Kotlin's ecosystem has many examples of this design pattern, such as in the buildList() and buildString() functions from the standard library.

> Lambda expressions with receivers can be combined with type-safe builders in Kotlin to make DSLs that detect any problems with types at compile time rather than at runtime. To learn more, see Type-safe builders.

Practice

Exercise 1

You have a fetchData() function that accepts a lambda expression with receiver. Update the lambda expression to use the append() function so that the output of your code is: Data received - Processed.

```kotlin
fun fetchData(callback: StringBuilder.() -> Unit) {
    val builder = StringBuilder("Data received")
    builder.callback()
}

fun main() {
    fetchData {
        // Write your code here
        // Data received - Processed
    }
}
```

```kotlin
fun fetchData(callback: StringBuilder.() -> Unit) {
    val builder = StringBuilder("Data received")
    builder.callback()
}

fun main() {
    fetchData {
        append(" - Processed")
        println(this.toString())
        // Data received - Processed
    }
}
```

Exercise 2

You have a Button class and ButtonEvent and Position data classes. Write some code that triggers the onEvent() member function of the Button class to trigger a double-click event. Your code should print "Double click!".

```kotlin
class Button {
    fun onEvent(action: ButtonEvent.() -> Unit) {
        // Simulate a double-click event (not a right-click)
        val event = ButtonEvent(isRightClick = false, amount = 2, position = Position(100, 200))
        event.action() // Trigger the event callback
    }
}

data class ButtonEvent(
    val isRightClick: Boolean,
    val amount: Int,
    val position: Position
)

data class Position(
    val x: Int,
    val y: Int
)

fun main() {
    val button = Button()

    button.onEvent {
        // Write your code here
        // Double click!
    }
}
```

```kotlin
class Button {
    fun onEvent(action: ButtonEvent.() -> Unit) {
        // Simulate a double-click event (not a right-click)
        val event = ButtonEvent(isRightClick = false, amount = 2, position = Position(100, 200))
        event.action() // Trigger the event callback
    }
}

data class ButtonEvent(
    val isRightClick: Boolean,
    val amount: Int,
    val position: Position
)

data class Position(
    val x: Int,
    val y: Int
)

fun main() {
    val button = Button()

    button.onEvent {
        if (!isRightClick && amount == 2) {
            println("Double click!")
            // Double click!
        }
    }
}
```

Exercise 3

Write a function that creates a copy of a list of integers where every element is incremented by 1. Use the provided function skeleton that extends List<Int> with an incremented function.

```
fun List<Int>.incremented(): List<Int> {
    val originalList = this
    return buildList {
        // Write your code here
    }
}

fun main() {
    val originalList = listOf(1, 2, 3)
    val newList = originalList.incremented()
    println(newList)
    // [2, 3, 4]
}
```

```
fun List<Int>.incremented(): List<Int> {
    val originalList = this
    return buildList {
        for (n in originalList) add(n + 1)
    }
}

fun main() {
    val originalList = listOf(1, 2, 3)
    val newList = originalList.incremented()
    println(newList)
    // [2, 3, 4]
}
```

Next step

Intermediate: Classes and interfaces

Intermediate: Classes and interfaces

In the beginner tour, you learned how to use classes and data classes to store data and maintain a collection of characteristics that can be shared in your code. Eventually, you will want to create a hierarchy to efficiently share code within your projects. This chapter explains the options Kotlin provides for sharing code and how they can make your code safer and easier to maintain.

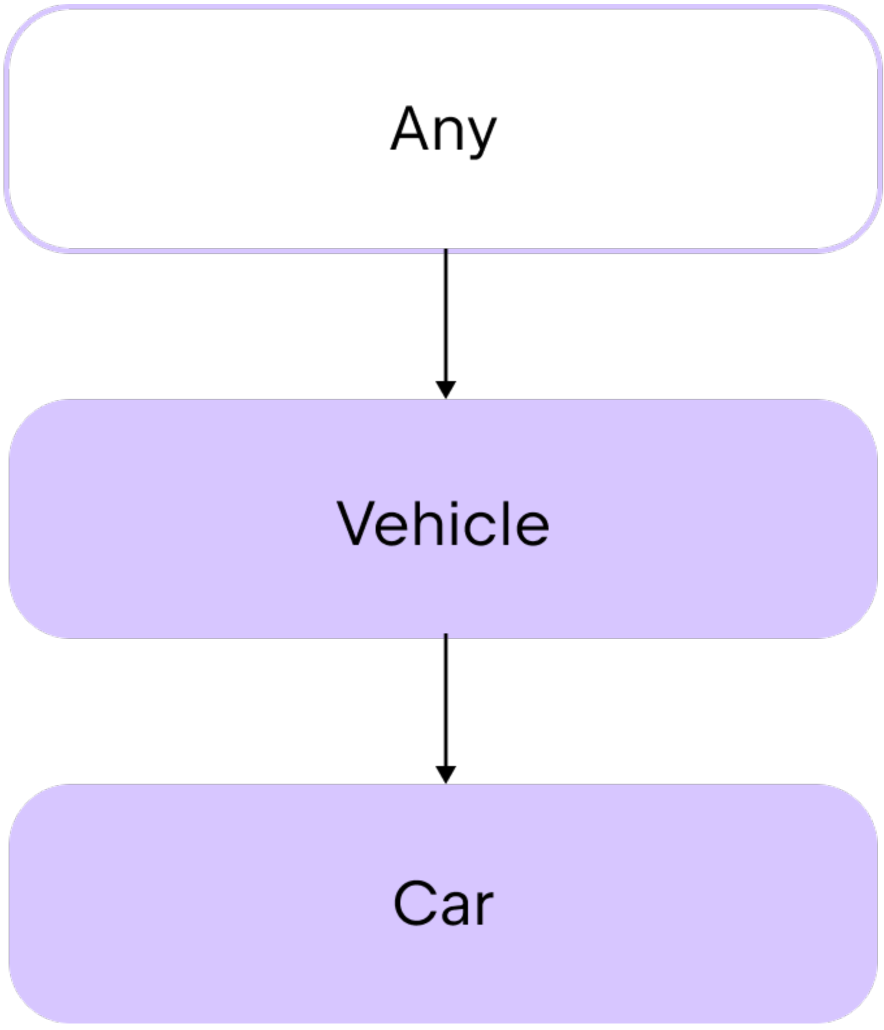
Class inheritance

In a previous chapter, we covered how you can use extension functions to extend classes without modifying the original source code. But what if you are working on something complex where sharing code between classes would be useful? In such cases, you can use class inheritance.

By default, classes in Kotlin can't be inherited. Kotlin is designed this way to prevent unintended inheritance and make your classes easier to maintain.

Kotlin classes only support single inheritance, meaning it is only possible to inherit from one class at a time. This class is called the parent.

The parent of a class inherits from another class (the grandparent), forming a hierarchy. At the top of Kotlin's class hierarchy is the common parent class: Any. All classes ultimately inherit from the Any class:



An example of the class hierarchy with Any type

The Any class provides the toString() function as a member function automatically. Therefore, you can use this inherited function in any of your classes. For example:

```kotlin
class Car(val make: String, val model: String, val numberOfDoors: Int)

fun main() {
        val car1 = Car("Toyota", "Corolla", 4)

    // Uses the .toString() function via string templates to print class properties
    println("Car1: make=${car1.make}, model=${car1.model}, numberOfDoors=${car1.numberOfDoors}")
    // Car1: make=Toyota, model=Corolla, numberOfDoors=4
    //sampleEnd
}
```

If you want to use inheritance to share some code between classes, first consider using abstract classes.

Abstract classes

Abstract classes can be inherited by default. The purpose of abstract classes is to provide members that other classes inherit or implement. As a result, they have a constructor, but you can't create instances from them. Within the child class, you define the behavior of the parent's properties and functions with the override keyword. In this way, you can say that the child class "overrides" the members of the parent class.

> When you define the behavior of an inherited function or property, we call that an implementation.

Abstract classes can contain both functions and properties with implementation as well as functions and properties without implementation, known as abstract functions and properties.

To create an abstract class, use the abstract keyword:

```
abstract class Animal
```

To declare a function or a property without an implementation, you also use the abstract keyword:

```
abstract fun makeSound()
abstract val sound: String
```

For example, let's say that you want to create an abstract class called Product that you can create child classes from to define different product categories:

```
abstract class Product(val name: String, var price: Double) {
    // Abstract property for the product category
    abstract val category: String

    // A function that can be shared by all products
    fun productInfo(): String {
        return "Product: $name, Category: $category, Price: $price"
    }
}
```

In the abstract class:

- The constructor has two parameters for the product's name and price.
- There is an abstract property that contains the product category as a string.
- There is a function that prints information about the product.

Let's create a child class for electronics. Before you define an implementation for the category property in the child class, you must use the override keyword:

```
class Electronic(name: String, price: Double, val warranty: Int) : Product(name, price) {
    override val category = "Electronic"
}
```

The Electronic class:

- Inherits from the Product abstract class.
- Has an additional parameter in the constructor: warranty, which is specific to electronics.
- Overrides the category property to contain the string "Electronic".

Now, you can use these classes like this:

```
abstract class Product(val name: String, var price: Double) {
    // Abstract property for the product category
    abstract val category: String

    // A function that can be shared by all products
    fun productInfo(): String {
        return "Product: $name, Category: $category, Price: $price"
    }
}

class Electronic(name: String, price: Double, val warranty: Int) : Product(name, price) {
    override val category = "Electronic"
}
```

```kotlin
fun main() {
    // Creates an instance of the Electronic class
    val laptop = Electronic(name = "Laptop", price = 1000.0, warranty = 2)

    println(laptop.productInfo())
    // Product: Laptop, Category: Electronic, Price: 1000.0
}
```

Although abstract classes are great for sharing code in this way, they are restricted because classes in Kotlin only support single inheritance. If you need to inherit from multiple sources, consider using interfaces.

Interfaces

Interfaces are similar to classes, but they have some differences:

- You can't create an instance of an interface. They don't have a constructor or header.
- Their functions and properties are implicitly inheritable by default. In Kotlin, we say that they are "open".
- You don't need to mark their functions as abstract if you don't give them an implementation.

Similar to abstract classes, you use interfaces to define a set of functions and properties that classes can inherit and implement later. This approach helps you focus on the abstraction described by the interface, rather than the specific implementation details. Using interfaces makes your code:

- More modular, as it isolates different parts, allowing them to evolve independently.
- Easier to understand by grouping related functions into a cohesive set.
- Easier to test, as you can quickly swap an implementation with a mock for testing.

To declare an interface, use the interface keyword:

```kotlin
interface PaymentMethod
```

Interface implementation

Interfaces support multiple inheritance so a class can implement multiple interfaces at once. First, let's consider the scenario where a class implementsone interface.

To create a class that implements an interface, add a colon after your class header, followed by the interface name that you want to implement. You don't use parentheses () after the interface name because interfaces don't have a constructor:

```kotlin
class CreditCardPayment : PaymentMethod
```

For example:

```kotlin
interface PaymentMethod {
    // Functions are inheritable by default
    fun initiatePayment(amount: Double): String
}

class CreditCardPayment(val cardNumber: String, val cardHolderName: String, val expiryDate: String) : PaymentMethod {
    override fun initiatePayment(amount: Double): String {
        // Simulate processing payment with credit card
        return "Payment of $$amount initiated using Credit Card ending in ${cardNumber.takeLast(4)}."
    }
}

fun main() {
    val paymentMethod = CreditCardPayment("1234 5678 9012 3456", "John Doe", "12/25")
    println(paymentMethod.initiatePayment(100.0))
    // Payment of $100.0 initiated using Credit Card ending in 3456.
}
```

In the example:

- PaymentMethod is an interface that has an initiatePayment() function without an implementation.

* CreditCardPayment is a class that implements the PaymentMethod interface.
* The CreditCardPayment class overrides the inherited initiatePayment() function.
* paymentMethod is an instance of the CreditCardPayment class.
* The overridden initiatePayment() function is called on the paymentMethod instance with a parameter of 100.0.

To create a class that implements multiple interfaces, add a colon after your class header followed by the name of the interfaces that you want to implement separated by a comma:

```kotlin
class CreditCardPayment : PaymentMethod, PaymentType
```

For example:

```kotlin
interface PaymentMethod {
    fun initiatePayment(amount: Double): String
}

interface PaymentType {
    val paymentType: String
}

class CreditCardPayment(val cardNumber: String, val cardHolderName: String, val expiryDate: String) : PaymentMethod,
    PaymentType {
    override fun initiatePayment(amount: Double): String {
        // Simulate processing payment with credit card
        return "Payment of $$amount initiated using Credit Card ending in ${cardNumber.takeLast(4)}."
    }

    override val paymentType: String = "Credit Card"
}

fun main() {
    val paymentMethod = CreditCardPayment("1234 5678 9012 3456", "John Doe", "12/25")
    println(paymentMethod.initiatePayment(100.0))
    // Payment of $100.0 initiated using Credit Card ending in 3456.

    println("Payment is by ${paymentMethod.paymentType}")
    // Payment is by Credit Card
}
```

In the example:

* PaymentMethod is an interface that has the initiatePayment() function without an implementation.
* PaymentType is an interface that has the paymentType property that isn't initialized.
* CreditCardPayment is a class that implements the PaymentMethod and PaymentType interfaces.
* The CreditCardPayment class overrides the inherited initiatePayment() function and the paymentType property.
* paymentMethod is an instance of the CreditCardPayment class.
* The overridden initiatePayment() function is called on the paymentMethod instance with a parameter of 100.0.
* The overridden paymentType property is accessed on the paymentMethod instance.

For more information about interfaces and interface inheritance, see Interfaces.

Delegation

Interfaces are useful, but if your interface contains many functions, child classes may end up with a lot of boilerplate code. When you only want to override a small part of your parent's behavior, you need to repeat yourself a lot.

> Boilerplate code is a chunk of code that is reused with little or no alteration in multiple parts of a software project.

For example, let's say that you have an interface called Drawable that contains a number of functions and one property called color:

```
interface Drawable {
    fun draw()
    fun resize()
    val color: String?
}
```

You create a class called Circle which implements the Drawable interface and provides implementations for all of its members:

```
class Circle : Drawable {
    override fun draw() {
        TODO("An example implementation")
    }

    override fun resize() {
        TODO("An example implementation")
    }
   override val color = null
}
```

If you wanted to create a child class of the Circle class which had the same behavior except for the value of the color property, you still need to add implementations for each member function of the Circle class:

```
class RedCircle(val circle: Circle) : Circle {

    // Start of boilerplate code
    override fun draw() {
        circle.draw()
    }

    override fun resize() {
        circle.resize()
    }

    // End of boilerplate code
    override val color = "red"
}
```

You can see that if you have a large number of member functions in the Drawable interface, the amount of boilerplate code in the RedCircle class can be very large. However, there is an alternative.

In Kotlin, you can use delegation to delegate the interface implementation to an instance of a class. For example, you can create an instance of the Circle class and delegate the implementations of the member functions of the Circle class to this instance. To do this, use the by keyword. For example:

```
class RedCircle(param: Circle) : Drawable by param
```

Here, param is the name of the instance of the Circle class that the implementations of member functions are delegated to.

Now you don't have to add implementations for the member functions in the RedCircle class. The compiler does this for you automatically from the Circle class. This saves you from having to write a lot of boilerplate code. Instead, you add code only for the behavior you want to change for your child class.

For example, if you want to change the value of the color property:

```
class RedCircle(param : Circle) : Drawable by param {
    // No boilerplate code!
    override val color = "red"
}
```

If you want to, you can also override the behavior of an inherited member function in the RedCircle class, but now you don't have to add new lines of code for every inherited member function.

For more information, see Delegation.

Practice

Exercise 1

Imagine you're working on a smart home system. A smart home typically has different types of devices that all have some basic features but also unique behaviors. In the code sample below, complete the abstract class called SmartDevice so that the child class SmartLight can compile successfully.

Then, create another child class called SmartThermostat that inherits from the SmartDevice class and implements turnOn() and turnOff() functions that return print statements describing which thermostat is heating or turned off. Finally, add another function called adjustTemperature() that accepts a temperature measurement as an input and prints: $name thermostat set to $temperature°C.

Hint

In the SmartDevice class, add the turnOn() and turnOff() functions so that you can override their behavior later in the SmartThermostat class.

```
abstract class // Write your code here

class SmartLight(name: String) : SmartDevice(name) {
    override fun turnOn() {
        println("$name is now ON.")
    }

    override fun turnOff() {
        println("$name is now OFF.")
    }

   fun adjustBrightness(level: Int) {
        println("Adjusting $name brightness to $level%.")
    }
}

class SmartThermostat // Write your code here

fun main() {
    val livingRoomLight = SmartLight("Living Room Light")
    val bedroomThermostat = SmartThermostat("Bedroom Thermostat")

    livingRoomLight.turnOn()
    // Living Room Light is now ON.
    livingRoomLight.adjustBrightness(10)
    // Adjusting Living Room Light brightness to 10%.
    livingRoomLight.turnOff()
    // Living Room Light is now OFF.

    bedroomThermostat.turnOn()
    // Bedroom Thermostat thermostat is now heating.
    bedroomThermostat.adjustTemperature(5)
    // Bedroom Thermostat thermostat set to 5°C.
    bedroomThermostat.turnOff()
    // Bedroom Thermostat thermostat is now off.
}
```

```
abstract class SmartDevice(val name: String) {
    abstract fun turnOn()
    abstract fun turnOff()
}

class SmartLight(name: String) : SmartDevice(name) {
    override fun turnOn() {
        println("$name is now ON.")
    }

    override fun turnOff() {
        println("$name is now OFF.")
    }

   fun adjustBrightness(level: Int) {
        println("Adjusting $name brightness to $level%.")
    }
}

class SmartThermostat(name: String) : SmartDevice(name) {
    override fun turnOn() {
        println("$name thermostat is now heating.")
    }

    override fun turnOff() {
        println("$name thermostat is now off.")
    }

   fun adjustTemperature(temperature: Int) {
        println("$name thermostat set to $temperature°C.")
    }
}


fun main() {
    val livingRoomLight = SmartLight("Living Room Light")
    val bedroomThermostat = SmartThermostat("Bedroom Thermostat")

    livingRoomLight.turnOn()
    // Living Room Light is now ON.
    livingRoomLight.adjustBrightness(10)
    // Adjusting Living Room Light brightness to 10%.
    livingRoomLight.turnOff()
    // Living Room Light is now OFF.

    bedroomThermostat.turnOn()
    // Bedroom Thermostat thermostat is now heating.
    bedroomThermostat.adjustTemperature(5)
    // Bedroom Thermostat thermostat set to 5°C.
    bedroomThermostat.turnOff()
    // Bedroom Thermostat thermostat is now off.
}
```

Exercise 2

Create an interface called Media that you can use to implement specific media classes like Audio, Video, or Podcast. Your interface must include:

- A property called title to represent the title of the media.
- A function called play() to play the media.

Then, create a class called Audio that implements the Media interface. The Audio class must use the title property in its constructor as well as have an additional property called composer that has String type. In the class, implement the play() function to print the following: "Playing audio: $title, composed by $composer".

Hint
You can use the override keyword in class headers to implement a property from an interface in the constructor.

```
interface // Write your code here

class // Write your code here

fun main() {
    val audio = Audio("Symphony No. 5", "Beethoven")
    audio.play()
   // Playing audio: Symphony No. 5, composed by Beethoven
}
```

```
interface Media {
    val title: String
    fun play()
}

class Audio(override val title: String, val composer: String) : Media {
    override fun play() {
        println("Playing audio: $title, composed by $composer")
    }
}

fun main() {
    val audio = Audio("Symphony No. 5", "Beethoven")
    audio.play()
   // Playing audio: Symphony No. 5, composed by Beethoven
}
```

Exercise 3

You're building a payment processing system for an e-commerce application. Each payment method needs to be able to authorize a payment and process a transaction. Some payments also need to be able to process refunds.

1. In the Refundable interface, add a function called refund() to process refunds.

2. In the PaymentMethod abstract class:

   - Add a function called authorize() that takes an amount and prints a message containing the amount.

   - Add an abstract function called processPayment() that also takes an amount.

3. Create a class called CreditCard that implements the Refundable interface and PaymentMethod abstract class. In this class, add implementations for the refund() and processPayment() functions so that they print the following statements:

   - "Refunding $amount to the credit card."

   - "Processing credit card payment of $amount."

```kotlin
interface Refundable {
    // Write your code here
}

abstract class PaymentMethod(val name: String) {
    // Write your code here
}

class CreditCard // Write your code here

fun main() {
    val visa = CreditCard("Visa")

    visa.authorize(100.0)
    // Authorizing payment of $100.0.
    visa.processPayment(100.0)
    // Processing credit card payment of $100.0.
    visa.refund(50.0)
    // Refunding $50.0 to the credit card.
}
```

```kotlin
interface Refundable {
    fun refund(amount: Double)
}

abstract class PaymentMethod(val name: String) {
    fun authorize(amount: Double) {
        println("Authorizing payment of $$amount.")
    }

    abstract fun processPayment(amount: Double)
}

class CreditCard(name: String) : PaymentMethod(name), Refundable {
    override fun processPayment(amount: Double) {
        println("Processing credit card payment of $$amount.")
    }

    override fun refund(amount: Double) {
        println("Refunding $$amount to the credit card.")
    }
}

fun main() {
    val visa = CreditCard("Visa")

    visa.authorize(100.0)
    // Authorizing payment of $100.0.
    visa.processPayment(100.0)
    // Processing credit card payment of $100.0.
    visa.refund(50.0)
    // Refunding $50.0 to the credit card.
}
```

Exercise 4

You have a simple messaging app that has some basic functionality, but you want to add some functionality for smart messages without significantly duplicating your code.

In the code below, define a class called SmartMessenger that inherits from the BasicMessenger class but delegates the implementation to an instance of the

BasicMessenger class.

In the SmartMessenger class, override the sendMessage() function to send smart messages. The function must accept a message as an input and return a printed statement: "Sending a smart message: $message". In addition, call the sendMessage() function from the BasicMessenger class and prefix the message with [smart].

You don't need to rewrite the receiveMessage() function in the SmartMessenger class.

```kotlin
interface Messenger {
    fun sendMessage(message: String)
    fun receiveMessage(): String
}

class BasicMessenger : Messenger {
    override fun sendMessage(message: String) {
        println("Sending message: $message")
    }

    override fun receiveMessage(): String {
        return "You've got a new message!"
    }
}

class SmartMessenger // Write your code here

fun main() {
    val basicMessenger = BasicMessenger()
    val smartMessenger = SmartMessenger(basicMessenger)

    basicMessenger.sendMessage("Hello!")
    // Sending message: Hello!
    println(smartMessenger.receiveMessage())
    // You've got a new message!
    smartMessenger.sendMessage("Hello from SmartMessenger!")
    // Sending a smart message: Hello from SmartMessenger!
    // Sending message: [smart] Hello from SmartMessenger!
}
```

```kotlin
interface Messenger {
    fun sendMessage(message: String)
    fun receiveMessage(): String
}

class BasicMessenger : Messenger {
    override fun sendMessage(message: String) {
        println("Sending message: $message")
    }

    override fun receiveMessage(): String {
        return "You've got a new message!"
    }
}

class SmartMessenger(val basicMessenger: BasicMessenger) : Messenger by basicMessenger {
    override fun sendMessage(message: String) {
        println("Sending a smart message: $message")
        basicMessenger.sendMessage("[smart] $message")
    }
}

fun main() {
    val basicMessenger = BasicMessenger()
    val smartMessenger = SmartMessenger(basicMessenger)

    basicMessenger.sendMessage("Hello!")
    // Sending message: Hello!
    println(smartMessenger.receiveMessage())
    // You've got a new message!
    smartMessenger.sendMessage("Hello from SmartMessenger!")
    // Sending a smart message: Hello from SmartMessenger!
    // Sending message: [smart] Hello from SmartMessenger!
}
```

Next step

Intermediate: Objects

Intermediate: Objects

In this chapter, you'll expand your understanding of classes by exploring object declarations. This knowledge will help you efficiently manage behavior across your projects.

Object declarations

In Kotlin, you can use object declarations to declare a class with a single instance. In a sense, you declare the class and create the single instance at the same time. Object declarations are useful when you want to create a class to use as a single reference point for your program or to coordinate behavior across a system.

> A class that has only one instance that is easily accessible is called a singleton.

Objects in Kotlin are lazy, meaning they are created only when accessed. Kotlin also ensures that all objects are created in a thread-safe manner so that you don't have to check this manually.

To create an object declaration, use the object keyword:

```
object DoAuth {}
```

Following the name of your object, add any properties or member functions within the object body defined by curly braces {}.

> Objects can't have constructors, so they don't have headers like classes.

For example, let's say that you wanted to create an object called DoAuth that is responsible for authentication:

```
object DoAuth {
    fun takeParams(username: String, password: String) {
        println("input Auth parameters = $username:$password")
    }
}

fun main(){
    // The object is created when the takeParams() function is called
    DoAuth.takeParams("coding_ninja", "N1njaC0ding!")
    // input Auth parameters = coding_ninja:N1njaC0ding!
}
```

The object has a member function called takeParams that accepts username and password variables as parameters and returns a string to the console. The DoAuth object is only created when the function is called for the first time.

> Objects can inherit from classes and interfaces. For example:
>
> ```
> interface Auth {
>     fun takeParams(username: String, password: String)
> }
>
> object DoAuth : Auth {
>     override fun takeParams(username: String, password: String) {
>         println("input Auth parameters = $username:$password")
>     }
> }
> ```

Data objects

To make it easier to print the contents of an object declaration, Kotlin has data objects. Similar to data classes, which you learned about in the beginner tour, data objects automatically come with additional member functions: toString() and equals().

> Unlike data classes, data objects do not come automatically with the copy() member function because they only have a single instance that can't be copied.

To create a data object, use the same syntax as for object declarations but prefix it with the data keyword:

```kotlin
data object AppConfig {}
```

For example:

```kotlin
data object AppConfig {
    var appName: String = "My Application"
    var version: String = "1.0.0"
}

fun main() {
    println(AppConfig)
    // AppConfig

    println(AppConfig.appName)
    // My Application
}
```

For more information about data objects, see Data objects.

Companion objects

In Kotlin, a class can have an object: a companion object. You can only have one companion object per class. A companion object is created only when its class is referenced for the first time.

Any properties or functions declared inside a companion object are shared across all class instances.

To create a companion object within a class, use the same syntax for an object declaration but prefix it with the companion keyword:

```kotlin
companion object Bonger {}
```

> A companion object doesn't have to have a name. If you don't define one, the default is Companion.

To access any properties or functions of the companion object, reference the class name. For example:

```kotlin
class BigBen {
    companion object Bonger {
        fun getBongs(nTimes: Int) {
            repeat(nTimes) { print("BONG ") }
            }
        }
    }

fun main() {
    // Companion object is created when the class is referenced for the
    // first time.
    BigBen.getBongs(12)
    // BONG BONG BONG BONG BONG BONG BONG BONG BONG BONG BONG BONG
}
```

This example creates a class called BigBen that contains a companion object called Bonger. The companion object has a member function called getBongs() that accepts an integer and prints "BONG" to the console the same number of times as the integer.

In the main() function, the getBongs() function is called by referring to the class name. The companion object is created at this point. The getBongs() function is called with parameter 12.

For more information, see Companion objects.

Practice

Exercise 1

You run a coffee shop and have a system for tracking customer orders. Consider the code below and complete the declaration of the second data object so that the following code in the main() function runs successfully:

```
interface Order {
    val orderId: String
    val customerName: String
    val orderTotal: Double
}

data object OrderOne: Order {
    override val orderId = "001"
    override val customerName = "Alice"
    override val orderTotal = 15.50
}

data object // Write your code here

fun main() {
    // Print the name of each data object
    println("Order name: $OrderOne")
    // Order name: OrderOne
    println("Order name: $OrderTwo")
    // Order name: OrderTwo

    // Check if the orders are identical
    println("Are the two orders identical? ${OrderOne == OrderTwo}")
    // Are the two orders identical? false

    if (OrderOne == OrderTwo) {
        println("The orders are identical.")
    } else {
        println("The orders are unique.")
        // The orders are unique.
    }

    println("Do the orders have the same customer name? ${OrderOne.customerName == OrderTwo.customerName}")
    // Do the orders have the same customer name? false
}
```

```
interface Order {
    val orderId: String
    val customerName: String
    val orderTotal: Double
}

data object OrderOne: Order {
    override val orderId = "001"
    override val customerName = "Alice"
    override val orderTotal = 15.50
}

data object OrderTwo: Order {
    override val orderId = "002"
    override val customerName = "Bob"
    override val orderTotal = 12.75
}

fun main() {
    // Print the name of each data object
    println("Order name: $OrderOne")
    // Order name: OrderOne
    println("Order name: $OrderTwo")
    // Order name: OrderTwo

    // Check if the orders are identical
    println("Are the two orders identical? ${OrderOne == OrderTwo}")
    // Are the two orders identical? false
    if (OrderOne == OrderTwo) {
        println("The orders are identical.")
    } else {
        println("The orders are unique.")
        // The orders are unique.
    }

    println("Do the orders have the same customer name? ${OrderOne.customerName == OrderTwo.customerName}")
    // Do the orders have the same customer name? false
}
```

Exercise 2

Create an object declaration that inherits from the Vehicle interface to create a unique vehicle type: FlyingSkateboard. Implement the name property and the move() function in your object so that the following code in the main() function runs successfully:

```
interface Vehicle {
    val name: String
    fun move(): String
}

object // Write your code here

fun main() {
    println("${FlyingSkateboard.name}: ${FlyingSkateboard.move()}")
    // Flying Skateboard: Glides through the air with a hover engine
    println("${FlyingSkateboard.name}: ${FlyingSkateboard.fly()}")
    // Flying Skateboard: Woooooooo
}
```

```
interface Vehicle {
    val name: String
    fun move(): String
}

object FlyingSkateboard : Vehicle {
    override val name = "Flying Skateboard"
    override fun move() = "Glides through the air with a hover engine"

   fun fly(): String = "Woooooooo"
}

fun main() {
    println("${FlyingSkateboard.name}: ${FlyingSkateboard.move()}")
    // Flying Skateboard: Glides through the air with a hover engine
    println("${FlyingSkateboard.name}: ${FlyingSkateboard.fly()}")
    // Flying Skateboard: Woooooooo
}
```

Exercise 3

You have an app where you want to record temperatures. The class itself stores the information in Celsius, but you want to provide an easy way to create an instance in Fahrenheit as well. Complete the data class so that the following code in the main() function runs successfully:

Hint
Use a companion object.

```
data class Temperature(val celsius: Double) {
    val fahrenheit: Double = celsius * 9 / 5 + 32

    // Write your code here
}

fun main() {
    val fahrenheit = 90.0
    val temp = Temperature.fromFahrenheit(fahrenheit)
    println("${temp.celsius}°C is $fahrenheit °F")
    // 32.22222222222222°C is 90.0 °F
}
```

```kotlin
data class Temperature(val celsius: Double) {
    val fahrenheit: Double = celsius * 9 / 5 + 32

    companion object {
        fun fromFahrenheit(fahrenheit: Double): Temperature = Temperature((fahrenheit - 32) * 5 / 9)
    }
}

fun main() {
    val fahrenheit = 90.0
    val temp = Temperature.fromFahrenheit(fahrenheit)
    println("${temp.celsius}°C is $fahrenheit °F")
    // 32.22222222222222°C is 90.0 °F
}
```

Next step

Intermediate: Open and special classes

Intermediate: Open and special classes

In this chapter, you'll learn about open classes, how they work with interfaces, and other special types of classes available in Kotlin.

Open classes

If you can't use interfaces or abstract classes, you can explicitly make a class inheritable by declaring it as open. To do this, use the open keyword before your class declaration:

```kotlin
open class Vehicle
```

To create a class that inherits from another, add a colon after your class header followed by a call to the constructor of the parent class that you want to inherit from:

```kotlin
class Car : Vehicle
```

In this example, the Car class inherits from the Vehicle class:

```kotlin
open class Vehicle(val make: String, val model: String)

class Car(make: String, model: String, val numberOfDoors: Int) : Vehicle(make, model)

fun main() {
    // Creates an instance of the Car class
    val car = Car("Toyota", "Corolla", 4)

    // Prints the details of the car
    println("Car Info: Make - ${car.make}, Model - ${car.model}, Number of doors - ${car.numberOfDoors}")
    // Car Info: Make - Toyota, Model - Corolla, Number of doors - 4
}
```

Just like when creating a normal class instance, if your class inherits from a parent class, then it must initialize all the parameters declared in the parent class header. So in the example, the car instance of the Car class initializes the parent class parameters: make and model.

Overriding inherited behavior

If you want to inherit from a class but change some of the behavior, you can override the inherited behavior.

By default, it's not possible to override a member function or property of a parent class. Just like with abstract classes, you need to add special keywords.

Member functions

To allow a function in the parent class to be overridden, use the open keyword before its declaration in the parent class:

```
open fun displayInfo() {}
```

To override an inherited member function, use the override keyword before the function declaration in the child class:

```
override fun displayInfo() {}
```

For example:

```
open class Vehicle(val make: String, val model: String) {
    open fun displayInfo() {
        println("Vehicle Info: Make - $make, Model - $model")
    }
}

class Car(make: String, model: String, val numberOfDoors: Int) : Vehicle(make, model) {
    override fun displayInfo() {
        println("Car Info: Make - $make, Model - $model, Number of Doors - $numberOfDoors")
    }
}

fun main() {
    val car1 = Car("Toyota", "Corolla", 4)
    val car2 = Car("Honda", "Civic", 2)

    // Uses the overridden displayInfo() function
    car1.displayInfo()
    // Car Info: Make - Toyota, Model - Corolla, Number of Doors - 4
    car2.displayInfo()
    // Car Info: Make - Honda, Model - Civic, Number of Doors - 2
}
```

This example:

- Creates two instances of the Car class that inherit from the Vehicle class: car1 and car2.
- Overrides the displayInfo() function in the Car class to also print the number of doors.
- Calls the overridden displayInfo() function on car1 and car2 instances.

Properties

In Kotlin, it's not common practice to make a property inheritable by using the open keyword and overriding it later. Most of the time, you use an abstract class or an interface where properties are inheritable by default.

Properties inside open classes are accessible by their child class. In general, it's better to access them directly rather than override them with a new property.

For example, let's say that you have a property called transmissionType that you want to override later. The syntax for overriding properties is exactly the same as for overriding member functions. You can do this:

```
open class Vehicle(val make: String, val model: String) {
    open val transmissionType: String = "Manual"
}

class Car(make: String, model: String, val numberOfDoors: Int) : Vehicle(make, model) {
    override val transmissionType: String = "Automatic"
}
```

However, this is not good practice. Instead, you can add the property to the constructor of your inheritable class and declare its value when you create theCar child class:

```
open class Vehicle(val make: String, val model: String, val transmissionType: String = "Manual")

class Car(make: String, model: String, val numberOfDoors: Int) : Vehicle(make, model, "Automatic")
```

Accessing properties directly, instead of overriding them, leads to simpler and more readable code. By declaring properties once in the parent class and passing their values through the constructor, you eliminate the need for unnecessary overrides in child classes.

For more information about class inheritance and overriding class behavior, see Inheritance.

Open classes and interfaces

You can create a class that inherits a class and implements multiple interfaces. In this case, you must declare the parent class first, after the colon, before listing the interfaces:

```kotlin
// Define interfaces
interface EcoFriendly {
    val emissionLevel: String
}

interface ElectricVehicle {
    val batteryCapacity: Double
}

// Parent class
open class Vehicle(val make: String, val model: String)

// Child class
open class Car(make: String, model: String, val numberOfDoors: Int) : Vehicle(make, model)

// New class that inherits from Car and implements two interfaces
class ElectricCar(
    make: String,
    model: String,
    numberOfDoors: Int,
    val capacity: Double,
    val emission: String
) : Car(make, model, numberOfDoors), EcoFriendly, ElectricVehicle {
    override val batteryCapacity: Double = capacity
    override val emissionLevel: String = emission
}
```

Special classes

In addition to abstract, open, and data classes, Kotlin has special types of classes designed for various purposes, such as restricting specific behavior or reducing the performance impact of creating small objects.

Sealed classes

There may be times when you want to restrict inheritance. You can do this with sealed classes. Sealed classes are a special type of abstract class. Once you declare that a class is sealed, you can only create child classes from it within the same package. It's not possible to inherit from the sealed class outside of this scope.

> A package is a collection of code with related classes and functions, typically within a directory. To learn more about packages in Kotlin, see Packages and imports.

To create a sealed class, use the sealed keyword:

```kotlin
sealed class Mammal
```

Sealed classes are particularly useful when combined with a when expression. By using a when expression, you can define the behavior for all possible child classes. For example:

```kotlin
sealed class Mammal(val name: String)

class Cat(val catName: String) : Mammal(catName)
class Human(val humanName: String, val job: String) : Mammal(humanName)

fun greetMammal(mammal: Mammal): String {
    when (mammal) {
        is Human -> return "Hello ${mammal.name}; You're working as a ${mammal.job}"
        is Cat -> return "Hello ${mammal.name}"
    }
}

fun main() {
    println(greetMammal(Cat("Snowy")))
    // Hello Snowy
}
```

In the example:

- There is a sealed class called Mammal that has the name parameter in the constructor.
- The Cat class inherits from the Mammal sealed class and uses the name parameter from the Mammal class as the catName parameter in its own constructor.
- The Human class inherits from the Mammal sealed class and uses the name parameter from the Mammal class as the humanName parameter in its own constructor. It also has the job parameter in its constructor.
- The greetMammal() function accepts an argument of Mammal type and returns a string.
- Within the greetMammal() function body, there's a when expression that uses the is operator to check the type of mammal and decide which action to perform.
- The main() function calls the greetMammal() function with an instance of the Cat class and name parameter called Snowy.

> This tour discusses the is operator in more detail in the Null safety chapter.

For more information about sealed classes and their recommended use cases, see Sealed classes and interfaces.

Enum classes

Enum classes are useful when you want to represent a finite set of distinct values in a class. An enum class contains enum constants, which are themselves instances of the enum class.

To create an enum class, use the enum keyword:

```
enum class State
```

Let's say that you want to create an enum class that contains the different states of a process. Each enum constant must be separated by a comma ,:

```
enum class State {
    IDLE, RUNNING, FINISHED
}
```

The State enum class has enum constants: IDLE, RUNNING, and FINISHED. To access an enum constant, use the class name followed by a . and the name of the enum constant:

```
val state = State.RUNNING
```

You can use this enum class with a when expression to define the action to take depending on the value of the enum constant:

```
enum class State {
    IDLE, RUNNING, FINISHED
}

fun main() {
    val state = State.RUNNING
    val message = when (state) {
        State.IDLE -> "It's idle"
        State.RUNNING -> "It's running"
        State.FINISHED -> "It's finished"
    }
    println(message)
    // It's running
}
```

Enum classes can have properties and member functions just like normal classes.

For example, let's say you're working with HTML and you want to create an enum class containing some colors. You want each color to have a property, let's call it rgb, that contains their RGB value as a hexadecimal. When creating the enum constants, you must initialize it with this property:

```
enum class Color(val rgb: Int) {
    RED(0xFF0000),
    GREEN(0x00FF00),
    BLUE(0x0000FF),
    YELLOW(0xFFFF00)
}
```

Kotlin stores hexadecimals as integers, so the rgb property has the Int type, not the String type.

To add a member function to this class, separate it from the enum constants with a semicolon ;:

```
enum class Color(val rgb: Int) {
    RED(0xFF0000),
    GREEN(0x00FF00),
    BLUE(0x0000FF),
    YELLOW(0xFFFF00);

    fun containsRed() = (this.rgb and 0xFF0000 != 0)
}

fun main() {
    val red = Color.RED

    // Calls containsRed() function on enum constant
    println(red.containsRed())
    // true

    // Calls containsRed() function on enum constants via class names
    println(Color.BLUE.containsRed())
    // false

    println(Color.YELLOW.containsRed())
    // true
}
```

In this example, the containsRed() member function accesses the value of the enum constant's rgb property using the this keyword and checks if the hexadecimal value contains FF as its first bits to return a boolean value.

For more information, see Enum classes.

Inline value classes

Sometimes in your code, you may want to create small objects from classes and use them only briefly. This approach can have a performance impact. Inline value classes are a special type of class that avoids this performance impact. However, they can only contain values.

To create an inline value class, use the value keyword and the @JvmInline annotation:

```
@JvmInline
value class Email
```

The @JvmInline annotation instructs Kotlin to optimize the code when it is compiled. To learn more, see Annotations.

An inline value class must have a single property initialized in the class header.

Let's say that you want to create a class that collects an email address:

```
// The address property is initialized in the class header.
@JvmInline
value class Email(val address: String)

fun sendEmail(email: Email) {
    println("Sending email to ${email.address}")
}

fun main() {
    val myEmail = Email("example@example.com")
    sendEmail(myEmail)
    // Sending email to example@example.com
}
```

In the example:

- Email is an inline value class that has one property in the class header: address.
- The sendEmail() function accepts objects with type Email and prints a string to the standard output.
- The main() function:
  - Creates an instance of the Email class called email.
  - Calls the sendEmail() function on the email object.

By using an inline value class, you make the class inlined and can use it directly in your code without creating an object. This can significantly reduce memory footprint and improve your code's runtime performance.

For more information about inline value classes, see Inline value classes.

Practice

Exercise 1

You manage a delivery service and need a way to track the status of packages. Create a sealed class called DeliveryStatus, containing data classes to represent the following statuses: Pending, InTransit, Delivered, Canceled. Complete the DeliveryStatus class declaration so that the code in the main() function runs successfully:

```
sealed class // Write your code here

fun printDeliveryStatus(status: DeliveryStatus) {
    when (status) {
        is DeliveryStatus.Pending -> {
            println("The package is pending pickup from ${status.sender}.")
        }
        is DeliveryStatus.InTransit -> {
            println("The package is in transit and expected to arrive by ${status.estimatedDeliveryDate}.")
        }
        is DeliveryStatus.Delivered -> {
            println("The package was delivered to ${status.recipient} on ${status.deliveryDate}.")
        }
        is DeliveryStatus.Canceled -> {
            println("The delivery was canceled due to: ${status.reason}.")
        }
    }
}

fun main() {
    val status1: DeliveryStatus = DeliveryStatus.Pending("Alice")
    val status2: DeliveryStatus = DeliveryStatus.InTransit("2024-11-20")
    val status3: DeliveryStatus = DeliveryStatus.Delivered("2024-11-18", "Bob")
    val status4: DeliveryStatus = DeliveryStatus.Canceled("Address not found")

    printDeliveryStatus(status1)
    // The package is pending pickup from Alice.
    printDeliveryStatus(status2)
    // The package is in transit and expected to arrive by 2024-11-20.
    printDeliveryStatus(status3)
    // The package was delivered to Bob on 2024-11-18.
    printDeliveryStatus(status4)
    // The delivery was canceled due to: Address not found.
}
```

```
sealed class DeliveryStatus {
    data class Pending(val sender: String) : DeliveryStatus()
    data class InTransit(val estimatedDeliveryDate: String) : DeliveryStatus()
    data class Delivered(val deliveryDate: String, val recipient: String) : DeliveryStatus()
    data class Canceled(val reason: String) : DeliveryStatus()
}

fun printDeliveryStatus(status: DeliveryStatus) {
    when (status) {
        is DeliveryStatus.Pending -> {
            println("The package is pending pickup from ${status.sender}.")
        }
        is DeliveryStatus.InTransit -> {
            println("The package is in transit and expected to arrive by ${status.estimatedDeliveryDate}.")
        }
        is DeliveryStatus.Delivered -> {
            println("The package was delivered to ${status.recipient} on ${status.deliveryDate}.")
        }
        is DeliveryStatus.Canceled -> {
            println("The delivery was canceled due to: ${status.reason}.")
        }
    }
}

fun main() {
    val status1: DeliveryStatus = DeliveryStatus.Pending("Alice")
    val status2: DeliveryStatus = DeliveryStatus.InTransit("2024-11-20")
    val status3: DeliveryStatus = DeliveryStatus.Delivered("2024-11-18", "Bob")
    val status4: DeliveryStatus = DeliveryStatus.Canceled("Address not found")

    printDeliveryStatus(status1)
    // The package is pending pickup from Alice.
    printDeliveryStatus(status2)
    // The package is in transit and expected to arrive by 2024-11-20.
    printDeliveryStatus(status3)
    // The package was delivered to Bob on 2024-11-18.
    printDeliveryStatus(status4)
    // The delivery was canceled due to: Address not found.
}
```

Exercise 2

In your program, you want to be able to handle different statuses and types of errors. You have a sealed class to capture the different statuses which are declared in data classes or objects. Complete the code below by creating an enum class called Problem that represents the different problem types: NETWORK, TIMEOUT, and UNKNOWN.

```
sealed class Status {
    data object Loading : Status()
    data class Error(val problem: Problem) : Status() {
        // Write your code here
    }

    data class OK(val data: List<String>) : Status()
}

fun handleStatus(status: Status) {
    when (status) {
        is Status.Loading -> println("Loading...")
        is Status.OK -> println("Data received: ${status.data}")
        is Status.Error -> when (status.problem) {
            Status.Error.Problem.NETWORK -> println("Network issue")
            Status.Error.Problem.TIMEOUT -> println("Request timed out")
            Status.Error.Problem.UNKNOWN -> println("Unknown error occurred")
        }
    }
}

fun main() {
    val status1: Status = Status.Error(Status.Error.Problem.NETWORK)
    val status2: Status = Status.OK(listOf("Data1", "Data2"))

    handleStatus(status1)
    // Network issue
    handleStatus(status2)
    // Data received: [Data1, Data2]
}
```

```
sealed class Status {
    data object Loading : Status()
    data class Error(val problem: Problem) : Status() {
        enum class Problem {
            NETWORK,
            TIMEOUT,
            UNKNOWN
        }
    }

    data class OK(val data: List<String>) : Status()
}

fun handleStatus(status: Status) {
    when (status) {
        is Status.Loading -> println("Loading...")
        is Status.OK -> println("Data received: ${status.data}")
        is Status.Error -> when (status.problem) {
            Status.Error.Problem.NETWORK -> println("Network issue")
            Status.Error.Problem.TIMEOUT -> println("Request timed out")
            Status.Error.Problem.UNKNOWN -> println("Unknown error occurred")
        }
    }
}

fun main() {
    val status1: Status = Status.Error(Status.Error.Problem.NETWORK)
    val status2: Status = Status.OK(listOf("Data1", "Data2"))

    handleStatus(status1)
    // Network issue
    handleStatus(status2)
    // Data received: [Data1, Data2]
}
```

Next step

Intermediate: Properties

Intermediate: Properties

In the beginner tour, you learned how properties are used to declare characteristics of class instances and how to access them. This chapter digs deeper into how properties work in Kotlin and explores other ways that you can use them in your code.

Backing fields

In Kotlin, properties have default get() and set() functions, known as property accessors, which handle retrieving and modifying their values. While these default functions are not explicitly visible in the code, the compiler automatically generates them to manage property access behind the scenes. These accessors use a backing field to store the actual property value.

Backing fields exist if either of the following is true:

- You use the default get() or set() functions for the property.
- You try to access the property value in code by using the field keyword.

> get() and set() functions are also called getters and setters.

For example, this code has the category property that has no custom get() or set() functions and therefore uses the default implementations:

```
class Contact(val id: Int, var email: String) {
    val category: String = ""
}
```

Under the hood, this is equivalent to this pseudocode:

```
class Contact(val id: Int, var email: String) {
    val category: String = ""
        get() = field
        set(value) {
            field = value
        }
}
```

In this example:

- The get() function retrieves the property value from the field: "".
- The set() function accepts value as a parameter and assigns it to the field, where value is "".

Access to the backing field is useful when you want to add extra logic in your get() or set() functions without causing an infinite loop. For example, you have a Person class with a name property:

```
class Person {
    var name: String = ""
}
```

You want to ensure that the first letter of the name property is capitalized, so you create a custom set() function that uses the .replaceFirstChar() and .uppercase() extension functions. However, if you refer to the property directly in your set() function, you create an infinite loop and see a StackOverflowError at runtime:

```
class Person {
    var name: String = ""
        set(value) {
            // This causes a runtime error
            name = value.replaceFirstChar { firstChar -> firstChar.uppercase() }
        }
}

fun main() {
    val person = Person()
    person.name = "kodee"
    println(person.name)
    // Exception in thread "main" java.lang.StackOverflowError
}
```

To fix this, you can use the backing field in your set() function instead by referencing it with the field keyword:

```
class Person {
    var name: String = ""
        set(value) {
            field = value.replaceFirstChar { firstChar -> firstChar.uppercase() }
        }
}

fun main() {
    val person = Person()
    person.name = "kodee"
    println(person.name)
    // Kodee
}
```

Backing fields are also useful when you want to add logging, send notifications when a property value changes, or use additional logic that compares the old and new property values.

For more information, see Backing fields.

Extension properties

Just like extension functions, there are also extension properties. Extension properties allow you to add new properties to existing classes without modifying their source code. However, extension properties in Kotlin do not have backing fields. This means that you need to write the get() and set() functions yourself. Additionally, the lack of a backing field means that they can't hold any state.

To declare an extension property, write the name of the class that you want to extend followed by a . and the name of your property. Just like with normal class properties, you need to declare a receiver type for your property. For example:

```
val String.lastChar: Char
```

Extension properties are most useful when you want a property to contain a computed value without using inheritance. You can think of extension properties working like a function with only one parameter: the receiver object.

For example, let's say that you have a data class called Person with two properties: firstName and lastName.

```
data class Person(val firstName: String, val lastName: String)
```

You want to be able to access the person's full name without modifying the Person data class or inheriting from it. You can do this by creating an extension property with a custom get() function:

```
data class Person(val firstName: String, val lastName: String)

// Extension property to get the full name
val Person.fullName: String
    get() = "$firstName $lastName"

fun main() {
    val person = Person(firstName = "John", lastName = "Doe")

    // Use the extension property
    println(person.fullName)
    // John Doe
}
```

Extension properties can't override existing properties of a class.

Just like with extension functions, the Kotlin standard library uses extension properties widely. For example, see the lastIndex property for a CharSequence.

Delegated properties

You already learned about delegation in the Classes and interfaces chapter. You can also use delegation with properties to delegate their property accessors to another object. This is useful when you have more complex requirements for storing properties that a simple backing field can't handle, such as storing values in a database table, browser session, or map. Using delegated properties also reduces boilerplate code because the logic for getting and setting your properties is contained only in the object that you delegate to.

The syntax is similar to using delegation with classes but operates on a different level. Declare your property, followed by the by keyword and the object you want to delegate to. For example:

```
val displayName: String by Delegate
```

Here, the delegated property displayName refers to the Delegate object for its property accessors.

Every object you delegate to must have a getValue() operator function, which Kotlin uses to retrieve the value of the delegated property. If the property is mutable, it must also have a setValue() operator function for Kotlin to set its value.

By default, the getValue() and setValue() functions have the following construction:

```
operator fun getValue(thisRef: Any?, property: KProperty<*>): String {}

operator fun setValue(thisRef: Any?, property: KProperty<*>, value: String) {}
```

In these functions:

- The operator keyword marks these functions as operator functions, enabling them to overload the get() and set() functions.
- The thisRef parameter refers to the object containing the delegated property. By default, the type is set to Any?, but you may need to declare a more specific type.
- The property parameter refers to the property whose value is accessed or changed. You can use this parameter to access information like the property's name

or type. By default, the type is set to Any?. You don't need to worry about changing this in your code.

The getValue() function has a return type of String by default, but you can adjust this if you want.

The setValue() function has an additional parameter value, which is used to hold the new value that's assigned to the property.

So, how does this look in practice? Suppose you want to have a computed property, like a user's display name, that is calculated only once because the operation is expensive and your application is performance-sensitive. You can use a delegated property to cache the display name so that it is only computed once but can be accessed anytime without performance impact.

First, you need to create the object to delegate to. In this case, the object will be an instance of the CachedStringDelegate class:

```kotlin
class CachedStringDelegate {
    var cachedValue: String? = null
}
```

The cachedValue property contains the cached value. Within the CachedStringDelegate class, add the behavior that you want from the get() function of the delegated property to the getValue() operator function body:

```kotlin
class CachedStringDelegate {
    var cachedValue: String? = null

    operator fun getValue(thisRef: Any?, property: Any?): String {
        if (cachedValue == null) {
            cachedValue = "Default Value"
            println("Computed and cached: $cachedValue")
        } else {
            println("Accessed from cache: $cachedValue")
        }
        return cachedValue ?: "Unknown"
    }
}
```

The getValue() function checks whether the cachedValue property is null. If it is, the function assigns the "Default value" and prints a string for logging purposes. If the cachedValue property has already been computed, the property isn't null. In this case, another string is printed for logging purposes. Finally, the function uses the Elvis operator to return the cached value or "Unknown" if the value is null.

Now you can delegate the property that you want to cache (val displayName) to an instance of the CachedStringDelegate class:

```kotlin
class CachedStringDelegate {
    var cachedValue: String? = null

    operator fun getValue(thisRef: User, property: Any?): String {
        if (cachedValue == null) {
            cachedValue = "${thisRef.firstName} ${thisRef.lastName}"
            println("Computed and cached: $cachedValue")
        } else {
            println("Accessed from cache: $cachedValue")
        }
        return cachedValue ?: "Unknown"
    }
}

class User(val firstName: String, val lastName: String) {
    val displayName: String by CachedStringDelegate()
}

fun main() {
    val user = User("John", "Doe")

    // First access computes and caches the value
    println(user.displayName)
    // Computed and cached: John Doe
    // John Doe

    // Subsequent accesses retrieve the value from cache
    println(user.displayName)
    // Accessed from cache: John Doe
    // John Doe
}
```

This example:

- Creates a User class that has two properties in the header, firstName, and lastName, and one property in the class body, displayName.
- Delegates the displayName property to an instance of the CachedStringDelegate class.
- Creates an instance of the User class called user.
- Prints the result of accessing the displayName property on the user instance.

Note that in the getValue() function, the type for the thisRef parameter is narrowed from Any? type to the object type: User. This is so that the compiler can access the firstName and lastName properties of the User class.

Standard delegates

The Kotlin standard library provides some useful delegates for you so you don't have to always create yours from scratch. If you use one of these delegates, you don't need to define getValue() and setValue() functions because the standard library automatically provides them.

Lazy properties

To initialize a property only when it's first accessed, use a lazy property. The standard library provides the Lazy interface for delegation.

To create an instance of the Lazy interface, use the lazy() function by providing it with a lambda expression to execute when the get() function is called for the first time. Any further calls of the get() function return the same result that was provided on the first call. Lazy properties use the trailing lambda syntax to pass the lambda expression.

For example:

```kotlin
class Database {
    fun connect() {
        println("Connecting to the database...")
    }

    fun query(sql: String): List<String> {
        return listOf("Data1", "Data2", "Data3")
    }
}

val databaseConnection: Database by lazy {
    val db = Database()
    db.connect()
    db
}

fun fetchData() {
    val data = databaseConnection.query("SELECT * FROM data")
    println("Data: $data")
}

fun main() {
    // First time accessing databaseConnection
    fetchData()
    // Connecting to the database...
    // Data: [Data1, Data2, Data3]

    // Subsequent access uses the existing connection
    fetchData()
    // Data: [Data1, Data2, Data3]
}
```

In this example:

- There is a Database class with connect() and query() member functions.
- The connect() function prints a string to the console, and the query() function accepts an SQL query and returns a list.
- There is a databaseConnection property that is a lazy property.
- The lambda expression provided to the lazy() function:
  - Creates an instance of the Database class.
  - Calls the connect() member function on this instance (db).

- Returns the instance.

- There is a fetchData() function that:
  - Creates an SQL query by calling the query() function on the databaseConnection property.
  - Assigns the SQL query to the data variable.
  - Prints the data variable to the console.
- The main() function calls the fetchData() function. The first time it is called, the lazy property is initialized. The second time, the same result is returned as the first call.

Lazy properties are useful not only when initialization is resource-intensive but also when a property might not be used in your code. Additionally, lazy properties are thread-safe by default, which is particularly beneficial if you are working in a concurrent environment.

For more information, see Lazy properties.

Observable properties

To monitor whether the value of a property changes, use an observable property. An observable property is useful when you want to detect a change in the property value and use this knowledge to trigger a reaction. The standard library provides the Delegates object for delegation.

To create an observable property, you must first import kotlin.properties.Delegates.observable. Then, use the observable() function and provide it with a lambda expression to execute whenever the property changes. Just like with lazy properties, observable properties use the trailing lambda syntax to pass the lambda expression.

For example:

```kotlin
import kotlin.properties.Delegates.observable

class Thermostat {
    var temperature: Double by observable(20.0) { _, old, new ->
        if (new > 25) {
            println("Warning: Temperature is too high! ($old°C -> $new°C)")
        } else {
            println("Temperature updated: $old°C -> $new°C")
        }
    }
}

fun main() {
    val thermostat = Thermostat()
    thermostat.temperature = 22.5
    // Temperature updated: 20.0°C -> 22.5°C

    thermostat.temperature = 27.0
    // Warning: Temperature is too high! (22.5°C -> 27.0°C)
}
```

In this example:

- There is a Thermostat class that contains an observable property: temperature.
- The observable() function accepts 20.0 as a parameter and uses it to initialize the property.
- The lambda expression provided to the observable() function:
  - Has three parameters:
    - _, which refers to the property itself.
    - old, which is the old value of the property.
    - new, which is the new value of the property.
  - Checks if the new parameter is greater than 25 and, depending on the result, prints a string to console.
- The main() function:
  - Creates an instance of the Thermostat class called thermostat.

- Updates the value of the temperature property of the instance to 22.5, which triggers a print statement with a temperature update.
- Updates the value of the temperature property of the instance to 27.0, which triggers a print statement with a warning.

Observable properties are useful not only for logging and debugging purposes. You can also use them for use cases like updating a UI or to perform additional checks, like verifying the validity of data.

For more information, see Observable properties.

Practice

Exercise 1

You manage an inventory system at a bookstore. The inventory is stored in a list where each item represents the quantity of a specific book. For example, listOf(3, 0, 7, 12) means the store has 3 copies of the first book, 0 of the second, 7 of the third, and 12 of the fourth.

Write a function called findOutOfStockBooks() that returns a list of indices for all the books that are out of stock.

Hint 1
Use the indices extension property from the standard library.

Hint 2
You can use the buildList() function to create and manage a list instead of manually creating and returning a mutable list. The buildList() function uses a lambda with a receiver, which you learned about in earlier chapters.

```kotlin
fun findOutOfStockBooks(inventory: List<Int>): List<Int> {
    // Write your code here
}

fun main() {
    val inventory = listOf(3, 0, 7, 0, 5)
    println(findOutOfStockBooks(inventory))
    // [1, 3]
}
```

```kotlin
fun findOutOfStockBooks(inventory: List<Int>): List<Int> {
    val outOfStockIndices = mutableListOf<Int>()
    for (index in inventory.indices) {
        if (inventory[index] == 0) {
            outOfStockIndices.add(index)
        }
    }
    return outOfStockIndices
}

fun main() {
    val inventory = listOf(3, 0, 7, 0, 5)
    println(findOutOfStockBooks(inventory))
    // [1, 3]
}
```

```kotlin
fun findOutOfStockBooks(inventory: List<Int>): List<Int> = buildList {
    for (index in inventory.indices) {
        if (inventory[index] == 0) {
            add(index)
        }
    }
}

fun main() {
    val inventory = listOf(3, 0, 7, 0, 5)
    println(findOutOfStockBooks(inventory))
    // [1, 3]
}
```

Exercise 2

You have a travel app that needs to display distances in both kilometers and miles. Create an extension property for the Double type called asMiles to convert a distance in kilometers to miles:

> The formula to convert kilometers to miles is miles = kilometers * 0.621371.

Hint
Remember that extension properties need a custom get() function.

```
val // Write your code here

fun main() {
    val distanceKm = 5.0
    println("$distanceKm km is ${distanceKm.asMiles} miles")
    // 5.0 km is 3.106855 miles

    val marathonDistance = 42.195
    println("$marathonDistance km is ${marathonDistance.asMiles} miles")
    // 42.195 km is 26.218757 miles
}
```

```
val Double.asMiles: Double
    get() = this * 0.621371

fun main() {
    val distanceKm = 5.0
    println("$distanceKm km is ${distanceKm.asMiles} miles")
    // 5.0 km is 3.106855 miles

    val marathonDistance = 42.195
    println("$marathonDistance km is ${marathonDistance.asMiles} miles")
    // 42.195 km is 26.218757 miles
}
```

Exercise 3

You have a system health checker that can determine the state of a cloud system. However, the two functions it can run to perform a health check are performance intensive. Use lazy properties to initialize the checks so that the expensive functions are only run when needed:

```
fun checkAppServer(): Boolean {
    println("Performing application server health check...")
    return true
}

fun checkDatabase(): Boolean {
    println("Performing database health check...")
    return false
}

fun main() {
    // Write your code here

    when {
        isAppServerHealthy -> println("Application server is online and healthy")
        isDatabaseHealthy -> println("Database is healthy")
        else -> println("System is offline")
    }
    // Performing application server health check...
    // Application server is online and healthy
}
```

```
fun checkAppServer(): Boolean {
    println("Performing application server health check...")
    return true
}

fun checkDatabase(): Boolean {
    println("Performing database health check...")
    return false
}

fun main() {
    val isAppServerHealthy by lazy { checkAppServer() }
    val isDatabaseHealthy by lazy { checkDatabase() }

    when {
        isAppServerHealthy -> println("Application server is online and healthy")
        isDatabaseHealthy -> println("Database is healthy")
        else -> println("System is offline")
    }
   // Performing application server health check...
   // Application server is online and healthy
}
```

Exercise 4

You're building a simple budget tracker app. The app needs to observe changes to the user's remaining budget and notify them whenever it goes below a certain threshold. You have a Budget class that is initialized with a totalBudget property that contains the initial budget amount. Within the class, create an observable property called remainingBudget that prints:

- A warning when the value is lower than 20% of the initial budget.
- An encouraging message when the budget is increased from the previous value.

```
import kotlin.properties.Delegates.observable

class Budget(val totalBudget: Int) {
    var remainingBudget: Int // Write your code here
}

fun main() {
    val myBudget = Budget(totalBudget = 1000)
    myBudget.remainingBudget = 800
    myBudget.remainingBudget = 150
    // Warning: Your remaining budget (150) is below 20% of your total budget.
    myBudget.remainingBudget = 50
    // Warning: Your remaining budget (50) is below 20% of your total budget.
    myBudget.remainingBudget = 300
    // Good news: Your remaining budget increased to 300.
}
```

```
import kotlin.properties.Delegates.observable

class Budget(val totalBudget: Int) {
  var remainingBudget: Int by observable(totalBudget) { _, oldValue, newValue ->
    if (newValue < totalBudget * 0.2) {
      println("Warning: Your remaining budget ($newValue) is below 20% of your total budget.")
    } else if (newValue > oldValue) {
      println("Good news: Your remaining budget increased to $newValue.")
    }
  }
}

fun main() {
  val myBudget = Budget(totalBudget = 1000)
  myBudget.remainingBudget = 800
  myBudget.remainingBudget = 150
  // Warning: Your remaining budget (150) is below 20% of your total budget.
  myBudget.remainingBudget = 50
  // Warning: Your remaining budget (50) is below 20% of your total budget.
  myBudget.remainingBudget = 300
  // Good news: Your remaining budget increased to 300.
}
```

Next step

Intermediate: Null safety

Intermediate: Null safety

In the beginner tour, you learned how to handle null values in your code. This chapter covers common use cases for null safety features and how to make the most of them.

Smart casts and safe casts

Kotlin can sometimes infer the type without explicit declaration. When you tell Kotlin to treat a variable or object as if it belongs to a specific type, this process is called casting. When a type is automatically cast, like when it's inferred, it's called smart casting.

is and !is operators

Before we explore how casting works, let's see how you can check if an object has a certain type. For this, you can use the is and !is operators with when or if conditional expressions:

- is checks if the object has the type and returns a boolean value.
- !is checks if the object doesn't have the type and returns a boolean value.

For example:

```kotlin
fun printObjectType(obj: Any) {
    when (obj) {
        is Int -> println("It's an Integer with value $obj")
        !is Double -> println("It's NOT a Double")
        else -> println("Unknown type")
    }
}

fun main() {
    val myInt = 42
    val myDouble = 3.14
    val myList = listOf(1, 2, 3)

    // The type is Int
    printObjectType(myInt)
    // It's an Integer with value 42

    // The type is List, so it's NOT a Double.
    printObjectType(myList)
    // It's NOT a Double

    // The type is Double, so the else branch is triggered.
    printObjectType(myDouble)
    // Unknown type
}
```

You've already seen an example of how to use a when conditional expression with the is and !is operators in the Open and other special classes chapter.

as and as? operators

To explicitly cast an object to any other type, use the as operator. This includes casting from a nullable type to its non-nullable counterpart. If the cast isn't possible, the program crashes at runtime. This is why it's called the unsafe cast operator.

```kotlin
fun main() {
    val a: String? = null
    val b = a as String

    // Triggers an error at runtime
    print(b)
}
```

To explicitly cast an object to a non-nullable type, but return null instead of throwing an error on failure, use the as? operator. Since the as? operator doesn't trigger an error on failure, it is called the safe operator.

```kotlin
fun main() {
    val a: String? = null
    val b = a as? String

    // Returns null value
    print(b)
    // null
}
```

You can combine the as? operator with the Elvis operator ?: to reduce several lines of code down to one. For example, the following calculateTotalStringLength() function calculates the total length of all strings provided in a mixed list:

```kotlin
fun calculateTotalStringLength(items: List<Any>): Int {
    var totalLength = 0

    for (item in items) {
        totalLength += if (item is String) {
            item.length
        } else {
            0  // Add 0 for non-String items
        }
    }

    return totalLength
}
```

The example:

- Uses the totalLength variable as a counter.
- Uses a for loop to loop through every item in the list.
- Uses an if and the is operator to check if the current item is a string:
  - If it is, the string's length is added to the counter.
  - If it is not, the counter isn't incremented.
- Returns the final value of the totalLength variable.

This code can be reduced to:

```kotlin
fun calculateTotalStringLength(items: List<Any>): Int {
    return items.sumOf { (it as? String)?.length ?: 0 }
}
```

The example uses the .sumOf() extension function and provides a lambda expression that:

- For each item in the list, performs a safe cast to String using as?.
- Uses a safe call ?. to access the length property if the call doesn't return a null value.
- Uses the Elvis operator ?: to return 0 if the safe call returns a null value.

Null values and collections

In Kotlin, working with collections often involves handling null values and filtering out unnecessary elements. Kotlin has useful functions that you can use to write clean, efficient, and null-safe code when working with lists, sets, maps, and other types of collections.

To filter null values from a list, use the filterNotNull() function:

```kotlin
fun main() {
    val emails: List<String?> = listOf("alice@example.com", null, "bob@example.com", null, "carol@example.com")

    val validEmails = emails.filterNotNull()

    println(validEmails)
    // [alice@example.com, bob@example.com, carol@example.com]
}
```

If you want to perform filtering of null values directly when creating a list, use the listOfNotNull() function:

```
fun main() {
    val serverConfig = mapOf(
        "appConfig.json" to "App Configuration",
        "dbConfig.json" to "Database Configuration"
    )

    val requestedFile = "appConfig.json"
    val configFiles = listOfNotNull(serverConfig[requestedFile])

    println(configFiles)
    // [App Configuration]
}
```

In both of these examples, if all items are null values, an empty list is returned.

Kotlin also provides functions that you can use to find values in collections. If a value isn't found, they return null values instead of triggering an error:

- singleOrNull() looks for only one item by its exact value. If one doesn't exist or there are multiple items with the same value, returns a null value.
- maxOrNull() finds the highest value. If one doesn't exist, returns a null value.
- minOrNull() finds the lowest value. If one doesn't exist, returns a null value.

For example:

```
fun main() {
    // Temperatures recorded over a week
    val temperatures = listOf(15, 18, 21, 21, 19, 17, 16)

    // Check if there was exactly one day with 30 degrees
    val singleHotDay = temperatures.singleOrNull()
    println("Single hot day with 30 degrees: ${singleHotDay ?: "None"}")
    // Single hot day with 30 degrees: None

    // Find the highest temperature of the week
    val maxTemperature = temperatures.maxOrNull()
    println("Highest temperature recorded: ${maxTemperature ?: "No data"}")
    // Highest temperature recorded: 21

    // Find the lowest temperature of the week
    val minTemperature = temperatures.minOrNull()
    println("Lowest temperature recorded: ${minTemperature ?: "No data"}")
    // Lowest temperature recorded: 15
}
```

This example uses the Elvis operator ?: to return a printed statement if the functions return a null value.

> The singleOrNull(), maxOrNull(), and minOrNull() functions are designed to be used with collections that don't contain null values. Otherwise, you can't tell whether the function couldn't find the desired value or whether it found a null value.

Some functions use a lambda expression to transform a collection and return null values if they can't fulfill their purpose.

For example, to transform a collection with a lambda expression and return the first value that isn't null, use the firstNotNullOfOrNull() function. If no such value exists, the function returns a null value:

```
fun main() {
    data class User(val name: String?, val age: Int?)

    val users = listOf(
        User(null, 25),
        User("Alice", null),
        User("Bob", 30)
    )

    val firstNonNullName = users.firstNotNullOfOrNull { it.name }
    println(firstNonNullName)
    // Alice
}
```

To use a lambda function to process each collection item sequentially and create an accumulated value (or return a null value if the collection is empty) use the reduceOrNull() function:

```
fun main() {
    // Prices of items in a shopping cart
    val itemPrices = listOf(20, 35, 15, 40, 10)

    // Calculate the total price using the reduceOrNull() function
    val totalPrice = itemPrices.reduceOrNull { runningTotal, price -> runningTotal + price }
    println("Total price of items in the cart: ${totalPrice ?: "No items"}")
    // Total price of items in the cart: 120

    val emptyCart = listOf<Int>()
    val emptyTotalPrice = emptyCart.reduceOrNull { runningTotal, price -> runningTotal + price }
    println("Total price of items in the empty cart: ${emptyTotalPrice ?: "No items"}")
    // Total price of items in the empty cart: No items
}
```

This example also uses the Elvis operator ?: to return a printed statement if the function returns a null value.

The reduceOrNull() function is designed to be used with collections that don't contain null values.

Explore Kotlin's standard library to find more functions that you can use to make your code safer.

Early returns and the Elvis operator

In the beginner tour, you learned how to use early returns to stop your function from being processed further than a certain point. You can use the Elvis operator ?: with an early return to check preconditions in a function. This approach is a great way to keep your code concise because you don't need to use nested checks. The reduced complexity of your code also makes it easier to maintain. For example:

```
data class User(
    val id: Int,
    val name: String,
    // List of friend user IDs
    val friends: List<Int>
)

// Function to get the number of friends for a user
fun getNumberOfFriends(users: Map<Int, User>, userId: Int): Int {
    // Retrieves the user or return -1 if not found
    val user = users[userId] ?: return -1
    // Returns the number of friends
    return user.friends.size
}

fun main() {
    // Creates some sample users
    val user1 = User(1, "Alice", listOf(2, 3))
    val user2 = User(2, "Bob", listOf(1))
    val user3 = User(3, "Charlie", listOf(1))

    // Creates a map of users
    val users = mapOf(1 to user1, 2 to user2, 3 to user3)

    println(getNumberOfFriends(users, 1))
    // 2
    println(getNumberOfFriends(users, 2))
    // 1
    println(getNumberOfFriends(users, 4))
    // -1
}
```

In this example:

- There is a User data class that has properties for the user's id, name and list of friends.
- The getNumberOfFriends() function:
  - Accepts a map of User instances and a user ID as an integer.

    - Accesses the value of the map of User instances with the provided user ID.
    - Uses an Elvis operator to return the function early with the value of -1 if the map value is a null value.
    - Assigns the value found from the map to the user variable.
    - Returns the number of friends in the user's friends list by using the size property.
- The main() function:
    - Creates three User instances.
    - Creates a map of these User instances and assigns them to the users variable.
    - Calls the getNumberOfFriends() function on the users variable with values 1 and 2 that returns two friends for "Alice" and one friend for "Bob".
    - Calls the getNumberOfFriends() function on the users variable with value 4, which triggers an early return with a value of -1.

You may notice that the code could be more concise without an early return. However, this approach needs multiple safe calls because the users[userId] might return a null value, making the code slightly harder to read:

```kotlin
fun getNumberOfFriends(users: Map<Int, User>, userId: Int): Int {
    // Retrieve the user or return -1 if not found
    return users[userId]?.friends?.size ?: -1
}
```

Although this example checks only one condition with the Elvis operator, you can add multiple checks to cover any critical error paths. Early returns with the Elvis operator prevent your program from doing unnecessary work and make your code safer by stopping as soon as a null value or invalid case is detected.

For more information about how you can use return in your code, see Returns and jumps.

Practice

Exercise 1

You are developing a notification system for an app where users can enable or disable different types of notifications. Complete the getNotificationPreferences() function so that:

1. The validUser variable uses the as? operator to check if user is an instance of the User class. If it isn't, return an empty list.
2. The userName variable uses the Elvis ?: operator to ensure that the user's name defaults to "Guest" if it is null.
3. The final return statement uses the .takeIf() function to include email and SMS notification preferences only if they are enabled.
4. The main() function runs successfully and prints the expected output.

The takeIf() function returns the original value if the given condition is true, otherwise it returns null. For example:

```kotlin
fun main() {
    // The user is logged in
    val userIsLoggedIn = true
    // The user has an active session
    val hasSession = true

    // Gives access to the dashboard if the user is logged in
    // and has an active session
    val canAccessDashboard = userIsLoggedIn.takeIf { hasSession }

    println(canAccessDashboard ?: "Access denied")
    // true
}
```

```kotlin
data class User(val name: String?)
```

```
fun getNotificationPreferences(user: Any, emailEnabled: Boolean, smsEnabled: Boolean): List<String> {
    val validUser = // Write your code here
    val userName = // Write your code here

    return listOfNotNull( /* Write your code here */)
}

fun main() {
    val user1 = User("Alice")
    val user2 = User(null)
    val invalidUser = "NotAUser"

    println(getNotificationPreferences(user1, emailEnabled = true, smsEnabled = false))
    // [Email Notifications enabled for Alice]
    println(getNotificationPreferences(user2, emailEnabled = false, smsEnabled = true))
    // [SMS Notifications enabled for Guest]
    println(getNotificationPreferences(invalidUser, emailEnabled = true, smsEnabled = true))
    // []
}
```

```
data class User(val name: String?)

fun getNotificationPreferences(user: Any, emailEnabled: Boolean, smsEnabled: Boolean): List<String> {
    val validUser = user as? User ?: return emptyList()
    val userName = validUser.name ?: "Guest"

    return listOfNotNull(
        "Email Notifications enabled for $userName".takeIf { emailEnabled },
        "SMS Notifications enabled for $userName".takeIf { smsEnabled }
    )
}

fun main() {
    val user1 = User("Alice")
    val user2 = User(null)
    val invalidUser = "NotAUser"

    println(getNotificationPreferences(user1, emailEnabled = true, smsEnabled = false))
    // [Email Notifications enabled for Alice]
    println(getNotificationPreferences(user2, emailEnabled = false, smsEnabled = true))
    // [SMS Notifications enabled for Guest]
    println(getNotificationPreferences(invalidUser, emailEnabled = true, smsEnabled = true))
    // []
}
```

Exercise 2

You are working on a subscription-based streaming service where users can have multiple subscriptions, but only one can be active at a time. Complete the getActiveSubscription() function so that it uses the singleOrNull() function with a predicate to return a null value if there is more than one active subscription:

```
data class Subscription(val name: String, val isActive: Boolean)

fun getActiveSubscription(subscriptions: List<Subscription>): Subscription? // Write your code here

fun main() {
    val userWithPremiumPlan = listOf(
        Subscription("Basic Plan", false),
        Subscription("Premium Plan", true)
    )

    val userWithConflictingPlans = listOf(
        Subscription("Basic Plan", true),
        Subscription("Premium Plan", true)
    )

    println(getActiveSubscription(userWithPremiumPlan))
    // Subscription(name=Premium Plan, isActive=true)

    println(getActiveSubscription(userWithConflictingPlans))
    // null
}
```

```
data class Subscription(val name: String, val isActive: Boolean)
```

```kotlin
fun getActiveSubscription(subscriptions: List<Subscription>): Subscription? {
    return subscriptions.singleOrNull { subscription -> subscription.isActive }
}

fun main() {
    val userWithPremiumPlan = listOf(
        Subscription("Basic Plan", false),
        Subscription("Premium Plan", true)
    )

    val userWithConflictingPlans = listOf(
        Subscription("Basic Plan", true),
        Subscription("Premium Plan", true)
    )

    println(getActiveSubscription(userWithPremiumPlan))
    // Subscription(name=Premium Plan, isActive=true)

    println(getActiveSubscription(userWithConflictingPlans))
    // null
}
```

```kotlin
data class Subscription(val name: String, val isActive: Boolean)

fun getActiveSubscription(subscriptions: List<Subscription>): Subscription? =
    subscriptions.singleOrNull { it.isActive }

fun main() {
    val userWithPremiumPlan = listOf(
        Subscription("Basic Plan", false),
        Subscription("Premium Plan", true)
    )

    val userWithConflictingPlans = listOf(
        Subscription("Basic Plan", true),
        Subscription("Premium Plan", true)
    )

    println(getActiveSubscription(userWithPremiumPlan))
    // Subscription(name=Premium Plan, isActive=true)

    println(getActiveSubscription(userWithConflictingPlans))
    // null
}
```

Exercise 3

You are working on a social media platform where users have usernames and account statuses. You want to see the list of currently active usernames. Complete the getActiveUsernames() function so that the mapNotNull() function has a predicate that returns the username if it is active or a null value if it isn't:

```kotlin
data class User(val username: String, val isActive: Boolean)

fun getActiveUsernames(users: List<User>): List<String> {
    return users.mapNotNull { /* Write your code here */ }
}

fun main() {
    val allUsers = listOf(
        User("alice123", true),
        User("bob_the_builder", false),
        User("charlie99", true)
    )

    println(getActiveUsernames(allUsers))
    // [alice123, charlie99]
}
```

Just like in Exercise 1, you can use the takeIf() function when you check if the user is active.

```kotlin
data class User(val username: String, val isActive: Boolean)

fun getActiveUsernames(users: List<User>): List<String> {
    return users.mapNotNull { user ->
        if (user.isActive) user.username else null
    }
}

fun main() {
    val allUsers = listOf(
        User("alice123", true),
        User("bob_the_builder", false),
        User("charlie99", true)
    )

    println(getActiveUsernames(allUsers))
    // [alice123, charlie99]
}
```

```kotlin
data class User(val username: String, val isActive: Boolean)

fun getActiveUsernames(users: List<User>): List<String> = users.mapNotNull { user -> user.username.takeIf { user.isActive } }

fun main() {
    val allUsers = listOf(
        User("alice123", true),
        User("bob_the_builder", false),
        User("charlie99", true)
    )

    println(getActiveUsernames(allUsers))
    // [alice123, charlie99]
}
```

Exercise 4

You are working on an inventory management system for an e-commerce platform. Before processing a sale, you need to check if the requested quantity of a product is valid based on the available stock.

Complete the validateStock() function so that it uses early returns and the Elvis operator (where applicable) to check if:

- The requested variable is null.
- The available variable is null.
- The requested variable is a negative value.
- The amount in the requested variable is higher than in the available variable.

In all of the above cases, the function must return early with the value of -1.

```kotlin
fun validateStock(requested: Int?, available: Int?): Int {
    // Write your code here
}

fun main() {
    println(validateStock(5,10))
    // 5
    println(validateStock(null,10))
    // -1
    println(validateStock(-2,10))
    // -1
}
```

```kotlin
fun validateStock(requested: Int?, available: Int?): Int {
    val validRequested = requested ?: return -1
    val validAvailable = available ?: return -1

    if (validRequested < 0) return -1
    if (validRequested > validAvailable) return -1
    return validRequested
}

fun main() {
    println(validateStock(5,10))
    // 5
    println(validateStock(null,10))
    // -1
    println(validateStock(-2,10))
    // -1
}
```

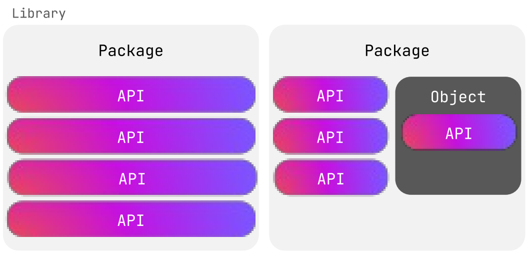
Next step

Intermediate: Libraries and APIs

Intermediate: Libraries and APIs

To get the most out of Kotlin, use existing libraries and APIs so you can spend more time coding and less time reinventing the wheel.

Libraries distribute reusable code that simplifies common tasks. Within libraries, there are packages and objects that group related classes, functions, and utilities. Libraries expose APIs (Application Programming Interfaces) as a set of functions, classes, or properties that developers can use in their code.



Kotlin libraries and APIs

Let's explore what's possible with Kotlin.

The standard library

Kotlin has a standard library that provides essential types, functions, collections, and utilities to make your code concise and expressive. A large portion of the standard library (everything in the kotlin package) is readily available in any Kotlin file without the need to import it explicitly:

```
fun main() {
    val text = "emosewa si niltoK"

   // Use the reversed() function from the standard library
    val reversedText = text.reversed()

    // Use the print() function from the standard library
    print(reversedText)
    // Kotlin is awesome
}
```

However, some parts of the standard library require an import before you can use them in your code. For example, if you want to use the standard library's time measurement features, you need to import the kotlin.time package.

At the top of your file, add the import keyword followed by the package that you need:

```
import kotlin.time.*
```

The asterisk * is a wildcard import that tells Kotlin to import everything within the package. You can't use the asterisk * with companion objects. Instead, you need to explicitly declare the members of a companion object that you want to use.

For example:

```
import kotlin.time.Duration
import kotlin.time.Duration.Companion.hours
import kotlin.time.Duration.Companion.minutes

fun main() {
    val thirtyMinutes: Duration = 30.minutes
    val halfHour: Duration = 0.5.hours
    println(thirtyMinutes == halfHour)
    // true
}
```

This example:

- Imports the Duration class and the hours and minutes extension properties from its companion object.
- Uses the minutes property to convert 30 into a Duration of 30 minutes.
- Uses the hours property to convert 0.5 into a Duration of 30 minutes.
- Checks if both durations are equal and prints the result.

Search before you build

Before you decide to write your own code, check the standard library to see if what you're looking for already exists. Here's a list of areas where the standard library already provides a number of classes, functions, and properties for you:

- Collections
- Sequences
- String manipulation
- Time management

To learn more about what else is in the standard library, explore its API reference.

Kotlin libraries

The standard library covers many common use cases, but there are some that it doesn't address. Fortunately, the Kotlin team and the rest of the community have developed a wide range of libraries to complement the standard library. For example, kotlinx-datetime helps you manage time across different platforms.

You can find useful libraries on our search platform. To use them, you need to take extra steps, like adding a dependency or plugin. Each library has a GitHub repository with instructions on how to include it in your Kotlin projects.

Once you add the library, you can import any package within it. Here's an example of how to import the kotlinx-datetime package to find the current time in New York:

```
import kotlinx.datetime.*

fun main() {
    val now = Clock.System.now() // Get current instant
    println("Current instant: $now")

    val zone = TimeZone.of("America/New_York")
    val localDateTime = now.toLocalDateTime(zone)
    println("Local date-time in NY: $localDateTime")
}
```

This example:

- Imports the kotlinx.datetime package.
- Uses the Clock.System.now() function to create an instance of the Instant class that contains the current time and assigns the result to the now variable.
- Prints the current time.
- Uses the TimeZone.of() function to find the time zone for New York and assigns the result to the zone variable.

- Calls the .toLocalDateTime() function on the instance containing the current time, with the New York time zone as an argument.
- Assigns the result to the localDateTime variable.
- Prints the time adjusted for the time zone in New York.

To explore the functions and classes that this example uses in more detail, see the API reference.

Opt in to APIs

Library authors may mark certain APIs as requiring opt-in before you can use them in your code. They usually do this when an API is still in development and may change in the future. If you don't opt in, you see warnings or errors like this:

```
This declaration needs opt-in. Its usage should be marked with '@...' or '@OptIn(...)'
```

To opt in, write @OptIn followed by parentheses containing the class name that categorizes the API, appended by two colons :: and class.

For example, the uintArrayOf() function from the standard library falls under @ExperimentalUnsignedTypes, as shown in the API reference:

```
@ExperimentalUnsignedTypes
inline fun uintArrayOf(vararg elements: UInt): UIntArray
```

In your code, the opt-in looks like:

```
@OptIn(ExperimentalUnsignedTypes::class)
```

Here's an example that opts in to use the uintArrayOf() function to create an array of unsigned integers and modifies one of its elements:

```
@OptIn(ExperimentalUnsignedTypes::class)
fun main() {
    // Create an unsigned integer array
    val unsignedArray: UIntArray = uintArrayOf(1u, 2u, 3u, 4u, 5u)

    // Modify an element
    unsignedArray[2] = 42u
    println("Updated array: ${unsignedArray.joinToString()}")
    // Updated array: 1, 2, 42, 4, 5
}
```

This is the easiest way to opt in, but there are other ways. To learn more, see Opt-in requirements.

Practice

Exercise 1

You are developing a financial application that helps users calculate the future value of their investments. The formula to calculate compound interest is:

$$A = P \times (1 + \frac{r}{n})^{nt}$$

Where:

- A is the amount of money accumulated after interest (principal + interest).
- P is the principal amount (the initial investment).
- r is the annual interest rate (decimal).
- n is the number of times interest is compounded per year.
- t is the time the money is invested for (in years).

Update the code to:

1. Import the necessary functions from the kotlin.math package.
2. Add a body to the calculateCompoundInterest() function that calculates the final amount after applying compound interest.

```
// Write your code here

fun calculateCompoundInterest(P: Double, r: Double, n: Int, t: Int): Double {
    // Write your code here
}

fun main() {
    val principal = 1000.0
    val rate = 0.05
    val timesCompounded = 4
    val years = 5
    val amount = calculateCompoundInterest(principal, rate, timesCompounded, years)
    println("The accumulated amount is: $amount")
    // The accumulated amount is: 1282.0372317085844
}
```

```
import kotlin.math.*

fun calculateCompoundInterest(P: Double, r: Double, n: Int, t: Int): Double {
    return P * (1 + r / n).pow(n * t)
}

fun main() {
    val principal = 1000.0
    val rate = 0.05
    val timesCompounded = 4
    val years = 5
    val amount = calculateCompoundInterest(principal, rate, timesCompounded, years)
    println("The accumulated amount is: $amount")
    // The accumulated amount is: 1282.0372317085844
}
```

Exercise 2

You want to measure the time it takes to perform multiple data processing tasks in your program. Update the code to add the correct import statements and functions from the kotlin.time package:

```
// Write your code here

fun main() {
    val timeTaken = /* Write your code here */ {
    // Simulate some data processing
    val data = List(1000) { it * 2 }
    val filteredData = data.filter { it % 3 == 0 }

    // Simulate processing the filtered data
    val processedData = filteredData.map { it / 2 }
    println("Processed data")
}

println("Time taken: $timeTaken") // e.g. 16 ms
}
```

```
import kotlin.time.measureTime

fun main() {
    val timeTaken = measureTime {
        // Simulate some data processing
        val data = List(1000) { it * 2 }
        val filteredData = data.filter { it % 3 == 0 }

        // Simulate processing the filtered data
        val processedData = filteredData.map { it / 2 }
        println("Processed data")
    }
    println("Time taken: $timeTaken") // e.g. 16 ms
}
```

Exercise 3

There's a new feature in the standard library available in the latest Kotlin release. You want to try it out, but it requires opt-in. The feature falls under @ExperimentalStdlibApi. What should the opt-in look like in your code?

```
@OptIn(ExperimentalStdlibApi::class)
```

What's next?

Congratulations! You've completed the intermediate tour! As a next step, check out our tutorials for popular Kotlin applications:

- Create a backend application with Spring Boot and Kotlin
- Create a cross-platform application for Android and iOS from scratch and:
  - Share business logic while keeping the UI native
  - Share business logic and UI

Kotlin for server side

Kotlin is a great fit for developing server-side applications. It allows you to write concise and expressive code while maintaining full compatibility with existing Java-based technology stacks, all with a smooth learning curve:

- Expressiveness: Kotlin's innovative language features, such as its support for type-safe builders and delegated properties, help build powerful and easy-to-use abstractions.
- Scalability: Kotlin's support for coroutines helps build server-side applications that scale to massive numbers of clients with modest hardware requirements.
- Interoperability: Kotlin is fully compatible with all Java-based frameworks, so you can use your familiar technology stack while reaping the benefits of a more modern language.
- Migration: Kotlin supports gradual migration of large codebases from Java to Kotlin. You can start writing new code in Kotlin while keeping older parts of your system in Java.
- Tooling: In addition to great IDE support in general, Kotlin offers framework-specific tooling (for example, for Spring and Ktor) in the plugin for IntelliJ IDEA Ultimate.
- Learning Curve: For a Java developer, getting started with Kotlin is very easy. The automated Java-to-Kotlin converter included in the Kotlin plugin helps with your first steps. Kotlin Koans guide you through key language features with a series of interactive exercises. Kotlin-specific frameworks like Ktor offer a simple, straightforward approach without the hidden complexities of larger frameworks.

Frameworks for server-side development with Kotlin

Here are some examples of the server-side frameworks for Kotlin:

- Spring makes use of Kotlin's language features to offer more concise APIs, starting with version 5.0. The online project generator allows you to quickly generate a new project in Kotlin.
- Ktor is a framework built by JetBrains for creating Web applications in Kotlin, making use of coroutines for high scalability and offering an easy-to-use and idiomatic API.
- Quarkus provides first class support for using Kotlin. The framework is open source and maintained by Red Hat. Quarkus was built from the ground up for Kubernetes and provides a cohesive full-stack framework by leveraging a growing list of hundreds of best-of-breed libraries.
- Vert.x, a framework for building reactive Web applications on the JVM, offers dedicated support for Kotlin, including full documentation.
- kotlinx.html is a DSL that can be used to build HTML in Web applications. It serves as an alternative to traditional templating systems such as JSP and

FreeMarker.

- Micronaut is a modern JVM-based full-stack framework for building modular, easily testable microservices and serverless applications. It comes with a lot of useful built-in features.
- http4k is the functional toolkit with a tiny footprint for Kotlin HTTP applications, written in pure Kotlin. The library is based on the "Your Server as a Function" paper from Twitter and represents modeling both HTTP servers and clients as simple Kotlin functions that can be composed together.
- Javalin is a very lightweight web framework for Kotlin and Java which supports WebSockets, HTTP2, and async requests.
- The available options for persistence include direct JDBC access, JPA, and using NoSQL databases through their Java drivers. For JPA, the kotlin-jpa compiler plugin adapts Kotlin-compiled classes to the requirements of the framework.

You can find more frameworks at https://kotlin.link/.

Deploying Kotlin server-side applications

Kotlin applications can be deployed into any host that supports Java Web applications, including Amazon Web Services, Google Cloud Platform, and more.

To deploy Kotlin applications on Heroku, you can follow the official Heroku tutorial.

AWS Labs provides a sample project showing the use of Kotlin for writing AWS Lambda functions.

Google Cloud Platform offers a series of tutorials for deploying Kotlin applications to GCP, both for Ktor and App Engine and Spring and App engine. In addition, there is an interactive code lab for deploying a Kotlin Spring application.

Products that use Kotlin on the server side

Corda is an open-source distributed ledger platform that is supported by major banks and built entirely in Kotlin.

JetBrains Account, the system responsible for the entire license sales and validation process at JetBrains, is written in 100% Kotlin and has been running in production since 2015 with no major issues.

Chess.com is a website dedicated to chess and the millions of players around the world who love the game. Chess.com uses Ktor for the seamless configuration of multiple HTTP clients.

Engineers at Adobe use Kotlin for server-side app development and Ktor for prototyping in the Adobe Experience Platform, which enables organizations to centralize and standardize customer data before applying data science and machine learning.

Next steps

- For a more in-depth introduction to the language, check out the Kotlin documentation on this site and Kotlin Koans.
- Explore how to build asynchronous server applications with Ktor, a framework that uses Kotlin coroutines.
- Watch a webinar "Micronaut for microservices with Kotlin" and explore a detailed guide showing how you can use Kotlin extension functions in the Micronaut framework.
- http4k provides the CLI to generate fully formed projects, and a starter repo to generate an entire CD pipeline using GitHub, Travis, and Heroku with a single bash command.
- Want to migrate from Java to Kotlin? Learn how to perform typical tasks with strings in Java and Kotlin.

Kotlin for Android

Android mobile development has been Kotlin-first since Google I/O in 2019.

Over 50% of professional Android developers use Kotlin as their primary language, while only 30% use Java as their main language. 70% of developers whose primary language is Kotlin say that Kotlin makes them more productive.

Using Kotlin for Android development, you can benefit from:

- Less code combined with greater readability. Spend less time writing your code and working to understand the code of others.
- Fewer common errors. Apps built with Kotlin are 20% less likely to crash based on Google's internal data.
- Kotlin support in Jetpack libraries. Jetpack Compose is Android's recommended modern toolkit for building native UI in Kotlin. KTX extensions add Kotlin language features, like coroutines, extension functions, lambdas, and named parameters to existing Android libraries.
- Support for multiplatform development. Kotlin Multiplatform allows development for not only Android but also iOS, backend, and web applications. Some Jetpack libraries are already multiplatform. Compose Multiplatform, JetBrains' declarative UI framework based on Kotlin and Jetpack Compose, makes it possible to share UIs across platforms – iOS, Android, desktop, and web.
- Mature language and environment. Since its creation in 2011, Kotlin has developed continuously, not only as a language but as a whole ecosystem with robust tooling. Now it's seamlessly integrated into Android Studio and is actively used by many companies for developing Android applications.
- Interoperability with Java. You can use Kotlin along with the Java programming language in your applications without needing to migrate all your code to Kotlin.
- Easy learning. Kotlin is very easy to learn, especially for Java developers.
- Big community. Kotlin has great support and many contributions from the community, which is growing all over the world. Over 95% of the top thousand Android apps use Kotlin.

Many startups and Fortune 500 companies have already developed Android applications using Kotlin, see the list on the Google website for Android developers.

To start using Kotlin for:

- Android development, read Google's documentation for developing Android apps with Kotlin.
- Developing cross-platform mobile applications, see Create an app with shared logic and native UI.

Kotlin/Wasm

Kotlin/Wasm is in Alpha. It may be changed at any time. You can use it in scenarios before production. We would appreciate your feedback in YouTrack.

Join the Kotlin/Wasm community.

Kotlin/Wasm has the power to compile your Kotlin code into WebAssembly (Wasm) format. With Kotlin/Wasm, you can create applications that run on different environments and devices, which support Wasm and meet Kotlin's requirements.

Wasm is a binary instruction format for a stack-based virtual machine. This format is platform-independent because it runs on its own virtual machine. Wasm provides Kotlin and other languages with a compilation target.

You can use Kotlin/Wasm in different target environments, such as browsers, for developing web applications built with Compose Multiplatform, or outside the browser in standalone Wasm virtual machines. In the outside-of-browser case, WebAssembly System Interface (WASI) provides access to platform APIs, which you can also utilize.

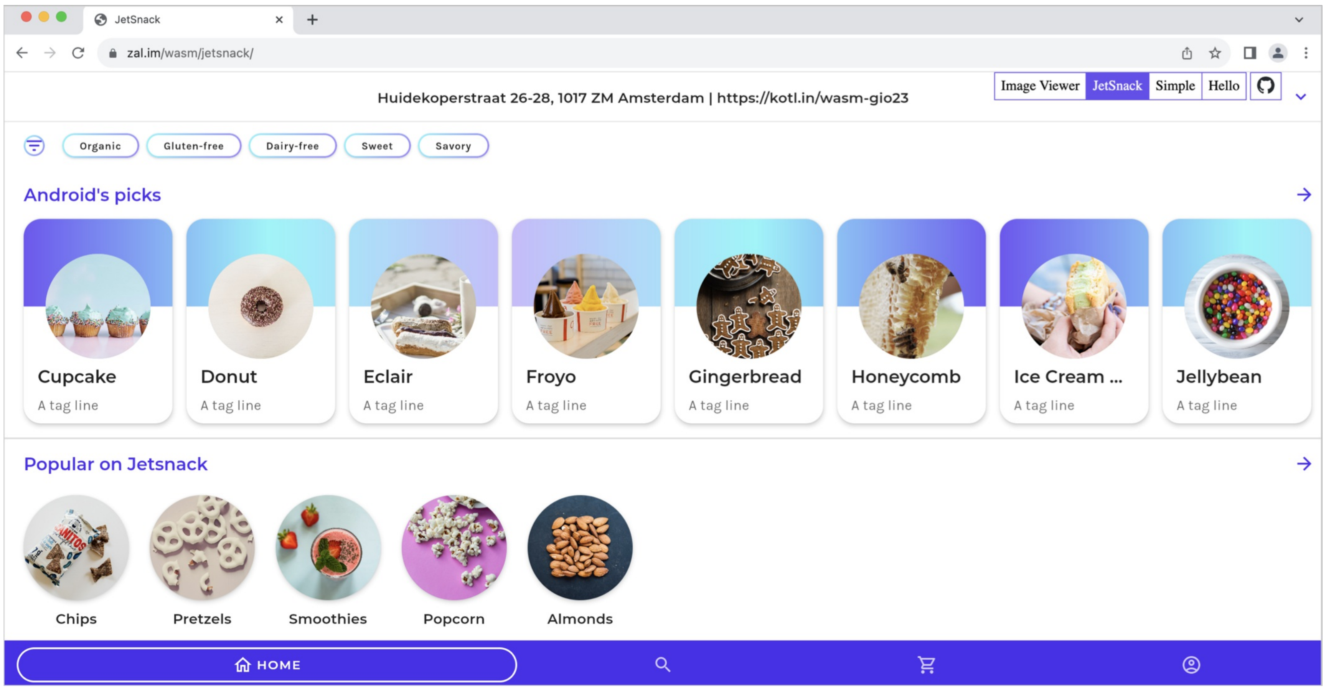
Kotlin/Wasm and Compose Multiplatform

With Kotlin, you have the power to build applications and reuse mobile and desktop user interfaces (UIs) in your web projects through Compose Multiplatform and Kotlin/Wasm.

Compose Multiplatform is a declarative framework based on Kotlin and Jetpack Compose that allows you to implement the UI once and share it across all the platforms you target.

For web platforms, Compose Multiplatform uses Kotlin/Wasm as its compilation target. Applications built with Kotlin/Wasm and Compose Multiplatform use a wasm-js target and run in browsers.

Explore our online demo of an application built with Compose Multiplatform and Kotlin/Wasm



Kotlin/Wasm demo

> To run applications built with Kotlin/Wasm in a browser, you need a browser version that supports the new garbage collection and legacy exception handling proposals. To check the browser support status, see the WebAssembly roadmap.

Additionally, you can use the most popular Kotlin libraries in Kotlin/Wasm out of the box. Like in other Kotlin and Multiplatform projects, you can include dependency declarations in the build script. For more information, see Adding dependencies on multiplatform libraries.

Would you like to try it yourself?

Get started with Kotlin/Wasm

Kotlin/Wasm and WASI

Kotlin/Wasm uses the WebAssembly System Interface (WASI) for server-side applications. Applications built with Kotlin/Wasm and WASI use a Wasm-WASI target, allowing you to call the WASI API and run applications outside the browser environment.

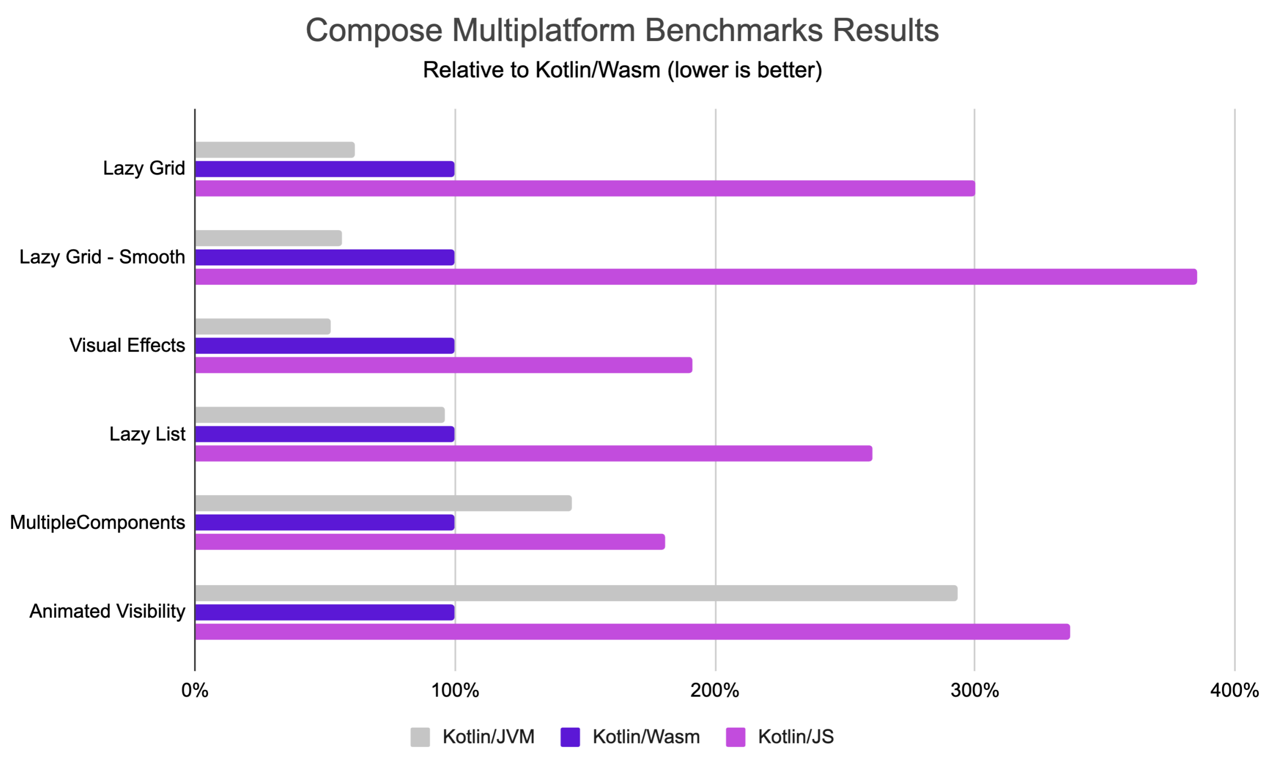
Kotlin/Wasm leverages WASI to abstract away platform-specific details, allowing the same Kotlin code to run across diverse platforms. This expands the reach of Kotlin/Wasm beyond web applications without requiring custom handling for each runtime.

WASI provides a secure standard interface for running Kotlin applications compiled to WebAssembly across different environments.

> To see Kotlin/Wasm and WASI in action, check the Get started with Kotlin/Wasm and WASI tutorial.

Kotlin/Wasm performance

Although Kotlin/Wasm is still in Alpha, Compose Multiplatform running on Kotlin/Wasm already shows encouraging performance traits. You can see that its execution speed outperforms JavaScript and is approaching that of the JVM:



Kotlin/Wasm performance

We regularly run benchmarks on Kotlin/Wasm, and these results come from our testing in a recent version of Google Chrome.

Browser API support

The Kotlin/Wasm standard library provides declarations for browser APIs, including the DOM API. With these declarations, you can directly use the Kotlin API to access and utilize various browser functionalities. For example, in your Kotlin/Wasm applications, you can use manipulation with DOM elements or fetch the API without defining these declarations from scratch. To learn more, see our Kotlin/Wasm browser example.

The declarations for browser API support are defined using JavaScript interoperability capabilities. You can use the same capabilities to define your own declarations. In addition, Kotlin/Wasm–JavaScript interoperability allows you to use Kotlin code from JavaScript. For more information, see Use Kotlin code in JavaScript.

Leave feedback

Kotlin/Wasm feedback

- Slack: Get a Slack invite and provide your feedback directly to developers in our #webassembly channel.
- Report any issues in YouTrack.

Compose Multiplatform feedback

- Slack: provide your feedback in the #compose-web public channel.
- Report any issues in GitHub.

Learn more

* Learn more about Kotlin/Wasm in this YouTube playlist.
* Explore the Kotlin/Wasm examples in our GitHub repository.

Kotlin/Native

Kotlin/Native is a technology for compiling Kotlin code to native binaries that can run without a virtual machine. Kotlin/Native includes an LLVM-based backend for the Kotlin compiler and a native implementation of the Kotlin standard library.

Why Kotlin/Native?

Kotlin/Native is primarily designed to allow compilation for platforms on which virtual machines are not desirable or possible, such as embedded devices or iOS. It's ideal for situations when you need to to produce a self-contained program that doesn't require an additional runtime or a virtual machine.

It's easy to include compiled Kotlin code in existing projects written in C, C++, Swift, Objective-C, and other languages. You can also use existing native code, static or dynamic C libraries, Swift/Objective-C frameworks, graphical engines, and anything else directly from Kotlin/Native.

Get started with Kotlin/Native

Get started with Kotlin/Native

Target platforms

Kotlin/Native supports the following platforms:

* Linux
* Windows (through MinGW)
* Android NDK
* Apple targets for macOS, iOS, tvOS, and watchOS

> To compile Apple targets, you need to install Xcode and its command-line tools.

See the full list of supported targets.

Interoperability

Kotlin/Native supports two-way interoperability with native programming languages for different operating systems. The compiler can create executables for many platforms, static or dynamic C libraries, and Swift/Objective-C frameworks.

Interoperability with C

Kotlin/Native provides interoperability with C. You can use existing C libraries directly from Kotlin code.

To learn more, complete the following tutorials:

* Create a dynamic library with C headers for C/C++ projects
* Learn how C types are mapped into Kotlin
* Create a native HTTP client using C interop and libcurl

Interoperability with Swift/Objective-C

Kotlin/Native provides interoperability with Swift through Objective-C. You can use Kotlin code directly from Swift/Objective-C applications on macOS and iOS.

To learn more, complete the Kotlin/Native as an Apple framework tutorial.

Sharing code between platforms

Kotlin/Native includes a set of prebuilt platform libraries that help share Kotlin code between projects. POSIX, gzip, OpenGL, Metal, Foundation, and many other popular libraries and Apple frameworks are pre-imported and included as Kotlin/Native libraries in the compiler package.

Kotlin/Native is a part of the Kotlin Multiplatform technology that helps share common code across multiple platforms, including Android, iOS, JVM, web, and native. Multiplatform libraries provide the necessary APIs for common Kotlin code and allow writing shared parts of projects in Kotlin all in one place.

Memory manager

Kotlin/Native uses an automatic memory manager that is similar to the JVM and Go. It has its own tracing garbage collector, which is also integrated with Swift/Objective-C's ARC.

The memory consumption is controlled by a custom memory allocator. It optimizes memory usage and helps prevent sudden surges in memory allocation.

Kotlin for JavaScript

Kotlin/JS provides the ability to transpile your Kotlin code, the Kotlin standard library, and any compatible dependencies to JavaScript. The current implementation of Kotlin/JS targets ES5.

The recommended way to use Kotlin/JS is via the kotlin.multiplatform Gradle plugin. It lets you easily set up and control Kotlin projects targeting JavaScript in one place. This includes essential functionality such as controlling the bundling of your application, adding JavaScript dependencies directly from npm, and more. To get an overview of the available options, check out Set up a Kotlin/JS project.

Kotlin/JS IR compiler

The Kotlin/JS IR compiler comes with a number of improvements over the old default compiler. For example, it reduces the size of generated executables via dead code elimination and provides smoother interoperability with the JavaScript ecosystem and its tooling.

> The old compiler has been deprecated since the Kotlin 1.8.0 release.

By generating TypeScript declaration files (d.ts) from Kotlin code, the IR compiler makes it easier to create "hybrid" applications that mix TypeScript and Kotlin code and to leverage code-sharing functionality using Kotlin Multiplatform.

To learn more about the available features in the Kotlin/JS IR compiler and how to try it for your project, visit the Kotlin/JS IR compiler documentation page and the migration guide.

Kotlin/JS frameworks

Modern web development benefits significantly from frameworks that simplify building web applications. Here are a few examples of popular web frameworks for Kotlin/JS written by different authors:

Kobweb

Kobweb is an opinionated Kotlin framework for creating websites and web apps. It leverages Compose HTML and live-reloading for fast development. Inspired by Next.js, Kobweb promotes a standard structure for adding widgets, layouts, and pages.

Out of the box, Kobweb provides page routing, light/dark mode, CSS styling, Markdown support, backend APIs, and more features. It also includes a UI library called Silk, a set of versatile widgets for modern UIs.

Kobweb also supports site export, generating page snapshots for SEO and automatic search indexing. Additionally, Kobweb makes it easy to create DOM-based UIs that efficiently update in response to state changes.

Visit the Kobweb site for documentation and examples.

For updates and discussions about the framework, join the #kobweb and #compose-web channels in the Kotlin Slack.

KVision

KVision is an object-oriented web framework that makes it possible to write applications in Kotlin/JS with ready-to-use components that can be used as building blocks for your application's user interface. You can use both reactive and imperative programming models to build your frontend, use connectors for Ktor, Spring Boot, and other frameworks to integrate it with your server-side applications, and share code using Kotlin Multiplatform.

Visit KVision site for documentation, tutorials, and examples.

For updates and discussions about the framework, join the #kvision and #javascript channels in the Kotlin Slack.

fritz2

fritz2 is a standalone framework for building reactive web user interfaces. It provides its own type-safe DSL for building and rendering HTML elements, and it makes use of Kotlin's coroutines and flows to express components and their data bindings. It provides state management, validation, routing, and more out of the box, and integrates with Kotlin Multiplatform projects.

Visit fritz2 site for documentation, tutorials, and examples.

For updates and discussions about the framework, join the #fritz2 and #javascript channels in the Kotlin Slack.

Doodle

Doodle is a vector-based UI framework for Kotlin/JS. Doodle applications use the browser's graphics capabilities to draw user interfaces instead of relying on DOM, CSS, or Javascript. By using this approach, Doodle gives you precise control over the rendering of arbitrary UI elements, vector shapes, gradients, and custom visualizations.

Visit Doodle site for documentation, tutorials, and examples.

For updates and discussions about the framework, join the #doodle and #javascript channels in the Kotlin Slack.

Join the Kotlin/JS community

You can join the #javascript channel in the official Kotlin Slack to chat with the community and the team.

Kotlin for data analysis

Exploring and analyzing data is something you may not do every day, but it's a crucial skill you need as a software developer.

Let's think about software development duties where data analysis is key: analyzing what's actually inside collections when debugging, digging into memory dumps or databases, or receiving JSON files with large amounts of data when working with REST APIs, to mention some.

With Kotlin's Exploratory Data Analysis (EDA) tools, such as Kotlin notebooks, Kotlin DataFrame, and Kandy, you have at your disposal a rich set of capabilities to enhance your analytics skills and support you across different scenarios:

- Load, transform, and visualize data in various formats: with our Kotlin EDA tools, you can perform tasks like filtering, sorting, and aggregating data. Our tools can seamlessly read data right in the IDE from different file formats, including CSV, JSON, and TXT.

  Kandy, our plotting tool, allows you to create a wide range of charts to visualize and gain insights from the dataset.

- Efficiently analyze data stored in relational databases: Kotlin DataFrame seamlessly integrates with databases and provides capabilities similar to SQL queries. You can retrieve, manipulate, and visualize data directly from various databases.

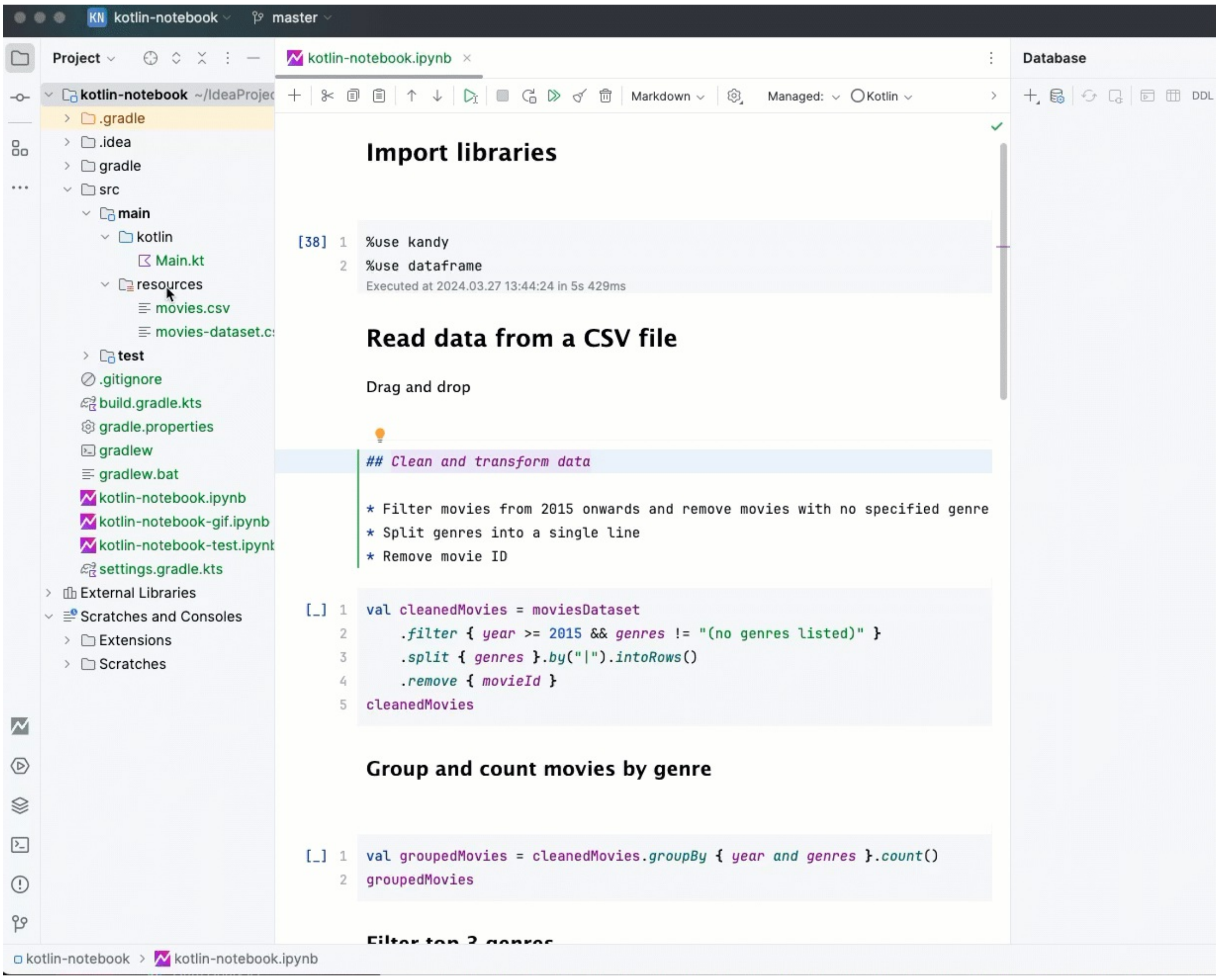
- Fetch and analyze real-time and dynamic datasets from web APIs: the EDA tools' flexibility allows integration with external APIs via protocols like OpenAPI. This feature helps you fetch data from web APIs, to then clean and transform the data to your needs.

Would you like to try our Kotlin tools for data analysis?

Get started with Kotlin Notebook

Get started with Kotlin Notebook

Our Kotlin data analysis tools let you smoothly handle your data from start to finish. Effortlessly retrieve your data with simple drag-and-drop functionality in our Kotlin Notebook. Clean, transform, and visualize it with just a few lines of code. Additionally, export your output charts in a matter of clicks.



Import libraries

```
%use kandy
%use dataframe
```

Executed at 2024.03.27 13:44:24 in 5s 429ms

Read data from a CSV file

Drag and drop

```
## Clean and transform data

* Filter movies from 2015 onwards and remove movies with no specified genre
* Split genres into a single line
* Remove movie ID
```

```
val cleanedMovies = moviesDataset
    .filter { year >= 2015 && genres != "(no genres listed)" }
    .split { genres }.by("|").intoRows()
    .remove { movieId }
cleanedMovies
```

Group and count movies by genre

```
val groupedMovies = cleanedMovies.groupBy { year and genres }.count()
groupedMovies
```

Notebooks

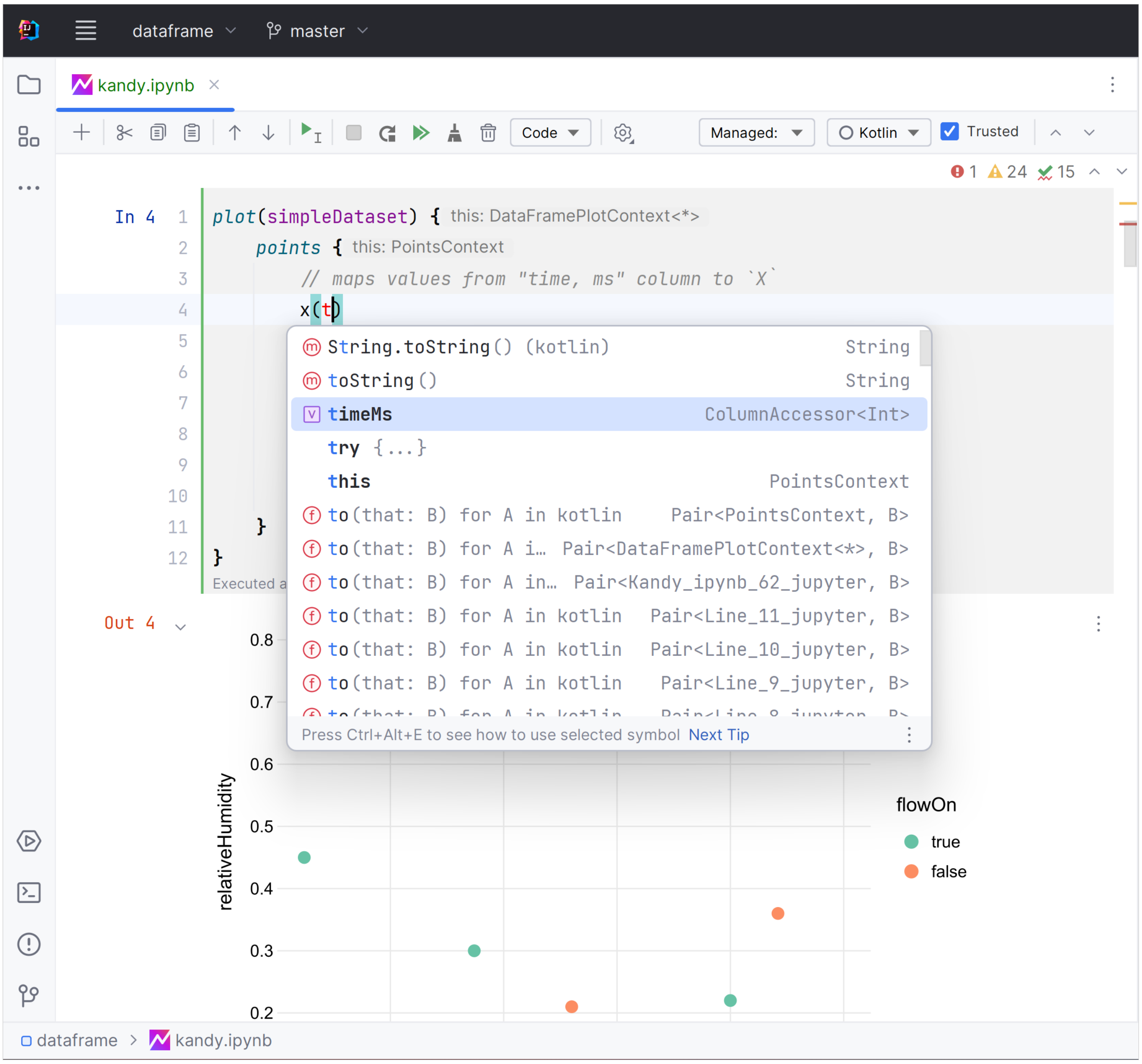
Notebooks are interactive editors that integrate code, graphics, and text in a single environment. When using a notebook, you can run code cells and immediately see the output.

Kotlin offers different notebook solutions, such as Kotlin Notebook, Datalore, and Kotlin-Jupyter Notebook, providing convenient features for data retrieving, transformation, exploration, modeling, and more. These Kotlin notebook solutions are based on our Kotlin Kernel.

You can seamlessly share your code among Kotlin Notebook, Datalore, and Kotlin-Jupyter Notebook. Create a project in one of our Kotlin notebooks and continue working in another notebook without compatibility issues.

Benefit from the features of our powerful Kotlin notebooks and the perks of coding with Kotlin. Kotlin integrates with these notebooks to help you manage data and share your findings with colleagues while building up your data science and machine learning skills.

Discover the features of our different Kotlin notebook solutions and choose the one that best aligns with your project requirements.



```
plot(simpleDataset) { this: DataFramePlotContext<*>
    points { this: PointsContext
        // maps values from "time, ms" column to `X`
        x(t)
    }
}
```

```
String.toString() (kotlin)                              String
toString()                                              String
timeMs                                      ColumnAccessor<Int>
try {...}
this                                              PointsContext
to(that: B) for A in kotlin           Pair<PointsContext, B>
to(that: B) for A i…   Pair<DataFramePlotContext<*>, B>
to(that: B) for A in…  Pair<Kandy_ipynb_62_jupyter, B>
to(that: B) for A in kotlin      Pair<Line_11_jupyter, B>
to(that: B) for A in kotlin      Pair<Line_10_jupyter, B>
to(that: B) for A in kotlin       Pair<Line_9_jupyter, B>
```

Kotlin Notebook

Kotlin Notebook

The Kotlin Notebook is a plugin for IntelliJ IDEA that allows you to create notebooks in Kotlin. It provides our IDE experience with all common IDE features, offering real-time code insights and project integration.

Kotlin notebooks in Datalore

With Datalore, you can use Kotlin in the browser straight out of the box without additional installation. You can also share your notebooks and run them remotely, collaborate with other Kotlin notebooks in real-time, receive smart coding assistance as you write code, and export results through interactive or static reports.

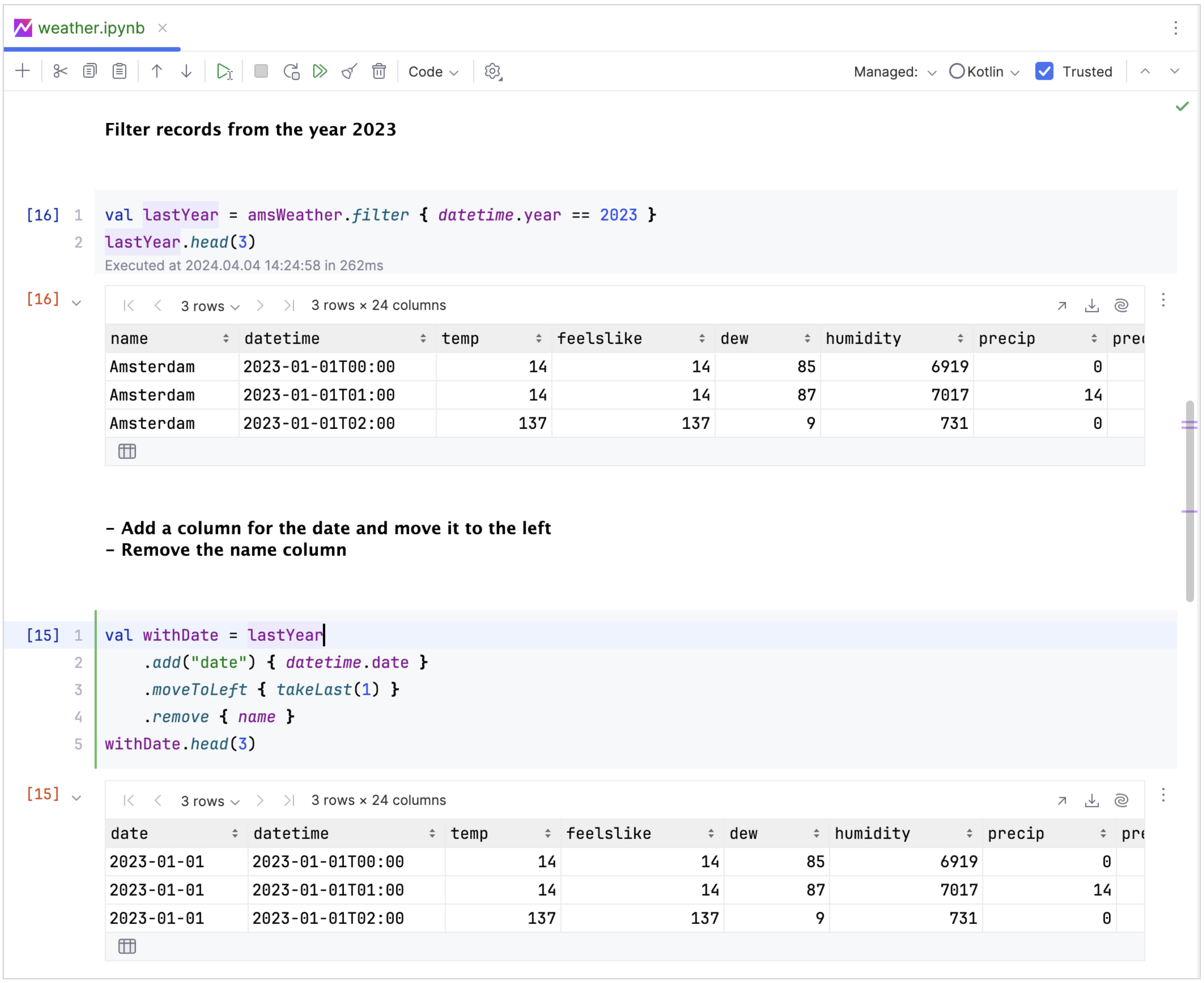
Jupyter Notebook with Kotlin Kernel

Jupyter Notebook is an open-source web application that allows you to create and share documents containing code, visualizations, and Markdown text. Kotlin-Jupyter is an open-source project that brings Kotlin support to Jupyter Notebook to harness Kotlin's power within the Jupyter environment.

Kotlin DataFrame

The Kotlin DataFrame library lets you manipulate structured data in your Kotlin projects. From data creation and cleaning to in-depth analysis and feature engineering, this library has you covered.

With the Kotlin DataFrame library, you can work with different file formats, including CSV, JSON, XLS, and XLSX. This library also facilitates the data retrieval process with its ability to connect with SQL databases or APIs.


weather.ipynb

Managed: Kotlin Trusted

Filter records from the year 2023

[16]
```kotlin
val lastYear = amsWeather.filter { datetime.year == 2023 }
lastYear.head(3)
```
Executed at 2024.04.04 14:24:58 in 262ms

[16] 3 rows × 24 columns

name	datetime	temp	feelslike	dew	humidity	precip	pre
Amsterdam	2023-01-01T00:00	14	14	85	6919	0	
Amsterdam	2023-01-01T01:00	14	14	87	7017	14	
Amsterdam	2023-01-01T02:00	137	137	9	731	0	

– Add a column for the date and move it to the left
– Remove the name column

[15]
```kotlin
val withDate = lastYear
    .add("date") { datetime.date }
    .moveToLeft { takeLast(1) }
    .remove { name }
withDate.head(3)
```

[15] 3 rows × 24 columns

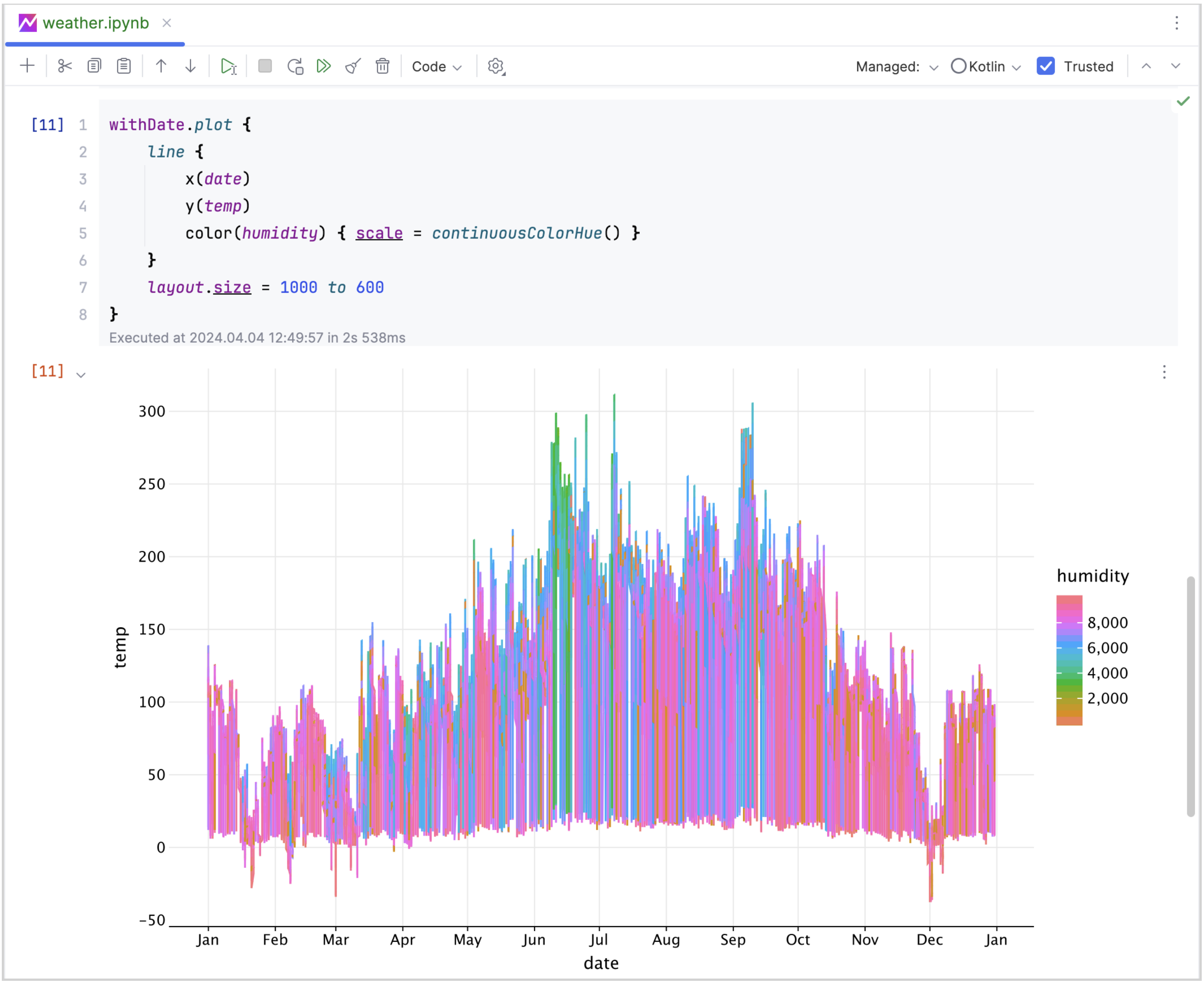
date	datetime	temp	feelslike	dew	humidity	precip	pre
2023-01-01	2023-01-01T00:00	14	14	85	6919	0	
2023-01-01	2023-01-01T01:00	14	14	87	7017	14	
2023-01-01	2023-01-01T02:00	137	137	9	731	0	

Kotlin DataFrame

Kandy

Kandy is an open-source Kotlin library that provides a powerful and flexible DSL for plotting charts of various types. This library is a simple, idiomatic, readable, and type-safe tool to visualize data.

Kandy has seamless integration with Kotlin Notebook, Datalore, and Kotlin-Jupyter Notebook. You can also easily combine the Kandy and Kotlin DataFrame libraries to complete different data-related tasks.



```
withDate.plot {
    line {
        x(date)
        y(temp)
        color(humidity) { scale = continuousColorHue() }
    }
    layout.size = 1000 to 600
}
```

Executed at 2024.04.04 12:49:57 in 2s 538ms

Kandy

What's next

- Get started with Kotlin Notebook
- Retrieve and transform data using the Kotlin DataFrame library
- Visualize data using the Kandy library
- Learn more about Kotlin and Java libraries for data analysis

Kotlin for AI-powered app development

Kotlin provides a modern and pragmatic foundation for building AI-powered applications.
It can be used across platforms, integrates well with established AI frameworks, and supports common AI development patterns.

This page introduces how Kotlin is used in real-world AI scenarios with working examples from the Kotlin-AI-Examples repository.

Kotlin AI agentic framework – Koog

Koog is a Kotlin-based framework for creating and running AI agents locally, without requiring external services. Koog is JetBrains' innovative, open-source agentic framework that empowers developers to build AI agents within the JVM ecosystem. It provides a pure Kotlin implementation for building intelligent agents that can interact with tools, handle complex workflows, and communicate with users.

More use cases

There are many other use cases where Kotlin can help with AI development. From integrating language models into backend services to building AI-powered user interfaces, these examples showcase the versatility of Kotlin in various AI applications.

Retrieval-augmented generation

Use Kotlin to build retrieval-augmented generation (RAG) pipelines that connect language models to external sources like documentation, vector stores, or APIs. For example:

- springAI-demo: A Spring Boot app that loads Kotlin standard library docs into a vector store and supports document-based Q&A.
- langchain4j-spring-boot: A minimal RAG example using LangChain4j.

Agent-based applications

Build AI agents in Kotlin that reason, plan, and act using language models and tools. For example:

- koog: Shows how to use the Kotlin agentic framework Koog to build AI agents.
- langchain4j-spring-boot: Includes a simple tool-using agent built with LangChain4j.

Chain of thought prompting

Implement structured prompting techniques that guide language models through multistep reasoning. For example:

- LangChain4j_Overview.ipynb: A Kotlin Notebook demonstrating chain of thought and structured output.

LLMs in backend services

Integrate LLMs into business logic or REST APIs using Kotlin and Spring. For example:

- spring-ai-examples: Includes classification, chat, and summarization examples.
- springAI-demo: Demonstrates full integration of LLM responses with application logic.

Multiplatform user interfaces with AI

Use Compose Multiplatform to build interactive AI-powered UIs in Kotlin. For example:

- mcp-demo: A desktop UI that connects to Claude and OpenAI, and presents responses using Compose Multiplatform.

Explore examples

You can explore and run examples from the Kotlin-AI-Examples repository.
Each project is self-contained. You can use each project as a reference or template for building Kotlin-based AI applications.

What's next

- Complete the Build a Kotlin app that uses Spring AI to answer questions based on documents stored in the Qdrant tutorial to learn more about using Spring AI with Kotlin in IntelliJ IDEA
- Join the Kotlin community to connect with other developers building AI applications with Kotlin

Kotlin for competitive programming

This tutorial is designed both for competitive programmers that did not use Kotlin before and for Kotlin developers that did not participate in any competitive programming events before. It assumes the corresponding programming skills.

Competitive programming is a mind sport where contestants write programs to solve precisely specified algorithmic problems within strict constraints. Problems can range from simple ones that can be solved by any software developer and require little code to get a correct solution, to complex ones that require knowledge of special algorithms, data structures, and a lot of practice. While not being specifically designed for competitive programming, Kotlin incidentally fits well in this domain, reducing the typical amount of boilerplate that a programmer needs to write and read while working with the code almost to the level offered by dynamically-typed scripting languages, while having tooling and performance of a statically-typed language.

See Get started with Kotlin/JVM on how to set up development environment for Kotlin. In competitive programming, a single project is usually created and each problem's solution is written in a single source file.

Simple example: Reachable Numbers problem

Let's take a look at a concrete example.

Codeforces Round 555 was held on April 26th for 3rd Division, which means it had problems fit for any developer to try. You can use this link to read the problems. The simplest problem in the set is the Problem A: Reachable Numbers. It asks to implement a straightforward algorithm described in the problem statement.

We'd start solving it by creating a Kotlin source file with an arbitrary name. A.kt will do well. First, you need to implement a function specified in the problem statement as:

Let's denote a function f(x) in such a way: we add 1 to x, then, while there is at least one trailing zero in the resulting number, we remove that zero.

Kotlin is a pragmatic and unopinionated language, supporting both imperative and function programming styles without pushing the developer towards either one. You can implement the function f in functional style, using such Kotlin features as tail recursion:

```kotlin
tailrec fun removeZeroes(x: Int): Int =
    if (x % 10 == 0) removeZeroes(x / 10) else x

fun f(x: Int) = removeZeroes(x + 1)
```

Alternatively, you can write an imperative implementation of the function f using the traditional while loop and mutable variables that are denoted in Kotlin with var:

```kotlin
fun f(x: Int): Int {
    var cur = x + 1
    while (cur % 10 == 0) cur /= 10
    return cur
}
```

Types in Kotlin are optional in many places due to pervasive use of type-inference, but every declaration still has a well-defined static type that is known at compilation.

Now, all is left is to write the main function that reads the input and implements the rest of the algorithm that the problem statement asks for — to compute the number of different integers that are produced while repeatedly applying function f to the initial number n that is given in the standard input.

By default, Kotlin runs on JVM and gives direct access to a rich and efficient collections library with general-purpose collections and data-structures like dynamically-sized arrays (ArrayList), hash-based maps and sets (HashMap/HashSet), tree-based ordered maps and sets (TreeMap/TreeSet). Using a hash-set of integers to track values that were already reached while applying function f, the straightforward imperative version of a solution to the problem can be written as shown below:

Kotlin 1.6.0 and later

```kotlin
fun main() {
    var n = readln().toInt() // read integer from the input
    val reached = HashSet<Int>() // a mutable hash set
    while (reached.add(n)) n = f(n) // iterate function f
    println(reached.size) // print answer to the output
}
```

There is no need to handle the case of misformatted input in competitive programming. An input format is always precisely specified in competitive programming, and the actual input cannot deviate from the input specification in the problem statement. That's why you can use Kotlin's readln() function. It asserts that the input string is present and throws an exception otherwise. Likewise, the String.toInt() function throws an exception if the input string is not an integer.

Earlier versions

```
fun main() {
    var n = readLine()!!.toInt() // read integer from the input
    val reached = HashSet<Int>() // a mutable hash set
    while (reached.add(n)) n = f(n) // iterate function f
    println(reached.size) // print answer to the output
}
```

Note the use of Kotlin's null-assertion operator !! after the readLine() function call. Kotlin's readLine() function is defined to return a nullable type String? and returns null on the end of the input, which explicitly forces the developer to handle the case of missing input.

There is no need to handle the case of misformatted input in competitive programming. In competitive programming, an input format is always precisely specified and the actual input cannot deviate from the input specification in the problem statement. That's what the null-assertion operator !! essentially does — it asserts that the input string is present and throws an exception otherwise. Likewise, the String.toInt().

All online competitive programming events allow the use of pre-written code, so you can define your own library of utility functions that are geared towards competitive programming to make your actual solution code somewhat easier to read and write. You would then use this code as a template for your solutions. For example, you can define the following helper functions for reading inputs in competitive programming:

Kotlin 1.6.0 and later

```
private fun readStr() = readln() // string line
private fun readInt() = readStr().toInt() // single int
// similar for other types you'd use in your solutions
```

Earlier versions

```
private fun readStr() = readLine()!! // string line
private fun readInt() = readStr().toInt() // single int
// similar for other types you'd use in your solutions
```

Note the use of private visibility modifier here. While the concept of visibility modifier is not relevant for competitive programming at all, it allows you to place multiple solution files based on the same template without getting an error for conflicting public declarations in the same package.

Functional operators example: Long Number problem

For more complicated problems, Kotlin's extensive library of functional operations on collections comes in handy to minimize the boilerplate and turn the code into a linear top-to-bottom and left-to-right fluent data transformation pipeline. For example, the Problem B: Long Number problem takes a simple greedy algorithm to implement and it can be written using this style without a single mutable variable:

Kotlin 1.6.0 and later

```
fun main() {
    // read input
    val n = readln().toInt()
    val s = readln()
    val fl = readln().split(" ").map { it.toInt() }
    // define local function f
    fun f(c: Char) = '0' + fl[c - '1']
    // greedily find first and last indices
    val i = s.indexOfFirst { c -> f(c) > c }
        .takeIf { it >= 0 } ?: s.length
    val j = s.withIndex().indexOfFirst { (j, c) -> j > i && f(c) < c }
        .takeIf { it >= 0 } ?: s.length
    // compose and write the answer
    val ans =
        s.substring(0, i) +
        s.substring(i, j).map { c -> f(c) }.joinToString("") +
        s.substring(j)
    println(ans)
}
```

Earlier versions

```kotlin
fun main() {
    // read input
    val n = readLine()!!.toInt()
    val s = readLine()!!
    val fl = readLine()!!.split(" ").map { it.toInt() }
    // define local function f
    fun f(c: Char) = '0' + fl[c - '1']
    // greedily find first and last indices
    val i = s.indexOfFirst { c -> f(c) > c }
        .takeIf { it >= 0 } ?: s.length
    val j = s.withIndex().indexOfFirst { (j, c) -> j > i && f(c) < c }
        .takeIf { it >= 0 } ?: s.length
    // compose and write the answer
    val ans =
        s.substring(0, i) +
        s.substring(i, j).map { c -> f(c) }.joinToString("") +
        s.substring(j)
    println(ans)
}
```

In this dense code, in addition to collection transformations, you can see such handy Kotlin features as local functions and the elvis operator ?: that allow to express idioms like "take the value if it is positive or else use length" with a concise and readable expressions like .takeIf { it >= 0 } ?: s.length, yet it is perfectly fine with Kotlin to create additional mutable variables and express the same code in imperative style, too.

To make reading the input in competitive programming tasks like this more concise, you can have the following list of helper input-reading functions:

Kotlin 1.6.0 and later

```kotlin
private fun readStr() = readln() // string line
private fun readInt() = readStr().toInt() // single int
private fun readStrings() = readStr().split(" ") // list of strings
private fun readInts() = readStrings().map { it.toInt() } // list of ints
```

Earlier versions

```kotlin
private fun readStr() = readLine()!! // string line
private fun readInt() = readStr().toInt() // single int
private fun readStrings() = readStr().split(" ") // list of strings
private fun readInts() = readStrings().map { it.toInt() } // list of ints
```

With these helpers, the part of code for reading input becomes simpler, closely following the input specification in the problem statement line by line:

```kotlin
// read input
val n = readInt()
val s = readStr()
val fl = readInts()
```

Note that in competitive programming it is customary to give variables shorter names than it is typical in industrial programming practice, since the code is to be written just once and not supported thereafter. However, these names are usually still mnemonic — a for arrays, i, j, and others for indices, r, and c for row and column numbers in tables, x and y for coordinates, and so on. It is easier to keep the same names for input data as it is given in the problem statement. However, more complex problems require more code which leads to using longer self-explanatory variable and function names.

More tips and tricks

Competitive programming problems often have input like this:

The first line of the input contains two integers n and k

In Kotlin this line can be concisely parsed with the following statement using destructuring declaration from a list of integers:

```kotlin
val (n, k) = readInts()
```

It might be temping to use JVM's java.util.Scanner class to parse less structured input formats. Kotlin is designed to interoperate well with JVM libraries, so that their use feels quite natural in Kotlin. However, beware that java.util.Scanner is extremely slow. So slow, in fact, that parsing 105 or more integers with it might not fit into a typical 2 second time-limit, which a simple Kotlin's split(" ").map { it.toInt() } would handle.

Writing output in Kotlin is usually straightforward with println(...) calls and using Kotlin's string templates. However, care must be taken when output contains on order of 105 lines or more. Issuing so many println calls is too slow, since the output in Kotlin is automatically flushed after each line. A faster way to write many lines from an array or a list is using joinToString() function with "\n" as the separator, like this:

```
println(a.joinToString("\n")) // each element of array/list of a separate line
```

Learning Kotlin

Kotlin is easy to learn, especially for those who already know Java. A short introduction to the basic syntax of Kotlin for software developers can be found directly in the reference section of the website starting from basic syntax.

IDEA has built-in Java-to-Kotlin converter. It can be used by people familiar with Java to learn the corresponding Kotlin syntactic constructions, but it is not perfect, and it is still worth familiarizing yourself with Kotlin and learning the Kotlin idioms.

A great resource to study Kotlin syntax and API of the Kotlin standard library are Kotlin Koans.

What's new in Kotlin 2.2.0

Released: June 23, 2025

The Kotlin 2.2.0 release is here! Here are the main highlights:

- Language: new language features in preview, including context parameters. Several previously experimental features are now Stable, such as guard conditions, non-local break and continue, and multi-dollar interpolation.
- Kotlin compiler: unified management of compiler warnings.
- Kotlin/JVM: changes to default method generation for interface functions.
- Kotlin/Native: LLVM 19 and new features for tracking and adjusting memory consumption.
- Kotlin/Wasm: separated Wasm target and the ability to configure Binaryen per project.
- Kotlin/JS: fix for the copy() method generated for @JsPlainObject interfaces.
- Gradle: binary compatibility validation in the Kotlin Gradle plugin.
- Standard library: stable Base64 and HexFormat APIs.
- Documentation: our documentation survey is open, and notable improvements have been made to the Kotlin documentation.

IDE support

The Kotlin plugins that support 2.2.0 are bundled in the latest versions of IntelliJ IDEA and Android Studio. You don't need to update the Kotlin plugin in your IDE. All you need to do is to change the Kotlin version to 2.2.0 in your build scripts.

See Update to a new release for details.

Language

This release promotes guard conditions, non-local break and continue, and multi-dollar interpolation to Stable. Additionally, several features, such as context parameters and context-sensitive resolution, are introduced in preview.

Preview of context parameters

Context parameters allow functions and properties to declare dependencies that are implicitly available in the surrounding context.

With context parameters, you don't need to manually pass around values, such as services or dependencies, that are shared and rarely change across sets of function calls.

Context parameters replace an older experimental feature called context receivers. To migrate from context receivers to context parameters, you can use assisted support in IntelliJ IDEA, as described in the blog post.

The main difference is that context parameters are not introduced as receivers in the body of a function. As a result, you need to use the name of the context parameters to access their members, unlike with context receivers, where the context is implicitly available.

Context parameters in Kotlin represent a significant improvement in managing dependencies through simplified dependency injection, improved DSL design, and scoped operations. For more information, see the feature's KEEP.

How to declare context parameters

You can declare context parameters for properties and functions using the context keyword followed by a list of parameters, each of the form name: Type. Here is an example with a dependency on the UserService interface:

```kotlin
// UserService defines the dependency required in the context
interface UserService {
    fun log(message: String)
    fun findUserById(id: Int): String
}

// Declares a function with a context parameter
context(users: UserService)
fun outputMessage(message: String) {
    // Uses log from the context
    users.log("Log: $message")
}

// Declares a property with a context parameter
context(users: UserService)
val firstUser: String
    // Uses findUserById from the context
    get() = users.findUserById(1)
```

You can use _ as a context parameter name. In this case, the parameter's value is available for resolution but is not accessible by name inside the block:

```kotlin
// Uses "_" as context parameter name
context(_: UserService)
fun logWelcome() {
    // Finds the appropriate log function from UserService
    outputMessage("Welcome!")
}
```

How to enable context parameters

To enable context parameters in your project, use the following compiler option in the command line:

```
-Xcontext-parameters
```

Or add it to the compilerOptions {} block of your Gradle build file:

```kotlin
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xcontext-parameters")
    }
}
```

Specifying both -Xcontext-receivers and -Xcontext-parameters compiler options simultaneously leads to an error.

Leave your feedback

This feature is planned to be stabilized and improved in future Kotlin releases. We would appreciate your feedback on our issue tracker, YouTrack.

Preview of context-sensitive resolution

Kotlin 2.2.0 introduces an implementation of context-sensitive resolution in preview.

Previously, you had to write the full name of enum entries or sealed class members, even when the type could be inferred from the context. For example:

```kotlin
enum class Problem {
    CONNECTION, AUTHENTICATION, DATABASE, UNKNOWN
}

fun message(problem: Problem): String = when (problem) {
    Problem.CONNECTION -> "connection"
    Problem.AUTHENTICATION -> "authentication"
    Problem.DATABASE -> "database"
    Problem.UNKNOWN -> "unknown"
}
```

Now, with context-sensitive resolution, you can omit the type name in contexts where the expected type is known:

```kotlin
enum class Problem {
    CONNECTION, AUTHENTICATION, DATABASE, UNKNOWN
}

// Resolves enum entries based on the known type of problem
fun message(problem: Problem): String = when (problem) {
    CONNECTION -> "connection"
    AUTHENTICATION -> "authentication"
    DATABASE -> "database"
    UNKNOWN -> "unknown"
}
```

The compiler uses this contextual type information to resolve the correct member. This information includes, among other things:

- The subject of a when expression
- An explicit return type
- A declared variable type
- Type checks (is) and casts (as)
- The known type of a sealed class hierarchy
- The declared type of a parameter

Context-sensitive resolution doesn't apply to functions, properties with parameters, or extension properties with receivers.

To try out context-sensitive resolution in your project, use the following compiler option in the command line:

```
-Xcontext-sensitive-resolution
```

Or add it to the compilerOptions {} block of your Gradle build file:

```kotlin
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xcontext-sensitive-resolution")
    }
}
```

We plan to stabilize and improve this feature in future Kotlin releases and would appreciate your feedback on our issue tracker YouTrack.

Preview of features for annotation use-site targets

Kotlin 2.2.0 introduces a couple of features that make working with annotation use-site targets more convenient.

@all meta-target for properties

Kotlin allows you to attach annotations to specific parts of a declaration, known as use-site targets. However, annotating each target individually was complex and error-prone:

```kotlin
data class User(
    val username: String,

    @param:Email      // Constructor parameter
    @field:Email      // Backing field
    @get:Email        // Getter method
    @property:Email   // Kotlin property reference
    val email: String,
) {
    @field:Email
    @get:Email
    @property:Email
    val secondaryEmail: String? = null
}
```

To simplify this, Kotlin introduces the new @all meta-target for properties. This feature tells the compiler to apply the annotation to all relevant parts of the property. When you use it, @all attempts to apply the annotation to:

- param: the constructor parameter, if declared in the primary constructor.
- property: the Kotlin property itself.
- field: the backing field, if it exists.
- get: the getter method.
- set_param: the parameter of the setter method, if the property is defined as var.
- RECORD_COMPONENT: if the class is a @JvmRecord, the annotation applies to the Java record component. This behavior mimics the way Java handles annotations on record components.

The compiler only applies the annotation to the targets for the given property.

In the example below, the @Email annotation is applied to all relevant targets of each property:

```kotlin
data class User(
    val username: String,

    // Applies @Email to param, property, field,
    // get, and set_param (if var)
    @all:Email val email: String,
) {
    // Applies @Email to property, field, and getter
    // (no param since it's not in the constructor)
    @all:Email val secondaryEmail: String? = null
}
```

You can use the @all meta-target with any property, both inside and outside the primary constructor. However, you can't use the @all meta-target with multiple annotations.

This new feature simplifies the syntax, ensures consistency, and improves interoperability with Java records.

To enable the @all meta-target in your project, use the following compiler option in the command line:

```
-Xannotation-target-all
```

Or add it to the compilerOptions {} block of your Gradle build file:

```kotlin
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xannotation-target-all")
    }
}
```

This feature is in preview. Please report any problems to our issue tracker, YouTrack. For more information about the @all meta-target, read this KEEP proposal.

New defaulting rules for use-site annotation targets

Kotlin 2.2.0 introduces new defaulting rules for propagating annotations to parameters, fields, and properties. Where previously an annotation was applied by default only to one of param, property, or field, defaults are now more in line with what is expected of an annotation.

If there are multiple applicable targets, one or more is chosen as follows:

- If the constructor parameter target (param) is applicable, it is used.
- If the property target (property) is applicable, it is used.
- If the field target (field) is applicable while property isn't, field is used.

If there are multiple targets, and none of param, property, or field are applicable, the annotation results in an error.

To enable this feature, add it to the compilerOptions {} block of your Gradle build file:

```kotlin
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xannotation-default-target=param-property")
    }
}
```

Or use the command-line argument for the compiler:

```
-Xannotation-default-target=param-property
```

Whenever you'd like to use the old behavior, you can:

- In a specific case, define the necessary target explicitly, for example, using @param:Annotation instead of @Annotation.
- For a whole project, use this flag in your Gradle build file:

  ```kotlin
  // build.gradle.kts
  kotlin {
      compilerOptions {
          freeCompilerArgs.add("-Xannotation-default-target=first-only")
      }
  }
  ```

This feature is in preview. Please report any problems to our issue tracker, YouTrack. For more information about the new defaulting rules for annotation use-site targets, read this KEEP proposal.

Support for nested type aliases

Previously, you could only declare type aliases at the top level of a Kotlin file. This meant that even internal or domain-specific type aliases had to live outside the class where they were used.

Starting from 2.2.0, you can define type aliases inside other declarations, as long as they don't capture type parameters from their outer class:

```kotlin
class Dijkstra {
    typealias VisitedNodes = Set<Node>

    private fun step(visited: VisitedNodes, ...) = ...
}
```

Nested type aliases have a few additional constraints, like not being able to mention type parameters. Check the documentation for the entire set of rules.

Nested type aliases allow for cleaner, more maintainable code by improving encapsulation, reducing package-level clutter, and simplifying internal implementations.

How to enable nested type aliases

To enable nested type aliases in your project, use the following compiler option in the command line:

```
-Xnested-type-aliases
```

Or add it to the compilerOptions {} block of your Gradle build file:

```
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xnested-type-aliases")
    }
}
```

Share your feedback

Nested type aliases are currently in Beta. Please report any problems to our issue tracker, YouTrack. For more information about this feature, read this KEEP proposal.

Stable features: guard conditions, non-local break and continue, and multi-dollar interpolation

In Kotlin 2.1.0, several new language features were introduced in preview. We're happy to announce that the following language features are now Stable in this release:

- Guard conditions in when with a subject
- Non-local break and continue
- Multi-dollar interpolation: improved handling of $ in string literals

See the full list of Kotlin language design features and proposals.

Kotlin compiler: unified management of compiler warnings

Kotlin 2.2.0 introduces a new compiler option, -Xwarning-level. It's designed to provide a unified way of managing compiler warnings in Kotlin projects.

Previously, you could only apply general module-wide rules, like disabling all warnings with -nowarn, turning all warnings to compilation errors with -Werror, or enabling additional compiler checks with -Wextra. The only option to adjust them for specific warnings was the -Xsuppress-warning option.

With the new solution, you can override general rules and exclude specific diagnostics in a consistent way.

How to apply

The new compiler option has the following syntax:

```
-Xwarning-level=DIAGNOSTIC_NAME:(error|warning|disabled)
```

- error: raises the specified warning to an error.
- warning: emits a warning and is enabled by default.
- disabled: completely suppresses the specified warning module-wide.

Keep in mind that you can only configure the severity level of warnings with the new compiler option.

Use cases

With the new solution, you can better fine-tune warning reporting in your project by combining general rules with specific ones. Choose your use case:

Suppress warnings

Command	Description
-nowarn	Suppresses all warnings during compilation.

Command	Description
-Xwarning-level=DIAGNOSTIC_NAME:disabled	Suppresses only specified warnings.
-nowarn -Xwarning-level=DIAGNOSTIC_NAME:warning	Suppresses all warnings except for the specified ones.

Raise warnings to errors

Command	Description
-Werror	Raises all warnings to compilation errors.
-Xwarning-level=DIAGNOSTIC_NAME:error	Raises only specified warnings to errors.
-Werror -Xwarning-level=DIAGNOSTIC_NAME:warning	Raises all warnings to errors except for the specified ones.

Enable additional compiler warnings

Command	Description
-Wextra	Enables all additional declaration, expression, and type compiler checks that emit warnings if true.
-Xwarning-level=DIAGNOSTIC_NAME:warning	Enables only specified additional compiler checks.
-Wextra -Xwarning-level=DIAGNOSTIC_NAME:disabled	Enables all additional checks except for the specified ones.

Warning lists

In case you have many warnings you want to exclude from general rules, you can list them in a separate file through @argfile.

Leave feedback

The new compiler option is still Experimental. Please report any problems to our issue tracker, YouTrack.

Kotlin/JVM

Kotlin 2.2.0 brings many updates to the JVM. The compiler now supports Java 24 bytecode and introduces changes to default method generation for interface functions. The release also simplifies working with annotations in Kotlin metadata, improves Java interop with inline value classes, and includes better support for annotating JVM records.

Changes to default method generation for interface functions

Starting from Kotlin 2.2.0, functions declared in interfaces are compiled to JVM default methods unless configured otherwise. This change affects how Kotlin's interface functions with implementations are compiled to bytecode.

This behavior is controlled by the new stable compiler option -jvm-default, replacing the deprecated -Xjvm-default option.

You can control the behavior of the -jvm-default option using the following values:

- enable (default): generates default implementations in interfaces and includes bridge functions in subclasses and DefaultImpls classes. Use this mode to maintain binary compatibility with older Kotlin versions.
- no-compatibility: generates only default implementations in interfaces. This mode skips compatibility bridges and DefaultImpls classes, making it suitable for new code.
- disable: disables default implementations in interfaces. Only bridge functions and DefaultImpls classes are generated, matching the behavior before Kotlin 2.2.0.

To configure the -jvm-default compiler option, set the jvmDefault property in your Gradle Kotlin DSL:

```
// build.gradle.kts
kotlin {
    compilerOptions {
        jvmDefault = JvmDefaultMode.NO_COMPATIBILITY
    }
}
```

Support for reading and writing annotations in Kotlin metadata

Previously, you had to read annotations from compiled JVM class files using reflection or bytecode analysis and manually match them to metadata entries based on signatures. This process was error-prone, especially for overloaded functions.

Now, in Kotlin 2.2.0, the Kotlin Metadata JVM library introduces support for reading annotations stored in Kotlin metadata.

To make annotations available in the metadata for your compiled files, add the following compiler option:

```
-Xannotations-in-metadata
```

Alternatively, add it to the compilerOptions {} block of your Gradle build file:

```
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xannotations-in-metadata")
    }
}
```

With this option enabled, the Kotlin compiler writes annotations into metadata alongside the JVM bytecode, making them accessible to the kotlin-metadata-jvm library.

The library provides the following APIs for accessing annotations:

- KmClass.annotations
- KmFunction.annotations
- KmProperty.annotations
- KmConstructor.annotations
- KmPropertyAccessorAttributes.annotations
- KmValueParameter.annotations
- KmFunction.extensionReceiverAnnotations
- KmProperty.extensionReceiverAnnotations
- KmProperty.backingFieldAnnotations
- KmProperty.delegateFieldAnnotations
- KmEnumEntry.annotations

These APIs are Experimental. To opt in, use the @OptIn(ExperimentalAnnotationsInMetadata::class) annotation.

Here's an example of reading annotations from Kotlin metadata:

```kotlin
@file:OptIn(ExperimentalAnnotationsInMetadata::class)

import kotlin.metadata.ExperimentalAnnotationsInMetadata
import kotlin.metadata.jvm.KotlinClassMetadata

annotation class Label(val value: String)

@Label("Message class")
class Message

fun main() {
    val metadata = Message::class.java.getAnnotation(Metadata::class.java)
    val kmClass = (KotlinClassMetadata.readStrict(metadata) as KotlinClassMetadata.Class).kmClass
    println(kmClass.annotations)
    // [@Label(value = StringValue("Message class"))]
}
```

> If you use the kotlin-metadata-jvm library in your projects, we recommend testing and updating your code to support annotations. Otherwise, when annotations in metadata become enabled by default in a future Kotlin version, your projects may produce invalid or incomplete metadata.
>
> If you experience any problems, please report them in our issue tracker.

Improved Java interop with inline value classes

Kotlin 2.2.0 introduces a new experimental annotation: @JvmExposeBoxed. This annotation makes it easier to consume inline value classes from Java.

By default, Kotlin compiles inline value classes to use unboxed representations, which are more performant but often hard or even impossible to use from Java. For example:

```kotlin
@JvmInline value class PositiveInt(val number: Int) {
    init { require(number >= 0) }
}
```

In this case, because the class is unboxed, there is no constructor available for Java to call. There's also no way for Java to trigger the init block to ensure that number is positive.

When you annotate the class with @JvmExposeBoxed, Kotlin generates a public constructor that Java can call directly, ensuring that the init block also runs.

You can apply the @JvmExposeBoxed annotation at the class, constructor, or function level to gain fine-grained control over what's exposed to Java.

For example, in the following code, the extension function .timesTwoBoxed() is not accessible from Java:

```kotlin
@JvmInline
value class MyInt(val value: Int)

fun MyInt.timesTwoBoxed(): MyInt = MyInt(this.value * 2)
```

To make it possible to create an instance of the MyInt class and call the .timesTwoBoxed() function from Java code, add the @JvmExposeBoxed annotation to both the class and the function:

```kotlin
@JvmExposeBoxed
@JvmInline
value class MyInt(val value: Int)

@JvmExposeBoxed
fun MyInt.timesTwoBoxed(): MyInt = MyInt(this.value * 2)
```

With these annotations, the Kotlin compiler generates a Java-accessible constructor for the MyInt class. It also generates an overload for the extension function that uses the boxed form of the value class. As a result, the following Java code runs successfully:

```java
MyInt input = new MyInt(5);
MyInt output = ExampleKt.timesTwoBoxed(input);
```

If you don't want to annotate every part of the inline value classes that you want to expose, you can effectively apply the annotation to a whole module. To apply this behavior to a module, compile it with the -Xjvm-expose-boxed option. Compiling with this option has the same effect as if every declaration in the module had the @JvmExposeBoxed annotation.

This new annotation does not change how Kotlin compiles or uses value classes internally, and all existing compiled code remains valid. It simply adds new capabilities to improve Java interoperability. The performance of Kotlin code using value classes is not impacted.

The @JvmExposeBoxed annotation is useful for library authors who want to expose boxed variants of member functions and receive boxed return types. It eliminates the need to choose between an inline value class (efficient but Kotlin-only) and a data class (Java-compatible but always boxed).

For a more detailed explanation of how the @JvmExposedBoxed annotation works and the problems it solves, see this KEEP proposal.

Improved support for annotating JVM records

Kotlin has supported JVM records since Kotlin 1.5.0. Now, Kotlin 2.2.0 improves how Kotlin handles annotations on record components, particularly in relation to Java's RECORD_COMPONENT target.

Firstly, if you want to use a RECORD_COMPONENT as an annotation target, you need to manually add annotations for Kotlin (@Target) and Java. This is because Kotlin's @Target annotation doesn't support RECORD_COMPONENT. For example:

```
@Target(AnnotationTarget.CLASS, AnnotationTarget.PROPERTY)
@java.lang.annotation.Target(ElementType.CLASS, ElementType.RECORD_COMPONENT)
annotation class exampleClass
```

Maintaining both lists manually can be error-prone, so Kotlin 2.2.0 introduces a compiler warning if the Kotlin and Java targets don't match. For instance, if you omit ElementType.CLASS in the Java target list, the compiler reports:

```
Incompatible annotation targets: Java target 'CLASS' missing, corresponding to Kotlin targets 'CLASS'.
```

Secondly, Kotlin's behavior differs from Java when it comes to propagating annotations in records. In Java, annotations on a record component automatically apply to the backing field, getter, and constructor parameter. Kotlin doesn't do this by default, but you can now replicate the behavior using the @all: use-site target.

For example:

```
@JvmRecord
data class Person(val name: String, @all:Positive val age: Int)
```

When you use @JvmRecord with @all:, Kotlin now:

- Propagates the annotation to the property, backing field, constructor parameter, and getter.
- Applies the annotation to the record component, as well, if the annotation supports Java's RECORD_COMPONENT.

Kotlin/Native

Starting with 2.2.0, Kotlin/Native uses LLVM 19. This release also brings several experimental features designed to track and adjust memory consumption.

Per-object memory allocation

Kotlin/Native's memory allocator can now reserve memory on a per-object basis. In some cases, it may help you satisfy strict memory limitations or reduce memory consumption on the application's startup.

The new feature is designed to replace the -Xallocator=std compiler option, which enabled the system memory allocator instead of the default one. Now, you can disable buffering (paging of allocations) without switching memory allocators.

The feature is currently Experimental. To enable it, set the following option in your gradle.properties file:

```
kotlin.native.binary.pagedAllocator=false
```

Please report any problems to our issue tracker, YouTrack.

Support for Latin-1 encoded strings at runtime

Kotlin now supports Latin-1-encoded strings, similarly to the JVM. This should help reduce the application's binary size and adjust memory consumption.

By default, strings in Kotlin are stored using UTF-16 encoding, where each character is represented by two bytes. In some cases, this leads to strings taking up twice as much space in the binary compared to the source code, and reading data from a simple ASCII file can take up twice as much memory as storing the file on disk.

In turn, Latin-1 (ISO 8859-1) encoding represents each of the first 256 Unicode characters with just one byte. With Latin-1 support enabled, strings are stored in Latin-1 encoding as long as all the characters fall within its range. Otherwise, the default UTF-16 encoding is used.

How to enable Latin-1 support

The feature is currently Experimental. To enable it, set the following option in your gradle.properties file:

```
kotlin.native.binary.latin1Strings=true
```

Known issues

As long as the feature is Experimental, the cinterop extension functions String.pin, String.usePinned, and String.refTo become less efficient. Each call to them may trigger automatic string conversion to UTF-16.

The Kotlin team is very grateful to our colleagues at Google and Sonya Valchuk in particular for implementing this feature.

For more information on memory consumption in Kotlin, see the documentation.

Improved tracking of memory consumption on Apple platforms

Starting with Kotlin 2.2.0, memory allocated by Kotlin code is now tagged. This can help you debug memory issues on Apple platforms.

When inspecting your application's high memory usage, you can now identify how much memory is reserved by Kotlin code. Kotlin's share is tagged with an identifier and can be tracked through tools like VM Tracker in Xcode Instruments.

This feature is enabled by default but is available only in the Kotlin/Native default memory allocator when all the following conditions are met:

- Tagging enabled. The memory should be tagged with a valid identifier. Apple recommends numbers between 240 and 255; the default value is 246.

  If you set up the kotlin.native.binary.mmapTag=0 Gradle property, tagging is disabled.

- Allocation with mmap. The allocator should use the mmap system call to map files into memory.

  If you set up the kotlin.native.binary.disableMmap=true Gradle property, the default allocator uses malloc instead of mmap.

- Paging enabled. Paging of allocations (buffering) should be enabled.

  If you set up the kotlin.native.binary.pagedAllocator=false Gradle property, the memory is reserved on a per-object basis instead.

For more information on memory consumption in Kotlin, see the documentation.

LLVM update from 16 to 19

In Kotlin 2.2.0, we updated LLVM from version 16 to 19. The new version includes performance improvements, bug fixes, and security updates.

This update shouldn't affect your code, but if you encounter any issues, please report them to our issue tracker.

Windows 7 target deprecated

Starting with Kotlin 2.2.0, the minimal supported Windows version has been raised from Windows 7 to Windows 10. Since Microsoft ended support for Windows 7 in January 2025, we also decided to deprecate this legacy target.

For more information, see Kotlin/Native target support.

Kotlin/Wasm

In this release, the build infrastructure for the Wasm target is separated from the JavaScript target. Additionally, now you can configure the Binaryen tool per project or module.

Build infrastructure for Wasm target separated from JavaScript target

Before, the wasmJs target shared the same infrastructure as the js target. As a result, both targets were hosted in the same directory (build/js) and used the same NPM tasks and configurations.

Now, the wasmJs target has its own infrastructure separate from the js target. This allows Wasm tasks and types to be distinct from JavaScript ones, enabling independent configuration.

Additionally, Wasm-related project files and NPM dependencies are now stored in a separate build/wasm directory.

New NPM-related tasks have been introduced for Wasm, while existing JavaScript tasks are now dedicated only to JavaScript:

Wasm tasks	JavaScript tasks
kotlinWasmNpmInstall	kotlinNpmInstall
wasmRootPackageJson	rootPackageJson

Similarly, new Wasm-specific declarations have been added:

Wasm declarations	JavaScript declarations
WasmNodeJsRootPlugin	NodeJsRootPlugin
WasmNodeJsPlugin	NodeJsPlugin
WasmYarnPlugin	YarnPlugin
WasmNodeJsRootExtension	NodeJsRootExtension
WasmNodeJsEnvSpec	NodeJsEnvSpec
WasmYarnRootEnvSpec	YarnRootEnvSpec

You can now work with the Wasm target independently of the JavaScript target, which simplifies the configuration process.

This change is enabled by default and requires no additional setup.

Per-project Binaryen configuration

The Binaryen tool, used in Kotlin/Wasm to optimize production builds, was previously configured once in the root project.

Now, you can configure the Binaryen tool per project or module. This change aligns with Gradle's best practices and ensures better support for features like project isolation, improving build performance and reliability in complex builds.

Additionally, you can now configure different versions of Binaryen for different modules, if needed.

This feature is enabled by default. However, if you have a custom configuration of Binaryen, you now need to apply it per project, rather than only in the root project.

Kotlin/JS

This release improves the copy() function in @JsPlainObject interfaces, type aliases in files with the @JsModule annotation, and other Kotlin/JS features.

Fix for copy() in @JsPlainObject interfaces

Kotlin/JS has an experimental plugin called js-plain-objects, which introduced a copy() function for interfaces annotated with @JsPlainObject. You can use the copy() function to manipulate objects.

However, the initial implementation of copy() was not compatible with inheritance, and this caused issues when a @JsPlainObject interface extended other interfaces.

To avoid limitations on plain objects, the copy() function has been moved from the object itself to its companion object:

```kotlin
@JsPlainObject
external interface User {
    val name: String
    val age: Int
}

fun main() {
    val user = User(name = "SomeUser", age = 21)
    // This syntax is not valid anymore
    val copy = user.copy(age = 35)
    // This is the correct syntax
    val copy = User.copy(user, age = 35)
}
```

This change resolves conflicts in the inheritance hierarchy and eliminates ambiguity. It is enabled by default starting from Kotlin 2.2.0.

Support for type aliases in files with @JsModule annotation

Previously, files annotated with @JsModule to import declarations from JavaScript modules were restricted to external declarations only. This meant that you couldn't declare a typealias in such files.

Starting with Kotlin 2.2.0, you can declare type aliases inside files marked with @JsModule:

```kotlin
@file:JsModule("somepackage")
package somepackage
typealias SomeClass = Any
```

This change reduces an aspect of Kotlin/JS interoperability limitations, and more improvements are planned for future releases.

Support for type aliases in files with @JsModule is enabled by default.

Support for @JsExport in multiplatform expect declarations

When working with the expect/actual mechanism in Kotlin Multiplatform projects, it was not possible to use the @JsExport annotation for expect declarations in common code.

Starting with this release, you can apply @JsExport directly to expect declarations:

```kotlin
// commonMain

// Produced error, but now works correctly
@JsExport
expect class WindowManager {
    fun close()
}

@JsExport
fun acceptWindowManager(manager: WindowManager) {
    ...
}

// jsMain

@JsExport
actual class WindowManager {
    fun close() {
        window.close()
    }
}
```

You must also annotate with @JsExport the corresponding actual implementation in the JavaScript source set, and it has to use only exportable types.

This fix allows shared code defined in commonMain to be correctly exported to JavaScript. You can now expose your multiplatform code to JavaScript consumers without having to use manual workarounds.

This change is enabled by default.

Ability to use @JsExport with the Promise<Unit> type

Previously, when you tried to export a function returning the Promise<Unit> type with the @JsExport annotation, the Kotlin compiler produced an error.

While return types like Promise<Int> worked correctly, using Promise<Unit> triggered a "non-exportable type" warning, even though it correctly mapped to Promise<void> in TypeScript.

This restriction has been removed. Now, the following code compiles without error:

```
// Worked correctly before
@JsExport
fun fooInt(): Promise<Int> = GlobalScope.promise {
    delay(100)
    return@promise 42
}

// Produced error, but now works correctly
@JsExport
fun fooUnit(): Promise<Unit> = GlobalScope.promise {
    delay(100)
}
```

This change removes an unnecessary restriction in the Kotlin/JS interop model. This fix is enabled by default.

Gradle

Kotlin 2.2.0 is fully compatible with Gradle 7.6.3 through 8.14. You can also use Gradle versions up to the latest Gradle release. However, be aware that doing so may result in deprecation warnings, and some new Gradle features might not work.

In this release, the Kotlin Gradle plugin comes with several improvements to its diagnostics. It also introduces an experimental integration of binary compatibility validation, making it easier to work on libraries.

Binary compatibility validation included in Kotlin Gradle plugin

To make it easier to check for binary compatibility between library versions, we're experimenting with moving the functionality of the binary compatibility validator into the Kotlin Gradle plugin (KGP). You can try it out in toy projects, but we don't recommend using it in production yet.

The original binary compatibility validator continues to be maintained during this experimental phase.

Kotlin libraries can use one of two binary formats: JVM class files or klib. Since these formats aren't compatible, the KGP works with each of them separately.

To enable the binary compatibility validation feature set, add the following to the kotlin{} block in your build.gradle.kts file:

```
// build.gradle.kts
kotlin {
    @OptIn(org.jetbrains.kotlin.gradle.dsl.abi.ExperimentalAbiValidation::class)
    abiValidation {
        // Use the set() function to ensure compatibility with older Gradle versions
        enabled.set(true)
    }
}
```

If your project has multiple modules where you want to check for binary compatibility, configure the feature in each module separately. Each module can have its own custom configuration.

Once enabled, run the checkLegacyAbi Gradle task to check for binary compatibility issues. You can run the task in IntelliJ IDEA or from the command line in your project directory:

```
./gradlew checkLegacyAbi
```

This task generates an application binary interface (ABI) dump from the current code as a UTF-8 text file. The task then compares the new dump with the one from the previous release. If the task finds any differences, it reports them as errors. After reviewing the errors, if you decide the changes are acceptable, you can update the reference ABI dump by running the updateLegacyAbi Gradle task.

Filter classes

The feature lets you filter classes in the ABI dump. You can include or exclude classes explicitly by name or partial name, or by the annotations (or parts of annotation names) that mark them.

For example, this sample excludes all classes in the com.company package:

```
// build.gradle.kts
kotlin {
    @OptIn(org.jetbrains.kotlin.gradle.dsl.abi.ExperimentalAbiValidation::class)
    abiValidation {
        filters.excluded.byNames.add("com.company.**")
    }
}
```

Explore the KGP API reference to learn more about configuring the binary compatibility validator.

Multiplatform limitations

In multiplatform projects, if your host doesn't support cross-compilation for all targets, the KGP tries to infer the ABI changes for unsupported targets by checking the ABI dumps from other ones. This approach helps avoid false validation failures if you later switch to a host that can compile all targets.

You can change this default behavior so that the KGP doesn't infer ABI changes for unsupported targets by adding the following to your build.gradle.kts file:

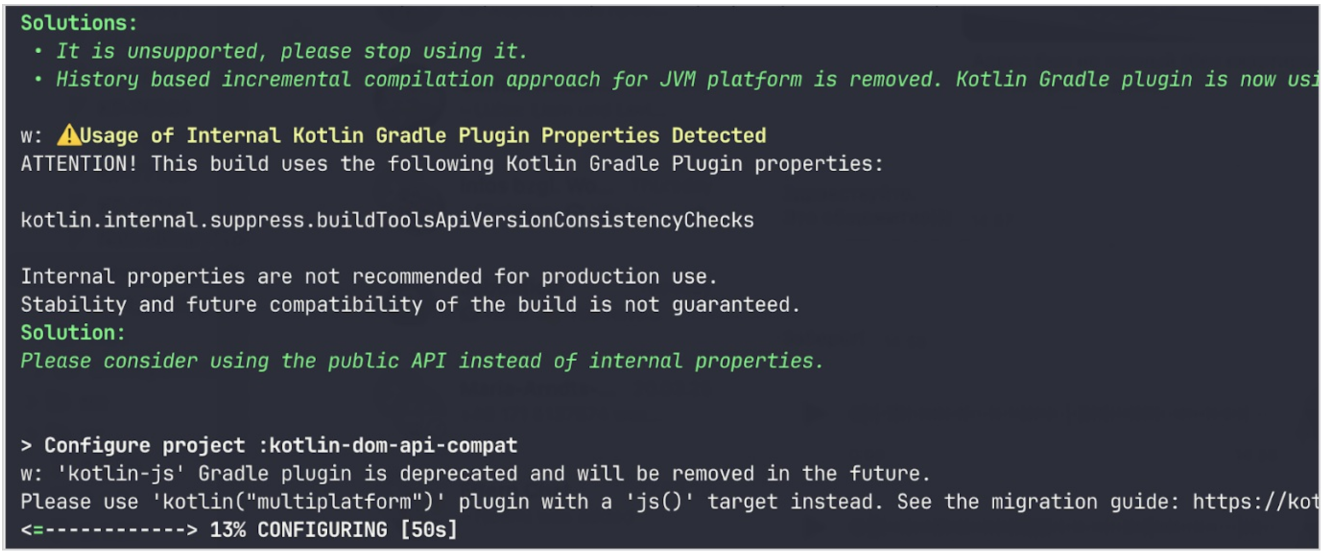
```
// build.gradle.kts
kotlin {
    @OptIn(org.jetbrains.kotlin.gradle.dsl.abi.ExperimentalAbiValidation::class)
    abiValidation {
        klib {
            keepUnsupportedTargets = false
        }
    }
}
```

However, if you have an unsupported target in your project, running the checkLegacyAbi task fails because the task can't create an ABI dump. This behavior may be desirable if it's more important for the check to fail than to miss an incompatible change due to inferred ABI changes from other targets.

Support for rich output in console for Kotlin Gradle plugin

In Kotlin 2.2.0, we support color and other rich output in the console during the Gradle build process, making it easier to read and understand the reported diagnostics.

Rich output is available in supported terminal emulators for Linux and macOS, and we're working on adding support for Windows.



```
Solutions:
 • It is unsupported, please stop using it.
 • History based incremental compilation approach for JVM platform is removed. Kotlin Gradle plugin is now usi

w: ⚠Usage of Internal Kotlin Gradle Plugin Properties Detected
ATTENTION! This build uses the following Kotlin Gradle Plugin properties:

kotlin.internal.suppress.buildToolsApiVersionConsistencyChecks

Internal properties are not recommended for production use.
Stability and future compatibility of the build is not guaranteed.
Solution:
Please consider using the public API instead of internal properties.


> Configure project :kotlin-dom-api-compat
w: 'kotlin-js' Gradle plugin is deprecated and will be removed in the future.
Please use 'kotlin("multiplatform")' plugin with a 'js()' target instead. See the migration guide: https://kot
<=------------> 13% CONFIGURING [50s]
```

Gradle console

This feature is enabled by default, but if you want to override it, add the following Gradle property to your gradle.properties file:

```
org.gradle.console=plain
```

For more information about this property and its options, see Gradle's documentation on Customizing log format.

Integration of Problems API within KGP diagnostics

Previously, the Kotlin Gradle Plugin (KGP) was only able to report diagnostics such as warnings and errors as plain text output to the console or logs.

Starting with 2.2.0, the KGP introduces an additional reporting mechanism: it now uses Gradle's Problems API, a standardized way to report rich, structured problem information during the build process.

The KGP diagnostics are now easier to read and more consistently displayed across different interfaces, such as the Gradle CLI and IntelliJ IDEA.

This integration is enabled by default, starting with Gradle 8.6 or later. As the API is still evolving, use the most recent Gradle version to benefit from the latest improvements.

KGP compatibility with --warning-mode

The Kotlin Gradle Plugin (KGP) diagnostics reported issues using fixed severity levels, meaning Gradle's --warning-mode command-line option had no effect on how the KGP displayed errors.

Now, the KGP diagnostics are compatible with the --warning-mode option, providing more flexibility. For example, you can convert all warnings into errors or disable warnings entirely.

With this change, the KGP diagnostics adjust the output based on the selected warning mode:

- When you set --warning-mode=fail, diagnostics with Severity.Warning are now elevated to Severity.Error.
- When you set --warning-mode=none, diagnostics with Severity.Warning are not logged.

This behavior is enabled by default starting with 2.2.0.

To ignore the --warning-mode option, set the following Gradle property to your gradle.properties file:

```
kotlin.internal.diagnostics.ignoreWarningMode=true
```

New experimental build tools API

You can use Kotlin with various build systems, such as Gradle, Maven, Amper, and others. However, integrating Kotlin into each system to support the full feature set, such as incremental compilation and compatibility with Kotlin compiler plugins, daemons, and Kotlin Multiplatform, requires significant effort.

To simplify this process, Kotlin 2.2.0 introduces a new experimental build tools API (BTA). The BTA is a universal API that acts as an abstraction layer between build systems and the Kotlin compiler ecosystem. With this approach, each build system only needs to support a single BTA entry point.

Currently, the BTA supports Kotlin/JVM only. The Kotlin team at JetBrains already uses it in the Kotlin Gradle plugin (KGP) and the kotlin-maven-plugin. You can try the BTA through these plugins, but the API itself isn't ready yet for general use in your own build tool integrations. If you're curious about the BTA proposal or want to share your feedback, see this KEEP proposal.

To try the BTA in:

- The KGP, add the following property to your gradle.properties file:

```
kotlin.compiler.runViaBuildToolsApi=true
```

- Maven, you don't need to do anything. It's enabled by default.

The BTA currently has no direct benefits for the Maven plugin, but it lays a solid foundation for the faster delivery of new features, such as support for the Kotlin daemon and the stabilization of incremental compilation.

For the KGP, using the BTA already has the following benefits:

- Improved “in process” compiler execution strategy
- More flexibility to configure different compiler versions from Kotlin

Improved “in process” compiler execution strategy

The KGP supports three Kotlin compiler execution strategies. The “in process” strategy, which runs the compiler inside the Gradle daemon process, previously didn't support incremental compilation.

Now, using the BTA, the “in-process” strategy does support incremental compilation. To use it, add the following property to your gradle.properties file:

```
kotlin.compiler.execution.strategy=in-process
```

Flexibility to configure different compiler versions from Kotlin

Sometimes you might want to use a newer Kotlin compiler version in your code while keeping the KGP on an older one – for example, to try new language features while still working through build script deprecations. Or you might want to update the version of the KGP but keep an older Kotlin compiler version.

The BTA makes this possible. Here's how you can configure it in your build.gradle.kts file:

```
// build.gradle.kts
import org.jetbrains.kotlin.buildtools.api.ExperimentalBuildToolsApi
import org.jetbrains.kotlin.gradle.ExperimentalKotlinGradlePluginApi

plugins {
    kotlin("jvm") version "2.2.0"
}

group = "org.jetbrains.example"
version = "1.0-SNAPSHOT"

repositories {
    mavenCentral()
}

kotlin {
    jvmToolchain(8)
    @OptIn(ExperimentalBuildToolsApi::class, ExperimentalKotlinGradlePluginApi::class)
    compilerVersion.set("2.1.21") // Different version than 2.2.0
}
```

The BTA supports configuring the KGP and Kotlin compiler versions with the three previous major versions and one subsequent major version. So in KGP 2.2.0, Kotlin compiler versions 2.1.x, 2.0.x, and 1.9.25 are supported. KGP 2.2.0 is also compatible with future Kotlin compiler versions 2.2.x and 2.3.x.

However, keep in mind that using different compiler versions together with compiler plugins may lead to Kotlin compiler exceptions. The Kotlin team plans to address these kinds of problems in future releases.

Try out the BTA with these plugins and send us your feedback in the dedicated YouTrack tickets for the KGP and the Maven plugin.

Kotlin standard library

In Kotlin 2.2.0, the Base64 API and HexFormat API are now Stable.

Stable Base64 encoding and decoding

Kotlin 1.8.20 introduced Experimental support for Base64 encoding and decoding. In Kotlin 2.2.0, the Base64 API is now Stable and includes four encoding schemes, with the new Base64.Pem added in this release:

- Base64.Default uses the standard Base64 encoding scheme.

> The Base64.Default is the companion object of the Base64 class. As a result, you can call its functions with Base64.encode() and Base64.decode() instead of Base64.Default.encode() and Base64.Default.decode().

- Base64.UrlSafe uses the "URL and Filename safe" encoding scheme.
- Base64.Mime uses the MIME encoding scheme, inserting a line separator every 76 characters during encoding and skipping illegal characters during decoding.
- Base64.Pem encodes data like Base64.Mime but limits the line length to 64 characters.

You can use the Base64 API to encode binary data into a Base64 string and decode it back into bytes.

Here's an example:

```kotlin
val foBytes = "fo".map { it.code.toByte() }.toByteArray()
Base64.Default.encode(foBytes) // "Zm8="
// Alternatively:
// Base64.encode(foBytes)

val foobarBytes = "foobar".map { it.code.toByte() }.toByteArray()
Base64.UrlSafe.encode(foobarBytes) // "Zm9vYmFy"

Base64.Default.decode("Zm8=") // foBytes
// Alternatively:
// Base64.decode("Zm8=")

Base64.UrlSafe.decode("Zm9vYmFy") // foobarBytes
```

On the JVM, use the .encodingWith() and .decodingWith() extension functions to encode and decode Base64 with input and output streams:

```kotlin
import kotlin.io.encoding.*
import java.io.ByteArrayOutputStream

fun main() {
    val output = ByteArrayOutputStream()
    val base64Output = output.encodingWith(Base64.Default)

    base64Output.use { stream ->
        stream.write("Hello World!!".encodeToByteArray())
    }

    println(output.toString())
    // SGVsbG8gV29ybGQhIQ==
}
```

Stable Hexadecimal parsing and formatting with the HexFormat API

The HexFormat API introduced in Kotlin 1.9.0 is now Stable. You can use it to convert between numerical values and hexadecimal strings.

For example:

```kotlin
fun main() {
        println(93.toHexString())
    //sampleEnd
}
```

For more information, see New HexFormat class to format and parse hexadecimals.

Compose compiler

In this release, the Compose compiler introduces support for composable function references and changes defaults for several feature flags.

Support for @Composable function references

The Compose compiler supports the declaration and usage of composable function references starting from the Kotlin 2.2.0 release:

```kotlin
val content: @Composable (String) -> Unit = ::Text

@Composable fun App() {
    content("My App")
}
```

Composable function references behave slightly differently from composable lambda objects at runtime. In particular, composable lambdas allow for finer control over skipping by extending the ComposableLambda class. Function references are expected to implement the KCallable interface, so the same optimization cannot be applied to them.

PausableComposition feature flag enabled by default

The PausableComposition feature flag is enabled by default starting from Kotlin 2.2.0. This flag adjusts the Compose compiler output for restartable functions, allowing runtime to force skipping behavior and therefore effectively pause composition by skipping each function. This allows heavy compositions to be split between frames, which will be used by prefetching in a future release.

To disable this feature flag, add the following to your Gradle configuration:

```kotlin
// build.gradle.kts
composeCompiler {
    featureFlag = setOf(ComposeFeatureFlag.PausableComposition.disabled())
}
```

OptimizeNonSkippingGroups feature flag enabled by default

The OptimizeNonSkippingGroups feature flag is enabled by default starting from Kotlin 2.2.0. This optimization improves runtime performance by removing group calls generated for non-skipping composable functions. It should not result in any observable behavior changes at runtime.

If you encounter any issues, you can validate that this change causes the issue by disabling the feature flag. Please report any issues to the Jetpack Compose issue tracker.

To disable the OptimizeNonSkippingGroups flag, add the following to your Gradle configuration:

```kotlin
composeCompiler {
    featureFlag = setOf(ComposeFeatureFlag.OptimizeNonSkippingGroups.disabled())
}
```

Deprecated feature flags

The StrongSkipping and IntrinsicRemember feature flags are now deprecated and will be removed in a future release. If you encounter any issues that make you disable these feature flags, please report them to the Jetpack Compose issue tracker.

Breaking changes and deprecations

- Starting with Kotlin 2.2.0, support for the Ant build system is deprecated. Kotlin support for Ant hasn't been in active development for a long time, and there are no plans to maintain it further due to its relatively small user base.

We plan to remove Ant support in 2.3.0. However, Kotlin remains open to contribution. If you're interested in becoming an external maintainer for Ant, leave a comment with the “jetbrains-team” visibility setting in this YouTrack issue.

- Kotlin 2.2.0 raises the deprecation level of the kotlinOptions{} block in Gradle to error. Use the compilerOptions{} block instead. For guidance on updating your build scripts, see Migrate from kotlinOptions{} to compilerOptions{}.
- Kotlin scripting remains an important part of Kotlin's ecosystem, but we're focusing on specific use cases such as custom scripting, as well as gradle.kts and main.kts scripts, to provide a better experience. To learn more, see our updated blog post. As a result, Kotlin 2.2.0 deprecates support for:
  - REPL: To continue to use REPL via kotlinc, opt in with the -Xrepl compiler option.
  - JSR-223: Since this JSR is in the Withdrawn state, the JSR-223 implementation continues to work with language version 1.9 but won't be migrated to use the K2 compiler in the future.
  - The KotlinScriptMojo Maven plugin: We didn't see enough traction with this plugin. You will see compiler warnings if you continue to use it.
-
- In Kotlin 2.2.0, the setSource() function in KotlinCompileTool now replaces configured sources instead of adding to them. If you want to add sources without replacing existing ones, use the source() function.
- The type of annotationProcessorOptionProviders in BaseKapt has been changed from MutableList<Any> to MutableList<CommandLineArgumentProvider>. If your code currently adds a list as a single element, use the addAll() function instead of the add() function.
- Following the deprecation of the dead code elimination (DCE) tool used in the legacy Kotlin/JS backend, the remaining DSLs related to DCE are now removed from the Kotlin Gradle plugin:
  - The org.jetbrains.kotlin.gradle.dsl.KotlinJsDce interface
  - The org.jetbrains.kotlin.gradle.targets.js.dsl.KotlinJsBrowserDsl.dceTask(body: Action<KotlinJsDce>) function
  - The org.jetbrains.kotlin.gradle.dsl.KotlinJsDceCompilerToolOptions interface
  - The org.jetbrains.kotlin.gradle.dsl.KotlinJsDceOptions interface

  The current JS IR compiler supports DCE out of the box, and the @JsExport annotation allows specifying which Kotlin functions and classes to retain during DCE.
- The deprecated kotlin-android-extensions plugin is removed in Kotlin 2.2.0. Use the kotlin-parcelize plugin for the Parcelable implementation generator and the Android Jetpack's view bindings for synthetic views instead.
- Experimental kotlinArtifacts API is deprecated in Kotlin 2.2.0. Use the current DSL available in the Kotlin Gradle plugin to build final native binaries. If it's not sufficient for migration, leave a comment in this YT issue.
- KotlinCompilation.source, deprecated in Kotlin 1.9.0, is now removed from the Kotlin Gradle plugin.
- The parameters for experimental commonization modes are deprecated in Kotlin 2.2.0. Clear the commonization cache to delete invalid compilation artifacts.
- The deprecated konanVersion property is now removed from the CInteropProcess task. Use CInteropProcess.kotlinNativeVersion instead.
- Usage of the deprecated destinationDir property will now lead to an error. Use CInteropProcess.destinationDirectory.set() instead.

Documentation updates

This release brings notable documentation changes, including the migration of Kotlin Multiplatform documentation to the KMP portal.

Additionally, we launched a documentation survey, created new pages and tutorials, and revamped existing ones.

Kotlin's documentation survey

We're looking for genuine feedback to make the Kotlin documentation better.

The survey takes around 15 minutes to complete, and your input will help shape the future of Kotlin docs.

Take the survey here.

New and revamped tutorials

- Kotlin intermediate tour – Take your understanding of Kotlin to the next level. Learn when to use extension functions, interfaces, classes, and more.
- Build a Kotlin app that uses Spring AI – Learn how to create a Kotlin app that answers questions using OpenAI and a vector database.
- Create a Spring Boot project with Kotlin – Learn how to create a Spring Boot project with Gradle using IntelliJ IDEA's New Project wizard.
- Mapping Kotlin and C tutorial series – Learn how different types and constructs are mapped between Kotlin and C.
- Create an app using C interop and libcurl – Create a simple HTTP client that can run natively using the libcurl C library.
- Create your Kotlin Multiplatform library – Learn how to create and publish a multiplatform library using IntelliJ IDEA.
- Build a full-stack application with Ktor and Kotlin Multiplatform – This tutorial now uses IntelliJ IDEA instead of Fleet, along with Material 3 and the latest versions of Ktor and Kotlin.
- Manage local resource environment in your Compose Multiplatform app – Learn how to manage the application's resource environment, like in-app theme and language.

New and revamped pages

- Kotlin for AI overview – Discover Kotlin's capabilities for building AI-powered applications.
- Dokka migration guide – Learn how to migrate to v2 of the Dokka Gradle plugin.
- Kotlin Metadata JVM library – Explore guidance on reading, modifying, and generating metadata for Kotlin classes compiled for the JVM.
- CocoaPods integration – Learn how to set up the environment, add Pod dependencies, or use a Kotlin project as a CocoaPod dependency through tutorials and sample projects.
- New pages for Compose Multiplatform to support the iOS stable release:
  - Navigation and Deep linking in particular.
  - Implementing layouts in Compose.
  - Localizing strings and other i18n pages like support for RTL languages.
- Compose Hot Reload – Learn how to use Compose Hot Reload with your desktop targets and how to add it to an existing project.
- Exposed migrations – Learn about the tools Exposed provides for managing database schema changes.

How to update to Kotlin 2.2.0

The Kotlin plugin is distributed as a bundled plugin in IntelliJ IDEA and Android Studio.

To update to the new Kotlin version, change the Kotlin version to 2.2.0 in your build scripts.

What's new in Kotlin 2.1.0

Released: November 27, 2024

The Kotlin 2.1.0 release is here! Here are the main highlights:

- New language features in preview: Guard conditions in when with a subject, non-local break and continue, and multi-dollar string interpolation.
- K2 compiler updates: More flexibility around compiler checks and improvements to the kapt implementation.
- Kotlin Multiplatform: Introduced basic support for Swift export, stable Gradle DSL for compiler options, and more.
- Kotlin/Native: Improved support for iosArm64 and other updates.
- Kotlin/Wasm: Multiple updates, including support for incremental compilation.
- Gradle support: Improved compatibility with newer versions of Gradle and the Android Gradle plugin, along with updates to the Kotlin Gradle plugin API.
- Documentation: Significant improvements to the Kotlin documentation.

IDE support

The Kotlin plugins that support 2.1.0 are bundled in the latest IntelliJ IDEA and Android Studio. You don't need to update the Kotlin plugin in your IDE. All you need to do is change the Kotlin version to 2.1.0 in your build scripts.

See Update to a new Kotlin version for details.

Language

After the Kotlin 2.0.0 release with the K2 compiler, the JetBrains team is focusing on improving the language with new features. In this release, we are excited to announce several new language design improvements.

These features are available in preview, and we encourage you to try them and share your feedback:

- Guard conditions in when with a subject
- Non-local break and continue
- Multi-dollar interpolation: improved handling of $ in string literals

> All the features have IDE support in the latest 2024.3 version of IntelliJ IDEA with K2 mode enabled.
>
> Learn more in the IntelliJ IDEA 2024.3 blog post.

See the full list of Kotlin language design features and proposals.

This release also brings the following language updates:

- Support for requiring opt-in to extend APIs
- Improved overload resolution for functions with generic types
- Improved exhaustiveness checks for when expressions with sealed classes

Guard conditions in when with a subject

> This feature is In preview, and opt-in is required (see details below).
>
> We would appreciate your feedback in YouTrack.

Starting from 2.1.0, you can use guard conditions in when expressions or statements with subjects.

Guard conditions allow you to include more than one condition for the branches of a when expression, making complex control flows more explicit and concise as well as flattening the code structure.

To include a guard condition in a branch, place it after the primary condition, separated by if:

```kotlin
sealed interface Animal {
    data class Cat(val mouseHunter: Boolean) : Animal {
        fun feedCat() {}
    }

    data class Dog(val breed: String) : Animal {
        fun feedDog() {}
    }
}

fun feedAnimal(animal: Animal) {
    when (animal) {
        // Branch with only the primary condition. Calls `feedDog()` when `animal` is `Dog`
        is Animal.Dog -> animal.feedDog()
        // Branch with both primary and guard conditions. Calls `feedCat()` when `animal` is `Cat` and is not `mouseHunter`
        is Animal.Cat if !animal.mouseHunter -> animal.feedCat()
        // Prints "Unknown animal" if none of the above conditions match
        else -> println("Unknown animal")
    }
}
```

In a single when expression, you can combine branches with and without guard conditions. The code in a branch with a guard condition runs only if both the primary condition and the guard condition are true. If the primary condition does not match, the guard condition is not evaluated. Additionally, guard conditions support else if.

To enable guard conditions in your project, use the following compiler option in the command line:

```
kotlinc -Xwhen-guards main.kt
```

Or add it to the compilerOptions {} block of your Gradle build file:

```
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xwhen-guards")
    }
}
```

Non-local break and continue

> This feature is In preview, and opt-in is required (see details below).
>
> We would appreciate your feedback in YouTrack.

Kotlin 2.1.0 adds a preview of another long-awaited feature, the ability to use non-local break and continue. This feature expands the toolset you can use in the scope of inline functions and reduces boilerplate code in your project.

Previously, you could use only non-local returns. Now, Kotlin also supports break and continue jump expressions non-locally. This means that you can apply them within lambdas passed as arguments to an inline function that encloses the loop:

```
fun processList(elements: List<Int>): Boolean {
    for (element in elements) {
        val variable = element.nullableMethod() ?: run {
            log.warning("Element is null or invalid, continuing...")
            continue
        }
        if (variable == 0) return true // If variable is zero, return true
    }
    return false
}
```

To try the feature in your project, use the -Xnon-local-break-continue compiler option in the command line:

```
kotlinc -Xnon-local-break-continue main.kt
```

Or add it in the compilerOptions {} block of your Gradle build file:

```
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xnon-local-break-continue")
    }
}
```

We're planning to make this feature Stable in future Kotlin releases. If you encounter any issues when using non-local break and continue, please report them to our issue tracker.

Multi-dollar string interpolation

The feature is In preview and opt-in is required (see details below).

We would appreciate your feedback in YouTrack.

Kotlin 2.1.0 introduces support for multi-dollar string interpolation, improving how the dollar sign ($) is handled within string literals. This feature is helpful in contexts that require multiple dollar signs, such as templating engines, JSON schemas, or other data formats.

String interpolation in Kotlin uses a single dollar sign. However, using a literal dollar sign in a string, which is common in financial data and templating systems, required workarounds such as ${'$'}. With the multi-dollar interpolation feature enabled, you can configure how many dollar signs trigger interpolation, with fewer dollar signs being treated as string literals.

Here's an example of how to generate an JSON schema multi-line string with placeholders using $:

```kotlin
val KClass<*>.jsonSchema : String
    get() = $$"""
    {
      "$schema": "https://json-schema.org/draft/2020-12/schema",
      "$id": "https://example.com/product.schema.json",
      "$dynamicAnchor": "meta"
      "title": "$${simpleName ?: qualifiedName ?: "unknown"}",
      "type": "object"
    }
    """
```

In this example, the initial $$ means that you need two dollar signs ($$) to trigger interpolation. It prevents $schema, $id, and $dynamicAnchor from being interpreted as interpolation markers.

This approach is especially helpful when working with systems that use dollar signs for placeholder syntax.

To enable the feature, use the following compiler option in the command line:

```
kotlinc -Xmulti-dollar-interpolation main.kt
```

Alternatively, update the compilerOptions {} block of your Gradle build file:

```kotlin
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xmulti-dollar-interpolation")
    }
}
```

If your code already uses standard string interpolation with a single dollar sign, no changes are needed. You can use $$ whenever you need literal dollar signs in your strings.

Support for requiring opt-in to extend APIs

Kotlin 2.1.0 introduces the @SubclassOptInRequired annotation, which allows library authors to require an explicit opt-in before users can implement experimental interfaces or extend experimental classes.

This feature can be useful when a library API is stable enough to use but might evolve with new abstract functions, making it unstable for inheritance.

To add the opt-in requirement to an API element, use the @SubclassOptInRequired annotation with a reference to the annotation class:

```kotlin
@RequiresOptIn(
level = RequiresOptIn.Level.WARNING,
message = "Interfaces in this library are experimental"
)
annotation class UnstableApi()

@SubclassOptInRequired(UnstableApi::class)
interface CoreLibraryApi
```

In this example, the CoreLibraryApi interface requires users to opt in before they can implement it. A user can opt in like this:

```kotlin
@OptIn(UnstableApi::class)
```

```
interface MyImplementation: CoreLibraryApi
```

When you use the @SubclassOptInRequired annotation to require opt-in, the requirement is not propagated to any inner or nested classes.

For a real-world example of how to use the @SubclassOptInRequired annotation in your API, check out the SharedFlow interface in the kotlinx.coroutines library.

Improved overload resolution for functions with generic types

Previously, if you had a number of overloads for a function where some had value parameters of a generic type and others had function types in the same position, the resolution behavior could sometimes be inconsistent.

This led to different behavior depending on whether your overloads were member functions or extension functions. For example:

```
class KeyValueStore<K, V> {
    fun store(key: K, value: V) {} // 1
    fun store(key: K, lazyValue: () -> V) {} // 2
}

fun <K, V> KeyValueStore<K, V>.storeExtension(key: K, value: V) {} // 1
fun <K, V> KeyValueStore<K, V>.storeExtension(key: K, lazyValue: () -> V) {} // 2

fun test(kvs: KeyValueStore<String, Int>) {
    // Member functions
    kvs.store("", 1)    // Resolves to 1
    kvs.store("") { 1 } // Resolves to 2

    // Extension functions
    kvs.storeExtension("", 1)    // Resolves to 1
    kvs.storeExtension("") { 1 } // Doesn't resolve
}
```

In this example, the KeyValueStore class has two overloads for the store() function, where one overload has function parameters with generic types K and V, and another has a lambda function that returns a generic type V. Similarly, there are two overloads for the extension function: storeExtension().

When the store() function was called with and without a lambda function, the compiler successfully resolved the correct overloads. However, when the extension function storeExtension() was called with a lambda function, the compiler didn't resolve the correct overload because it incorrectly considered both overloads to be applicable.

To fix this problem, we've introduced a new heuristic so that the compiler can discard a possible overload when a function parameter with a generic type can't accept a lambda function based on information from a different argument. This change makes the behavior of member functions and extension functions consistent, and it is enabled by default in Kotlin 2.1.0.

Improved exhaustiveness checks for when expressions with sealed classes

In previous versions of Kotlin, the compiler required an else branch in when expressions for type parameters with sealed upper bounds, even when all cases in the sealed class hierarchy were covered. This behavior is addressed and improved in Kotlin 2.1.0, making exhaustiveness checks more powerful and allowing you to remove redundant else branches, keeping when expressions cleaner and more intuitive.

Here's an example demonstrating the change:

```
sealed class Result
object Error: Result()
class Success(val value: String): Result()

fun <T : Result> render(result: T) = when (result) {
    Error -> "Error!"
    is Success -> result.value
    // Requires no else branch
}
```

Kotlin K2 compiler

With Kotlin 2.1.0, the K2 compiler now provides more flexibility when working with compiler checks and warnings, as well as improved support for the kapt plugin.

Extra compiler checks

With Kotlin 2.1.0, you can now enable additional checks in the K2 compiler. These are extra declaration, expression, and type checks that are usually not crucial for compilation but can still be useful if you want to validate the following cases:

Check type	Comment
REDUNDANT_NULLABLE	Boolean?? is used instead of Boolean?
PLATFORM_CLASS_MAPPED_TO_KOTLIN	java.lang.String is used instead of kotlin.String
ARRAY_EQUALITY_OPERATOR_CAN_BE_REPLACED_WITH_EQUALS	arrayOf("") == arrayOf("") is used instead of arrayOf("").contentEquals(arrayOf(""))
REDUNDANT_CALL_OF_CONVERSION_METHOD	42.toInt() is used instead of 42
USELESS_CALL_ON_NOT_NULL	"".orEmpty() is used instead of ""
REDUNDANT_SINGLE_EXPRESSION_STRING_TEMPLATE	"$string" is used instead of string
UNUSED_ANONYMOUS_PARAMETER	A parameter is passed in the lambda expression but never used
REDUNDANT_VISIBILITY_MODIFIER	public class Klass is used instead of class Klass
REDUNDANT_MODALITY_MODIFIER	final class Klass is used instead of class Klass
REDUNDANT_SETTER_PARAMETER_TYPE	set(value: Int) is used instead of set(value)
CAN_BE_VAL	var local = 0 is defined but never reassigned, can be val local = 42 instead
ASSIGNED_VALUE_IS_NEVER_READ	val local = 42 is defined but never used afterward in the code
UNUSED_VARIABLE	val local = 0 is defined but never used in the code
REDUNDANT_RETURN_UNIT_TYPE	fun foo(): Unit {} is used instead of fun foo() {}
UNREACHABLE_CODE	Code statement is present but can never be executed

If the check is true, you'll receive a compiler warning with a suggestion on how to fix the problem.

Extra checks are disabled by default. To enable them, use the -Wextra compiler option in the command line or specify extraWarnings in the compilerOptions {} block of your Gradle build file:

```kotlin
// build.gradle.kts
kotlin {
    compilerOptions {
        extraWarnings.set(true)
    }
}
```

For more information on how to define and use compiler options, see Compiler options in the Kotlin Gradle plugin.

Global warning suppression

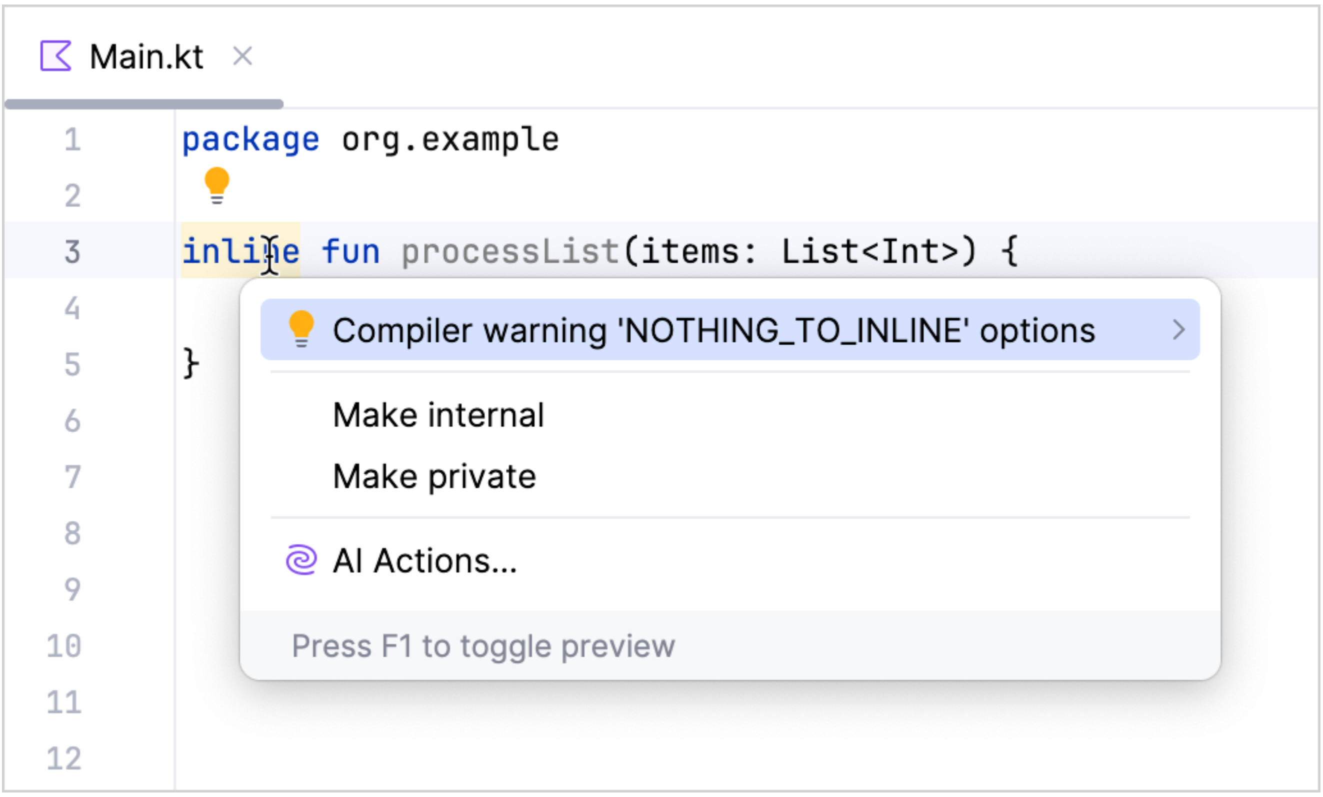
In 2.1.0, the Kotlin compiler has received a highly requested feature – the ability to suppress warnings globally.

You can now suppress specific warnings in the whole project by using the -Xsuppress-warning=WARNING_NAME syntax in the command line or the freeCompilerArgs attribute in the compilerOptions {} block of your build file.

For example, if you have extra compiler checks enabled in your project but want to suppress one of them, use:

```
// build.gradle.kts
kotlin {
    compilerOptions {
        extraWarnings.set(true)
        freeCompilerArgs.add("-Xsuppress-warning=CAN_BE_VAL")
    }
}
```

If you want to suppress a warning but don't know its name, select the element and click the light bulb icon (or use Cmd + Enter/Alt + Enter):



```
package org.example

inline fun processList(items: List<Int>) {

}
```

Main.kt
Compiler warning 'NOTHING_TO_INLINE' options
Make internal
Make private
AI Actions...
Press F1 to toggle preview

Warning name intention

The new compiler option is currently Experimental. The following details are also worth noting:

- Error suppression is not allowed.
- If you pass an unknown warning name, compilation will result in an error.
- You can specify several warnings at once:

Command line

```
kotlinc -Xsuppress-warning=NOTHING_TO_INLINE -Xsuppress-warning=NO_TAIL_CALLS_FOUND main.kt
```

Build file

```
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.addAll(
            listOf(
                "-Xsuppress-warning=NOTHING_TO_INLINE",
                "-Xsuppress-warning=NO_TAIL_CALLS_FOUND"
            )
        )
    }
}
```

Improved K2 kapt implementation

> The kapt plugin for the K2 compiler (K2 kapt) is in Alpha. It may be changed at any time.
>
> We would appreciate your feedback in YouTrack.

Currently, projects using the kapt plugin work with the K1 compiler by default, supporting Kotlin versions up to 1.9.

In Kotlin 1.9.20, we launched an experimental implementation of the kapt plugin with the K2 compiler (K2 kapt). We have now improved K2 kapt's internal implementation to mitigate technical and performance issues.

While the new K2 kapt implementation doesn't introduce new features, its performance has significantly improved compared to the previous K2 kapt implementation. Additionally, the K2 kapt plugin's behavior is now much closer to that of K1 kapt.

To use the new K2 kapt plugin implementation, enable it just like you did the previous K2 kapt plugin. Add the following option to the gradle.properties file of your project:

```
kapt.use.k2=true
```

In upcoming releases, the K2 kapt implementation will be enabled by default instead of K1 kapt, so you will no longer need to enable it manually.

We highly appreciate your feedback before the new implementation is stabilized.

Resolution for overload conflicts between unsigned and non-primitive types

This release addresses the issue of resolution for overload conflicts that could occur in previous versions when functions were overloaded for unsigned and non-primitive types, as in the following examples:

Overloaded extension functions

```
fun Any.doStuff() = "Any"
fun UByte.doStuff() = "UByte"

fun main() {
    val uByte: UByte = UByte.MIN_VALUE
    uByte.doStuff() // Overload resolution ambiguity before Kotlin 2.1.0
}
```

In earlier versions, calling uByte.doStuff() led to ambiguity because both the Any and UByte extensions were applicable.

Overloaded top-level functions

```
fun doStuff(value: Any) = "Any"
fun doStuff(value: UByte) = "UByte"

fun main() {
    val uByte: UByte = UByte.MIN_VALUE
    doStuff(uByte) // Overload resolution ambiguity before Kotlin 2.1.0
}
```

Similarly, the call to doStuff(uByte) was ambiguous because the compiler couldn't decide whether to use the Any or UByte version. With 2.1.0, the compiler now handles these cases correctly, resolving the ambiguity by giving precedence to the more specific type, in this case UByte.

Kotlin/JVM

Starting with version 2.1.0, the compiler can generate classes containing Java 23 bytecode.

Change of JSpecify nullability mismatch diagnostics severity to strict

Kotlin 2.1.0 enforces strict handling of nullability annotations from org.jspecify.annotations, improving type safety for Java interoperability.

The following nullability annotations are affected:

- org.jspecify.annotations.Nullable
- org.jspecify.annotations.NonNull
- org.jspecify.annotations.NullMarked
- Legacy annotations in org.jspecify.nullness (JSpecify 0.2 and earlier)

Starting from Kotlin 2.1.0, nullability mismatches are raised from warnings to errors by default. This ensures that annotations like @NonNull and @Nullable are enforced during type checks, preventing unexpected nullability issues at runtime.

The @NullMarked annotation also affects the nullability of all members within its scope, making the behavior more predictable when you're working with annotated Java code.

Here's an example demonstrating the new default behavior:

```
// Java
import org.jspecify.annotations.*;
public class SomeJavaClass {
    @NonNull
    public String foo() { //...
    }

    @Nullable
    public String bar() { //...
    }
}
```

```
// Kotlin
fun test(sjc: SomeJavaClass) {
    // Accesses a non-null result, which is allowed
    sjc.foo().length

    // Raises an error in the default strict mode because the result is nullable
    // To avoid the error, use ?.length instead
    sjc.bar().length
}
```

You can manually control the severity of diagnostics for these annotations. To do so, use the -Xnullability-annotations compiler option to choose a mode:

- ignore: Ignore nullability mismatches.
- warning: Report warnings for nullability mismatches.
- strict: Report errors for nullability mismatches (default mode).

For more information, see Nullability annotations.

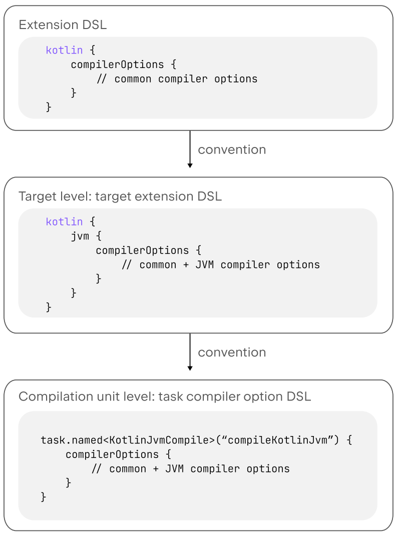
Kotlin Multiplatform

Kotlin 2.1.0 introduces basic support for Swift export and makes publishing Kotlin Multiplatform libraries easier. It also focuses on improvements around Gradle that stabilize the new DSL for configuring compiler options and bring a preview of the Isolated Projects feature.

New Gradle DSL for compiler options in multiplatform projects promoted to Stable

In Kotlin 2.0.0, we introduced a new Experimental Gradle DSL to simplify the configuration of compiler options across your multiplatform projects. In Kotlin 2.1.0, this DSL has been promoted to Stable.

The overall project configuration now has three layers. The highest is the extension level, then the target level, and the lowest is the compilation unit (which is usually a compilation task):


Extension DSL
convention
Target level: target extension DSL
convention
Compilation unit level: task compiler option DSL

```
kotlin {
    compilerOptions {
        // common compiler options
    }
}
```

```
kotlin {
    jvm {
        compilerOptions {
            // common + JVM compiler options
        }
    }
}
```

```
task.named<KotlinJvmCompile>("compileKotlinJvm") {
    compilerOptions {
        // common + JVM compiler options
    }
}
```

Kotlin compiler options levels

To learn more about the different levels and how compiler options can be configured between them, see Compiler options.

Preview Gradle's Isolated Projects in Kotlin Multiplatform

> This feature is Experimental and is currently in a pre-Alpha state in Gradle. Use it only with Gradle version 8.10 and solely for evaluation purposes. The feature may be dropped or changed at any time.
>
> We would appreciate your feedback on it in YouTrack. Opt-in is required (see details below).

In Kotlin 2.1.0, you can preview Gradle's Isolated Projects feature in your multiplatform projects.

The Isolated Projects feature in Gradle improves build performance by "isolating" configuration of individual Gradle projects from each other. Each project's build logic is restricted from directly accessing the mutable state of other projects, allowing them to safely run in parallel. To support this feature, we made some changes to the Kotlin Gradle plugin's model, and we are interested in hearing about your experiences during this preview phase.

There are two ways to enable the Kotlin Gradle plugin's new model:

- Option 1: Testing compatibility without enabling Isolated Projects – To check compatibility with the Kotlin Gradle plugin's new model without enabling the Isolated Projects feature, add the following Gradle property in the gradle.properties file of your project:

  ```
  # gradle.properties
  kotlin.kmp.isolated-projects.support=enable
  ```

- Option 2: Testing with Isolated Projects enabled – Enabling the Isolated Projects feature in Gradle automatically configures the Kotlin Gradle plugin to use the new model. To enable the Isolated Projects feature, set the system property. In this case, you don't need to add the Gradle property for the Kotlin Gradle plugin to your project.

Basic support for Swift export

This feature is currently in the early stages of development. It may be dropped or changed at any time. Opt-in is required (see the details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Version 2.1.0 takes the first step towards providing support for Swift export in Kotlin, allowing you to export Kotlin sources directly to the Swift interface without using Objective-C headers. This should make multiplatform development for Apple targets easier.

The current basic support includes the ability to:

- Export multiple Gradle modules from Kotlin directly to Swift.
- Define custom Swift module names with the moduleName property.
- Set collapse rules for the package structure with the flattenPackage property.

You can use the following build file in your project as a starting point for setting up Swift export:

```
// build.gradle.kts
kotlin {

    iosX64()
    iosArm64()
    iosSimulatorArm64()

    @OptIn(ExperimentalSwiftExportDsl::class)
    swiftExport {
        // Root module name
        moduleName = "Shared"

        // Collapse rule
        // Removes package prefix from generated Swift code
        flattenPackage = "com.example.sandbox"

        // Export external modules
        export(project(":subproject")) {
            // Exported module name
            moduleName = "Subproject"
            // Collapse exported dependency rule
            flattenPackage = "com.subproject.library"
        }
    }
}
```

You can also clone our public sample with Swift export already set up.

The compiler automatically generates all the necessary files (including swiftmodule files, static a library, and header and modulemap files) and copies them into the app's build directory, which you can access from Xcode.

How to enable Swift export

Keep in mind that the feature is currently only in the early stages of development.

Swift export currently works in projects that use direct integration to connect the iOS framework to the Xcode project. This is a standard configuration for Kotlin Multiplatform projects created in Android Studio or through the web wizard.

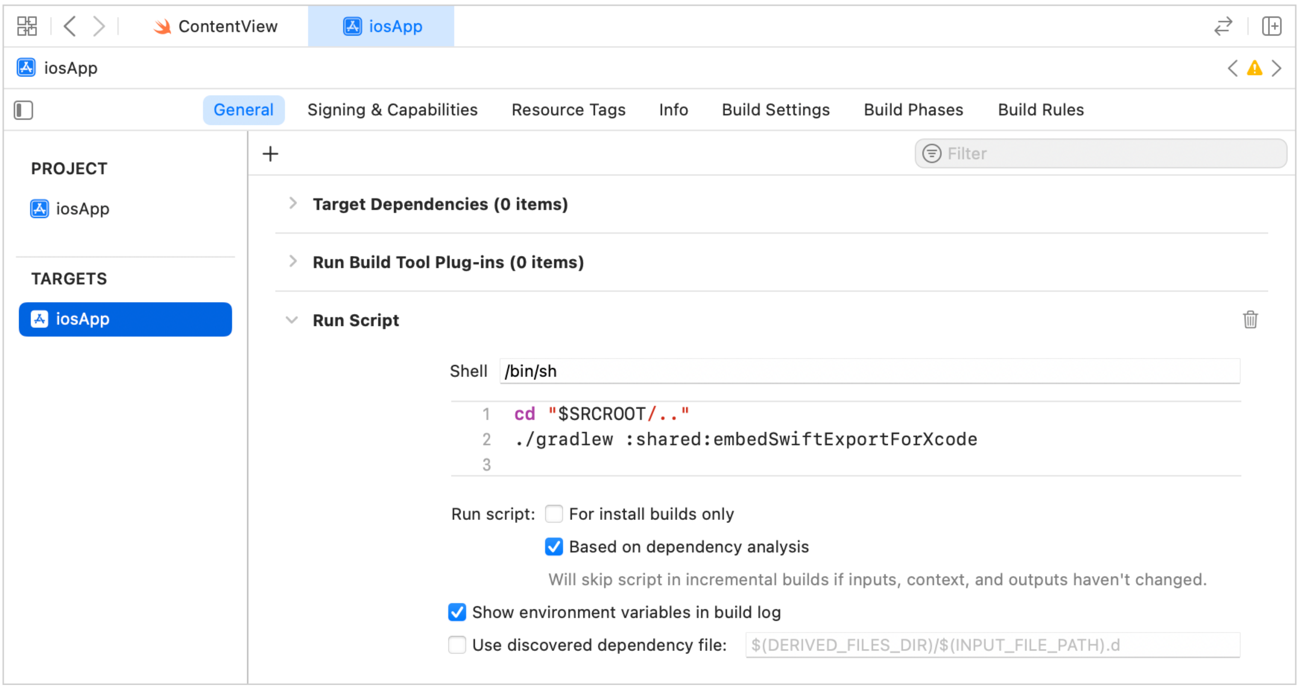
To try out Swift export in your project:

1. Add the following Gradle option to your gradle.properties file:

```
# gradle.properties
kotlin.experimental.swift-export.enabled=true
```

2. In Xcode, open the project settings.
3. On the Build Phases tab, locate the Run Script phase with the embedAndSignAppleFrameworkForXcode task.
4. Adjust the script to feature the embedSwiftExportForXcode task instead in the run script phase:

```
./gradlew :<Shared module name>:embedSwiftExportForXcode
```



Shell /bin/sh

```
cd "$SRCROOT/.."
./gradlew :shared:embedSwiftExportForXcode
```

Run script: For install builds only
[✓] Based on dependency analysis
Will skip script in incremental builds if inputs, context, and outputs haven't changed.
[✓] Show environment variables in build log
Use discovered dependency file: $(DERIVED_FILES_DIR)/$(INPUT_FILE_PATH).d

Add the Swift export script

Leave feedback on Swift export

We're planning to expand and stabilize Swift export support in future Kotlin releases. Please leave your feedback in this YouTrack issue.

Ability to publish Kotlin libraries from any host

This feature is currently Experimental. Opt-in is required (see the details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

The Kotlin compiler produces .klib artifacts for publishing Kotlin libraries. Previously, you could get the necessary artifacts from any host, except for Apple platform targets that required a Mac machine. That put a special restraint on Kotlin Multiplatform projects that targeted iOS, macOS, tvOS, and watchOS targets.

Kotlin 2.1.0 lifts this restriction, adding support for cross-compilation. Now you can use any host to produce .klib artifacts, which should greatly simplify the publishing process for Kotlin and Kotlin Multiplatform libraries.

How to enable publishing libraries from any host

To try cross-compilation out in your project, add the following binary option to your gradle.properties file:

```
# gradle.properties
kotlin.native.enableKlibsCrossCompilation=true
```

This feature is currently Experimental and has some limitations. You still need to use a Mac machine if:

- Your library has a cinterop dependency.
- You have CocoaPods integration set up in your project.
- You need to build or test final binaries for Apple targets.

Leave feedback on publishing libraries from any host

We're planning to stabilize this feature and further improve library publication in future Kotlin releases. Please leave your feedback in our issue tracker YouTrack.

For more information, see Publishing multiplatform libraries.

Support for non-packed klibs

Kotlin 2.1.0 makes it possible to generate non-packed .klib file artifacts. This gives you the option to configure dependencies on klibs directly rather than unpack them first.

This change can also improve performance, decreasing compilation and linking time in your Kotlin/Wasm, Kotlin/JS, and Kotlin/Native projects.

For example, our benchmark shows a performance improvement of roughly 3% in total build time on the project with 1 linking and 10 compilation tasks (the project builds a single native executable binary that depends on 9 simplified projects). However, the actual impact on build time depends on both the number of subprojects and their respective sizes.

How to set up your project

By default, Kotlin compilation and linking tasks are now configured to use the new non-packed artifacts.

If you have set up custom build logic for resolving klibs and want to use the new unpacked artifacts, you need to explicitly specify the preferred variant of klib package resolution in your Gradle build file:

```kotlin
// build.gradle.kts
import org.jetbrains.kotlin.gradle.plugin.attributes.KlibPackaging
// ...
val resolvableConfiguration = configurations.resolvable("resolvable") {

    // For the new non-packed configuration:
    attributes.attribute(KlibPackaging.ATTRIBUTE, project.objects.named(KlibPackaging.NON_PACKED))

    // For the previous packed configuration:
    attributes.attribute(KlibPackaging.ATTRIBUTE, project.objects.named(KlibPackaging.PACKED))
}
```

Non-packed .klib files are generated at the same path in your project's build directory as the packed ones previously were. In turn, packed klibs are now located in the build/libs directory.

If no attribute is specified, the packed variant is used. You can check the list of available attributes and variants with the following console command:

```
./gradlew outgoingVariants
```

We would appreciate your feedback on this feature in YouTrack.

Further deprecation of old android target

In Kotlin 2.1.0, the deprecation warning for the old android target name has been raised to an error.

Currently, we recommend using the androidTarget option in your Kotlin Multiplatform projects targeting Android. This is a temporary solution that is necessary to free the android name for the upcoming Android/KMP plugin from Google.

We'll provide further migration instructions when the new plugin is available. The new DSL from Google will be the preferred option for Android target support in Kotlin Multiplatform.

For more information, see the Kotlin Multiplatform compatibility guide.

Dropped support for declaring multiple targets of the same type

Before Kotlin 2.1.0, you could declare multiple targets of the same type in your multiplatform projects. However, this made it challenging to distinguish between targets and to support shared source sets effectively. In most cases, a simpler setup, such as using separate Gradle projects, works better. For detailed guidance and an example of how to migrate, see Declaring several similar targets in the Kotlin Multiplatform compatibility guide.

Kotlin 1.9.20 triggered a deprecation warning if you declared multiple targets of the same type in your multiplatform projects. In Kotlin 2.1.0, this deprecation warning is now an error for all targets except Kotlin/JS ones. To learn more about why Kotlin/JS targets are exempt, see this issue in YouTrack.

Kotlin/Native

Kotlin 2.1.0 includes an upgrade for the iosArm64 target support, improved cinterop caching process, and other updates.

iosArm64 promoted to Tier 1

The iosArm64 target, which is crucial for Kotlin Multiplatform development, has been promoted to Tier 1. This is the highest level of support in the Kotlin/Native compiler.

This means the target is regularly tested on the CI pipeline to ensure that it's able to compile and run. We also provide source and binary compatibility between compiler releases for the target.

For more information on target tiers, see Kotlin/Native target support.

LLVM update from 11.1.0 to 16.0.0

In Kotlin 2.1.0, we updated LLVM from version 11.1.0 to 16.0.0. The new version includes bug fixes and security updates. In certain cases, it also provides compiler optimizations and faster compilation.

If you have Linux targets in your project, take note that the Kotlin/Native compiler now uses the lld linker by default for all Linux targets.

This update shouldn't affect your code, but if you encounter any issues, please report them to our issue tracker.

Changes to caching in cinterop

In Kotlin 2.1.0, we're making changes to the cinterop caching process. It no longer has the CacheableTask annotation type. The new recommended approach is to use the cacheIf output type to cache the results of the task.

This should resolve issues where UP-TO-DATE checks failed to detect changes to header files specified in the definition file, preventing the build system from recompiling the code.

Deprecation of the mimalloc memory allocator

Back in Kotlin 1.9.0, we introduced the new memory allocator, and then we enabled it by default in Kotlin 1.9.20. The new allocator has been designed to make garbage collection more efficient and improve the Kotlin/Native memory manager's runtime performance.

The new memory allocator replaced the previous default allocator, mimalloc. Now, it's time to deprecate mimalloc in the Kotlin/Native compiler.

You can now remove the -Xallocator=mimalloc compiler option from your build scripts. If you encounter any issues, please report them to our issue tracker.

For more information on the memory allocator and garbage collection in Kotlin, see Kotlin/Native memory management.

Kotlin/Wasm

Kotlin/Wasm received multiple updates along with support for incremental compilation.

Support for incremental compilation

Previously, when you changed something in your Kotlin code, the Kotlin/Wasm toolchain had to recompile the entire codebase.

Starting from 2.1.0, incremental compilation is supported for Wasm targets. In development tasks, the compiler now recompiles only files relevant to changes from the last compilation, which noticeably reduces the compilation time.

This change currently doubles the compilation speed, and there are plans to improve it further in future releases.

In the current setup, incremental compilation for Wasm targets is disabled by default. To enable incremental compilation, add the following line to your project's local.properties or gradle.properties file:

```
# gradle.properties
kotlin.incremental.wasm=true
```

Try out Kotlin/Wasm incremental compilation and share your feedback. Your insights will help make this feature Stable and enabled by default sooner.

Browser APIs moved to the kotlinx-browser stand-alone library

Previously, the declarations for web APIs and related target utilities were part of the Kotlin/Wasm standard library.

In this release, the org.w3c.* declarations have been moved from the Kotlin/Wasm standard library to the new kotlinx-browser library. This library also includes other web-related packages, such as org.khronos.webgl, kotlin.dom, and kotlinx.browser.

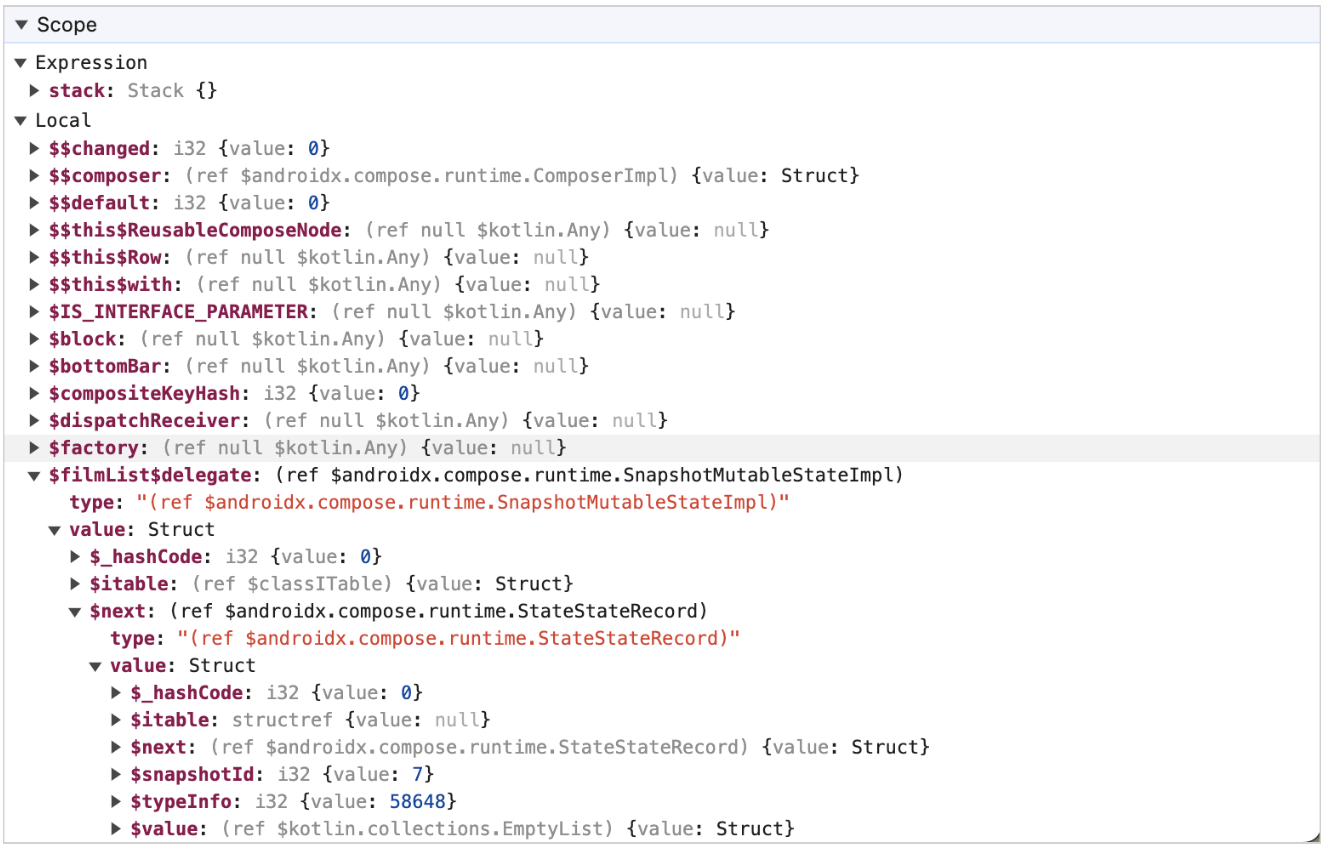
This separation provides modularity, enabling independent updates for web-related APIs outside of Kotlin's release cycle. Additionally, the Kotlin/Wasm standard library now contains only declarations available in any JavaScript environment.

To use the declarations from the moved packages, you need to add the kotlinx-browser dependency to your project's build configuration file:

```
// build.gradle.kts
val wasmJsMain by getting {
    dependencies {
        implementation("org.jetbrains.kotlinx:kotlinx-browser:0.3")
    }
}
```

Improved debugging experience for Kotlin/Wasm

Previously, when debugging Kotlin/Wasm code in web browsers, you might have encountered a low-level representation of variable values in the debugging interface. This often made it challenging to track the current state of the application.

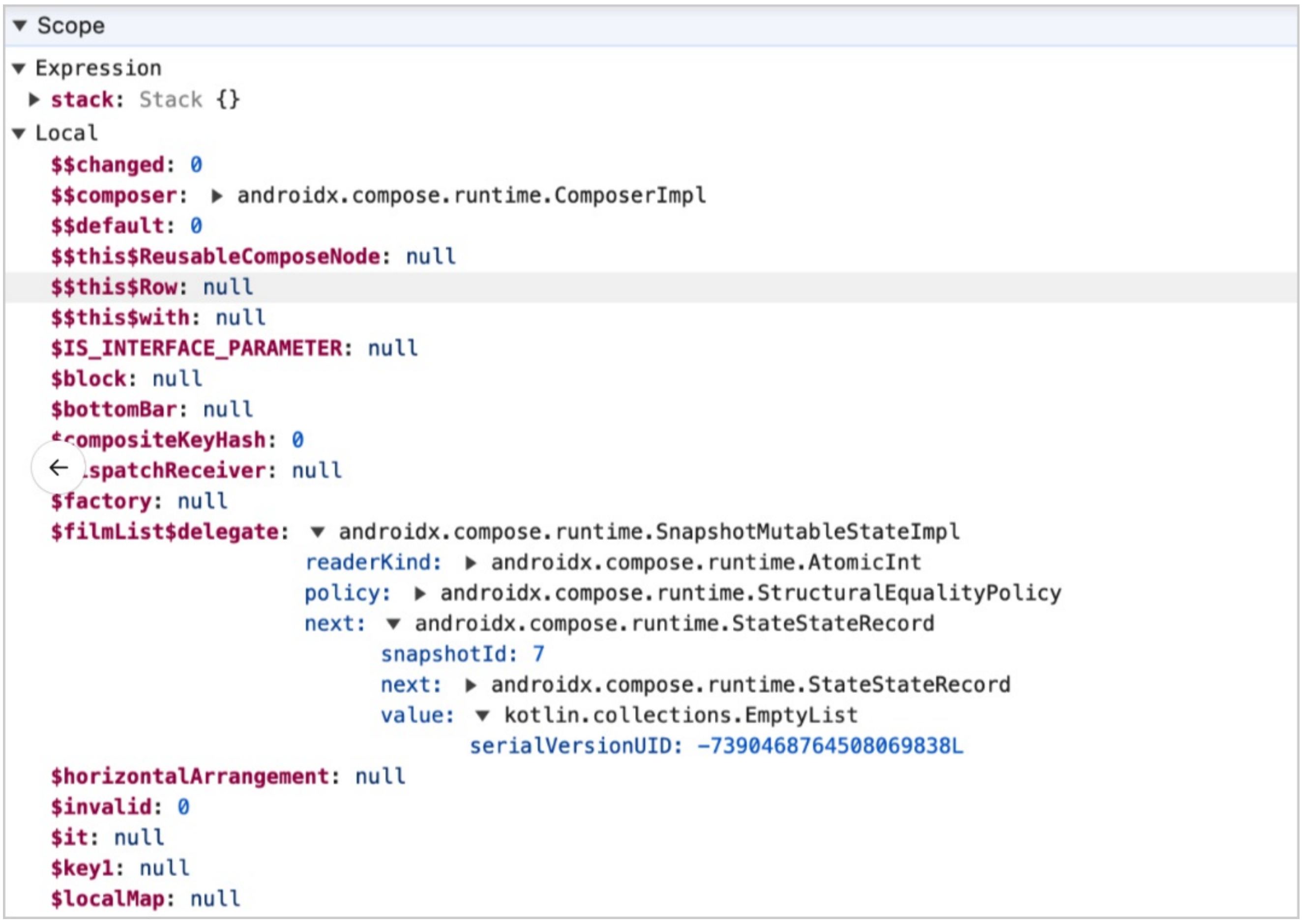


```
▼ Scope
▼ Expression
  ▶ stack: Stack {}
▼ Local
  ▶ $$changed: i32 {value: 0}
  ▶ $$composer: (ref $androidx.compose.runtime.ComposerImpl) {value: Struct}
  ▶ $$default: i32 {value: 0}
  ▶ $$this$ReusableComposeNode: (ref null $kotlin.Any) {value: null}
  ▶ $$this$Row: (ref null $kotlin.Any) {value: null}
  ▶ $$this$with: (ref null $kotlin.Any) {value: null}
  ▶ $IS_INTERFACE_PARAMETER: (ref null $kotlin.Any) {value: null}
  ▶ $block: (ref null $kotlin.Any) {value: null}
  ▶ $bottomBar: (ref null $kotlin.Any) {value: null}
  ▶ $compositeKeyHash: i32 {value: 0}
  ▶ $dispatchReceiver: (ref null $kotlin.Any) {value: null}
  ▶ $factory: (ref null $kotlin.Any) {value: null}
  ▼ $filmList$delegate: (ref $androidx.compose.runtime.SnapshotMutableStateImpl)
      type: "(ref $androidx.compose.runtime.SnapshotMutableStateImpl)"
    ▼ value: Struct
      ▶ $_hashCode: i32 {value: 0}
      ▶ $itable: (ref $classITable) {value: Struct}
      ▼ $next: (ref $androidx.compose.runtime.StateStateRecord)
          type: "(ref $androidx.compose.runtime.StateStateRecord)"
        ▼ value: Struct
          ▶ $_hashCode: i32 {value: 0}
          ▶ $itable: structref {value: null}
          ▶ $next: (ref $androidx.compose.runtime.StateStateRecord) {value: Struct}
          ▶ $snapshotId: i32 {value: 7}
          ▶ $typeInfo: i32 {value: 58648}
          ▶ $value: (ref $kotlin.collections.EmptyList) {value: Struct}
```

Kotlin/Wasm old debugger

To improve this experience, custom formatters have been added in the variable view. The implementation uses the custom formatters API, which is supported across major browsers like Firefox and Chromium-based ones.

With this change, you can now display and locate variable values in a more user-friendly and comprehensible manner.



```
▼ Scope
▼ Expression
 ▶ stack: Stack {}
▼ Local
   $$changed: 0
   $$composer: ▶ androidx.compose.runtime.ComposerImpl
   $$default: 0
   $$this$ReusableComposeNode: null
   $$this$Row: null
   $$this$with: null
   $IS_INTERFACE_PARAMETER: null
   $block: null
   $bottomBar: null
   $compositeKeyHash: 0
   $dispatchReceiver: null
   $factory: null
   $filmList$delegate: ▼ androidx.compose.runtime.SnapshotMutableStateImpl
                         readerKind: ▶ androidx.compose.runtime.AtomicInt
                         policy: ▶ androidx.compose.runtime.StructuralEqualityPolicy
                         next: ▼ androidx.compose.runtime.StateStateRecord
                               snapshotId: 7
                               next: ▶ androidx.compose.runtime.StateStateRecord
                               value: ▼ kotlin.collections.EmptyList
                                      serialVersionUID: -7390468764508069838L
   $horizontalArrangement: null
   $invalid: 0
   $it: null
   $key1: null
   $localMap: null
```

Kotlin/Wasm improved debugger

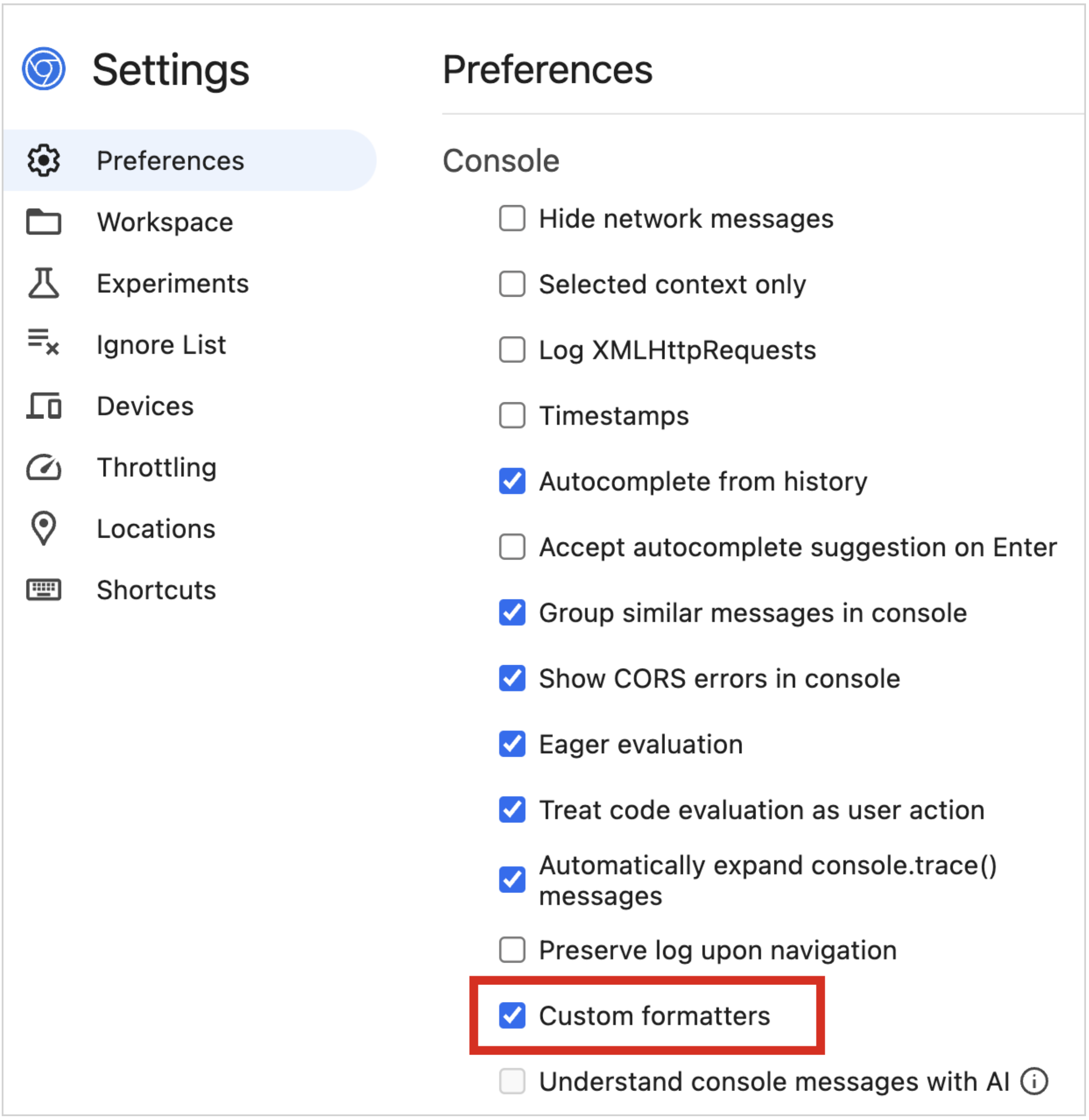
To try the new debugging experience:

1. Add the following compiler option to the wasmJs {} compiler options:

```
// build.gradle.kts
kotlin {
    wasmJs {
        // ...

        compilerOptions {
            freeCompilerArgs.add("-Xwasm-debugger-custom-formatters")
        }
    }
}
```

2. Enable custom formatters in your browser:

- In Chrome DevTools, it's available via Settings | Preferences | Console:


Settings

- Preferences
- Workspace
- Experiments
- Ignore List
- Devices
- Throttling
- Locations
- Shortcuts

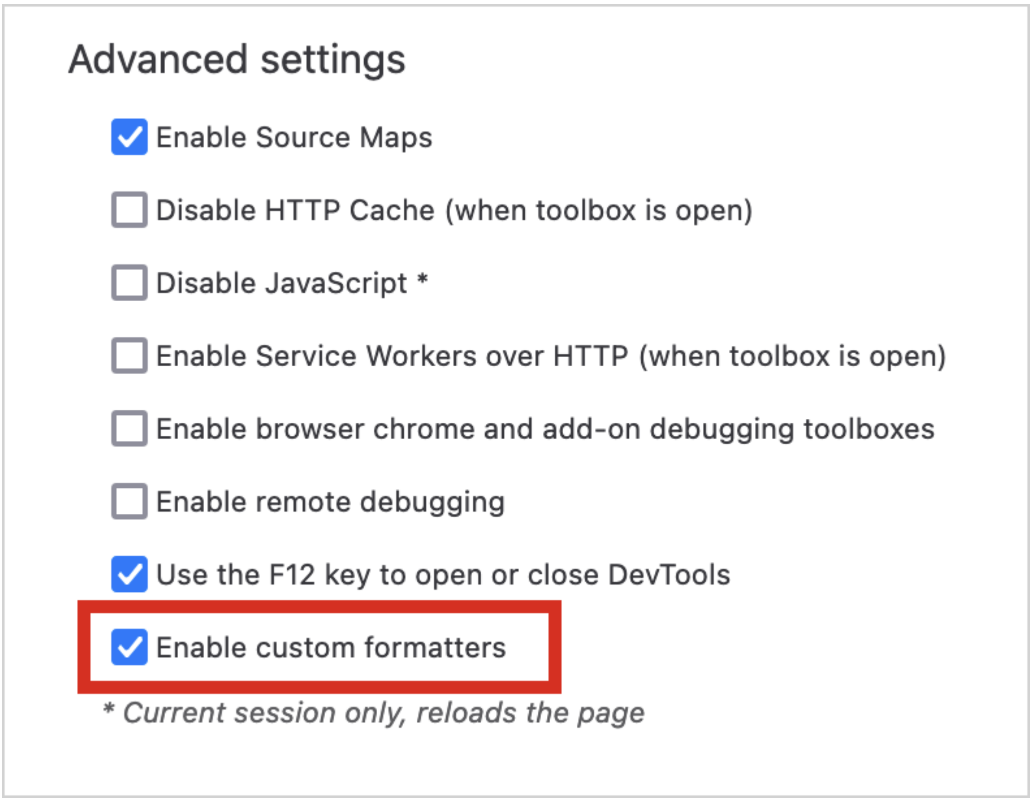
Preferences

Console

- [ ] Hide network messages
- [ ] Selected context only
- [ ] Log XMLHttpRequests
- [ ] Timestamps
- [✓] Autocomplete from history
- [ ] Accept autocomplete suggestion on Enter
- [✓] Group similar messages in console
- [✓] Show CORS errors in console
- [✓] Eager evaluation
- [✓] Treat code evaluation as user action
- [✓] Automatically expand console.trace() messages
- [ ] Preserve log upon navigation
- [✓] Custom formatters
- [ ] Understand console messages with AI ⓘ

Enable custom formatters in Chrome

- In Firefox DevTools, it's available via Settings | Advanced settings:


Advanced settings

- [✓] Enable Source Maps
- [ ] Disable HTTP Cache (when toolbox is open)
- [ ] Disable JavaScript *
- [ ] Enable Service Workers over HTTP (when toolbox is open)
- [ ] Enable browser chrome and add-on debugging toolboxes
- [ ] Enable remote debugging
- [✓] Use the F12 key to open or close DevTools
- [✓] Enable custom formatters

** Current session only, reloads the page*

Enable custom formatters in Firefox

Reduced size of Kotlin/Wasm binaries

The size of your Wasm binaries produced by production builds will be reduced by up to 30%, and you may see some performance improvements. This is because the --closed-world, --type-ssa, and --type-merging Binaryen options are now considered safe to use for all Kotlin/Wasm projects and are enabled by default.

Improved JavaScript array interoperability in Kotlin/Wasm

While Kotlin/Wasm's standard library provides the JsArray<T> type for JavaScript arrays, there was no direct method to transform JsArray<T> into Kotlin's native Array or List types.

This gap required creating custom functions for array transformations, complicating interoperability between Kotlin and JavaScript code.

This release introduces an adapter function that automatically converts JsArray<T> to Array<T> and vice versa, simplifying array operations.

Here's an example of conversion between generic types: Kotlin List<T> and Array<T> to JavaScript JsArray<T>.

```
val list: List<JsString> =
    listOf("Kotlin", "Wasm").map { it.toJsString() }

// Uses .toJsArray() to convert List or Array to JsArray
val jsArray: JsArray<JsString> = list.toJsArray()

// Uses .toArray() and .toList() to convert it back to Kotlin types
val kotlinArray: Array<JsString> = jsArray.toArray()
val kotlinList: List<JsString> = jsArray.toList()
```

Similar methods are available for converting typed arrays to their Kotlin equivalents (for example, IntArray and Int32Array). For detailed information and implementation, see the kotlinx-browser repository.

Here's an example of conversion between typed arrays: Kotlin IntArray to JavaScript Int32Array.

```
import org.khronos.webgl.*

    // ...
    val intArray: IntArray = intArrayOf(1, 2, 3)

    // Uses .toInt32Array() to convert Kotlin IntArray to JavaScript Int32Array
    val jsInt32Array: Int32Array = intArray.toInt32Array()

    // Uses toIntArray() to convert JavaScript Int32Array back to Kotlin IntArray
    val kotlinIntArray: IntArray = jsInt32Array.toIntArray()
```

Support for accessing JavaScript exception details in Kotlin/Wasm

Previously, when a JavaScript exception occurred in Kotlin/Wasm, the JsException type provided only a generic message without details from the original JavaScript error.

Starting from Kotlin 2.1.0, you can configure JsException to include the original error message and stack trace by enabling a specific compiler option. This provides more context to help diagnose issues originating from JavaScript.

This behavior depends on the WebAssembly.JSTag API, which is available only in certain browsers:

- Chrome: Supported from version 115
- Firefox: Supported from version 129
- Safari: Not yet supported

To enable this feature, which is disabled by default, add the following compiler option to your build.gradle.kts file:

```
// build.gradle.kts
kotlin {
    wasmJs {
        compilerOptions {
            freeCompilerArgs.add("-Xwasm-attach-js-exception")
        }
    }
}
```

Here's an example demonstrating the new behavior:

```
external object JSON {
    fun <T: JsAny> parse(json: String): T
}

fun main() {
    try {
        JSON.parse("an invalid JSON")
    } catch (e: JsException) {
        println("Thrown value is: ${e.thrownValue}")
        // SyntaxError: Unexpected token 'a', "an invalid JSON" is not valid JSON

        println("Message: ${e.message}")
        // Message: Unexpected token 'a', "an invalid JSON" is not valid JSON

        println("Stacktrace:")
        // Stacktrace:

        // Prints the full JavaScript stack trace
        e.printStackTrace()
    }
}
```

With the -Xwasm-attach-js-exception option enabled, JsException provides specific details from the JavaScript error. Without the option, JsException includes only a generic message stating that an exception was thrown while running JavaScript code.

Deprecation of default exports

As part of the migration to named exports, an error was previously printed to the console when a default import was used for Kotlin/Wasm exports in JavaScript.

In 2.1.0, default imports have been completely removed to fully support named exports.

When coding in JavaScript for the Kotlin/Wasm target, you now need to use the corresponding named imports instead of default imports.

This change marks the last phase of a deprecation cycle to migrate to named exports:

In version 2.0.0: A warning message was printed to the console, explaining that exporting entities via default exports is deprecated.

In version 2.0.20: An error occurred, requesting the use of the corresponding named import.

In version 2.1.0: The use of default imports has been completely removed.

Subproject-specific Node.js settings

You can configure Node.js settings for your project by defining properties of the NodeJsRootPlugin class for rootProject. In 2.1.0, you can configure these settings for each subproject using a new class, NodeJsPlugin. Here's an example demonstrating how to set a specific Node.js version for a subproject:

```kotlin
// build.gradle.kts
project.plugins.withType<org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsPlugin> {
    project.the<org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsEnvSpec>().version = "22.0.0"
}
```

To use the new class for the entire project, add the same code in the allprojects {} block:

```kotlin
// build.gradle.kts
allprojects {
    project.plugins.withType<org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsPlugin> {
        project.the<org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsEnvSpec>().version = "your Node.js version"
    }
}
```

You can also use Gradle convention plugins to apply the settings to a particular set of subprojects.

Kotlin/JS

Support for non-identifier characters in properties

Kotlin/JS previously did not allow using names for test methods with spaces enclosed in backticks.

Similarly, it was not possible to access JavaScript object properties that contained characters not permitted in Kotlin identifiers, such as hyphens or spaces:

```kotlin
external interface Headers {
    var accept: String?

    // Invalid Kotlin identifier due to hyphen
    var `content-length`: String?
}

val headers: Headers = TODO("value provided by a JS library")
val accept = headers.accept
// Causes error due to the hyphen in property name
val length = headers.`content-length`
```

This behavior differed from JavaScript and TypeScript, which allow such properties to be accessed using non-identifier characters.

Starting from Kotlin 2.1.0, this feature is enabled by default. Kotlin/JS now allows you to use the backticks (``) and the @JsName annotation to interact with JavaScript properties containing non-identifier characters and to use names for test methods.

Additionally, you can use the @JsName and @JsQualifier annotations to map Kotlin property names to JavaScript equivalents:

```kotlin
object Bar {
    val `property example`: String = "bar"
}

@JsQualifier("fooNamespace")
external object Foo {
    val `property example`: String
}

@JsExport
object Baz {
    val `property example`: String = "bar"
}
```

```
fun main() {
    // In JavaScript, this is compiled into Bar.property_example_HASH
    println(Bar.`property example`)
    // In JavaScript, this is compiled into fooNamespace["property example"]
    println(Foo.`property example`)
    // In JavaScript, this is compiled into Baz["property example"]
    println(Baz.`property example`)
}
```

Support for generating ES2015 arrow functions

In Kotlin 2.1.0, Kotlin/JS introduces support for generating ES2015 arrow functions, such as (a, b) => expression, instead of anonymous functions.

Using arrow functions can reduce the bundle size of your project, especially when using the experimental -Xir-generate-inline-anonymous-functions mode. This also makes the generated code more aligned with modern JS.

This feature is enabled by default when targeting ES2015. Alternatively, you can enable it by using the -Xes-arrow-functions command line argument.

Learn more about ES2015 (ECMAScript 2015, ES6) in the official documentation.

Gradle improvements

Kotlin 2.1.0 is fully compatible with Gradle 7.6.3 through 8.6. Gradle versions 8.7 to 8.10 are also supported, with only one exception. If you use the Kotlin Multiplatform Gradle plugin, you may see deprecation warnings in your multiplatform projects calling the withJava() function in the JVM target. We plan to fix this issue as soon as possible.

For more information, see the related issue in YouTrack.

You can also use Gradle versions up to the latest Gradle release, but if you do, keep in mind that you might encounter deprecation warnings or some new Gradle features might not work.

Minimum supported AGP version bumped to 7.3.1

Starting with Kotlin 2.1.0, the minimum supported Android Gradle plugin version is 7.3.1.

Minimum supported Gradle version bumped to 7.6.3

Starting with Kotlin 2.1.0, the minimum supported Gradle version is 7.6.3.

New API for Kotlin Gradle plugin extensions

Kotlin 2.1.0 introduces a new API to make it easier to create your own plugins for configuring the Kotlin Gradle plugin. This change deprecates the KotlinTopLevelExtension and KotlinTopLevelExtensionConfig interfaces and introduces the following interfaces for plugin authors:

Name	Description
KotlinBaseExtension	A plugin DSL extension type for configuring common Kotlin JVM, Android, and Multiplatform plugin options for the entire project: • org.jetbrains.kotlin.jvm • org.jetbrains.kotlin.android • org.jetbrains.kotlin.multiplatform
KotlinJvmExtension	A plugin DSL extension type for configuring Kotlin JVM plugin options for the entire project.
KotlinAndroidExtension	A plugin DSL extension type for configuring Kotlin Android plugin options for the entire project.

For example, if you want to configure compiler options for both JVM and Android projects, use KotlinBaseExtension:

```
configure<KotlinBaseExtension> {
    if (this is HasConfigurableKotlinCompilerOptions<*>) {
        with(compilerOptions) {
            if (this is KotlinJvmCompilerOptions) {
                jvmTarget.set(JvmTarget.JVM_17)
            }
        }
    }
}
```

This configures the JVM target to 17 for both JVM and Android projects.

To configure compiler options specifically for JVM projects, use KotlinJvmExtension:

```
configure<KotlinJvmExtension> {
    compilerOptions {
        jvmTarget.set(JvmTarget.JVM_17)
    }

    target.mavenPublication {
        groupId = "com.example"
        artifactId = "example-project"
        version = "1.0-SNAPSHOT"
    }
}
```

This example similarly configures the JVM target to 17 for JVM projects. It also configures a Maven publication for the project so that its output is published to a Maven repository.

You can use the KotlinAndroidExtension in exactly the same way.

Compiler symbols hidden from the Kotlin Gradle plugin API

Previously, KGP included org.jetbrains.kotlin:kotlin-compiler-embeddable in its runtime dependencies, making internal compiler symbols available in the build script classpath. These symbols were intended for internal use only.

Starting with Kotlin 2.1.0, KGP bundles a subset of org.jetbrains.kotlin:kotlin-compiler-embeddable class files in its JAR file and progressively removes them. This change aims to prevent compatibility issues and simplify KGP maintenance.

If other parts of your build logic, such as plugins like kotlinter, depend on a different version of org.jetbrains.kotlin:kotlin-compiler-embeddable than the one bundled with KGP, it can lead to conflicts and runtime exceptions.

To prevent such issues, KGP now shows a warning if org.jetbrains.kotlin:kotlin-compiler-embeddable is present in the build classpath alongside KGP.

As a long-term solution, if you're a plugin author using org.jetbrains.kotlin:kotlin-compiler-embeddable classes, we recommend running them in an isolated classloader. For example, you can achieve it using the Gradle Workers API with classloader or process isolation.

Using the Gradle Workers API

This example demonstrates how to safely use the Kotlin compiler in a project producing a Gradle plugin. First, add a compile-only dependency in your build script. This makes the symbol available at compile time only:

```
// build.gradle.kts
dependencies {
    compileOnly("org.jetbrains.kotlin:kotlin-compiler-embeddable:2.2.0")
}
```

Next, define a Gradle work action to print the Kotlin compiler version:

```
import org.gradle.workers.WorkAction
import org.gradle.workers.WorkParameters
import org.jetbrains.kotlin.config.KotlinCompilerVersion
abstract class ActionUsingKotlinCompiler : WorkAction<WorkParameters.None> {
    override fun execute() {
        println("Kotlin compiler version: ${KotlinCompilerVersion.getVersion()}")
    }
}
```

Now create a task that submits this action to the worker executor using classloader isolation:

```
import org.gradle.api.DefaultTask
import org.gradle.api.file.ConfigurableFileCollection
import org.gradle.api.tasks.Classpath
import org.gradle.api.tasks.TaskAction
import org.gradle.workers.WorkerExecutor
import javax.inject.Inject
abstract class TaskUsingKotlinCompiler: DefaultTask() {
    @get:Inject
    abstract val executor: WorkerExecutor

    @get:Classpath
    abstract val kotlinCompiler: ConfigurableFileCollection

    @TaskAction
    fun compile() {
        val workQueue = executor.classLoaderIsolation {
            classpath.from(kotlinCompiler)
        }
        workQueue.submit(ActionUsingKotlinCompiler::class.java) {}
    }
}
```

Finally, configure the Kotlin compiler classpath in your Gradle plugin:

```
import org.gradle.api.Plugin
import org.gradle.api.Project
abstract class MyPlugin: Plugin<Project> {
    override fun apply(target: Project) {
        val myDependencyScope = target.configurations.create("myDependencyScope")
        target.dependencies.add(myDependencyScope.name, "$KOTLIN_COMPILER_EMBEDDABLE:$KOTLIN_COMPILER_VERSION")
        val myResolvableConfiguration = target.configurations.create("myResolvable") {
            extendsFrom(myDependencyScope)
        }
        target.tasks.register("myTask", TaskUsingKotlinCompiler::class.java) {
            kotlinCompiler.from(myResolvableConfiguration)
        }
    }

    companion object {
        const val KOTLIN_COMPILER_EMBEDDABLE = "org.jetbrains.kotlin:kotlin-compiler-embeddable"
        const val KOTLIN_COMPILER_VERSION = "2.2.0"
    }
}
```

Compose compiler updates

Support for multiple stability configuration files

The Compose compiler can interpret multiple stability configuration files, but the stabilityConfigurationFile option of the Compose Compiler Gradle plugin previously allowed for only a single file to be specified. In Kotlin 2.1.0, this functionality was reworked to allow you to use several stability configuration files for a single module:

- The stabilityConfigurationFile option is deprecated.
- There is a new option, stabilityConfigurationFiles, with the type ListProperty<RegularFile>.

Here's how to pass several files to the Compose compiler using the new option:

```
// build.gradle.kt
composeCompiler {
    stabilityConfigurationFiles.addAll(
        project.layout.projectDirectory.file("configuration-file1.conf"),
        project.layout.projectDirectory.file("configuration-file2.conf"),
    )
}
```

Pausable composition

Pausable composition is a new Experimental feature that changes how the compiler generates skippable functions. With this feature enabled, composition can be suspended on skipping points during runtime, allowing long-running composition processes to be split across multiple frames. Pausable composition is used in lazy lists and other performance-intensive components for prefetching content that might cause frames to drop when executed in a blocking manner.

To try out pausable composition, add the following feature flag in the Gradle configuration for the Compose compiler:

```
// build.gradle.kts
composeCompiler {
    featureFlags = setOf(
        ComposeFeatureFlag.PausableComposition
    )
}
```

Runtime support for this feature was added in the 1.8.0-alpha02 version of androidx.compose.runtime. The feature flag has no effect when used with older runtime versions.

Changes to open and overridden @Composable functions

Virtual (open, abstract, and overridden) @Composable functions can no longer be restartable. The codegen for restartable groups was generating calls that did not work correctly with inheritance, resulting in runtime crashes.

This means that virtual functions won't be restarted or skipped: whenever their state is invalidated, runtime will recompose their parent composable instead. If your code is sensitive to recompositions, you may notice changes in runtime behavior.

Performance improvements

The Compose compiler used to create a full copy of module's IR to transform @Composable types. Apart from increased memory consumption when copying elements that were not related to Compose, this behavior was also breaking downstream compiler plugins in certain edge cases.

This copy operation was removed, resulting in potentially faster compilation times.

Standard library

Changes to the deprecation severity of standard library APIs

In Kotlin 2.1.0, we are raising the deprecation severity level of several standard library APIs from warning to error. If your code relies on these APIs, you need to update it to ensure compatibility. The most notable changes include:

- Locale-sensitive case conversion functions for Char and String are deprecated: Functions like Char.toLowerCase(), Char.toUpperCase(), String.toUpperCase(), and String.toLowerCase() are now deprecated, and using them results in an error. Replace them with locale-agnostic function alternatives or other case conversion mechanisms. If you want to continue using the default locale, replace calls like String.toLowerCase() with String.lowercase(Locale.getDefault()), explicitly specifying the locale. For a locale-agnostic conversion, replace them with String.lowercase(), which uses the invariant locale by default.

- Kotlin/Native freezing API is deprecated: Using the freezing-related declarations previously marked with the @FreezingIsDeprecated annotation now results in an error. This change reflects the transition from the legacy memory manager in Kotlin/Native, which required freezing objects to share them between threads. To learn how to migrate from freezing-related APIs in the new memory model, see the Kotlin/Native migration guide. For more information, see the announcement about the deprecation of freezing.

- appendln() is deprecated in favor of appendLine(): The StringBuilder.appendln() and Appendable.appendln() functions are now deprecated, and using them results in an error. To replace them, use the StringBuilder.appendLine() or Appendable.appendLine() functions instead. The appendln() function is deprecated because, on Kotlin/JVM, it uses the line.separator system property, which has a different default value on each OS. On Kotlin/JVM, this property defaults to \r\n (CR LF) on Windows and \n (LF) on other systems. On the other hand, the appendLine() function consistently uses \n (LF) as the line separator, ensuring consistent behavior across platforms.

For a complete list of affected APIs in this release, see the KT-71628 YouTrack issue.

Stable file tree traversal extensions for java.nio.file.Path

Kotlin 1.7.20 introduced Experimental extension functions for the java.nio.file.Path class, which allows you to walk through a file tree. In Kotlin 2.1.0, the following file tree traversal extensions are now Stable:

- walk() lazily traverses the file tree rooted at the specified path.
- fileVisitor() makes it possible to create a FileVisitor separately. FileVisitor specifies the actions to be performed on directories and files during traversal.
- visitFileTree(fileVisitor: FileVisitor, ...) traverses through a file tree, invoking the specified FileVisitor on each encountered entry, and it uses the java.nio.file.Files.walkFileTree() function under the hood.
- visitFileTree(..., builderAction: FileVisitorBuilder.() -> Unit) creates a FileVisitor with the provided builderAction and calls the visitFileTree(fileVisitor, ...) function.
- sealed interface FileVisitorBuilder allows you to define a custom FileVisitor implementation.
- enum class PathWalkOption provides traversal options for the Path.walk() function.

The examples below demonstrate how to use these file traversal APIs to create custom FileVisitor behaviors, which allows you to define specific actions for visiting files and directories.

For instance, you can explicitly create a FileVisitor and use it later:

```kotlin
val cleanVisitor = fileVisitor {
    onPreVisitDirectory { directory, attributes ->
        // Placeholder: Add logic on visiting directories
        FileVisitResult.CONTINUE
    }

    onVisitFile { file, attributes ->
        // Placeholder: Add logic on visiting files
        FileVisitResult.CONTINUE
    }
}

// Placeholder: Add logic here for general setup before traversal
projectDirectory.visitFileTree(cleanVisitor)
```

You can also create a FileVisitor with the builderAction and use it immediately for the traversal:

```kotlin
projectDirectory.visitFileTree {
    // Defines the builderAction:
    onPreVisitDirectory { directory, attributes ->
        // Some logic on visiting directories
        FileVisitResult.CONTINUE
    }

    onVisitFile { file, attributes ->
        // Some logic on visiting files
        FileVisitResult.CONTINUE
    }
}
```

Additionally, you can traverse a file tree rooted at the specified path with the walk() function:

```kotlin
fun traverseFileTree() {
    val cleanVisitor = fileVisitor {
        onPreVisitDirectory { directory, _ ->
            if (directory.name == "build") {
                directory.toFile().deleteRecursively()
                FileVisitResult.SKIP_SUBTREE
            } else {
                FileVisitResult.CONTINUE
            }
        }

        // Deletes files with the .class extension
        onVisitFile { file, _ ->
            if (file.extension == "class") {
                file.deleteExisting()
            }
            FileVisitResult.CONTINUE
        }
    }

    // Sets up the root directory and files
    val rootDirectory = createTempDirectory("Project")

    // Creates the src directory with A.kt and A.class files
    rootDirectory.resolve("src").let { srcDirectory ->
```

```
        srcDirectory.createDirectory()
        srcDirectory.resolve("A.kt").createFile()
        srcDirectory.resolve("A.class").createFile()
    }

    // Creates the build directory with a Project.jar file
    rootDirectory.resolve("build").let { buildDirectory ->
        buildDirectory.createDirectory()
        buildDirectory.resolve("Project.jar").createFile()
    }

    // Uses the walk() function:
    val directoryStructure = rootDirectory.walk(PathWalkOption.INCLUDE_DIRECTORIES)
        .map { it.relativeTo(rootDirectory).toString() }
        .toList().sorted()
    println(directoryStructure)
    // "[, build, build/Project.jar, src, src/A.class, src/A.kt]"

    // Traverses the file tree with cleanVisitor, applying the rootDirectory.visitFileTree(cleanVisitor) cleanup rules
    val directoryStructureAfterClean = rootDirectory.walk(PathWalkOption.INCLUDE_DIRECTORIES)
        .map { it.relativeTo(rootDirectory).toString() }
        .toList().sorted()
    println(directoryStructureAfterClean)
    // "[, src, src/A.kt]"
}
```

Documentation updates

The Kotlin documentation has received some notable changes:

Language concepts

- Improved Null safety page – Learn how to handle null values safely in your code.
- Improved Objects declarations and expressions page – Learn how to define a class and create an instance in a single step.
- Improved When expressions and statements section – Learn about the when conditional and how you can use it.
- Updated Kotlin roadmap, Kotlin evolution principles, and Kotlin language features and proposals pages – Learn about Kotlin's plans, ongoing developments, and guiding principles.

Compose compiler

- Compose compiler documentation now located in the Compiler and plugins section – Learn about the Compose compiler, the compiler options, and the steps to migrate.

API references

- New Kotlin Gradle plugins API reference – Explore the API references for the Kotlin Gradle plugin and the Compose compiler Gradle plugin.

Multiplatform development

- New Building a Kotlin library for multiplatform page – Learn how to design your Kotlin libraries for Kotlin Multiplatform.
- New Introduction to Kotlin Multiplatform page – Learn about Kotlin Multiplatform's key concepts, dependencies, libraries, and more.
- Updated Kotlin Multiplatform overview page – Navigate through the essentials of Kotlin Multiplatform and popular use cases.
- New iOS integration section – Learn how to integrate a Kotlin Multiplatform shared module into your iOS app.
- New Kotlin/Native's definition file page – Learn how to create a definition file to consume C and Objective-C libraries.
- Get started with WASI – Learn how to run a simple Kotlin/Wasm application using WASI in various WebAssembly virtual machines.

Tooling

- New Dokka migration guide – Learn how to migrate to Dokka Gradle plugin v2.

Compatibility guide for Kotlin 2.1.0

Kotlin 2.1.0 is a feature release and can, therefore, bring changes that are incompatible with your code written for earlier versions of the language. Find the detailed list of these changes in the Compatibility guide for Kotlin 2.1.0.

Install Kotlin 2.1.0

Starting from IntelliJ IDEA 2023.3 and Android Studio Iguana (2023.2.1) Canary 15, the Kotlin plugin is distributed as a bundled plugin included in your IDE. This means that you can't install the plugin from JetBrains Marketplace anymore.

To update to the new Kotlin version, change the Kotlin version to 2.1.0 in your build scripts.

What's new in Kotlin 2.1.20

Released: March 20, 2025

The Kotlin 2.1.20 release is here! Here are the main highlights:

- K2 compiler updates: updates to the new kapt and Lombok plugins
- Kotlin Multiplatform: new DSL to replace Gradle's Application plugin
- Kotlin/Native: support for Xcode 16.3 and a new inlining optimization
- Kotlin/Wasm: default custom formatters, support for DWARF, and migration to Provider API
- Gradle support: compatibility with Gradle's Isolated Projects and custom publication variants
- Standard library: common atomic types, improved UUID support, and new time-tracking functionality
- Compose compiler: relaxed restrictions on @Composable functions and other updates
- Documentation: notable improvements to the Kotlin documentation.

IDE support

The Kotlin plugins that support 2.1.20 are bundled in the latest IntelliJ IDEA and Android Studio. You don't need to update the Kotlin plugin in your IDE. All you need to do is to change the Kotlin version to 2.1.20 in your build scripts.

See Update to a new release for details.

Download sources for Kotlin artifacts in projects with OSGi support

Sources of all dependencies of the kotlin-osgi-bundle library are now included in its distribution. This allows IntelliJ IDEA to download these sources to provide documentation for Kotlin symbols and improve the debugging experience.

Kotlin K2 compiler

We're continuing to improve plugin support for the new Kotlin K2 compiler. This release brings updates to the new kapt and Lombok plugins.

New default kapt plugin

Starting with Kotlin 2.1.20, the K2 implementation of the kapt compiler plugin is enabled by default for all the projects.

The JetBrains team launched the new implementation of the kapt plugin with the K2 compiler back in Kotlin 1.9.20. Since then, we have further developed the internal implementation of K2 kapt and made its behavior similar to that of the K1 version, while significantly improving its performance as well.

If you encounter any issues when using kapt with the K2 compiler, you can temporarily revert to the previous plugin implementation.

To do this, add the following option to the gradle.properties file of your project:

```
kapt.use.k2=false
```

Please report any issues to our issue tracker.

Lombok compiler plugin: support for @SuperBuilder and updates on @Builder

The Kotlin Lombok compiler plugin now supports the @SuperBuilder annotation, making it easier to create builders for class hierarchies. Previously, developers using Lombok in Kotlin had to manually define builders when working with inheritance. With @SuperBuilder, the builder automatically inherits superclass fields, allowing you to initialize them when constructing an object.

Additionally, this update includes several improvements and bug fixes:

- The @Builder annotation now works on constructors, allowing more flexible object creation. For more details, see the corresponding YouTrack issue.
- Several issues related to Lombok's code generation in Kotlin have been resolved, improving overall compatibility. For more details, see the GitHub changelog.

For more information about the @SuperBuilder annotation, see the official Lombok documentation.

Kotlin Multiplatform: new DSL to replace Gradle's Application plugin

Starting with Gradle 8.7, the Application plugin is no longer compatible with the Kotlin Multiplatform Gradle plugin. Kotlin 2.1.20 introduces an Experimental DSL to achieve similar functionality. The new executable {} block configures execution tasks and Gradle distributions for JVM targets.

Before the executable {} block in your build script, add the following @OptIn annotation:

```
@OptIn(ExperimentalKotlinGradlePluginApi::class)
```

For example:

```
kotlin {
    jvm {
        @OptIn(ExperimentalKotlinGradlePluginApi::class)
        binaries {
            // Configures a JavaExec task named "runJvm" and a Gradle distribution for the "main" compilation in this target
            executable {
                mainClass.set("foo.MainKt")
            }

            // Configures a JavaExec task named "runJvmAnother" and a Gradle distribution for the "main" compilation
            executable(KotlinCompilation.MAIN_COMPILATION_NAME, "another") {
                // Set a different class
                mainClass.set("foo.MainAnotherKt")
            }

            // Configures a JavaExec task named "runJvmTest" and a Gradle distribution for the "test" compilation
            executable(KotlinCompilation.TEST_COMPILATION_NAME) {
                mainClass.set("foo.MainTestKt")
            }

            // Configures a JavaExec task named "runJvmTestAnother" and a Gradle distribution for the "test" compilation
            executable(KotlinCompilation.TEST_COMPILATION_NAME, "another") {
                mainClass.set("foo.MainAnotherTestKt")
            }
        }
    }
}
```

In this example, Gradle's Distribution plugin is applied on the first executable {} block.

If you run into any issues, report them in our issue tracker or let us know in our public Slack channel.

Kotlin/Native

Support for Xcode 16.3

Starting with Kotlin 2.1.21, the Kotlin/Native compiler supports Xcode 16.3 – the latest stable version of Xcode. Feel free to update your Xcode and continue working on your Kotlin projects for Apple operating systems.

The 2.1.21 release also fixes the related cinterop issue that caused compilation failures in Kotlin Multiplatform projects.

New inlining optimization

Kotlin 2.1.20 introduces a new inlining optimization pass, which comes before the actual code generation phase.

The new inlining pass in the Kotlin/Native compiler should perform better than the standard LLVM inliner and improve the runtime performance of the generated code.

The new inlining pass is currently Experimental. To try it out, use the following compiler option:

```
-Xbinary=preCodegenInlineThreshold=40
```

Our experiments show that setting the threshold to 40 tokens (code units parsed by the compiler) provides a reasonable compromise for compilation optimization. According to our benchmarks, this gives an overall performance improvement of 9.5%. Of course, you can try out other values, too.

If you experience increased binary size or compilation time, please report such issues via YouTrack.

Kotlin/Wasm

This release improves Kotlin/Wasm debugging and property usage. Custom formatters now work out of the box in development builds, while DWARF debugging facilitates code inspection. Additionally, the Provider API simplifies property usage in Kotlin/Wasm and Kotlin/JS.

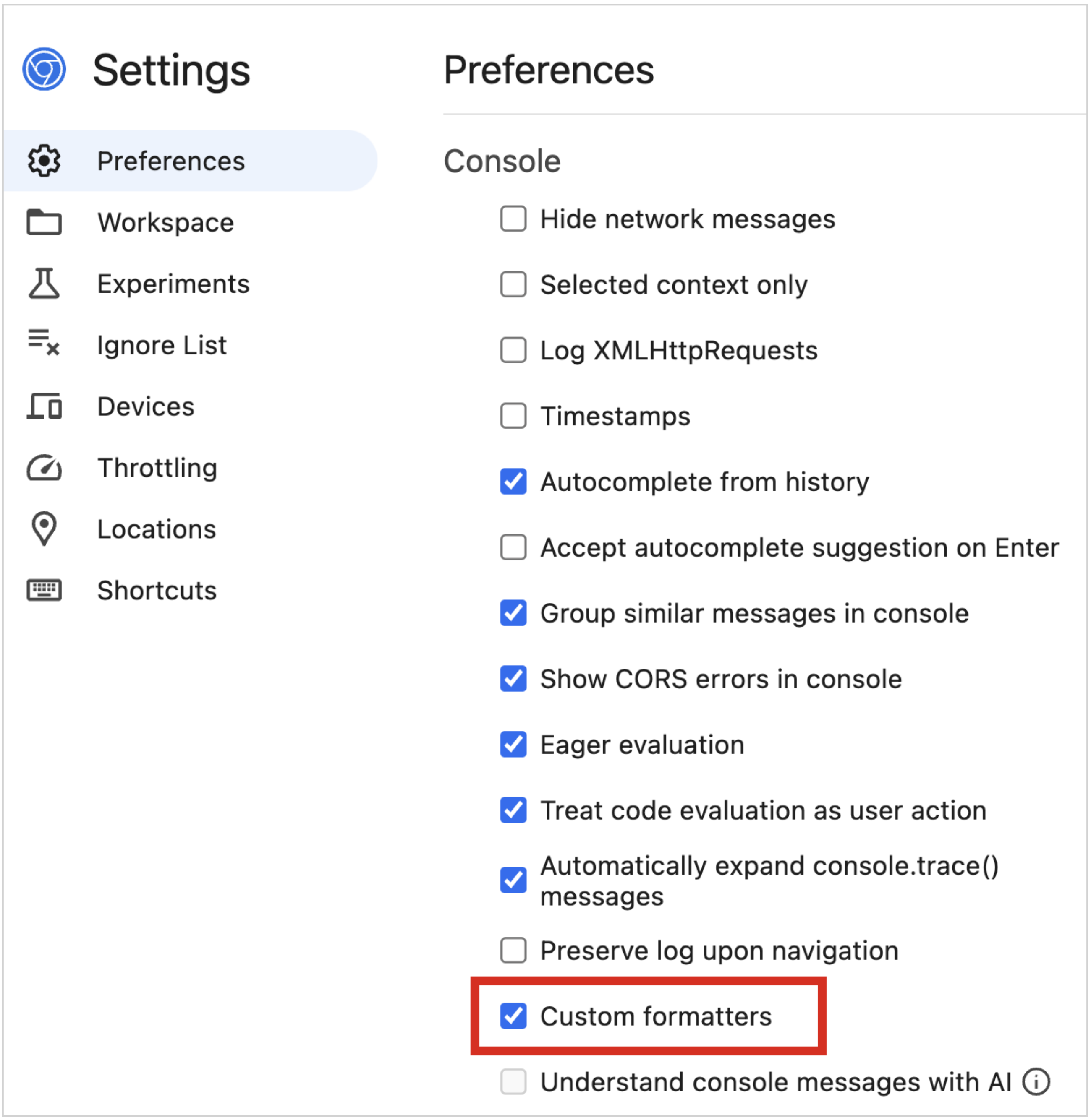
Custom formatters enabled by default

Before, you had to manually configure custom formatters to improve debugging in web browsers when working with Kotlin/Wasm code.

In this release, custom formatters are enabled by default in development builds, so you don't need additional Gradle configurations.

To use this feature, you only need to ensure that custom formatters are enabled in your browser's developer tools:

- In Chrome DevTools, find the custom formatters checkbox in Settings | Preferences | Console:



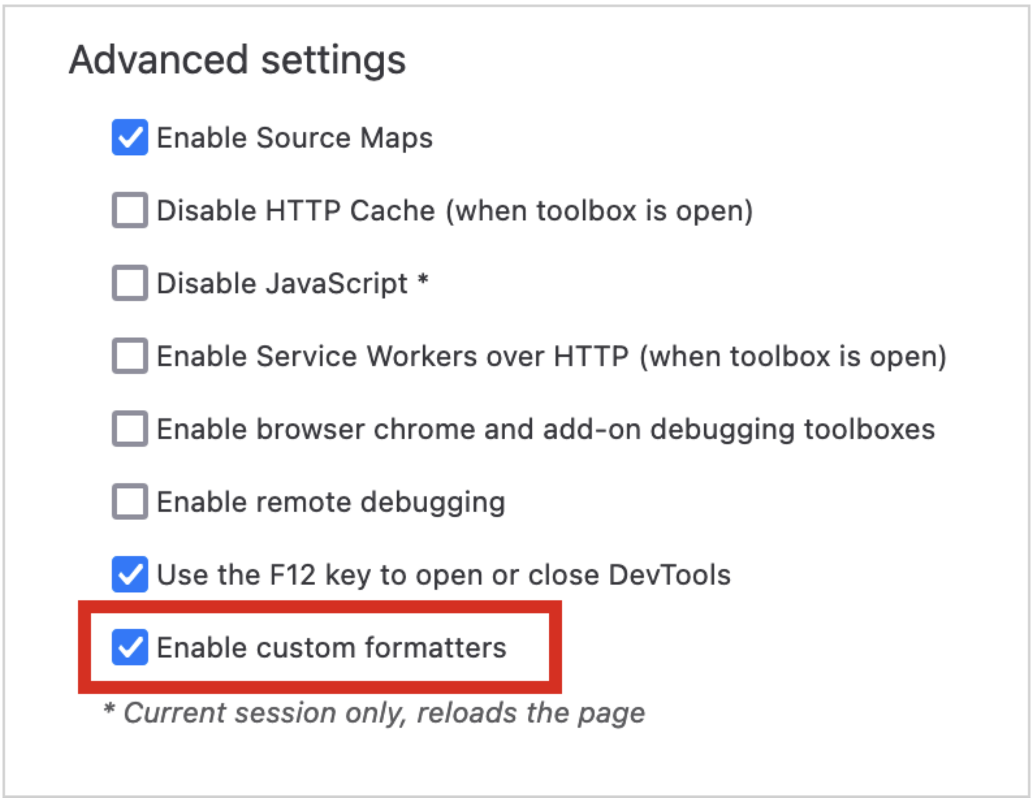
Preferences

Console

- [ ] Hide network messages
- [ ] Selected context only
- [ ] Log XMLHttpRequests
- [ ] Timestamps
- [✓] Autocomplete from history
- [ ] Accept autocomplete suggestion on Enter
- [✓] Group similar messages in console
- [✓] Show CORS errors in console
- [✓] Eager evaluation
- [✓] Treat code evaluation as user action
- [✓] Automatically expand console.trace() messages
- [ ] Preserve log upon navigation
- [✓] Custom formatters
- [ ] Understand console messages with AI

Enable custom formatters in Chrome

- In Firefox DevTools, find the custom formatters checkbox in Settings | Advanced settings:


Advanced settings

- [✓] Enable Source Maps
- [ ] Disable HTTP Cache (when toolbox is open)
- [ ] Disable JavaScript *
- [ ] Enable Service Workers over HTTP (when toolbox is open)
- [ ] Enable browser chrome and add-on debugging toolboxes
- [ ] Enable remote debugging
- [✓] Use the F12 key to open or close DevTools
- [✓] Enable custom formatters

Current session only, reloads the page

Enable custom formatters in Firefox

This change primarily affects Kotlin/Wasm development builds. If you have specific requirements for production builds, you need to adjust your Gradle configuration accordingly. To do so, add the following compiler option to the wasmJs {} block:

```
// build.gradle.kts
kotlin {
    wasmJs {
        // ...

        compilerOptions {
            freeCompilerArgs.add("-Xwasm-debugger-custom-formatters")
        }
    }
}
```

Support for DWARF to debug Kotlin/Wasm code

Kotlin 2.1.20 introduces support for DWARF (debugging with arbitrary record format) in Kotlin/Wasm.

With this change, the Kotlin/Wasm compiler is able to embed DWARF data into the generated WebAssembly (Wasm) binary. Many debuggers and virtual machines can read this data to provide insights into the compiled code.

DWARF is mainly useful for debugging Kotlin/Wasm applications inside standalone Wasm virtual machines (VMs). To use this feature, the Wasm VM and debugger must support DWARF.

With DWARF support, you can step through Kotlin/Wasm applications, inspect variables, and gain code insights. To enable this feature, use the following compiler option:

```
-Xwasm-generate-dwarf
```

Migration to Provider API for Kotlin/Wasm and Kotlin/JS properties

Previously, properties in Kotlin/Wasm and Kotlin/JS extensions were mutable (var) and assigned directly in build scripts:

```
the<NodeJsExtension>().version = "2.0.0"
```

Now, properties are exposed through the Provider API, and you must use the .set() function to assign values:

```
the<NodeJsEnvSpec>().version.set("2.0.0")
```

The Provider API ensures that values are lazily computed and properly integrated with task dependencies, improving build performance.

With this change, direct property assignments are deprecated in favor of *EnvSpec classes, such as NodeJsEnvSpec and YarnRootEnvSpec.

Additionally, several alias tasks have been removed to avoid confusion:

Deprecated task	Replacement
wasmJsRun	wasmJsBrowserDevelopmentRun
wasmJsBrowserRun	wasmJsBrowserDevelopmentRun
wasmJsNodeRun	wasmJsNodeDevelopmentRun
wasmJsBrowserWebpack	wasmJsBrowserProductionWebpack or wasmJsBrowserDistribution
jsRun	jsBrowserDevelopmentRun
jsBrowserRun	jsBrowserDevelopmentRun
jsNodeRun	jsNodeDevelopmentRun
jsBrowserWebpack	jsBrowserProductionWebpack or jsBrowserDistribution

If you only use Kotlin/JS or Kotlin/Wasm in build scripts, no action is required as Gradle automatically handles assignments.

However, if you maintain a plugin based on the Kotlin Gradle Plugin, and your plugin does not apply kotlin-dsl, you must update property assignments to use the .set() function.

Gradle

Kotlin 2.1.20 is fully compatible with Gradle 7.6.3 through 8.11. You can also use Gradle versions up to the latest Gradle release. However, be aware that doing so may result in deprecation warnings, and some new Gradle features might not work.

This version of Kotlin includes compatibility of Kotlin Gradle plugins with Gradle's Isolated Projects as well as support for custom Gradle publication variants.

Kotlin Gradle plugins compatible with Gradle's Isolated Projects

This feature is currently in a pre-Alpha state in Gradle. JS and Wasm targets are not supported at the moment. Use it only with Gradle version 8.10 or higher and solely for evaluation purposes.

Since Kotlin 2.1.0, you've been able to preview Gradle's Isolated Projects feature in your projects.

Previously, you had to configure the Kotlin Gradle plugin to make your project compatible with the Isolated Projects feature before you could try it out. In Kotlin

2.1.20, this additional step is no longer necessary.

Now, to enable the Isolated Projects feature, you only need to set the system property.

Gradle's Isolated Projects feature is supported in Kotlin Gradle plugins for both multiplatform projects and projects that contain only the JVM or Android target.

Specifically for multiplatform projects, if you notice problems with your Gradle build after upgrading, you can opt out of the new Kotlin Gradle plugin behavior by adding:

```
kotlin.kmp.isolated-projects.support=disable
```

However, if you use this Gradle property in your multiplatform project, you can't use the Isolated Projects feature.

Let us know about your experience with this feature in YouTrack.

Support for adding custom Gradle publication variants

Kotlin 2.1.20 introduces support for adding custom Gradle publication variants. This feature is available for multiplatform projects and projects targeting the JVM.

> You cannot modify existing Gradle variants with this feature.

This feature is Experimental. To opt in, use the @OptIn(ExperimentalKotlinGradlePluginApi::class) annotation.

To add a custom Gradle publication variant, invoke the adhocSoftwareComponent() function, which returns an instance of AdhocComponentWithVariants that you can configure in the Kotlin DSL:

```
plugins {
    // Only JVM and Multiplatform are supported
    kotlin("jvm")
    // or
    kotlin("multiplatform")
}


kotlin {
    @OptIn(ExperimentalKotlinGradlePluginApi::class)
    publishing {
        // Returns an instance of AdhocSoftwareComponent
        adhocSoftwareComponent()
        // Alternatively, you can configure AdhocSoftwareComponent in the DSL block as follows
        adhocSoftwareComponent {
            // Add your custom variants here using the AdhocSoftwareComponent API
        }
    }
}
```

> For more information on variants, see Gradle's Customizing publishing guide.

Standard library

This release brings new Experimental features to the standard library: common atomic types, improved support for UUIDs, and new time-tracking functionality.

Common atomic types

In Kotlin 2.1.20, we are introducing common atomic types in the standard library's kotlin.concurrent.atomics package, enabling shared, platform-independent code for thread-safe operations. This simplifies development for Kotlin Multiplatform projects by removing the need to duplicate atomic-dependent logic across source sets.

The kotlin.concurrent.atomics package and its properties are Experimental. To opt in, use the @OptIn(ExperimentalAtomicApi::class) annotation or the compiler option -opt-in=kotlin.ExperimentalAtomicApi.

Here's an example that shows how you can use AtomicInt to safely count processed items across multiple threads:

```
// Imports the necessary libraries
import kotlin.concurrent.atomics.*
import kotlinx.coroutines.*

@OptIn(ExperimentalAtomicApi::class)
suspend fun main() {
    // Initializes the atomic counter for processed items
    var processedItems = AtomicInt(0)
    val totalItems = 100
    val items = List(totalItems) { "item$it" }
    // Splits the items into chunks for processing by multiple coroutines
    val chunkSize = 20
    val itemChunks = items.chunked(chunkSize)
    coroutineScope {
        for (chunk in itemChunks) {
            launch {
                for (item in chunk) {
                    println("Processing $item in thread ${Thread.currentThread()}")
                    processedItems += 1 // Increment counter atomically
                }
            }
         }
    }
    // Prints the total number of processed items
    println("Total processed items: ${processedItems.load()}")
}
```

To enable seamless interoperability between Kotlin's atomic types and Java's java.util.concurrent.atomic atomic types, the API provides the .asJavaAtomic() and .asKotlinAtomic() extension functions. On the JVM, Kotlin atomics and Java atomics are the same types in runtime, so you can transform Java atomics into Kotlin atomics and vice versa without any overhead.

Here's an example that shows how Kotlin and Java atomic types can work together:

```
// Imports the necessary libraries
import kotlin.concurrent.atomics.*
import java.util.concurrent.atomic.*

@OptIn(ExperimentalAtomicApi::class)
fun main() {
    // Converts Kotlin AtomicInt to Java's AtomicInteger
    val kotlinAtomic = AtomicInt(42)
    val javaAtomic: AtomicInteger = kotlinAtomic.asJavaAtomic()
    println("Java atomic value: ${javaAtomic.get()}")
    // Java atomic value: 42

    // Converts Java's AtomicInteger back to Kotlin's AtomicInt
    val kotlinAgain: AtomicInt = javaAtomic.asKotlinAtomic()
    println("Kotlin atomic value: ${kotlinAgain.load()}")
    // Kotlin atomic value: 42
}
```

Changes in UUID parsing, formatting, and comparability

The JetBrains team continues to improve the support for UUIDs introduced to the standard library in 2.0.20.

Previously, the parse() function only accepted UUIDs in the hex-and-dash format. With Kotlin 2.1.20, you can use parse() for both the hex-and-dash and the plain hexadecimal (without dashes) formats.

We've also introduced functions specific to operations with the hex-and-dash format in this release:

- parseHexDash() parses UUIDs from the hex-and-dash format.
- toHexDashString() converts a Uuid into a String in the hex-and-dash format (mirroring the functionality of toString()).

These functions work similarly to parseHex() and toHexString(), which were introduced earlier for the hexadecimal format. Explicit naming for parsing and formatting functionality should improve code clarity and your overall experience with UUIDs.

UUIDs in Kotlin are now Comparable. Starting with Kotlin 2.1.20, you can directly compare and sort values of the Uuid type. This enables the use of the < and > operators and standard library extensions available exclusively for Comparable types or their collections (such as sorted()), and it also allows passing UUIDs to any functions or APIs that require the Comparable interface.

Remember that the UUID support in the standard library is still Experimental. To opt in, use the @OptIn(ExperimentalUuidApi::class) annotation or the compiler option -opt-in=kotlin.uuid.ExperimentalUuidApi:

```
import kotlin.uuid.ExperimentalUuidApi
import kotlin.uuid.Uuid

@OptIn(ExperimentalUuidApi::class)
fun main() {
    // parse() accepts a UUID in a plain hexadecimal format
    val uuid = Uuid.parse("550e8400e29b41d4a716446655440000")

    // Converts it to the hex-and-dash format
    val hexDashFormat = uuid.toHexDashString()

    // Outputs the UUID in the hex-and-dash format
    println(hexDashFormat)

    // Outputs UUIDs in ascending order
    println(
        listOf(
            uuid,
            Uuid.parse("780e8400e29b41d4a716446655440005"),
            Uuid.parse("5ab88400e29b41d4a716446655440076")
        ).sorted()
    )
   }
```

New time tracking functionality

Starting with Kotlin 2.1.20, the standard library provides the ability to represent a moment in time. This functionality was previously only available in kotlinx-datetime, an official Kotlin library.

The kotlinx.datetime.Clock interface is introduced to the standard library as kotlin.time.Clock and the kotlinx.datetime.Instant class as kotlin.time.Instant. These concepts naturally align with the time package in the standard library because they're only concerned with moments in time compared to a more complex calendar and timezone functionality that remains in kotlinx-datetime.

Instant and Clock are useful when you need precise time tracking without considering time zones or dates. For example, you can use them to log events with timestamps, measure durations between two points in time, and obtain the current moment for system processes.

To provide interoperability with other languages, additional converter functions are available:

- .toKotlinInstant() converts a time value to a kotlin.time.Instant instance.
- .toJavaInstant() converts the kotlin.time.Instant value to a java.time.Instant value.
- Instant.toJSDate() converts the kotlin.time.Instant value to an instance of the JS Date class. This conversion is not precise; JS uses millisecond precision to represent dates, while Kotlin allows for nanosecond resolution.

The new time features of the standard library are still Experimental. To opt in, use the @OptIn(ExperimentalTime::class) annotation:

```
import kotlin.time.*

@OptIn(ExperimentalTime::class)
fun main() {

    // Get the current moment in time
    val currentInstant = Clock.System.now()
    println("Current time: $currentInstant")

    // Find the difference between two moments in time
    val pastInstant = Instant.parse("2023-01-01T00:00:00Z")
    val duration = currentInstant - pastInstant

    println("Time elapsed since 2023-01-01: $duration")
}
```

For more information on the implementation, see this KEEP proposal.

Compose compiler

In 2.1.20, the Compose compiler relaxes some restrictions on @Composable functions introduced in previous releases. In addition, the Compose compiler Gradle plugin is set to include source information by default, aligning the behavior on all platforms with Android.

Support for default arguments in open @Composable functions

The compiler previously restricted default arguments in open @Composable functions due to incorrect compiler output, which would result in crashes at runtime. The underlying issue is now resolved, and default arguments are fully supported when used with Kotlin 2.1.20 or newer.

Compose compiler allowed default arguments in open functions before version 1.5.8, so the support depends on project configuration:

- If an open composable function is compiled with Kotlin version 2.1.20 or newer, the compiler generates correct wrappers for default arguments. This includes wrappers compatible with pre-1.5.8 binaries, meaning that downstream libraries will also be able to use this open function.
- If the open composable function is compiled with Kotlin older than 2.1.20, Compose uses a compatibility mode, which might result in runtime crashes. When using the compatibility mode, the compiler emits a warning to highlight potential problems.

Final overridden functions are allowed to be restartable

Virtual functions (overrides of open and abstract, including interfaces) were forced to be non-restartable with the 2.1.0 release. This restriction is now relaxed for functions that are members of final classes or are final themselves – they will be restarted or skipped as usual.

You might observe some behavior changes in affected functions after upgrading to Kotlin 2.1.20. To force non-restartable logic from the previous version, apply the @NonRestartableComposable annotation to the function.

ComposableSingletons removed from public API

ComposableSingletons is a class created by the Compose compiler when optimizing @Composable lambdas. Lambdas that do not capture any parameters are allocated once and cached in a property of the class, saving allocations during runtime. The class is generated with internal visibility and is only intended for optimizing lambdas inside a compilation unit (usually a file).

However, this optimization was also applied to inline function bodies, which resulted in singleton lambda instances leaking into the public API. To fix this problem, starting with 2.1.20, @Composable lambdas are no longer optimized into singletons inside inline functions. At the same time, the Compose compiler will continue generating singleton classes and lambdas for inline functions to support binary compatibility for modules that were compiled under the previous model.

Source information included by default

The Compose compiler Gradle plugin already has the including source information feature enabled by default on Android. Starting with Kotlin 2.1.20, this feature will be enabled by default on all platforms.

Remember to check if you set this option using freeCompilerArgs. This method can cause the build to fail when used alongside the plugin, due to an option being effectively set twice.

Breaking changes and deprecations

- To align Kotlin Multiplatform with upcoming changes in Gradle, we are phasing out the withJava() function. Java source sets are now created by default. If you use the Java test fixtures Gradle plugin, upgrade directly to Kotlin 2.1.21 to avoid compatibility issues.
- The JetBrains team is proceeding with the deprecation of the kotlin-android-extensions plugin. If you try to use it in your project, you'll now get a configuration error, and no plugin code will be executed.
- The legacy kotlin.incremental.classpath.snapshot.enabled property has been removed from the Kotlin Gradle plugin. The property used to provide an opportunity to fall back to a built-in ABI snapshot on the JVM. The plugin now uses other methods to detect and avoid unnecessary recompilations, making the property obsolete.

Documentation updates

The Kotlin documentation has received some notable changes:

Revamped and new pages

- Kotlin roadmap – see the updated list of Kotlin's priorities on language and ecosystem evolution.
- Gradle best practices page – learn essential best practices for optimizing your Gradle builds and improving performance.
- Compose Multiplatform and Jetpack Compose – an overview of the relation between the two UI frameworks.

* Kotlin Multiplatform and Flutter – see the comparison of two popular cross-platform frameworks.
* Interoperability with C – explore the details of Kotlin's interoperability with C.
* Numbers – learn about different Kotlin types for representing numbers.

New and updated tutorials

* Publish your library to Maven Central – learn how to publish KMP library artifacts to the most popular Maven repository.
* Kotlin/Native as a dynamic library – create a dynamic Kotlin library.
* Kotlin/Native as an Apple framework – create your own framework and use Kotlin/Native code from Swift/Objective-C applications on macOS and iOS.

How to update to Kotlin 2.1.20

Starting from IntelliJ IDEA 2023.3 and Android Studio Iguana (2023.2.1) Canary 15, the Kotlin plugin is distributed as a bundled plugin included in your IDE. This means that you can't install the plugin from JetBrains Marketplace anymore.

To update to the new Kotlin version, change the Kotlin version to 2.1.20 in your build scripts.

What's new in Kotlin 2.0.20

Released: August 22, 2024

The Kotlin 2.0.20 release is out! This version includes performance improvements and bug fixes for Kotlin 2.0.0, where we announced the Kotlin K2 compiler as Stable. Here are some additional highlights from this release:

* The data class copy function to have the same visibility as the constructor
* Static accessors for source sets from the default target hierarchy are now available in multiplatform projects
* Concurrent marking for Kotlin/Native has been made possible in the garbage collector
* The @ExperimentalWasmDsl annotation in Kotlin/Wasm has a new location
* Support has been added for Gradle versions 8.6–8.8
* A new option allows sharing JVM artifacts between Gradle projects as class files
* The Compose compiler has been updated
* Support for UUIDs has been added to the common Kotlin standard library

IDE support

The Kotlin plugins that support 2.0.20 are bundled in the latest IntelliJ IDEA and Android Studio. You don't need to update the Kotlin plugin in your IDE. All you need to do is to change the Kotlin version to 2.0.20 in your build scripts.

See Update to a new release for details.

Language

Kotlin 2.0.20 begins to introduce changes to improve consistency in data classes and replace the Experimental context receivers feature.

Data class copy function to have the same visibility as constructor

Currently, if you create a data class using a private constructor, the automatically generated copy() function doesn't have the same visibility. This can cause problems later in your code. In future Kotlin releases, we will introduce the behavior that the default visibility of the copy() function is the same as the constructor. This change will be introduced gradually to help you migrate your code as smoothly as possible.

Our migration plan starts with Kotlin 2.0.20, which issues warnings in your code where the visibility will change in the future. For example:

```
// Triggers a warning in 2.0.20
data class PositiveInteger private constructor(val number: Int) {
    companion object {
        fun create(number: Int): PositiveInteger? = if (number > 0) PositiveInteger(number) else null
    }
}

fun main() {
    val positiveNumber = PositiveInteger.create(42) ?: return
    // Triggers a warning in 2.0.20
    val negativeNumber = positiveNumber.copy(number = -1)
    // Warning: Non-public primary constructor is exposed via the generated 'copy()' method of the 'data' class.
    // The generated 'copy()' will change its visibility in future releases.
}
```

For the latest information about our migration plan, see the corresponding issue in YouTrack.

To give you more control over this behavior, in Kotlin 2.0.20 we've introduced two annotations:

- @ConsistentCopyVisibility to opt in to the behavior now before we make it the default in a later release.
- @ExposedCopyVisibility to opt out of the behavior and suppress warnings at the declaration site. Note that even with this annotation, the compiler still reports warnings when the copy() function is called.

If you want to opt in to the new behavior already in 2.0.20 for a whole module rather than in individual classes, you can use the -Xconsistent-data-class-copy-visibility compiler option. This option has the same effect as adding the @ConsistentCopyVisibility annotation to all data classes in a module.

Phased replacement of context receivers with context parameters

In Kotlin 1.6.20, we introduced context receivers as an Experimental feature. After listening to community feedback, we've decided not to continue with this approach and will take a different direction.

In future Kotlin releases, context receivers will be replaced by context parameters. Context parameters are still in the design phase, and you can find the proposal in the KEEP.

Since the implementation of context parameters requires significant changes to the compiler, we've decided not to support context receivers and context parameters simultaneously. This decision greatly simplifies the implementation and minimizes the risk of unstable behavior.

We understand that context receivers are already being used by a large number of developers. Therefore, we will begin gradually removing support for context receivers. Our migration plan starts with Kotlin 2.0.20, where warnings are issued in your code when context receivers are used with the -Xcontext-receivers compiler option. For example:

```
class MyContext

context(MyContext)
// Warning: Experimental context receivers are deprecated and will be superseded by context parameters.
// Please don't use context receivers. You can either pass parameters explicitly or use members with extensions.
fun someFunction() {
}
```

This warning will become an error in future Kotlin releases.

If you use context receivers in your code, we recommend that you migrate your code to use either of the following:

- Explicit parameters.

Before	After

`context(ContextReceiverType)`
`fun someFunction() {`
`    contextReceiverMember()`
`}`
	`fun someFunction(explicitContext: ContextReceiverType) {`
	`    explicitContext.contextReceiverMember()`
	`}`

- Extension member functions (if possible).

Before	After

```
context(ContextReceiverType)
fun contextReceiverMember() = TODO()

context(ContextReceiverType)
fun someFunction() {
    contextReceiverMember()
}
```
	```
	class ContextReceiverType {
	    fun contextReceiverMember() =
	TODO()
	}

	fun ContextReceiverType.someFunction() {
	    contextReceiverMember()
	}
	```

Alternatively, you can wait until the Kotlin release where context parameters are supported in the compiler. Note that context parameters will initially be introduced as an Experimental feature.

Kotlin Multiplatform

Kotlin 2.0.20 brings improvements to source set management in multiplatform projects as well as deprecates compatibility with some Gradle Java plugins due to recent changes in Gradle.

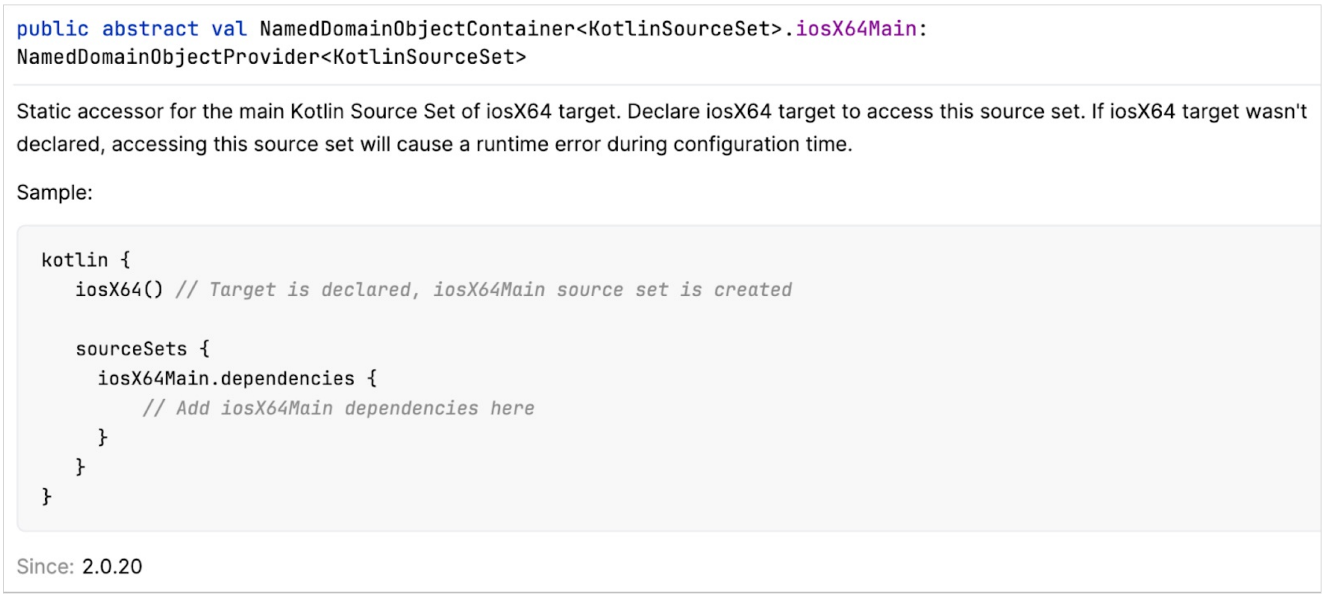
Static accessors for source sets from the default target hierarchy

Since Kotlin 1.9.20, the default hierarchy template is automatically applied to all Kotlin Multiplatform projects. And for all of the source sets from the default hierarchy template, the Kotlin Gradle plugin provided type-safe accessors. That way, you could finally access source sets for all the specified targets without having to use by getting or by creating constructs.

Kotlin 2.0.20 aims to improve your IDE experience even further. It now provides static accessors in the sourceSets {} block for all the source sets from the default hierarchy template. We believe this change will make accessing source sets by name easier and more predictable.

Each such source set now has a detailed KDoc comment with a sample and a diagnostic message with a warning in case you try to access the source set without declaring the corresponding target first:

```
kotlin {
    jvm()
    linuxX64()
    linuxArm64()
    mingwX64()

    sourceSets {
        commonMain.languageSettings {
            progressiveMode = true
        }


        jvmMain { }
        linuxX64Main { }
        linuxArm64Main { }
        // Warning: accessing source set without registering the target
        iosX64Main { }
    }
}
```



```
public abstract val NamedDomainObjectContainer<KotlinSourceSet>.iosX64Main:
NamedDomainObjectProvider<KotlinSourceSet>
```

Static accessor for the main Kotlin Source Set of iosX64 target. Declare iosX64 target to access this source set. If iosX64 target wasn't declared, accessing this source set will cause a runtime error during configuration time.

Sample:

```
kotlin {
   iosX64() // Target is declared, iosX64Main source set is created

   sourceSets {
     iosX64Main.dependencies {
         // Add iosX64Main dependencies here
     }
   }
}
```

Since: 2.0.20

Accessing the source sets by name

Learn more about the hierarchical project structure in Kotlin Multiplatform.

Deprecated compatibility with Kotlin Multiplatform Gradle plugin and Gradle Java plugins

In Kotlin 2.0.20, we introduce a deprecation warning when you apply the Kotlin Multiplatform Gradle plugin and any of the following Gradle Java plugins to the same project: Java, Java Library, and Application. The warning also appears when another Gradle plugin in your multiplatform project applies a Gradle Java plugin. For example, the Spring Boot Gradle Plugin automatically applies the Application plugin.

We've added this deprecation warning due to fundamental compatibility issues between Kotlin Multiplatform's project model and Gradle's Java ecosystem plugins. Gradle's Java ecosystem plugins currently don't take into account that other plugins may:

- Also publish or compile for the JVM target in a different way than the Java ecosystem plugins.
- Have two different JVM targets in the same project, such as JVM and Android.
- Have a complex multiplatform project structure with potentially multiple non-JVM targets.

Unfortunately, Gradle doesn't currently provide any API to address these issues.

We previously used some workarounds in Kotlin Multiplatform to help with the integration of Java ecosystem plugins. However, these workarounds never truly solved the compatibility issues, and since the release of Gradle 8.8, these workarounds are no longer possible. For more information, see our YouTrack issue.

While we don't yet know exactly how to resolve this compatibility problem, we are committed to continuing support for some form of Java source compilation in your Kotlin Multiplatform projects. At a minimum, we will support the compilation of Java sources and using Gradle's java-base plugin within your multiplatform projects.

In the meantime, if you see this deprecation warning in your multiplatform project, we recommend that you:

1. Determine whether you actually need the Gradle Java plugin in your project. If not, consider removing it.
2. Check if the Gradle Java plugin is only used for a single task. If so, you might be able to remove the plugin without much effort. For example, if the task uses a Gradle Java plugin to create a Javadoc JAR file, you can define the Javadoc task manually instead.

Otherwise, if you want to use both the Kotlin Multiplatform Gradle plugin and these Gradle plugins for Java in your multiplatform project, we recommend that you:

1. Create a separate subproject in your multiplatform project.
2. In the separate subproject, apply the Gradle plugin for Java.
3. In the separate subproject, add a dependency on your parent multiplatform project.

The separate subproject must not be a multiplatform project, and you must only use it to set up a dependency on your multiplatform project.

For example, you have a multiplatform project called my-main-project and you want to use the Application Gradle plugin to run a JVM application.

Once you've created a subproject, let's call it subproject-A, your parent project structure should look like this:

```
.
├── build.gradle.kts
├── settings.gradle
├── subproject-A
    └── build.gradle.kts
    └── src
        └── Main.java
```

In your subproject's build.gradle.kts file, apply the Application plugin in the plugins {} block:

Kotlin

```kotlin
plugins {
    id("application")
}
```

Groovy

```groovy
plugins {
    id('application')
}
```

In your subproject's build.gradle.kts file, add a dependency on your parent multiplatform project:

Kotlin

```kotlin
dependencies {
    implementation(project(":my-main-project")) // The name of your parent multiplatform project
}
```

Groovy

```groovy
dependencies {
    implementation project(':my-main-project') // The name of your parent multiplatform project
}
```

Your parent project is now set up to work with both plugins.

Kotlin/Native

Kotlin/Native receives improvements in the garbage collector and for calling Kotlin suspending functions from Swift/Objective-C.

Concurrent marking in garbage collector

In Kotlin 2.0.20, the JetBrains team takes another step toward improving Kotlin/Native runtime performance. We've added experimental support for concurrent marking in the garbage collector (GC).

By default, application threads must be paused when GC is marking objects in the heap. This greatly affects the duration of the GC pause time, which is important for the performance of latency-critical applications, such as UI applications built with Compose Multiplatform.

Now, the marking phase of the garbage collection can be run simultaneously with application threads. This should significantly shorten the GC pause time and help improve app responsiveness.

How to enable

The feature is currently Experimental. To enable it, set the following option in your gradle.properties file:

```
kotlin.native.binary.gc=cms
```

Please report any problems to our issue tracker YouTrack.

Support for bitcode embedding removed

Starting with Kotlin 2.0.20, the Kotlin/Native compiler no longer supports bitcode embedding. Bitcode embedding was deprecated in Xcode 14 and removed in Xcode 15 for all Apple targets.

Now, the embedBitcode parameter for the framework configuration, as well as the -Xembed-bitcode and -Xembed-bitcode-marker command line arguments are deprecated.

If you still use earlier versions of Xcode but want to upgrade to Kotlin 2.0.20, disable bitcode embedding in your Xcode projects.

Changes to GC performance monitoring with signposts

Kotlin 2.0.0 made it possible to monitor the performance of the Kotlin/Native garbage collector (GC) through Xcode Instruments. Instruments include the signposts tool, which can show GC pauses as events. This comes in handy when checking GC-related freezes in your iOS apps.

The feature was enabled by default, but unfortunately, it sometimes led to crashes when the application was run simultaneously with Xcode Instruments. Starting with Kotlin 2.0.20, it requires an explicit opt-in with the following compiler option:

```
-Xbinary=enableSafepointSignposts=true
```

Learn more about GC performance analysis in the documentation.

Ability to call Kotlin suspending functions from Swift/Objective-C on non-main threads

Previously, Kotlin/Native had a default restriction, limiting the ability to call Kotlin suspending functions from Swift and Objective-C to only the main thread. Kotlin 2.0.20 lifts that limitation, allowing you to run Kotlin suspend functions from Swift/Objective-C on any thread.

If you've previously switched the default behavior for non-main threads with the kotlin.native.binary.objcExportSuspendFunctionLaunchThreadRestriction=none binary option, you can now remove it from your gradle.properties file.

Kotlin/Wasm

In Kotlin 2.0.20, Kotlin/Wasm continues the migration towards named exports and relocates the @ExperimentalWasmDsl annotation.

Error in default export usage

As part of the migration towards named exports, a warning message was previously printed to the console when using a default import for Kotlin/Wasm exports in JavaScript.

To fully support named exports, this warning has now been upgraded to an error. If you use a default import, you encounter the following error message:

```
Do not use default import. Use the corresponding named import instead.
```

This change is part of a deprecation cycle to migrate towards named exports. Here's what you can expect during each phase:

- In version 2.0.0: A warning message is printed to the console, explaining that exporting entities via default exports is deprecated.
- In version 2.0.20: An error occurs, requesting the use of the corresponding named import.
- In version 2.1.0: The use of default imports is completely removed.

New location of ExperimentalWasmDsl annotation

Previously, the @ExperimentalWasmDsl annotation for WebAssembly (Wasm) features was placed in this location within the Kotlin Gradle plugin:

```
org.jetbrains.kotlin.gradle.targets.js.dsl.ExperimentalWasmDsl
```

In 2.0.20, the @ExperimentalWasmDsl annotation has been relocated to:

```
org.jetbrains.kotlin.gradle.ExperimentalWasmDsl
```

The previous location is now deprecated and might lead to build failures with unresolved references.

To reflect the new location of the @ExperimentalWasmDsl annotation, update the import statement in your Gradle build scripts. Use an explicit import for the new @ExperimentalWasmDsl location:

```
import org.jetbrains.kotlin.gradle.ExperimentalWasmDsl
```

Alternatively, remove this star import statement from the old package:

```
import org.jetbrains.kotlin.gradle.targets.js.dsl.*
```

Kotlin/JS

Kotlin/JS introduces some Experimental features to support static members in JavaScript and to create Kotlin collections from JavaScript.

Support for using Kotlin static members in JavaScript

This feature is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Starting with Kotlin 2.0.20, you can use the @JsStatic annotation. It works similarly to @JvmStatic and instructs the compiler to generate additional static methods for the target declaration. This helps you use static members from your Kotlin code directly in JavaScript.

You can use the @JsStatic annotation for functions defined in named objects, as well as in companion objects declared inside classes and interfaces. The compiler generates both a static method of the object and an instance method in the object itself. For example:

```
class C {
    companion object {
        @JsStatic
        fun callStatic() {}
        fun callNonStatic() {}
    }
}
```

Now, callStatic() is static in JavaScript while callNonStatic() is not:

```
C.callStatic();              // Works, accessing the static function
C.callNonStatic();           // Error, not a static function in the generated JavaScript
C.Companion.callStatic();    // Instance method remains
C.Companion.callNonStatic(); // The only way it works
```

It's also possible to apply the @JsStatic annotation to a property of an object or a companion object, making its getter and setter methods static members in that object or the class containing the companion object.

Ability to create Kotlin collections from JavaScript

This feature is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Kotlin 2.0.0 introduced the ability to export Kotlin collections to JavaScript (and TypeScript). Now, the JetBrains team is taking another step to improve collection interoperability. Starting with Kotlin 2.0.20, it's possible to create Kotlin collections directly from the JavaScript/TypeScript side.

You can create Kotlin collections from JavaScript and pass them as arguments to the exported constructors or functions. As soon as you mention a collection inside an exported declaration, Kotlin generates a factory for the collection that is available in JavaScript/TypeScript.

Take a look at the following exported function:

```
// Kotlin
@JsExport
fun consumeMutableMap(map: MutableMap<String, Int>)
```

Since the MutableMap collection is mentioned, Kotlin generates an object with a factory method available from JavaScript/TypeScript. This factory method then creates a MutableMap from a JavaScript Map:

```
// JavaScript
import { consumeMutableMap } from "an-awesome-kotlin-module"
import { KtMutableMap } from "an-awesome-kotlin-module/kotlin-kotlin-stdlib"

consumeMutableMap(
    KtMutableMap.fromJsMap(new Map([["First", 1], ["Second", 2]]))
)
```

This feature is available for the Set, Map, and List Kotlin collection types and their mutable counterparts.

Gradle

Kotlin 2.0.20 is fully compatible with Gradle 6.8.3 through 8.6. Gradle 8.7 and 8.8 are also supported, with only one exception: If you use the Kotlin Multiplatform Gradle plugin, you may see deprecation warnings in your multiplatform projects calling the withJava() function in the JVM target. We plan to fix this issue as soon as possible.

For more information, see the issue in YouTrack.

You can also use Gradle versions up to the latest Gradle release, but if you do, keep in mind that you might encounter deprecation warnings or some new Gradle features might not work.

This version brings changes such as beginning the deprecation process for the old incremental compilation approach based on JVM history files, as well as a new way of sharing JVM artifacts between projects.

Deprecated incremental compilation based on JVM history files

In Kotlin 2.0.20, the incremental compilation approach based on JVM history files is deprecated in favor of the new incremental compilation approach that has been enabled by default since Kotlin 1.8.20.

The incremental compilation approach based on JVM history files suffered from limitations, such as not working with Gradle's build cache and not supporting compilation avoidance. In contrast, the new incremental compilation approach overcomes these limitations and has performed well since its introduction.

Given that the new incremental compilation approach has been used by default for the last two major Kotlin releases, the kotlin.incremental.useClasspathSnapshot Gradle property is deprecated in Kotlin 2.0.20. Therefore, if you use it to opt out, you will see a deprecation warning.

Option to share JVM artifacts between projects as class files

This feature is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack. Opt-in is required (see details below).

In Kotlin 2.0.20, we introduce a new approach that changes the way the outputs of Kotlin/JVM compilations, such as JAR files, are shared between projects. With this approach, Gradle's apiElements configuration now has a secondary variant that provides access to the directory containing compiled .class files. When configured, your project uses this directory instead of requesting the compressed JAR artifact during compilation. This reduces the number of times JAR files are compressed and decompressed, especially for incremental builds.

Our testing shows that this new approach can provide build performance improvements for Linux and macOS hosts. However, on Windows hosts, we have seen a degradation in performance due to how Windows handles I/O operations when working with files.

To try this new approach, add the following property to your gradle.properties file:

```
kotlin.jvm.addClassesVariant=true
```

By default, this property is set to false and the apiElements variant in Gradle requests the compressed JAR artifact.

> Gradle has a related property that you can use in your Java-only projects to only expose the compressed JAR artifact during compilation instead of the directories containing compiled .class files:
>
> ```
> org.gradle.java.compile-classpath-packaging=true
> ```
>
> For more information on this property and its purpose, see Gradle's documentation on the Significant build performance drop on Windows for huge multi-projects.

We would appreciate your feedback on this new approach. Have you noticed any performance improvements while using it? Let us know by adding a comment in YouTrack.

Aligned dependency behavior of Kotlin Gradle plugin with java-test-fixtures plugin

Prior to Kotlin 2.0.20, if you used the java-test-fixtures plugin in your project, there was a difference between Gradle and the Kotlin Gradle plugin in how dependencies were propagated.

The Kotlin Gradle plugin propagated dependencies:

- From the java-test-fixtures plugin's implementation and api dependency types to the test source set compilation classpath.
- From the main source set's implementation and api dependency types to the java-test-fixtures plugin's source set compilation classpath.

However, Gradle only propagated dependencies in the api dependency types.

This difference in behavior led to some projects finding resource files multiple times in the classpath.

As of Kotlin 2.0.20, the Kotlin Gradle plugin's behavior is aligned with Gradle's java-test-fixtures plugin so this problem no longer occurs for this or other Gradle plugins.

As a result of this change, some dependencies in the test and testFixtures source sets may no longer be accessible. If this happens, either change the dependency declaration type from implementation to api or add a new dependency declaration on the affected source set.

Added task dependency for rare cases when the compile task lacks one on an artifact

Prior to 2.0.20, we found that there were scenarios where a compile task was missing a task dependency for one of its artifact inputs. This meant that the result of the dependent compile task was unstable, as sometimes the artifact had been generated in time, but sometimes, it hadn't.

To fix this issue, the Kotlin Gradle plugin now automatically adds the required task dependency in these scenarios.

In very rare cases, we've found that this new behavior can cause a circular dependency error. For example, if you have multiple compilations where one compilation can see all internal declarations of the other, and the generated artifact relies on the output of both compilation tasks, you could see an error like:

```
FAILURE: Build failed with an exception.

What went wrong:
Circular dependency between the following tasks:
:lib:compileKotlinJvm
--- :lib:jvmJar
     \--- :lib:compileKotlinJvm (*)
(*) - details omitted (listed previously)
```

To fix this circular dependency error, we've added a Gradle property: archivesTaskOutputAsFriendModule.

By default, this property is set to true to track the task dependency. To disable the use of the artifact in the compilation task, so that no task dependency is required, add the following in your gradle.properties file:

```
kotlin.build.archivesTaskOutputAsFriendModule=false
```

For more information, see the issue in YouTrack.

Compose compiler

In Kotlin 2.0.20, the Compose compiler gets a few improvements.

Fix for the unnecessary recompositions issue introduced in 2.0.0

Compose compiler 2.0.0 has an issue where it sometimes incorrectly infers the stability of types in multiplatform projects with non-JVM targets. This can lead to unnecessary (or even endless) recompositions. We strongly recommended updating your Compose apps made for Kotlin 2.0.0 to version 2.0.10 or newer.

If your app is built with Compose compiler 2.0.10 or newer but uses dependencies built with version 2.0.0, these older dependencies may still cause recomposition issues. To prevent this, update your dependencies to versions built with the same Compose compiler as your app.

New way to configure compiler options

We've introduced a new option configuration mechanism to avoid the churn of top-level parameters. It's harder for the Compose compiler team to test things out by creating or removing top-level entries for the composeCompiler {} block. So, options such as strong skipping mode and non-skipping group optimizations are now enabled through the featureFlags property. This property will be used to test new Compose compiler options that will eventually become default.

This change has also been applied to the Compose compiler Gradle plugin. To configure feature flags going forward, use the following syntax (this code will flip all of the default values):

```
composeCompiler {
    featureFlags = setOf(
        ComposeFeatureFlag.IntrinsicRemember.disabled(),
        ComposeFeatureFlag.OptimizeNonSkippingGroups,
        ComposeFeatureFlag.StrongSkipping.disabled()
    )
}
```

Or, if you are configuring the Compose compiler directly, use the following syntax:

```
-P plugin:androidx.compose.compiler.plugins.kotlin:featureFlag=IntrinsicRemember
```

The enableIntrinsicRemember, enableNonSkippingGroupOptimization, and enableStrongSkippingMode properties have been therefore deprecated.

We would appreciate any feedback you have on this new approach in YouTrack.

Strong skipping mode enabled by default

Strong skipping mode for the Compose compiler is now enabled by default.

Strong skipping mode is a Compose compiler configuration option that changes the rules for what composables can be skipped. With strong skipping mode enabled, composables with unstable parameters can now also be skipped. Strong skipping mode also automatically remembers lambdas used in composable functions, so you should no longer need to wrap your lambdas with remember to avoid recomposition.

For more details, see the strong skipping mode documentation.

Composition trace markers enabled by default

The includeTraceMarkers option is now set to true by default in the Compose compiler Gradle plugin to match the default value in the compiler plugin. This allows you to see composable functions in the Android Studio system trace profiler. For details about composition tracing, see this Android Developers blog post.

Non-skipping group optimizations

This release includes a new compiler option: when enabled, non-skippable and non-restartable composable functions will no longer generate a group around the body of the composable. This leads to fewer allocations and thus to improved performance. This option is experimental and disabled by default but can be enabled with the feature flag OptimizeNonSkippingGroups as shown above.

This feature flag is now ready for wider testing. Any issues found when enabling the feature can be filed on the Google issue tracker.

Support for default parameters in abstract composable functions

You can now add default parameters to abstract composable functions.

Previously, the Compose compiler would report an error when attempting to do this even though it is valid Kotlin code. We've now added support for this in the Compose compiler, and the restriction has been removed. This is especially useful for including default Modifier values:

```
abstract class Composables {
    @Composable
    abstract fun Composable(modifier: Modifier = Modifier)
}
```

Default parameters for open composable functions are still restricted in 2.0.20. This restriction will be addressed in future releases.

Standard library

The standard library now supports universally unique identifiers as an Experimental feature and includes some changes to Base64 decoding.

Support for UUIDs in the common Kotlin standard library

This feature is Experimental. To opt in, use the @ExperimentalUuidApi annotation or the compiler option -opt-in=kotlin.uuid.ExperimentalUuidApi.

Kotlin 2.0.20 introduces a class for representing UUIDs (universally unique identifiers) in the common Kotlin standard library to address the challenge of uniquely identifying items.

Additionally, this feature provides APIs for the following UUID-related operations:

- Generating UUIDs.
- Parsing UUIDs from and formatting them to their string representations.
- Creating UUIDs from specified 128-bit values.
- Accessing the 128 bits of a UUID.

The following code example demonstrates these operations:

```
// Constructs a byte array for UUID creation
val byteArray = byteArrayOf(
    0x55, 0x0E, 0x84.toByte(), 0x00, 0xE2.toByte(), 0x9B.toByte(), 0x41, 0xD4.toByte(),
    0xA7.toByte(), 0x16, 0x44, 0x66, 0x55, 0x44, 0x00, 0x00
)

val uuid1 = Uuid.fromByteArray(byteArray)
val uuid2 = Uuid.fromULongs(0x550E8400E29B41D4uL, 0xA716446655440000uL)
val uuid3 = Uuid.parse("550e8400-e29b-41d4-a716-446655440000")

println(uuid1)
// 550e8400-e29b-41d4-a716-446655440000
println(uuid1 == uuid2)
// true
println(uuid2 == uuid3)
// true

// Accesses UUID bits
val version = uuid1.toLongs { mostSignificantBits, _ ->
    ((mostSignificantBits shr 12) and 0xF).toInt()
}
println(version)
// 4

// Generates a random UUID
val randomUuid = Uuid.random()

println(uuid1 == randomUuid)
```

```
// false
```

To maintain compatibility with APIs that use java.util.UUID, there are two extension functions in Kotlin/JVM for converting between java.util.UUID and kotlin.uuid.Uuid: .toJavaUuid() and .toKotlinUuid(). For example:

```
val kotlinUuid = Uuid.parseHex("550e8400e29b41d4a716446655440000")
// Converts Kotlin UUID to java.util.UUID
val javaUuid = kotlinUuid.toJavaUuid()

val javaUuid = java.util.UUID.fromString("550e8400-e29b-41d4-a716-446655440000")
// Converts Java UUID to kotlin.uuid.Uuid
val kotlinUuid = javaUuid.toKotlinUuid()
```

This feature and the provided APIs simplify multiplatform software development by allowing code sharing among multiple platforms. UUIDs are also ideal in environments where generating unique identifiers is difficult.

Some example use cases involving UUIDs include:

- Assigning unique IDs to database records.
- Generating web session identifiers.
- Any scenario requiring unique identification or tracking.

Support for minLength in HexFormat

> The HexFormat class and its properties are Experimental. To opt in, use the @OptIn(ExperimentalStdlibApi::class) annotation or the compiler option -opt-in=kotlin.ExperimentalStdlibApi.

Kotlin 2.0.20 adds a new minLength property to the NumberHexFormat class, accessed through HexFormat.number. This property lets you specify the minimum number of digits in hexadecimal representations of numeric values, enabling padding with zeros to meet the required length. Additionally, leading zeros can be trimmed using the removeLeadingZeros property:

```
fun main() {
    println(93.toHexString(HexFormat {
        number.minLength = 4
        number.removeLeadingZeros = true
    }))
    // "005d"
}
```

The minLength property does not affect parsing. However, parsing now allows hex strings to have more digits than the type's width if the extra leading digits are zeros.

Changes to the Base64's decoder behavior

> The Base64 class and its related features are Experimental. To opt in, use the @OptIn(ExperimentalEncodingApi::class) annotation or the compiler option -opt-in=kotlin.io.encoding.ExperimentalEncodingApi.

Two changes were introduced to the Base64 decoder's behavior in Kotlin 2.0.20:

- The Base64 decoder now requires padding
- A withPadding function has been added for padding configuration

The Base64 decoder now requires padding

The Base64 encoder now adds padding by default, and the decoder requires padding and prohibits non-zero pad bits when decoding.

withPadding function for padding configuration

A new .withPadding() function has been introduced to give users control over the padding behavior of Base64 encoding and decoding:

```
val base64 = Base64.UrlSafe.withPadding(Base64.PaddingOption.ABSENT_OPTIONAL)
```

This function enables the creation of Base64 instances with different padding options:

PaddingOption	On encode	On decode
PRESENT	Add padding	Padding is required
ABSENT	Omit padding	No padding allowed
PRESENT_OPTIONAL	Add padding	Padding is optional
ABSENT_OPTIONAL	Omit padding	Padding is optional

You can create Base64 instances with different padding options and use them to encode and decode data:

```
import kotlin.io.encoding.Base64
import kotlin.io.encoding.ExperimentalEncodingApi

@OptIn(ExperimentalEncodingApi::class)
fun main() {
    // Example data to encode
    val data = "fooba".toByteArray()

    // Creates a Base64 instance with URL-safe alphabet and PRESENT padding
    val base64Present = Base64.UrlSafe.withPadding(Base64.PaddingOption.PRESENT)
    val encodedDataPresent = base64Present.encode(data)
    println("Encoded data with PRESENT padding: $encodedDataPresent")
    // Encoded data with PRESENT padding: Zm9vYmE=

    // Creates a Base64 instance with URL-safe alphabet and ABSENT padding
    val base64Absent = Base64.UrlSafe.withPadding(Base64.PaddingOption.ABSENT)
    val encodedDataAbsent = base64Absent.encode(data)
    println("Encoded data with ABSENT padding: $encodedDataAbsent")
    // Encoded data with ABSENT padding: Zm9vYmE

    // Decodes the data back
    val decodedDataPresent = base64Present.decode(encodedDataPresent)
    println("Decoded data with PRESENT padding: ${String(decodedDataPresent)}")
    // Decoded data with PRESENT padding: fooba

    val decodedDataAbsent = base64Absent.decode(encodedDataAbsent)
    println("Decoded data with ABSENT padding: ${String(decodedDataAbsent)}")
    // Decoded data with ABSENT padding: fooba
}
```

Documentation updates

The Kotlin documentation has received some notable changes:

- Improved Standard input page - Learn how to use Java Scanner and readln().
- Improved K2 compiler migration guide - Learn about performance improvements, compatibility with Kotlin libraries and what to do with your custom compiler plugins.
- Improved Exceptions page - Learn about exceptions, how to throw and catch them.
- Improved Test code using JUnit in JVM - tutorial - Learn how to create tests using JUnit.
- Improved Interoperability with Swift/Objective-C page - Learn how to use Kotlin declarations in Swift/Objective-C code and Objective-C declarations in Kotlin

code.

- Improved Swift package export setup page - Learn how to set up Kotlin/Native output that can be consumed by a Swift package manager dependency.

Install Kotlin 2.0.20

Starting from IntelliJ IDEA 2023.3 and Android Studio Iguana (2023.2.1) Canary 15, the Kotlin plugin is distributed as a bundled plugin included in your IDE. This means that you can't install the plugin from JetBrains Marketplace anymore.

To update to the new Kotlin version, change the Kotlin version to 2.0.20 in your build scripts.

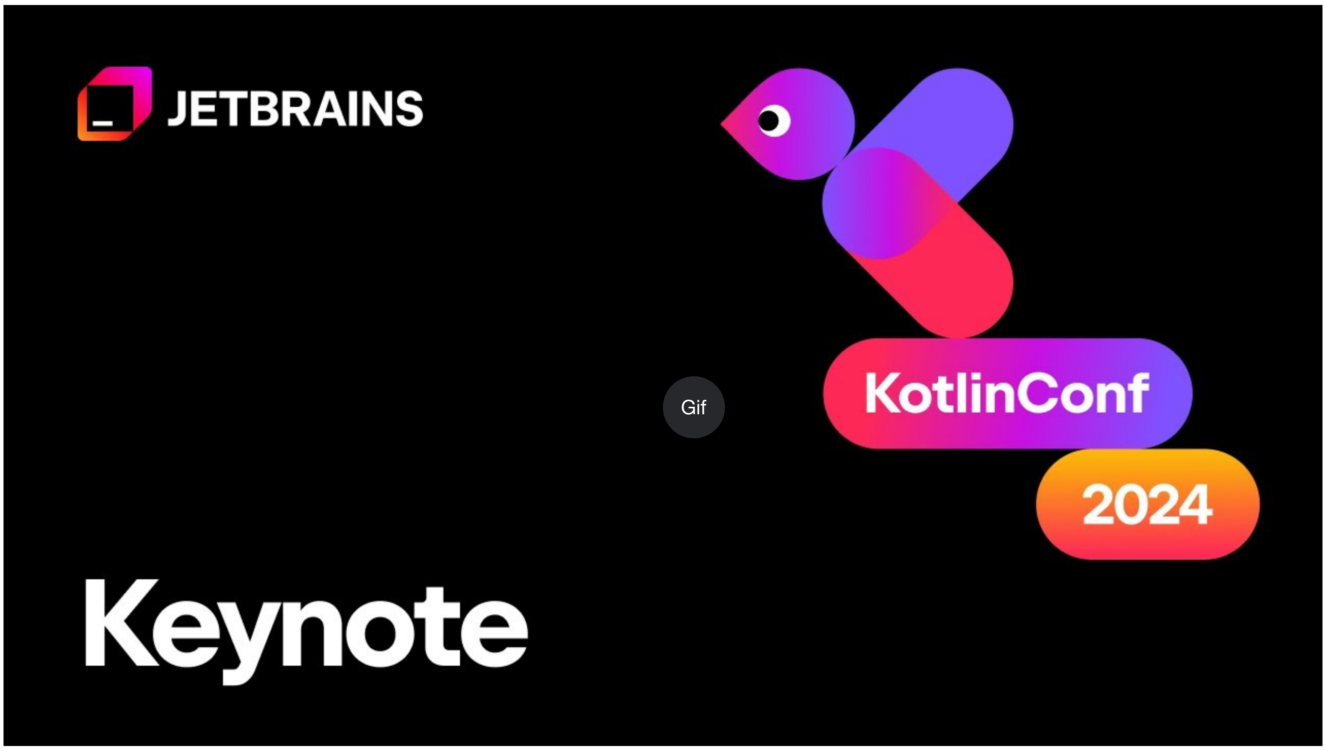
What's new in Kotlin 2.0.0

Released: May 21, 2024

The Kotlin 2.0.0 release is out and the new Kotlin K2 compiler is Stable! Additionally, here are some other highlights:

- New Compose compiler Gradle plugin
- Generation of lambda functions using invokedynamic
- The kotlinx-metadata-jvm library is now Stable
- Monitoring GC performance in Kotlin/Native with signposts on Apple platforms
- Resolving conflicts in Kotlin/Native with Objective-C methods
- Support for named export in Kotlin/Wasm
- Support for unsigned primitive types in functions with @JsExport in Kotlin/Wasm
- Optimize production builds by default using Binaryen
- New Gradle DSL for compiler options in multiplatform projects
- Stable replacement of the enum class values generic function
- Stable AutoCloseable interface

Kotlin 2.0 is a huge milestone for the JetBrains team. This release was the center of KotlinConf 2024. Check out the opening keynote, where we announced exciting updates and addressed the recent work on the Kotlin language:



Watch video online.

IDE support

The Kotlin plugins that support Kotlin 2.0.0 are bundled in the latest IntelliJ IDEA and Android Studio. You don't need to update the Kotlin plugin in your IDE. All you need to do is to change the Kotlin version to Kotlin 2.0.0 in your build scripts.

- For details about IntelliJ IDEA's support for the Kotlin K2 compiler, see Support in IDEs.
- For more details about IntelliJ IDEA's support for Kotlin, see Kotlin releases.

Kotlin K2 compiler

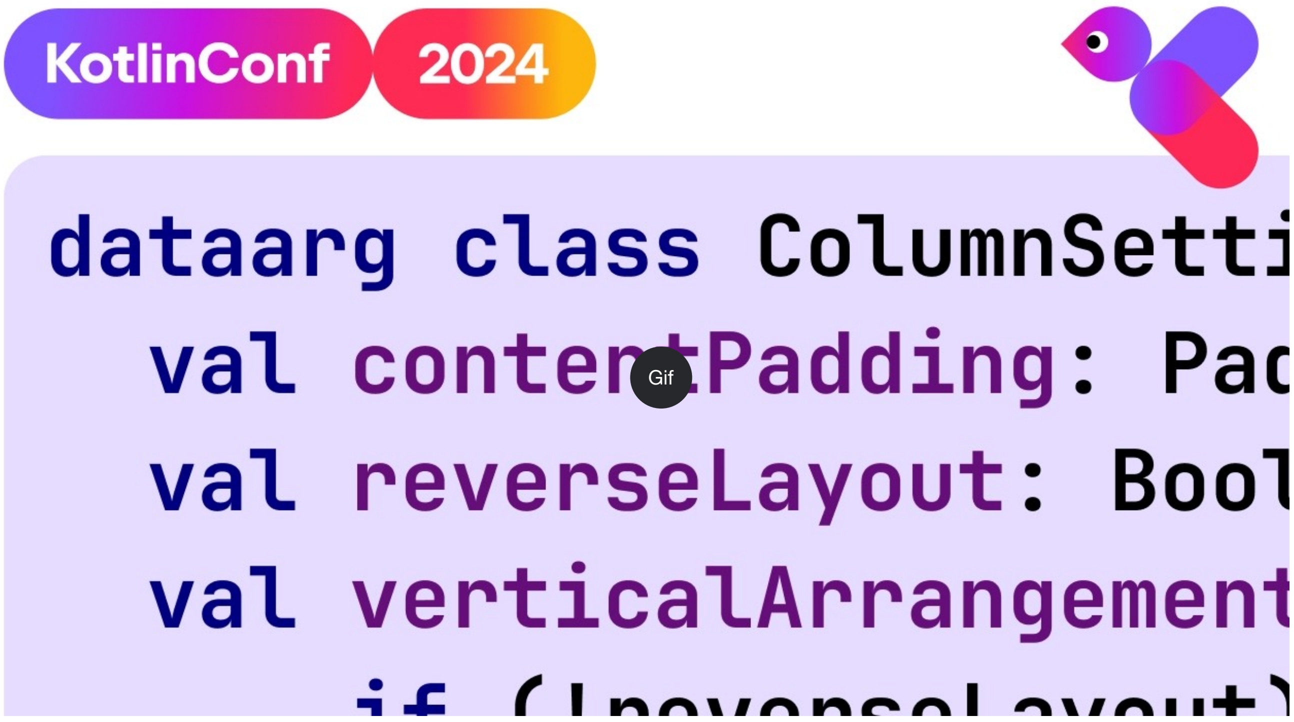
The road to the K2 compiler has been a long one, but now the JetBrains team is finally ready to announce its stabilization. In Kotlin 2.0.0, the new Kotlin K2 compiler is used by default and it is Stable for all target platforms: JVM, Native, Wasm, and JS. The new compiler brings major performance improvements, speeds up new language feature development, unifies all platforms that Kotlin supports, and provides a better architecture for multiplatform projects.

The JetBrains team has ensured the quality of the new compiler by successfully compiling 10 million lines of code from selected user and internal projects. 18,000 developers were involved in the stabilization process, testing the new K2 compiler across a total of 80,000 projects and reporting any problems they found.

To help make the migration process to the new compiler as smooth as possible, we've created a K2 compiler migration guide. This guide explains the many benefits of the compiler, highlights any changes you might encounter, and describes how to roll back to the previous version if necessary.

In a blog post, we explored the performance of the K2 compiler in different projects. Check it out if you'd like to see real data on how the K2 compiler performs and find instructions on how to collect performance benchmarks from your own projects.

You can also watch this talk from KotlinConf 2024, where Michail Zarečenskij, the lead language designer, discusses the feature evolution in Kotlin and the K2 compiler:



```
dataarg class ColumnSetti
   val contentPadding: Pad
   val reverseLayout: Bool
   val verticalArrangement
```

Watch video online.

Current K2 compiler limitations

Enabling K2 in your Gradle project comes with certain limitations that can affect projects using Gradle versions below 8.3 in the following cases:

- Compilation of source code from buildSrc.
- Compilation of Gradle plugins in included builds.
- Compilation of other Gradle plugins if they are used in projects with Gradle versions below 8.3.
- Building Gradle plugin dependencies.

If you encounter any of the problems mentioned above, you can take the following steps to address them:

- Set the language version for buildSrc, any Gradle plugins, and their dependencies:

```
kotlin {
    compilerOptions {
        languageVersion.set(org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9)
        apiVersion.set(org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9)
    }
}
```

> If you configure language and API versions for specific tasks, these values will override the values set by the compilerOptions extension. In this case, language and API versions should not be higher than 1.9.

- Update the Gradle version in your project to 8.3 or later.

Smart cast improvements

The Kotlin compiler can automatically cast an object to a type in specific cases, saving you the trouble of having to explicitly cast it yourself. This is called smart casting. The Kotlin K2 compiler now performs smart casts in even more scenarios than before.

In Kotlin 2.0.0, we've made improvements related to smart casts in the following areas:

Local variables and further scopes

Previously, if a variable was evaluated as not null within an if condition, the variable would be smart-cast. Information about this variable would then be shared further within the scope of the if block.

However, if you declared the variable outside the if condition, no information about the variable would be available within the if condition, so it couldn't be smart-cast. This behavior was also seen with when expressions and while loops.

From Kotlin 2.0.0, if you declare a variable before using it in your if, when, or while condition, then any information collected by the compiler about the variable will be accessible in the corresponding block for smart-casting.

This can be useful when you want to do things like extract boolean conditions into variables. Then, you can give the variable a meaningful name, which will improve your code readability and make it possible to reuse the variable later in your code. For example:

```kotlin
class Cat {
    fun purr() {
        println("Purr purr")
    }
}

fun petAnimal(animal: Any) {
    val isCat = animal is Cat
    if (isCat) {
        // In Kotlin 2.0.0, the compiler can access
        // information about isCat, so it knows that
        // animal was smart-cast to the type Cat.
        // Therefore, the purr() function can be called.
        // In Kotlin 1.9.20, the compiler doesn't know
        // about the smart cast, so calling the purr()
        // function triggers an error.
        animal.purr()
    }
}

fun main() {
    val kitty = Cat()
    petAnimal(kitty)
    // Purr purr
}
```

Type checks with logical or operator

In Kotlin 2.0.0, if you combine type checks for objects with an or operator (||), a smart cast is made to their closest common supertype. Before this change, a smart cast was always made to the Any type.

In this case, you still had to manually check the object type afterward before you could access any of its properties or call its functions. For example:

```kotlin
interface Status {
    fun signal() {}
}

interface Ok : Status
interface Postponed : Status
interface Declined : Status

fun signalCheck(signalStatus: Any) {
    if (signalStatus is Postponed || signalStatus is Declined) {
        // signalStatus is smart-cast to a common supertype Status
        signalStatus.signal()
        // Prior to Kotlin 2.0.0, signalStatus is smart cast
        // to type Any, so calling the signal() function triggered an
        // Unresolved reference error. The signal() function can only
        // be called successfully after another type check:

        // check(signalStatus is Status)
        // signalStatus.signal()
    }
}
```

The common supertype is an approximation of a union type. Union types are not supported in Kotlin.

Inline functions

In Kotlin 2.0.0, the K2 compiler treats inline functions differently, allowing it to determine in combination with other compiler analyses whether it's safe to smart-cast.

Specifically, inline functions are now treated as having an implicit callsInPlace contract. This means that any lambda functions passed to an inline function are called in place. Since lambda functions are called in place, the compiler knows that a lambda function can't leak references to any variables contained within its function body.

The compiler uses this knowledge along with other compiler analyses to decide whether it's safe to smart-cast any of the captured variables. For example:

```kotlin
interface Processor {
    fun process()
}

inline fun inlineAction(f: () -> Unit) = f()

fun nextProcessor(): Processor? = null

fun runProcessor(): Processor? {
    var processor: Processor? = null
    inlineAction {
        // In Kotlin 2.0.0, the compiler knows that processor
        // is a local variable, and inlineAction() is an inline function, so
        // references to processor can't be leaked. Therefore, it's safe
        // to smart-cast processor.

        // If processor isn't null, processor is smart-cast
        if (processor != null) {
            // The compiler knows that processor isn't null, so no safe call
            // is needed
            processor.process()

            // In Kotlin 1.9.20, you have to perform a safe call:
            // processor?.process()
        }

        processor = nextProcessor()
    }

    return processor
}
```

Properties with function types

In previous versions of Kotlin, there was a bug that meant that class properties with a function type weren't smart-cast. We fixed this behavior in Kotlin 2.0.0 and the K2 compiler. For example:

```kotlin
class Holder(val provider: (() -> Unit)?) {
    fun process() {
        // In Kotlin 2.0.0, if provider isn't null, then
        // provider is smart-cast
        if (provider != null) {
            // The compiler knows that provider isn't null
            provider()

            // In 1.9.20, the compiler doesn't know that provider isn't
            // null, so it triggers an error:
            // Reference has a nullable type '(() -> Unit)?', use explicit '?.invoke()' to make a function-like call instead
        }
    }
}
```

This change also applies if you overload your invoke operator. For example:

```
interface Provider {
    operator fun invoke()
}

interface Processor : () -> String

class Holder(val provider: Provider?, val processor: Processor?) {
    fun process() {
        if (provider != null) {
            provider()
            // In 1.9.20, the compiler triggers an error:
            // Reference has a nullable type 'Provider?' use explicit '?.invoke()' to make a function-like call instead
        }
    }
}
```

Exception handling

In Kotlin 2.0.0, we've made improvements to exception handling so that smart cast information can be passed on to catch and finally blocks. This change makes your code safer as the compiler keeps track of whether your object has a nullable type. For example:

```
fun testString() {
    var stringInput: String? = null
    // stringInput is smart-cast to String type
    stringInput = ""
    try {
        // The compiler knows that stringInput isn't null
        println(stringInput.length)
        // 0

        // The compiler rejects previous smart cast information for
        // stringInput. Now stringInput has the String? type.
        stringInput = null

        // Trigger an exception
        if (2 > 1) throw Exception()
        stringInput = ""
    } catch (exception: Exception) {
        // In Kotlin 2.0.0, the compiler knows stringInput
        // can be null, so stringInput stays nullable.
        println(stringInput?.length)
        // null

        // In Kotlin 1.9.20, the compiler says that a safe call isn't
        // needed, but this is incorrect.
    }
}

fun main() {
    testString()
}
```

Increment and decrement operators

Prior to Kotlin 2.0.0, the compiler didn't understand that the type of an object can change after using an increment or decrement operator. As the compiler couldn't accurately track the object type, your code could lead to unresolved reference errors. In Kotlin 2.0.0, this has been fixed:

```
interface Rho {
    operator fun inc(): Sigma = TODO()
}

interface Sigma : Rho {
    fun sigma() = Unit
}

interface Tau {
    fun tau() = Unit
}
```

```kotlin
fun main(input: Rho) {
    var unknownObject: Rho = input

    // Check if unknownObject inherits from the Tau interface
    // Note, it's possible that unknownObject inherits from both
    // Rho and Tau interfaces.
    if (unknownObject is Tau) {

        // Use the overloaded inc() operator from interface Rho.
        // In Kotlin 2.0.0, the type of unknownObject is smart-cast to
        // Sigma.
        ++unknownObject

        // In Kotlin 2.0.0, the compiler knows unknownObject has type
        // Sigma, so the sigma() function can be called successfully.
        unknownObject.sigma()

        // In Kotlin 1.9.20, the compiler doesn't perform a smart cast
        // when inc() is called so the compiler still thinks that
        // unknownObject has type Tau. Calling the sigma() function
        // throws a compile-time error.

        // In Kotlin 2.0.0, the compiler knows unknownObject has type
        // Sigma, so calling the tau() function throws a compile-time
        // error.
        unknownObject.tau()
        // Unresolved reference 'tau'

        // In Kotlin 1.9.20, since the compiler mistakenly thinks that
        // unknownObject has type Tau, the tau() function can be called,
        // but it throws a ClassCastException.
    }
}
```

Kotlin Multiplatform improvements

In Kotlin 2.0.0, we've made improvements in the K2 compiler related to Kotlin Multiplatform in the following areas:

- Separation of common and platform sources during compilation
- Different visibility levels of expected and actual declarations

Separation of common and platform sources during compilation

Previously, the design of the Kotlin compiler prevented it from keeping common and platform source sets separate at compile time. As a consequence, common code could access platform code, which resulted in different behavior between platforms. In addition, some compiler settings and dependencies from common code used to leak into platform code.

In Kotlin 2.0.0, our implementation of the new Kotlin K2 compiler included a redesign of the compilation scheme to ensure strict separation between common and platform source sets. This change is most noticeable when you use expected and actual functions. Previously, it was possible for a function call in your common code to resolve to a function in platform code. For example:

Common code

```kotlin
fun foo(x: Any) = println("common foo")

fun exampleFunction() {
    foo(42)
}
```

Platform code

```kotlin
// JVM
fun foo(x: Int) = println("platform foo")

// JavaScript
// There is no foo() function overload
// on the JavaScript platform
```

In this example, the common code has different behavior depending on which platform it is run on:

- On the JVM platform, calling the foo() function in the common code results in the foo() function from the platform code being called as platform foo.
- On the JavaScript platform, calling the foo() function in the common code results in the foo() function from the common code being called as common foo, as there is no such function available in the platform code.

In Kotlin 2.0.0, common code doesn't have access to platform code, so both platforms successfully resolve the foo() function to the foo() function in the common code: common foo.

In addition to the improved consistency of behavior across platforms, we also worked hard to fix cases where there was conflicting behavior between IntelliJ IDEA or Android Studio and the compiler. For instance, when you used expected and actual classes, the following would happen:

Common code	Platform code

`expect class Identity { fun confirmIdentity(): String }`
`fun common() { // Before 2.0.0, // it triggers an IDE-only error Identity().confirmIdentity() // RESOLUTION_TO_CLASSIFIER : Expected class // Identity has no default constructor. }`
	`actual class Identity { actual fun confirmIdentity() = "expect class fun: jvm" }`

```kotlin
expect class Identity {
    fun confirmIdentity(): String
}

fun common() {
    // Before 2.0.0,
    // it triggers an IDE-only error
    Identity().confirmIdentity()
    // RESOLUTION_TO_CLASSIFIER : Expected class
    // Identity has no default constructor.
}
```

```kotlin
actual class Identity {
    actual fun confirmIdentity() = "expect class fun:
jvm"
}
```

In this example, the expected class Identity has no default constructor, so it can't be called successfully in common code. Previously, an error was only reported by the IDE, but the code still compiled successfully on the JVM. However, now the compiler correctly reports an error:

```
Expected class 'expect class Identity : Any' does not have default constructor
```

When resolution behavior doesn't change

We're still in the process of migrating to the new compilation scheme, so the resolution behavior is still the same when you call functions that aren't within the same source set. You'll notice this difference mainly when you use overloads from a multiplatform library in your common code.

Suppose you have a library, which has two whichFun() functions with different signatures:

```kotlin
// Example library

// MODULE: common
fun whichFun(x: Any) = println("common function")

// MODULE: JVM
fun whichFun(x: Int) = println("platform function")
```

If you call the whichFun() function in your common code, the function that has the most relevant argument type in the library is resolved:

```kotlin
// A project that uses the example library for the JVM target

// MODULE: common
fun main() {
    whichFun(2)
    // platform function
}
```

In comparison, if you declare the overloads for whichFun() within the same source set, the function from the common code will be resolved because your code doesn't have access to the platform-specific version:

```kotlin
// Example library isn't used

// MODULE: common
fun whichFun(x: Any) = println("common function")

fun main() {
    whichFun(2)
    // common function
}

// MODULE: JVM
fun whichFun(x: Int) = println("platform function")
```

Similar to multiplatform libraries, since the commonTest module is in a separate source set, it also still has access to platform-specific code. Therefore, the resolution of calls to functions in the commonTest module exhibits the same behavior as in the old compilation scheme.

In the future, these remaining cases will be more consistent with the new compilation scheme.

Different visibility levels of expected and actual declarations

Before Kotlin 2.0.0, if you used expected and actual declarations in your Kotlin Multiplatform project, they had to have the same visibility level. Kotlin 2.0.0 now also supports different visibility levels but only if the actual declaration is more permissive than the expected declaration. For example:

```
expect internal class Attribute // Visibility is internal
actual class Attribute          // Visibility is public by default,
                                // which is more permissive
```

Similarly, if you are using a type alias in your actual declaration, the visibility of the underlying type should be the same or more permissive than the expected declaration. For example:

```
expect internal class Attribute                 // Visibility is internal
internal actual typealias Attribute = Expanded

class Expanded                                  // Visibility is public by default,
                                                // which is more permissive
```

Compiler plugins support

Currently, the Kotlin K2 compiler supports the following Kotlin compiler plugins:

- all-open
- AtomicFU
- jvm-abi-gen
- js-plain-objects
- kapt
- Lombok
- no-arg
- Parcelize
- SAM with receiver
- serialization
- Power-assert

In addition, the Kotlin K2 compiler supports:

- The Jetpack Compose compiler plugin 2.0.0, which was moved into the Kotlin repository.
- The Kotlin Symbol Processing (KSP) plugin since KSP2.

> If you use any additional compiler plugins, check their documentation to see if they are compatible with K2.

Experimental Kotlin Power-assert compiler plugin

> The Kotlin Power-assert plugin is Experimental. It may be changed at any time.

Kotlin 2.0.0 introduces an experimental Power-assert compiler plugin. This plugin improves the experience of writing tests by including contextual information in failure messages, making debugging easier and more efficient.

Developers often need to use complex assertion libraries to write effective tests. The Power-assert plugin simplifies this process by automatically generating failure messages that include intermediate values of the assertion expression. This helps developers quickly understand why a test failed.

When an assertion fails in a test, the improved error message shows the values of all variables and sub-expressions within the assertion, making it clear which part of the condition caused the failure. This is particularly useful for complex assertions where multiple conditions are checked.

To enable the plugin in your project, configure it in your build.gradle(.kts) file:

Kotlin

```kotlin
plugins {
    kotlin("multiplatform") version "2.0.0"
    kotlin("plugin.power-assert") version "2.0.0"
}

powerAssert {
    functions = listOf("kotlin.assert", "kotlin.test.assertTrue")
}
```

Groovy

```groovy
plugins {
    id 'org.jetbrains.kotlin.multiplatform' version '2.0.0'
    id 'org.jetbrains.kotlin.plugin.power-assert' version '2.0.0'
}

powerAssert {
    functions = ["kotlin.assert", "kotlin.test.assertTrue"]
}
```

Learn more about the Kotlin Power-assert plugin in the documentation.

How to enable the Kotlin K2 compiler

Starting with Kotlin 2.0.0, the Kotlin K2 compiler is enabled by default. No additional actions are required.

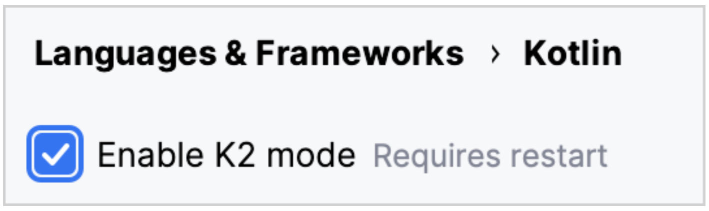
Try the Kotlin K2 compiler in Kotlin Playground

Kotlin Playground supports the 2.0.0 release. Check it out!

Support in IDEs

By default, IntelliJ IDEA and Android Studio still use the previous compiler for code analysis, code completion, highlighting, and other IDE-related features. To get the full Kotlin 2.0 experience in your IDE, enable K2 mode.

In your IDE, go to Settings | Languages & Frameworks | Kotlin and select the Enable K2 mode option. The IDE will analyze your code using its K2 mode.


Languages & Frameworks › Kotlin

[✓] Enable K2 mode Requires restart

Enable K2 mode

After enabling K2 mode, you may notice differences in IDE analysis due to changes in compiler behavior. Learn how the new K2 compiler differs from the previous one in our migration guide.

- Learn more about K2 mode in our blog.

- We are actively collecting feedback about K2 mode, so please share your thoughts in our public Slack channel.

Leave your feedback on the new K2 compiler

We would appreciate any feedback you may have!

- Report any problems you face with the new K2 compiler in our issue tracker.
- Enable the "Send usage statistics" option to allow JetBrains to collect anonymous data about K2 usage.

Kotlin/JVM

Starting with version 2.0.0, the compiler can generate classes containing Java 22 bytecode. This version also brings the following changes:

- Generation of lambda functions using invokedynamic
- The kotlinx-metadata-jvm library is now Stable

Generation of lambda functions using invokedynamic

Kotlin 2.0.0 introduces a new default method for generating lambda functions using invokedynamic. This change reduces the binary sizes of applications compared to the traditional anonymous class generation.

Since the first version, Kotlin has generated lambdas as anonymous classes. However, starting from Kotlin 1.5.0, the option for invokedynamic generation has been available by using the -Xlambdas=indy compiler option. In Kotlin 2.0.0, invokedynamic has become the default method for lambda generation. This method produces lighter binaries and aligns Kotlin with JVM optimizations, ensuring applications benefit from ongoing and future improvements in JVM performance.

Currently, it has three limitations compared to ordinary lambda compilation:

- A lambda compiled into invokedynamic is not serializable.
- Experimental reflect() API does not support lambdas generated by invokedynamic.
- Calling .toString() on such a lambda produces a less readable string representation:

```
fun main() {
    println({})

    // With Kotlin 1.9.24 and reflection, returns
    // () -> kotlin.Unit

    // With Kotlin 2.0.0, returns
    // FileKt$$Lambda$13/0x00007f88a0004608@506e1b77
}
```

To retain the legacy behavior of generating lambda functions, you can either:

- Annotate specific lambdas with @JvmSerializableLambda.
- Use the compiler option -Xlambdas=class to generate all lambdas in a module using the legacy method.

The kotlinx-metadata-jvm library is Stable

In Kotlin 2.0.0, the kotlinx-metadata-jvm library became Stable. Now that the library has changed to the kotlin package and coordinates, you can find it as kotlin-metadata-jvm (without the "x").

Previously, the kotlinx-metadata-jvm library had its own publishing scheme and version. Now, we will build and publish the kotlin-metadata-jvm updates as part of the Kotlin release cycle, with the same backward compatibility guarantees as the Kotlin standard library.

The kotlin-metadata-jvm library provides an API to read and modify metadata of binary files generated by the Kotlin/JVM compiler.

Kotlin/Native

This version brings the following changes:

- Monitoring GC performance with signposts
- Resolving conflicts with Objective-C methods
- Changed log level for compiler arguments in Kotlin/Native
- Explicitly added standard library and platform dependencies to Kotlin/Native
- Tasks error in Gradle configuration cache

Monitoring GC performance with signposts on Apple platforms

Previously, it was only possible to monitor the performance of Kotlin/Native's garbage collector (GC) by looking into logs. However, these logs were not integrated with Xcode Instruments, a popular toolkit for investigating issues with iOS apps' performance.

Since Kotlin 2.0.0, GC reports pauses with signposts that are available in Instruments. Signposts allow for custom logging within your app, so now, when debugging iOS app performance, you can check if a GC pause corresponds to the application freeze.

Learn more about GC performance analysis in the documentation.

Resolving conflicts with Objective-C methods

Objective-C methods can have different names, but the same number and types of parameters. For example, locationManager:didEnterRegion: and locationManager:didExitRegion:. In Kotlin, these methods have the same signature, so an attempt to use them triggers a conflicting overloads error.

Previously, you had to manually suppress conflicting overloads to avoid this compilation error. To improve Kotlin interoperability with Objective-C, the Kotlin 2.0.0 introduces the new @ObjCSignatureOverride annotation.

The annotation instructs the Kotlin compiler to ignore conflicting overloads, in case several functions with the same argument types but different argument names are inherited from the Objective-C class.

Applying this annotation is also safer than general error suppression. This annotation can only be used in the case of overriding Objective-C methods, which are supported and tested, while general suppression may hide important errors and lead to silently broken code.

Changed log level for compiler arguments

In this release, the log level for compiler arguments in Kotlin/Native Gradle tasks, such as compile, link, and cinterop, has changed from info to debug.

With debug as its default value, the log level is consistent with other Gradle compilation tasks and provides detailed debugging information, including all compiler arguments.

Explicitly added standard library and platform dependencies to Kotlin/Native

Previously, the Kotlin/Native compiler resolved standard library and platform dependencies implicitly, which caused inconsistencies in the way the Kotlin Gradle plugin worked across Kotlin targets.

Now, each Kotlin/Native Gradle compilation explicitly includes standard library and platform dependencies in its compile-time library path via the compileDependencyFiles compilation parameter.

Tasks error in Gradle configuration cache

Since Kotlin 2.0.0, you may encounter a configuration cache error with messages indicating: invocation of Task.project at execution time is unsupported.

This error appears in tasks such as NativeDistributionCommonizerTask and KotlinNativeCompile.

However, this is a false-positive error. The underlying issue is the presence of tasks that are not compatible with the Gradle configuration cache, like the publish* task.

This discrepancy may not be immediately apparent, as the error message suggests a different root cause.

As the precise cause isn't explicitly stated in the error report, the Gradle team is already addressing the issue to fix reports.

Kotlin/Wasm

Kotlin 2.0.0 improves performance and interoperability with JavaScript:

- Optimized production builds by default using Binaryen
- Support for named export
- Support for unsigned primitive types in functions with @JsExport
- Generation of TypeScript declaration files in Kotlin/Wasm
- Support for catching JavaScript exceptions
- New exception handling proposal is now supported as an option
- The withWasm() function is split into JS and WASI variants

Optimized production builds by default using Binaryen

The Kotlin/Wasm toolchain now applies the Binaryen tool during production compilation to all projects, as opposed to the previous manual setup approach. By our estimations, it should improve runtime performance and reduce the binary size for your project.

> This change only affects production compilation. The development compilation process stays the same.

Support for named export

Previously, all exported declarations from Kotlin/Wasm were imported into JavaScript using default export:

```
//JavaScript:
import Module from "./index.mjs"

Module.add()
```

Now, you can import each Kotlin declaration marked with @JsExport by name:

```
// Kotlin:
@JsExport
fun add(a: Int, b: Int) = a + b
```

```
//JavaScript:
import { add } from "./index.mjs"
```

Named exports make it easier to share code between Kotlin and JavaScript modules. They improve readability and help you manage dependencies between modules.

Support for unsigned primitive types in functions with @JsExport

Starting from Kotlin 2.0.0, you can use unsigned primitive types inside external declarations and functions with the @JsExport annotation that makes Kotlin/Wasm functions available in JavaScript code.

This helps to mitigate the previous limitation that prevented the unsigned primitives from being used directly inside exported and external declarations. Now you can export functions with unsigned primitives as a return or parameter type and consume external declarations that return or consume unsigned primitives.

For more information on Kotlin/Wasm interoperability with JavaScript, see the documentation.

Generation of TypeScript declaration files in Kotlin/Wasm

> Generating TypeScript declaration files in Kotlin/Wasm is Experimental. It may be dropped or changed at any time.

In Kotlin 2.0.0, the Kotlin/Wasm compiler is now capable of generating TypeScript definitions from any @JsExport declarations in your Kotlin code. These definitions can be used by IDEs and JavaScript tools to provide code autocompletion, help with type checks, and make it easier to include Kotlin code in JavaScript.

The Kotlin/Wasm compiler collects any top-level functions marked with @JsExport and automatically generates TypeScript definitions in a .d.ts file.

To generate TypeScript definitions, in your build.gradle(.kts) file in the wasmJs {} block, add the generateTypeScriptDefinitions() function:

```kotlin
kotlin {
    wasmJs {
        binaries.executable()
        browser {
        }
        generateTypeScriptDefinitions()
    }
}
```

Support for catching JavaScript exceptions

Previously, Kotlin/Wasm code could not catch JavaScript exceptions, making it difficult to handle errors originating from the JavaScript side of the program.

In Kotlin 2.0.0, we have implemented support for catching JavaScript exceptions within Kotlin/Wasm. This implementation allows you to use try-catch blocks, with specific types like Throwable or JsException, to handle these errors properly.

Additionally, finally blocks, which help execute code regardless of exceptions, also work correctly. While we're introducing support for catching JavaScript exceptions, no additional information is provided when a JavaScript exception, like a call stack, occurs. However, we are working on these implementations.

New exception handling proposal is now supported as an option

In this release, we introduce support for the new version of WebAssembly's exception handling proposal within Kotlin/Wasm.

This update ensures the new proposal aligns with Kotlin requirements, enabling the use of Kotlin/Wasm on virtual machines that only support the latest version of the proposal.

Activate the new exception handling proposal by using the -Xwasm-use-new-exception-proposal compiler option, which is turned off by default.

The withWasm() function is split into JS and WASI variants

The withWasm() function, which used to provide Wasm targets for hierarchy templates, is deprecated in favor of specialized withWasmJs() and withWasmWasi() functions.

Now you can separate the WASI and JS targets between different groups in the tree definition.

Kotlin/JS

Among other changes, this version brings modern JS compilation to Kotlin, supporting more features from the ES2015 standard:

- New compilation target
- Suspend functions as ES2015 generators
- Passing arguments to the main function
- Per-file compilation for Kotlin/JS projects
- Improved collection interoperability
- Support for createInstance()
- Support for type-safe plain JavaScript objects
- Support for npm package manager
- Changes to compilation tasks
- Discontinuing legacy Kotlin/JS JAR artifacts

New compilation target

In Kotlin 2.0.0, we're adding a new compilation target to Kotlin/JS, es2015. This is a new way for you to enable all the ES2015 features supported in Kotlin at once.

You can set it up in your build.gradle(.kts) file like this:

```
kotlin {
    js {
        compilerOptions {
            target.set("es2015")
        }
    }
}
```

The new target automatically turns on ES classes and modules and the newly supported ES generators.

Suspend functions as ES2015 generators

This release introduces Experimental support for ES2015 generators for compiling suspend functions.

Using generators instead of state machines should improve the final bundle size of your project. For example, the JetBrains team managed to decrease the bundle size of its Space project by 20% by using the ES2015 generators.

Learn more about ES2015 (ECMAScript 2015, ES6) in the official documentation.

Passing arguments to the main function

Starting with Kotlin 2.0.0, you can specify a source of your args for the main() function. This feature makes it easier to work with the command line and pass the arguments.

To do this, define the js {} block with the new passAsArgumentToMainFunction() function, which returns an array of strings:

```
kotlin {
    js {
        binary.executable()
        passAsArgumentToMainFunction("Deno.args")
    }
}
```

The function is executed at runtime. It takes the JavaScript expression and uses it as the args: Array<String> argument instead of the main() function call.

Also, if you use the Node.js runtime, you can take advantage of a special alias. It allows you to pass process.argv to the args parameter once instead of adding it manually every time:

```
kotlin {
    js {
        binary.executable()
        nodejs {
            passProcessArgvToMainFunction()
        }
    }
}
```

Per-file compilation for Kotlin/JS projects

Kotlin 2.0.0 introduces a new granularity option for the Kotlin/JS project output. You can now set up a per-file compilation that generates one JavaScript file for each Kotlin file. It helps to significantly optimize the size of the final bundle and improve the loading time of the program.

Previously, there were only two output options. The Kotlin/JS compiler could generate a single .js file for the whole project. However, this file might be too large and inconvenient to use. Whenever you wanted to use a function from your project, you had to include the entire JavaScript file as a dependency. Alternatively, you could configure a compilation of a separate .js file for each project module. This is still the default option.

Since module files could also be too large, with Kotlin 2.0.0, we add a more granular output that generates one (or two, if the file contains exported declarations) JavaScript file per each Kotlin file. To enable the per-file compilation mode:

1. Add the useEsModules() function to your build file to support ECMAScript modules:

   ```
   // build.gradle.kts
   ```

```
kotlin {
    js(IR) {
        useEsModules() // Enables ES2015 modules
        browser()
    }
}
```

You can also use the new es2015 compilation target for that.

2. Apply the -Xir-per-file compiler option or update your gradle.properties file with:

```
# gradle.properties
kotlin.js.ir.output.granularity=per-file // `per-module` is the default
```

Improved collection interoperability

Starting with Kotlin 2.0.0, it's possible to export declarations with a Kotlin collection type inside the signature to JavaScript (and TypeScript). This applies to Set, Map, and List collection types and their mutable counterparts.

To use Kotlin collections in JavaScript, first mark the necessary declarations with @JsExport annotation:

```
// Kotlin
@JsExport
data class User(
    val name: String,
    val friends: List<User> = emptyList()
)

@JsExport
val me = User(
    name = "Me",
    friends = listOf(User(name = "Kodee"))
)
```

You can then consume them from JavaScript as regular JavaScript arrays:

```
// JavaScript
import { User, me, KtList } from "my-module"

const allMyFriendNames = me.friends
    .asJsReadonlyArrayView()
    .map(x => x.name) // ['Kodee']
```

Unfortunately, creating Kotlin collections from JavaScript is still unavailable. We're planning to add this functionality in Kotlin 2.0.20.

Support for createInstance()

Starting with Kotlin 2.0.0, you can use the createInstance() function from the Kotlin/JS target. Previously, it was only available on the JVM.

This function from the KClass interface creates a new instance of the specified class, which is useful for getting the runtime reference to a Kotlin class.

Support for type-safe plain JavaScript objects

The js-plain-objects plugin is Experimental. It may be dropped or changed at any time. The js-plain-objects plugin only supports the K2 compiler.

To make it easier to work with JavaScript APIs, in Kotlin 2.0.0, we provide a new plugin: js-plain-objects, which you can use to create type-safe plain JavaScript objects. The plugin checks your code for any external interfaces that have a @JsPlainObject annotation and adds:

- An inline invoke operator function inside the companion object that you can use as a constructor.
- A .copy() function that you can use to create a copy of your object while adjusting some of its properties.

For example:

```kotlin
import kotlinx.js.JsPlainObject

@JsPlainObject
external interface User {
    var name: String
    val age: Int
    val email: String?
}

fun main() {
    // Creates a JavaScript object
    val user = User(name = "Name", age = 10)
    // Copies the object and adds an email
    val copy = user.copy(age = 11, email = "some@user.com")

    println(JSON.stringify(user))
    // { "name": "Name", "age": 10 }
    println(JSON.stringify(copy))
    // { "name": "Name", "age": 11, "email": "some@user.com" }
}
```

Any JavaScript objects created with this approach are safer because instead of only seeing errors at runtime, you can see them at compile time or even highlighted by your IDE.

Consider this example, which uses a fetch() function to interact with a JavaScript API using external interfaces to describe the shape of the JavaScript objects:

```kotlin
import kotlinx.js.JsPlainObject

@JsPlainObject
external interface FetchOptions {
    val body: String?
    val method: String
}

// A wrapper for Window.fetch
suspend fun fetch(url: String, options: FetchOptions? = null) = TODO("Add your custom behavior here")

// A compile-time error is triggered as "metod" is not recognized
// as method
fetch("https://google.com", options = FetchOptions(metod = "POST"))
// A compile-time error is triggered as method is required
fetch("https://google.com", options = FetchOptions(body = "SOME STRING"))
```

In comparison, if you use the js() function instead to create your JavaScript objects, errors are only found at runtime or aren't triggered at all:

```kotlin
suspend fun fetch(url: String, options: FetchOptions? = null) = TODO("Add your custom behavior here")

// No error is triggered. As "metod" is not recognized, the wrong method
// (GET) is used.
fetch("https://google.com", options = js("{ metod: 'POST' }"))

// By default, the GET method is used. A runtime error is triggered as
// body shouldn't be present.
fetch("https://google.com", options = js("{ body: 'SOME STRING' }"))
// TypeError: Window.fetch: HEAD or GET Request cannot have a body
```

To use the js-plain-objects plugin, add the following to your build.gradle(.kts) file:

Kotlin

```kotlin
plugins {
    kotlin("plugin.js-plain-objects") version "2.0.0"
}
```

Groovy

```groovy
plugins {
    id "org.jetbrains.kotlin.plugin.js-plain-objects" version "2.0.0"
}
```

Support for npm package manager

Previously, it was only possible for the Kotlin Multiplatform Gradle plugin to use Yarn as a package manager to download and install npm dependencies. From Kotlin 2.0.0, you can use npm as your package manager instead. Using npm as a package manager means that you have one less tool to manage during your setup.

For backward compatibility, Yarn is still the default package manager. To use npm as your package manager, set the following property in your gradle.properties file:

```
kotlin.js.yarn = false
```

Changes to compilation tasks

Previously, the webpack and distributeResources compilation tasks both targeted the same directories. Moreover, the distribution task declared the dist as its output directory as well. This resulted in overlapping outputs and produced a compilation warning.

So, starting with Kotlin 2.0.0, we've implemented the following changes:

- The webpack task now targets a separate folder.
- The distributeResources task has been completely removed.
- The distribution task now has the Copy type and targets the dist folder.

Discontinuing legacy Kotlin/JS JAR artifacts

Starting with Kotlin 2.0.0, the Kotlin distribution no longer contains legacy Kotlin/JS artifacts with the .jar extension. Legacy artifacts were used in the unsupported old Kotlin/JS compiler and unnecessary for the IR compiler, which uses the klib format.

Gradle improvements

Kotlin 2.0.0 is fully compatible with Gradle 6.8.3 through 8.5. You can also use Gradle versions up to the latest Gradle release, but if you do, keep in mind that you might encounter deprecation warnings or some new Gradle features might not work.

This version brings the following changes:

- New Gradle DSL for compiler options in multiplatform projects
- New Compose compiler Gradle plugin
- New attribute to distinguish JVM and Android published libraries
- Improved Gradle dependency handling for CInteropProcess in Kotlin/Native
- Visibility changes in Gradle
- New directory for Kotlin data in Gradle projects
- Kotlin/Native compiler downloaded when needed
- Deprecating old ways of defining compiler options
- Bumped minimum AGP supported version
- New Gradle property for trying the latest language version
- New JSON output format for build reports
- kapt configurations inherit annotation processors from superconfigurations
- Kotlin Gradle plugin no longer uses deprecated Gradle conventions

New Gradle DSL for compiler options in multiplatform projects

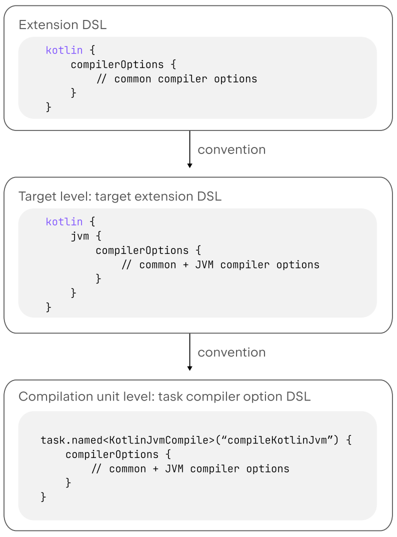
This feature is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Prior to Kotlin 2.0.0, configuring compiler options in a multiplatform project with Gradle was only possible at a low level, such as per task, compilation, or source set. To make it easier to configure compiler options more generally in your projects, Kotlin 2.0.0 comes with a new Gradle DSL.

With this new DSL, you can configure compiler options at the extension level for all the targets and shared source sets like commonMain and at a target level for a specific target:

```
kotlin {
    compilerOptions {
        // Extension-level common compiler options that are used as defaults
        // for all targets and shared source sets
        allWarningsAsErrors.set(true)
    }
    jvm {
        compilerOptions {
            // Target-level JVM compiler options that are used as defaults
            // for all compilations in this target
            noJdk.set(true)
        }
    }
}
```

The overall project configuration now has three layers. The highest is the extension level, then the target level and the lowest is the compilation unit (which is usually a compilation task):


Extension DSL
convention
Target level: target extension DSL
convention
Compilation unit level: task compiler option DSL

```
kotlin {
    compilerOptions {
        // common compiler options
    }
}
```

```
kotlin {
    jvm {
        compilerOptions {
            // common + JVM compiler options
        }
    }
}
```

```
task.named<KotlinJvmCompile>("compileKotlinJvm") {
    compilerOptions {
        // common + JVM compiler options
    }
}
```

Kotlin compiler options levels

The settings at a higher level are used as a convention (default) for a lower level:

- The values of extension compiler options are the default for target compiler options, including shared source sets, like commonMain, nativeMain, and commonTest.
- The values of target compiler options are used as the default for compilation unit (task) compiler options, for example, compileKotlinJvm and compileTestKotlinJvm tasks.

In turn, configurations made at a lower level override related settings at a higher level:

- Task-level compiler options override related configurations at the target or the extension level.
- Target-level compiler options override related configurations at the extension level.

When configuring your project, keep in mind that some old ways of setting up compiler options have been deprecated.

We encourage you to try the new DSL out in your multiplatform projects and leave feedback in YouTrack, as we plan to make this DSL the recommended approach for configuring compiler options.

New Compose compiler Gradle plugin

The Jetpack Compose compiler, which translates composables into Kotlin code, has now been merged into the Kotlin repository. This will help transition Compose projects to Kotlin 2.0.0, as the Compose compiler will always ship simultaneously with Kotlin. This also bumps the Compose compiler version to 2.0.0.

To use the new Compose compiler in your projects, apply the org.jetbrains.kotlin.plugin.compose Gradle plugin in your build.gradle(.kts) file and set its version equal to Kotlin 2.0.0.

To learn more about this change and see the migration instructions, see the Compose compiler documentation.

New attribute to distinguish JVM and Android-published libraries

Starting with Kotlin 2.0.0, the org.gradle.jvm.environment Gradle attribute is published by default with all Kotlin variants.

The attribute helps distinguish JVM and Android variants of Kotlin Multiplatform libraries. It indicates that a certain library variant is better suited for a certain JVM environment. The target environment could be "android", "standard-jvm", or "no-jvm".

Publishing this attribute should make consuming Kotlin Multiplatform libraries with JVM and Android targets more robust from non-multiplatform clients as well, such as Java-only projects.

If necessary, you can disable attribute publication. To do that, add the following Gradle option to your gradle.properties file:

```
kotlin.publishJvmEnvironmentAttribute=false
```

Improved Gradle dependency handling for CInteropProcess in Kotlin/Native

In this release, we enhanced the handling of the defFile property to ensure better Gradle task dependency management in Kotlin/Native projects.

Before this update, Gradle builds could fail if the defFile property was designated as an output of another task that hadn't been executed yet. The workaround for this issue was to add a dependency on this task:

```
kotlin {
    macosArm64("native") {
        compilations.getByName("main") {
            cinterops {
                val cinterop by creating {
                    defFileProperty.set(createDefFileTask.flatMap { it.defFile.asFile })
                    project.tasks.named(interopProcessingTaskName).configure {
                        dependsOn(createDefFileTask)
                    }
                }
            }
        }
    }
}
```

To fix this, there is a new RegularFileProperty property called definitionFile. Now, Gradle lazily verifies the presence of the definitionFile property after the connected task has run later in the build process. This new approach eliminates the need for additional dependencies.

The CInteropProcess task and the CInteropSettings class use the definitionFile property instead of defFile and defFileProperty:

Kotlin

```
kotlin {
    macosArm64("native") {
        compilations.getByName("main") {
            cinterops {
                val cinterop by creating {
                    definitionFile.set(project.file("def-file.def"))
                }
            }
        }
    }
}
```

Groovy

```
kotlin {
    macosArm64("native") {
        compilations.main {
            cinterops {
                cinterop {
                    definitionFile.set(project.file("def-file.def"))
                }
            }
        }
    }
}
```

defFile and defFileProperty parameters are deprecated.

Visibility changes in Gradle

This change impacts only Kotlin DSL users.

In Kotlin 2.0.0, we've modified the Kotlin Gradle Plugin for better control and safety in your build scripts. Previously, certain Kotlin DSL functions and properties intended for a specific DSL context would inadvertently leak into other DSL contexts. This leakage could lead to the use of incorrect compiler options, settings being applied multiple times, and other misconfigurations:

```
kotlin {
    // Target DSL couldn't access methods and properties defined in the
    // kotlin{} extension DSL
    jvm {
        // Compilation DSL couldn't access methods and properties defined
        // in the kotlin{} extension DSL and Kotlin jvm{} target DSL
        compilations.configureEach {
            // Compilation task DSLs couldn't access methods and
            // properties defined in the kotlin{} extension, Kotlin jvm{}
            // target or Kotlin compilation DSL
            compileTaskProvider.configure {
                // For example:
                explicitApi()
                // ERROR as it is defined in the kotlin{} extension DSL
                mavenPublication {}
                // ERROR as it is defined in the Kotlin jvm{} target DSL
                defaultSourceSet {}
                // ERROR as it is defined in the Kotlin compilation DSL
            }
        }
    }
}
```

To fix this issue, we've added the @KotlinGradlePluginDsl annotation, preventing the exposure of the Kotlin Gradle plugin DSL functions and properties to levels where they are not intended to be available. The following levels are separated from each other:

- Kotlin extension
- Kotlin target
- Kotlin compilation
- Kotlin compilation task

For the most popular cases, we've added compiler warnings with suggestions on how to fix them if your build script is configured incorrectly. For example:

```
kotlin {
    jvm {
        sourceSets.getByName("jvmMain").dependencies {
            implementation("org.jetbrains.kotlinx:kotlinx-coroutines-core-jvm:1.7.3")
        }
    }
}
```

In this case, the warning message for sourceSets is:

```
[DEPRECATION] 'sourceSets: NamedDomainObjectContainer<KotlinSourceSet>' is deprecated.Accessing 'sourceSets' container on the Kotlin
target level DSL is deprecated. Consider configuring 'sourceSets' on the Kotlin extension level.
```

We would appreciate your feedback on this change! Share your comments directly to Kotlin developers in our #gradle Slack channel. Get a Slack invite.

New directory for Kotlin data in Gradle projects

> Do not commit the .kotlin directory to version control. For example, if you are using Git, add .kotlin to your project's .gitignore file.

In Kotlin 1.8.20, the Kotlin Gradle plugin switched to storing its data in the Gradle project cache directory: <project-root-directory>/.gradle/kotlin. However, the .gradle directory is reserved for Gradle only, and as a result it's not future-proof.

To solve this, as of Kotlin 2.0.0, we will store Kotlin data in your <project-root-directory>/.kotlin by default. We will continue to store some data in the .gradle/kotlin directory for backward compatibility.

The new Gradle properties you can configure are:

Gradle property	Description
kotlin.project.persistent.dir	Configures the location where your project-level data is stored. Default: <project-root-directory>/.kotlin
kotlin.project.persistent.dir.gradle.disableWrite	A boolean value that controls whether writing Kotlin data to the .gradle directory is disabled. Default: false

Add these properties to the gradle.properties file in your projects for them to take effect.

Kotlin/Native compiler downloaded when needed

Before Kotlin 2.0.0, if you had a Kotlin/Native target configured in the Gradle build script of your multiplatform project, Gradle would always download the Kotlin/Native compiler in the configuration phase.

This happened even if there was no task to compile code for a Kotlin/Native target that was due to run in the execution phase. Downloading the Kotlin/Native compiler in this way was particularly inefficient for users who only wanted to check the JVM or JavaScript code in their projects. For example, to perform tests or checks with their Kotlin project as part of a CI process.

In Kotlin 2.0.0, we changed this behavior in the Kotlin Gradle plugin so that the Kotlin/Native compiler is downloaded in the execution phase and only when a compilation is requested for a Kotlin/Native target.

In turn, the Kotlin/Native compiler's dependencies are now downloaded not as a part of the compiler, but in the execution phase as well.

If you encounter any issues with the new behavior, you can temporarily switch back to the previous behavior by adding the following Gradle property to your gradle.properties file:

```
kotlin.native.toolchain.enabled=false
```

Starting with Kotlin 1.9.20-Beta, the Kotlin/Native distribution is published to Maven Central along with the CDN.

This allowed us to change how Kotlin looks for and downloads the necessary artifacts. Instead of the CDN, by default, it now uses the Maven repositories that you specified in the repositories {} block of your project.

You can temporarily switch this behavior back by setting the following Gradle property in your gradle.properties file:

```
kotlin.native.distribution.downloadFromMaven=false
```

Please report any problems to our issue tracker YouTrack. Both of these Gradle properties that change the default behavior are temporary and will be removed in future releases.

Deprecated old ways of defining compiler options

In this release, we continue to refine how you can set up compiler options. It should resolve ambiguity between different ways and make the project configuration more straightforward.

Since Kotlin 2.0.0, the following DSLs for specifying compiler options are deprecated:

- The kotlinOptions DSL from the KotlinCompile interface that implements all Kotlin compilation tasks. Use KotlinCompilationTask<CompilerOptions> instead.
- The compilerOptions property with the HasCompilerOptions type from the KotlinCompilation interface. This DSL was inconsistent with other DSLs and configured the same KotlinCommonCompilerOptions object as compilerOptions inside the KotlinCompilation.compileTaskProvider compilation task, which was confusing.

  Instead, we recommend using the compilerOptions property from the Kotlin compilation task:

  ```
  kotlinCompilation.compileTaskProvider.configure {
      compilerOptions { ... }
  }
  ```

  For example:

  ```
  kotlin {
      js(IR) {
          compilations.all {
              compileTaskProvider.configure {
                  compilerOptions.freeCompilerArgs.add("-Xir-minimized-member-names=false")
              }
          }
      }
  }
  ```

- The kotlinOptions DSL from the KotlinCompilation interface.
- The kotlinOptions DSL from the KotlinNativeArtifactConfig interface, the KotlinNativeLink class, and the KotlinNativeLinkArtifactTask class. Use the toolOptions DSL instead.
- The dceOptions DSL from the KotlinJsDce interface. Use the toolOptions DSL instead.

For more information on how to specify compiler options in the Kotlin Gradle plugin, see How to define options.

Bumped minimum supported AGP version

Starting with Kotlin 2.0.0, the minimum supported Android Gradle plugin version is 7.1.3.

New Gradle property for trying the latest language version

Prior to Kotlin 2.0.0, we had the following Gradle property to try out the new K2 compiler: kotlin.experimental.tryK2. Now that the K2 compiler is enabled by default in Kotlin 2.0.0, we decided to evolve this property into a new form that you can use to try the latest language version in your projects: kotlin.experimental.tryNext. When you use this property in your gradle.properties file, the Kotlin Gradle plugin increments the language version to one above the default value for your Kotlin version. For example, in Kotlin 2.0.0, the default language version is 2.0, so the property configures language version 2.1.

This new Gradle property produces similar metrics in build reports as before with kotlin.experimental.tryK2. The language version configured is included in the output. For example:

```
##### 'kotlin.experimental.tryNext' results #####
:app:compileKotlin: 2.1 language version
:lib:compileKotlin: 2.1 language version
##### 100% (2/2) tasks have been compiled with Kotlin 2.1 #####
```

To learn more about how to enable build reports and their content, see Build reports.

New JSON output format for build reports

In Kotlin 1.7.0, we introduced build reports to help track compiler performance. Over time, we've added more metrics to make these reports even more detailed and helpful when investigating performance issues. Previously, the only output format for a local file was the *.txt format. In Kotlin 2.0.0, we support the JSON output format to make it even easier to analyze using other tools.

To configure JSON output format for your build reports, declare the following properties in your gradle.properties file:

```
kotlin.build.report.output=json

// The directory to store your build reports
kotlin.build.report.json.directory=my/directory/path
```

Alternatively, you can run the following command:

```
./gradlew assemble -Pkotlin.build.report.output=json -Pkotlin.build.report.json.directory="my/directory/path"
```

Once configured, Gradle generates your build reports in the directory that you specify with the name: ${project_name}-date-time-<sequence_number>.json.

Here's an example snippet from a build report with JSON output format that contains build metrics and aggregated metrics:

```
"buildOperationRecord": [
    {
     "path": ":lib:compileKotlin",
      "classFqName": "org.jetbrains.kotlin.gradle.tasks.KotlinCompile_Decorated",
      "startTimeMs": 1714730820601,
      "totalTimeMs": 2724,
      "buildMetrics": {
        "buildTimes": {
          "buildTimesNs": {
            "CLEAR_OUTPUT": 713417,
            "SHRINK_AND_SAVE_CURRENT_CLASSPATH_SNAPSHOT_AFTER_COMPILATION": 19699333,
            "IR_TRANSLATION": 281000000,
            "NON_INCREMENTAL_LOAD_CURRENT_CLASSPATH_SNAPSHOT": 14088042,
            "CALCULATE_OUTPUT_SIZE": 1301500,
            "GRADLE_TASK": 2724000000,
            "COMPILER_INITIALIZATION": 263000000,
            "IR_GENERATION": 74000000,
...
          }
        }
...
 "aggregatedMetrics": {
    "buildTimes": {
      "buildTimesNs": {
        "CLEAR_OUTPUT": 782667,
        "SHRINK_AND_SAVE_CURRENT_CLASSPATH_SNAPSHOT_AFTER_COMPILATION": 22031833,
        "IR_TRANSLATION": 333000000,
        "NON_INCREMENTAL_LOAD_CURRENT_CLASSPATH_SNAPSHOT": 14890292,
        "CALCULATE_OUTPUT_SIZE": 2370750,
        "GRADLE_TASK": 3234000000,
        "COMPILER_INITIALIZATION": 292000000,
        "IR_GENERATION": 89000000,
...
      }
    }
```

kapt configurations inherit annotation processors from superconfigurations

Prior to Kotlin 2.0.0, if you wanted to define a common set of annotation processors in a separate Gradle configuration and extend this configuration in kapt-specific configurations for your subprojects, kapt would skip annotation processing because it couldn't find any annotation processors. In Kotlin 2.0.0, kapt can successfully detect that there are indirect dependencies on your annotation processors.

As an example, for a subproject using Dagger, in your build.gradle(.kts) file, use the following configuration:

```kotlin
val commonAnnotationProcessors by configurations.creating
configurations.named("kapt") { extendsFrom(commonAnnotationProcessors) }

dependencies {
    implementation("com.google.dagger:dagger:2.48.1")
    commonAnnotationProcessors("com.google.dagger:dagger-compiler:2.48.1")
}
```

In this example, the commonAnnotationProcessors Gradle configuration is your common configuration for annotation processing that you want to be used for all your projects. You use the extendsFrom() method to add commonAnnotationProcessors as a superconfiguration. kapt sees that the commonAnnotationProcessors Gradle configuration has a dependency on the Dagger annotation processor. Therefore, kapt includes the Dagger annotation processor in its configuration for annotation processing.

Thanks to Christoph Loy for the implementation!

Kotlin Gradle plugin no longer uses deprecated Gradle conventions

Prior to Kotlin 2.0.0, if you used Gradle 8.2 or higher, the Kotlin Gradle plugin incorrectly used Gradle conventions that had been deprecated in Gradle 8.2. This led to Gradle reporting build deprecations. In Kotlin 2.0.0, the Kotlin Gradle plugin has been updated to no longer trigger these deprecation warnings when you use Gradle 8.2 or higher.

Standard library

This release brings further stability to the Kotlin standard library and makes even more existing functions common for all platforms:

- Stable replacement of the enum class values generic function
- Stable AutoCloseable interface
- Common protected property AbstractMutableList.modCount
- Common protected function AbstractMutableList.removeRange
- Common String.toCharArray(destination)

Stable replacement of the enum class values generic function

In Kotlin 2.0.0, the enumEntries<T>() function becomes Stable. The enumEntries<T>() function is a replacement for the generic enumValues<T>() function. The new function returns a list of all enum entries for the given enum type T. The entries property for enum classes was previously introduced and also stabilized to replace the synthetic values() function. For more information about the entries property, see What's new in Kotlin 1.8.20.

> The enumValues<T>() function is still supported, but we recommend that you use the enumEntries<T>() function instead because it has less of a performance impact. Every time you call enumValues<T>(), a new array is created, whereas whenever you call enumEntries<T>(), the same list is returned each time, which is far more efficient.

For example:

```kotlin
enum class RGB { RED, GREEN, BLUE }

inline fun <reified T : Enum<T>> printAllValues() {
    print(enumEntries<T>().joinToString { it.name })
}

printAllValues<RGB>()
// RED, GREEN, BLUE
```

Stable AutoCloseable interface

In Kotlin 2.0.0, the common AutoCloseable interface becomes Stable. It allows you to easily close resources and includes a couple of useful functions:

- The use() extension function, which executes a given block function on the selected resource and then closes it down correctly, whether an exception is thrown or not.
- The AutoCloseable() constructor function, which creates instances of the AutoCloseable interface.

In the example below, we define the XMLWriter interface and assume that there is a resource that implements it. For example, this resource could be a class that opens a file, writes XML content, and then closes it:

```kotlin
interface XMLWriter {
    fun document(encoding: String, version: String, content: XMLWriter.() -> Unit)
    fun element(name: String, content: XMLWriter.() -> Unit)
    fun attribute(name: String, value: String)
    fun text(value: String)

    fun flushAndClose()
}

fun writeBooksTo(writer: XMLWriter) {
    val autoCloseable = AutoCloseable { writer.flushAndClose() }
    autoCloseable.use {
        writer.document(encoding = "UTF-8", version = "1.0") {
            element("bookstore") {
                element("book") {
                    attribute("category", "fiction")
                    element("title") { text("Harry Potter and the Prisoner of Azkaban") }
                    element("author") { text("J. K. Rowling") }
                    element("year") { text("1999") }
                    element("price") { text("29.99") }
                }
                element("book") {
                    attribute("category", "programming")
                    element("title") { text("Kotlin in Action") }
                    element("author") { text("Dmitry Jemerov") }
                    element("author") { text("Svetlana Isakova") }
                    element("year") { text("2017") }
                    element("price") { text("25.19") }
                }
            }
        }
    }
}
```

Common protected property AbstractMutableList.modCount

In this release, the modCount protectedproperty of the AbstractMutableList interface becomes common. Previously, the modCount property was available on each platform but not for the common target. Now, you can create custom implementations of AbstractMutableList and access the property in common code.

The property keeps track of the number of structural modifications made to the collection. This includes operations that change the collection size or alter the list in a way that may cause iterations in progress to return incorrect results.

You can use the modCount property to register and detect concurrent modifications when implementing a custom list.

Common protected function AbstractMutableList.removeRange

In this release, the removeRange() protectedfunction of the AbstractMutableList interface becomes common. Previously, it was available on each platform but not for the common target. Now, you can create custom implementations of AbstractMutableList and override the function in common code.

The function removes elements from this list following the specified range. By overriding this function, you can take advantage of the custom implementations and improve the performance of the list operation.

Common String.toCharArray(destination) function

This release introduces a common String.toCharArray(destination) function. Previously, it was only available on the JVM.

Let's compare it with the existing String.toCharArray() function. It creates a new CharArray that contains characters from the specified string. The new common String.toCharArray(destination) function, however, moves String characters into an existing destination CharArray. This is useful if you already have a buffer that you want to fill:

```
fun main() {
    val myString = "Kotlin is awesome!"
    val destinationArray = CharArray(myString.length)

    // Convert the string and store it in the destinationArray:
    myString.toCharArray(destinationArray)

    for (char in destinationArray) {
        print("$char ")
        // K o t l i n   i s   a w e s o m e !
    }
}
```

Install Kotlin 2.0.0

Starting from IntelliJ IDEA 2023.3 and Android Studio Iguana (2023.2.1) Canary 15, the Kotlin plugin is distributed as a bundled plugin included in your IDE. This means that you can't install the plugin from JetBrains Marketplace anymore.

To update to the new Kotlin version, change the Kotlin version to 2.0.0 in your build scripts.

What's new in Kotlin 1.9.20

Released: November 1, 2023

The Kotlin 1.9.20 release is out, the K2 compiler for all the targets is now in Beta, and Kotlin Multiplatform is now Stable. Additionally, here are some of the main highlights:

- New default hierarchy template for setting up multiplatform projects
- Full support for the Gradle configuration cache in Kotlin Multiplatform
- Custom memory allocator enabled by default in Kotlin/Native
- Performance improvements for the garbage collector in Kotlin/Native
- New and renamed targets in Kotlin/Wasm
- Support for the WASI API in the standard library for Kotlin/Wasm

You can also find a short overview of the updates in this video:

Watch video online.

IDE support

The Kotlin plugins that support 1.9.20 are available for:

IDE	Supported versions
IntelliJ IDEA	2023.1.x, 2023.2.x, 2023.x
Android Studio	Hedgehog (2023.1.1), Iguana (2023.2.1)

> Starting from IntelliJ IDEA 2023.3.x and Android Studio Iguana (2023.2.1) Canary 15, the Kotlin plugin is automatically included and updated. All you need to do is update the Kotlin version in your projects.

New Kotlin K2 compiler updates

The Kotlin team at JetBrains is continuing to stabilize the new K2 compiler, which will bring major performance improvements, speed up new language feature development, unify all the platforms that Kotlin supports, and provide a better architecture for multiplatform projects.

K2 is currently in Beta for all targets. Read more in the release blog post

Support for Kotlin/Wasm

Since this release, the Kotlin/Wasm supports the new K2 compiler. Learn how to enable it in your project.

Preview kapt compiler plugin with K2

> Support for K2 in the kapt compiler plugin is Experimental. Opt-in is required (see details below), and you should use it only for evaluation purposes.

In 1.9.20, you can try using the kapt compiler plugin with the K2 compiler. To use the K2 compiler in your project, add the following options to your gradle.properties file:

```
kotlin.experimental.tryK2=true
kapt.use.k2=true
```

Alternatively, you can enable K2 for kapt by completing the following steps:

1. In your build.gradle.kts file, set the language version to 2.0.
2. In your gradle.properties file, add kapt.use.k2=true.

If you encounter any issues when using kapt with the K2 compiler, please report them to our issue tracker.

How to enable the Kotlin K2 compiler

Enable K2 in Gradle

To enable and test the Kotlin K2 compiler, use the new language version with the following compiler option:

```
-language-version 2.0
```

You can specify it in your build.gradle.kts file:

```
kotlin {
    sourceSets.all {
        languageSettings {
            languageVersion = "2.0"
        }
    }
}
```

Enable K2 in Maven

To enable and test the Kotlin K2 compiler, update the <project/> section of your pom.xml file:

```
<properties>
    <kotlin.compiler.languageVersion>2.0</kotlin.compiler.languageVersion>
</properties>
```

Enable K2 in IntelliJ IDEA

To enable and test the Kotlin K2 compiler in IntelliJ IDEA, go to Settings | Build, Execution, Deployment | Compiler | Kotlin Compiler and update the Language Version field to 2.0 (experimental).

Leave your feedback on the new K2 compiler

We would appreciate any feedback you may have!

- Provide your feedback directly to K2 developers on Kotlin Slack – get an invite and join the #k2-early-adopters channel.
- Report any problems you faced with the new K2 compiler on our issue tracker.
- Enable the Send usage statistics option to allow JetBrains to collect anonymous data about K2 usage.

Kotlin/JVM

Starting with version 1.9.20, the compiler can generate classes containing Java 21 bytecode.

Kotlin/Native

Kotlin 1.9.20 includes a Stable memory manager with the new memory allocator enabled by default, performance improvements for the garbage collector, and other updates:

- Custom memory allocator enabled by default
- Performance improvements for the garbage collector
- Incremental compilation of klib artifacts
- Managing library linkage issues
- Companion object initialization on class constructor calls
- Opt-in requirement for all cinterop declarations
- Custom message for linker errors
- Removal of the legacy memory manager
- Change to our target tiers policy

Custom memory allocator enabled by default

Kotlin 1.9.20 comes with the new memory allocator enabled by default. It's designed to replace the previous default allocator, mimalloc, to make garbage collection more efficient and improve the runtime performance of the Kotlin/Native memory manager.

The new custom allocator divides system memory into pages, allowing independent sweeping in consecutive order. Each allocation becomes a memory block within a page, and the page keeps track of block sizes. Different page types are optimized for various allocation sizes. The consecutive arrangement of memory blocks ensures efficient iteration through all allocated blocks.

When a thread allocates memory, it searches for a suitable page based on the allocation size. Threads maintain a set of pages for different size categories. Typically, the current page for a given size can accommodate the allocation. If not, the thread requests a different page from the shared allocation space. This page may already be available, require sweeping, or have to be created first.

The new allocator allows for multiple independent allocation spaces simultaneously, which will enable the Kotlin team to experiment with different page layouts to improve performance even further.

How to enable the custom memory allocator

Starting with Kotlin 1.9.20, the new memory allocator is the default. No additional setup is required.

If you experience high memory consumption, you can switch back to mimalloc or the system allocator with -Xallocator=mimalloc or -Xallocator=std in your Gradle build script. Please report such issues in YouTrack to help us improve the new memory allocator.

For the technical details of the new allocator's design, see this README.

Performance improvements for the garbage collector

The Kotlin team continues to improve the performance and stability of the new Kotlin/Native memory manager. This release brings a number of significant changes to the garbage collector (GC), including the following 1.9.20 highlights:

- Full parallel mark to reduce the pause time for the GC
- Tracking memory in big chunks to improve the allocation performance

Full parallel mark to reduce the pause time for the GC

Previously, the default garbage collector performed only a partial parallel mark. When the mutator thread was paused, it would mark the GC's start from its own roots, like thread–local variables and the call stack. Meanwhile, a separate GC thread was responsible for marking the start from global roots, as well as the roots of all mutators that were actively running the native code and therefore not paused.

This approach worked well in cases where there were a limited number of global objects and the mutator threads spent a considerable amount of time in a runnable state executing Kotlin code. However, this is not the case for typical iOS applications.

Now the GC uses a full parallel mark that combines paused mutators, the GC thread, and optional marker threads to process the mark queue. By default, the marking process is performed by:

- Paused mutators. Instead of processing their own roots and then being idle while not actively executing code, they contribute to the whole marking process.
- The GC thread. This ensures that at least one thread will perform marking.

This new approach makes the marking process more efficient, reducing the pause time of the GC.

Tracking memory in big chunks to improve the allocation performance

Previously, the GC scheduler tracked the allocation of each object individually. However, neither the new default custom allocator nor the mimalloc memory allocator allocates separate storage for each object; they allocate large areas for several objects at once.

In Kotlin 1.9.20, the GC tracks areas instead of individual objects. This speeds up the allocation of small objects by reducing the number of tasks performed on each allocation and, therefore, helps to minimize the garbage collector's memory usage.

Incremental compilation of klib artifacts

This feature is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below). Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Kotlin 1.9.20 introduces a new compilation time optimization for Kotlin/Native. The compilation of klib artifacts into native code is now partially incremental.

When compiling Kotlin source code into native binary in debug mode, the compilation goes through two stages:

1. Source code is compiled into klib artifacts.

2. klib artifacts, along with dependencies, are compiled into a binary.

To optimize the compilation time in the second stage, the team has already implemented compiler caches for dependencies. They are compiled into native code only once, and the result is reused every time a binary is compiled. But klib artifacts built from project sources were always fully recompiled into native code at every project change.

With the new incremental compilation, if the project module change causes only a partial recompilation of source code into klib artifacts, just a part of the klib is further recompiled into a binary.

To enable incremental compilation, add the following option to your gradle.properties file:

```
kotlin.incremental.native=true
```

If you face any issues, report such cases to YouTrack.

Managing library linkage issues

This release improves the way the Kotlin/Native compiler handles linkage issues in Kotlin libraries. Error messages now include more readable declarations as they use signature names instead of hashes, helping you find and fix the issue more easily. Here's an example:

```
No function found for symbol 'org.samples/MyClass.removedFunction|removedFunction(kotlin.Int;kotlin.String){}[0]'
```

The Kotlin/Native compiler detects linkage issues between third-party Kotlin libraries and reports errors at runtime. You might face such issues if the author of one third-party Kotlin library makes an incompatible change in experimental APIs that another third-party Kotlin library consumes.

Starting with Kotlin 1.9.20, the compiler detects linkage issues in silent mode by default. You can adjust this setting in your projects:

- If you want to record these issues in your compilation logs, enable warnings with the -Xpartial-linkage-loglevel=WARNING compiler option.
- It's also possible to raise the severity of reported warnings to compilation errors with -Xpartial-linkage-loglevel=ERROR. In this case, the compilation fails, and you get all the errors in the compilation log. Use this option to examine the linkage issues more closely.

```
// An example of passing compiler options in a Gradle build file:
kotlin {
    macosX64("native") {
        binaries.executable()

        compilations.configureEach {
            compilerOptions.configure {
                // To report linkage issues as warnings:
                freeCompilerArgs.add("-Xpartial-linkage-loglevel=WARNING")

                // To raise linkage warnings to errors:
                freeCompilerArgs.add("-Xpartial-linkage-loglevel=ERROR")
            }
        }
    }
}
```

If you face unexpected problems with this feature, you can always opt out with the -Xpartial-linkage=disable compiler option. Don't hesitate to report such cases to our issue tracker.

Companion object initialization on class constructor calls

Starting with Kotlin 1.9.20, the Kotlin/Native backend calls static initializers for companion objects in class constructors:

```
class Greeting {
    companion object {
        init {
            print("Hello, Kotlin!")
        }
    }
}

fun main() {
    val start = Greeting() // Prints "Hello, Kotlin!"
}
```

The behavior is now unified with Kotlin/JVM, where a companion object is initialized when the corresponding class matching the semantics of a Java static initializer is loaded (resolved).

Now that the implementation of this feature is more consistent between platforms, it's easier to share code in Kotlin Multiplatform projects.

Opt-in requirement for all cinterop declarations

Starting with Kotlin 1.9.20, all Kotlin declarations generated by the cinterop tool from C and Objective-C libraries, like libcurl and libxml, are marked with @ExperimentalForeignApi. If the opt-in annotation is missing, your code won't compile.

This requirement reflects the Experimental status of the import of C and Objective-C libraries. We recommend that you confine its use to specific areas in your projects. This will make your migration easier once we begin stabilizing the import.

> As for native platform libraries shipped with Kotlin/Native (like Foundation, UIKit, and POSIX), only some of their APIs need an opt-in with @ExperimentalForeignApi. In such cases, you get a warning with an opt-in requirement.

Custom message for linker errors

If you're a library author, you can now help your users resolve linker errors with custom messages.

If your Kotlin library depends on C or Objective-C libraries, for example, using the CocoaPods integration, its users need to have these dependent libraries locally on the machine or configure them explicitly in the project build script. If this was not the case, users used to get a confusing "Framework not found" message.

You can now provide a specific instruction or a link in the compilation failure message. To do that, pass the -Xuser-setup-hint compiler option to cinterop or add a userSetupHint=message property to your .def file.

Removal of the legacy memory manager

The new memory manager was introduced in Kotlin 1.6.20 and became the default in 1.7.20. Since then, it has been receiving further updates and performance improvements and has become Stable.

The time has come to complete the deprecation cycle and remove the legacy memory manager. If you're still using it, remove the kotlin.native.binary.memoryModel=strict option from your gradle.properties and follow our Migration guide to make the necessary changes.

Change to our target tiers policy

We've decided to upgrade the requirements for tier 1 support. The Kotlin team is now committed to providing source and binary compatibility between compiler releases for targets eligible for tier 1. They must also be regularly tested with CI tools to be able to compile and run. Currently, tier 1 includes the following targets for macOS hosts:

- macosX64
- macosArm64
- iosSimulatorArm64
- iosX64

In Kotlin 1.9.20, we've also removed a number of previously deprecated targets, namely:

- iosArm32
- watchosX86
- wasm32
- mingwX86
- linuxMips32
- linuxMipsel32

See the full list of currently supported targets.

Kotlin Multiplatform

Kotlin 1.9.20 focuses on the stabilization of Kotlin Multiplatform and makes new steps in improving developer experience with the new project wizards and other notable features:

- Kotlin Multiplatform is Stable
- Template for configuring multiplatform projects
- New project wizard
- Full support for the Gradle Configuration cache
- Easier configuration of new standard library versions in Gradle
- Default support for third-party cinterop libraries
- Support for Kotlin/Native compilation caches in Compose Multiplatform projects
- Compatibility guidelines

Kotlin Multiplatform is Stable

The 1.9.20 release marks an important milestone in the evolution of Kotlin: Kotlin Multiplatform has finally become Stable. This means that the technology is safe to use in your projects and 100% ready for production. It also means that further development of Kotlin Multiplatform will continue according to our strict backward compatibility rules.

Please note that some advanced features of Kotlin Multiplatform are still evolving. When using them, you'll receive a warning that describes the current stability status of the feature you're using. Before using any experimental functionality in IntelliJ IDEA,
you'll need to enable it explicitly in Settings | Advanced Settings | Kotlin | Experimental Multiplatform.

- Visit the Kotlin blog to learn more about the Kotlin Multiplatform stabilization and future plans.
- Check out the Multiplatform compatibility guide to see what significant changes were made on the way to stabilization.
- Read about the mechanism of expected and actual declarations, an important part of Kotlin Multiplatform that was also partially stabilized in this release.

Template for configuring multiplatform projects

Starting with Kotlin 1.9.20, the Kotlin Gradle plugin automatically creates shared source sets for popular multiplatform scenarios. If your project setup is one of them, you don't need to configure the source set hierarchy manually. Just explicitly specify the targets necessary for your project.

Setup is now easier thanks to the default hierarchy template, a new feature of the Kotlin Gradle plugin. It's a predefined template of a source set hierarchy built into the plugin. It includes intermediate source sets that Kotlin automatically creates for the targets you declared. See the full template.

Create your project easier

Consider a multiplatform project that targets both Android and iPhone devices and is developed on an Apple silicon MacBook. Compare how this project is set up between different versions of Kotlin:

Kotlin 1.9.0 and earlier (a standard setup)	Kotlin 1.9.20

Kotlin 1.9.0 and earlier (a standard setup)

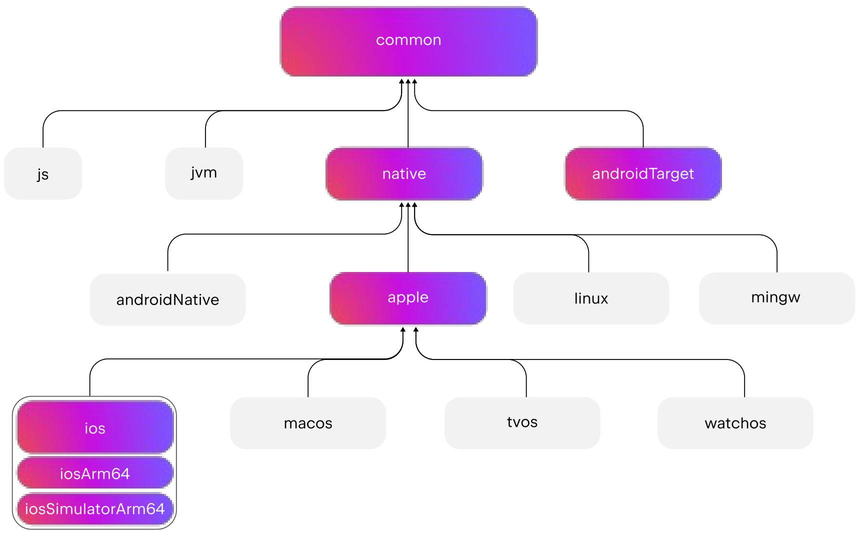
```
kotlin {
    androidTarget()
    iosArm64()
    iosSimulatorArm64()

    sourceSets {
        val commonMain by getting

        val iosMain by creating {
            dependsOn(commonMain)
        }

        val iosArm64Main by getting {
            dependsOn(iosMain)
        }

        val iosSimulatorArm64Main by getting
{
            dependsOn(iosMain)
        }
    }
}
```

Kotlin 1.9.20

```
kotlin {
    androidTarget()
    iosArm64()
    iosSimulatorArm64()

    // The iosMain source set is created automatically
}
```

Notice how the use of the default hierarchy template considerably reduces the amount of boilerplate code needed to set up your project.

When you declare the androidTarget, iosArm64, and iosSimulatorArm64 targets in your code, the Kotlin Gradle plugin finds suitable shared source sets from the template and creates them for you. The resulting hierarchy looks like this:

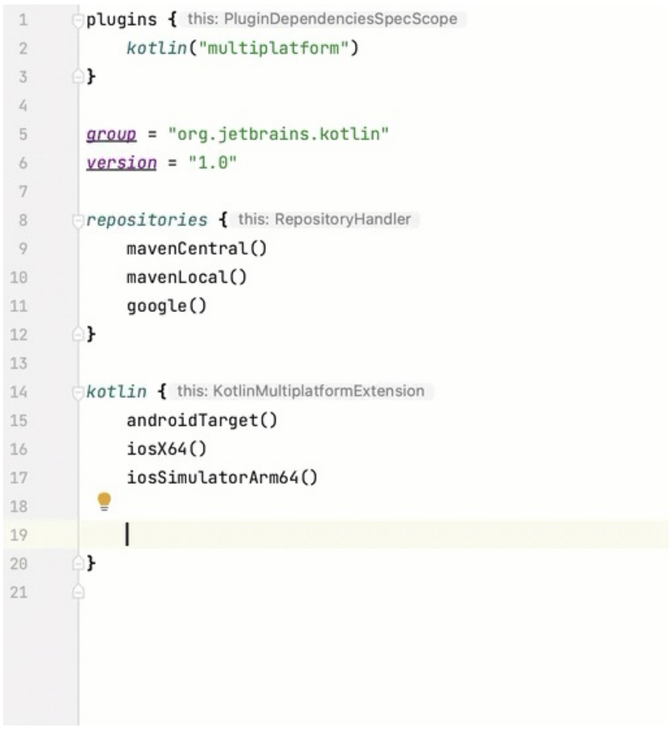


An example of the default target hierarchy in use

Green source sets are actually created and included in the project, while gray ones from the default template are ignored.

Use completion for source sets

To make it easier to work with the created project structure, IntelliJ IDEA now provides completion for source sets created with the default hierarchy template:


```
plugins { this: PluginDependenciesSpecScope
    kotlin("multiplatform")
}

group = "org.jetbrains.kotlin"
version = "1.0"

repositories { this: RepositoryHandler
    mavenCentral()
    mavenLocal()
    google()
}

kotlin { this: KotlinMultiplatformExtension
    androidTarget()
    iosX64()
    iosSimulatorArm64()


}
```

Kotlin also warns you if you attempt to access a source set that doesn't exist because you haven't declared the respective target. In the example below, there is no JVM target (only androidTarget, which is not the same). But let's try to use the jvmMain source set and see what happens:

```
kotlin {
    androidTarget()
    iosArm64()
    iosSimulatorArm64()

    sourceSets {
        jvmMain {
        }
    }
}
```

In this case, Kotlin reports a warning in the build log:

```
w: Accessed 'source set jvmMain' without registering the jvm target:
  kotlin {
      jvm() /* <- register the 'jvm' target */

      sourceSets.jvmMain.dependencies {

      }
  }
```

Set up the target hierarchy

Starting with Kotlin 1.9.20, the default hierarchy template is automatically enabled. In most cases, no additional setup is required.

However, if you're migrating existing projects created before 1.9.20, you might encounter a warning if you had previously introduced intermediate sources manually with dependsOn() calls. To solve this issue, do the following:

- If your intermediate source sets are currently covered by the default hierarchy template, remove all manual dependsOn() calls and source sets created with by creating constructions.

  To check the list of all default source sets, see the full hierarchy template.

- If you want to have additional source sets that the default hierarchy template doesn't provide, for example, one that shares code between a macOS and a JVM target, adjust the hierarchy by reapplying the template explicitly with applyDefaultHierarchyTemplate() and configuring additional source sets manually as usual with dependsOn():

```
kotlin {
    jvm()
    macosArm64()
    iosArm64()
    iosSimulatorArm64()

    // Apply the default hierarchy explicitly. It'll create, for example, the iosMain source set:
    applyDefaultHierarchyTemplate()

    sourceSets {
        // Create an additional jvmAndMacos source set
        val jvmAndMacos by creating {
            dependsOn(commonMain.get())
        }

        macosArm64Main.get().dependsOn(jvmAndMacos)
        jvmMain.get().dependsOn(jvmAndMacos)
    }
}
```

- If there are already source sets in your project that have the exact same names as those generated by the template but that are shared among different sets of targets, there's currently no way to modify the default dependsOn relations between the template's source sets.

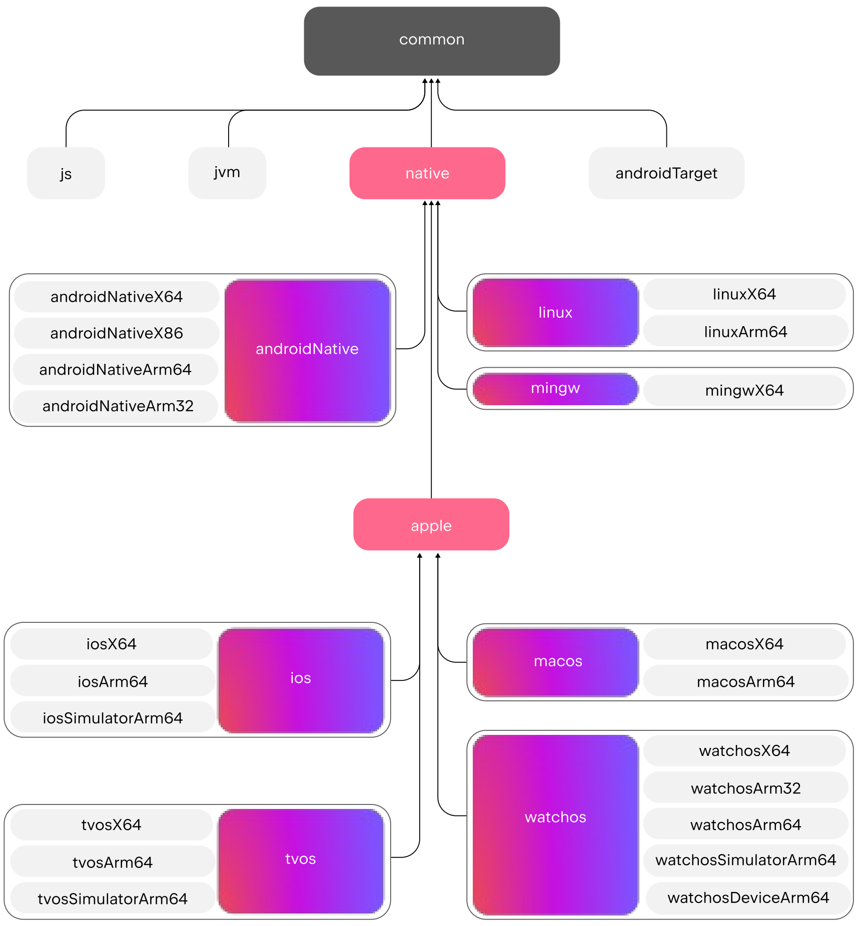
  One option you have here is to find different source sets for your purposes, either in the default hierarchy template or ones that have been manually created. Another is to opt out of the template completely.

  To opt out, add kotlin.mpp.applyDefaultHierarchyTemplate=false to your gradle.properties and configure all other source sets manually.

  We're currently working on an API for creating your own hierarchy templates to simplify the setup process in such cases.

See the full hierarchy template

When you declare the targets to which your project compiles, the plugin picks the shared source sets from the template accordingly and creates them in your project.



Default hierarchy template

This example only shows the production part of the project, omitting the Main suffix (for example, using common instead of commonMain). However, everything is the same for *Test sources as well.

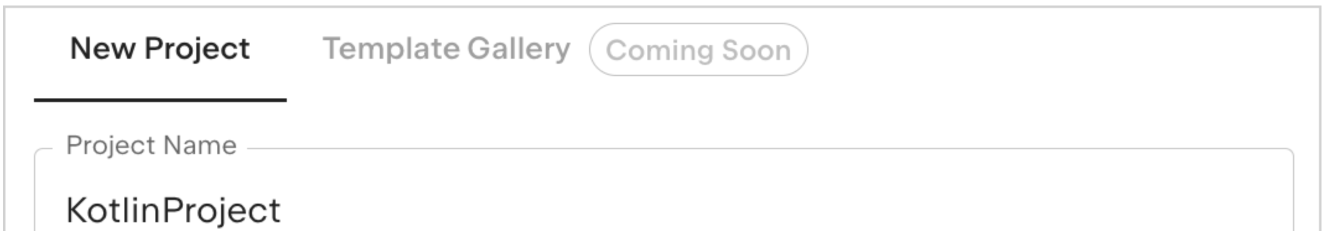
New project wizard

The JetBrains team is introducing a new way of creating cross–platform projects – the Kotlin Multiplatform web wizard.

This first implementation of the new Kotlin Multiplatform wizard covers the most popular Kotlin Multiplatform use cases. It incorporates all the feedback about previous project templates and makes the architecture as robust and reliable as possible.

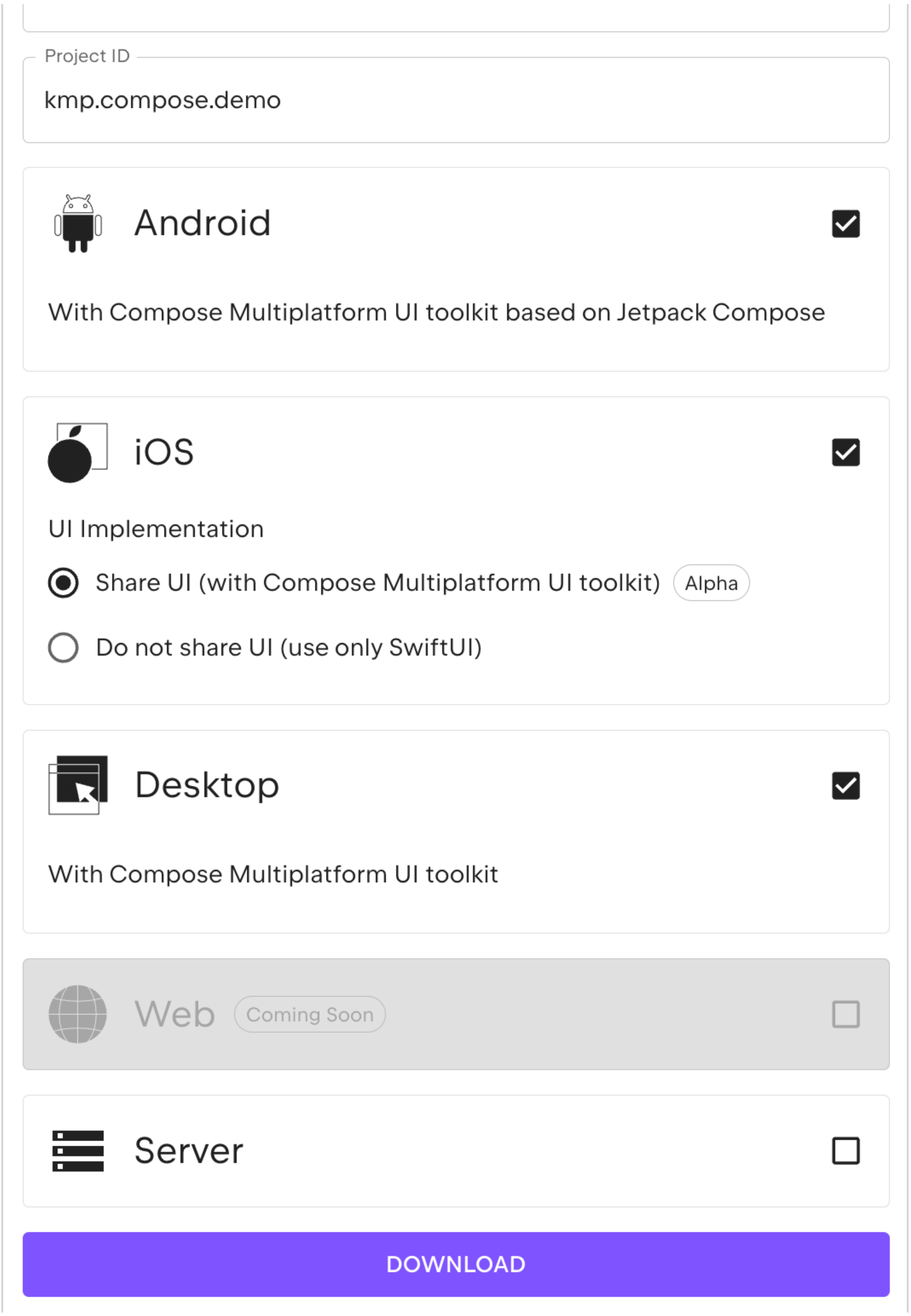
The new wizard has a distributed architecture that allows us to have a unified backend and different frontends, with the web version being the first step. We're considering both implementing an IDE version and creating a command-line tool in the future. On the web, you always get the latest version of the wizard, while in IDEs you'll need to wait for the next release.

With the new wizard, project setup is easier than ever. You can tailor your projects to your needs by choosing the target platforms for mobile, server, and desktop development. We also plan to add web development in future releases.



Project Name

KotlinProject



Project ID

kmp.compose.demo

Android [✓]

With Compose Multiplatform UI toolkit based on Jetpack Compose

iOS [✓]

UI Implementation

[✓ Share UI (with Compose Multiplatform UI toolkit)] Alpha

Do not share UI (use only SwiftUI)

Desktop [✓]

With Compose Multiplatform UI toolkit

Web Coming Soon [ ]

Server [ ]

Multiplatform web wizard

The new project wizard is now the preferred way to create cross–platform projects with Kotlin. Since 1.9.20, the Kotlin plugin no longer provides a Kotlin Multiplatform project wizard in IntelliJ IDEA.

The new wizard will guide you easily through the initial setup, making the onboarding process much smoother. If you encounter any issues, please report them to YouTrack to help us improve your experience with the wizard.

Create project →

Create a project

Full support for the Gradle configuration cache in Kotlin Multiplatform

Previously, we introduced a preview of the Gradle configuration cache, which was available for Kotlin multiplatform libraries. With 1.9.20, the Kotlin Multiplatform plugin takes a step further.

It now supports the Gradle configuration cache in the Kotlin CocoaPods Gradle plugin, as well as in the integration tasks that are necessary for Xcode builds, like embedAndSignAppleFrameworkForXcode.

Now all multiplatform projects can take advantage of the improved build time. The Gradle configuration cache speeds up the build process by reusing the results of the configuration phase for subsequent builds. For more details and setup instructions, see the Gradle documentation.

Easier configuration of new standard library versions in Gradle

When you create a multiplatform project, a dependency for the standard library (stdlib) is added automatically to each source set. This is the easiest way to get started with your multiplatform projects.

Previously, if you wanted to configure a dependency on the standard library manually, you needed to configure it for each source set individually. From kotlin-stdlib:1.9.20 onward, you only need to configure the dependency once in the commonMain root source set:

Standard library version 1.9.10 and earlier

```
kotlin {
    sourceSets {
        // For the common source set
        val commonMain by getting {
            dependencies {
                implementation("org.jetbrains.kotlin:kotlin-
stdlib-common:1.9.10")
            }
        }

        // For the JVM source set
        val jvmMain by getting {
            dependencies {
                implementation("org.jetbrains.kotlin:kotlin-
stdlib:1.9.10")
            }
        }

        // For the JS source set
        val jsMain by getting {
            dependencies {
                implementation("org.jetbrains.kotlin:kotlin-
stdlib-js:1.9.10")
            }
        }
    }
}
```

Standard library version 1.9.20

```
kotlin {
    sourceSets {
        commonMain {
            dependencies {
implementation("org.jetbrains.kotlin:kotlin-stdlib:1.9.20")
            }
        }
    }
}
```

This change was made possible by including new information in the Gradle metadata of the standard library. This allows Gradle to automatically resolve the correct standard library artifacts for the other source sets.

Default support for third-party cinterop libraries

Kotlin 1.9.20 adds default support (rather than support by opt-in) for all cinterop dependencies in projects that have the Kotlin CocoaPods Gradle plugin applied.

This means you can now share more native code without being limited by platform–specific dependencies. For example, you can add dependencies on Pod libraries to the iosMain shared source set.

Previously, this only worked with platform-specific libraries shipped with a Kotlin/Native distribution (like Foundation, UIKit, and POSIX). All third-party Pod libraries are now available in shared source sets by default. You no longer need to specify a separate Gradle property to support them.

Support for Kotlin/Native compilation caches in Compose Multiplatform projects

This release resolves a compatibility issue with the Compose Multiplatform compiler plugin, which mostly affected Compose Multiplatform projects for iOS.

To work around this issue, you had to disable caching by using the kotlin.native.cacheKind=none Gradle property. However, this workaround came at a performance cost: It slowed down compilation time as caching didn't work in the Kotlin/Native compiler.

Now that the issue is fixed, you can remove kotlin.native.cacheKind=none from your gradle.properties file and enjoy the improved compilation times in your Compose Multiplatform projects.

For more tips on improving compilation times, see the Kotlin/Native documentation.

Compatibility guidelines

When configuring your projects, check the Kotlin Multiplatform Gradle plugin's compatibility with the available Gradle, Xcode, and Android Gradle plugin (AGP) versions:

Kotlin Multiplatform Gradle plugin	Gradle	Android Gradle plugin	Xcode
1.9.20	7.5 and later	7.4.2–8.2	15.0. See details below

As of this release, the recommended version of Xcode is 15.0. Libraries delivered with Xcode 15.0 are fully supported, and you can access them from anywhere in your Kotlin code.

However, XCode 14.3 should still work in the majority of cases. Keep in mind that if you use version 14.3 on your local machine, libraries delivered with Xcode 15 will be visible but not accessible.

Kotlin/Wasm

In 1.9.20, Kotlin Wasm reached the Alpha level of stability.

- Compatibility with Wasm GC phase 4 and final opcodes
- New wasm-wasi target, and the renaming of the wasm target to wasm-js
- Support for the WASI API in standard library
- Kotlin/Wasm API improvements

Kotlin Wasm is Alpha. It is subject to change at any time. Use it only for evaluation purposes.

We would appreciate your feedback on it in YouTrack.

Compatibility with Wasm GC phase 4 and final opcodes

Wasm GC moves to the final phase and it requires updates of opcodes – constant numbers used in the binary representation. Kotlin 1.9.20 supports the latest opcodes, so we strongly recommend that you update your Wasm projects to the latest version of Kotlin. We also recommend using the latest versions of browsers with the Wasm environment:

- Version 119 or newer for Chrome and Chromium–based browsers.
- Version 119 or newer for Firefox. Note that in Firefox 119, you need to turn on Wasm GC manually.

New wasm-wasi target, and the renaming of the wasm target to wasm-js

In this release, we're introducing a new target for Kotlin/Wasm – wasm-wasi. We're also renaming the wasm target to wasm-js. In the Gradle DSL, these targets are available as wasmWasi {} and wasmJs {}, respectively.

To use these targets in your project, update the build.gradle.kts file:

```
kotlin {
    wasmWasi {
        // ...
    }
    wasmJs {
        // ...
    }
}
```

The previously introduced wasm {} block has been deprecated in favor of wasmJs {}.

To migrate your existing Kotlin/Wasm project, do the following:

- In the build.gradle.kts file, rename the wasm {} block to wasmJs {}.
- In your project structure, rename the wasmMain directory to wasmJsMain.

Support for the WASI API in the standard library

In this release, we have included support for WASI, a system interface for the Wasm platform. WASI support makes it easier for you to use Kotlin/Wasm outside of browsers, for example in server–side applications, by offering a standardized set of APIs for accessing system resources. In addition, WASI provides capability–based security – another layer of security when accessing external resources.

To run Kotlin/Wasm applications, you need a VM that supports Wasm Garbage Collection (GC), for example, Node.js or Deno. Wasmtime, WasmEdge, and others are still working towards full Wasm GC support.

To import a WASI function, use the @WasmImport annotation:

```
import kotlin.wasm.WasmImport

@WasmImport("wasi_snapshot_preview1", "clock_time_get")
private external fun wasiRawClockTimeGet(clockId: Int, precision: Long, resultPtr: Int): Int
```

You can find a full example in our GitHub repository.

> It isn't possible to use interoperability with JavaScript, while targeting wasmWasi.

Kotlin/Wasm API improvements

This release delivers several quality-of-life improvements to the Kotlin/Wasm API. For example, you're no longer required to return a value for DOM event listeners:

Before 1.9.20	In 1.9.20

Before 1.9.20	In 1.9.20

```
fun main() {
    window.onload = {

document.body?.sayHello()
        null
    }
}
```

```
fun main() {
    window.onload = { document.body?.sayHello() }
}
```

Gradle

Kotlin 1.9.20 is fully compatible with Gradle 6.8.3 through 8.1. You can also use Gradle versions up to the latest Gradle release, but if you do, keep in mind that you might encounter deprecation warnings or some new Gradle features might not work.

This version brings the following changes:

- Support for test fixtures to access internal declarations
- New property to configure paths to Konan directories
- New build report metrics for Kotlin/Native tasks

Support for test fixtures to access internal declarations

In Kotlin 1.9.20, if you use Gradle's java-test-fixtures plugin, then your test fixtures now have access to internal declarations within main source set classes. In addition, any test sources can also see any internal declarations within test fixtures classes.

New property to configure paths to Konan directories

In Kotlin 1.9.20, the kotlin.data.dir Gradle property is available to customize your path to the ~/.konan directory so that you don't have to configure it through the environment variable KONAN_DATA_DIR.

Alternatively, you can use the -Xkonan-data-dir compiler option to configure your custom path to the ~/.konan directory via the cinterop and konanc tools.

New build report metrics for Kotlin/Native tasks

In Kotlin 1.9.20, Gradle build reports now include metrics for Kotlin/Native tasks. Here is an example of a build report containing these metrics:

```
Total time for Kotlin tasks: 20.81 s (93.1 % of all tasks time)
Time   |% of Kotlin time|Task
15.24 s|73.2 %          |:compileCommonMainKotlinMetadata
5.57 s |26.8 %          |:compileNativeMainKotlinMetadata

Task ':compileCommonMainKotlinMetadata' finished in 15.24 s
Task info:
  Kotlin language version: 2.0
Time metrics:
  Total Gradle task time: 15.24 s
  Spent time before task action: 0.16 s
  Task action before worker execution: 0.21 s
  Run native in process: 2.70 s
    Run entry point: 2.64 s
Size metrics:
  Start time of task action: 2023-07-27T11:04:17

Task ':compileNativeMainKotlinMetadata' finished in 5.57 s
Task info:
  Kotlin language version: 2.0
Time metrics:
  Total Gradle task time: 5.57 s
  Spent time before task action: 0.04 s
  Task action before worker execution: 0.02 s
  Run native in process: 1.48 s
    Run entry point: 1.47 s
```

```
Size metrics:
  Start time of task action: 2023-07-27T11:04:32
```

In addition, the kotlin.experimental.tryK2 build report now includes any Kotlin/Native tasks that were compiled and lists the language version used:

```
##### 'kotlin.experimental.tryK2' results #####
:lib:compileCommonMainKotlinMetadata: 2.0 language version
:lib:compileKotlinJvm: 2.0 language version
:lib:compileKotlinIosArm64: 2.0 language version
:lib:compileKotlinIosSimulatorArm64: 2.0 language version
:lib:compileKotlinLinuxX64: 2.0 language version
:lib:compileTestKotlinJvm: 2.0 language version
:lib:compileTestKotlinIosSimulatorArm64: 2.0 language version
:lib:compileTestKotlinLinuxX64: 2.0 language version
##### 100% (8/8) tasks have been compiled with Kotlin 2.0 #####
```

If you use Gradle 8.0, you might come across some problems with build reports, especially when Gradle configuration caching is enabled. This is a known issue, which is fixed in Gradle 8.1 and later.

Standard library

In Kotlin 1.9.20, the Kotlin/Native standard library becomes Stable, and there are some new features:

- Replacement of the Enum class values generic function
- Improved performance of HashMap operations in Kotlin/JS

Replacement of the Enum class values generic function

This feature is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below). Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

In Kotlin 1.9.0, the entries property for enum classes became Stable. The entries property is a modern and performant replacement for the synthetic values() function. As part of Kotlin 1.9.20, there is a replacement for the generic enumValues<T>() function: enumEntries<T>().

The enumValues<T>() function is still supported, but we recommend that you use the enumEntries<T>() function instead because it has less performance impact. Every time you call enumValues<T>(), a new array is created, whereas whenever you call enumEntries<T>(), the same list is returned each time, which is far more efficient.

For example:

```kotlin
enum class RGB { RED, GREEN, BLUE }

@OptIn(ExperimentalStdlibApi::class)
inline fun <reified T : Enum<T>> printAllValues() {
    print(enumEntries<T>().joinToString { it.name })
}

printAllValues<RGB>()
// RED, GREEN, BLUE
```

How to enable the enumEntries function

To try this feature, opt in with @OptIn(ExperimentalStdlibApi) and use language version 1.9 or later. If you use the latest version of the Kotlin Gradle plugin, you don't need to specify the language version to test the feature.

The Kotlin/Native standard library becomes Stable

In Kotlin 1.9.0, we explained the actions we've taken to bring the Kotlin/Native standard library closer to our goal of stabilization. In Kotlin 1.9.20, we finally conclude this work and make the Kotlin/Native standard library Stable. Here are some highlights from this release:

- The Vector128 class was moved from the kotlin.native package to the kotlinx.cinterop package.
- The opt-in requirement level for ExperimentalNativeApi and NativeRuntimeApi annotations, which were introduced as part of Kotlin 1.9.0, has been raised from WARNING to ERROR.
- Kotlin/Native collections now detect concurrent modifications, for example, in the ArrayList and HashMap collections.
- The printStackTrace() function from the Throwable class now prints to STDERR instead of STDOUT.

> The output format of printStackTrace() isn't Stable and is subject to change.

Improvements to the Atomics API

In Kotlin 1.9.0, we said that the Atomics API would be ready to become Stable when the Kotlin/Native standard library becomes Stable. Kotlin 1.9.20 includes the following additional changes:

- Experimental AtomicIntArray, AtomicLongArray, and AtomicArray<T> classes are introduced. These new classes are designed specifically to be consistent with Java's atomic arrays so that in the future, they can be included in the common standard library.

> The AtomicIntArray, AtomicLongArray, and AtomicArray<T> classes are Experimental. They may be dropped or changed at any time. To try them, opt in with @OptIn(ExperimentalStdlibApi). Use them only for evaluation purposes. We would appreciate your feedback in YouTrack.

- In the kotlin.native.concurrent package, the Atomics API that was deprecated in Kotlin 1.9.0 with deprecation level WARNING has had its deprecation level raised to ERROR.
- In the kotlin.concurrent package, member functions of the AtomicInt and AtomicLong classes that had deprecation level: ERROR, have been removed.
- All member functions of the AtomicReference class now use atomic intrinsic functions.

For more information on all of the changes in Kotlin 1.9.20, see our YouTrack ticket.

Improved performance of HashMap operations in Kotlin/JS

Kotlin 1.9.20 improves the performance of HashMap operations and reduces their memory footprint in Kotlin/JS. Internally, Kotlin/JS has changed its internal implementation to open addressing. This means that you should see performance improvements when you:

- Insert new elements into a HashMap.
- Search for existing elements in a HashMap.
- Iterate through keys or values in a HashMap.

Documentation updates

The Kotlin documentation has received some notable changes:

- The JVM Metadata API reference – Explore how you can parse metadata with Kotlin/JVM.
- Time measurement guide – Learn how to calculate and measure time in Kotlin.
- Improved Collections chapter in the tour of Kotlin – Learn the fundamentals of the Kotlin programming language with chapters including both theory and practice.
- Definitely non-nullable types – Learn about definitely non-nullable generic types.
- Improved Arrays page – Learn about arrays and when to use them.
- Expected and actual declarations in Kotlin Multiplatform – Learn about the Kotlin mechanism of expected and actual declarations in Kotlin Multiplatform.

Install Kotlin 1.9.20

Check the IDE version

IntelliJ IDEA 2023.1.x and 2023.2.x automatically suggest updating the Kotlin plugin to version 1.9.20. IntelliJ IDEA 2023.3 will include the Kotlin 1.9.20 plugin.

Android Studio Hedgehog (231) and Iguana (232) will support Kotlin 1.9.20 in their upcoming releases.

The new command–line compiler is available for download on the GitHub release page.

Configure Gradle settings

To download Kotlin artifacts and dependencies, update your settings.gradle(.kts) file to use the Maven Central repository:

```
pluginManagement {
    repositories {
        mavenCentral()
        gradlePluginPortal()
    }
}
```

If the repository is not specified, Gradle uses the sunset JCenter repository, which could lead to issues with Kotlin artifacts.

What's new in Kotlin 1.9.0

Release date: July 6, 2023

The Kotlin 1.9.0 release is out and the K2 compiler for the JVM is now in Beta. Additionally, here are some of the main highlights:

- New Kotlin K2 compiler updates
- Stable replacement of the enum class values function
- Stable ..< operator for open-ended ranges
- New common function to get regex capture group by name
- New path utility to create parent directories
- Preview of the Gradle configuration cache in Kotlin Multiplatform
- Changes to Android target support in Kotlin Multiplatform
- Preview of custom memory allocator in Kotlin/Native
- Library linkage in Kotlin/Native
- Size-related optimizations in Kotlin/Wasm

You can also find a short overview of the updates in this video:

Watch video online.

IDE support

The Kotlin plugins that support 1.9.0 are available for:

IDE	Supported versions
IntelliJ IDEA	2022.3.x, 2023.1.x
Android Studio	Giraffe (223), Hedgehog (231)*

*The Kotlin 1.9.0 plugin will be included with Android Studio Giraffe (223) and Hedgehog (231) in their upcoming releases.

The Kotlin 1.9.0 plugin will be included with IntelliJ IDEA 2023.2 in the upcoming releases.

To download Kotlin artifacts and dependencies, configure your Gradle settings to use the Maven Central Repository.

New Kotlin K2 compiler updates

The Kotlin team at JetBrains continues to stabilize the K2 compiler, and the 1.9.0 release introduces further advancements. The K2 compiler for the JVM is now in Beta.

There's now also basic support for Kotlin/Native and multiplatform projects.

Compatibility of the kapt compiler plugin with the K2 compiler

You can use the kapt plugin in your project along with the K2 compiler, but with some restrictions. Despite setting languageVersion to 2.0, the kapt compiler plugin still utilizes the old compiler.

If you execute the kapt compiler plugin within a project where languageVersion is set to 2.0, kapt will automatically switch to 1.9 and disable specific version compatibility checks. This behavior is equivalent to including the following command arguments:

- -Xskip-metadata-version-check
- -Xskip-prerelease-check
- -Xallow-unstable-dependencies

These checks are exclusively disabled for kapt tasks. All other compilation tasks will continue to utilize the new K2 compiler.

If you encounter any issues when using kapt with the K2 compiler, please report them to our issue tracker.

Try the K2 compiler in your project

Starting with 1.9.0 and until the release of Kotlin 2.0, you can easily test the K2 compiler by adding the kotlin.experimental.tryK2=true Gradle property to your gradle.properties file. You can also run the following command:

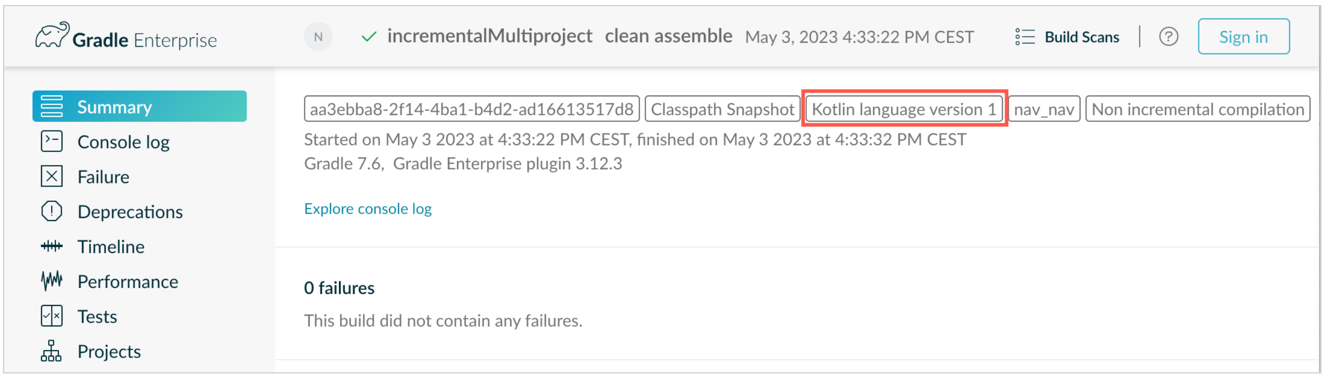
```
./gradlew assemble -Pkotlin.experimental.tryK2=true
```

This Gradle property automatically sets the language version to 2.0 and updates the build report with the number of Kotlin tasks compiled using the K2 compiler compared to the current compiler:

```
##### 'kotlin.experimental.tryK2' results (Kotlin/Native not checked) #####
:lib:compileKotlin: 2.0 language version
:app:compileKotlin: 2.0 language version
##### 100% (2/2) tasks have been compiled with Kotlin 2.0 #####
```

Gradle build reports

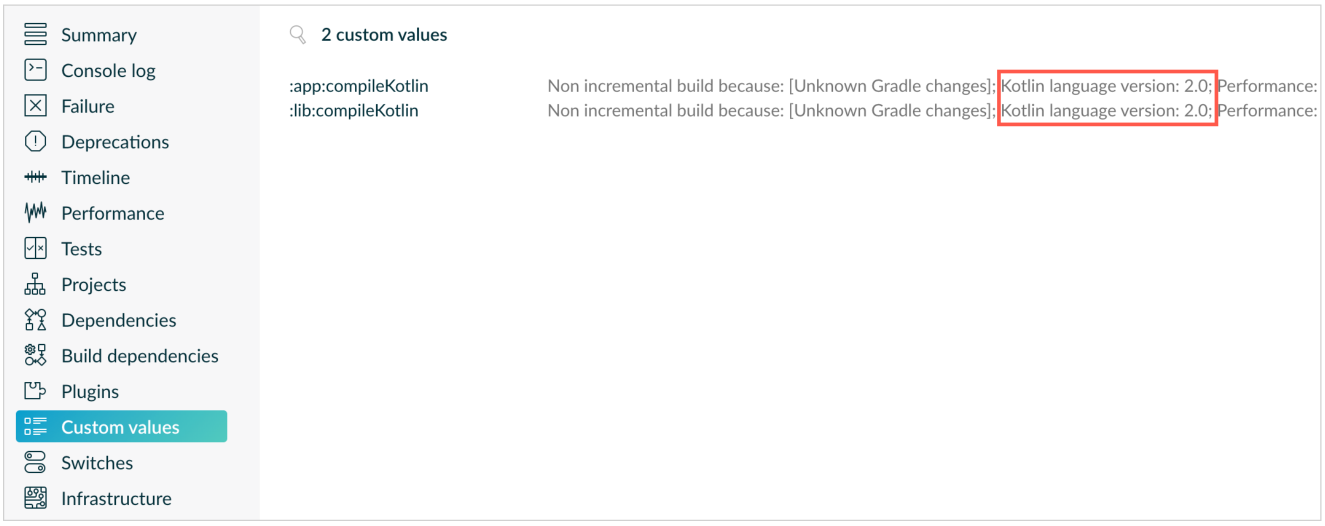
Gradle build reports now show whether the current or the K2 compiler was used to compile the code. In Kotlin 1.9.0, you can see this information in your Gradle build scans:


Gradle Enterprise
N
incrementalMultiproject clean assemble May 3, 2023 4:33:22 PM CEST
Build Scans
Sign in
Summary
Console log
Failure
Deprecations
Timeline
Performance
Tests
Projects
aa3ebba8-2f14-4ba1-b4d2-ad16613517d8
Classpath Snapshot
Kotlin language version 1
nav_nav
Non incremental compilation
Explore console log

Started on May 3 2023 at 4:33:22 PM CEST, finished on May 3 2023 at 4:33:32 PM CEST
Gradle 7.6, Gradle Enterprise plugin 3.12.3

0 failures
This build did not contain any failures.

Gradle build scan - K1



```
:app:compileKotlin    Non incremental build because: [Unknown Gradle changes]; Kotlin language version: 2.0; Performance:
:lib:compileKotlin    Non incremental build because: [Unknown Gradle changes]; Kotlin language version: 2.0; Performance:
```

Gradle build scan - K2

You can also find the Kotlin version used in the project right in the build report:

```
Task info:
  Kotlin language version: 1.9
```

If you use Gradle 8.0, you might come across some problems with build reports, especially when Gradle configuration caching is enabled. This is a known issue, fixed in Gradle 8.1 and later.

Current K2 compiler limitations

Enabling K2 in your Gradle project comes with certain limitations that can affect projects using Gradle versions below 8.3 in the following cases:

- Compilation of source code from buildSrc.
- Compilation of Gradle plugins in included builds.
- Compilation of other Gradle plugins if they are used in projects with Gradle versions below 8.3.
- Building Gradle plugin dependencies.

If you encounter any of the problems mentioned above, you can take the following steps to address them:

- Set the language version for buildSrc, any Gradle plugins, and their dependencies:

```
kotlin {
    compilerOptions {
        languageVersion.set(org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9)
        apiVersion.set(org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9)
    }
}
```

- Update the Gradle version in your project to 8.3 when it becomes available.

Leave your feedback on the new K2 compiler

We'd appreciate any feedback you may have!

- Provide your feedback directly to K2 developers Kotlin's Slack – get an invite and join the #k2-early-adopters channel.
- Report any problems you've faced with the new K2 compiler on our issue tracker.
- Enable the Send usage statistics option to allow JetBrains to collect anonymous data about K2 usage.

Language

In Kotlin 1.9.0, we're stabilizing some new language features that were introduced earlier:

- Replacement of the enum class values function
- Data object symmetry with data classes
- Support for secondary constructors with bodies in inline value classes

Stable replacement of the enum class values function

In 1.8.20, the entries property for enum classes was introduced as an Experimental feature. The entries property is a modern and performant replacement for the synthetic values() function. In 1.9.0, the entries property is Stable.

> The values() function is still supported, but we recommend that you use the entries property instead.

```
enum class Color(val colorName: String, val rgb: String) {
    RED("Red", "#FF0000"),
    ORANGE("Orange", "#FF7F00"),
    YELLOW("Yellow", "#FFFF00")
}

fun findByRgb(rgb: String): Color? = Color.entries.find { it.rgb == rgb }
```

For more information about the entries property for enum classes, see What's new in Kotlin 1.8.20.

Stable data objects for symmetry with data classes

Data object declarations, which were introduced in Kotlin 1.8.20, are now Stable. This includes the functions added for symmetry with data classes: toString(), equals(), and hashCode().

This feature is particularly useful with sealed hierarchies (like a sealed class or sealed interface hierarchy), because data object declarations can be used conveniently alongside data class declarations. In this example, declaring EndOfFile as a data object instead of a plain object means that it automatically has a toString() function without the need to override it manually. This maintains symmetry with the accompanying data class definitions.

```
sealed interface ReadResult
data class Number(val number: Int) : ReadResult
data class Text(val text: String) : ReadResult
data object EndOfFile : ReadResult

fun main() {
    println(Number(7)) // Number(number=7)
    println(EndOfFile) // EndOfFile
}
```

For more information, see What's new in Kotlin 1.8.20.

Support for secondary constructors with bodies in inline value classes

Starting with Kotlin 1.9.0, the use of secondary constructors with bodies in inline value classes is available by default:

```
@JvmInline
value class Person(private val fullName: String) {
    // Allowed since Kotlin 1.4.30:
    init {
        check(fullName.isNotBlank()) {
            "Full name shouldn't be empty"
        }
    }
    // Allowed by default since Kotlin 1.9.0:
    constructor(name: String, lastName: String) : this("$name $lastName") {
        check(lastName.isNotBlank()) {
            "Last name shouldn't be empty"
        }
    }
}
```

Previously, Kotlin allowed only public primary constructors in inline classes. As a result, it was impossible to encapsulate underlying values or create an inline class that would represent some constrained values.

As Kotlin developed, these issues were fixed. Kotlin 1.4.30 lifted restrictions on init blocks and then Kotlin 1.8.20 came with a preview of secondary constructors with bodies. They are now available by default. Learn more about the development of Kotlin inline classes in this KEEP.

Kotlin/JVM

Starting with version 1.9.0, the compiler can generate classes with a bytecode version corresponding to JVM 20. In addition, the deprecation of the JvmDefault annotation and legacy -Xjvm-default modes continues.

Deprecation of JvmDefault annotation and legacy -Xjvm-default modes

Starting from Kotlin 1.5, the usage of the JvmDefault annotation has been deprecated in favor of the newer -Xjvm-default modes: all and all-compatibility. With the introduction of JvmDefaultWithoutCompatibility in Kotlin 1.4 and JvmDefaultWithCompatibility in Kotlin 1.6, these modes offer comprehensive control over the generation of DefaultImpls classes, ensuring seamless compatibility with older Kotlin code.

Consequently in Kotlin 1.9.0, the JvmDefault annotation no longer holds any significance and has been marked as deprecated, resulting in an error. It will eventually be removed from Kotlin.

Kotlin/Native

Among other improvements, this release brings further advancements to the Kotlin/Native memory manager that should enhance its robustness and performance:

- Preview of custom memory allocator
- Objective-C or Swift object deallocation hook on the main thread
- No object initialization when accessing constant values in Kotlin/Native
- Ability to configure standalone mode for iOS simulator tests
- Library linkage in Kotlin/Native

Preview of custom memory allocator

Kotlin 1.9.0 introduces the preview of a custom memory allocator. Its allocation system improves the runtime performance of the Kotlin/Native memory manager.

The current object allocation system in Kotlin/Native uses a general-purpose allocator that doesn't have the functionality for efficient garbage collection. To compensate, it maintains thread-local linked lists of all allocated objects before the garbage collector (GC) merges them into a single list, which can be iterated during sweeping. This approach comes with several performance downsides:

- The sweeping order lacks memory locality and often results in scattered memory access patterns, leading to potential performance issues.
- Linked lists require additional memory for each object, increasing memory usage, particularly when dealing with many small objects.
- The single list of allocated objects makes it challenging to parallelize sweeping, which can cause memory usage problems when mutator threads allocate objects faster than the GC thread can collect them.

To address these issues, Kotlin 1.9.0 introduces a preview of the custom allocator. It divides system memory into pages, allowing independent sweeping in consecutive order. Each allocation becomes a memory block within a page, and the page keeps track of block sizes. Different page types are optimized for various allocation sizes. The consecutive arrangement of memory blocks ensures efficient iteration through all allocated blocks.

When a thread allocates memory, it searches for a suitable page based on the allocation size. Threads maintain a set of pages for different size categories. Typically, the current page for a given size can accommodate the allocation. If not, the thread requests a different page from the shared allocation space. This page may already be available, require sweeping, or should be created first.

The new allocator allows having multiple independent allocation spaces simultaneously, which will allow the Kotlin team to experiment with different page layouts to improve performance even further.

For more information on the design of the new allocator, see this README.

How to enable

Add the -Xallocator=custom compiler option:

```
kotlin {
    macosX64("native") {
        binaries.executable()

        compilations.configureEach {
            compilerOptions.configure {
                freeCompilerArgs.add("-Xallocator=custom")
            }
        }
    }
}
```

Leave feedback

We would appreciate your feedback in YouTrack to improve the custom allocator.

Objective-C or Swift object deallocation hook on the main thread

Starting with Kotlin 1.9.0, the Objective-C or Swift object deallocation hook is called on the main thread if the object is passed to Kotlin there. The way the Kotlin/Native memory manager previously handled references to Objective-C objects could lead to memory leaks. We believe the new behavior should improve the robustness of the memory manager.

Consider an Objective-C object that is referenced in Kotlin code, for example, when passed as an argument, returned by a function, or retrieved from a collection. In this case, Kotlin creates its own object that holds the reference to the Objective-C object. When the Kotlin object gets deallocated, the Kotlin/Native runtime calls the objc_release function that releases that Objective-C reference.

Previously, the Kotlin/Native memory manager ran objc_release on a special GC thread. If it's the last object reference, the object gets deallocated. Issues could come up when Objective-C objects have custom deallocation hooks like the dealloc method in Objective-C or the deinit block in Swift, and these hooks expect to be called on a specific thread.

Since hooks for objects on the main thread usually expect to be called there, Kotlin/Native runtime now calls objc_release on the main thread as well. It should cover the cases when the Objective-C object was passed to Kotlin on the main thread, creating a Kotlin peer object there. This only works if the main dispatch queue is processed, which is the case for regular UI applications. When it's not the main queue or the object was passed to Kotlin on a thread other than main, the objc_release is called on a special GC thread as before.

How to opt out

In case you face issues, you can disable this behavior in your gradle.properties file with the following option:

```
kotlin.native.binary.objcDisposeOnMain=false
```

Don't hesitate to report such cases to our issue tracker.

No object initialization when accessing constant values in Kotlin/Native

Starting with Kotlin 1.9.0, the Kotlin/Native backend doesn't initialize objects when accessing const val fields:

```
object MyObject {
    init {
        println("side effect!")
    }

    const val y = 1
}

fun main() {
    println(MyObject.y) // No initialization at first
    val x = MyObject    // Initialization occurs
    println(x.y)
}
```

The behavior is now unified with Kotlin/JVM, where the implementation is consistent with Java and objects are never initialized in this case. You can also expect some performance improvements in your Kotlin/Native projects thanks to this change.

Ability to configure standalone mode for iOS simulator tests in Kotlin/Native

By default, when running iOS simulator tests for Kotlin/Native, the --standalone flag is used to avoid manual simulator booting and shutdown. In 1.9.0, you can now configure whether this flag is used in a Gradle task via the standalone property. By default, the --standalone flag is used so standalone mode is enabled.

Here is an example of how to disable standalone mode in your build.gradle.kts file:

```
tasks.withType<org.jetbrains.kotlin.gradle.targets.native.tasks.KotlinNativeSimulatorTest>().configureEach {
    standalone.set(false)
}
```

> If you disable standalone mode, you must boot the simulator manually. To boot your simulator from CLI, you can use the following command:
>
> ```
> /usr/bin/xcrun simctl boot <DeviceId>
> ```

Library linkage in Kotlin/Native

Starting with Kotlin 1.9.0, the Kotlin/Native compiler treats linkage issues in Kotlin libraries the same way as Kotlin/JVM. You might face such issues if the author of one third-party Kotlin library makes an incompatible change in experimental APIs that another third-party Kotlin library consumes.

Now builds don't fail during compilation in case of linkage issues between third-party Kotlin libraries. Instead, you'll only encounter these errors in run time, exactly as on the JVM.

The Kotlin/Native compiler reports warnings every time it detects issues with library linkage. You can find such warnings in your compilation logs, for example:

```
No function found for symbol 'org.samples/MyRemovedClass.doSomething|3657632771909858561[0]'

Can not get instance of singleton 'MyEnumClass.REMOVED_ENTRY': No enum entry found for symbol
'org.samples/MyEnumClass.REMOVED_ENTRY|null[0]'

Function 'getMyRemovedClass' can not be called: Function uses unlinked class symbol 'org.samples/MyRemovedClass|null[0]'
```

You can further configure or even disable this behavior in your projects:

- If you don't want to see these warnings in your compilation logs, suppress them with the -Xpartial-linkage-loglevel=INFO compiler option.
- It's also possible to raise the severity of reported warnings to compilation errors with -Xpartial-linkage-loglevel=ERROR. In this case, the compilation fails and you'll see all the errors in the compilation log. Use this option to examine the linkage issues more closely.
- If you face unexpected problems with this feature, you can always opt out with the -Xpartial-linkage=disable compiler option. Don't hesitate to report such cases to our issue tracker.

```
// An example of passing compiler options via Gradle build file.
kotlin {
    macosX64("native") {
        binaries.executable()

        compilations.configureEach {
            compilerOptions.configure {
                // To suppress linkage warnings:
                freeCompilerArgs.add("-Xpartial-linkage-loglevel=INFO")

                // To raise linkage warnings to errors:
                freeCompilerArgs.add("-Xpartial-linkage-loglevel=ERROR")

                // To disable the feature completely:
                freeCompilerArgs.add("-Xpartial-linkage=disable")
            }
        }
    }
}
```

Compiler option for C interop implicit integer conversions

We have introduced a compiler option for C interop that allows you to use implicit integer conversions. After careful consideration, we've introduced this compiler option to prevent unintentional use as this feature still has room for improvement and our aim is to have an API of the highest quality.

In this code sample an implicit integer conversion allows options = 0 even though options has unsigned type UInt and 0 is signed.

```
val today = NSDate()
val tomorrow = NSCalendar.currentCalendar.dateByAddingUnit(
    unit = NSCalendarUnitDay,
    value = 1,
    toDate = today,
    options = 0
)
```

To use implicit conversions with native interop libraries, use the -XXLanguage:+ImplicitSignedToUnsignedIntegerConversion compiler option.

You can configure this in your Gradle build.gradle.kts file:

```
tasks.withType<org.jetbrains.kotlin.gradle.tasks.KotlinNativeCompile>().configureEach {
    compilerOptions.freeCompilerArgs.addAll(
        "-XXLanguage:+ImplicitSignedToUnsignedIntegerConversion"
    )
}
```

Kotlin Multiplatform

Kotlin Multiplatform has received some notable updates in 1.9.0 designed to improve your developer experience:

- Changes to Android target support
- New Android source set layout enabled by default
- Preview of the Gradle configuration cache in multiplatform projects

Changes to Android target support

We continue our efforts to stabilize Kotlin Multiplatform. An essential step is to provide first-class support for the Android target. We're excited to announce that in the future, the Android team from Google will provide its own Gradle plugin to support Android in Kotlin Multiplatform.

To open the way for this new solution from Google, we're renaming the android block in the current Kotlin DSL in 1.9.0. Please change all the occurrences of the android block to androidTarget in your build scripts. This is a temporary change that is necessary to free the android name for the upcoming DSL from Google.

The Google plugin will be the preferred way of working with Android in multiplatform projects. When it's ready, we'll provide the necessary migration instructions so that you'll be able to use the short android name as before.

New Android source set layout enabled by default

Starting with Kotlin 1.9.0, the new Android source set layout is the default. It replaced the previous naming schema for directories, which was confusing in multiple ways. The new layout has a number of advantages:

- Simplified type semantics – The new Android source layout provides clear and consistent naming conventions that help to distinguish between different types of source sets.
- Improved source directory layout – With the new layout, the SourceDirectories arrangement becomes more coherent, making it easier to organize code and locate source files.
- Clear naming schema for Gradle configurations – The schema is now more consistent and predictable in both KotlinSourceSets and AndroidSourceSets.

The new layout requires the Android Gradle plugin version 7.0 or later and is supported in Android Studio 2022.3 and later. See our migration guide to make the necessary changes in your build.gradle(.kts) file.

Preview of the Gradle configuration cache

Kotlin 1.9.0 comes with support for the Gradle configuration cache in multiplatform libraries. If you're a library author, you can already benefit from the improved build performance.

The Gradle configuration cache speeds up the build process by reusing the results of the configuration phase for subsequent builds. The feature has become Stable since Gradle 8.1. To enable it, follow the instructions in the Gradle documentation.

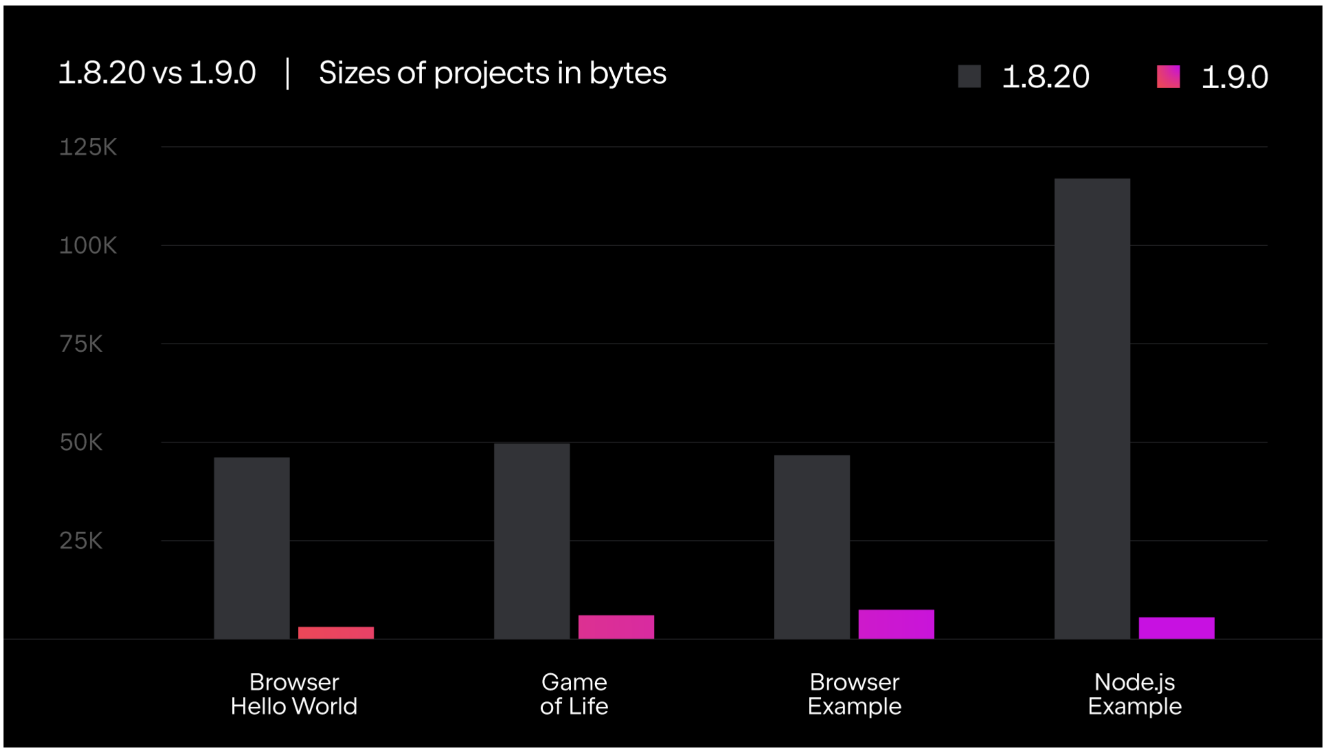
The Kotlin Multiplatform plugin still doesn't support the Gradle configuration cache with Xcode integration tasks or the Kotlin CocoaPods Gradle plugin. We expect to add this feature in future Kotlin releases.

Kotlin/Wasm

The Kotlin team continues to experiment with the new Kotlin/Wasm target. This release introduces several performance and size-related optimizations, along with updates in JavaScript interop.

Size-related optimizations

Kotlin 1.9.0 introduces significant size improvements for WebAssembly (Wasm) projects. Comparing two "Hello World" projects, the code footprint for Wasm in Kotlin 1.9.0 is now over 10 times smaller than in Kotlin 1.8.20.



Kotlin/Wasm size-related optimizations

These size optimizations result in more efficient resource utilization and improved performance when targeting Wasm platforms with Kotlin code.

Updates in JavaScript interop

This Kotlin update introduces changes to the interoperability between Kotlin and JavaScript for Kotlin/Wasm. As Kotlin/Wasm is an Experimental feature, certain limitations apply to its interoperability.

Restriction of Dynamic types

Starting with version 1.9.0, Kotlin no longer supports the use of Dynamic types in Kotlin/Wasm. This is now deprecated in favor of the new universal JsAny type, which facilitates JavaScript interoperability.

For more details, see the Kotlin/Wasm interoperability with JavaScript documentation.

Restriction of non-external types

Kotlin/Wasm supports conversions for specific Kotlin static types when passing values to and from JavaScript. These supported types include:

- Primitives, such as signed numbers, Boolean, and Char.
- String.
- Function types.

Other types were passed without conversion as opaque references, leading to inconsistencies between JavaScript and Kotlin subtyping.

To address this, Kotlin restricts JavaScript interop to a well-supported set of types. Starting from Kotlin 1.9.0, only external, primitive, string, and function types are supported in Kotlin/Wasm JavaScript interop. Furthermore, a separate explicit type called JsReference has been introduced to represent handles to Kotlin/Wasm objects that can be used in JavaScript interop.

For more details, refer to the Kotlin/Wasm interoperability with JavaScript documentation.

Kotlin/Wasm in Kotlin Playground

Kotlin Playground supports the Kotlin/Wasm target. You can write, run, and share your Kotlin code that targets the Kotlin/Wasm. Check it out!

Using Kotlin/Wasm requires enabling experimental features in your browser.

Learn more about how to enable these features.

```kotlin
import kotlin.time.*
import kotlin.time.measureTime

fun main() {
    println("Hello from Kotlin/Wasm!")
    computeAck(3, 10)
}

tailrec fun ack(m: Int, n: Int): Int = when {
    m == 0 -> n + 1
    n == 0 -> ack(m - 1, 1)
    else -> ack(m - 1, ack(m, n - 1))
}

fun computeAck(m: Int, n: Int) {
    var res = 0
    val t = measureTime {
        res = ack(m, n)
    }
    println()
    println("ack($m, $n) = ${res}")
    println("duration: ${t.inWholeNanoseconds / 1e6} ms")
}
```

Kotlin/JS

This release introduces updates for Kotlin/JS, including the removal of the old Kotlin/JS compiler, Kotlin/JS Gradle plugin deprecation and Experimental support for ES2015:

- Removal of the old Kotlin/JS compiler
- Deprecation of the Kotlin/JS Gradle plugin
- Deprecation of external enum
- Experimental support for ES2015 classes and modules
- Changed default destination of JS production distribution
- Extract org.w3c declarations from stdlib-js

Starting from version 1.9.0, partial library linkage is also enabled for Kotlin/JS.

Removal of the old Kotlin/JS compiler

In Kotlin 1.8.0, we announced that the IR-based backend became Stable. Since then, not specifying the compiler has become an error, and using the old compiler leads to warnings.

In Kotlin 1.9.0, using the old backend results in an error. Please migrate to the IR compiler by following our migration guide.

Deprecation of the Kotlin/JS Gradle plugin

Starting with Kotlin 1.9.0, the kotlin-js Gradle plugin is deprecated. We encourage you to use the kotlin-multiplatform Gradle plugin with the js() target instead.

The functionality of the Kotlin/JS Gradle plugin essentially duplicated the kotlin-multiplatform plugin and shared the same implementation under the hood. This overlap created confusion and increased maintenance load on the Kotlin team.

Refer to our Compatibility guide for Kotlin Multiplatform for migration instructions. If you find any issues that aren't covered in the guide, please report them to our issue tracker.

Deprecation of external enum

In Kotlin 1.9.0, the use of external enums will be deprecated due to issues with static enum members like entries, that can't exist outside Kotlin. We recommend using an external sealed class with object subclasses instead:

```kotlin
// Before
external enum class ExternalEnum { A, B }

// After
external sealed class ExternalEnum {
    object A: ExternalEnum
    object B: ExternalEnum
}
```

By switching to an external sealed class with object subclasses, you can achieve similar functionality to external enums while avoiding the problems associated with default methods.

Starting from Kotlin 1.9.0, the use of external enums will be marked as deprecated. We encourage you to update your code to utilize the suggested external sealed class implementation for compatibility and future maintenance.

Experimental support for ES2015 classes and modules

This release introduces Experimental support for ES2015 modules and generation of ES2015 classes:

- Modules offer a way to simplify your codebase and improve maintainability.
- Classes allow you to incorporate object-oriented programming (OOP) principles, resulting in cleaner and more intuitive code.

To enable these features, update your build.gradle.kts file accordingly:

```kotlin
// build.gradle.kts
kotlin {
    js(IR) {
        useEsModules() // Enables ES2015 modules
        browser()
    }
}

// Enables ES2015 classes generation
tasks.withType<KotlinJsCompile>().configureEach {
    kotlinOptions {
        useEsClasses = true
    }
}
```

Learn more about ES2015 (ECMAScript 2015, ES6) in the official documentation.

Changed default destination of JS production distribution

Prior to Kotlin 1.9.0, the distribution target directory was build/distributions. However, this is a common directory for Gradle archives. To resolve this issue, we've changed the default distribution target directory in Kotlin 1.9.0 to: build/dist/<targetName>/<binaryName>.

For example, productionExecutable was in build/distributions. In Kotlin 1.9.0, it's in build/dist/js/productionExecutable.

> If you have a pipeline in place that uses the results of these builds, make sure to update the directory.

Extract org.w3c declarations from stdlib-js

Since Kotlin 1.9.0, the stdlib-js no longer includes org.w3c declarations. Instead, these declarations have been moved to a separate Gradle dependency. When you add the Kotlin Multiplatform Gradle plugin to your build.gradle.kts file, these declarations will be automatically included in your project, similar to the standard library.

There is no need for any manual action or migration. The necessary adjustments will be handled automatically.

Gradle

Kotlin 1.9.0 comes with new Gradle compiler options and a lot more:

- Removed classpath property
- New Gradle compiler options
- Project-level compiler options for Kotlin/JVM
- Compiler option for Kotlin/Native module name
- Separate compiler plugins for official Kotlin libraries
- Incremented minimum supported version
- kapt doesn't cause eager task creation
- Programmatic configuration of the JVM target validation mode

Removed classpath property

In Kotlin 1.7.0, we announced the start of a deprecation cycle for the KotlinCompile task's property: classpath. The deprecation level was raised to ERROR in Kotlin 1.8.0. In this release, we've finally removed the classpath property. All compile tasks should now use the libraries input for a list of libraries required for compilation.

New compiler options

The Kotlin Gradle plugin now provides new properties for opt-ins and the compiler's progressive mode.

- To opt in to new APIs, you can now use the optIn property and pass a list of strings like: optIn.set(listOf(a, b, c)).
- To enable progressive mode, use progressiveMode.set(true).

Project-level compiler options for Kotlin/JVM

Starting with Kotlin 1.9.0, a new compilerOptions block is available inside the kotlin configuration block:

```
kotlin {
    compilerOptions {
        jvmTarget.set(JVM.Target_11)
    }
}
```

It makes configuring compiler options much easier. However, it is important to note some important details:

- This configuration only works on the project level.

- For the Android plugin, this block configures the same object as:

```
android {
    kotlinOptions {}
}
```

- The android.kotlinOptions and kotlin.compilerOptions configuration blocks override each other. The last (lowest) block in the build file always takes effect.
- If moduleName is configured on the project level, its value could be changed when passed to the compiler. It's not the case for the main compilation, but for other types, for example, test sources, the Kotlin Gradle plugin will add the _test suffix.
- The configuration inside the tasks.withType<KotlinJvmCompile>().configureEach {} (or tasks.named<KotlinJvmCompile>("compileKotlin") { }) overrides both kotlin.compilerOptions and android.kotlinOptions.

Compiler option for Kotlin/Native module name

The Kotlin/Native module-name compiler option is now easily available in the Kotlin Gradle plugin.

This option specifies a name for the compilation module and can also be used for adding a name prefix for declarations exported to Objective-C.

You can now set the module name directly in the compilerOptions block of your Gradle build files:

Kotlin

```
tasks.named<org.jetbrains.kotlin.gradle.tasks.KotlinNativeCompile>("compileKotlinLinuxX64") {
    compilerOptions {
        moduleName.set("my-module-name")
    }
}
```

Groovy

```
tasks.named("compileKotlinLinuxX64", org.jetbrains.kotlin.gradle.tasks.KotlinNativeCompile.class) {
    compilerOptions {
        moduleName = "my-module-name"
    }
}
```

Separate compiler plugins for official Kotlin libraries

Kotlin 1.9.0 introduces separate compiler plugins for its official libraries. Previously, compiler plugins were embedded into their corresponding Gradle plugins. This could cause compatibility issues in case the compiler plugin was compiled against a Kotlin version higher than the Gradle build's Kotlin runtime version.

Now compiler plugins are added as separate dependencies, so you'll no longer face compatibility issues with older Gradle versions. Another major advantage of the new approach is that new compiler plugins can be used with other build systems like Bazel.

Here's the list of new compiler plugins we're now publishing to Maven Central:

- kotlin-atomicfu-compiler-plugin
- kotlin-allopen-compiler-plugin
- kotlin-lombok-compiler-plugin
- kotlin-noarg-compiler-plugin
- kotlin-sam-with-receiver-compiler-plugin
- kotlinx-serialization-compiler-plugin

Every plugin has its -embeddable counterpart, for example, kotlin-allopen-compiler-plugin-embeddable is designed for working with the kotlin-compiler-embeddable artifact, the default option for scripting artifacts.

Gradle adds these plugins as compiler arguments. You don't need to make any changes to your existing projects.

Incremented minimum supported version

Starting with Kotlin 1.9.0, the minimum supported Android Gradle plugin version is 4.2.2.

See the Kotlin Gradle plugin's compatibility with available Gradle versions in our documentation.

kapt doesn't cause eager task creation in Gradle

Prior to 1.9.0, the kapt compiler plugin caused eager task creation by requesting the configured instance of the Kotlin compilation task. This behavior has been fixed in Kotlin 1.9.0. If you use the default configuration for your build.gradle.kts file then your setup is not affected by this change.

> If you use a custom configuration, your setup will be adversely affected. For example, if you have modified the KotlinJvmCompile task using Gradle's tasks API, you must similarly modify the KaptGenerateStubs task in your build script.
>
> For example, if your script has the following configuration for the KotlinJvmCompile task:
>
> ```
> tasks.named<KotlinJvmCompile>("compileKotlin") { // Your custom configuration }
> ```
>
> In this case, you need to make sure that the same modification is included as part of the KaptGenerateStubs task:
>
> ```
> tasks.named<KaptGenerateStubs>("kaptGenerateStubs") { // Your custom configuration }
> ```

For more information, see our YouTrack ticket.

Programmatic configuration of the JVM target validation mode

Before Kotlin 1.9.0, there was only one way to adjust the detection of JVM target incompatibility between Kotlin and Java. You had to set kotlin.jvm.target.validation.mode=ERROR in your gradle.properties for the whole project.

You can now also configure it on the task level in your build.gradle.kts file:

```
tasks.named<org.jetbrains.kotlin.gradle.tasks.KotlinJvmCompile>("compileKotlin") {
    jvmTargetValidationMode.set(org.jetbrains.kotlin.gradle.dsl.jvm.JvmTargetValidationMode.WARNING)
}
```

Standard library

Kotlin 1.9.0 has some great improvements for the standard library:

- The ..< operator and time API are Stable.
- The Kotlin/Native standard library has been thoroughly reviewed and updated
- The @Volatile annotation can be used on more platforms
- There's a common function to get a regex capture group by name
- The HexFormat class has been introduced to format and parse hexadecimals

Stable ..< operator for open-ended ranges

The new ..< operator for open-ended ranges that was introduced in Kotlin 1.7.20 and became Stable in 1.8.0. In 1.9.0, the standard library API for working with open-ended ranges is also Stable.

Our research shows that the new ..< operator makes it easier to understand when an open-ended range is declared. If you use the until infix function, it's easy to make the mistake of assuming that the upper bound is included.

Here is an example using the until function:

```
fun main() {
```

```
    for (number in 2 until 10) {
        if (number % 2 == 0) {
            print("$number ")
        }
    }
    // 2 4 6 8
}
```

And here is an example using the new ..< operator:

```
fun main() {
    for (number in 2..<10) {
        if (number % 2 == 0) {
            print("$number ")
        }
    }
    // 2 4 6 8
}
```

From IntelliJ IDEA version 2023.1.1, a new code inspection is available that highlights when you can use the ..< operator.

For more information about what you can do with this operator, see What's new in Kotlin 1.7.20.

Stable time API

Since 1.3.50, we have previewed a new time measurement API. The duration part of the API became Stable in 1.6.0. In 1.9.0, the remaining time measurement API is Stable.

The old time API provided the measureTimeMillis and measureNanoTime functions, which aren't intuitive to use. Although it is clear that they both measure time in different units, it isn't clear that measureTimeMillisuses a wall clock to measure time, whereas measureNanoTime uses a monotonic time source. The new time API resolves this and other issues to make the API more user friendly.

With the new time API, you can easily:

- Measure the time taken to execute some code using a monotonic time source with your desired time unit.
- Mark a moment in time.
- Compare and find the difference between two moments in time.
- Check how much time has passed since a specific moment in time.
- Check whether the current time has passed a specific moment in time.

Measure code execution time

To measure the time taken to execute a block of code, use the measureTime inline function.

To measure the time taken to execute a block of code and return the result of the block of code, use the measureTimedValue inline function.

By default, both functions use a monotonic time source. However, if you want to use an elapsed real-time source, you can. For example, on Android the default time source System.nanoTime() only counts time while the device is active. It loses track of time when the device enters deep sleep. To keep track of time while the device is in deep sleep, you can create a time source that uses SystemClock.elapsedRealtimeNanos() instead:

```
object RealtimeMonotonicTimeSource : AbstractLongTimeSource(DurationUnit.NANOSECONDS) {
    override fun read(): Long = SystemClock.elapsedRealtimeNanos()
}
```

Mark and measure differences in time

To mark a specific moment in time, use the TimeSource interface and the markNow() function to create a TimeMark. To measure differences between TimeMarks from the same time source, use the subtraction operator (-):

```
import kotlin.time.*
```

```
fun main() {
    val timeSource = TimeSource.Monotonic
    val mark1 = timeSource.markNow()
    Thread.sleep(500) // Sleep 0.5 seconds.
    val mark2 = timeSource.markNow()

    repeat(4) { n ->
        val mark3 = timeSource.markNow()
        val elapsed1 = mark3 - mark1
        val elapsed2 = mark3 - mark2

        println("Measurement 1.${n + 1}: elapsed1=$elapsed1, elapsed2=$elapsed2, diff=${elapsed1 - elapsed2}")
    }
    // It's also possible to compare time marks with each other.
    println(mark2 > mark1) // This is true, as mark2 was captured later than mark1.
}
```

To check if a deadline has passed or a timeout has been reached, use the hasPassedNow() and hasNotPassedNow() extension functions:

```
import kotlin.time.*
import kotlin.time.Duration.Companion.seconds

fun main() {
    val timeSource = TimeSource.Monotonic
    val mark1 = timeSource.markNow()
    val fiveSeconds: Duration = 5.seconds
    val mark2 = mark1 + fiveSeconds

    // It hasn't been 5 seconds yet
    println(mark2.hasPassedNow())
    // false

    // Wait six seconds
    Thread.sleep(6000)
    println(mark2.hasPassedNow())
    // true
}
```

The Kotlin/Native standard library's journey towards stabilization

As our standard library for Kotlin/Native continues to grow, we decided that it was time for a complete review to ensure that it meets our high standards. As part of this, we carefully reviewed every existing public signature. For each signature, we considered whether it:

- Has a unique purpose.
- Is consistent with other Kotlin APIs.
- Has similar behavior to its counterpart for the JVM.
- Is future-proof.

Based on these considerations, we made one of the following decisions:

- Made it Stable.
- Made it Experimental.
- Marked it as private.
- Modified its behavior.
- Moved it to a different location.
- Deprecated it.
- Marked it as obsolete.

If an existing signature has been:

- Moved to another package, then the signature still exists in the original package but it's now deprecated with deprecation level: WARNING. IntelliJ IDEA will automatically suggest replacements upon code inspection.
- Deprecated, then it's been deprecated with deprecation level: WARNING.
- Marked as obsolete, then you can keep using it, but it will be replaced in future.

We won't list all of the results of the review here, but here are some of the highlights:

- We stabilized the Atomics API.
- We made kotlinx.cinterop Experimental and now require different opt-ins for the package to be used. For more information, see Explicit C-interoperability stability guarantees.
- We marked the Worker class and its related APIs as obsolete.
- We marked the BitSet class as obsolete.
- We marked all public APIs in the kotlin.native.internal package as private or moved them to other packages.

Explicit C-interoperability stability guarantees

To maintain the high quality of our API, we decided to make kotlinx.cinterop Experimental. Although kotlinx.cinterop has been thoroughly tried and tested, there is still room for improvement before we are satisfied enough to make it Stable. We recommend that you use this API for interoperability but that you try to confine its use to specific areas in your projects. This will make your migration easier once we begin evolving this API to make it Stable.

If you want to use C-like foreign APIs such as pointers, you must opt in with @OptIn(ExperimentalForeignApi), otherwise your code won't compile.

To use the remainder of kotlinx.cinterop, which covers Objective-C/Swift interoperability, you must opt in with @OptIn(BetaInteropApi). If you try to use this API without the opt-in, your code will compile but the compiler will raise warnings that provide a clear explanation of what behavior you can expect.

For more information about these annotations, see our source code for Annotations.kt.

For more information on all of the changes as part of this review, see our YouTrack ticket.

We'd appreciate any feedback you might have! You can provide your feedback directly by commenting on the ticket.

Stable @Volatile annotation

If you annotate a var property with @Volatile, then the backing field is marked so that any reads or writes to this field are atomic, and writes are always made visible to other threads.

Prior to 1.8.20, the kotlin.jvm.Volatile annotation was available in the common standard library. However, this annotation was only effective on the JVM. If you used it on other platforms, it was ignored, which led to errors.

In 1.8.20, we introduced an experimental common annotation, kotlin.concurrent.Volatile, which you could preview in both the JVM and Kotlin/Native.

In 1.9.0, kotlin.concurrent.Volatile is Stable. If you use kotlin.jvm.Volatile in your multiplatform projects, we recommend that you migrate to kotlin.concurrent.Volatile.

New common function to get regex capture group by name

Prior to 1.9.0, every platform had its own extension to get a regular expression capture group by its name from a regular expression match. However there was no common function. It wasn't possible to have a common function prior to Kotlin 1.8.0, because the standard library still supported JVM targets 1.6 and 1.7.

As of Kotlin 1.8.0, the standard library is compiled with JVM target 1.8. So in 1.9.0, there is now a common groups function that you can use to retrieve a group's contents by its name for a regular expression match. This is useful when you want to access the results of regular expression matches belonging to a particular capture group.

Here is an example with a regular expression containing three capture groups: city, state, and areaCode. You can use these group names to access the matched values:

```kotlin
fun main() {
    val regex = """\b(?<city>[A-Za-z\s]+),\s(?<state>[A-Z]{2}):\s(?<areaCode>[0-9]{3})\b""".toRegex()
    val input = "Coordinates: Austin, TX: 123"

    val match = regex.find(input)!!
    println(match.groups["city"]?.value)
    // Austin
    println(match.groups["state"]?.value)
    // TX
    println(match.groups["areaCode"]?.value)
    // 123
}
```

New path utility to create parent directories

In 1.9.0 there is a new createParentDirectories() extension function that you can use to create a new file with all the necessary parent directories. When you provide a file path to createParentDirectories() it checks whether the parent directories already exist. If they do, it does nothing. However, if they do not, it creates them for you.

createParentDirectories() is particularly useful when you are copying files. For example, you can use it in combination with the copyToRecursively() function:

```
sourcePath.copyToRecursively(
   destinationPath.createParentDirectories(),
   followLinks = false
)
```

New HexFormat class to format and parse hexadecimals

> The new HexFormat class and its related extension functions are Experimental, and to use them, you can opt in with @OptIn(ExperimentalStdlibApi::class) or the compiler argument -opt-in=kotlin.ExperimentalStdlibApi.

In 1.9.0, the HexFormat class and its related extension functions are provided as an Experimental feature that allows you to convert between numerical values and hexadecimal strings. Specifically, you can use the extension functions to convert between hexadecimal strings and ByteArrays or other numeric types (Int, Short, Long).

For example:

```
println(93.toHexString()) // "0000005d"
```

The HexFormat class includes formatting options that you can configure with the HexFormat{} builder.

If you are working with ByteArrays you have the following options, which are configurable by properties:

Option	Description
upperCase	Whether hexadecimal digits are upper or lower case. By default, lower case is assumed. upperCase = false.
bytes.bytesPerLine	The maximum number of bytes per line.
bytes.bytesPerGroup	The maximum number of bytes per group.
bytes.bytesSeparator	The separator between bytes. Nothing by default.
bytes.bytesPrefix	The string that immediately precedes a two-digit hexadecimal representation of each byte, nothing by default.

Option	Description
bytes.bytesSuffix	The string that immediately succeeds a two-digit hexadecimal representation of each byte, nothing by default.

For example:

```kotlin
val macAddress = "001b638445e6".hexToByteArray()

// Use HexFormat{} builder to separate the hexadecimal string by colons
println(macAddress.toHexString(HexFormat { bytes.byteSeparator = ":" }))
// "00:1b:63:84:45:e6"

// Use HexFormat{} builder to:
// * Make the hexadecimal string uppercase
// * Group the bytes in pairs
// * Separate by periods
val threeGroupFormat = HexFormat { upperCase = true; bytes.bytesPerGroup = 2; bytes.groupSeparator = "." }

println(macAddress.toHexString(threeGroupFormat))
// "001B.6384.45E6"
```

If you are working with numeric types, you have the following options, which are configurable by properties:

Option	Description
number.prefix	The prefix of a hexadecimal string, nothing by default.
number.suffix	The suffix of a hexadecimal string, nothing by default.
number.removeLeadingZeros	Whether to remove leading zeros in a hexadecimal string. By default, no leading zeros are removed. number.removeLeadingZeros = false

For example:

```kotlin
// Use HexFormat{} builder to parse a hexadecimal that has prefix: "0x".
println("0x3a".hexToInt(HexFormat { number.prefix = "0x" })) // "58"
```

Documentation updates

The Kotlin documentation has received some notable changes:

- The tour of Kotlin – Learn the fundamentals of the Kotlin programming language with chapters including both theory and practice.
- Android source set layout – Learn about the new Android source set layout.
- Compatibility guide for Kotlin Multiplatform – Learn about the incompatible changes you might encounter while developing projects with Kotlin Multiplatform.
- Kotlin Wasm – Learn about Kotlin/Wasm and how you can use it in your Kotlin Multiplatform projects.

Install Kotlin 1.9.0

Check the IDE version

IntelliJ IDEA 2022.3.3 and 2023.1.1 automatically suggest updating the Kotlin plugin to version 1.9.0. IntelliJ IDEA 2023.2 will include the Kotlin 1.9.0 plugin.

Android Studio Giraffe (223) and Hedgehog (231) will support Kotlin 1.9.0 in their upcoming releases.

The new command-line compiler is available for download on the GitHub release page.

Configure Gradle settings

To download Kotlin artifacts and dependencies, update your settings.gradle(.kts) file to use the Maven Central repository:

```
pluginManagement {
    repositories {
        mavenCentral()
        gradlePluginPortal()
    }
}
```

If the repository is not specified, Gradle uses the sunset JCenter repository, which could lead to issues with Kotlin artifacts.

Compatibility guide for Kotlin 1.9.0

Kotlin 1.9.0 is a feature release and can, therefore, bring changes that are incompatible with your code written for earlier versions of the language. Find the detailed list of these changes in the Compatibility guide for Kotlin 1.9.0.

What's new in Kotlin 1.8.20

Released: 25 April 2023

The Kotlin 1.8.20 release is out and here are some of its biggest highlights:

- New Kotlin K2 compiler updates
- New experimental Kotlin/Wasm target
- New JVM incremental compilation by default in Gradle
- Update for Kotlin/Native targets
- Preview of Gradle composite builds in Kotlin Multiplatform
- Improved output for Gradle errors in Xcode
- Experimental support for the AutoCloseable interface in the standard library
- Experimental support for Base64 encoding in the standard library

You can also find a short overview of the changes in this video:

Watch video online.

IDE support

The Kotlin plugins that support 1.8.20 are available for:

IDE	Supported versions
IntelliJ IDEA	2022.2.x, 2022.3.x, 2023.1.x
Android Studio	Flamingo (222)

To download Kotlin artifacts and dependencies properly, configure Gradle settings to use the Maven Central repository.

New Kotlin K2 compiler updates

The Kotlin team continues to stabilize the K2 compiler. As mentioned in the Kotlin 1.7.0 announcement, it's still in Alpha. This release introduces further improvements on the road to K2 Beta.

Starting with this 1.8.20 release, the Kotlin K2 compiler:

- Has a preview version of the serialization plugin.
- Provides Alpha support for the JS IR compiler.
- Introduces the future release of the new language version, Kotlin 2.0.

Learn more about the new compiler and its benefits in the following videos:

- What Everyone Must Know About The NEW Kotlin K2 Compiler

- The New Kotlin K2 Compiler: Expert Review

How to enable the Kotlin K2 compiler

To enable and test the Kotlin K2 compiler, use the new language version with the following compiler option:

```
-language-version 2.0
```

You can specify it in your build.gradle(.kts) file:

```
kotlin {
   sourceSets.all {
       languageSettings {
           languageVersion = "2.0"
       }
   }
}
```

The previous -Xuse-k2 compiler option has been deprecated.

> The Alpha version of the new K2 compiler only works with JVM and JS IR projects. It doesn't support Kotlin/Native or any of the multiplatform projects yet.

Leave your feedback on the new K2 compiler

We would appreciate any feedback you may have!

- Provide your feedback directly to K2 developers on Kotlin Slack – get an invite and join the #k2-early-adopters channel.
- Report any problems you faced with the new K2 compiler on our issue tracker.
- Enable the Send usage statistics option to allow JetBrains to collect anonymous data about K2 usage.

Language

As Kotlin continues to evolve, we're introducing preview versions for new language features in 1.8.20:

- A modern and performant replacement of the Enum class values function
- Data objects for symmetry with data classes
- Lifting restrictions on secondary constructors with bodies in inline classes

A modern and performant replacement of the Enum class values function

> This feature is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below). Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Enum classes have a synthetic values() function, which returns an array of defined enum constants. However, using an array can lead to hidden performance issues in Kotlin and Java. In addition, most of the APIs use collections, which require eventual conversion. To fix these problems, we've introduced the entries property for Enum classes, which should be used instead of the values() function. When called, the entries property returns a pre-allocated immutable list of defined enum constants.

> The values() function is still supported, but we recommend that you use the entries property instead.

```
enum class Color(val colorName: String, val rgb: String) {
    RED("Red", "#FF0000"),
    ORANGE("Orange", "#FF7F00"),
    YELLOW("Yellow", "#FFFF00")
}

@OptIn(ExperimentalStdlibApi::class)
fun findByRgb(rgb: String): Color? = Color.entries.find { it.rgb == rgb }
```

How to enable the entries property

To try this feature out, opt in with @OptIn(ExperimentalStdlibApi) and enable the -language-version 1.9 compiler option. In a Gradle project, you can do so by adding the following to your build.gradle(.kts) file:

Kotlin

```
tasks
    .withType<org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask<*>>()
    .configureEach {
        compilerOptions
            .languageVersion
            .set(
                org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9
            )
    }
```

Groovy

```
tasks
    .withType(org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask.class)
    .configureEach {
        compilerOptions.languageVersion =
            org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9
    }
```

Starting with IntelliJ IDEA 2023.1, if you have opted in to this feature, the appropriate IDE inspection will notify you about converting from values() to entries and offer a quick-fix.

For more information on the proposal, see the KEEP note.

Preview of data objects for symmetry with data classes

Data objects allow you to declare objects with singleton semantics and a clean toString() representation. In this snippet, you can see how adding the data keyword to an object declaration improves the readability of its toString() output:

```
package org.example
object MyObject
data object MyDataObject

fun main() {
    println(MyObject) // org.example.MyObject@1f32e575
    println(MyDataObject) // MyDataObject
}
```

Especially for sealed hierarchies (like a sealed class or sealed interface hierarchy), data objects are an excellent fit because they can be used conveniently alongside data class declarations. In this snippet, declaring EndOfFile as a data object instead of a plain object means that it will get a pretty toString without the need to override it manually. This maintains symmetry with the accompanying data class definitions.

```
sealed interface ReadResult
data class Number(val number: Int) : ReadResult
data class Text(val text: String) : ReadResult
data object EndOfFile : ReadResult

fun main() {
    println(Number(7)) // Number(number=7)
    println(EndOfFile) // EndOfFile
}
```

Semantics of data objects

Since their first preview version in Kotlin 1.7.20, the semantics of data objects have been refined. The compiler now automatically generates a number of convenience functions for them:

toString

The toString() function of a data object returns the simple name of the object:

```
data object MyDataObject {
    val x: Int = 3
}

fun main() {
    println(MyDataObject) // MyDataObject
}
```

equals and hashCode

The equals() function for a data object ensures that all objects that have the type of your data object are considered equal. In most cases, you will only have a single instance of your data object at runtime (after all, a data object declares a singleton). However, in the edge case where another object of the same type is generated at runtime (for example, via platform reflection through java.lang.reflect, or by using a JVM serialization library that uses this API under the hood), this ensures that the objects are treated as equal.

Make sure to only compare data objects structurally (using the == operator) and never by reference (the === operator). This helps avoid pitfalls when more than one instance of a data object exists at runtime. The following snippet illustrates this specific edge case:

```
import java.lang.reflect.Constructor

data object MySingleton

fun main() {
    val evilTwin = createInstanceViaReflection()

    println(MySingleton) // MySingleton
    println(evilTwin) // MySingleton

    // Even when a library forcefully creates a second instance of MySingleton, its `equals` method returns true:
    println(MySingleton == evilTwin) // true

    // Do not compare data objects via ===.
    println(MySingleton === evilTwin) // false
}

fun createInstanceViaReflection(): MySingleton {
    // Kotlin reflection does not permit the instantiation of data objects.
    // This creates a new MySingleton instance "by force" (i.e., Java platform reflection)
    // Don't do this yourself!
    return (MySingleton.javaClass.declaredConstructors[0].apply { isAccessible = true } as Constructor<MySingleton>).newInstance()
}
```

The behavior of the generated hashCode() function is consistent with that of the equals() function, so that all runtime instances of a data object have the same hash code.

No copy and componentN functions for data objects

While data object and data class declarations are often used together and have some similarities, there are some functions that are not generated for a data object:

Because a data object declaration is intended to be used as a singleton object, no copy() function is generated. The singleton pattern restricts the instantiation of a class to a single instance, and allowing copies of the instance to be created would violate that restriction.

Also, unlike a data class, a data object does not have any data properties. Since attempting to destructure such an object would not make sense, no componentN() functions are generated.

We would appreciate your feedback on this feature in YouTrack.

How to enable the data objects preview

To try this feature out, enable the -language-version 1.9 compiler option. In a Gradle project, you can do so by adding the following to your build.gradle(.kts) file:

Kotlin

```
tasks
    .withType<org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask<*>>()
    .configureEach {
        compilerOptions
            .languageVersion
            .set(
                org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9
            )
    }
```

Groovy

```
tasks
    .withType(org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask.class)
    .configureEach {
        compilerOptions.languageVersion =
            org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9
    }
```

Preview of lifting restriction on secondary constructors with bodies in inline classes

This feature is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below). Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Kotlin 1.8.20 lifts restrictions on the use of secondary constructors with bodies in inline classes.

Inline classes used to allow only a public primary constructor without init blocks or secondary constructors to have clear initialization semantics. As a result, it was impossible to encapsulate underlying values or create an inline class that would represent some constrained values.

These issues were fixed when Kotlin 1.4.30 lifted restrictions on init blocks. Now we're taking it a step further and allowing secondary constructors with bodies in preview mode:

```
@JvmInline
value class Person(private val fullName: String) {
    // Allowed since Kotlin 1.4.30:
    init {
        check(fullName.isNotBlank()) {
            "Full name shouldn't be empty"
        }
    }

    // Preview available since Kotlin 1.8.20:
    constructor(name: String, lastName: String) : this("$name $lastName") {
        check(lastName.isNotBlank()) {
            "Last name shouldn't be empty"
        }
    }
}
```

How to enable secondary constructors with bodies

To try this feature out, enable the -language-version 1.9 compiler option. In a Gradle project, you can do so by adding the following to your build.gradle(.kts):

Kotlin

```
tasks
    .withType<org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask<*>>()
    .configureEach {
        compilerOptions
            .languageVersion
            .set(
                org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9
            )
    }
```

Groovy

```
tasks
    .withType(org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask.class)
    .configureEach {
        compilerOptions.languageVersion =
            org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9
    }
```

We encourage you to try this feature out and submit all reports in YouTrack to help us make it the default in Kotlin 1.9.0.

Learn more about the development of Kotlin inline classes in this KEEP.

New Kotlin/Wasm target

Kotlin/Wasm (Kotlin WebAssembly) goes Experimental in this release. The Kotlin team finds WebAssembly to be a promising technology and wants to find better ways for you to use it and get all of the benefits of Kotlin.

WebAssembly binary format is independent of the platform because it runs using its own virtual machine. Almost all modern browsers already support WebAssembly 1.0. To set up the environment to run WebAssembly, you only need to enable an experimental garbage collection mode that Kotlin/Wasm targets. You can find detailed instructions here: How to enable Kotlin/Wasm.

We want to highlight the following advantages of the new Kotlin/Wasm target:

- Faster compilation speed compared to the wasm32 Kotlin/Native target, since Kotlin/Wasm doesn't have to use LLVM.
- Easier interoperability with JS and integration with browsers compared to the wasm32 target, thanks to the Wasm garbage collection.
- Potentially faster application startup compared to Kotlin/JS and JavaScript because Wasm has a compact and easy-to-parse bytecode.
- Improved application runtime performance compared to Kotlin/JS and JavaScript because Wasm is a statically typed language.

Starting with the 1.8.20 release, you can use Kotlin/Wasm in your experimental projects. We provide the Kotlin standard library (stdlib) and test library (kotlin.test) for Kotlin/Wasm out of the box. IDE support will be added in future releases.

Learn more about Kotlin/Wasm in this YouTube video.

How to enable Kotlin/Wasm

To enable and test Kotlin/Wasm, update your build.gradle.kts file:

```
plugins {
    kotlin("multiplatform") version "1.8.20"
}

kotlin {
    wasm {
        binaries.executable()
        browser {
        }
    }
    sourceSets {
        val commonMain by getting
        val commonTest by getting {
            dependencies {
                implementation(kotlin("test"))
            }
        }
        val wasmMain by getting
        val wasmTest by getting
    }
}
```

Check out the GitHub repository with Kotlin/Wasm examples.

To run a Kotlin/Wasm project, you need to update the settings of the target environment:

Chrome

- For version 109:

  Run the application with the --js-flags=--experimental-wasm-gc command line argument.

- For version 110 or later:

  1. Go to chrome://flags/#enable-webassembly-garbage-collection in your browser.
  2. Enable WebAssembly Garbage Collection.
  3. Relaunch your browser.

Firefox

For version 109 or later:

1. Go to about:config in your browser.
2. Enable javascript.options.wasm_function_references and javascript.options.wasm_gc options.
3. Relaunch your browser.

Edge

For version 109 or later:

Run the application with the --js-flags=--experimental-wasm-gc command line argument.

Leave your feedback on Kotlin/Wasm

We would appreciate any feedback you may have!

- Provide your feedback directly to developers in Kotlin Slack – get an invite and join the #webassembly channel.
- Report any problems you faced with Kotlin/Wasm on this YouTrack issue.

Kotlin/JVM

Kotlin 1.8.20 introduces a preview of Java synthetic property references and support for the JVM IR backend in the kapt stub generating task by default.

Preview of Java synthetic property references

This feature is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Kotlin 1.8.20 introduces the ability to create references to Java synthetic properties, for example, for such Java code:

```
public class Person {
    private String name;
    private int age;

    public Person(String name, int age) {
        this.name = name;
        this.age = age;
    }

    public String getName() {
        return name;
    }

    public int getAge() {
        return age;
    }
}
```

Kotlin has always allowed you to write person.age, where age is a synthetic property. Now, you can also create references to Person::age and person::age. All the same works for name, as well.

```kotlin
val persons = listOf(Person("Jack", 11), Person("Sofie", 12), Person("Peter", 11))
    persons
        // Call a reference to Java synthetic property:
        .sortedBy(Person::age)
        // Call Java getter via the Kotlin property syntax:
        .forEach { person -> println(person.name) }
```

How to enable Java synthetic property references

To try this feature out, enable the -language-version 1.9 compiler option. In a Gradle project, you can do so by adding the following to your build.gradle(.kts):

Kotlin

```kotlin
tasks
    .withType<org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask<*>>()
    .configureEach {
        compilerOptions
            .languageVersion
            .set(
                org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9
            )
    }
```

Groovy

```groovy
tasks
    .withType(org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask.class)
    .configureEach {
        compilerOptions.languageVersion =
            org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9
    }
```

Support for the JVM IR backend in kapt stub generating task by default

In Kotlin 1.7.20, we introduced support for the JVM IR backend in the kapt stub generating task. Starting with this release, this support works by default. You no longer need to specify kapt.use.jvm.ir=true in your gradle.properties to enable it. We would appreciate your feedback on this feature in YouTrack.

Kotlin/Native

Kotlin 1.8.20 includes changes to supported Kotlin/Native targets, interoperability with Objective-C, and improvements to the CocoaPods Gradle plugin, among other updates:

- Update for Kotlin/Native targets
- Deprecation of the legacy memory manager
- Support for Objective-C headers with @import directives
- Support for link-only mode in the Cocoapods Gradle plugin
- Import Objective-C extensions as class members in UIKit
- Reimplementation of compiler cache management in the compiler
- Deprecation of useLibraries() in Cocoapods Gradle plugin

Update for Kotlin/Native targets

The Kotlin team decided to revisit the list of targets supported by Kotlin/Native, split them into tiers, and deprecate some of them starting with Kotlin 1.8.20. See the Kotlin/Native target support section for the full list of supported and deprecated targets.

The following targets have been deprecated with Kotlin 1.8.20 and will be removed in 1.9.20:

- iosArm32
- watchosX86
- wasm32
- mingwX86
- linuxArm32Hfp
- linuxMips32
- linuxMipsel32

As for the remaining targets, there are now three tiers of support depending on how well a target is supported and tested in the Kotlin/Native compiler. A target can be moved to a different tier. For example, we'll do our best to provide full support for iosArm64 in the future, as it is important for Kotlin Multiplatform.

If you're a library author, these target tiers can help you decide which targets to test on CI tools and which ones to skip. The Kotlin team will use the same approach when developing official Kotlin libraries, like kotlinx.coroutines.

Check out our blog post to learn more about the reasons for these changes.

Deprecation of the legacy memory manager

Starting with 1.8.20, the legacy memory manager is deprecated and will be removed in 1.9.20. The new memory manager was enabled by default in 1.7.20 and has been receiving further stability updates and performance improvements.

If you're still using the legacy memory manager, remove the kotlin.native.binary.memoryModel=strict option from your gradle.properties and follow our Migration guide to make the necessary changes.

The new memory manager doesn't support the wasm32 target. This target is also deprecated starting with this release and will be removed in 1.9.20.

Support for Objective-C headers with @import directives

This feature is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below). Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Kotlin/Native can now import Objective-C headers with @import directives. This feature is useful for consuming Swift libraries that have auto-generated Objective-C headers or classes of CocoaPods dependencies written in Swift.

Previously, the cinterop tool failed to analyze headers that depended on Objective-C modules via the @import directive. The reason was that it lacked support for the -fmodules option.

Starting with Kotlin 1.8.20, you can use Objective-C headers with @import. To do so, pass the -fmodules option to the compiler in the definition file as compilerOpts. If you use CocoaPods integration, specify the cinterop option in the configuration block of the pod() function like this:

```
kotlin {
    ios()

    cocoapods {
        summary = "CocoaPods test library"
        homepage = "https://github.com/JetBrains/kotlin"

        ios.deploymentTarget = "13.5"

        pod("PodName") {
            extraOpts = listOf("-compiler-option", "-fmodules")
        }
    }
}
```

This was a highly awaited feature, and we welcome your feedback about it in YouTrack to help us make it the default in future releases.

Support for the link-only mode in Cocoapods Gradle plugin

With Kotlin 1.8.20, you can use Pod dependencies with dynamic frameworks only for linking, without generating cinterop bindings. This may come in handy when cinterop bindings are already generated.

Consider a project with 2 modules, a library and an app. The library depends on a Pod but doesn't produce a framework, only a .klib. The app depends on the library and produces a dynamic framework. In this case, you need to link this framework with the Pods that the library depends on, but you don't need cinterop bindings because they are already generated for the library.

To enable the feature, use the linkOnly option or a builder property when adding a dependency on a Pod:

```
cocoapods {
    summary = "CocoaPods test library"
    homepage = "https://github.com/JetBrains/kotlin"

    pod("Alamofire", linkOnly = true) {
        version = "5.7.0"
    }
}
```

If you use this option with static frameworks, it will remove the Pod dependency entirely because Pods are not used for static framework linking.

Import Objective-C extensions as class members in UIKit

Since Xcode 14.1, some methods from Objective-C classes have been moved to category members. That led to the generation of a different Kotlin API, and these methods were imported as Kotlin extensions instead of methods.

You may have experienced issues resulting from this when overriding methods using UIKit. For example, it became impossible to override drawRect() or layoutSubviews() methods when subclassing a UIVIew in Kotlin.

Since 1.8.20, category members that are declared in the same headers as NSView and UIView classes are imported as members of these classes. This means that the methods subclassing from NSView and UIView can be easily overridden, like any other method.

If everything goes well, we're planning to enable this behavior by default for all of the Objective-C classes.

Reimplementation of compiler cache management in the compiler

To speed up the evolution of compiler caches, we've moved compiler cache management from the Kotlin Gradle plugin to the Kotlin/Native compiler. This unblocks work on several important improvements, including those to do with compilation times and compiler cache flexibility.

If you encounter some problem and need to return to the old behavior, use the kotlin.native.cacheOrchestration=gradle Gradle property.

We would appreciate your feedback on this in YouTrack.

Deprecation of useLibraries() in Cocoapods Gradle plugin

Kotlin 1.8.20 starts the deprecation cycle of the useLibraries() function used in the CocoaPods integration for static libraries.

We introduced the useLibraries() function to allow dependencies on Pods containing static libraries. With time, this case has become very rare. Most of the Pods are distributed by sources, and Objective-C frameworks or XCFrameworks are a common choice for binary distribution.

Since this function is unpopular and it creates issues that complicate the development of the Kotlin CocoaPods Gradle plugin, we've decided to deprecate it.

For more information on frameworks and XCFrameworks, see Build final native binaries.

Kotlin Multiplatform

Kotlin 1.8.20 strives to improve the developer experience with the following updates to Kotlin Multiplatform:

- New approach for setting up source set hierarchy

- Preview of Gradle composite builds support in Kotlin Multiplatform
- Improved output for Gradle errors in Xcode

New approach to source set hierarchy

> The new approach to source set hierarchy is Experimental. It may be changed in future Kotlin releases without prior notice. Opt-in is required (see the details below). We would appreciate your feedback in YouTrack.

Kotlin 1.8.20 offers a new way of setting up source set hierarchy in your multiplatform projects – the default target hierarchy. The new approach is intended to replace target shortcuts like ios, which have their design flaws.

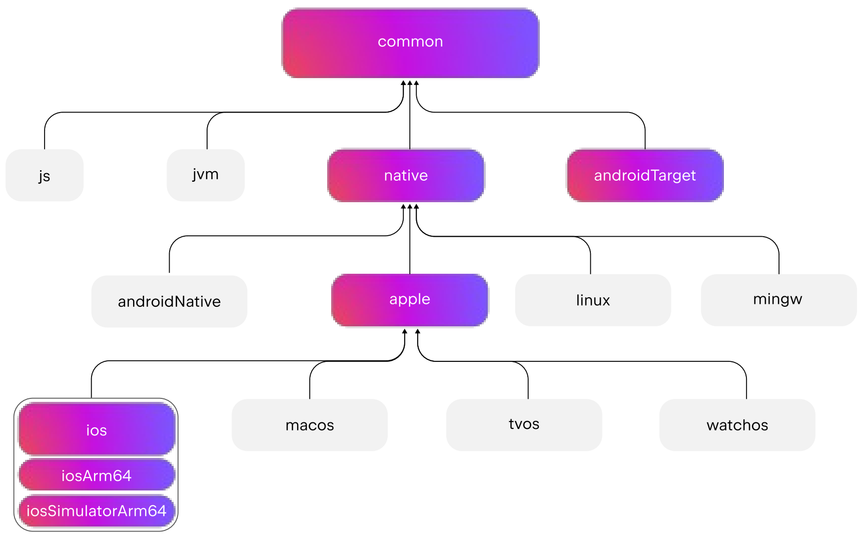
The idea behind the default target hierarchy is simple: You explicitly declare all the targets to which your project compiles, and the Kotlin Gradle plugin automatically creates shared source sets based on the specified targets.

Set up your project

Consider this example of a simple multiplatform mobile app:

```
@OptIn(ExperimentalKotlinGradlePluginApi::class)
kotlin {
    // Enable the default target hierarchy:
    targetHierarchy.default()

    android()
    iosArm64()
    iosSimulatorArm64()
}
```

You can think of the default target hierarchy as a template for all possible targets and their shared source sets. When you declare the final targets android, iosArm64, and iosSimulatorArm64 in your code, the Kotlin Gradle plugin finds suitable shared source sets from the template and creates them for you. The resulting hierarchy looks like this:



An example of using the default target hierarchy

Green source sets are actually created and present in the project, while gray ones from the default template are ignored. As you can see, the Kotlin Gradle plugin hasn't created the watchos source set, for example, because there are no watchOS targets in the project.

If you add a watchOS target, such as watchosArm64, the watchos source set is created, and the code from the apple, native, and common source sets is compiled to watchosArm64, as well.

You can find the complete scheme for the default target hierarchy in the documentation.

> In this example, the apple and native source sets compile only to the iosArm64 and iosSimulatorArm64 targets. Therefore, despite their names, they have access to the full iOS API. This might be counter-intuitive for source sets like native, as you may expect that only APIs available on all native targets are accessible in this source set. This behavior may change in the future.

Why replace shortcuts

Creating source sets hierarchies can be verbose, error-prone, and unfriendly for beginners. Our previous solution was to introduce shortcuts like ios that create a part of the hierarchy for you. However, working with shortcuts proved they have a big design flaw: they're difficult to change.

Take the ios shortcut, for example. It creates only the iosArm64 and iosX64 targets, which can be confusing and may lead to issues when working on an M1-based host that requires the iosSimulatorArm64 target as well. However, adding the iosSimulatorArm64 target can be a very disruptive change for user projects:

- All dependencies used in the iosMain source set have to support the iosSimulatorArm64 target; otherwise, the dependency resolution fails.
- Some native APIs used in iosMain may disappear when adding a new target (though this is unlikely in the case of iosSimulatorArm64).
- In some cases, such as when writing a small pet project on your Intel-based MacBook, you might not even need this change.

It became clear that shortcuts didn't solve the problem of configuring hierarchies, which is why we stopped adding new shortcuts at some point.

The default target hierarchy may look similar to shortcuts at first glance, but they have a crucial distinction: users have to explicitly specify the set of targets. This set defines how your project is compiled and published and how it participates in dependency resolution. Since this set is fixed, changes to the default configuration from the Kotlin Gradle plugin should cause significantly less distress in the ecosystem, and it will be much easier to provide tooling-assisted migration.

How to enable the default hierarchy

This new feature is Experimental. For Kotlin Gradle build scripts, you need to opt in with @OptIn(ExperimentalKotlinGradlePluginApi::class).

For more information, see Hierarchical project structure.

Leave feedback

This is a significant change to multiplatform projects. We would appreciate your feedback to help make it even better.

Preview of Gradle composite builds support in Kotlin Multiplatform

> This feature has been supported in Gradle builds since Kotlin Gradle Plugin 1.8.20. For IDE support, use IntelliJ IDEA 2023.1 Beta 2 (231.8109.2) or later and the Kotlin Gradle plugin 1.8.20 with any Kotlin IDE plugin.

Starting with 1.8.20, Kotlin Multiplatform supports Gradle composite builds. Composite builds allow you to include builds of separate projects or parts of the same project into a single build.

Due to some technical challenges, using Gradle composite builds with Kotlin Multiplatform was only partially supported. Kotlin 1.8.20 contains a preview of the improved support that should work with a larger variety of projects. To try it out, add the following option to your gradle.properties:

```
kotlin.mpp.import.enableKgpDependencyResolution=true
```

This option enables a preview of the new import mode. Besides the support for composite builds, it provides a smoother import experience in multiplatform projects, as we've included major bug fixes and improvements to make the import more stable.

Known issues

It's still a preview version that needs further stabilization, and you might encounter some issues with import along the way. Here are some known issues we're planning to fix before the final release of Kotlin 1.8.20:

- There's no Kotlin 1.8.20 plugin available for IntelliJ IDEA 2023.1 EAP yet. Despite that, you can still set the Kotlin Gradle plugin version to 1.8.20 and try out composite builds in this IDE.

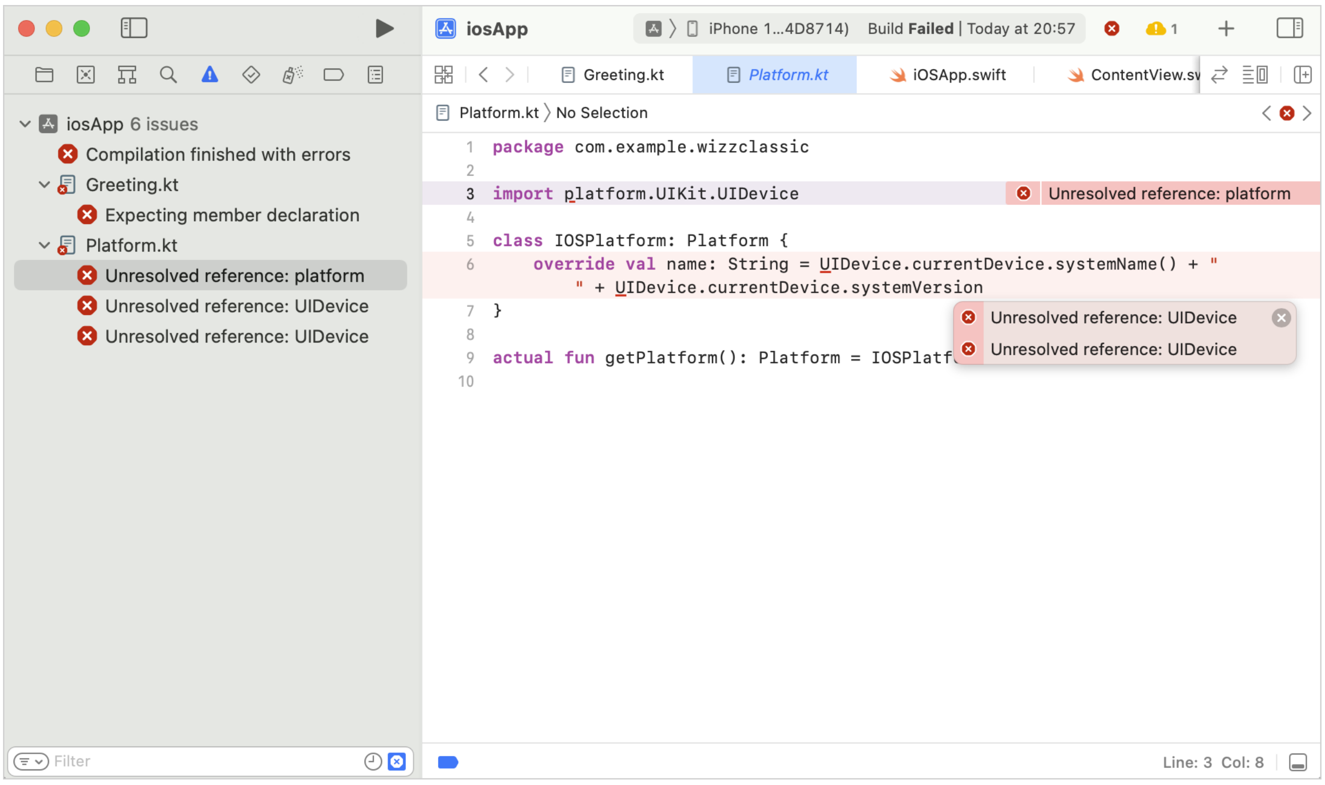
- If your projects include builds with a specified rootProject.name, composite builds may fail to resolve the Kotlin metadata. For the workaround and details, see this Youtrack issue.

We encourage you to try it out and submit all reports on YouTrack to help us make it the default in Kotlin 1.9.0.

Improved output for Gradle errors in Xcode

If you had issues building your multiplatform projects in Xcode, you might have encountered a "Command PhaseScriptExecution failed with a nonzero exit code" error. This message signals that the Gradle invocation has failed, but it's not very helpful when trying to detect the problem.

Starting with Kotlin 1.8.20, Xcode can parse the output from the Kotlin/Native compiler. Furthermore, in case the Gradle build fails, you'll see an additional error message from the root cause exception in Xcode. In most cases, it'll help to identify the root problem.



iosApp 6 issues
- Compilation finished with errors
- Greeting.kt
  - Expecting member declaration
- Platform.kt
  - Unresolved reference: platform
  - Unresolved reference: UIDevice
  - Unresolved reference: UIDevice

```
package com.example.wizzclassic

import platform.UIKit.UIDevice                    Unresolved reference: platform

class IOSPlatform: Platform {
    override val name: String = UIDevice.currentDevice.systemName() + "
        " + UIDevice.currentDevice.systemVersion
}

actual fun getPlatform(): Platform = IOSPlatf
```

Unresolved reference: UIDevice
Unresolved reference: UIDevice

Improved output for Gradle errors in Xcode

The new behavior is enabled by default for the standard Gradle tasks for Xcode integration, like embedAndSignAppleFrameworkForXcode that can connect the iOS framework from your multiplatform project to the iOS application in Xcode. It can also be enabled (or disabled) with the kotlin.native.useXcodeMessageStyle Gradle property.

Kotlin/JavaScript

Kotlin 1.8.20 changes the ways TypeScript definitions can be generated. It also includes a change designed to improve your debugging experience:

- Removal of Dukat integration from the Gradle plugin
- Kotlin variable and function names in source maps
- Opt in for generation of TypeScript definition files

Removal of Dukat integration from Gradle plugin

In Kotlin 1.8.20, we've removed our Experimental Dukat integration from the Kotlin/JavaScript Gradle plugin. The Dukat integration supported the automatic conversion of TypeScript declaration files (.d.ts) into Kotlin external declarations.

You can still convert TypeScript declaration files (.d.ts) into Kotlin external declarations by using our Dukat tool instead.

The Dukat tool is Experimental. It may be dropped or changed at any time.

Kotlin variable and function names in source maps

To help with debugging, we've introduced the ability to add the names that you declared in Kotlin code for variables and functions into your source maps. Prior to 1.8.20, these weren't available in source maps, so in the debugger, you always saw the variable and function names of the generated JavaScript.

You can configure what is added by using sourceMapNamesPolicy in your Gradle file build.gradle.kts, or the -source-map-names-policy compiler option. The table below lists the possible settings:

Setting	Description	Example output
simple-names	Variable names and simple function names are added. (Default)	main
fully-qualified-names	Variable names and fully qualified function names are added.	com.example.kjs.playground.main
no	No variable or function names are added.	N/A

See below for an example configuration in a build.gradle.kts file:

```
tasks.withType<org.jetbrains.kotlin.gradle.tasks.Kotlin2JsCompile>().configureEach {

compilercompileOptions.sourceMapNamesPolicy.set(org.jetbrains.kotlin.gradle.dsl.JsSourceMapNamesPolicy.SOURCE_MAP_NAMES_POLICY_FQ_NAMES
// or SOURCE_MAP_NAMES_POLICY_NO, or SOURCE_MAP_NAMES_POLICY_SIMPLE_NAMES
}
```

Debugging tools like those provided in Chromium-based browsers can pick up the original Kotlin names from your source map to improve the readability of your stack trace. Happy debugging!

The addition of variable and function names in source maps is Experimental. It may be dropped or changed at any time.

Opt in for generation of TypeScript definition files

Previously, if you had a project that produced executable files (binaries.executable()), the Kotlin/JS IR compiler collected any top-level declarations marked with @JsExport and automatically generated TypeScript definitions in a .d.ts file.

As this isn't useful for every project, we've changed the behavior in Kotlin 1.8.20. If you want to generate TypeScript definitions, you have to explicitly configure this in your Gradle build file. Add generateTypeScriptDefinitions() to your build.gradle.kts.file in the js section. For example:

```
kotlin {
    js {
        binaries.executable()
        browser {
        }
        generateTypeScriptDefinitions()
    }
}
```

The generation of TypeScript definitions (d.ts) is Experimental. It may be dropped or changed at any time.

Gradle

Kotlin 1.8.20 is fully compatible with Gradle 6.8 through 7.6 except for some special cases in the Multiplatform plugin. You can also use Gradle versions up to the latest Gradle release, but if you do, keep in mind that you might encounter deprecation warnings or some new Gradle features might not work.

This version brings the following changes:

- New alignment of Gradle plugins' versions
- New JVM incremental compilation by default in Gradle
- Precise backup of compilation tasks' outputs
- Lazy Kotlin/JVM task creation for all Gradle versions
- Non-default location of compile tasks' destinationDirectory
- Ability to opt-out from reporting compiler arguments to an HTTP statistics service

New Gradle plugins versions alignment

Gradle provides a way to ensure dependencies that must work together are always aligned in their versions. Kotlin 1.8.20 adopted this approach, too. It works by default so that you don't need to change or update your configuration to enable it. In addition, you no longer need to resort to this workaround for resolving Kotlin Gradle plugins' transitive dependencies.

We would appreciate your feedback on this feature in YouTrack.

New JVM incremental compilation by default in Gradle

The new approach to incremental compilation, which has been available since Kotlin 1.7.0, now works by default. You no longer need to specify kotlin.incremental.useClasspathSnapshot=true in your gradle.properties to enable it.

We would appreciate your feedback on this. You can file an issue in YouTrack.

Precise backup of compilation tasks' outputs

> Precise backup of compilation tasks' outputs is Experimental. To use it, add kotlin.compiler.preciseCompilationResultsBackup=true to gradle.properties. We would appreciate your feedback on it in YouTrack.

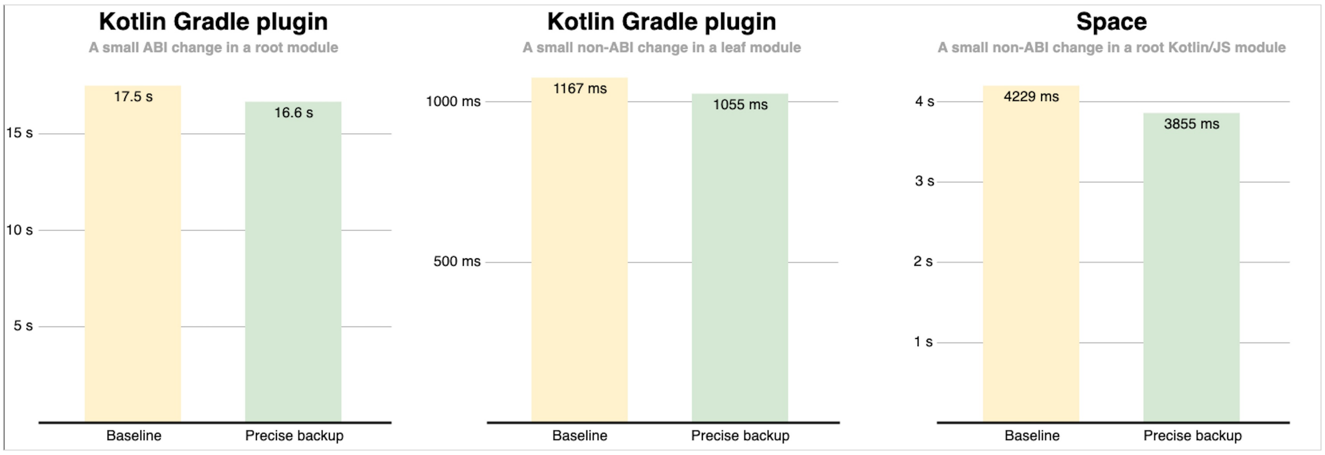
Starting with Kotlin 1.8.20, you can enable precise backup, whereby only those classes that Kotlin recompiles in the incremental compilation will be backed up. Both full and precise backups help to run builds incrementally again after compilation errors. Precise backup also saves build time compared to full backup. Full backup may take noticeable build time in large projects or if many tasks are making backups, especially if a project is located on a slow HDD.

This optimization is Experimental. You can enable it by adding the kotlin.compiler.preciseCompilationResultsBackup Gradle property to the gradle.properties file:

```
kotlin.compiler.preciseCompilationResultsBackup=true
```

Example of precise backup usage in JetBrains

In the following charts, you can see examples of using precise backup compared to full backup:



Comparison of full and precise backups

The first and second charts show how precise backup in the Kotlin project affects building the Kotlin Gradle plugin:

1. After making a small ABI change – adding a new public method – to a module that lots of modules depend on.
2. After making a small non-ABI change – adding a private function – to a module that no other modules depend on.

The third chart shows how precise backup in the Space project affects building a web frontend after a small non-ABI change – adding a private function – to a Kotlin/JS module that lots of modules depend on.

These measurements were performed on a computer with the Apple M1 Max CPU; different computers will yield slightly different results. The factors affecting performance include but are not limited to:

- How warm the Kotlin daemon and the Gradle daemon are.
- How fast or slow the disk is.
- The CPU model and how busy it is.
- Which modules are affected by the changes and how big these modules are.
- Whether the changes are ABI or non-ABI.

Evaluating optimizations with build reports

To estimate the impact of the optimization on your computer for your project and your scenarios, you can use Kotlin build reports. Enable reports in the text file format by adding the following property to your gradle.properties file:

```
kotlin.build.report.output=file
```

Here is an example of a relevant part of the report before enabling precise backup:

```
Task ':kotlin-gradle-plugin:compileCommonKotlin' finished in 0.59 s
<...>
Time metrics:
 Total Gradle task time: 0.59 s
 Task action before worker execution: 0.24 s
  Backup output: 0.22 s // Pay attention to this number
<...>
```

And here is an example of a relevant part of the report after enabling precise backup:

```
Task ':kotlin-gradle-plugin:compileCommonKotlin' finished in 0.46 s
<...>
Time metrics:
 Total Gradle task time: 0.46 s
 Task action before worker execution: 0.07 s
  Backup output: 0.05 s // The time has reduced
 Run compilation in Gradle worker: 0.32 s
```

```
  Clear jar cache: 0.00 s
  Precise backup output: 0.00 s // Related to precise backup
  Cleaning up the backup stash: 0.00 s // Related to precise backup
<...>
```

Lazy Kotlin/JVM tasks creation for all Gradle versions

For projects with the org.jetbrains.kotlin.gradle.jvm plugin on Gradle 7.3+, the Kotlin Gradle plugin no longer creates and configures the task compileKotlin eagerly. On lower Gradle versions, it simply registers all the tasks and doesn't configure them on a dry run. The same behavior is now in place when using Gradle 7.3+.

Non-default location of compile tasks' destinationDirectory

Update your build script with some additional code if you do one of the following:

- Override the Kotlin/JVM KotlinJvmCompile/KotlinCompile task's destinationDirectory location.
- Use a deprecated Kotlin/JS/Non-IR variant and override the Kotlin2JsCompile task's destinationDirectory.

You need to explicitly add sourceSets.main.kotlin.classesDirectories to sourceSets.main.outputs in your JAR file:

```
tasks.jar(type: Jar) {
    from sourceSets.main.outputs
    from sourceSets.main.kotlin.classesDirectories
}
```

Ability to opt-out from reporting compiler arguments to an HTTP statistics service

You can now control whether the Kotlin Gradle plugin should include compiler arguments in HTTP build reports. Sometimes, you might not need the plugin to report these arguments. If a project contains many modules, its compiler arguments in the report can be very heavy and not that helpful. There is now a way to disable it and thus save memory. In your gradle.properties or local.properties, use the kotlin.build.report.include_compiler_arguments=(true|false) property.

We would appreciate your feedback on this feature on YouTrack.

Standard library

Kotlin 1.8.20 adds a variety of new features, including some that are particularly useful for Kotlin/Native development:

- Support for the AutoCloseable interface
- Support for Base64 encoding and decoding
- Support for @Volatile in Kotlin/Native
- Bug fix for stack overflow when using regex in Kotlin/Native

Support for the AutoCloseable interface

The new AutoCloseable interface is Experimental, and to use it you need to opt in with @OptIn(ExperimentalStdlibApi::class) or the compiler argument -opt-in=kotlin.ExperimentalStdlibApi.

The AutoCloseable interface has been added to the common standard library so that you can use one common interface for all libraries to close resources. In Kotlin/JVM, the AutoCloseable interface is an alias for java.lang.AutoClosable.

In addition, the extension function use() is now included, which executes a given block function on the selected resource and then closes it down correctly, whether an exception is thrown or not.

There is no public class in the common standard library that implements the AutoCloseable interface. In the example below, we define the XMLWriter interface and assume that there is a resource that implements it. For example, this resource could be a class that opens a file, writes XML content, and then closes it.

```
interface XMLWriter : AutoCloseable {
    fun document(encoding: String, version: String, content: XMLWriter.() -> Unit)
    fun element(name: String, content: XMLWriter.() -> Unit)
    fun attribute(name: String, value: String)
    fun text(value: String)
}

fun writeBooksTo(writer: XMLWriter) {
    writer.use { xml ->
        xml.document(encoding = "UTF-8", version = "1.0") {
            element("bookstore") {
                element("book") {
                    attribute("category", "fiction")
                    element("title") { text("Harry Potter and the Prisoner of Azkaban") }
                    element("author") { text("J. K. Rowling") }
                    element("year") { text("1999") }
                    element("price") { text("29.99") }
                }
                element("book") {
                    attribute("category", "programming")
                    element("title") { text("Kotlin in Action") }
                    element("author") { text("Dmitry Jemerov") }
                    element("author") { text("Svetlana Isakova") }
                    element("year") { text("2017") }
                    element("price") { text("25.19") }
                }
            }
        }
    }
}
```

Support for Base64 encoding

The new encoding and decoding functionality is Experimental, and to use it, you need to opt in with @OptIn(ExperimentalEncodingApi::class) or the compiler argument -opt-in=kotlin.io.encoding.ExperimentalEncodingApi.

We've added support for Base64 encoding and decoding. We provide 3 class instances, each using different encoding schemes and displaying different behaviors. Use the Base64.Default instance for the standard Base64 encoding scheme.

Use the Base64.UrlSafe instance for the "URL and Filename safe" encoding scheme.

Use the Base64.Mime instance for the MIME encoding scheme. When you use the Base64.Mime instance, all encoding functions insert a line separator every 76 characters. In the case of decoding, any illegal characters are skipped and don't throw an exception.

The Base64.Default instance is the companion object of the Base64 class. As a result, you can call its functions via Base64.encode() and Base64.decode() instead of Base64.Default.encode() and Base64.Default.decode().

```
val foBytes = "fo".map { it.code.toByte() }.toByteArray()
Base64.Default.encode(foBytes) // "Zm8="
// Alternatively:
// Base64.encode(foBytes)

val foobarBytes = "foobar".map { it.code.toByte() }.toByteArray()
Base64.UrlSafe.encode(foobarBytes) // "Zm9vYmFy"

Base64.Default.decode("Zm8=") // foBytes
// Alternatively:
// Base64.decode("Zm8=")

Base64.UrlSafe.decode("Zm9vYmFy") // foobarBytes
```

You can use additional functions to encode or decode bytes into an existing buffer, as well as to append the encoding result to a provided Appendable type object.

In Kotlin/JVM, we've also added the extension functions encodingWith() and decodingWith() to enable you to perform Base64 encoding and decoding with input and output streams.

Support for @Volatile in Kotlin/Native

@Volatile in Kotlin/Native is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below). Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

If you annotate a var property with @Volatile, then the backing field is marked so that any reads or writes to this field are atomic, and writes are always made visible to other threads.

Prior to 1.8.20, the kotlin.jvm.Volatile annotation was available in the common standard library. However, this annotation is only effective in the JVM. If you use it in Kotlin/Native, it is ignored, which can lead to errors.

In 1.8.20, we've introduced a common annotation, kotlin.concurrent.Volatile, that you can use in both the JVM and Kotlin/Native.

How to enable

To try this feature out, opt in with @OptIn(ExperimentalStdlibApi) and enable the -language-version 1.9 compiler option. In a Gradle project, you can do so by adding the following to your build.gradle(.kts) file:

Kotlin

```kotlin
tasks
    .withType<org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask<*>>()
    .configureEach {
        compilerOptions
            .languageVersion
            .set(
                org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9
            )
    }
```

Groovy

```groovy
tasks
    .withType(org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask.class)
    .configureEach {
        compilerOptions.languageVersion =
            org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_1_9
    }
```

Bug fix for stack overflow when using regex in Kotlin/Native

In previous versions of Kotlin, a crash could occur if your regex input contained a large number of characters, even when the regex pattern was very simple. In 1.8.20, this issue has been resolved. For more information, see KT-46211.

Serialization updates

Kotlin 1.8.20 comes with Alpha support for the Kotlin K2 compiler and prohibits serializer customization via companion object.

Prototype serialization compiler plugin for Kotlin K2 compiler

Support for the serialization compiler plugin for K2 is in Alpha. To use it, enable the Kotlin K2 compiler.

Starting with 1.8.20, the serialization compiler plugin works with the Kotlin K2 compiler. Give it a try and share your feedback with us!

Prohibit implicit serializer customization via companion object

Currently, it is possible to declare a class as serializable with the @Serializable annotation and, at the same time, declare a custom serializer with the @Serializer annotation on its companion object.

For example:

```
import kotlinx.serialization.*

@Serializable
class Foo(val a: Int) {
    @Serializer(Foo::class)
    companion object {
        // Custom implementation of KSerializer<Foo>
    }
}
```

In this case, it's not clear from the @Serializable annotation which serializer is used. In actual fact, class Foo has a custom serializer.

To prevent this kind of confusion, in Kotlin 1.8.20 we've introduced a compiler warning for when this scenario is detected. The warning includes a possible migration path to resolve this issue.

If you use such constructs in your code, we recommend updating them to the below:

```
import kotlinx.serialization.*

@Serializable(Foo.Companion::class)
class Foo(val a: Int) {
    // Doesn't matter if you use @Serializer(Foo::class) or not
    companion object: KSerializer<Foo> {
        // Custom implementation of KSerializer<Foo>
    }
}
```

With this approach, it is clear that the Foo class uses the custom serializer declared in the companion object. For more information, see our YouTrack ticket.

In Kotlin 2.0, we plan to promote the compile warning to a compiler error. We recommend that you migrate your code if you see this warning.

Documentation updates

The Kotlin documentation has received some notable changes:

- Get started with Spring Boot and Kotlin – create a simple application with a database and learn more about the features of Spring Boot and Kotlin.
- Scope functions – learn how to simplify your code with useful scope functions from the standard library.
- CocoaPods integration – set up an environment to work with CocoaPods.

Install Kotlin 1.8.20

Check the IDE version

IntelliJ IDEA 2022.2 and 2022.3 automatically suggest updating the Kotlin plugin to version 1.8.20. IntelliJ IDEA 2023.1 has the built-in Kotlin plugin 1.8.20.

Android Studio Flamingo (222) and Giraffe (223) will support Kotlin 1.8.20 in the next releases.

The new command-line compiler is available for download on the GitHub release page.

Configure Gradle settings

To download Kotlin artifacts and dependencies properly, update your settings.gradle(.kts) file to use the Maven Central repository:

```
pluginManagement {
    repositories {
        mavenCentral()
        gradlePluginPortal()
    }
}
```

If the repository is not specified, Gradle uses the sunset JCenter repository that could lead to issues with Kotlin artifacts.

What's new in Kotlin 1.8.0

Released: 28 December 2022

The Kotlin 1.8.0 release is out and here are some of its biggest highlights:

- New experimental functions for JVM: recursively copy or delete directory content
- Improved kotlin-reflect performance
- New -Xdebug compiler option for better debugging experience
- kotlin-stdlib-jdk7 and kotlin-stdlib-jdk8 merged into kotlin-stdlib
- Improved Objective-C/Swift interoperability
- Compatibility with Gradle 7.3

IDE support

The Kotlin plugin that supports 1.8.0 is available for:

IDE	Supported versions
IntelliJ IDEA	2021.3, 2022.1, 2022.2
Android Studio	Electric Eel (221), Flamingo (222)

You can update your projects to Kotlin 1.8.0 in IntelliJ IDEA 2022.3 without updating the IDE plugin.

To migrate existing projects to Kotlin 1.8.0 in IntelliJ IDEA 2022.3, change the Kotlin version to 1.8.0 and reimport your Gradle or Maven project.

Kotlin/JVM

Starting with version 1.8.0, the compiler can generate classes with a bytecode version corresponding to JVM 19. The new language version also includes:

- A compiler option for switching off the generation of JVM annotation targets
- A new -Xdebug compiler option for disabling optimizations
- The removal of the old backend
- Support for Lombok's @Builder annotation

Ability to not generate TYPE_USE and TYPE_PARAMETER annotation targets

If a Kotlin annotation has TYPE among its Kotlin targets, the annotation maps to java.lang.annotation.ElementType.TYPE_USE in its list of Java annotation targets. This is just like how the TYPE_PARAMETER Kotlin target maps to the java.lang.annotation.ElementType.TYPE_PARAMETER Java target. This is an issue for Android clients with API levels less than 26, which don't have these targets in the API.

Starting with Kotlin 1.8.0, you can use the new compiler option -Xno-new-java-annotation-targets to avoid generating the TYPE_USE and TYPE_PARAMETER annotation targets.

A new compiler option for disabling optimizations

Kotlin 1.8.0 adds a new -Xdebug compiler option, which disables optimizations for a better debugging experience. For now, the option disables the "was optimized out" feature for coroutines. In the future, after we add more optimizations, this option will disable them, too.

The "was optimized out" feature optimizes variables when you use suspend functions. However, it is difficult to debug code with optimized variables because you don't see their values.

> Never use this option in production: Disabling this feature via -Xdebug can cause memory leaks.

Removal of the old backend

In Kotlin 1.5.0, we announced that the IR-based backend became Stable. That meant that the old backend from Kotlin 1.4.* was deprecated. In Kotlin 1.8.0, we've removed the old backend completely. By extension, we've removed the compiler option -Xuse-old-backend and the Gradle useOldBackend option.

Support for Lombok's @Builder annotation

The community has added so many votes for the Kotlin Lombok: Support generated builders (@Builder) YouTrack issue that we just had to support the @Builder annotation.

We don't yet have plans to support the @SuperBuilder or @Tolerate annotations, but we'll reconsider if enough people vote for the @SuperBuilder and @Tolerate issues.

Learn how to configure the Lombok compiler plugin.

Kotlin/Native

Kotlin 1.8.0 includes changes to Objective-C and Swift interoperability, support for Xcode 14.1, and improvements to the CocoaPods Gradle plugin:

- Support for Xcode 14.1
- Improved Objective-C/Swift interoperability
- Dynamic frameworks by default in the CocoaPods Gradle plugin

Support for Xcode 14.1

The Kotlin/Native compiler now supports the latest stable Xcode version, 14.1. The compatibility improvements include the following changes:

- There's a new watchosDeviceArm64 preset for the watchOS target that supports Apple watchOS on ARM64 platforms.
- The Kotlin CocoaPods Gradle plugin no longer has bitcode embedding for Apple frameworks by default.
- Platform libraries were updated to reflect the changes to Objective-C frameworks for Apple targets.

Improved Objective-C/Swift interoperability

To make Kotlin more interoperable with Objective-C and Swift, three new annotations were added:

- @ObjCName allows you to specify a more idiomatic name in Swift or Objective-C, instead of renaming the Kotlin declaration.

  The annotation instructs the Kotlin compiler to use a custom Objective-C and Swift name for this class, property, parameter, or function:

  ```
  @ObjCName(swiftName = "MySwiftArray")
  class MyKotlinArray {
      @ObjCName("index")
      fun indexOf(@ObjCName("of") element: String): Int = TODO()
  }

  // Usage with the ObjCName annotations
  let array = MySwiftArray()
  let index = array.index(of: "element")
  ```

- @HiddenFromObjC allows you to hide a Kotlin declaration from Objective-C.

  The annotation instructs the Kotlin compiler not to export a function or property to Objective-C and, consequently, Swift. This can make your Kotlin code more Objective-C/Swift-friendly.

- @ShouldRefineInSwift is useful for replacing a Kotlin declaration with a wrapper written in Swift.

  The annotation instructs the Kotlin compiler to mark a function or property as swift_private in the generated Objective-C API. Such declarations get the __ prefix, which makes them invisible to Swift code.

  You can still use these declarations in your Swift code to create a Swift-friendly API, but they won't be suggested by Xcode's autocompletion, for example.

  For more information on refining Objective-C declarations in Swift, see the official Apple documentation.

The new annotations require opt-in.

The Kotlin team is very grateful to Rick Clephas for implementing these annotations.

Dynamic frameworks by default in the CocoaPods Gradle plugin

Starting with Kotlin 1.8.0, Kotlin frameworks registered by the CocoaPods Gradle plugin are linked dynamically by default. The previous static implementation was inconsistent with the behavior of the Kotlin Gradle plugin.

```
kotlin {
    cocoapods {
        framework {
            baseName = "MyFramework"
            isStatic = false // Now dynamic by default
        }
    }
}
```

If you have an existing project with a static linking type and you upgrade to Kotlin 1.8.0 (or change the linking type explicitly), you may encounter an error with the project's execution. To fix it, close your Xcode project and run pod install in the Podfile directory.

For more information, see the CocoaPods Gradle plugin DSL reference.

Kotlin Multiplatform: A new Android source set layout

Kotlin 1.8.0 introduces a new Android source set layout that replaces the previous naming schema for directories, which is confusing in multiple ways.

Consider an example of two androidTest directories created in the current layout. One is for KotlinSourceSets and the other is for AndroidSourceSets:

- They have different semantics: Kotlin's androidTest belongs to the unitTest type, whereas Android's belongs to the integrationTest type.
- They create a confusing SourceDirectories layout, as src/androidTest/kotlin has a UnitTest and src/androidTest/java has an InstrumentedTest.
- Both KotlinSourceSets and AndroidSourceSets use a similar naming schema for Gradle configurations, so the resulting configurations of androidTest for both Kotlin's and Android's source sets are the same: androidTestImplementation, androidTestApi, androidTestRuntimeOnly, and androidTestCompileOnly.

To address these and other existing issues, we've introduced a new Android source set layout. Here are some of the key differences between the two layouts:

KotlinSourceSet naming schema

Current source set layout	New source set layout
targetName + AndroidSourceSet.name	targetName + AndroidVariantType

{AndroidSourceSet.name} maps to {KotlinSourceSet.name} as follows:

	Current source set layout	New source set layout

	Current source set layout	New source set layout
main	androidMain	androidMain
test	androidTest	androidUnitTest
androidTest	androidAndroidTest	androidInstrumentedTest

SourceDirectories

Current source set layout	New source set layout
The layout adds additional /kotlin SourceDirectories	src/{AndroidSourceSet.name}/kotlin, src/{KotlinSourceSet.name}/kotlin

{AndroidSourceSet.name} maps to {SourceDirectories included} as follows:

	Current source set layout	New source set layout
main	src/androidMain/kotlin, src/main/kotlin, src/main/java	src/androidMain/kotlin, src/main/kotlin, src/main/java
test	src/androidTest/kotlin, src/test/kotlin, src/test/java	src/androidUnitTest/kotlin, src/test/kotlin, src/test/java
androidTest	src/androidAndroidTest/kotlin, src/androidTest/java	src/androidInstrumentedTest/kotlin, src/androidTest/java, src/androidTest/kotlin

The location of the AndroidManifest.xml file

Current source set layout	New source set layout
src/{AndroidSourceSet.name}/AndroidManifest.xml	src/{KotlinSourceSet.name}/AndroidManifest.xml

{AndroidSourceSet.name} maps to{AndroidManifest.xml location} as follows:

	Current source set layout	New source set layout
main	src/main/AndroidManifest.xml	src/androidMain/AndroidManifest.xml
debug	src/debug/AndroidManifest.xml	src/androidDebug/AndroidManifest.xml

The relation between Android and common tests

The new Android source set layout changes the relation between Android-instrumented tests (renamed to androidInstrumentedTest in the new layout) and common tests.

Previously, there was a default dependsOn relation between androidAndroidTest and commonTest. In practice, it meant the following:

- The code in commonTest was available in androidAndroidTest.
- expect declarations in commonTest had to have corresponding actual implementations in androidAndroidTest.
- Tests declared in commonTest were also running as Android instrumented tests.

In the new Android source set layout, the dependsOn relation is not added by default. If you prefer the previous behavior, manually declare this relation in your build.gradle.kts file:

```
kotlin {
    // ...
    sourceSets {
        val commonTest by getting
        val androidInstrumentedTest by getting {
            dependsOn(commonTest)
        }
    }
}
```

Support for Android flavors

Previously, the Kotlin Gradle plugin eagerly created source sets that correspond to Android source sets with debug and release build types or custom flavors like demo and full. It made them accessible by constructions like val androidDebug by getting { ... }.

In the new Android source set layout, those source sets are created in the afterEvaluate phase. It makes such expressions invalid, leading to errors like org.gradle.api.UnknownDomainObjectException: KotlinSourceSet with name 'androidDebug' not found.

To work around that, use the new invokeWhenCreated() API in your build.gradle.kts file:

```
kotlin {
    // ...
    sourceSets.invokeWhenCreated("androidFreeDebug") {
        // ...
    }
}
```

Configuration and setup

The new layout will become the default in future releases. You can enable it now with the following Gradle option:

```
kotlin.mpp.androidSourceSetLayoutVersion=2
```

> The new layout requires Android Gradle plugin 7.0 or later and is supported in Android Studio 2022.3 and later.

The usage of the previous Android-style directories is now discouraged. Kotlin 1.8.0 marks the start of the deprecation cycle, introducing a warning for the current layout. You can suppress the warning with the following Gradle property:

```
kotlin.mpp.androidSourceSetLayoutVersion1.nowarn=true
```

Kotlin/JS

Kotlin 1.8.0 stabilizes the JS IR compiler backend and brings new features to JavaScript-related Gradle build scripts:

- Stable JS IR compiler backend
- New settings for reporting that yarn.lock has been updated
- Add test targets for browsers via Gradle properties
- New approach to adding CSS support to your project

Stable JS IR compiler backend

Starting with this release, the Kotlin/JS intermediate representation (IR-based) compiler backend is Stable. It took a while to unify infrastructure for all three backends, but they now work with the same IR for Kotlin code.

As a consequence of the stable JS IR compiler backend, the old one is deprecated from now on.

Incremental compilation is enabled by default along with the stable JS IR compiler.

If you still use the old compiler, switch your project to the new backend with the help of our migration guide.

New settings for reporting that yarn.lock has been updated

If you use the yarn package manager, there are three new special Gradle settings that could notify you if the yarn.lock file has been updated. You can use these settings when you want to be notified if yarn.lock has been changed silently during the CI build process.

These three new Gradle properties are:

- YarnLockMismatchReport, which specifies how changes to the yarn.lock file are reported. You can use one of the following values:
  - FAIL fails the corresponding Gradle task. This is the default.
  - WARNING writes the information about changes in the warning log.
  - NONE disables reporting.
- reportNewYarnLock, which reports about the recently created yarn.lock file explicitly. By default, this option is disabled: it's a common practice to generate a new yarn.lock file at the first start. You can use this option to ensure that the file has been committed to your repository.
- yarnLockAutoReplace, which replaces yarn.lock automatically every time the Gradle task is run.

To use these options, update your build script file build.gradle.kts as follows:

```
import org.jetbrains.kotlin.gradle.targets.js.yarn.YarnLockMismatchReport
import org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension

rootProject.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin::class.java) {
    rootProject.the<YarnRootExtension>().yarnLockMismatchReport =
        YarnLockMismatchReport.WARNING // NONE | FAIL
    rootProject.the<YarnRootExtension>().reportNewYarnLock = false // true
    rootProject.the<YarnRootExtension>().yarnLockAutoReplace = false // true
}
```

Add test targets for browsers via Gradle properties

Starting with Kotlin 1.8.0, you can set test targets for different browsers right in the Gradle properties file. Doing so shrinks the size of the build script file as you no longer need to write all targets in build.gradle.kts.

You can use this property to define a list of browsers for all modules, and then add specific browsers in the build scripts of particular modules.

For example, the following line in your Gradle property file will run the test in Firefox and Safari for all modules:

```
kotlin.js.browser.karma.browsers=firefox,safari
```

See the full list of available values for the property on GitHub.

The Kotlin team is very grateful to Martynas Petuška for implementing this feature.

New approach to adding CSS support to your project

This release provides a new approach to adding CSS support to your project. We assume that this will affect a lot of projects, so don't forget to update your Gradle build script files as described below.

Before Kotlin 1.8.0, the cssSupport.enabled property was used to add CSS support:

```
browser {
    commonWebpackConfig {
        cssSupport.enabled = true
    }
}
```

Now you should use the enabled.set() method in the cssSupport {} block:

```
browser {
    commonWebpackConfig {
        cssSupport {
            enabled.set(true)
        }
    }
}
```

Gradle

Kotlin 1.8.0 fully supports Gradle versions 7.2 and 7.3. You can also use Gradle versions up to the latest Gradle release, but if you do, keep in mind that you might encounter deprecation warnings or some new Gradle features might not work.

This version brings lots of changes:

- Exposing Kotlin compiler options as Gradle lazy properties
- Bumping the minimum supported versions
- Ability to disable the Kotlin daemon fallback strategy
- Usage of the latest kotlin-stdlib version in transitive dependencies
- Obligatory check for JVM target compatibility equality of related Kotlin and Java compile tasks
- Resolution of Kotlin Gradle plugins' transitive dependencies
- Deprecations and removals

Exposing Kotlin compiler options as Gradle lazy properties

To expose available Kotlin compiler options as Gradle lazy properties and to integrate them better into the Kotlin tasks, we made lots of changes:

- Compile tasks have the new compilerOptions input, which is similar to the existing kotlinOptions but uses Property from the Gradle Properties API as the return type:

  ```
  tasks.named("compileKotlin", org.jetbrains.kotlin.gradle.tasks.KotlinJvmCompile::class.java) {
      compilerOptions {
          useK2.set(true)
      }
  }
  ```

- The Kotlin tools tasks KotlinJsDce and KotlinNativeLink have the new toolOptions input, which is similar to the existing kotlinOptions input.
- New inputs have the @Nested Gradle annotation. Every property inside the inputs has a related Gradle annotation, such as @Input or @Internal.
- The Kotlin Gradle plugin API artifact has two new interfaces:
  - org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask, which has the compilerOptions input and the compileOptions() method. All Kotlin compilation tasks implement this interface.
  - org.jetbrains.kotlin.gradle.tasks.KotlinToolTask, which has the toolOptions input and the toolOptions() method. All Kotlin tool tasks – KotlinJsDce, KotlinNativeLink, and KotlinNativeLinkArtifactTask – implement this interface.
- Some compilerOptions use the new types instead of the String type:
  - JvmTarget
  - KotlinVersion (for the apiVersion and the languageVersion inputs)
  - JsMainFunctionExecutionMode

- JsModuleKind
- JsSourceMapEmbedMode

For example, you can use compilerOptions.jvmTarget.set(JvmTarget.JVM_11) instead of kotlinOptions.jvmTarget = "11".

The kotlinOptions types didn't change, and they are internally converted to compilerOptions types.

- The Kotlin Gradle plugin API is binary-compatible with previous releases. There are, however, some source and ABI-breaking changes in the kotlin-gradle-plugin artifact. Most of these changes involve additional generic parameters to some internal types. One important change is that the KotlinNativeLink task no longer inherits the AbstractKotlinNativeCompile task.
- KotlinJsCompilerOptions.outputFile and the related KotlinJsOptions.outputFile options are deprecated. Use the Kotlin2JsCompile.outputFileProperty task input instead.

The Kotlin Gradle plugin still adds the KotlinJvmOptions DSL to the Android extension:

```
android {
    kotlinOptions {
        jvmTarget = "11"
    }
}
```

This will be changed in the scope of this issue, when the compilerOptions DSL will be added to a module level.

Limitations

The kotlinOptions task input and the kotlinOptions{...} task DSL are in support mode and will be deprecated in upcoming releases. Improvements will be made only to compilerOptions and toolOptions.

Calling any setter or getter on kotlinOptions delegates to the related property in the compilerOptions. This introduces the following limitations:

- compilerOptions and kotlinOptions cannot be changed in the task execution phase (see one exception in the paragraph below).
- freeCompilerArgs returns an immutable List<String>, which means that, for example, kotlinOptions.freeCompilerArgs.remove("something") will fail.

Several plugins, including kotlin-dsl and the Android Gradle plugin (AGP) with Jetpack Compose enabled, try to modify the freeCompilerArgs attribute in the task execution phase. We've added a workaround for them in Kotlin 1.8.0. This workaround allows any build script or plugin to modify kotlinOptions.freeCompilerArgs in the execution phase but produces a warning in the build log. To disable this warning, use the new Gradle property kotlin.options.suppressFreeCompilerArgsModificationWarning=true. Gradle is going to add fixes for the kotlin-dsl plugin and AGP with Jetpack Compose enabled.

Bumping the minimum supported versions

Starting with Kotlin 1.8.0, the minimum supported Gradle version is 6.8.3 and the minimum supported Android Gradle plugin version is 4.1.3.

See the Kotlin Gradle plugin compatibility with available Gradle versions in our documentation

Ability to disable the Kotlin daemon fallback strategy

There is a new Gradle property kotlin.daemon.useFallbackStrategy, whose default value is true. When the value is false, builds fail on problems with the daemon's startup or communication. There is also a new useDaemonFallbackStrategy property in Kotlin compile tasks, which takes priority over the Gradle property if you use both. If there is insufficient memory to run the compilation, you can see a message about it in the logs.

The Kotlin compiler's fallback strategy is to run a compilation outside the Kotlin daemon if the daemon somehow fails. If the Gradle daemon is on, the compiler uses the "In process" strategy. If the Gradle daemon is off, the compiler uses the "Out of process" strategy. Learn more about these execution strategies in the documentation. Note that silent fallback to another strategy can consume a lot of system resources or lead to non-deterministic builds; see this YouTrack issue for more details.

Usage of the latest kotlin-stdlib version in transitive dependencies

If you explicitly write Kotlin version 1.8.0 or higher in your dependencies, for example: implementation("org.jetbrains.kotlin:kotlin-stdlib:1.8.0"), then the Kotlin Gradle Plugin will use that Kotlin version for transitive kotlin-stdlib-jdk7 and kotlin-stdlib-jdk8 dependencies. This is done to avoid class duplication from different stdlib versions (learn more about merging kotlin-stdlib-jdk7 and kotlin-stdlib-jdk8 into kotlin-stdlib). You can disable this behavior with the kotlin.stdlib.jdk.variants.version.alignment Gradle property:

```
kotlin.stdlib.jdk.variants.version.alignment=false
```

If you run into issues with version alignment, align all versions via the Kotlin BOM by declaring a platform dependency on kotlin-bom in your build script:

```
implementation(platform("org.jetbrains.kotlin:kotlin-bom:1.8.0"))
```

Learn about other cases and our suggested solutions in the documentation.

Obligatory check for JVM targets of related Kotlin and Java compile tasks

This section applies to your JVM project even if your source files are only in Kotlin and you don't use Java.

Starting from this release, the default value for the kotlin.jvm.target.validation.mode property is error for projects on Gradle 8.0+ (this version of Gradle has not been released yet), and the plugin will fail the build in the event of JVM target incompatibility.

The shift of the default value from warning to error is a preparation step for a smooth migration to Gradle 8.0. We encourage you to set this property to error and configure a toolchain or align JVM versions manually.

Learn more about what can go wrong if you don't check the targets' compatibility.

Resolution of Kotlin Gradle plugins' transitive dependencies

In Kotlin 1.7.0, we introduced support for Gradle plugin variants. Because of these plugin variants, a build classpath can have different versions of the Kotlin Gradle plugins that depend on different versions of some dependency, usually kotlin-gradle-plugin-api. This can lead to a resolution problem, and we would like to propose the following workaround, using the kotlin-dsl plugin as an example.

The kotlin-dsl plugin in Gradle 7.6 depends on the org.jetbrains.kotlin.plugin.sam.with.receiver:1.7.10 plugin, which depends on kotlin-gradle-plugin-api:1.7.10. If you add the org.jetbrains.kotlin.gradle.jvm:1.8.0 plugin, this kotlin-gradle-plugin-api:1.7.10 transitive dependency may lead to a dependency resolution error because of a mismatch between the versions (1.8.0 and 1.7.10) and the variant attributes' org.gradle.plugin.api-version values. As a workaround, add this constraint to align the versions. This workaround may be needed until we implement the Kotlin Gradle Plugin libraries alignment platform, which is in the plans:

```
dependencies {
    constraints {
        implementation("org.jetbrains.kotlin:kotlin-sam-with-receiver:1.8.0")
    }
}
```

This constraint forces the org.jetbrains.kotlin:kotlin-sam-with-receiver:1.8.0 version to be used in the build classpath for transitive dependencies. Learn more about one similar case in the Gradle issue tracker.

Deprecations and removals

In Kotlin 1.8.0, the deprecation cycle continues for the following properties and methods:

- In the notes for Kotlin 1.7.0 that the KotlinCompile task still had the deprecated Kotlin property classpath, which would be removed in future releases. Now, we've changed the deprecation level to error for the KotlinCompile task's classpath property. All compile tasks use the libraries input for a list of libraries required for compilation.
- We removed the kapt.use.worker.api property that allowed running kapt via the Gradle Workers API. By default, kapt has been using Gradle workers since Kotlin 1.3.70, and we recommend sticking to this method.
- In Kotlin 1.7.0, we announced the start of a deprecation cycle for the kotlin.compiler.execution.strategy property. In this release, we removed this property. Learn how to define a Kotlin compiler execution strategy in other ways.

Standard library

Kotlin 1.8.0:

- Updates JVM compilation target.
- Stabilizes a number of functions – TimeUnit conversion between Java and Kotlin, cbrt(), Java Optionals extension functions.
- Provides a preview for comparable and subtractable TimeMarks.
- Includes experimental extension functions for java.nio.file.path.
- Presents improved kotlin-reflect performance.

Updated JVM compilation target

In Kotlin 1.8.0, the standard libraries (kotlin-stdlib, kotlin-reflect, and kotlin-script-*) are compiled with JVM target 1.8. Previously, the standard libraries were compiled with JVM target 1.6.

Kotlin 1.8.0 no longer supports JVM targets 1.6 and 1.7. As a result, you no longer need to declare kotlin-stdlib-jdk7 and kotlin-stdlib-jdk8 separately in build scripts because the contents of these artifacts have been merged into kotlin-stdlib.

> If you have explicitly declared kotlin-stdlib-jdk7 and kotlin-stdlib-jdk8 as dependencies in your build scripts, then you should replace them with kotlin-stdlib.

Note that mixing different versions of stdlib artifacts could lead to class duplication or to missing classes. To avoid that, the Kotlin Gradle plugin can help you align stdlib versions.

cbrt()

The cbrt() function, which allows you to compute the real cube root of a double or float, is now Stable.

```
import kotlin.math.*

fun main() {
    val num = 27
    val negNum = -num

    println("The cube root of ${num.toDouble()} is: " +
            cbrt(num.toDouble()))
    println("The cube root of ${negNum.toDouble()} is: " +
            cbrt(negNum.toDouble()))
}
```

TimeUnit conversion between Java and Kotlin

The toTimeUnit() and toDurationUnit() functions in kotlin.time are now Stable. Introduced as Experimental in Kotlin 1.6.0, these functions improve interoperability between Kotlin and Java. You can now easily convert between Java java.util.concurrent.TimeUnit and Kotlin kotlin.time.DurationUnit. These functions are supported on the JVM only.

```
import kotlin.time.*

// For use from Java
fun wait(timeout: Long, unit: TimeUnit) {
    val duration: Duration = timeout.toDuration(unit.toDurationUnit())
    ...
}
```

Comparable and subtractable TimeMarks

> The new functionality of TimeMarks is Experimental, and to use it you need to opt in by using @OptIn(ExperimentalTime::class) or @ExperimentalTime.

Before Kotlin 1.8.0, if you wanted to calculate the time difference between multiple TimeMarks and now, you could only call elapsedNow() on one TimeMark at a time. This made it difficult to compare the results because the two elapsedNow() function calls couldn't be executed at exactly the same time.

To solve this, in Kotlin 1.8.0 you can subtract and compare TimeMarks from the same time source. Now you can create a new TimeMark instance to represent now and subtract other TimeMarks from it. This way, the results that you collect from these calculations are guaranteed to be relative to each other.

```
import kotlin.time.*
fun main() {
    val timeSource = TimeSource.Monotonic
    val mark1 = timeSource.markNow()
    Thread.sleep(500) // Sleep 0.5 seconds
    val mark2 = timeSource.markNow()

    // Before 1.8.0
    repeat(4) { n ->
        val elapsed1 = mark1.elapsedNow()
        val elapsed2 = mark2.elapsedNow()

        // Difference between elapsed1 and elapsed2 can vary depending
        // on how much time passes between the two elapsedNow() calls
        println("Measurement 1.${n + 1}: elapsed1=$elapsed1, " +
                "elapsed2=$elapsed2, diff=${elapsed1 - elapsed2}")
    }
    println()

    // Since 1.8.0
    repeat(4) { n ->
        val mark3 = timeSource.markNow()
        val elapsed1 = mark3 - mark1
        val elapsed2 = mark3 - mark2

        // Now the elapsed times are calculated relative to mark3,
        // which is a fixed value
        println("Measurement 2.${n + 1}: elapsed1=$elapsed1, " +
                "elapsed2=$elapsed2, diff=${elapsed1 - elapsed2}")
    }
    // It's also possible to compare time marks with each other
    // This is true, as mark2 was captured later than mark1
    println(mark2 > mark1)
}
```

This new functionality is particularly useful in animation calculations where you want to calculate the difference between, or compare, multiple TimeMarks representing different frames.

Recursive copying or deletion of directories

These new functions for java.nio.file.path are Experimental. To use them, you need to opt in with @OptIn(kotlin.io.path.ExperimentalPathApi::class) or @kotlin.io.path.ExperimentalPathApi. Alternatively, you can use the compiler option -opt-in=kotlin.io.path.ExperimentalPathApi.

We have introduced two new extension functions for java.nio.file.Path, copyToRecursively() and deleteRecursively(), which allow you to recursively:

- Copy a directory and its contents to another destination.
- Delete a directory and its contents.

These functions can be very useful as part of a backup process.

Error handling

Using copyToRecursively(), you can define what should happen if an exception occurs while copying, by overloading the onError lambda function:

```
sourceRoot.copyToRecursively(destinationRoot, followLinks = false,
    onError = { source, target, exception ->
        logger.logError(exception, "Failed to copy $source to $target")
        OnErrorResult.TERMINATE
    })
```

When you use deleteRecursively(), if an exception occurs while deleting a file or folder, then the file or folder is skipped. Once the deletion has completed, deleteRecursively() throws an IOException containing all the exceptions that occurred as suppressed exceptions.

File overwrite

If copyToRecursively() finds that a file already exists in the destination directory, then an exception occurs. If you want to overwrite the file instead, use the overload that has overwrite as an argument and set it to true:

```
fun setUpEnvironment(projectDirectory: Path, fixtureName: String) {
    fixturesRoot.resolve(COMMON_FIXTURE_NAME)
        .copyToRecursively(projectDirectory, followLinks = false)
    fixturesRoot.resolve(fixtureName)
        .copyToRecursively(projectDirectory, followLinks = false,
            overwrite = true) // patches the common fixture
}
```

Custom copying action

To define your own custom logic for copying, use the overload that has copyAction as an additional argument. By using copyAction you can provide a lambda function, for example, with your preferred actions:

```
sourceRoot.copyToRecursively(destinationRoot, followLinks = false) { source, target ->
    if (source.name.startsWith(".")) {
        CopyActionResult.SKIP_SUBTREE
    } else {
        source.copyToIgnoringExistingDirectory(target, followLinks = false)
        CopyActionResult.CONTINUE
    }
}
```

For more information on these extension functions, see our API reference.

Java Optionals extension functions

The extension functions that were introduced in Kotlin 1.7.0 are now Stable. These functions simplify working with Optional classes in Java. They can be used to unwrap and convert Optional objects on the JVM, and to make working with Java APIs more concise. For more information, see What's new in Kotlin 1.7.0.

Improved kotlin-reflect performance

Taking advantage of the fact that kotlin-reflect is now compiled with JVM target 1.8, we migrated our internal cache mechanism to Java's ClassValue. Previously we only cached KClass, but we now also cache KType and KDeclarationContainer. These changes have led to significant performance improvements when invoking typeOf().

Documentation updates

The Kotlin documentation has received some notable changes:

Revamped and new pages

- Gradle overview – learn how to configure and build a Kotlin project with the Gradle build system, available compiler options, compilation, and caches in the Kotlin Gradle plugin.
- Nullability in Java and Kotlin – see the differences between Java's and Kotlin's approaches to handling possibly nullable variables.
- Lincheck guide – learn how to set up and use the Lincheck framework for testing concurrent algorithms on the JVM.

New and updated tutorials

- Get started with Gradle and Kotlin/JVM – create a console application using IntelliJ IDEA and Gradle.
- Create a multiplatform app using Ktor and SQLDelight – create a mobile application for iOS and Android using Kotlin Multiplatform Mobile.
- Get started with Kotlin Multiplatform – learn about cross-platform mobile development with Kotlin and create an app that works on both Android and iOS.

Install Kotlin 1.8.0

IntelliJ IDEA 2021.3, 2022.1, and 2022.2 automatically suggest updating the Kotlin plugin to version 1.8.0. IntelliJ IDEA 2022.3 will have the 1.8.0 version of the Kotlin plugin bundled in an upcoming minor update.

To migrate existing projects to Kotlin 1.8.0 in IntelliJ IDEA 2022.3, change the Kotlin version to 1.8.0 and reimport your Gradle or Maven project.

For Android Studio Electric Eel (221) and Flamingo (222), version 1.8.0 of the Kotlin plugin will be delivered with the upcoming Android Studios updates. The new command-line compiler is available for download on the GitHub release page.

Compatibility guide for Kotlin 1.8.0

Kotlin 1.8.0 is a feature release and can, therefore, bring changes that are incompatible with your code written for earlier versions of the language. Find the detailed list of these changes in the Compatibility guide for Kotlin 1.8.0.

What's new in Kotlin 1.7.20

Released: 29 September 2022

The Kotlin 1.7.20 release is out! Here are some highlights from this release:

- The new Kotlin K2 compiler supports all-open, SAM with receiver, Lombok, and other compiler plugins
- We introduced the preview of the ..< operator for creating open-ended ranges
- The new Kotlin/Native memory manager is now enabled by default
- We introduced a new experimental feature for JVM: inline classes with a generic underlying type

You can also find a short overview of the changes in this video:

Watch video online.

Support for Kotlin K2 compiler plugins

The Kotlin team continues to stabilize the K2 compiler. K2 is still in Alpha (as announced in the Kotlin 1.7.0 release), but it now supports several compiler plugins. You can follow this YouTrack issue to get updates from the Kotlin team on the new compiler.

Starting with this 1.7.20 release, the Kotlin K2 compiler supports the following plugins:

- all-open
- no-arg
- SAM with receiver
- Lombok
- AtomicFU
- jvm-abi-gen

The Alpha version of the new K2 compiler only works with JVM projects. It doesn't support Kotlin/JS, Kotlin/Native, or other multiplatform projects.

Learn more about the new compiler and its benefits in the following videos:

- The Road to the New Kotlin Compiler
- K2 Compiler: a Top-Down View

How to enable the Kotlin K2 compiler

To enable the Kotlin K2 compiler and test it, use the following compiler option:

```
-Xuse-k2
```

You can specify it in your build.gradle(.kts) file:

Kotlin

```kotlin
tasks.withType<KotlinCompile> {
    kotlinOptions.useK2 = true
}
```

Groovy

```groovy
compileKotlin {
    kotlinOptions.useK2 = true
}
```

Check out the performance boost on your JVM projects and compare it with the results of the old compiler.

Leave your feedback on the new K2 compiler

We really appreciate your feedback in any form:

- Provide your feedback directly to K2 developers in Kotlin Slack: get an invite and join the #k2-early-adopters channel.
- Report any problems you faced with the new K2 compiler to our issue tracker.
- Enable the Send usage statistics option to allow JetBrains collecting anonymous data about K2 usage.

Language

Kotlin 1.7.20 introduces preview versions for new language features, as well as puts restrictions on builder type inference:

- Preview of the ..< operator for creating open-ended ranges
- New data object declarations
- Builder type inference restrictions

Preview of the ..< operator for creating open-ended ranges

> The new operator is Experimental, and it has limited support in the IDE.

This release introduces the new ..< operator. Kotlin has the .. operator to express a range of values. The new ..< operator acts like the until function and helps you define the open-ended range.

Watch video online.

Our research shows that this new operator does a better job at expressing open-ended ranges and making it clear that the upper bound is not included.

Here is an example of using the ..< operator in a when expression:

```
when (value) {
    in 0.0..<0.25 -> // First quarter
    in 0.25..<0.5 -> // Second quarter
    in 0.5..<0.75 -> // Third quarter
    in 0.75..1.0 ->  // Last quarter  <- Note closed range here
}
```

Standard library API changes

The following new types and operations will be introduced in the kotlin.ranges packages in the common Kotlin standard library:

New OpenEndRange<T> interface

The new interface to represent open-ended ranges is very similar to the existing ClosedRange<T> interface:

```
interface OpenEndRange<T : Comparable<T>> {
    // Lower bound
    val start: T
    // Upper bound, not included in the range
    val endExclusive: T
    operator fun contains(value: T): Boolean = value >= start && value < endExclusive
    fun isEmpty(): Boolean = start >= endExclusive
}
```

Implementing OpenEndRange in the existing iterable ranges

When developers need to get a range with an excluded upper bound, they currently use the until function to effectively produce a closed iterable range with the same values. To make these ranges acceptable in the new API that takes OpenEndRange<T>, we want to implement that interface in the existing iterable ranges: IntRange, LongRange, CharRange, UIntRange, and ULongRange. So they will simultaneously implement both the ClosedRange<T> and OpenEndRange<T> interfaces.

```
class IntRange : IntProgression(...), ClosedRange<Int>, OpenEndRange<Int> {
    override val start: Int
    override val endInclusive: Int
    override val endExclusive: Int
}
```

rangeUntil operators for the standard types

The rangeUntil operators will be provided for the same types and combinations currently defined by the rangeTo operator. We provide them as extension functions for prototype purposes, but for consistency, we plan to make them members later before stabilizing the open-ended ranges API.

How to enable the ..< operator

To use the ..< operator or to implement that operator convention for your own types, enable the -language-version 1.8 compiler option.

The new API elements introduced to support the open-ended ranges of the standard types require an opt-in, as usual for an experimental stdlib API: @OptIn(ExperimentalStdlibApi::class). Alternatively, you could use the -opt-in=kotlin.ExperimentalStdlibApi compiler option.

Read more about the new operator in this KEEP document.

Improved string representations for singletons and sealed class hierarchies with data objects

Data objects are Experimental, and have limited support in the IDE at the moment.

This release introduces a new type of object declaration for you to use: data object. Data object behaves conceptually identical to a regular object declaration but comes with a clean toString representation out of the box.

Watch video online.

```kotlin
package org.example
object MyObject
data object MyDataObject

fun main() {
    println(MyObject) // org.example.MyObject@1f32e575
    println(MyDataObject) // MyDataObject
}
```

This makes data object declarations perfect for sealed class hierarchies, where you may use them alongside data class declarations. In this snippet, declaring EndOfFile as a data object instead of a plain object means that it will get a pretty toString without the need to override it manually, maintaining symmetry with the accompanying data class definitions:

```kotlin
sealed class ReadResult {
    data class Number(val value: Int) : ReadResult()
    data class Text(val value: String) : ReadResult()
    data object EndOfFile : ReadResult()
}

fun main() {
    println(ReadResult.Number(1)) // Number(value=1)
    println(ReadResult.Text("Foo")) // Text(value=Foo)
    println(ReadResult.EndOfFile) // EndOfFile
}
```

How to enable data objects

To use data object declarations in your code, enable the -language-version 1.9 compiler option. In a Gradle project, you can do so by adding the following to your build.gradle(.kts):

Kotlin

```kotlin
tasks.withType<org.jetbrains.kotlin.gradle.tasks.KotlinCompile>().configureEach {
    // ...
    kotlinOptions.languageVersion = "1.9"
}
```

Groovy

```groovy
compileKotlin {
    // ...
    kotlinOptions.languageVersion = '1.9'
}
```

Read more about data objects, and share your feedback on their implementation in the respective KEEP document.

New builder type inference restrictions

Kotlin 1.7.20 places some major restrictions on the use of builder type inference that could affect your code. These restrictions apply to code containing builder lambda functions, where it's impossible to derive the parameter without analyzing the lambda itself. The parameter is used as an argument. Now, the compiler will always show an error for such code and ask you to specify the type explicitly.

This is a breaking change, but our research shows that these cases are very rare, and the restrictions shouldn't affect your code. If they do, consider the following cases:

- Builder inference with extension that hides members.

  If your code contains an extension function with the same name that will be used during the builder inference, the compiler will show you an error:

  ```kotlin
  class Data {
      fun doSmth() {} // 1
  }

  fun <T> T.doSmth() {} // 2

  fun test() {
      buildList {
          this.add(Data())
          this.get(0).doSmth() // Resolves to 2 and leads to error
      }
  }
  ```

  To fix the code, you should specify the type explicitly:

  ```kotlin
  class Data {
      fun doSmth() {} // 1
  }

  fun <T> T.doSmth() {} // 2

  fun test() {
      buildList<Data> { // Type argument!
          this.add(Data())
          this.get(0).doSmth() // Resolves to 1
      }
  }
  ```

- Builder inference with multiple lambdas and the type arguments are not specified explicitly.

  If there are two or more lambda blocks in builder inference, they affect the type. To prevent an error, the compiler requires you to specify the type:

  ```kotlin
  fun <T: Any> buildList(
      first: MutableList<T>.() -> Unit,
      second: MutableList<T>.() -> Unit
  ): List<T> {
      val list = mutableListOf<T>()
      list.first()
      list.second()
      return list
  }

  fun main() {
      buildList(
          first = { // this: MutableList<String>
              add("")
          },
          second = { // this: MutableList<Int>
              val i: Int = get(0)
  ```

```
            println(i)
        }
    )
}
```

To fix the error, you should specify the type explicitly and fix the type mismatch:

```
fun main() {
    buildList<Int>(
        first = { // this: MutableList<Int>
            add(0)
        },
        second = { // this: MutableList<Int>
            val i: Int = get(0)
            println(i)
        }
    )
}
```

If you haven't found your case mentioned above, file an issue to our team.

See this YouTrack issue for more information about this builder inference update.

Kotlin/JVM

Kotlin 1.7.20 introduces generic inline classes, adds more bytecode optimizations for delegated properties, and supports IR in the kapt stub generating task, making it possible to use all the newest Kotlin features with kapt:

- Generic inline classes
- More optimized cases of delegated properties
- Support for the JVM IR backend in kapt stub generating task

Generic inline classes

Generic inline classes is an Experimental feature. It may be dropped or changed at any time. Opt-in is required (see details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Kotlin 1.7.20 allows the underlying type of JVM inline classes to be a type parameter. The compiler maps it to `Any?` or, generally, to the upper bound of the type parameter.

Watch video online.

Consider the following example:

```
@JvmInline
value class UserId<T>(val value: T)

fun compute(s: UserId<String>) {} // Compiler generates fun compute-<hashcode>(s: Any?)
```

The function accepts the inline class as a parameter. The parameter is mapped to the upper bound, not the type argument.

To enable this feature, use the -language-version 1.8 compiler option.

We would appreciate your feedback on this feature in YouTrack.

More optimized cases of delegated properties

In Kotlin 1.6.0, we optimized the case of delegating to a property by omitting the $delegate field and generating immediate access to the referenced property. In 1.7.20, we've implemented this optimization for more cases. The $delegate field will now be omitted if a delegate is:

- A named object:

  ```
  object NamedObject {
      operator fun getValue(thisRef: Any?, property: KProperty<*>): String = ...
  }

  val s: String by NamedObject
  ```

- A final val property with a backing field and a default getter in the same module:

  ```
  val impl: ReadOnlyProperty<Any?, String> = ...

  class A {
      val s: String by impl
  }
  ```

- A constant expression, an enum entry, this, or null. Here's an example of this:

```
class A {
    operator fun getValue(thisRef: Any?, property: KProperty<*>) ...

    val s by this
}
```

Learn more about delegated properties.

We would appreciate your feedback on this feature in YouTrack.

Support for the JVM IR backend in kapt stub generating task

> Support for the JVM IR backend in the kapt stub generating task is an Experimental feature. It may be changed at any time. Opt-in is required (see details below), and you should use it only for evaluation purposes.

Before 1.7.20, the kapt stub generating task used the old backend, and repeatable annotations didn't work with kapt. With Kotlin 1.7.20, we've added support for the JVM IR backend in the kapt stub generating task. This makes it possible to use all the newest Kotlin features with kapt, including repeatable annotations.

To use the IR backend in kapt, add the following option to your gradle.properties file:

```
kapt.use.jvm.ir=true
```

We would appreciate your feedback on this feature in YouTrack.

Kotlin/Native

Kotlin 1.7.20 comes with the new Kotlin/Native memory manager enabled by default and gives you the option to customize the Info.plist file:

- The new default memory manager
- Customizing the Info.plist file

The new Kotlin/Native memory manager enabled by default

This release brings further stability and performance improvements to the new memory manager, allowing us to promote the new memory manager to Beta.

The previous memory manager complicated writing concurrent and asynchronous code, including issues with implementing the kotlinx.coroutines library. This blocked the adoption of Kotlin Multiplatform Mobile because concurrency limitations created problems with sharing Kotlin code between iOS and Android platforms. The new memory manager finally paves the way to promote Kotlin Multiplatform Mobile to Beta.

The new memory manager also supports the compiler cache that makes compilation times comparable to previous releases. For more on the benefits of the new memory manager, see our original blog post for the preview version. You can find more technical details in the documentation.

Configuration and setup

Starting with Kotlin 1.7.20, the new memory manager is the default. Not much additional setup is required.

If you've already turned it on manually, you can remove the kotlin.native.binary.memoryModel=experimental option from your gradle.properties or binaryOptions["memoryModel"] = "experimental" from the build.gradle(.kts) file.

If necessary, you can switch back to the legacy memory manager with the kotlin.native.binary.memoryModel=strict option in your gradle.properties. However, compiler cache support is no longer available for the legacy memory manager, so compilation times might worsen.

Freezing

In the new memory manager, freezing is deprecated. Don't use it unless you need your code to work with the legacy manager (where freezing is still required). This may be helpful for library authors that need to maintain support for the legacy memory manager or developers who want to have a fallback if they encounter issues with the new memory manager.

In such cases, you can temporarily support code for both new and legacy memory managers. To ignore deprecation warnings, do one of the following:

- Annotate usages of the deprecated API with @OptIn(FreezingIsDeprecated::class).
- Apply languageSettings.optIn("kotlin.native.FreezingIsDeprecated") to all the Kotlin source sets in Gradle.
- Pass the compiler flag -opt-in=kotlin.native.FreezingIsDeprecated.

Calling Kotlin suspending functions from Swift/Objective-C

The new memory manager still restricts calling Kotlin suspend functions from Swift and Objective-C from threads other than the main one, but you can lift it with a new Gradle option.

This restriction was originally introduced in the legacy memory manager due to cases where the code dispatched a continuation to be resumed on the original thread. If this thread didn't have a supported event loop, the task would never run, and the coroutine would never be resumed.

In certain cases, this restriction is no longer required, but a check of all the necessary conditions can't be easily implemented. Because of this, we decided to keep it in the new memory manager while introducing an option for you to disable it. For this, add the following option to your gradle.properties:

```
kotlin.native.binary.objcExportSuspendFunctionLaunchThreadRestriction=none
```

> Do not add this option if you use the native-mt version of kotlinx.coroutines or other libraries that have the same "dispatch to the original thread" approach.

The Kotlin team is very grateful to Ahmed El-Helw for implementing this option.

Leave your feedback

This is a significant change to our ecosystem. We would appreciate your feedback to help make it even better.

Try the new memory manager on your projects and share feedback in our issue tracker, YouTrack.

Customizing the Info.plist file

When producing a framework, the Kotlin/Native compiler generates the information property list file, Info.plist. Previously, it was cumbersome to customize its contents. With Kotlin 1.7.20, you can directly set the following properties:

Property	Binary option
CFBundleIdentifier	bundleId
CFBundleShortVersionString	bundleShortVersionString
CFBundleVersion	bundleVersion

To do that, use the corresponding binary option. Pass the -Xbinary=$option=$value compiler flag or set the binaryOption(option, value) Gradle DSL for the necessary framework.

The Kotlin team is very grateful to Mads Ager for implementing this feature.

Kotlin/JS

Kotlin/JS has received some enhancements that improve the developer experience and boost performance:

- Klib generation is faster in both incremental and clean builds, thanks to efficiency improvements for the loading of dependencies.
- Incremental compilation for development binaries has been reworked, resulting in major improvements in clean build scenarios, faster incremental builds, and

stability fixes.

- We've improved .d.ts generation for nested objects, sealed classes, and optional parameters in constructors.

Gradle

The updates for the Kotlin Gradle plugin are focused on compatibility with the new Gradle features and the latest Gradle versions.

Kotlin 1.7.20 contains changes to support Gradle 7.1. Deprecated methods and properties were removed or replaced, reducing the number of deprecation warnings produced by the Kotlin Gradle plugin and unblocking future support for Gradle 8.0.

There are, however, some potentially breaking changes that may need your attention:

Target configuration

- org.jetbrains.kotlin.gradle.dsl.SingleTargetExtension now has a generic parameter, SingleTargetExtension<T : KotlinTarget>.
- The kotlin.targets.fromPreset() convention has been deprecated. Instead, you can still use kotlin.targets { fromPreset() }, but we recommend setting up targets explicitly.
- Target accessors auto-generated by Gradle are no longer available inside the kotlin.targets { } block. Please use the findByName("targetName") method instead.

  Note that such accessors are still available in the case of kotlin.targets, for example, kotlin.targets.linuxX64.

Source directories configuration

The Kotlin Gradle plugin now adds Kotlin SourceDirectorySet as a kotlin extension to Java's SourceSet group. This makes it possible to configure source directories in the build.gradle.kts file similarly to how they are configured in Java, Groovy, and Scala:

```
sourceSets {
    main {
        kotlin {
            java.setSrcDirs(listOf("src/java"))
            kotlin.setSrcDirs(listOf("src/kotlin"))
        }
    }
}
```

You no longer need to use a deprecated Gradle convention and specify the source directories for Kotlin.

Remember that you can also use the kotlin extension to access KotlinSourceSet:

```
kotlin {
    sourceSets {
        main {
        // ...
        }
    }
}
```

New method for JVM toolchain configuration

This release provides a new jvmToolchain() method for enabling the JVM toolchain feature. If you don't need any additional configuration fields, such as implementation or vendor, you can use this method from the Kotlin extension:

```
kotlin {
    jvmToolchain(17)
}
```

This simplifies the Kotlin project setup process without any additional configuration. Before this release, you could specify the JDK version only in the following way:

```
kotlin {
    jvmToolchain {
        languageVersion.set(JavaLanguageVersion.of(17))
    }
}
```

Standard library

Kotlin 1.7.20 offers new extension functions for the java.nio.file.Path class, which allows you to walk through a file tree:

- walk() lazily traverses the file tree rooted at the specified path.
- fileVisitor() makes it possible to create a FileVisitor separately. FileVisitor defines actions on directories and files when traversing them.
- visitFileTree(fileVisitor: FileVisitor, ...) consumes a ready FileVisitor and uses java.nio.file.Files.walkFileTree() under the hood.
- visitFileTree(..., builderAction: FileVisitorBuilder.() -> Unit) creates a FileVisitor with the builderAction and calls the visitFileTree(fileVisitor, ...) function.
- FileVisitResult, return type of FileVisitor, has the CONTINUE default value that continues the processing of the file.

The new extension functions for java.nio.file.Path are Experimental. They may be changed at any time. Opt-in is required (see details below), and you should use them only for evaluation purposes.

Here are some things you can do with these new extension functions:

- Explicitly create a FileVisitor and then use:

```
val cleanVisitor = fileVisitor {
    onPreVisitDirectory { directory, attributes ->
        // Some logic on visiting directories
        FileVisitResult.CONTINUE
    }

    onVisitFile { file, attributes ->
        // Some logic on visiting files
        FileVisitResult.CONTINUE
    }
}

// Some logic may go here

projectDirectory.visitFileTree(cleanVisitor)
```

- Create a FileVisitor with the builderAction and use it immediately:

```
projectDirectory.visitFileTree {
// Definition of the builderAction:
    onPreVisitDirectory { directory, attributes ->
        // Some logic on visiting directories
        FileVisitResult.CONTINUE
    }

    onVisitFile { file, attributes ->
        // Some logic on visiting files
        FileVisitResult.CONTINUE
    }
}
```

- Traverse a file tree rooted at the specified path with the walk() function:

```
@OptIn(kotlin.io.path.ExperimentalPathApi::class)
fun traverseFileTree() {
    val cleanVisitor = fileVisitor {
        onPreVisitDirectory { directory, _ ->
            if (directory.name == "build") {
                directory.toFile().deleteRecursively()
                FileVisitResult.SKIP_SUBTREE
            } else {
                FileVisitResult.CONTINUE
            }
        }

        onVisitFile { file, _ ->
```

```
            if (file.extension == "class") {
                file.deleteExisting()
            }
            FileVisitResult.CONTINUE
        }
    }

    val rootDirectory = createTempDirectory("Project")

    rootDirectory.resolve("src").let { srcDirectory ->
        srcDirectory.createDirectory()
        srcDirectory.resolve("A.kt").createFile()
        srcDirectory.resolve("A.class").createFile()
    }

    rootDirectory.resolve("build").let { buildDirectory ->
        buildDirectory.createDirectory()
        buildDirectory.resolve("Project.jar").createFile()
    }


// Use walk function:
    val directoryStructure = rootDirectory.walk(PathWalkOption.INCLUDE_DIRECTORIES)
        .map { it.relativeTo(rootDirectory).toString() }
        .toList().sorted()
    assertPrints(directoryStructure, "[, build, build/Project.jar, src, src/A.class, src/A.kt]")

    rootDirectory.visitFileTree(cleanVisitor)

    val directoryStructureAfterClean = rootDirectory.walk(PathWalkOption.INCLUDE_DIRECTORIES)
        .map { it.relativeTo(rootDirectory).toString() }
        .toList().sorted()
    assertPrints(directoryStructureAfterClean, "[, src, src/A.kt]")
}
```

As is usual for an experimental API, the new extensions require an opt-in: @OptIn(kotlin.io.path.ExperimentalPathApi::class) or @kotlin.io.path.ExperimentalPathApi. Alternatively, you can use a compiler option: -opt-in=kotlin.io.path.ExperimentalPathApi.

We would appreciate your feedback on the walk() function and the visit extension functions in YouTrack.

Documentation updates

Since the previous release, the Kotlin documentation has received some notable changes:

Revamped and improved pages

- Basic types overview – learn about the basic types used in Kotlin: numbers, Booleans, characters, strings, arrays, and unsigned integer numbers.
- IDEs for Kotlin development – see the list of IDEs with official Kotlin support and tools that have community-supported plugins.

New articles in the Kotlin Multiplatform journal

- Native and cross-platform app development: how to choose? – check out our overview and advantages of cross-platform app development and the native approach.
- The six best cross-platform app development frameworks – read about the key aspects to help you choose the right framework for your cross-platform project.

New and updated tutorials

- Get started with Kotlin Multiplatform – learn about cross-platform mobile development with Kotlin and create an app that works on both Android and iOS.
- Build a web application with React and Kotlin/JS – create a browser app exploring Kotlin's DSLs and features of a typical React program.

Changes in release documentation

We no longer provide a list of recommended kotlinx libraries for each release. This list included only the versions recommended and tested with Kotlin itself. It didn't take into account that some libraries depend on each other and require a special kotlinx version, which may differ from the recommended Kotlin version.

We're working on finding a way to provide information on how libraries interrelate and depend on each other so that it will be clear which kotlinx library version you should use when you upgrade the Kotlin version in your project.

Install Kotlin 1.7.20

IntelliJ IDEA 2021.3, 2022.1, and 2022.2 automatically suggest updating the Kotlin plugin to 1.7.20.

For Android Studio Dolphin (213), Electric Eel (221), and Flamingo (222), the Kotlin plugin 1.7.20 will be delivered with upcoming Android Studios updates.

The new command-line compiler is available for download on the GitHub release page.

Compatibility guide for Kotlin 1.7.20

Although Kotlin 1.7.20 is an incremental release, there are still incompatible changes we had to make to limit spread of the issues introduced in Kotlin 1.7.0.

Find the detailed list of such changes in the Compatibility guide for Kotlin 1.7.20.

What's new in Kotlin 1.7.0

Released: 9 June 2022

Kotlin 1.7.0 has been released. It unveils the Alpha version of the new Kotlin/JVM K2 compiler, stabilizes language features, and brings performance improvements for the JVM, JS, and Native platforms.

Here is a list of the major updates in this version:

- The new Kotlin K2 compiler is in Alpha now, and it offers serious performance improvements. It is available only for the JVM, and none of the compiler plugins, including kapt, work with it.
- A new approach to the incremental compilation in Gradle. Incremental compilation is now also supported for changes made inside dependent non-Kotlin modules and is compatible with Gradle.
- We've stabilized opt-in requirement annotations, definitely non-nullable types, and builder inference.
- There's now an underscore operator for type args. You can use it to automatically infer a type of argument when other types are specified.
- This release allows implementation by delegation to an inlined value of an inline class. You can now create lightweight wrappers that do not allocate memory in most cases.

You can also find a short overview of the changes in this video:

Watch video online.

New Kotlin K2 compiler for the JVM in Alpha

This Kotlin release introduces the Alpha version of the new Kotlin K2 compiler. The new compiler aims to speed up the development of new language features, unify all of the platforms Kotlin supports, bring performance improvements, and provide an API for compiler extensions.

We've already published some detailed explanations of our new compiler and its benefits:

- The Road to the New Kotlin Compiler
- K2 Compiler: a Top-Down View

It's important to point out that with the Alpha version of the new K2 compiler we were primarily focused on performance improvements, and it only works with JVM projects. It doesn't support Kotlin/JS, Kotlin/Native, or other multi-platform projects, and none of compiler plugins, including kapt, work with it.

Our benchmarks show some outstanding results on our internal projects:

Project	Current Kotlin compiler performance	New K2 Kotlin compiler performance	Performance boost
Kotlin	2.2 KLOC/s	4.8 KLOC/s	~ x2.2
YouTrack	1.8 KLOC/s	4.2 KLOC/s	~ x2.3
IntelliJ IDEA	1.8 KLOC/s	3.9 KLOC/s	~ x2.2
Space	1.2 KLOC/s	2.8 KLOC/s	~ x2.3

The KLOC/s performance numbers stand for the number of thousands of lines of code that the compiler processes per second.

You can check out the performance boost on your JVM projects and compare it with the results of the old compiler. To enable the Kotlin K2 compiler, use the following compiler option:

```
-Xuse-k2
```

Also, the K2 compiler includes a number of bugfixes. Please note that even issues with State: Open from this list are in fact fixed in K2.

The next Kotlin releases will improve the stability of the K2 compiler and provide more features, so stay tuned!

If you face any performance issues with the Kotlin K2 compiler, please report them to our issue tracker.

Language

Kotlin 1.7.0 introduces support for implementation by delegation and a new underscore operator for type arguments. It also stabilizes several language features introduced as previews in previous releases:

- Implementation by delegation to inlined value of inline class
- Underscore operator for type arguments
- Stable builder inference
- Stable opt-in requirements
- Stable definitely non-nullable types

Allow implementation by delegation to an inlined value of an inline class

If you want to create a lightweight wrapper for a value or class instance, it's necessary to implement all interface methods by hand. Implementation by delegation solves this issue, but it did not work with inline classes before 1.7.0. This restriction has been removed, so you can now create lightweight wrappers that do not allocate memory in most cases.

```kotlin
interface Bar {
    fun foo() = "foo"
}

@JvmInline
value class BarWrapper(val bar: Bar): Bar by bar

fun main() {
    val bw = BarWrapper(object: Bar {})
    println(bw.foo())
}
```

Underscore operator for type arguments

Kotlin 1.7.0 introduces an underscore operator, _, for type arguments. You can use it to automatically infer a type argument when other types are specified:

```kotlin
abstract class SomeClass<T> {
    abstract fun execute(): T
}

class SomeImplementation : SomeClass<String>() {
    override fun execute(): String = "Test"
}

class OtherImplementation : SomeClass<Int>() {
    override fun execute(): Int = 42
}

object Runner {
    inline fun <reified S: SomeClass<T>, T> run(): T {
        return S::class.java.getDeclaredConstructor().newInstance().execute()
    }
}

fun main() {
    // T is inferred as String because SomeImplementation derives from SomeClass<String>
    val s = Runner.run<SomeImplementation, _>()
    assert(s == "Test")

    // T is inferred as Int because OtherImplementation derives from SomeClass<Int>
    val n = Runner.run<OtherImplementation, _>()
    assert(n == 42)
}
```

You can use the underscore operator in any position in the variables list to infer a type argument.

Stable builder inference

Builder inference is a special kind of type inference that is useful when calling generic builder functions. It helps the compiler infer the type arguments of a call using the type information about other calls inside its lambda argument.

Starting with 1.7.0, builder inference is automatically activated if a regular type inference cannot get enough information about a type without specifying the -Xenable-builder-inference compiler option, which was introduced in 1.6.0.

Learn how to write custom generic builders.

Stable opt-in requirements

Opt-in requirements are now Stable and do not require additional compiler configuration.

Before 1.7.0, the opt-in feature itself required the argument -opt-in=kotlin.RequiresOptIn to avoid a warning. It no longer requires this; however, you can still use the compiler argument -opt-in to opt-in for other annotations, a module.

Stable definitely non-nullable types

In Kotlin 1.7.0, definitely non-nullable types have been promoted to Stable. They provide better interoperability when extending generic Java classes and interfaces.

You can mark a generic type parameter as definitely non-nullable at the use site with the new syntax T & Any. The syntactic form comes from the notation for intersection types and is now limited to a type parameter with nullable upper bounds on the left side of & and a non-nullable Any on the right side:

```
fun <T> elvisLike(x: T, y: T & Any): T & Any = x ?: y

fun main() {
    // OK
    elvisLike<String>("", "").length
    // Error: 'null' cannot be a value of a non-null type
    elvisLike<String>("", null).length

    // OK
    elvisLike<String?>(null, "").length
    // Error: 'null' cannot be a value of a non-null type
    elvisLike<String?>(null, null).length
}
```

Learn more about definitely non-nullable types in this KEEP.

Kotlin/JVM

This release brings performance improvements for the Kotlin/JVM compiler and a new compiler option. Additionally, callable references to functional interface constructors have become Stable. Note that since 1.7.0, the default target version for Kotlin/JVM compilations is 1.8.

- Compiler performance optimizations
- New compiler option -Xjdk-release
- Stable callable references to functional interface constructors
- Removed the JVM target version 1.6

Compiler performance optimizations

Kotlin 1.7.0 introduces performance improvements for the Kotlin/JVM compiler. According to our benchmarks, compilation time has been reduced by 10% on average compared to Kotlin 1.6.0. Projects with lots of usages of inline functions, for example, projects using kotlinx.html, will compile faster thanks to the improvements to the bytecode postprocessing.

New compiler option: -Xjdk-release

Kotlin 1.7.0 presents a new compiler option, -Xjdk-release. This option is similar to the javac's command-line --release option. The -Xjdk-release option controls the target bytecode version and limits the API of the JDK in the classpath to the specified Java version. For example, kotlinc -Xjdk-release=1.8 won't allow referencing java.lang.Module even if the JDK in the dependencies is version 9 or higher.

> This option is not guaranteed to be effective for each JDK distribution.

Please leave your feedback on this YouTrack ticket.

Stable callable references to functional interface constructors

Callable references to functional interface constructors are now Stable. Learn how to migrate from an interface with a constructor function to a functional interface using callable references.

Please report any issues you find in YouTrack.

Removed JVM target version 1.6

The default target version for Kotlin/JVM compilations is 1.8. The 1.6 target has been removed.

Please migrate to JVM target 1.8 or above. Learn how to update the JVM target version for:

- Gradle
- Maven
- The command-line compiler

Kotlin/Native

Kotlin 1.7.0 includes changes to Objective-C and Swift interoperability and stabilizes features that were introduced in previous releases. It also brings performance improvements for the new memory manager along with other updates:

- Performance improvements for the new memory manager
- Unified compiler plugin ABI with JVM and JS IR backends
- Support for standalone Android executables
- Interop with Swift async/await: returning Void instead of KotlinUnit
- Prohibited undeclared exceptions through Objective-C bridges
- Improved CocoaPods integration
- Overriding of the Kotlin/Native compiler download URL

Performance improvements for the new memory manager

> The new Kotlin/Native memory manager is in Alpha. It may change incompatibly and require manual migration in the future. We would appreciate your feedback in YouTrack.

The new memory manager is still in Alpha, but it is on its way to becoming Stable. This release delivers significant performance improvements for the new memory manager, especially in garbage collection (GC). In particular, concurrent implementation of the sweep phase, introduced in 1.6.20, is now enabled by default. This helps reduce the time the application is paused for GC. The new GC scheduler is better at choosing the GC frequency, especially for larger heaps.

Also, we've specifically optimized debug binaries, ensuring that the proper optimization level and link-time optimizations are used in the implementation code of the memory manager. This helped us improve execution time by roughly 30% for debug binaries on our benchmarks.

Try using the new memory manager in your projects to see how it works, and share your feedback with us in YouTrack.

Unified compiler plugin ABI with JVM and JS IR backends

Starting with Kotlin 1.7.0, the Kotlin Multiplatform Gradle plugin uses the embeddable compiler jar for Kotlin/Native by default. This feature was announced in 1.6.0 as Experimental, and now it's Stable and ready to use.

This improvement is very handy for library authors, as it improves the compiler plugin development experience. Before this release, you had to provide separate artifacts for Kotlin/Native, but now you can use the same compiler plugin artifacts for Native and other supported platforms.

> This feature might require plugin developers to take migration steps for their existing plugins.
>
> Learn how to prepare your plugin for the update in this YouTrack issue.

Support for standalone Android executables

Kotlin 1.7.0 provides full support for generating standard executables for Android Native targets. It was introduced in 1.6.20, and now it's enabled by default.

If you want to roll back to the previous behavior when Kotlin/Native generated shared libraries, use the following setting:

```
binaryOptions["androidProgramType"] = "nativeActivity"
```

Interop with Swift async/await: returning Void instead of KotlinUnit

Kotlin suspend functions now return the Void type instead of KotlinUnit in Swift. This is the result of the improved interop with Swift's async/await. This feature was introduced in 1.6.20, and this release enables this behavior by default.

You don't need to use the kotlin.native.binary.unitSuspendFunctionObjCExport=proper property anymore to return the proper type for such functions.

Prohibited undeclared exceptions through Objective-C bridges

When you call Kotlin code from Swift/Objective-C code (or vice versa) and this code throws an exception, it should be handled by the code where the exception occurred, unless you specifically allowed the forwarding of exceptions between languages with proper conversion (for example, using the @Throws annotation).

Previously, Kotlin had another unintended behavior where undeclared exceptions could "leak" from one language to another in some cases. Kotlin 1.7.0 fixes that issue, and now such cases lead to program termination.

So, for example, if you have a { throw Exception() } lambda in Kotlin and call it from Swift, in Kotlin 1.7.0 it will terminate as soon as the exception reaches the Swift code. In previous Kotlin versions, such an exception could leak to the Swift code.

The @Throws annotation continues to work as before.

Improved CocoaPods integration

Starting with Kotlin 1.7.0, you no longer need to install the cocoapods-generate plugin if you want to integrate CocoaPods in your projects.

Previously, you needed to install both the CocoaPods dependency manager and the cocoapods-generate plugin to use CocoaPods, for example, to handle iOS dependencies in Kotlin Multiplatform Mobile projects.

Now setting up the CocoaPods integration is easier, and we've resolved the issue when cocoapods-generate couldn't be installed on Ruby 3 and later. Now the newest Ruby versions that work better on Apple M1 are also supported.

See how to set up the initial CocoaPods integration.

Overriding the Kotlin/Native compiler download URL

Starting with Kotlin 1.7.0, you can customize the download URL for the Kotlin/Native compiler. This is useful when external links on the CI are forbidden.

To override the default base URL https://download.jetbrains.com/kotlin/native/builds, use the following Gradle property:

```
kotlin.native.distribution.baseDownloadUrl=https://example.com
```

The downloader will append the native version and target OS to this base URL to ensure it downloads the actual compiler distribution.

Kotlin/JS

Kotlin/JS is receiving further improvements to the JS IR compiler backend along with other updates that can make your development experience better:

- Performance improvements for the new IR backend
- Minification for member names when using IR
- Support for older browsers via polyfills in the IR backend
- Dynamically load JavaScript modules from js expressions
- Specify environment variables for JavaScript test runners

Performance improvements for the new IR backend

This release has some major updates that should improve your development experience:

- Incremental compilation performance of Kotlin/JS has been significantly improved. It takes less time to build your JS projects. Incremental rebuilds should now be roughly on par with the legacy backend in many cases now.
- The Kotlin/JS final bundle requires less space, as we have significantly reduced the size of the final artifacts. We've measured up to a 20% reduction in the production bundle size compared to the legacy backend for some large projects.
- Type checking for interfaces has been improved by orders of magnitude.
- Kotlin generates higher-quality JS code

Minification for member names when using IR

The Kotlin/JS IR compiler now uses its internal information about the relationships of your Kotlin classes and functions to apply more efficient minification, shortening the names of functions, properties, and classes. This shrinks the resulting bundled applications.

This type of minification is automatically applied when you build your Kotlin/JS application in production mode and is enabled by default. To disable member name minification, use the -Xir-minimized-member-names compiler flag:

```
kotlin {
    js(IR) {
        compilations.all {
            compileKotlinTask.kotlinOptions.freeCompilerArgs += listOf("-Xir-minimized-member-names=false")
        }
    }
}
```

Support for older browsers via polyfills in the IR backend

The IR compiler backend for Kotlin/JS now includes the same polyfills as the legacy backend. This allows code compiled with the new compiler to run in older browsers that do not support all the methods from ES2015 used by the Kotlin standard library. Only those polyfills actually used by the project are included in the final bundle, which minimizes their potential impact on the bundle size.

This feature is enabled by default when using the IR compiler, and you don't need to configure it.

Dynamically load JavaScript modules from js expressions

When working with the JavaScript modules, most applications use static imports, whose use is covered with the JavaScript module integration. However, Kotlin/JS was missing a mechanism to load JavaScript modules dynamically at runtime in your applications.

Starting with Kotlin 1.7.0, the import statement from JavaScript is supported in js blocks, allowing you to dynamically bring packages into your application at runtime:

```
val myPackage = js("import('my-package')")
```

Specify environment variables for JavaScript test runners

To tune Node.js package resolution or pass external information to Node.js tests, you can now specify environment variables used by the JavaScript test runners. To define an environment variable, use the environment() function with a key-value pair inside the testTask block in your build script:

```
kotlin {
    js {
        nodejs {
            testTask {
                environment("key", "value")
            }
        }
    }
}
```

Standard library

In Kotlin 1.7.0, the standard library has received a range of changes and improvements. They introduce new features, stabilize experimental ones, and unify support for named capturing groups for Native, JS, and the JVM:

- min() and max() collection functions return as non-nullable
- Regular expression matching at specific indices
- Extended support of previous language and API versions
- Access to annotations via reflection
- Stable deep recursive functions
- Time marks based on inline classes for default time source
- New experimental extension functions for Java Optionals
- Support for named capturing groups in JS and Native

min() and max() collection functions return as non-nullable

In Kotlin 1.4.0, we renamed the min() and max() collection functions to minOrNull() and maxOrNull(). These new names better reflect their behavior – returning null if the receiver collection is empty. It also helped align the functions' behavior with naming conventions used throughout the Kotlin collections API.

The same was true of minBy(), maxBy(), minWith(), and maxWith(), which all got their *OrNull() synonyms in Kotlin 1.4.0. Older functions affected by this change were gradually deprecated.

Kotlin 1.7.0 reintroduces the original function names, but with a non-nullable return type. The new min(), max(), minBy(), maxBy(), minWith(), and maxWith() functions now strictly return the collection element or throw an exception.

```
fun main() {
    val numbers = listOf<Int>()
    println(numbers.maxOrNull()) // "null"
    println(numbers.max()) // "Exception in... Collection is empty."
}
```

Regular expression matching at specific indices

The Regex.matchAt() and Regex.matchesAt() functions, introduced in 1.5.30, are now Stable. They provide a way to check whether a regular expression has an exact match at a particular position in a String or CharSequence.

matchesAt() checks for a match and returns a boolean result:

```
fun main() {
    val releaseText = "Kotlin 1.7.0 is on its way!"
    // regular expression: one digit, dot, one digit, dot, one or more digits
    val versionRegex = "\\d[.]\\d[.]\\d+".toRegex()

    println(versionRegex.matchesAt(releaseText, 0)) // "false"
    println(versionRegex.matchesAt(releaseText, 7)) // "true"
}
```

matchAt() returns the match if it's found, or null if it isn't:

```
fun main() {
    val releaseText = "Kotlin 1.7.0 is on its way!"
    val versionRegex = "\\d[.]\\d[.]\\d+".toRegex()

    println(versionRegex.matchAt(releaseText, 0)) // "null"
    println(versionRegex.matchAt(releaseText, 7)?.value) // "1.7.0"
}
```

We'd be grateful for your feedback on this YouTrack issue.

Extended support for previous language and API versions

To support library authors developing libraries that are meant to be consumable in a wide range of previous Kotlin versions, and to address the increased frequency of major Kotlin releases, we have extended our support for previous language and API versions.

With Kotlin 1.7.0, we're supporting three previous language and API versions rather than two. This means Kotlin 1.7.0 supports the development of libraries targeting Kotlin versions down to 1.4.0. For more information on backward compatibility, see Compatibility modes.

Access to annotations via reflection

The KAnnotatedElement.findAnnotations() extension function, which was first introduced in 1.6.0, is now Stable. This reflection function returns all annotations of a given type on an element, including individually applied and repeated annotations.

```
@Repeatable
annotation class Tag(val name: String)

@Tag("First Tag")
@Tag("Second Tag")
fun taggedFunction() {
    println("I'm a tagged function!")
}

fun main() {
    val x = ::taggedFunction
    val foo = x as KAnnotatedElement
    println(foo.findAnnotations<Tag>()) // [@Tag(name=First Tag), @Tag(name=Second Tag)]
}
```

Stable deep recursive functions

Deep recursive functions have been available as an experimental feature since Kotlin 1.4.0, and they are now Stable in Kotlin 1.7.0. Using DeepRecursiveFunction, you can define a function that keeps its stack on the heap instead of using the actual call stack. This allows you to run very deep recursive computations. To call a deep recursive function, invoke it.

In this example, a deep recursive function is used to calculate the depth of a binary tree recursively. Even though this sample function calls itself recursively 100,000 times, no StackOverflowError is thrown:

```
class Tree(val left: Tree?, val right: Tree?)

val calculateDepth = DeepRecursiveFunction<Tree?, Int> { t ->
    if (t == null) 0 else maxOf(
        callRecursive(t.left),
        callRecursive(t.right)
    ) + 1
}

fun main() {
    // Generate a tree with a depth of 100_000
    val deepTree = generateSequence(Tree(null, null)) { prev ->
        Tree(prev, null)
    }.take(100_000).last()

    println(calculateDepth(deepTree)) // 100000
}
```

Consider using deep recursive functions in your code where your recursion depth exceeds 1000 calls.

Time marks based on inline classes for default time source

Kotlin 1.7.0 improves the performance of time measurement functionality by changing the time marks returned by TimeSource.Monotonic into inline value classes. This means that calling functions like markNow(), elapsedNow(), measureTime(), and measureTimedValue() doesn't allocate wrapper classes for their TimeMark instances. Especially when measuring a piece of code that is part of a hot path, this can help minimize the performance impact of the measurement:

```
@OptIn(ExperimentalTime::class)
fun main() {
    val mark = TimeSource.Monotonic.markNow() // Returned `TimeMark` is inline class
    val elapsedDuration = mark.elapsedNow()
}
```

This optimization is only available if the time source from which the TimeMark is obtained is statically known to be TimeSource.Monotonic.

New experimental extension functions for Java Optionals

Kotlin 1.7.0 comes with new convenience functions that simplify working with Optional classes in Java. These new functions can be used to unwrap and convert optional objects on the JVM and help make working with Java APIs more concise.

The getOrNull(), getOrDefault(), and getOrElse() extension functions allow you to get the value of an Optional if it's present. Otherwise, you get null, a default value, or a value returned by a function, respectively:

```
val presentOptional = Optional.of("I'm here!")

println(presentOptional.getOrNull())
// "I'm here!"

val absentOptional = Optional.empty<String>()

println(absentOptional.getOrNull())
// null
println(absentOptional.getOrDefault("Nobody here!"))
// "Nobody here!"
println(absentOptional.getOrElse {
    println("Optional was absent!")
    "Default value!"
})
// "Optional was absent!"
// "Default value!"
```

The toList(), toSet(), and asSequence() extension functions convert the value of a present Optional to a list, set, or sequence, or return an empty collection otherwise. The toCollection() extension function appends the Optional value to an already existing destination collection:

```
val presentOptional = Optional.of("I'm here!")
val absentOptional = Optional.empty<String>()
println(presentOptional.toList() + "," + absentOptional.toList())
// ["I'm here!"], []
println(presentOptional.toSet() + "," + absentOptional.toSet())
// ["I'm here!"], []
val myCollection = mutableListOf<String>()
absentOptional.toCollection(myCollection)
println(myCollection)
// []
presentOptional.toCollection(myCollection)
println(myCollection)
```

```kotlin
// ["I'm here!"]
val list = listOf(presentOptional, absentOptional).flatMap { it.asSequence() }
println(list)
// ["I'm here!"]
```

These extension functions are being introduced as Experimental in Kotlin 1.7.0. You can learn more about Optional extensions in this KEEP. As always, we welcome your feedback in the Kotlin issue tracker.

Support for named capturing groups in JS and Native

Starting with Kotlin 1.7.0, named capturing groups are supported not only on the JVM, but on the JS and Native platforms as well.

To give a name to a capturing group, use the (?<name>group) syntax in your regular expression. To get the text matched by a group, call the newly introduced MatchGroupCollection.get() function and pass the group name.

Retrieve matched group value by name

Consider this example for matching city coordinates. To get a collection of groups matched by the regular expression, use groups. Compare retrieving a group's contents by its number (index) and by its name using value:

```kotlin
fun main() {
    val regex = "\\b(?<city>[A-Za-z\\s]+),\\s(?<state>[A-Z]{2}):\\s(?<areaCode>[0-9]{3})\\b".toRegex()
    val input = "Coordinates: Austin, TX: 123"
    val match = regex.find(input)!!
    println(match.groups["city"]?.value) // "Austin" — by name
    println(match.groups[2]?.value) // "TX" — by number
}
```

Named backreferencing

You can now also use group names when backreferencing groups. Backreferences match the same text that was previously matched by a capturing group. For this, use the \k<name> syntax in your regular expression:

```kotlin
fun backRef() {
    val regex = "(?<title>\\w+), yes \\k<title>".toRegex()
    val match = regex.find("Do you copy? Sir, yes Sir!")!!
    println(match.value) // "Sir, yes Sir"
    println(match.groups["title"]?.value) // "Sir"
}
```

Named groups in replacement expressions

Named group references can be used with replacement expressions. Consider the replace() function that substitutes all occurrences of the specified regular expression in the input with a replacement expression, and the replaceFirst() function that swaps the first match only.

Occurrences of ${name} in the replacement string are substituted with the subsequences corresponding to the captured groups with the specified name. You can compare replacements in group references by name and index:

```kotlin
fun dateReplace() {
    val dateRegex = Regex("(?<dd>\\d{2})-(?<mm>\\d{2})-(?<yyyy>\\d{4})")
    val input = "Date of birth: 27-04-2022"
    println(dateRegex.replace(input, "\${yyyy}-\${mm}-\${dd}")) // "Date of birth: 2022-04-27" — by name
    println(dateRegex.replace(input, "\$3-\$2-\$1")) // "Date of birth: 2022-04-27" — by number
}
```

Gradle

This release introduces new build reports, support for Gradle plugin variants, new statistics in kapt, and a lot more:

- A new approach to incremental compilation
- New build reports for tracking compiler performance

- Changes to the minimum supported versions of Gradle and the Android Gradle plugin
- Support for Gradle plugin variants
- Updates in the Kotlin Gradle plugin API
- Availability of the sam-with-receiver plugin via the plugins API
- Changes in compile tasks
- New statistics of generated files by each annotation processor in kapt
- Deprecation of the kotlin.compiler.execution.strategy system property
- Removal of deprecated options, methods, and plugins

A new approach to incremental compilation

> The new approach to incremental compilation is Experimental. It may be dropped or changed at any time. Opt-in is required (see the details below). We encourage you to use it only for evaluation purposes, and we would appreciate your feedback in YouTrack.

In Kotlin 1.7.0, we've reworked incremental compilation for cross-module changes. Now incremental compilation is also supported for changes made inside dependent non-Kotlin modules, and it is compatible with the Gradle build cache. Support for compilation avoidance has also been improved.

We expect you'll see the most significant benefit of the new approach if you use the build cache or frequently make changes in non-Kotlin Gradle modules. Our tests for the Kotlin project on the kotlin-gradle-plugin module show an improvement of greater than 80% for the changes after the cache hit.

To try this new approach, set the following option in your gradle.properties:

```
kotlin.incremental.useClasspathSnapshot=true
```

> The new approach to incremental compilation is currently available for the JVM backend in the Gradle build system only.

Learn how the new approach to incremental compilation is implemented under the hood in this blog post.

Our plan is to stabilize this technology and add support for other backends (JS, for instance) and build systems. We'd appreciate your reports in YouTrack about any issues or strange behavior you encounter in this compilation scheme. Thank you!

The Kotlin team is very grateful to Ivan Gavrilovic, Hung Nguyen, Cédric Champeau, and other external contributors for their help.

Build reports for Kotlin compiler tasks

> Kotlin build reports are Experimental. They may be dropped or changed at any time. Opt-in is required (see details below). Use them only for evaluation purposes. We appreciate your feedback on them in YouTrack.

Kotlin 1.7.0 introduces build reports that help track compiler performance. Reports contain the durations of different compilation phases and reasons why compilation couldn't be incremental.

Build reports come in handy when you want to investigate issues with compiler tasks, for example:

- When the Gradle build takes too much time and you want to understand the root cause of the poor performance.
- When the compilation time for the same project differs, sometimes taking seconds, sometimes taking minutes.

To enable build reports, declare where to save the build report output in gradle.properties:

```
kotlin.build.report.output=file
```

The following values (and their combinations) are available:

- file saves build reports in a local file.
- build_scan saves build reports in the custom values section of the build scan.

> The Gradle Enterprise plugin limits the number of custom values and their length. In big projects, some values could be lost.

- http posts build reports using HTTP(S). The POST method sends metrics in the JSON format. Data may change from version to version. You can see the current version of the sent data in the Kotlin repository.

There are two common cases that analyzing build reports for long-running compilations can help you resolve:

- The build wasn't incremental. Analyze the reasons and fix underlying problems.
- The build was incremental, but took too much time. Try to reorganize source files — split big files, save separate classes in different files, refactor large classes, declare top-level functions in different files, and so on.

Learn more about new build reports in this blog post.

You are welcome to try using build reports in your infrastructure. If you have any feedback, encounter any issues, or want to suggest improvements, please don't hesitate to report them in our issue tracker. Thank you!

Bumping minimum supported versions

Starting with Kotlin 1.7.0, the minimum supported Gradle version is 6.7.1. We had to raise the version to support Gradle plugin variants and the new Gradle API. In the future, we should not have to raise the minimum supported version as often, thanks to the Gradle plugin variants feature.

Also, the minimal supported Android Gradle plugin version is now 3.6.4.

Support for Gradle plugin variants

Gradle 7.0 introduced a new feature for Gradle plugin authors — plugins with variants. This feature makes it easier to add support for new Gradle features while maintaining compatibility for Gradle versions below 7.1. Learn more about variant selection in Gradle.

With Gradle plugin variants, we can ship different Kotlin Gradle plugin variants for different Gradle versions. The goal is to support the base Kotlin compilation in the main variant, which corresponds to the oldest supported versions of Gradle. Each variant will have implementations for Gradle features from a corresponding release. The latest variant will support the widest Gradle feature set. With this approach, we can extend support for older Gradle versions with limited functionality.

Currently, there are only two variants of the Kotlin Gradle plugin:

- main for Gradle versions 6.7.1–6.9.3
- gradle70 for Gradle versions 7.0 and higher

In future Kotlin releases, we may add more.

To check which variant your build uses, enable the --info log level and find a string in the output starting with Using Kotlin Gradle plugin, for example, Using Kotlin Gradle plugin main variant.

> Here are workarounds for some known issues with variant selection in Gradle:
>
> - ResolutionStrategy in pluginManagement is not working for plugins with multivariants
> - Plugin variants are ignored when a plugin is added as the buildSrc common dependency

Leave your feedback on this YouTrack ticket.

Updates in the Kotlin Gradle plugin API

The Kotlin Gradle plugin API artifact has received several improvements:

- There are new interfaces for Kotlin/JVM and Kotlin/kapt tasks with user-configurable inputs.
- There is a new KotlinBasePlugin interface that all Kotlin plugins inherit from. Use this interface when you want to trigger some configuration action whenever any Kotlin Gradle plugin (JVM, JS, Multiplatform, Native, and other platforms) is applied:

  ```
  project.plugins.withType<org.jetbrains.kotlin.gradle.plugin.KotlinBasePlugin>() {
      // Configure your action here
  }
  ```

  You can leave your feedback about the KotlinBasePlugin in this YouTrack ticket.
- We've laid the groundwork for the Android Gradle plugin to configure Kotlin compilation within itself, meaning you won't need to add the Kotlin Android Gradle plugin to your build. Follow Android Gradle Plugin release announcements to learn about the added support and try it out!

The sam-with-receiver plugin is available via the plugins API

The sam-with-receiver compiler plugin is now available via the Gradle plugins DSL:

```
plugins {
    id("org.jetbrains.kotlin.plugin.sam.with.receiver") version "$kotlin_version"
}
```

Changes in compile tasks

Compile tasks have received lots of changes in this release:

- Kotlin compile tasks no longer inherit the Gradle AbstractCompile task. They inherit only the DefaultTask.
- The AbstractCompile task has the sourceCompatibility and targetCompatibility inputs. Since the AbstractCompile task is no longer inherited, these inputs are no longer available in Kotlin users' scripts.
- The SourceTask.stableSources input is no longer available, and you should use the sources input. setSource(...) methods are still available.
- All compile tasks now use the libraries input for a list of libraries required for compilation. The KotlinCompile task still has the deprecated Kotlin property classpath, which will be removed in future releases.
- Compile tasks still implement the PatternFilterable interface, which allows the filtering of Kotlin sources. The sourceFilesExtensions input was removed in favor of using PatternFilterable methods.
- The deprecated Gradle destinationDir: File output was replaced with the destinationDirectory: DirectoryProperty output.
- The Kotlin/Native AbstractNativeCompile task now inherits the AbstractKotlinCompileTool base class. This is an initial step toward integrating Kotlin/Native build tools into all the other tools.

Please leave your feedback in this YouTrack ticket.

Statistics of generated files by each annotation processor in kapt

The kotlin-kapt Gradle plugin already reports performance statistics for each processor. Starting with Kotlin 1.7.0, it can also report statistics on the number of generated files for each annotation processor.

This is useful to track if there are unused annotation processors as a part of the build. You can use the generated report to find modules that trigger unnecessary annotation processors and update the modules to prevent that.

Enable the statistics in two steps:

- Set the showProcessorStats flag to true in your build.gradle.kts:

  ```
  kapt {
      showProcessorStats = true
  }
  ```
- Set the kapt.verbose Gradle property to true in your gradle.properties:

  ```
  kapt.verbose=true
  ```

You can also enable verbose output via the command line option verbose.

The statistics will appear in the logs with the info level. You'll see the Annotation processor stats: line followed by statistics on the execution time of each annotation processor. After these lines, there will be the Generated files report: line followed by statistics on the number of generated files for each annotation processor. For example:

```
[INFO] Annotation processor stats:
[INFO] org.mapstruct.ap.MappingProcessor: total: 290 ms, init: 1 ms, 3 round(s): 289 ms, 0 ms, 0 ms
[INFO] Generated files report:
[INFO] org.mapstruct.ap.MappingProcessor: total sources: 2, sources per round: 2, 0, 0
```

Please leave your feedback in this YouTrack ticket.

Deprecation of the kotlin.compiler.execution.strategy system property

Kotlin 1.6.20 introduced new properties for defining a Kotlin compiler execution strategy. In Kotlin 1.7.0, a deprecation cycle has started for the old system property kotlin.compiler.execution.strategy in favor of the new properties.

When using the kotlin.compiler.execution.strategy system property, you'll receive a warning. This property will be deleted in future releases. To preserve the old behavior, replace the system property with the Gradle property of the same name. You can do this in gradle.properties, for example:

```
kotlin.compiler.execution.strategy=out-of-process
```

You can also use the compile task property compilerExecutionStrategy. Learn more about this on the Gradle page.

Removal of deprecated options, methods, and plugins

Removal of the useExperimentalAnnotation method

In Kotlin 1.7.0, we completed the deprecation cycle for the useExperimentalAnnotation Gradle method. Use optIn() instead to opt in to using an API in a module.

For example, if your Gradle module is multiplatform:

```
sourceSets {
    all {
        languageSettings.optIn("org.mylibrary.OptInAnnotation")
    }
}
```

Learn more about opt-in requirements in Kotlin.

Removal of deprecated compiler options

We've completed the deprecation cycle for several compiler options:

- The kotlinOptions.jdkHome compiler option was deprecated in 1.5.30 and has been removed in the current release. Gradle builds now fail if they contain this option. We encourage you to use Java toolchains, which have been supported since Kotlin 1.5.30.
- The deprecated noStdlib compiler option has also been removed. The Gradle plugin uses the kotlin.stdlib.default.dependency=true property to control whether the Kotlin standard library is present.

The compiler arguments -jdkHome and -no-stdlib are still available.

Removal of deprecated plugins

In Kotlin 1.4.0, the kotlin2js and kotlin-dce-plugin plugins were deprecated, and they have been removed in this release. Instead of kotlin2js, use the new org.jetbrains.kotlin.js plugin. Dead code elimination (DCE) works when the Kotlin/JS Gradle plugin is properly configured.

In Kotlin 1.6.0, we changed the deprecation level of the KotlinGradleSubplugin class to ERROR. Developers used this class for writing compiler plugins. In this release, this class has been removed. Use the KotlinCompilerPluginSupportPlugin class instead.

> The best practice is to use Kotlin plugins with versions 1.7.0 and higher throughout your project.

Removal of the deprecated coroutines DSL option and property

We removed the deprecated kotlin.experimental.coroutines Gradle DSL option and the kotlin.coroutines property used in gradle.properties. Now you can just use suspending functions or add the kotlinx.coroutines dependency to your build script.

Learn more about coroutines in the Coroutines guide.

Removal of the type cast in the toolchain extension method

Before Kotlin 1.7.0, you had to do the type cast into the JavaToolchainSpec class when configuring the Gradle toolchain with Kotlin DSL:

```
kotlin {
    jvmToolchain {
        (this as JavaToolchainSpec).languageVersion.set(JavaLanguageVersion.of(<MAJOR_JDK_VERSION>)
    }
}
```

Now, you can omit the (this as JavaToolchainSpec) part:

```
kotlin {
    jvmToolchain {
        languageVersion.set(JavaLanguageVersion.of(<MAJOR_JDK_VERSION>)
    }
}
```

Migrating to Kotlin 1.7.0

Install Kotlin 1.7.0

IntelliJ IDEA 2022.1 and Android Studio Chipmunk (212) automatically suggest updating the Kotlin plugin to 1.7.0.

> For IntelliJ IDEA 2022.2, and Android Studio Dolphin (213) or Android Studio Electric Eel (221), the Kotlin plugin 1.7.0 will be delivered with upcoming IntelliJ IDEA and Android Studios updates.

The new command-line compiler is available for download on the GitHub release page.

Migrate existing or start a new project with Kotlin 1.7.0

- To migrate existing projects to Kotlin 1.7.0, change the Kotlin version to 1.7.0 and reimport your Gradle or Maven project. Learn how to update to Kotlin 1.7.0.
- To start a new project with Kotlin 1.7.0, update the Kotlin plugin and run the Project Wizard from File | New | Project.

Compatibility guide for Kotlin 1.7.0

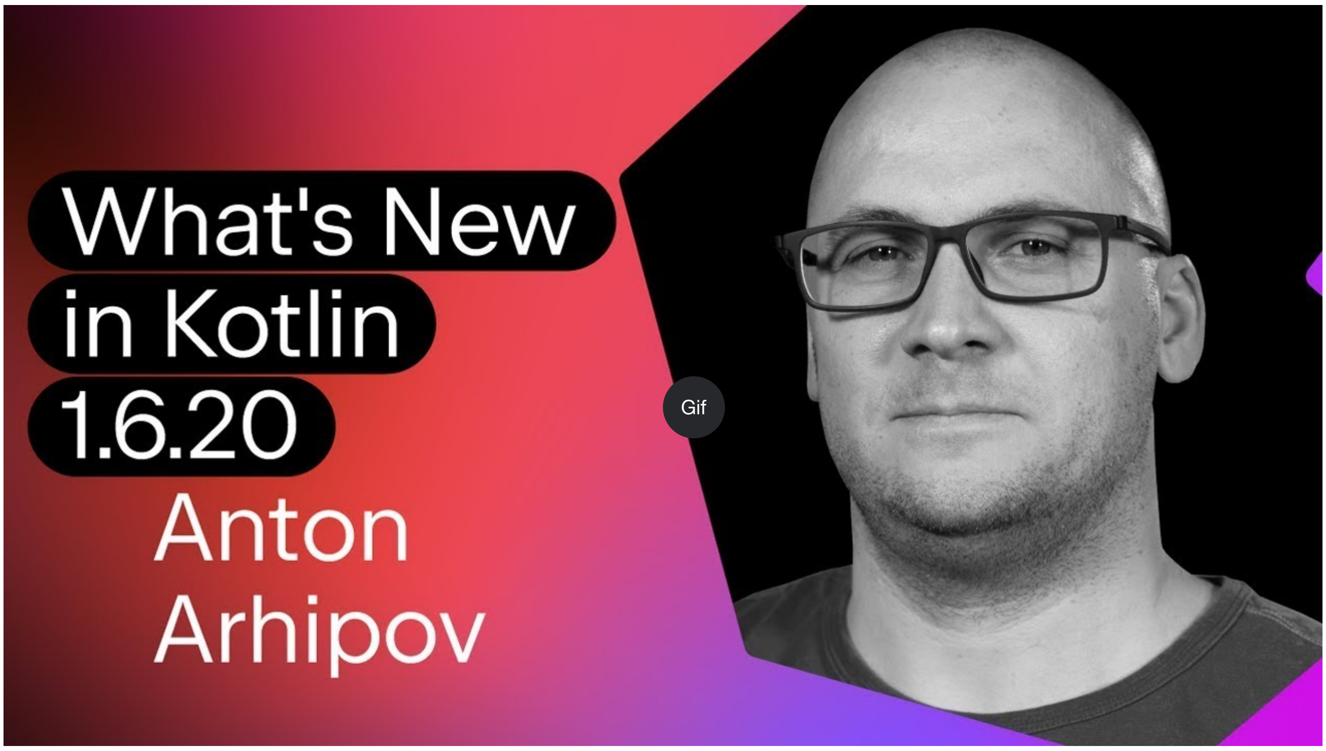
Kotlin 1.7.0 is a feature release and can, therefore, bring changes that are incompatible with your code written for earlier versions of the language. Find the detailed list of such changes in the Compatibility guide for Kotlin 1.7.0.

What's new in Kotlin 1.6.20

Released: 4 April 2022

Kotlin 1.6.20 reveals previews of the future language features, makes the hierarchical structure the default for multiplatform projects, and brings evolutionary improvements to other components.

You can also find a short overview of the changes in this video:



Watch video online.

Language

In Kotlin 1.6.20, you can try two new language features:

- Prototype of context receivers for Kotlin/JVM
- Definitely non-nullable types

Prototype of context receivers for Kotlin/JVM

> The feature is a prototype available only for Kotlin/JVM. With -Xcontext-receivers enabled, the compiler will produce pre-release binaries that cannot be used in production code. Use context receivers only in your toy projects. We appreciate your feedback in YouTrack.

With Kotlin 1.6.20, you are no longer limited to having one receiver. If you need more, you can make functions, properties, and classes context-dependent (or contextual) by adding context receivers to their declaration. A contextual declaration does the following:

- It requires all declared context receivers to be present in a caller's scope as implicit receivers.
- It brings declared context receivers into its body scope as implicit receivers.

```
interface LoggingContext {
    val log: Logger // This context provides a reference to a logger
}

context(LoggingContext)
fun startBusinessOperation() {
    // You can access the log property since LoggingContext is an implicit receiver
    log.info("Operation has started")
}

fun test(loggingContext: LoggingContext) {
    with(loggingContext) {
        // You need to have LoggingContext in a scope as an implicit receiver
        // to call startBusinessOperation()
        startBusinessOperation()
    }
}
```

To enable context receivers in your project, use the -Xcontext-receivers compiler option. You can find a detailed description of the feature and its syntax in the KEEP.

Please note that the implementation is a prototype:

- With -Xcontext-receivers enabled, the compiler will produce pre-release binaries that cannot be used in production code
- The IDE support for context receivers is minimal for now

Try the feature in your toy projects and share your thoughts and experience with us in this YouTrack issue. If you run into any problems, please file a new issue.

Definitely non-nullable types

Definitely non-nullable types are in Beta. They are almost stable, but migration steps may be required in the future. We'll do our best to minimize any changes you have to make.

To provide better interoperability when extending generic Java classes and interfaces, Kotlin 1.6.20 allows you to mark a generic type parameter as definitely non-nullable on the use site with the new syntax T & Any. The syntactic form comes from a notation of intersection types and is now limited to a type parameter with nullable upper bounds on the left side of & and non-nullable Any on the right side:

```
fun <T> elvisLike(x: T, y: T & Any): T & Any = x ?: y

fun main() {
    // OK
    elvisLike<String>("", "").length
    // Error: 'null' cannot be a value of a non-null type
    elvisLike<String>("", null).length

    // OK
    elvisLike<String?>(null, "").length
    // Error: 'null' cannot be a value of a non-null type
    elvisLike<String?>(null, null).length
}
```

Set the language version to 1.7 to enable the feature:

Kotlin

```
kotlin {
    sourceSets.all {
        languageSettings.apply {
            languageVersion = "1.7"
        }
    }
}
```

Groovy

```
kotlin {
    sourceSets.all {
        languageSettings {
            languageVersion = '1.7'
        }
    }
}
```

Learn more about definitely non-nullable types in the KEEP.

Kotlin/JVM

Kotlin 1.6.20 introduces:

- Compatibility improvements of default methods in JVM interfaces: new @JvmDefaultWithCompatibility annotation for interfaces and compatibility changes in the -Xjvm-default modes
- Support for parallel compilation of a single module in the JVM backend
- Support for callable references to functional interface constructors

New @JvmDefaultWithCompatibility annotation for interfaces

Kotlin 1.6.20 introduces the new annotation @JvmDefaultWithCompatibility: use it along with the -Xjvm-default=all compiler option to create the default method in JVM interface for any non-abstract member in any Kotlin interface.

If there are clients that use your Kotlin interfaces compiled without the -Xjvm-default=all option, they may be binary-incompatible with the code compiled with this option. Before Kotlin 1.6.20, to avoid this compatibility issue, the recommended approach was to use the -Xjvm-default=all-compatibility mode and also the @JvmDefaultWithoutCompatibility annotation for interfaces that didn't need this type of compatibility.

This approach had some disadvantages:

- You could easily forget to add the annotation when a new interface was added.
- Usually there are more interfaces in non-public parts than in the public API, so you end up having this annotation in many places in your code.

Now, you can use the -Xjvm-default=all mode and mark interfaces with the @JvmDefaultWithCompatibility annotation. This allows you to add this annotation to all interfaces in the public API once, and you won't need to use any annotations for new non-public code.

Leave your feedback about this new annotation in this YouTrack ticket.

Compatibility changes in the -Xjvm-default modes

Kotlin 1.6.20 adds the option to compile modules in the default mode (the -Xjvm-default=disable compiler option) against modules compiled with the -Xjvm-default=all or -Xjvm-default=all-compatibility modes. As before, compilations will also be successful if all modules have the -Xjvm-default=all or -Xjvm-default=all-compatibility modes. You can leave your feedback in this YouTrack issue.

Kotlin 1.6.20 deprecates the compatibility and enable modes of the compiler option -Xjvm-default. There are changes in other modes' descriptions regarding the compatibility, but the overall logic remains the same. You can check out the updated descriptions.

For more information about default methods in the Java interop, see the interoperability documentation and this blog post.

Support for parallel compilation of a single module in the JVM backend

> Support for parallel compilation of a single module in the JVM backend is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

We are continuing our work to improve the new JVM IR backend compilation time. In Kotlin 1.6.20, we added the experimental JVM IR backend mode to compile all the files in a module in parallel. Parallel compilation can reduce the total compilation time by up to 15%.

Enable the experimental parallel backend mode with the compiler option -Xbackend-threads. Use the following arguments for this option:

- N is the number of threads you want to use. It should not be greater than your number of CPU cores; otherwise, parallelization stops being effective because of switching context between threads
- 0 to use a separate thread for each CPU core

Gradle can run tasks in parallel, but this type of parallelization doesn't help a lot when a project (or a major part of a project) is just one big task from Gradle's perspective. If you have a very big monolithic module, use parallel compilation to compile more quickly. If your project consists of lots of small modules and has a build parallelized by Gradle, adding another layer of parallelization may hurt performance because of context switching.

Parallel compilation has some constraints:

- It doesn't work with kapt because kapt disables the IR backend
- It requires more JVM heap by design. The amount of heap is proportional to the number of threads

Support for callable references to functional interface constructors

Support for callable references to functional interface constructors is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Support for callable references to functional interface constructors adds a source-compatible way to migrate from an interface with a constructor function to a functional interface.

Consider the following code:

```
interface Printer {
    fun print()
}

fun Printer(block: () -> Unit): Printer = object : Printer { override fun print() = block() }
```

With callable references to functional interface constructors enabled, this code can be replaced with just a functional interface declaration:

```
fun interface Printer {
    fun print()
}
```

Its constructor will be created implicitly, and any code using the ::Printer function reference will compile. For example:

```
documentsStorage.addPrinter(::Printer)
```

Preserve the binary compatibility by marking the legacy function Printer with the @Deprecated annotation with DeprecationLevel.HIDDEN:

```
@Deprecated(message = "Your message about the deprecation", level = DeprecationLevel.HIDDEN)
fun Printer(...) {...}
```

Use the compiler option -XXLanguage:+KotlinFunInterfaceConstructorReference to enable this feature.

Kotlin/Native

Kotlin/Native 1.6.20 marks continued development of its new components. We've taken another step toward consistent experience with Kotlin on other platforms:

- An update on the new memory manager
- Concurrent implementation for the sweep phase in new memory manager
- Instantiation of annotation classes
- Interop with Swift async/await: returning Swift's Void instead of KotlinUnit
- Better stack traces with libbacktrace
- Support for standalone Android executables
- Performance improvements
- Improved error handling during cinterop modules import
- Support for Xcode 13 libraries

An update on the new memory manager

> The new Kotlin/Native memory manager is in Alpha. It may change incompatibly and require manual migration in the future. We would appreciate your feedback on it in YouTrack.

With Kotlin 1.6.20, you can try the Alpha version of the new Kotlin/Native memory manager. It eliminates the differences between the JVM and Native platforms to provide a consistent developer experience in multiplatform projects. For example, you'll have a much easier time creating new cross-platform mobile applications that work on both Android and iOS.

The new Kotlin/Native memory manager lifts restrictions on object-sharing between threads. It also provides leak-free concurrent programming primitives that are safe and don't require any special management or annotations.

The new memory manager will become the default in future versions, so we encourage you to try it now. Check out our blog post to learn more about the new memory manager and explore demo projects, or jump right to the migration instructions to try it yourself.

Try using the new memory manager on your projects to see how it works and share feedback in our issue tracker, YouTrack.

Concurrent implementation for the sweep phase in new memory manager

If you have already switched to our new memory manager, which was announced in Kotlin 1.6, you might notice a huge execution time improvement: our benchmarks show 35% improvement on average. Starting with 1.6.20, there is also a concurrent implementation for the sweep phase available for the new memory manager. This should also improve the performance and decrease the duration of garbage collector pauses.

To enable the feature for the new Kotlin/Native memory manager, pass the following compiler option:

```
-Xgc=cms
```

Feel free to share your feedback on the new memory manager performance in this YouTrack issue.

Instantiation of annotation classes

In Kotlin 1.6.0, instantiation of annotation classes became Stable for Kotlin/JVM and Kotlin/JS. The 1.6.20 version delivers support for Kotlin/Native.

Learn more about instantiation of annotation classes.

Interop with Swift async/await: returning Void instead of KotlinUnit

> Concurrency interoperability with Swift async/await is Experimental. It may be dropped or changed at any time. You should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

We've continued working on the experimental interop with Swift's async/await (available since Swift 5.5). Kotlin 1.6.20 differs from previous versions in the way it works with suspend functions with the Unit return type.

Previously, such functions were presented in Swift as async functions returning KotlinUnit. However, the proper return type for them is Void, similar to non-suspending functions.

To avoid breaking the existing code, we're introducing a Gradle property that makes the compiler translate Unit-returning suspend functions to async Swift with the Void return type:

```
# gradle.properties
kotlin.native.binary.unitSuspendFunctionObjCExport=proper
```

We plan to make this behavior the default in future Kotlin releases.

Better stack traces with libbacktrace

Using libbacktrace for resolving source locations is Experimental. It may be dropped or changed at any time. You should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Kotlin/Native is now able to produce detailed stack traces with file locations and line numbers for better debugging of linux* (except linuxMips32 and linuxMipsel32) and androidNative* targets.

This feature uses the libbacktrace library under the hood. Take a look at the following code to see an example of the difference:

```kotlin
fun main() = bar()
fun bar() = baz()
inline fun baz() {
    error("")
}
```

- Before 1.6.20:

```
Uncaught Kotlin exception: kotlin.IllegalStateException:
   at 0   example.kexe        0x227190       kfun:kotlin.Throwable#<init>(kotlin.String?){} + 96
   at 1   example.kexe        0x221e4c       kfun:kotlin.Exception#<init>(kotlin.String?){} + 92
   at 2   example.kexe        0x221f4c       kfun:kotlin.RuntimeException#<init>(kotlin.String?){} + 92
   at 3   example.kexe        0x22234c       kfun:kotlin.IllegalStateException#<init>(kotlin.String?){} + 92
   at 4   example.kexe        0x25d708       kfun:#bar(){} + 104
   at 5   example.kexe        0x25d68c       kfun:#main(){} + 12
```

- 1.6.20 with libbacktrace:

```
Uncaught Kotlin exception: kotlin.IllegalStateException:
   at 0   example.kexe        0x229550    kfun:kotlin.Throwable#<init>(kotlin.String?){} + 96
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/kotlin-native/runtime/src/main/kotlin/kotlin/Throwable.kt:24:37)
   at 1   example.kexe        0x22420c    kfun:kotlin.Exception#<init>(kotlin.String?){} + 92
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/kotlin-native/runtime/src/main/kotlin/kotlin/Exceptions.kt:23:44)
   at 2   example.kexe        0x22430c    kfun:kotlin.RuntimeException#<init>(kotlin.String?){} + 92
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/kotlin-native/runtime/src/main/kotlin/kotlin/Exceptions.kt:34:44)
   at 3   example.kexe        0x22470c    kfun:kotlin.IllegalStateException#<init>(kotlin.String?){} + 92
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/kotlin-native/runtime/src/main/kotlin/kotlin/Exceptions.kt:70:44)
   at 4   example.kexe        0x25fac8    kfun:#bar(){} + 104 [inlined]
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/libraries/stdlib/src/kotlin/util/Preconditions.kt:143:56)
   at 5   example.kexe        0x25fac8    kfun:#bar(){} + 104 [inlined] (/private/tmp/backtrace/src/commonMain/kotlin/app.kt:4:5)
   at 6   example.kexe        0x25fac8    kfun:#bar(){} + 104 (/private/tmp/backtrace/src/commonMain/kotlin/app.kt:2:13)
   at 7   example.kexe        0x25fa4c    kfun:#main(){} + 12 (/private/tmp/backtrace/src/commonMain/kotlin/app.kt:1:14)
```

On Apple targets, which already had file locations and line numbers in stack traces, libbacktrace provides more details for inline function calls:

- Before 1.6.20:

```
Uncaught Kotlin exception: kotlin.IllegalStateException:
   at 0   example.kexe    0x10a85a8f8    kfun:kotlin.Throwable#<init>(kotlin.String?){} + 88
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/kotlin-native/runtime/src/main/kotlin/kotlin/Throwable.kt:24:37)
   at 1   example.kexe    0x10a855846    kfun:kotlin.Exception#<init>(kotlin.String?){} + 86
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/kotlin-native/runtime/src/main/kotlin/kotlin/Exceptions.kt:23:44)
   at 2   example.kexe    0x10a855936    kfun:kotlin.RuntimeException#<init>(kotlin.String?){} + 86
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/kotlin-native/runtime/src/main/kotlin/kotlin/Exceptions.kt:34:44)
   at 3   example.kexe    0x10a855c86    kfun:kotlin.IllegalStateException#<init>(kotlin.String?){} + 86
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/kotlin-native/runtime/src/main/kotlin/kotlin/Exceptions.kt:70:44)
   at 4   example.kexe    0x10a8489a5    kfun:#bar(){} + 117 (/private/tmp/backtrace/src/commonMain/kotlin/app.kt:2:1)
   at 5   example.kexe    0x10a84891c    kfun:#main(){} + 12 (/private/tmp/backtrace/src/commonMain/kotlin/app.kt:1:14)
...
```

- 1.6.20 with libbacktrace:

```
Uncaught Kotlin exception: kotlin.IllegalStateException:
   at 0   example.kexe    0x10669bc88    kfun:kotlin.Throwable#<init>(kotlin.String?){} + 88
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/kotlin-native/runtime/src/main/kotlin/kotlin/Throwable.kt:24:37)
   at 1   example.kexe    0x106696bd6    kfun:kotlin.Exception#<init>(kotlin.String?){} + 86
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/kotlin-native/runtime/src/main/kotlin/kotlin/Exceptions.kt:23:44)
   at 2   example.kexe    0x106696cc6    kfun:kotlin.RuntimeException#<init>(kotlin.String?){} + 86
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/kotlin-native/runtime/src/main/kotlin/kotlin/Exceptions.kt:34:44)
   at 3   example.kexe    0x106697016    kfun:kotlin.IllegalStateException#<init>(kotlin.String?){} + 86
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/kotlin-native/runtime/src/main/kotlin/kotlin/Exceptions.kt:70:44)
   at 4   example.kexe    0x106689d35    kfun:#bar(){} + 117 [inlined]
```

```
(/opt/buildAgent/work/c3a91df21e46e2c8/kotlin/libraries/stdlib/src/kotlin/util/Preconditions.kt:143:56)
>>  at 5   example.kexe    0x106689d35    kfun:#bar(){} + 117 [inlined] (/private/tmp/backtrace/src/commonMain/kotlin/app.kt:4:5)
   at 6   example.kexe    0x106689d35    kfun:#bar(){} + 117 (/private/tmp/backtrace/src/commonMain/kotlin/app.kt:2:13)
   at 7   example.kexe    0x106689cac    kfun:#main(){} + 12 (/private/tmp/backtrace/src/commonMain/kotlin/app.kt:1:14)
...
```

To produce better stack traces with libbacktrace, add the following line to gradle.properties:

```
# gradle.properties
kotlin.native.binary.sourceInfoType=libbacktrace
```

Please tell us how debugging Kotlin/Native with libbacktrace works for you in this YouTrack issue.

Support for standalone Android executables

Previously, Android Native executables in Kotlin/Native were not actually executables but shared libraries that you could use as a NativeActivity. Now there's an option to generate standard executables for Android Native targets.

For that, in the build.gradle(.kts) part of your project, configure the executable block of your androidNative target. Add the following binary option:

```
kotlin {
    androidNativeX64("android") {
        binaries {
            executable {
                binaryOptions["androidProgramType"] = "standalone"
            }
        }
    }
}
```

Note that this feature will become the default in Kotlin 1.7.0. If you want to preserve the current behavior, use the following setting:

```
binaryOptions["androidProgramType"] = "nativeActivity"
```

Thanks to Mattia Iavarone for the implementation!

Performance improvements

We are working hard on Kotlin/Native to speed up the compilation process and improve your developing experience.

Kotlin 1.6.20 brings some performance updates and bug fixes that affect the LLVM IR that Kotlin generates. According to the benchmarks on our internal projects, we achieved the following performance boosts on average:

- 15% reduction in execution time
- 20% reduction in the code size of both release and debug binaries
- 26% reduction in the compilation time of release binaries

These changes also provide a 10% reduction in compilation time for a debug binary on a large internal project.

To achieve this, we've implemented static initialization for some of the compiler-generated synthetic objects, improved the way we structure LLVM IR for every function, and optimized the compiler caches.

Improved error handling during cinterop modules import

This release introduces improved error handling for cases where you import an Objective-C module using the cinterop tool (as is typical for CocoaPods pods). Previously, if you got an error while trying to work with an Objective-C module (for instance, when dealing with a compilation error in a header), you received an uninformative error message, such as fatal error: could not build module $name. We expanded upon this part of the cinterop tool, so you'll get an error message with an extended description.

Support for Xcode 13 libraries

Libraries delivered with Xcode 13 have full support as of this release. Feel free to access them from anywhere in your Kotlin code.

Kotlin Multiplatform

1.6.20 brings the following notable updates to Kotlin Multiplatform:

- Hierarchical structure support is now default for all new multiplatform projects
- Kotlin CocoaPods Gradle plugin received several useful features for CocoaPods integration

Hierarchical structure support for multiplatform projects

Kotlin 1.6.20 comes with hierarchical structure support enabled by default. Since introducing it in Kotlin 1.4.0, we've significantly improved the frontend and made IDE import stable.

Previously, there were two ways to add code in a multiplatform project. The first was to insert it in a platform-specific source set, which is limited to one target and can't be reused by other platforms. The second is to use a common source set shared across all the platforms that are currently supported by Kotlin.

Now you can share source code among several similar native targets that reuse a lot of the common logic and third-party APIs. The technology will provide the correct default dependencies and find the exact API available in the shared code. This eliminates a complex build setup and having to use workarounds to get IDE support for sharing source sets among native targets. It also helps prevent unsafe API usages meant for a different target.

The technology will come in handy for library authors, too, as a hierarchical project structure allows them to publish and consume libraries with common APIs for a subset of targets.

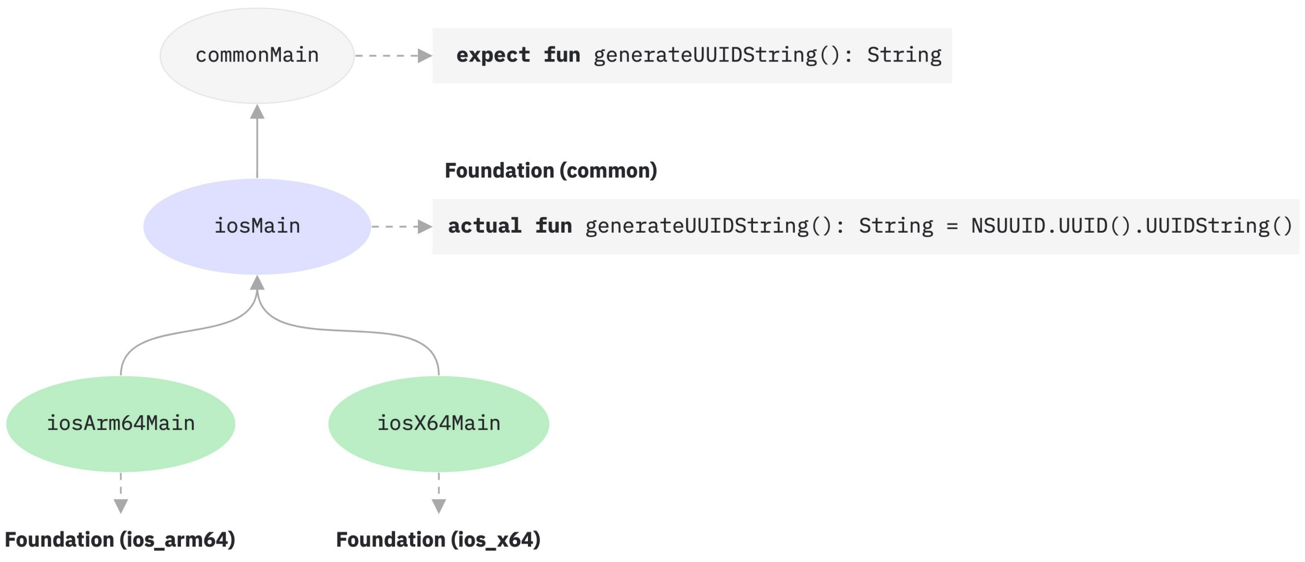
By default, libraries published with the hierarchical project structure are compatible only with hierarchical structure projects.

Better code-sharing in your project

Without hierarchical structure support, there is no straightforward way to share code across some but not all Kotlin targets. One popular example is sharing code across all iOS targets and having access to iOS-specific dependencies, like Foundation.

Thanks to the hierarchical project structure support, you can now achieve this out of the box. In the new structure, source sets form a hierarchy. You can use platform-specific language features and dependencies available for each target that a given source set compiles to.

For example, consider a typical multiplatform project with two targets — iosArm64 and iosX64 for iOS devices and simulators. The Kotlin tooling understands that both targets have the same function and allows you to access that function from the intermediate source set, iosMain.


commonMain
expect fun generateUUIDString(): String
Foundation (common)
iosMain
actual fun generateUUIDString(): String = NSUUID.UUID().UUIDString()
iosArm64Main
iosX64Main
Foundation (ios_arm64)
Foundation (ios_x64)

iOS hierarchy example

The Kotlin toolchain provides the correct default dependencies, like Kotlin/Native stdlib or native libraries. Moreover, Kotlin tooling will try its best to find exactly the API surface area available in the shared code. This prevents such cases as, for example, the use of a macOS-specific function in code shared for Windows.

More opportunities for library authors

When a multiplatform library is published, the API of its intermediate source sets is now properly published alongside it, making it available for consumers. Again, the Kotlin toolchain will automatically figure out the API available in the consumer source set while carefully watching out for unsafe usages, like using an API meant for the JVM in JS code. Learn more about sharing code in libraries.

Configuration and setup

Starting with Kotlin 1.6.20, all your new multiplatform projects will have a hierarchical project structure. No additional setup is required.

- If you've already turned it on manually, you can remove the deprecated options from gradle.properties:

```
# gradle.properties
kotlin.mpp.enableGranularSourceSetsMetadata=true
kotlin.native.enableDependencyPropagation=false // or 'true', depending on your previous setup
```

- For Kotlin 1.6.20, we recommend using Android Studio 2021.1.1 (Bumblebee) or later to get the best experience.

- You can also opt out. To disable hierarchical structure support, set the following options in gradle.properties:

```
# gradle.properties
kotlin.mpp.hierarchicalStructureSupport=false
```

Leave your feedback

This is a significant change to the whole ecosystem. We would appreciate your feedback to help make it even better.

Try it now and report any difficulties you encounter to our issue tracker.

Kotlin CocoaPods Gradle plugin

To simplify CocoaPods integration, Kotlin 1.6.20 delivers the following features:

- The CocoaPods plugin now has tasks that build XCFrameworks with all registered targets and generate the Podspec file. This can be useful when you don't want to integrate with Xcode directly, but you want to build artifacts and deploy them to your local CocoaPods repository.

  Learn more about building XCFrameworks.

- If you use CocoaPods integration in your projects, you're used to specifying the required Pod version for the entire Gradle project. Now you have more options:

  - Specify the Pod version directly in the cocoapods block
  - Continue using a Gradle project version

  If none of these properties is configured, you'll get an error.

- You can now configure the CocoaPod name in the cocoapods block instead of changing the name of the whole Gradle project.

- The CocoaPods plugin introduces a new extraSpecAttributes property, which you can use to configure properties in a Podspec file that were previously hard-coded, like libraries or vendored_frameworks.

```
kotlin {
    cocoapods {
        version = "1.0"
        name = "MyCocoaPod"
        extraSpecAttributes["social_media_url"] = 'https://twitter.com/kotlin'
        extraSpecAttributes["vendored_frameworks"] = 'CustomFramework.xcframework'
        extraSpecAttributes["libraries"] = 'xml'
    }
}
```

See the full Kotlin CocoaPods Gradle plugin DSL reference.

Kotlin/JS

Kotlin/JS improvements in 1.6.20 mainly affect the IR compiler:

- Incremental compilation for development binaries (IR)
- Lazy initialization of top-level properties by default (IR)
- Separate JS files for project modules by default (IR)
- Char class optimization (IR)
- Export improvements (both IR and legacy backends)
- @AfterTest guarantees for asynchronous tests

Incremental compilation for development binaries with IR compiler

To make Kotlin/JS development with the IR compiler more efficient, we're introducing a new incremental compilation mode.

When building development binaries with the compileDevelopmentExecutableKotlinJs Gradle task in this mode, the compiler caches the results of previous compilations on the module level. It uses the cached compilation results for unchanged source files during subsequent compilations, making them complete more quickly, especially with small changes. Note that this improvement exclusively targets the development process (shortening the edit-build-debug cycle) and doesn't affect the building of production artifacts.

To enable incremental compilation for development binaries, add the following line to the project's gradle.properties:

```
# gradle.properties
kotlin.incremental.js.ir=true // false by default
```

In our test projects, the new mode made incremental compilation up to 30% faster. However, the clean build in this mode became slower because of the need to create and populate the caches.

Please tell us what you think of using incremental compilation with your Kotlin/JS projects in this YouTrack issue.

Lazy initialization of top-level properties by default with IR compiler

In Kotlin 1.4.30, we presented a prototype of lazy initialization of top-level properties in the JS IR compiler. By eliminating the need to initialize all properties when the application launches, lazy initialization reduces the startup time. Our measurements showed about a 10% speed-up on a real-life Kotlin/JS application.

Now, having polished and properly tested this mechanism, we're making lazy initialization the default for top-level properties in the IR compiler.

```
// lazy initialization
val a = run {
    val result = // intensive computations
        println(result)
    result
} // run is executed upon the first usage of the variable
```

If for some reason you need to initialize a property eagerly (upon the application start), mark it with the @EagerInitialization annotation.

Separate JS files for project modules by default with IR compiler

Previously, the JS IR compiler offered an ability to generate separate .js files for project modules. This was an alternative to the default option – a single .js file for the whole project. This file might be too large and inconvenient to use, because whenever you want to use a function from your project, you have to include the entire JS file as a dependency. Having multiple files adds flexibility and decreases the size of such dependencies. This feature was available with the -Xir-per-module compiler option.

Starting from 1.6.20, the JS IR compiler generates separate .js files for project modules by default.

Compiling the project into a single .js file is now available with the following Gradle property:

```
# gradle.properties
kotlin.js.ir.output.granularity=whole-program // `per-module` is the default
```

In previous releases, the experimental per-module mode (available via the -Xir-per-module=true flag) invoked main() functions in each module. This is inconsistent with the regular single .js mode. Starting with 1.6.20, the main() function will be invoked in the main module only in both cases. If you do need to run some code when a module is loaded, you can use top-level properties annotated with the @EagerInitialization annotation. See Lazy initialization of top-level properties by default (IR).

Char class optimization

The Char class is now handled by the Kotlin/JS compiler without introducing boxing (similar to inline classes). This speeds up operations on chars in Kotlin/JS code.

Aside from the performance improvement, this changes the way Char is exported to JavaScript: it's now translated to Number.

Improvements to export and TypeScript declaration generation

Kotlin 1.6.20 is bringing multiple fixes and improvements to the export mechanism (the @JsExport annotation), including the generation of TypeScript declarations (.d.ts). We've added the ability to export interfaces and enums, and we've fixed the export behavior in some corner cases that were reported to us previously. For more details, see the list of export improvements in YouTrack.

Learn more about using Kotlin code from JavaScript.

@AfterTest guarantees for asynchronous tests

Kotlin 1.6.20 makes @AfterTest functions work properly with asynchronous tests on Kotlin/JS. If a test function's return type is statically resolved to Promise, the compiler now schedules the execution of the @AfterTest function to the corresponding then() callback.

Security

Kotlin 1.6.20 introduces a couple of features to improve the security of your code:

- Using relative paths in klibs
- Persisting yarn.lock for Kotlin/JS Gradle projects
- Installation of npm dependencies with --ignore-scripts by default

Using relative paths in klibs

A library in klib format contains a serialized IR representation of source files, which also includes their paths for generating proper debug information. Before Kotlin 1.6.20, stored file paths were absolute. Since the library author may not want to share absolute paths, the 1.6.20 version comes with an alternative option.

If you are publishing a klib and want to use only relative paths of source files in the artifact, you can now pass the -Xklib-relative-path-base compiler option with one or multiple base paths of source files:

Kotlin

```kotlin
tasks.withType(org.jetbrains.kotlin.gradle.dsl.KotlinCompile::class).configureEach {
    // $base is a base path of source files
    kotlinOptions.freeCompilerArgs += "-Xklib-relative-path-base=$base"
}
```

Groovy

```groovy
tasks.withType(org.jetbrains.kotlin.gradle.dsl.KotlinCompile).configureEach {
    kotlinOptions {
        // $base is a base path of source files
        freeCompilerArgs += "-Xklib-relative-path-base=$base"
    }
}
```

Persisting yarn.lock for Kotlin/JS Gradle projects

> The feature was backported to Kotlin 1.6.10.

The Kotlin/JS Gradle plugin now provides an ability to persist the yarn.lock file, making it possible to lock the versions of the npm dependencies for your project without additional Gradle configuration. The feature brings changes to the default project structure by adding the auto-generated kotlin-js-store directory to the project root. It holds the yarn.lock file inside.

We strongly recommend committing the kotlin-js-store directory and its contents to your version control system. Committing lockfiles to your version control system is a recommended practice because it ensures your application is being built with the exact same dependency tree on all machines, regardless of whether those are development environments on other machines or CI/CD services. Lockfiles also prevent your npm dependencies from being silently updated when a project is checked out on a new machine, which is a security concern.

Tools like Dependabot can also parse the yarn.lock files of your Kotlin/JS projects, and provide you with warnings if any npm package you depend on is compromised.

If needed, you can change both directory and lockfile names in the build script:

Kotlin

```
rootProject.plugins.withType<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin> {
    rootProject.the<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension>().lockFileDirectory =
        project.rootDir.resolve("my-kotlin-js-store")
    rootProject.the<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension>().lockFileName = "my-yarn.lock"
}
```

Groovy

```
rootProject.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin) {
    rootProject.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension).lockFileDirectory =
        file("my-kotlin-js-store")
    rootProject.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension).lockFileName = 'my-yarn.lock'
}
```

Changing the name of the lockfile may cause dependency inspection tools to no longer pick up the file.

Installation of npm dependencies with --ignore-scripts by default

The feature was backported to Kotlin 1.6.10.

The Kotlin/JS Gradle plugin now prevents the execution of lifecycle scripts during the installation of npm dependencies by default. The change is aimed at reducing the likelihood of executing malicious code from compromised npm packages.

To roll back to the old configuration, you can explicitly enable lifecycle scripts execution by adding the following lines to build.gradle(.kts):

Kotlin

```
rootProject.plugins.withType<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin> {
    rootProject.the<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension>().ignoreScripts = false
}
```

Groovy

```
rootProject.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin) {
    rootProject.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension).ignoreScripts = false
}
```

Learn more about npm dependencies of a Kotlin/JS Gradle project.

Gradle

Kotlin 1.6.20 brings the following changes for the Kotlin Gradle Plugin:

- New properties kotlin.compiler.execution.strategy and compilerExecutionStrategy for defining a Kotlin compiler execution strategy

- Deprecation of the options kapt.use.worker.api, kotlin.experimental.coroutines, and kotlin.coroutines
- Removal of the kotlin.parallel.tasks.in.project build option

Properties for defining Kotlin compiler execution strategy

Before Kotlin 1.6.20, you used the system property -Dkotlin.compiler.execution.strategy to define a Kotlin compiler execution strategy. This property might have been inconvenient in some cases. Kotlin 1.6.20 introduces a Gradle property with the same name, kotlin.compiler.execution.strategy, and the compile task property compilerExecutionStrategy.

The system property still works, but it will be removed in future releases.

The current priority of properties is the following:

- The task property compilerExecutionStrategy takes priority over the system property and the Gradle property kotlin.compiler.execution.strategy.
- The Gradle property takes priority over the system property.

There are three compiler execution strategies that you can assign to these properties:

Strategy	Where Kotlin compiler is executed	Incremental compilation	Other characteristics
Daemon	Inside its own daemon process	Yes	The default strategy. Can be shared between different Gradle daemons
In process	Inside the Gradle daemon process	No	May share the heap with the Gradle daemon
Out of process	In a separate process for each call	No	—

Accordingly, the available values for kotlin.compiler.execution.strategy properties (both system and Gradle's) are:

1. daemon (default)
2. in-process
3. out-of-process

Use the Gradle property kotlin.compiler.execution.strategy in gradle.properties:

```
# gradle.properties
kotlin.compiler.execution.strategy=out-of-process
```

The available values for the compilerExecutionStrategy task property are:

1. org.jetbrains.kotlin.gradle.tasks.KotlinCompilerExecutionStrategy.DAEMON (default)
2. org.jetbrains.kotlin.gradle.tasks.KotlinCompilerExecutionStrategy.IN_PROCESS
3. org.jetbrains.kotlin.gradle.tasks.KotlinCompilerExecutionStrategy.OUT_OF_PROCESS

Use the task property compilerExecutionStrategy in the build.gradle.kts build script:

```kotlin
import org.jetbrains.kotlin.gradle.dsl.KotlinCompile
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilerExecutionStrategy

// ...

tasks.withType<KotlinCompile>().configureEach {
    compilerExecutionStrategy.set(KotlinCompilerExecutionStrategy.IN_PROCESS)
}
```

Please leave your feedback in this YouTrack task.

Deprecation of build options for kapt and coroutines

In Kotlin 1.6.20, we changed deprecation levels of the properties:

- We deprecated the ability to run kapt via the Kotlin daemon with kapt.use.worker.api – now it produces a warning to Gradle's output. By default, kapt has been using Gradle workers since the 1.3.70 release, and we recommend sticking to this method.

  We are going to remove the option kapt.use.worker.api in future releases.

- We deprecated the kotlin.experimental.coroutines Gradle DSL option and the kotlin.coroutines property used in gradle.properties. Just use suspending functions or add the kotlinx.coroutines dependency to your build.gradle(.kts) file.

  Learn more about coroutines in the Coroutines guide.

Removal of the kotlin.parallel.tasks.in.project build option

In Kotlin 1.5.20, we announced the deprecation of the build option kotlin.parallel.tasks.in.project. This option has been removed in Kotlin 1.6.20.

Depending on the project, parallel compilation in the Kotlin daemon may require more memory. To reduce memory consumption, increase the heap size for the Kotlin daemon.

Learn more about the currently supported compiler options in the Kotlin Gradle plugin.

What's new in Kotlin 1.6.0

Released: 16 November 2021

Kotlin 1.6.0 introduces new language features, optimizations and improvements to existing features, and a lot of improvements to the Kotlin standard library.

You can also find an overview of the changes in the release blog post.

Language

Kotlin 1.6.0 brings stabilization to several language features introduced for preview in the previous 1.5.30 release:

- Stable exhaustive when statements for enum, sealed and Boolean subjects
- Stable suspending functions as supertypes
- Stable suspend conversions
- Stable instantiation of annotation classes

It also includes various type inference improvements and support for annotations on class type parameters:

- Improved type inference for recursive generic types
- Changes to builder inference
- Support for annotations on class type parameters

Stable exhaustive when statements for enum, sealed, and Boolean subjects

An exhaustive when statement contains branches for all possible types or values of its subject, or for some types plus an else branch. It covers all possible cases, making your code safer.

We will soon prohibit non-exhaustive when statements to make the behavior consistent with when expressions. To ensure smooth migration, Kotlin 1.6.0 reports warnings about non-exhaustive when statements with an enum, sealed, or Boolean subject. These warnings will become errors in future releases.

```
sealed class Contact {
    data class PhoneCall(val number: String) : Contact()
    data class TextMessage(val number: String) : Contact()
}

fun Contact.messageCost(): Int =
    when(this) { // Error: 'when' expression must be exhaustive
```

```
        is Contact.PhoneCall -> 42
    }

fun sendMessage(contact: Contact, message: String) {
    // Starting with 1.6.0

    // Warning: Non exhaustive 'when' statements on Boolean will be
    // prohibited in 1.7, add 'false' branch or 'else' branch instead
    when(message.isEmpty()) {
        true -> return
    }
    // Warning: Non exhaustive 'when' statements on sealed class/interface will be
    // prohibited in 1.7, add 'is TextMessage' branch or 'else' branch instead
    when(contact) {
        is Contact.PhoneCall -> TODO()
    }
}
```

See this YouTrack ticket for a more detailed explanation of the change and its effects.

Stable suspending functions as supertypes

Implementation of suspending functional types has become Stable in Kotlin 1.6.0. A preview was available in 1.5.30.

The feature can be useful when designing APIs that use Kotlin coroutines and accept suspending functional types. You can now streamline your code by enclosing the desired behavior in a separate class that implements a suspending functional type.

```
class MyClickAction : suspend () -> Unit {
    override suspend fun invoke() { TODO() }
}

fun launchOnClick(action: suspend () -> Unit) {}
```

You can use an instance of this class where only lambdas and suspending function references were allowed previously: launchOnClick(MyClickAction()).

There are currently two limitations coming from implementation details:

- You can't mix ordinary functional types and suspending ones in the list of supertypes.
- You can't use multiple suspending functional supertypes.

Stable suspend conversions

Kotlin 1.6.0 introduces Stable conversions from regular to suspending functional types. Starting from 1.4.0, the feature supported functional literals and callable references. With 1.6.0, it works with any form of expression. As a call argument, you can now pass any expression of a suitable regular functional type where suspending is expected. The compiler will perform an implicit conversion automatically.

```
fun getSuspending(suspending: suspend () -> Unit) {}

fun suspending() {}

fun test(regular: () -> Unit) {
    getSuspending { }           // OK
    getSuspending(::suspending) // OK
    getSuspending(regular)      // OK
}
```

Stable instantiation of annotation classes

Kotlin 1.5.30 introduced experimental support for instantiation of annotation classes on the JVM platform. With 1.6.0, the feature is available by default both for Kotlin/JVM and Kotlin/JS.

Learn more about instantiation of annotation classes in this KEEP.

Improved type inference for recursive generic types

Kotlin 1.5.30 introduced an improvement to type inference for recursive generic types, which allowed their type arguments to be inferred based only on the upper bounds of the corresponding type parameters. The improvement was available with the compiler option. In version 1.6.0 and later, it is enabled by default.

```
// Before 1.5.30
val containerA = PostgreSQLContainer<Nothing>(DockerImageName.parse("postgres:13-alpine")).apply {
  withDatabaseName("db")
  withUsername("user")
  withPassword("password")
  withInitScript("sql/schema.sql")
}

// With compiler option in 1.5.30 or by default starting with 1.6.0
val containerB = PostgreSQLContainer(DockerImageName.parse("postgres:13-alpine"))
  .withDatabaseName("db")
  .withUsername("user")
  .withPassword("password")
  .withInitScript("sql/schema.sql")
```

Changes to builder inference

Builder inference is a type inference flavor which is useful when calling generic builder functions. It can infer the type arguments of a call with the help of type information from calls inside its lambda argument.

We're making multiple changes that are bringing us closer to fully stable builder inference. Starting with 1.6.0:

- You can make calls returning an instance of a not yet inferred type inside a builder lambda without specifying the -Xunrestricted-builder-inference compiler option introduced in 1.5.30.
- With -Xenable-builder-inference, you can write your own builders without applying the @BuilderInference annotation.

  > Note that clients of these builders will need to specify the same -Xenable-builder-inference compiler option.

- With the -Xenable-builder-inference, builder inference automatically activates if a regular type inference cannot get enough information about a type.

Learn how to write custom generic builders.

Support for annotations on class type parameters

Support for annotations on class type parameters looks like this:

```
@Target(AnnotationTarget.TYPE_PARAMETER)
annotation class BoxContent

class Box<@BoxContent T> {}
```

Annotations on all type parameters are emitted into JVM bytecode so annotation processors are able to use them.

For the motivating use case, read this YouTrack ticket.

Learn more about annotations.

Supporting previous API versions for a longer period

Starting with Kotlin 1.6.0, we will support development for three previous API versions instead of two, along with the current stable one. Currently, we support versions 1.3, 1.4, 1.5, and 1.6.

Kotlin/JVM

For Kotlin/JVM, starting with 1.6.0, the compiler can generate classes with a bytecode version corresponding to JVM 17. The new language version also includes optimized delegated properties and repeatable annotations, which we had on the roadmap:

- Repeatable annotations with runtime retention for 1.8 JVM target
- Optimize delegated properties which call get/set on the given KProperty instance

Repeatable annotations with runtime retention for 1.8 JVM target

Java 8 introduced repeatable annotations, which can be applied multiple times to a single code element. The feature requires two declarations to be present in the Java code: the repeatable annotation itself marked with @java.lang.annotation.Repeatable and the containing annotation to hold its values.

Kotlin also has repeatable annotations, but requires only @kotlin.annotation.Repeatable to be present on an annotation declaration to make it repeatable. Before 1.6.0, the feature supported only SOURCE retention and was incompatible with Java's repeatable annotations. Kotlin 1.6.0 removes these limitations. @kotlin.annotation.Repeatable now accepts any retention and makes the annotation repeatable both in Kotlin and Java. Java's repeatable annotations are now also supported from the Kotlin side.

While you can declare a containing annotation, it's not necessary. For example:

- If an annotation @Tag is marked with @kotlin.annotation.Repeatable, the Kotlin compiler automatically generates a containing annotation class under the name of @Tag.Container:

  ```
  @Repeatable
  annotation class Tag(val name: String)

  // The compiler generates @Tag.Container containing annotation
  ```

- To set a custom name for a containing annotation, apply the @kotlin.jvm.JvmRepeatable meta-annotation and pass the explicitly declared containing annotation class as an argument:

  ```
  @JvmRepeatable(Tags::class)
  annotation class Tag(val name: String)

  annotation class Tags(val value: Array<Tag>)
  ```

Kotlin reflection now supports both Kotlin's and Java's repeatable annotations via a new function, KAnnotatedElement.findAnnotations().

Learn more about Kotlin repeatable annotations in this KEEP.

Optimize delegated properties which call get/set on the given KProperty instance

We optimized the generated JVM bytecode by omitting the $delegate field and generating immediate access to the referenced property.

For example, in the following code

```
class Box<T> {
    private var impl: T = ...

    var content: T by ::impl
}
```

Kotlin no longer generates the field content$delegate. Property accessors of the content variable invoke the impl variable directly, skipping the delegated property's getValue/setValue operators and thus avoiding the need for the property reference object of the KProperty type.

Thanks to our Google colleagues for the implementation!

Learn more about delegated properties.

Kotlin/Native

Kotlin/Native is receiving multiple improvements and component updates, some of them in the preview state:

- Preview of the new memory manager
- Support for Xcode 13
- Compilation of Windows targets on any host
- LLVM and linker updates
- Performance improvements
- Unified compiler plugin ABI with JVM and JS IR backends

- Detailed error messages for klib linkage failures
- Reworked unhandled exception handling API

Preview of the new memory manager

> The new Kotlin/Native memory manager is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

With Kotlin 1.6.0, you can try the development preview of the new Kotlin/Native memory manager. It moves us closer to eliminating the differences between the JVM and Native platforms to provide a consistent developer experience in multiplatform projects.

One of the notable changes is the lazy initialization of top-level properties, like in Kotlin/JVM. A top-level property gets initialized when a top-level property or function from the same file is accessed for the first time. This mode also includes global interprocedural optimization (enabled only for release binaries), which removes redundant initialization checks.

We've recently published a blog post about the new memory manager. Read it to learn about the current state of the new memory manager and find some demo projects, or jump right to the migration instructions to try it yourself. Please check how the new memory manager works on your projects and share feedback in our issue tracker, YouTrack.

Support for Xcode 13

Kotlin/Native 1.6.0 supports Xcode 13 – the latest version of Xcode. Feel free to update your Xcode and continue working on your Kotlin projects for Apple operating systems.

> New libraries added in Xcode 13 aren't available for use in Kotlin 1.6.0, but we're going to add support for them in upcoming versions.

Compilation of Windows targets on any host

Starting from 1.6.0, you don't need a Windows host to compile the Windows targets mingwX64 and mingwX86. They can be compiled on any host that supports Kotlin/Native.

LLVM and linker updates

We've reworked the LLVM dependency that Kotlin/Native uses under the hood. This brings various benefits, including:

- Updated LLVM version to 11.1.0.
- Decreased dependency size. For example, on macOS it's now about 300 MB instead of 1200 MB in the previous version.
- Excluded dependency on the ncurses5 library that isn't available in modern Linux distributions.

In addition to the LLVM update, Kotlin/Native now uses the LLD linker (a linker from the LLVM project) for MingGW targets. It provides various benefits over the previously used ld.bfd linker, and will allow us to improve runtime performance of produced binaries and support compiler caches for MinGW targets. Note that LLD requires import libraries for DLL linkage. Learn more in this Stack Overflow thread.

Performance improvements

Kotlin/Native 1.6.0 delivers the following performance improvements:

- Compilation time: compiler caches are enabled by default for linuxX64 and iosArm64 targets. This speeds up most compilations in debug mode (except the first one). Measurements showed about a 200% speed increase on our test projects. The compiler caches have been available for these targets since Kotlin 1.5.0 with additional Gradle properties; you can remove them now.
- Runtime: iterating over arrays with for loops is now up to 12% faster thanks to optimizations in the produced LLVM code.

Unified compiler plugin ABI with JVM and JS IR backends

The option to use the common IR compiler plugin ABI for Kotlin/Native is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

In previous versions, authors of compiler plugins had to provide separate artifacts for Kotlin/Native because of the differences in the ABI.

Starting from 1.6.0, the Kotlin Multiplatform Gradle plugin is able to use the embeddable compiler jar – the one used for the JVM and JS IR backends – for Kotlin/Native. This is a step toward unification of the compiler plugin development experience, as you can now use the same compiler plugin artifacts for Native and other supported platforms.

This is a preview version of such support, and it requires an opt-in. To start using generic compiler plugin artifacts for Kotlin/Native, add the following line to gradle.properties: kotlin.native.useEmbeddableCompilerJar=true.

We're planning to use the embeddable compiler jar for Kotlin/Native by default in the future, so it's vital for us to hear how the preview works for you.

If you are an author of a compiler plugin, please try this mode and check if it works for your plugin. Note that depending on your plugin's structure, migration steps may be required. See this YouTrack issue for migration instructions and leave your feedback in the comments.

Detailed error messages for klib linkage failures

The Kotlin/Native compiler now provides detailed error messages for klib linkage errors. The messages now have clear error descriptions, and they also include information about possible causes and ways to fix them.

For example:

- 1.5.30:

```
e: java.lang.IllegalStateException: IrTypeAliasSymbol expected: Unbound public symbol for public
kotlinx.coroutines/CancellationException|null[0]
<stack trace>
```

- 1.6.0:

```
e: The symbol of unexpected type encountered during IR deserialization: IrClassPublicSymbolImpl,
kotlinx.coroutines/CancellationException|null[0].
IrTypeAliasSymbol is expected.

This could happen if there are two libraries, where one library was compiled against the different version of the other library
than the one currently used in the project.
Please check that the project configuration is correct and has consistent versions of dependencies.

The list of libraries that depend on "org.jetbrains.kotlinx:kotlinx-coroutines-core (org.jetbrains.kotlinx:kotlinx-coroutines-
core-macosx64)" and may lead to conflicts:
<list of libraries and potential version mismatches>

Project dependencies:
<dependencies tree>
```

Reworked unhandled exception handling API

We've unified the processing of unhandled exceptions throughout the Kotlin/Native runtime and exposed the default processing as the function processUnhandledException(throwable: Throwable) for use by custom execution environments, like kotlinx.coroutines. This processing is also applied to exceptions that escape operation in Worker.executeAfter(), but only for the new memory manager.

API improvements also affected the hooks that have been set by setUnhandledExceptionHook(). Previously such hooks were reset after the Kotlin/Native runtime called the hook with an unhandled exception, and the program would always terminate right after. Now these hooks may be used more than once, and if you want the program to always terminate on an unhandled exception, either do not set an unhandled exception hook (setUnhandledExceptionHook()), or make sure to call terminateWithUnhandledException() at the end of your hook. This will help you send exceptions to a third-party crash reporting service (like Firebase Crashlytics) and then terminate the program. Exceptions that escape main() and exceptions that cross the interop boundary will always terminate the program, even if the hook did not call terminateWithUnhandledException().

Kotlin/JS

We're continuing to work on stabilizing the IR backend for the Kotlin/JS compiler. Kotlin/JS now has an option to disable downloading of Node.js and Yarn.

Option to use pre-installed Node.js and Yarn

You can now disable downloading Node.js and Yarn when building Kotlin/JS projects and use the instances already installed on the host. This is useful for building on servers without internet connectivity, such as CI servers.

To disable downloading external components, add the following lines to your build.gradle(.kts):

- Yarn:

  Kotlin

```kotlin
rootProject.plugins.withType<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin> {
    rootProject.the<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension>().download = false // or true for default
behavior
}
```

  Groovy

```groovy
rootProject.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin) {
    rootProject.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension).download = false
}
```

- Node.js:

  Kotlin

```kotlin
rootProject.plugins.withType<org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsRootPlugin> {
    rootProject.the<org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsRootExtension>().download = false // or true for default
behavior
}
```

  Groovy

```groovy
rootProject.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsRootPlugin) {
    rootProject.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsRootExtension).download = false
}
```

Kotlin Gradle plugin

In Kotlin 1.6.0, we changed the deprecation level of the KotlinGradleSubplugin class to 'ERROR'. This class was used for writing compiler plugins. In the following releases, we'll remove this class. Use the class KotlinCompilerPluginSupportPlugin instead.

We removed the kotlin.useFallbackCompilerSearch build option and the noReflect and includeRuntime compiler options. The useIR compiler option has been hidden and will be removed in upcoming releases.

Learn more about the currently supported compiler options in the Kotlin Gradle plugin.

Standard library

The new 1.6.0 version of the standard library stabilizes experimental features, introduces new ones, and unifies its behavior across the platforms:

- New readline functions
- Stable typeOf()
- Stable collection builders
- Stable Duration API
- Splitting Regex into a sequence
- Bit rotation operations on integers

- Changes for replace() and replaceFirst() in JS
- Improvements to the existing API
- Deprecations

New readline functions

Kotlin 1.6.0 offers new functions for handling standard input: readln() and readlnOrNull().

> For now, new functions are available for the JVM and Native target platforms only.

Earlier versions	1.6.0 alternative	Usage
readLine()!!	readln()	Reads a line from stdin and returns it, or throws a RuntimeException if EOF has been reached.
readLine()	readlnOrNull()	Reads a line from stdin and returns it, or returns null if EOF has been reached.

We believe that eliminating the need to use !! when reading a line will improve the experience for newcomers and simplify teaching Kotlin. To make the read-line operation name consistent with its println() counterpart, we've decided to shorten the names of new functions to 'ln'.

```
println("What is your nickname?")
val nickname = readln()
println("Hello, $nickname!")
```

```
fun main() {
    var sum = 0
    while (true) {
        val nextLine = readlnOrNull().takeUnless {
            it.isNullOrEmpty()
        } ?: break
        sum += nextLine.toInt()
    }
    println(sum)
}
```

The existing readLine() function will get a lower priority than readln() and readlnOrNull() in your IDE code completion. IDE inspections will also recommend using new functions instead of the legacy readLine().

We're planning to gradually deprecate the readLine() function in future releases.

Stable typeOf()

Version 1.6.0 brings a Stable typeOf() function, closing one of the major roadmap items.

Since 1.3.40, typeOf() was available on the JVM platform as an experimental API. Now you can use it in any Kotlin platform and get KType representation of any Kotlin type that the compiler can infer:

```
inline fun <reified T> renderType(): String {
    val type = typeOf<T>()
    return type.toString()
}

fun main() {
    val fromExplicitType = typeOf<Int>()
    val fromReifiedType = renderType<List<Int>>()
}
```

Stable collection builders

In Kotlin 1.6.0, collection builder functions have been promoted to Stable. Collections returned by collection builders are now serializable in their read-only state.

You can now use buildMap(), buildList(), and buildSet() without the opt-in annotation:

```
fun main() {
    val x = listOf('b', 'c')
    val y = buildList {
        add('a')
        addAll(x)
        add('d')
    }
    println(y)  // [a, b, c, d]
}
```

Stable Duration API

The Duration class for representing duration amounts in different time units has been promoted to Stable. In 1.6.0, the Duration API has received the following changes:

- The first component of the toComponents() function that decomposes the duration into days, hours, minutes, seconds, and nanoseconds now has the Long type instead of Int. Before, if the value didn't fit into the Int range, it was coerced into that range. With the Long type, you can decompose any value in the duration range without cutting off the values that don't fit into Int.
- The DurationUnit enum is now standalone and not a type alias of java.util.concurrent.TimeUnit on the JVM. We haven't found any convincing cases in which having typealias DurationUnit = TimeUnit could be useful. Also, exposing the TimeUnit API through a type alias might confuse DurationUnit users.
- In response to community feedback, we're bringing back extension properties like Int.seconds. But we'd like to limit their applicability, so we put them into the companion of the Duration class. While the IDE can still propose extensions in completion and automatically insert an import from the companion, in the future we plan to limit this behavior to cases when the Duration type is expected.

  ```
  import kotlin.time.Duration.Companion.seconds

  fun main() {
      val duration = 10000
      println("There are ${duration.seconds.inWholeMinutes} minutes in $duration seconds")
      // There are 166 minutes in 10000 seconds
  }
  ```

  We suggest replacing previously introduced companion functions, such as Duration.seconds(Int), and deprecated top-level extensions like Int.seconds with new extensions in Duration.Companion.

  Such a replacement may cause ambiguity between old top-level extensions and new companion extensions. Be sure to use the wildcard import of the kotlin.time package – import kotlin.time.* – before doing automated migration.

Splitting Regex into a sequence

The Regex.splitToSequence(CharSequence) and CharSequence.splitToSequence(Regex) functions are promoted to Stable. They split the string around matches of the given regex, but return the result as a Sequence so that all operations on this result are executed lazily:

```
fun main() {
    val colorsText = "green, red, brown&blue, orange, pink&green"
    val regex = "[,\\s]+".toRegex()
    val mixedColor = regex.splitToSequence(colorsText)
    // or
    // val mixedColor = colorsText.splitToSequence(regex)
        .onEach { println(it) }
        .firstOrNull { it.contains('&') }
    println(mixedColor) // "brown&blue"
}
```

Bit rotation operations on integers

In Kotlin 1.6.0, the rotateLeft() and rotateRight() functions for bit manipulations became Stable. The functions rotate the binary representation of the number left or right by a specified number of bits:

```
fun main() {
    val number: Short = 0b10001
    println(number
        .rotateRight(2)
        .toString(radix = 2)) // 100000000000100
    println(number
        .rotateLeft(2)
        .toString(radix = 2))  // 1000100
}
```

Changes for replace() and replaceFirst() in JS

Before Kotlin 1.6.0, the replace() and replaceFirst() Regex functions behaved differently in Java and JS when the replacement string contained a group reference. To make the behavior consistent across all target platforms, we've changed their implementation in JS.

Occurrences of ${name} or $index in the replacement string are substituted with the subsequences corresponding to the captured groups with the specified index or a name:

- $index – the first digit after '$' is always treated as a part of the group reference. Subsequent digits are incorporated into the index only if they form a valid group reference.Only digits '0'–'9' are considered potential components of the group reference. Note that indexes of captured groups start from '1'. The group with index '0' stands for the whole match.
- ${name} – the name can consist of Latin letters 'a'–'z', 'A'–'Z', or digits '0'–'9'. The first character must be a letter.

  Named groups in replacement patterns are currently supported only on the JVM.

- To include the succeeding character as a literal in the replacement string, use the backslash character \:

  ```
  fun main() {
      println(Regex("(.+)").replace("Kotlin", """\$ $1""")) // $ Kotlin
      println(Regex("(.+)").replaceFirst("1.6.0", """\\ $1""")) // \ 1.6.0
  }
  ```

  You can use Regex.escapeReplacement() if the replacement string has to be treated as a literal string.

Improvements to the existing API

- Version 1.6.0 added the infix extension function for Comparable.compareTo(). You can now use the infix form for comparing two objects for order:

  ```
  class WrappedText(val text: String) : Comparable<WrappedText> {
       override fun compareTo(other: WrappedText): Int =
           this.text compareTo other.text
  }
  ```

- Regex.replace() in JS is now also not inline to unify its implementation across all platforms.
- The compareTo() and equals() String functions, as well as the isBlank() CharSequence function now behave in JS exactly the same way they do on the JVM. Previously there were deviations when it came to non-ASCII characters.

Deprecations

In Kotlin 1.6.0, we're starting the deprecation cycle with a warning for some JS-only stdlib API.

concat(), match(), and matches() string functions

- To concatenate the string with the string representation of a given other object, use plus() instead of concat().
- To find all occurrences of a regular expression within the input, use findAll() of the Regex class instead of String.match(regex: String).
- To check if the regular expression matches the entire input, use matches() of the Regex class instead of String.matches(regex: String).

sort() on arrays taking comparison functions

We've deprecated the Array<out T>.sort() function and the inline functions ByteArray.sort(), ShortArray.sort(), IntArray.sort(), LongArray.sort(), FloatArray.sort(), DoubleArray.sort(), and CharArray.sort(), which sorted arrays following the order passed by the comparison function. Use other standard library functions for array sorting.

See the collection ordering section for reference.

Tools

Kover – a code coverage tool for Kotlin

> The Kover Gradle plugin is Experimental. We would appreciate your feedback on it in GitHub.

With Kotlin 1.6.0, we're introducing Kover – a Gradle plugin for the IntelliJ and JaCoCo Kotlin code coverage agents. It works with all language constructs, including inline functions.

Learn more about Kover on its GitHub repository or in this video:

Watch video online.

Coroutines 1.6.0-RC

kotlinx.coroutines 1.6.0-RC is out with multiple features and improvements:

- Support for the new Kotlin/Native memory manager
- Introduction of dispatcher views API, which allows limiting parallelism without creating additional threads
- Migrating from Java 6 to Java 8 target
- kotlinx-coroutines-test with the new reworked API and multiplatform support
- Introduction of CopyableThreadContextElement, which gives coroutines a thread-safe write access to ThreadLocal variables

Learn more in the changelog.

Migrating to Kotlin 1.6.0

IntelliJ IDEA and Android Studio will suggest updating the Kotlin plugin to 1.6.0 once it is available.

To migrate existing projects to Kotlin 1.6.0, change the Kotlin version to 1.6.0 and reimport your Gradle or Maven project. Learn how to update to Kotlin 1.6.0.

To start a new project with Kotlin 1.6.0, update the Kotlin plugin and run the Project Wizard from File | New | Project.

The new command-line compiler is available for download on the GitHub release page.

Kotlin 1.6.0 is a feature release and can, therefore, bring changes that are incompatible with your code written for earlier versions of the language. Find the detailed list of such changes in the Compatibility Guide for Kotlin 1.6.

What's new in Kotlin 1.5.30

Released: 24 August 2021

Kotlin 1.5.30 offers language updates including previews of future changes, various improvements in platform support and tooling, and new standard library functions.

Here are some major improvements:

- Language features, including experimental sealed `when` statements, changes in using opt-in requirement, and others
- Native support for Apple silicon
- Kotlin/JS IR backend reaches Beta
- Improved Gradle plugin experience

You can also find a short overview of the changes in the release blog post and this video:

Watch video online.

Language features

Kotlin 1.5.30 is presenting previews of future language changes and bringing improvements to the opt-in requirement mechanism and type inference:

- Exhaustive when statements for sealed and Boolean subjects
- Suspending functions as supertypes
- Requiring opt-in on implicit usages of experimental APIs
- Changes to using opt-in requirement annotations with different targets
- Improvements to type inference for recursive generic types
- Eliminating builder inference restrictions

Exhaustive when statements for sealed and Boolean subjects

Support for sealed (exhaustive) when statements is Experimental. It may be dropped or changed at any time. Opt-in is required (see the details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

An exhaustive when statement contains branches for either all possible types or values of its subject, or for certain types and includes an else branch to cover any remaining cases.

We're planning to prohibit non-exhaustive when statements soon to make the behavior consistent with when expressions. To ensure smooth migration, you can configure the compiler to report warnings about non-exhaustive when statements with a sealed class or a Boolean. Such warnings will appear by default in Kotlin 1.6 and will become errors later.

Enums already get a warning.

```kotlin
sealed class Mode {
    object ON : Mode()
    object OFF : Mode()
}

fun main() {
    val x: Mode = Mode.ON
    when (x) {
        Mode.ON -> println("ON")
    }
// WARNING: Non exhaustive 'when' statements on sealed classes/interfaces
// will be prohibited in 1.7, add an 'OFF' or 'else' branch instead

    val y: Boolean = true
    when (y) {
        true -> println("true")
    }
// WARNING: Non exhaustive 'when' statements on Booleans will be prohibited
// in 1.7, add a 'false' or 'else' branch instead
}
```

To enable this feature in Kotlin 1.5.30, use language version 1.6. You can also change the warnings to errors by enabling progressive mode.

Kotlin

```kotlin
kotlin {
    sourceSets.all {
        languageSettings.apply {
            languageVersion = "1.6"
            //progressiveMode = true // false by default
        }
    }
}
```

Groovy

```
kotlin {
    sourceSets.all {
        languageSettings {
            languageVersion = '1.6'
            //progressiveMode = true // false by default
        }
    }
}
```

Suspending functions as supertypes

Support for suspending functions as supertypes is Experimental. It may be dropped or changed at any time. Opt-in is required (see the details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Kotlin 1.5.30 provides a preview of the ability to use a suspend functional type as a supertype with some limitations.

```
class MyClass: suspend () -> Unit {
    override suspend fun invoke() { TODO() }
}
```

Use the -language-version 1.6 compiler option to enable the feature:

Kotlin

```
kotlin {
    sourceSets.all {
        languageSettings.apply {
            languageVersion = "1.6"
        }
    }
}
```

Groovy

```
kotlin {
    sourceSets.all {
        languageSettings {
            languageVersion = '1.6'
        }
    }
}
```

The feature has the following restrictions:

- You can't mix an ordinary functional type and a suspend functional type as supertype. This is because of the implementation details of suspend functional types in the JVM backend. They are represented in it as ordinary functional types with a marker interface. Because of the marker interface, there is no way to tell which of the superinterfaces are suspended and which are ordinary.
- You can't use multiple suspend functional supertypes. If there are type checks, you also can't use multiple ordinary functional supertypes.

Requiring opt-in on implicit usages of experimental APIs

The opt-in requirement mechanism is Experimental. It may change at any time. See how to opt-in. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

The author of a library can mark an experimental API as requiring opt-in to inform users about its experimental state. The compiler raises a warning or error when the API is used and requires explicit consent to suppress it.

In Kotlin 1.5.30, the compiler treats any declaration that has an experimental type in the signature as experimental. Namely, it requires opt-in even for implicit usages of an experimental API. For example, if the function's return type is marked as an experimental API element, a usage of the function requires you to opt-in even if the declaration is not marked as requiring an opt-in explicitly.

```kotlin
// Library code

@RequiresOptIn(message = "This API is experimental.")
@Retention(AnnotationRetention.BINARY)
@Target(AnnotationTarget.CLASS)
annotation class MyDateTime // Opt-in requirement annotation

@MyDateTime
class DateProvider // A class requiring opt-in

// Client code

// Warning: experimental API usage
fun createDateSource(): DateProvider { /* ... */ }

fun getDate(): Date {
    val dateSource = createDateSource() // Also warning: experimental API usage
    // ...
}
```

Learn more about opt-in requirements.

Changes to using opt-in requirement annotations with different targets

The opt-in requirement mechanism is Experimental. It may change at any time. See how to opt-in. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Kotlin 1.5.30 presents new rules for using and declaring opt-in requirement annotations on different targets. The compiler now reports an error for use cases that are impractical to handle at compile time. In Kotlin 1.5.30:

- Marking local variables and value parameters with opt-in requirement annotations is forbidden at the use site.
- Marking override is allowed only if its basic declaration is also marked.
- Marking backing fields and getters is forbidden. You can mark the basic property instead.
- Setting TYPE and TYPE_PARAMETER annotation targets is forbidden at the opt-in requirement annotation declaration site.

Learn more about opt-in requirements.

Improvements to type inference for recursive generic types

In Kotlin and Java, you can define a recursive generic type, which references itself in its type parameters. In Kotlin 1.5.30, the Kotlin compiler can infer a type argument based only on upper bounds of the corresponding type parameter if it is a recursive generic. This makes it possible to create various patterns with recursive generic types that are often used in Java to make builder APIs.

```kotlin
// Kotlin 1.5.20
val containerA = PostgreSQLContainer<Nothing>(DockerImageName.parse("postgres:13-alpine")).apply {
    withDatabaseName("db")
    withUsername("user")
    withPassword("password")
    withInitScript("sql/schema.sql")
}

// Kotlin 1.5.30
val containerB = PostgreSQLContainer(DockerImageName.parse("postgres:13-alpine"))
    .withDatabaseName("db")
    .withUsername("user")
    .withPassword("password")
    .withInitScript("sql/schema.sql")
```

You can enable the improvements by passing the -Xself-upper-bound-inference or the -language-version 1.6 compiler options. See other examples of newly supported use cases in this YouTrack ticket.

Eliminating builder inference restrictions

Builder inference is a special kind of type inference that allows you to infer the type arguments of a call based on type information from other calls inside its lambda argument. This can be useful when calling generic builder functions such as buildList() or sequence(): buildList { add("string") }.

Inside such a lambda argument, there was previously a limitation on using the type information that the builder inference tries to infer. This means you can only specify it and cannot get it. For example, you cannot call get() inside a lambda argument of buildList() without explicitly specified type arguments.

Kotlin 1.5.30 removes these limitations with the -Xunrestricted-builder-inference compiler option. Add this option to enable previously prohibited calls inside a lambda argument of generic builder functions:

```
@kotlin.ExperimentalStdlibApi
val list = buildList {
    add("a")
    add("b")
    set(1, null)
    val x = get(1)
    if (x != null) {
        removeAt(1)
    }
}

@kotlin.ExperimentalStdlibApi
val map = buildMap {
    put("a", 1)
    put("b", 1.1)
    put("c", 2f)
}
```

Also, you can enable this feature with the -language-version 1.6 compiler option.

Kotlin/JVM

With Kotlin 1.5.30, Kotlin/JVM receives the following features:

- Instantiation of annotation classes
- Improved nullability annotation support configuration

See the Gradle section for Kotlin Gradle plugin updates on the JVM platform.

Instantiation of annotation classes

> Instantiation of annotation classes is Experimental. It may be dropped or changed at any time. Opt-in is required (see the details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

With Kotlin 1.5.30 you can now call constructors of annotation classes in arbitrary code to obtain a resulting instance. This feature covers the same use cases as the Java convention that allows the implementation of an annotation interface.

```
annotation class InfoMarker(val info: String)

fun processInfo(marker: InfoMarker) = ...

fun main(args: Array<String>) {
    if (args.size != 0)
        processInfo(getAnnotationReflective(args))
    else
        processInfo(InfoMarker("default"))
}
```

Use the -language-version 1.6 compiler option to enable this feature. Note that all current annotation class limitations, such as restrictions to define non-val parameters or members different from secondary constructors, remain intact.

Learn more about instantiation of annotation classes in this KEEP

Improved nullability annotation support configuration

The Kotlin compiler can read various types of nullability annotations to get nullability information from Java. This information allows it to report nullability mismatches in Kotlin when calling Java code.

In Kotlin 1.5.30, you can specify whether the compiler reports a nullability mismatch based on the information from specific types of nullability annotations. Just use the compiler option -Xnullability-annotations=@<package-name>:<report-level>. In the argument, specify the fully qualified nullability annotations package and one of these report levels:

- ignore to ignore nullability mismatches
- warn to report warnings
- strict to report errors.

See the full list of supported nullability annotations along with their fully qualified package names.

Here is an example showing how to enable error reporting for the newly supported RxJava 3 nullability annotations: -Xnullability-annotations=@io.reactivex.rxjava3.annotations:strict. Note that all such nullability mismatches are warnings by default.

Kotlin/Native

Kotlin/Native has received various changes and improvements:

- Apple silicon support
- Improved Kotlin DSL for the CocoaPods Gradle plugin
- Experimental interoperability with Swift 5.5 async/await
- Improved Swift/Objective-C mapping for objects and companion objects
- Deprecation of linkage against DLLs without import libraries for MinGW targets

Apple silicon support

Kotlin 1.5.30 introduces native support for Apple silicon.

Previously, the Kotlin/Native compiler and tooling required the Rosetta translation environment for working on Apple silicon hosts. In Kotlin 1.5.30, the translation environment is no longer needed – the compiler and tooling can run on Apple silicon hardware without requiring any additional actions.

We've also introduced new targets that make Kotlin code run natively on Apple silicon:

- macosArm64
- iosSimulatorArm64
- watchosSimulatorArm64
- tvosSimulatorArm64

They are available on both Intel-based and Apple silicon hosts. All existing targets are available on Apple silicon hosts as well.

Note that in 1.5.30 we provide only basic support for Apple silicon targets in the kotlin-multiplatform Gradle plugin. Particularly, the new simulator targets aren't included in the ios, tvos, and watchos target shortcuts. We will keep working to improve the user experience with the new targets.

Improved Kotlin DSL for the CocoaPods Gradle plugin

New parameters for Kotlin/Native frameworks

Kotlin 1.5.30 introduces the improved CocoaPods Gradle plugin DSL for Kotlin/Native frameworks. In addition to the name of the framework, you can specify other parameters in the Pod configuration:

- Specify the dynamic or static version of the framework
- Enable export dependencies explicitly

- Enable Bitcode embedding

To use the new DSL, update your project to Kotlin 1.5.30, and specify the parameters in the cocoapods section of your build.gradle(.kts) file:

```
cocoapods {
    frameworkName = "MyFramework" // This property is deprecated
    // and will be removed in future versions
    // New DSL for framework configuration:
    framework {
        // All Framework properties are supported
        // Framework name configuration. Use this property instead of
        // deprecated 'frameworkName'
        baseName = "MyFramework"
        // Dynamic framework support
        isStatic = false
        // Dependency export
        export(project(":anotherKMMModule"))
        transitiveExport = false // This is default.
        // Bitcode embedding
        embedBitcode(BITCODE)
    }
}
```

Support custom names for Xcode configuration

The Kotlin CocoaPods Gradle plugin supports custom names in the Xcode build configuration. It will also help you if you're using special names for the build configuration in Xcode, for example Staging.

To specify a custom name, use the xcodeConfigurationToNativeBuildType parameter in the cocoapods section of your build.gradle(.kts) file:

```
cocoapods {
    // Maps custom Xcode configuration to NativeBuildType
    xcodeConfigurationToNativeBuildType["CUSTOM_DEBUG"] = NativeBuildType.DEBUG
    xcodeConfigurationToNativeBuildType["CUSTOM_RELEASE"] = NativeBuildType.RELEASE
}
```

This parameter will not appear in the Podspec file. When Xcode runs the Gradle build process, the Kotlin CocoaPods Gradle plugin will select the necessary native build type.

> There's no need to declare the Debug and Release configurations because they are supported by default.

Experimental interoperability with Swift 5.5 async/await

> Concurrency interoperability with Swift async/await is Experimental. It may be dropped or changed at any time. You should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

We added support for calling Kotlin's suspending functions from Objective-C and Swift in 1.4.0, and now we're improving it to keep up with a new Swift 5.5 feature – concurrency with async and await modifiers.

The Kotlin/Native compiler now emits the _Nullable_result attribute in the generated Objective-C headers for suspending functions with nullable return types. This makes it possible to call them from Swift as async functions with the proper nullability.

Note that this feature is experimental and can be affected in the future by changes in both Kotlin and Swift. For now, we're offering a preview of this feature that has certain limitations, and we are eager to hear what you think. Learn more about its current state and leave your feedback in this YouTrack issue.

Improved Swift/Objective-C mapping for objects and companion objects

Getting objects and companion objects can now be done in a way that is more intuitive for native iOS developers. For example, if you have the following objects in Kotlin:

```
object MyObject {
    val x = "Some value"
}
```

```
class MyClass {
    companion object {
        val x = "Some value"
    }
}
```

To access them in Swift, you can use the shared and companion properties:

```
MyObject.shared
MyObject.shared.x
MyClass.companion
MyClass.Companion.shared
```

Learn more about Swift/Objective-C interoperability.

Deprecation of linkage against DLLs without import libraries for MinGW targets

LLD is a linker from the LLVM project, which we plan to start using in Kotlin/Native for MinGW targets because of its benefits over the default ld.bfd – primarily its better performance.

However, the latest stable version of LLD doesn't support direct linkage against DLL for MinGW (Windows) targets. Such linkage requires using import libraries. Although they aren't needed with Kotlin/Native 1.5.30, we're adding a warning to inform you that such usage is incompatible with LLD that will become the default linker for MinGW in the future.

Please share your thoughts and concerns about the transition to the LLD linker in this YouTrack issue.

Kotlin Multiplatform

1.5.30 brings the following notable updates to Kotlin Multiplatform:

- Ability to use custom cinterop libraries in shared native code
- Support for XCFrameworks
- New default publishing setup for Android artifacts

Ability to use custom cinterop libraries in shared native code

Kotlin Multiplatform gives you an option to use platform-dependent interop libraries in shared source sets. Before 1.5.30, this worked only with platform libraries shipped with Kotlin/Native distribution. Starting from 1.5.30, you can use it with your custom cinterop libraries. To enable this feature, add the kotlin.mpp.enableCInteropCommonization=true property in your gradle.properties:

```
kotlin.mpp.enableGranularSourceSetsMetadata=true
kotlin.native.enableDependencyPropagation=false
kotlin.mpp.enableCInteropCommonization=true
```

Support for XCFrameworks

All Kotlin Multiplatform projects can now have XCFrameworks as an output format. Apple introduced XCFrameworks as a replacement for universal (fat) frameworks. With the help of XCFrameworks you:

- Can gather logic for all the target platforms and architectures in a single bundle.
- Don't need to remove all unnecessary architectures before publishing the application to the App Store.

XCFrameworks is useful if you want to use your Kotlin framework for devices and simulators on Apple M1.

To use XCFrameworks, update your build.gradle(.kts) script:

Kotlin

```
import org.jetbrains.kotlin.gradle.plugin.mpp.apple.XCFramework
```

```
plugins {
    kotlin("multiplatform")
}

kotlin {
    val xcf = XCFramework()

    ios {
        binaries.framework {
            baseName = "shared"
            xcf.add(this)
        }
    }
    watchos {
        binaries.framework {
            baseName = "shared"
            xcf.add(this)
        }
    }
    tvos {
        binaries.framework {
            baseName = "shared"
            xcf.add(this)
        }
    }
}
```

Groovy

```
import org.jetbrains.kotlin.gradle.plugin.mpp.apple.XCFrameworkConfig

plugins {
    id 'org.jetbrains.kotlin.multiplatform'
}

kotlin {
    def xcf = new XCFrameworkConfig(project)

    ios {
        binaries.framework {
            baseName = "shared"
            xcf.add(it)
        }
    }
    watchos {
        binaries.framework {
            baseName = "shared"
            xcf.add(it)
        }
    }
    tvos {
        binaries.framework {
            baseName = "shared"
            xcf.add(it)
        }
    }
}
```

When you declare XCFrameworks, these new Gradle tasks will be registered:

- assembleXCFramework
- assembleDebugXCFramework (additionally debug artifact that contains dSYMs)
- assembleReleaseXCFramework

Learn more about XCFrameworks in this WWDC video.

New default publishing setup for Android artifacts

Using the maven-publish Gradle plugin, you can publish your multiplatform library for the Android target by specifying Android variant names in the build script. The Kotlin Gradle plugin will generate publications automatically.

Before 1.5.30, the generated publication metadata included the build type attributes for every published Android variant, making it compatible only with the same build type used by the library consumer. Kotlin 1.5.30 introduces a new default publishing setup:

- If all Android variants that the project publishes have the same build type attribute, then the published variants won't have the build type attribute and will be compatible with any build type.
- If the published variants have different build type attributes, then only those with the release value will be published without the build type attribute. This makes the release variants compatible with any build type on the consumer side, while non-release variants will only be compatible with the matching consumer build types.

To opt-out and keep the build type attributes for all variants, you can set this Gradle property: kotlin.android.buildTypeAttribute.keep=true.

Kotlin/JS

Two major improvements are coming to Kotlin/JS with 1.5.30:

- JS IR compiler backend reaches Beta
- Better debugging experience for applications with the Kotlin/JS IR backend

JS IR compiler backend reaches Beta

The IR-based compiler backend for Kotlin/JS, which was introduced in 1.4.0 in Alpha, has reached Beta.

Previously, we published the migration guide for the JS IR backend to help you migrate your projects to the new backend. Now we would like to present the Kotlin/JS Inspection Pack IDE plugin, which displays the required changes directly in IntelliJ IDEA.

Better debugging experience for applications with the Kotlin/JS IR backend

Kotlin 1.5.30 brings JavaScript source map generation for the Kotlin/JS IR backend. This will improve the Kotlin/JS debugging experience when the IR backend is enabled, with full debugging support that includes breakpoints, stepping, and readable stack traces with proper source references.

Learn how to debug Kotlin/JS in the browser or IntelliJ IDEA Ultimate.

Gradle

As a part of our mission to improve the Kotlin Gradle plugin user experience, we've implemented the following features:

- Support for Java toolchains, which includes an ability to specify a JDK home with the UsesKotlinJavaToolchain interface for older Gradle versions
- An easier way to explicitly specify the Kotlin daemon's JVM arguments

Support for Java toolchains

Gradle 6.7 introduced the "Java toolchains support" feature. Using this feature, you can:

- Run compilations, tests, and executables using JDKs and JREs that are different from the Gradle ones.
- Compile and test code with an unreleased language version.

With toolchains support, Gradle can autodetect local JDKs and install missing JDKs that Gradle requires for the build. Now Gradle itself can run on any JDK and still reuse the build cache feature.

The Kotlin Gradle plugin supports Java toolchains for Kotlin/JVM compilation tasks. A Java toolchain:

- Sets the jdkHome option available for JVM targets.

  > The ability to set the jdkHome option directly has been deprecated.

- Sets the kotlinOptions.jvmTarget to the toolchain's JDK version if the user didn't set the jvmTarget option explicitly. If the toolchain is not configured, the jvmTarget field uses the default value. Learn more about JVM target compatibility.
- Affects which JDK kapt workers are running on.

Use the following code to set a toolchain. Replace the placeholder <MAJOR_JDK_VERSION> with the JDK version you would like to use:

Kotlin

```
kotlin {
    jvmToolchain {
        (this as JavaToolchainSpec).languageVersion.set(JavaLanguageVersion.of(<MAJOR_JDK_VERSION>)) // "8"
    }
}
```

Groovy

```
kotlin {
    jvmToolchain {
        languageVersion.set(JavaLanguageVersion.of(<MAJOR_JDK_VERSION>)) // "8"
    }
}
```

Note that setting a toolchain via the kotlin extension will update the toolchain for Java compile tasks as well.

You can set a toolchain via the java extension, and Kotlin compilation tasks will use it:

```
java {
    toolchain {
        languageVersion.set(JavaLanguageVersion.of(<MAJOR_JDK_VERSION>)) // "8"
    }
}
```

For information about setting any JDK version for KotlinCompile tasks, look through the docs about setting the JDK version with the Task DSL.

For Gradle versions from 6.1 to 6.6, use the UsesKotlinJavaToolchain interface to set the JDK home.

Ability to specify JDK home with UsesKotlinJavaToolchain interface

All Kotlin tasks that support setting the JDK via kotlinOptions now implement the UsesKotlinJavaToolchain interface. To set the JDK home, put a path to your JDK and replace the <JDK_VERSION> placeholder:

Kotlin

```
project.tasks
    .withType<UsesKotlinJavaToolchain>()
    .configureEach {
        it.kotlinJavaToolchain.jdk.use(
            "/path/to/local/jdk",
            JavaVersion.<LOCAL_JDK_VERSION>
        )
    }
```

Groovy

```
project.tasks
    .withType(UsesKotlinJavaToolchain.class)
    .configureEach {
        it.kotlinJavaToolchain.jdk.use(
            '/path/to/local/jdk',
            JavaVersion.<LOCAL_JDK_VERSION>
        )
    }
```

Use the UsesKotlinJavaToolchain interface for Gradle versions from 6.1 to 6.6. Starting from Gradle 6.7, use the Java toolchains instead.

When using this feature, note that kapt task workers will only use process isolation mode, and the kapt.workers.isolation property will be ignored.

Easier way to explicitly specify Kotlin daemon JVM arguments

In Kotlin 1.5.30, there's a new logic for the Kotlin daemon's JVM arguments. Each of the options in the following list overrides the ones that came before it:

- If nothing is specified, the Kotlin daemon inherits arguments from the Gradle daemon (as before). For example, in the gradle.properties file:

```
org.gradle.jvmargs=-Xmx1500m -Xms=500m
```

- If the Gradle daemon's JVM arguments have the kotlin.daemon.jvm.options system property, use it as before:

```
org.gradle.jvmargs=-Dkotlin.daemon.jvm.options=-Xmx1500m -Xms=500m
```

- You can add thekotlin.daemon.jvmargs property in the gradle.properties file:

```
kotlin.daemon.jvmargs=-Xmx1500m -Xms=500m
```

- You can specify arguments in the kotlin extension:

Kotlin

```kotlin
kotlin {
    kotlinDaemonJvmArgs = listOf("-Xmx486m", "-Xms256m", "-XX:+UseParallelGC")
}
```

Groovy

```groovy
kotlin {
    kotlinDaemonJvmArgs = ["-Xmx486m", "-Xms256m", "-XX:+UseParallelGC"]
}
```

- You can specify arguments for a specific task:

Kotlin

```kotlin
tasks
    .matching { it.name == "compileKotlin" && it is CompileUsingKotlinDaemon }
    .configureEach {
        (this as CompileUsingKotlinDaemon).kotlinDaemonJvmArguments.set(listOf("-Xmx486m", "-Xms256m", "-XX:+UseParallelGC"))
    }
```

Groovy

```groovy
tasks
    .matching {
        it.name == "compileKotlin" && it instanceof CompileUsingKotlinDaemon
    }
    .configureEach {
        kotlinDaemonJvmArguments.set(["-Xmx1g", "-Xms512m"])
    }
```

In this case a new Kotlin daemon instance can start on task execution. Learn more about the Kotlin daemon's interactions with JVM arguments.

For more information about the Kotlin daemon, see the Kotlin daemon and using it with Gradle.

Standard library

Kotlin 1.5.30 is bringing improvements to the standard library's Duration and Regex APIs:

- Changing Duration.toString() output

- Parsing Duration from String
- Matching with Regex at a particular position
- Splitting Regex to a sequence

Changing Duration.toString() output

> The Duration API is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate hearing your feedback on it in YouTrack.

Before Kotlin 1.5.30, the Duration.toString() function would return a string representation of its argument expressed in the unit that yielded the most compact and readable number value. From now on, it will return a string value expressed as a combination of numeric components, each in its own unit. Each component is a number followed by the unit's abbreviated name: d, h, m, s. For example:

Example of function call	Previous output	Current output
Duration.days(45).toString()	45.0d	45d
Duration.days(1.5).toString()	36.0h	1d 12h
Duration.minutes(1230).toString()	20.5h	20h 30m
Duration.minutes(2415).toString()	40.3h	1d 16h 15m
Duration.minutes(920).toString()	920m	15h 20m
Duration.seconds(1.546).toString()	1.55s	1.546s
Duration.milliseconds(25.12).toString()	25.1ms	25.12ms

The way negative durations are represented has also been changed. A negative duration is prefixed with a minus sign (-), and if it consists of multiple components, it is surrounded with parentheses: -12m and -(1h 30m).

Note that small durations of less than one second are represented as a single number with one of the subsecond units. For example, ms (milliseconds), us (microseconds), or ns (nanoseconds): 140.884ms, 500us, 24ns. Scientific notation is no longer used to represent them.

If you want to express duration in a single unit, use the overloaded Duration.toString(unit, decimals) function.

> We recommend using Duration.toIsoString() in certain cases, including serialization and interchange. Duration.toIsoString() uses the stricter ISO-8601 format instead of Duration.toString().

Parsing Duration from String

> The Duration API is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate hearing your feedback on it in this issue.

In Kotlin 1.5.30, there are new functions in the Duration API:

- parse(), which supports parsing the outputs of:
  - toString().
  - toString(unit, decimals).
  - toIsoString().
- parseIsoString(), which only parses from the format produced by toIsoString().
- parseOrNull() and parseIsoStringOrNull(), which behave like the functions above but return null instead of throwing IllegalArgumentException on invalid duration formats.

Here are some examples of parse() and parseOrNull() usages:

```
import kotlin.time.Duration
import kotlin.time.ExperimentalTime

@ExperimentalTime
fun main() {
    val isoFormatString = "PT1H30M"
    val defaultFormatString = "1h 30m"
    val singleUnitFormatString = "1.5h"
    val invalidFormatString = "1 hour 30 minutes"
    println(Duration.parse(isoFormatString)) // "1h 30m"
    println(Duration.parse(defaultFormatString)) // "1h 30m"
    println(Duration.parse(singleUnitFormatString)) // "1h 30m"
    //println(Duration.parse(invalidFormatString)) // throws exception
    println(Duration.parseOrNull(invalidFormatString)) // "null"
}
```

And here are some examples of parseIsoString() and parseIsoStringOrNull() usages:

```
import kotlin.time.Duration
import kotlin.time.ExperimentalTime

@ExperimentalTime
fun main() {
    val isoFormatString = "PT1H30M"
    val defaultFormatString = "1h 30m"
    println(Duration.parseIsoString(isoFormatString)) // "1h 30m"
    //println(Duration.parseIsoString(defaultFormatString)) // throws exception
    println(Duration.parseIsoStringOrNull(defaultFormatString)) // "null"
}
```

Matching with Regex at a particular position

Regex.matchAt() and Regex.matchesAt() functions are Experimental. They may be dropped or changed at any time. Use them only for evaluation purposes. We would appreciate hearing your feedback on them in YouTrack.

The new Regex.matchAt() and Regex.matchesAt() functions provide a way to check whether a regex has an exact match at a particular position in a String or CharSequence.

matchesAt() returns a boolean result:

```
fun main(){
    val releaseText = "Kotlin 1.5.30 is released!"
    // regular expression: one digit, dot, one digit, dot, one or more digits
    val versionRegex = "\\d[.]\\d[.]\\d+".toRegex()
    println(versionRegex.matchesAt(releaseText, 0)) // "false"
    println(versionRegex.matchesAt(releaseText, 7)) // "true"
}
```

matchAt() returns the match if one is found or null if one isn't:

```
fun main(){
    val releaseText = "Kotlin 1.5.30 is released!"
    val versionRegex = "\\d[.]\\d[.]\\d+".toRegex()
    println(versionRegex.matchAt(releaseText, 0)) // "null"
    println(versionRegex.matchAt(releaseText, 7)?.value) // "1.5.30"
}
```

Splitting Regex to a sequence

> Regex.splitToSequence() and CharSequence.splitToSequence(Regex) functions are Experimental. They may be dropped or changed at any time. Use them only for evaluation purposes. We would appreciate hearing your feedback on them in YouTrack.

The new Regex.splitToSequence() function is a lazy counterpart of split(). It splits the string around matches of the given regex, but it returns the result as a Sequence so that all operations on this result are executed lazily.

```
fun main(){
    val colorsText = "green, red , brown&blue, orange, pink&green"
    val regex = "[,\\s]+".toRegex()
    val mixedColor = regex.splitToSequence(colorsText)
        .onEach { println(it) }
        .firstOrNull { it.contains('&') }
    println(mixedColor) // "brown&blue"
}
```

A similar function was also added to CharSequence:

```
val mixedColor = colorsText.splitToSequence(regex)
```

Serialization 1.3.0-RC

kotlinx.serialization 1.3.0-RC is here with new JSON serialization capabilities:

- Java IO streams serialization
- Property-level control over default values
- An option to exclude null values from serialization
- Custom class discriminators in polymorphic serialization

Learn more in the changelog.

What's new in Kotlin 1.5.20

Released: 24 June 2021

Kotlin 1.5.20 has fixes for issues discovered in the new features of 1.5.0, and it also includes various tooling improvements.

You can find an overview of the changes in the release blog post and this video:

Watch video online.

Kotlin/JVM

Kotlin 1.5.20 is receiving the following updates on the JVM platform:

- String concatenation via invokedynamic
- Support for JSpecify nullness annotations
- Support for calling Java's Lombok-generated methods within modules that have Kotlin and Java code

String concatenation via invokedynamic

Kotlin 1.5.20 compiles string concatenations into dynamic invocations (invokedynamic) on JVM 9+ targets, thereby keeping up with modern Java versions. More precisely, it uses StringConcatFactory.makeConcatWithConstants() for string concatenation.

To switch back to concatenation via StringBuilder.append() used in previous versions, add the compiler option -Xstring-concat=inline.

Learn how to add compiler options in Gradle, Maven, and the command-line compiler.

Support for JSpecify nullness annotations

The Kotlin compiler can read various types of nullability annotations to pass nullability information from Java to Kotlin. Version 1.5.20 introduces support for the JSpecify project, which includes the standard unified set of Java nullness annotations.

With JSpecify, you can provide more detailed nullability information to help Kotlin keep null-safety interoperating with Java. You can set default nullability for the declaration, package, or module scope, specify parametric nullability, and more. You can find more details about this in the JSpecify user guide.

Here is the example of how Kotlin can handle JSpecify annotations:

```
// JavaClass.java
import org.jspecify.nullness.*;

@NullMarked
public class JavaClass {
  public String notNullableString() { return ""; }
  public @Nullable String nullableString() { return ""; }
}
```

```
// Test.kt
fun kotlinFun() = with(JavaClass()) {
  notNullableString().length // OK
  nullableString().length    // Warning: receiver nullability mismatch
}
```

In 1.5.20, all nullability mismatches according to the JSpecify-provided nullability information are reported as warnings. Use the -Xjspecify-annotations=strict and -Xtype-enhancement-improvements-strict-mode compiler options to enable strict mode (with error reporting) when working with JSpecify. Please note that the JSpecify project is under active development. Its API and implementation can change significantly at any time.

Learn more about null-safety and platform types.

Support for calling Java's Lombok-generated methods within modules that have Kotlin and Java code

The Lombok compiler plugin is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Kotlin 1.5.20 introduces an experimental Lombok compiler plugin. This plugin makes it possible to generate and use Java's Lombok declarations within modules that have Kotlin and Java code. Lombok annotations work only in Java sources and are ignored if you use them in Kotlin code.

The plugin supports the following annotations:

- @Getter, @Setter
- @NoArgsConstructor, @RequiredArgsConstructor, and @AllArgsConstructor
- @Data
- @With
- @Value

We're continuing to work on this plugin. To find out the detailed current state, visit the Lombok compiler plugin's README.

Currently, we don't have plans to support the @Builder annotation. However, we can consider this if you vote for @Builder in YouTrack.

Learn how to configure the Lombok compiler plugin.

Kotlin/Native

Kotlin/Native 1.5.20 offers a preview of the new feature and the tooling improvements:

- Opt-in export of KDoc comments to generated Objective-C headers
- Compiler bug fixes
- Improved performance of Array.copyInto() inside one array

Opt-in export of KDoc comments to generated Objective-C headers

The ability to export KDoc comments to generated Objective-C headers is Experimental. It may be dropped or changed at any time. Opt-in is required (see the details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

You can now set the Kotlin/Native compiler to export the documentation comments (KDoc) from Kotlin code to the Objective-C frameworks generated from it, making them visible to the frameworks' consumers.

For example, the following Kotlin code with KDoc:

```
/**
 * Prints the sum of the arguments.
 * Properly handles the case when the sum doesn't fit in 32-bit integer.
 */
fun printSum(a: Int, b: Int) = println(a.toLong() + b)
```

produces the following Objective-C headers:

```
/**
 * Prints the sum of the arguments.
 * Properly handles the case when the sum doesn't fit in 32-bit integer.
 */
+ (void)printSumA:(int32_t)a b:(int32_t)b __attribute__((swift_name("printSum(a:b:)")));
```

This also works well with Swift.

To try out this ability to export KDoc comments to Objective-C headers, use the -Xexport-kdoc compiler option. Add the following lines to build.gradle(.kts) of the Gradle projects you want to export comments from:

Kotlin

```
kotlin {
    targets.withType<org.jetbrains.kotlin.gradle.plugin.mpp.KotlinNativeTarget> {
        compilations.get("main").kotlinOptions.freeCompilerArgs += "-Xexport-kdoc"
    }
}
```

Groovy

```
kotlin {
    targets.withType(org.jetbrains.kotlin.gradle.plugin.mpp.KotlinNativeTarget) {
        compilations.get("main").kotlinOptions.freeCompilerArgs += "-Xexport-kdoc"
    }
}
```

We would be very grateful if you would share your feedback with us using this YouTrack ticket.

Compiler bug fixes

The Kotlin/Native compiler has received multiple bug fixes in 1.5.20. You can find the complete list in the changelog.

There is an important bug fix that affects compatibility: in previous versions, string constants that contained incorrect UTF surrogate pairs were losing their values during compilation. Now such values are preserved. Application developers can safely update to 1.5.20 – nothing will break. However, libraries compiled with 1.5.20 are incompatible with earlier compiler versions. See this YouTrack issue for details.

Improved performance of Array.copyInto() inside one array

We've improved the way Array.copyInto() works when its source and destination are the same array. Now such operations finish up to 20 times faster (depending on the number of objects being copied) due to memory management optimizations for this use case.

Kotlin/JS

With 1.5.20, we're publishing a guide that will help you migrate your projects to the new IR-based backend for Kotlin/JS.

Migration guide for the JS IR backend

The new migration guide for the JS IR backend identifies issues you may encounter during migration and provides solutions for them. If you find any issues that aren't covered in the guide, please report them to our issue tracker.

Gradle

Kotlin 1.5.20 introduces the following features that can improve the Gradle experience:

- Caching for annotation processors classloaders in kapt
- Deprecation of the kotlin.parallel.tasks.in.project build property

Caching for annotation processors' classloaders in kapt

> Caching for annotation processors' classloaders in kapt is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

There is now a new experimental feature that makes it possible to cache the classloaders of annotation processors in kapt. This feature can increase the speed of kapt for consecutive Gradle runs.

To enable this feature, use the following properties in your gradle.properties file:

```
# positive value will enable caching
# use the same value as the number of modules that use kapt
kapt.classloaders.cache.size=5

# disable for caching to work
kapt.include.compile.classpath=false
```

Learn more about kapt.

Deprecation of the kotlin.parallel.tasks.in.project build property

With this release, Kotlin parallel compilation is controlled by the Gradle parallel execution flag --parallel. Using this flag, Gradle executes tasks concurrently, increasing the speed of compiling tasks and utilizing the resources more efficiently.

You no longer need to use the kotlin.parallel.tasks.in.project property. This property has been deprecated and will be removed in the next major release.

Standard library

Kotlin 1.5.20 changes the platform-specific implementations of several functions for working with characters and as a result brings unification across platforms:

- Support for all Unicode digits in Char.digitToInt() for Kotlin/Native and Kotlin/JS.
- Unification of Char.isLowerCase()/isUpperCase() implementations across platforms.

Support for all Unicode digits in Char.digitToInt() in Kotlin/Native and Kotlin/JS

Char.digitToInt() returns the numeric value of the decimal digit that the character represents. Before 1.5.20, the function supported all Unicode digit characters only for Kotlin/JVM: implementations on the Native and JS platforms supported only ASCII digits.

From now, both with Kotlin/Native and Kotlin/JS, you can call Char.digitToInt() on any Unicode digit character and get its numeric representation.

```
fun main() {
    val ten = '\u0661'.digitToInt() + '\u0039'.digitToInt() // ARABIC-INDIC DIGIT ONE + DIGIT NINE
    println(ten)
}
```

Unification of Char.isLowerCase()/isUpperCase() implementations across platforms

The functions Char.isUpperCase() and Char.isLowerCase() return a boolean value depending on the case of the character. For Kotlin/JVM, the implementation checks both the General_Category and the Other_Uppercase/Other_Lowercase Unicode properties.

Prior to 1.5.20, implementations for other platforms worked differently and considered only the general category. In 1.5.20, implementations are unified across platforms and use both properties to determine the character case:

```kotlin
fun main() {
    val latinCapitalA = 'A' // has "Lu" general category
    val circledLatinCapitalA = 'Ⓐ' // has "Other_Uppercase" property
    println(latinCapitalA.isUpperCase() && circledLatinCapitalA.isUpperCase())
}
```

What's new in Kotlin 1.5.0

Released: 5 May 2021

Kotlin 1.5.0 introduces new language features, stable IR-based JVM compiler backend, performance improvements, and evolutionary changes such as stabilizing experimental features and deprecating outdated ones.

You can also find an overview of the changes in the release blog post.

Language features

Kotlin 1.5.0 brings stable versions of the new language features presented for preview in 1.4.30:

- JVM records support
- Sealed interfaces and sealed class improvements
- Inline classes

Detailed descriptions of these features are available in this blog post and the corresponding pages of Kotlin documentation.

JVM records support

Java is evolving fast, and to make sure Kotlin remains interoperable with it, we've introduced support for one of its latest features – record classes.

Kotlin's support for JVM records includes bidirectional interoperability:

- In Kotlin code, you can use Java record classes like you would use typical classes with properties.
- To use a Kotlin class as a record in Java code, make it a data class and mark it with the @JvmRecord annotation.

```kotlin
@JvmRecord
data class User(val name: String, val age: Int)
```

Learn more about using JVM records in Kotlin.

Watch video online.

Sealed interfaces

Kotlin interfaces can now have the sealed modifier, which works on interfaces in the same way it works on classes: all implementations of a sealed interface are known at compile time.

```kotlin
sealed interface Polygon
```

You can rely on that fact, for example, to write exhaustive when expressions.

```kotlin
fun draw(polygon: Polygon) = when (polygon) {
   is Rectangle -> // ...
   is Triangle -> // ...
   // else is not needed - all possible implementations are covered
}
```

Additionally, sealed interfaces enable more flexible restricted class hierarchies because a class can directly inherit more than one sealed interface.

```kotlin
class FilledRectangle: Polygon, Fillable
```

Learn more about sealed interfaces.

Watch video online.

Package-wide sealed class hierarchies

Sealed classes can now have subclasses in all files of the same compilation unit and the same package. Previously, all subclasses had to appear in the same file.

Direct subclasses may be top-level or nested inside any number of other named classes, named interfaces, or named objects.

The subclasses of a sealed class must have a name that is properly qualified – they cannot be local or anonymous objects.

Learn more about sealed class hierarchies.

Inline classes

Inline classes are a subset of value-based classes that only hold values. You can use them as wrappers for a value of a certain type without the additional overhead that comes from using memory allocations.

Inline classes can be declared with the value modifier before the name of the class:

```
value class Password(val s: String)
```

The JVM backend also requires a special @JvmInline annotation:

```
@JvmInline
value class Password(val s: String)
```

The inline modifier is now deprecated with a warning.

Learn more about inline classes.

Watch video online.

Kotlin/JVM

Kotlin/JVM has received a number of improvements, both internal and user-facing. Here are the most notable among them:

- Stable JVM IR backend
- New default JVM target: 1.8
- SAM adapters via invokedynamic
- Lambdas via invokedynamic
- Deprecation of @JvmDefault and old Xjvm-default modes
- Improvements to handling nullability annotations

Stable JVM IR backend

The IR-based backend for the Kotlin/JVM compiler is now Stable and enabled by default.

Starting from Kotlin 1.4.0, early versions of the IR-based backend were available for preview, and it has now become the default for language version 1.5. The old backend is still used by default for earlier language versions.

You can find more details about the benefits of the IR backend and its future development in this blog post.

If you need to use the old backend in Kotlin 1.5.0, you can add the following lines to the project's configuration file:

- In Gradle:

Kotlin

```kotlin
tasks.withType<org.jetbrains.kotlin.gradle.dsl.KotlinJvmCompile> {
  kotlinOptions.useOldBackend = true
}
```

Groovy

```
tasks.withType(org.jetbrains.kotlin.gradle.dsl.KotlinJvmCompile) {
 kotlinOptions.useOldBackend = true
}
```

- In Maven:

```
<configuration>
    <args>
        <arg>-Xuse-old-backend</arg>
    </args>
</configuration>
```

New default JVM target: 1.8

The default target version for Kotlin/JVM compilations is now 1.8. The 1.6 target is deprecated.

If you need a build for JVM 1.6, you can still switch to this target. Learn how:

- in Gradle
- in Maven
- in the command-line compiler

SAM adapters via invokedynamic

Kotlin 1.5.0 now uses dynamic invocations (invokedynamic) for compiling SAM (Single Abstract Method) conversions:

- Over any expression if the SAM type is a Java interface
- Over lambda if the SAM type is a Kotlin functional interface

The new implementation uses LambdaMetafactory.metafactory() and auxiliary wrapper classes are no longer generated during compilation. This decreases the size of the application's JAR, which improves the JVM startup performance.

To roll back to the old implementation scheme based on anonymous class generation, add the compiler option -Xsam-conversions=class.

Learn how to add compiler options in Gradle, Maven, and the command-line compiler.

Lambdas via invokedynamic

> Compiling plain Kotlin lambdas into invokedynamic is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below), and you should use it only for evaluation purposes. We would appreciate hearing your feedback on it in YouTrack.

Kotlin 1.5.0 is introducing experimental support for compiling plain Kotlin lambdas (which are not converted to an instance of a functional interface) into dynamic invocations (invokedynamic). The implementation produces lighter binaries by using LambdaMetafactory.metafactory(), which effectively generates the necessary classes at runtime. Currently, it has three limitations compared to ordinary lambda compilation:

- A lambda compiled into invokedynamic is not serializable.
- Calling toString() on such a lambda produces a less readable string representation.
- Experimental reflect API does not support lambdas created with LambdaMetafactory.

To try this feature, add the -Xlambdas=indy compiler option. We would be grateful if you could share your feedback on it using this YouTrack ticket.

Learn how to add compiler options in Gradle, Maven, and command-line compiler.

Deprecation of @JvmDefault and old Xjvm-default modes

Prior to Kotlin 1.4.0, there was the @JvmDefault annotation along with -Xjvm-default=enable and -Xjvm-default=compatibility modes. They served to create the JVM default method for any particular non-abstract member in the Kotlin interface.

In Kotlin 1.4.0, we introduced the new Xjvm-default modes, which switch on default method generation for the whole project.

In Kotlin 1.5.0, we are deprecating @JvmDefault and the old Xjvm-default modes: -Xjvm-default=enable and -Xjvm-default=compatibility.

Learn more about default methods in the Java interop.

Improvements to handling nullability annotations

Kotlin supports handling type nullability information from Java with nullability annotations. Kotlin 1.5.0 introduces a number of improvements for the feature:

- It reads nullability annotations on type arguments in compiled Java libraries that are used as dependencies.
- It supports nullability annotations with the TYPE_USE target for:
  - Arrays
  - Varargs
  - Fields
  - Type parameters and their bounds
  - Type arguments of base classes and interfaces
- If a nullability annotation has multiple targets applicable to a type, and one of these targets is TYPE_USE, then TYPE_USE is preferred. For example, the method signature @Nullable String[] f() becomes fun f(): Array<String?>! if @Nullable supports both TYPE_USE and METHODas targets.

For these newly supported cases, using the wrong type nullability when calling Java from Kotlin produces warnings. Use the -Xtype-enhancement-improvements-strict-mode compiler option to enable strict mode for these cases (with error reporting).

Learn more about null-safety and platform types.

Kotlin/Native

Kotlin/Native is now more performant and stable. The notable changes are:

- Performance improvements
- Deactivation of the memory leak checker

Performance improvements

In 1.5.0, Kotlin/Native is receiving a set of performance improvements that speed up both compilation and execution.

Compiler caches are now supported in debug mode for linuxX64 (only on Linux hosts) and iosArm64 targets. With compiler caches enabled, most debug compilations complete much faster, except for the first one. Measurements showed about a 200% speed increase on our test projects.

To use compiler caches for new targets, opt in by adding the following lines to the project's gradle.properties:

- For linuxX64: kotlin.native.cacheKind.linuxX64=static
- For iosArm64: kotlin.native.cacheKind.iosArm64=static

If you encounter any issues after enabling the compiler caches, please report them to our issue tracker YouTrack.

Other improvements speed up the execution of Kotlin/Native code:

- Trivial property accessors are inlined.
- trimIndent() on string literals is evaluated during the compilation.

Deactivation of the memory leak checker

The built-in Kotlin/Native memory leak checker has been disabled by default.

It was initially designed for internal use, and it is able to find leaks only in a limited number of cases, not all of them. Moreover, it later turned out to have issues that can cause application crashes. So we've decided to turn off the memory leak checker.

The memory leak checker can still be useful for certain cases, for example, unit testing. For these cases, you can enable it by adding the following line of code:

```
Platform.isMemoryLeakCheckerActive = true
```

Note that enabling the checker for the application runtime is not recommended.

Kotlin/JS

Kotlin/JS is receiving evolutionary changes in 1.5.0. We're continuing our work on moving the JS IR compiler backend towards stable and shipping other updates:

- Upgrade of webpack to version 5
- Frameworks and libraries for the IR compiler

Upgrade to webpack 5

The Kotlin/JS Gradle plugin now uses webpack 5 for browser targets instead of webpack 4. This is a major webpack upgrade that brings incompatible changes. If you're using a custom webpack configuration, be sure to check the webpack 5 release notes.

Learn more about bundling Kotlin/JS projects with webpack.

Frameworks and libraries for the IR compiler

> The Kotlin/JS IR compiler is in Alpha. It may change incompatibly and require manual migration in the future. We would appreciate your feedback on it in YouTrack.

Along with working on the IR-based backend for Kotlin/JS compiler, we encourage and help library authors to build their projects in both mode. This means they are able to produce artifacts for both Kotlin/JS compilers, therefore growing the ecosystem for the new compiler.

Many well-known frameworks and libraries are already available for the IR backend: KVision, fritz2, doodle, and others. If you're using them in your project, you can already build it with the IR backend and see the benefits it brings.

If you're writing your own library, compile it in the 'both' mode so that your clients can also use it with the new compiler.

Kotlin Multiplatform

In Kotlin 1.5.0, choosing a testing dependency for each platform has been simplified and it is now done automatically by the Gradle plugin.

A new API for getting a char category is now available in multiplatform projects.

Standard library

The standard library has received a range of changes and improvements, from stabilizing experimental parts to adding new features:

- Stable unsigned integer types
- Stable locale-agnostic API for uppercase/lowercase text
- Stable Char-to-integer conversion API
- Stable Path API
- Floored division and the mod operator
- Duration API changes
- New API for getting a char category now available in multiplatform code

- New collections function firstNotNullOf()
- Strict version of String?.toBoolean()

You can learn more about the standard library changes in this blog post.

Watch video online.

Stable unsigned integer types

The UInt, ULong, UByte, UShort unsigned integer types are now Stable. The same goes for operations on these types, ranges, and progressions of them. Unsigned arrays and operations on them remain in Beta.

Learn more about unsigned integer types.

Stable locale-agnostic API for upper/lowercasing text

This release brings a new locale-agnostic API for uppercase/lowercase text conversion. It provides an alternative to the toLowerCase(), toUpperCase(), capitalize(), and decapitalize() API functions, which are locale-sensitive. The new API helps you avoid errors due to different locale settings.

Kotlin 1.5.0 provides the following fully Stable alternatives:

- For String functions:

Earlier versions	1.5.0 alternative
String.toUpperCase()	String.uppercase()
String.toLowerCase()	String.lowercase()
String.capitalize()	String.replaceFirstChar { it.uppercase() }

Earlier versions	1.5.0 alternative
String.decapitalize()	String.replaceFirstChar { it.lowercase() }

- For Char functions:

Earlier versions	1.5.0 alternative
Char.toUpperCase()	Char.uppercaseChar(): Char Char.uppercase(): String
Char.toLowerCase()	Char.lowercaseChar(): Char Char.lowercase(): String
Char.toTitleCase()	Char.titlecaseChar(): Char Char.titlecase(): String

For Kotlin/JVM, there are also overloaded uppercase(), lowercase(), and titlecase() functions with an explicit Locale parameter.

The old API functions are marked as deprecated and will be removed in a future release.

See the full list of changes to the text processing functions in KEEP.

Stable char-to-integer conversion API

Starting from Kotlin 1.5.0, new char-to-code and char-to-digit conversion functions are Stable. These functions replace the current API functions, which were often confused with the similar string-to-Int conversion.

The new API removes this naming confusion, making the code behavior more transparent and unambiguous.

This release introduces Char conversions that are divided into the following sets of clearly named functions:

- Functions to get the integer code of Char and to construct Char from the given code:

```
fun Char(code: Int): Char
fun Char(code: UShort): Char
val Char.code: Int
```

- Functions to convert Char to the numeric value of the digit it represents:

```
fun Char.digitToInt(radix: Int): Int
fun Char.digitToIntOrNull(radix: Int): Int?
```

- An extension function for Int to convert the non-negative single digit it represents to the corresponding Char representation:

```
fun Int.digitToChar(radix: Int): Char
```

The old conversion APIs, including Number.toChar() with its implementations (all except Int.toChar()) and Char extensions for conversion to a numeric type, like Char.toInt(), are now deprecated.

Learn more about the char-to-integer conversion API in KEEP.

Stable Path API

The experimental Path API with extensions for java.nio.file.Path is now Stable.

```
// construct path with the div (/) operator
val baseDir = Path("/base")
val subDir = baseDir / "subdirectory"

// list files in a directory
val kotlinFiles: List<Path> = Path("/home/user").listDirectoryEntries("*.kt")
```

Learn more about the Path API.

Floored division and the mod operator

New operations for modular arithmetics have been added to the standard library:

- floorDiv() returns the result of floored division. It is available for integer types.
- mod() returns the remainder of floored division (modulus). It is available for all numeric types.

These operations look quite similar to the existing division of integers and rem() function (or the %operator), but they work differently on negative numbers:

- a.floorDiv(b) differs from a regular / in that floorDiv rounds the result down (towards the lesser integer), whereas / truncates the result to the integer closer to 0.
- a.mod(b) is the difference between a and a.floorDiv(b) * b. It's either zero or has the same sign as b, while a % b can have a different one.

```
fun main() {
    println("Floored division -5/3: ${(-5).floorDiv(3)}")
    println( "Modulus: ${(-5).mod(3)}")

    println("Truncated division -5/3: ${-5 / 3}")
    println( "Remainder: ${-5 % 3}")
}
```

Duration API changes

The Duration API is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate hearing your feedback on it in YouTrack.

There is an experimental Duration class for representing duration amounts in different time units. In 1.5.0, the Duration API has received the following changes:

- Internal value representation now uses Long instead of Double to provide better precision.
- There is a new API for conversion to a particular time unit in Long. It comes to replace the old API, which operates with Double values and is now deprecated. For example, Duration.inWholeMinutes returns the value of the duration expressed as Long and replaces Duration.inMinutes.
- There are new companion functions for constructing a Duration from a number. For example, Duration.seconds(Int) creates a Duration object representing an integer number of seconds. Old extension properties like Int.seconds are now deprecated.

```
import kotlin.time.Duration
import kotlin.time.ExperimentalTime

@ExperimentalTime
fun main() {
    val duration = Duration.milliseconds(120000)
    println("There are ${duration.inWholeSeconds} seconds in ${duration.inWholeMinutes} minutes")
}
```

New API for getting a char category now available in multiplatform code

Kotlin 1.5.0 introduces the new API for getting a character's category according to Unicode in multiplatform projects. Several functions are now available in all the platforms and in the common code.

Functions for checking whether a char is a letter or a digit:

- Char.isDigit()
- Char.isLetter()
- Char.isLetterOrDigit()

```
fun main() {
    val chars = listOf('a', '1', '+')
    val (letterOrDigitList, notLetterOrDigitList) = chars.partition { it.isLetterOrDigit() }
    println(letterOrDigitList) // [a, 1]
    println(notLetterOrDigitList) // [+]
}
```

Functions for checking the case of a char:

- Char.isLowerCase()
- Char.isUpperCase()
- Char.isTitleCase()

```
fun main() {
    val chars = listOf('ǅ', 'ǈ', 'ǋ', 'ǲ', '1', 'A', 'a', '+')
    val (titleCases, notTitleCases) = chars.partition { it.isTitleCase() }
    println(titleCases) // [ǅ, ǈ, ǋ, ǲ]
    println(notTitleCases) // [1, A, a, +]
}
```

Some other functions:

- Char.isDefined()
- Char.isISOControl()

The property Char.category and its return type enum class CharCategory, which indicates a char's general category according to Unicode, are now also available in multiplatform projects.

Learn more about characters.

New collections function firstNotNullOf()

The new firstNotNullOf() and firstNotNullOfOrNull() functions combine mapNotNull() with first() or firstOrNull(). They map the original collection with the custom selector function and return the first non-null value. If there is no such value, firstNotNullOf() throws an exception, and firstNotNullOfOrNull() returns null.

```
fun main() {
    val data = listOf("Kotlin", "1.5")
    println(data.firstNotNullOf(String::toDoubleOrNull))
    println(data.firstNotNullOfOrNull(String::toIntOrNull))
}
```

Strict version of String?.toBoolean()

Two new functions introduce case-sensitive strict versions of the existing String?.toBoolean():

- String.toBooleanStrict() throws an exception for all inputs except the literals true and false.
- String.toBooleanStrictOrNull() returns null for all inputs except the literals true and false.

```
fun main() {
    println("true".toBooleanStrict())
    println("1".toBooleanStrictOrNull())
    // println("1".toBooleanStrict()) // Exception
}
```

kotlin-test library

The kotlin-test library introduces some new features:

- Simplified test dependencies usage in multiplatform projects
- Automatic selection of a testing framework for Kotlin/JVM source sets
- Assertion function updates

Simplified test dependencies usage in multiplatform projects

Now you can use the kotlin-test dependency to add dependencies for testing in the commonTest source set, and the Gradle plugin will infer the corresponding platform dependencies for each test source set:

- kotlin-test-junit for JVM source sets, see automatic choice of a testing framework for Kotlin/JVM source sets
- kotlin-test-js for Kotlin/JS source sets
- kotlin-test-common and kotlin-test-annotations-common for common source sets
- No extra artifact for Kotlin/Native source sets

Additionally, you can use the kotlin-test dependency in any shared or platform-specific source set.

An existing kotlin-test setup with explicit dependencies will continue to work both in Gradle and in Maven.

Learn more about setting dependencies on test libraries.

Automatic selection of a testing framework for Kotlin/JVM source sets

The Gradle plugin now chooses and adds a dependency on a testing framework automatically. All you need to do is add the dependency kotlin-test in the common source set.

Gradle uses JUnit 4 by default. Therefore, the kotlin("test") dependency resolves to the variant for JUnit 4, namely kotlin-test-junit:

Kotlin

```
kotlin {
    sourceSets {
        val commonTest by getting {
            dependencies {
                implementation(kotlin("test")) // This brings the dependency
                                               // on JUnit 4 transitively
            }
        }
    }
}
```

Groovy

```
kotlin {
    sourceSets {
        commonTest {
            dependencies {
                implementation kotlin("test") // This brings the dependency
                                              // on JUnit 4 transitively
            }
        }
    }
}
```

You can choose JUnit 5 or TestNG by calling useJUnitPlatform() or useTestNG() in the test task:

```
tasks {
    test {
        // enable TestNG support
        useTestNG()
        // or
        // enable JUnit Platform (a.k.a. JUnit 5) support
        useJUnitPlatform()
    }
}
```

You can disable automatic testing framework selection by adding the line kotlin.test.infer.jvm.variant=false to the project's gradle.properties.

Learn more about setting dependencies on test libraries.

Assertion function updates

This release brings new assertion functions and improves the existing ones.

The kotlin-test library now has the following features:

- Checking the type of a value

  You can use the new assertIs<T> and assertIsNot<T> to check the type of a value:

```
@Test
fun testFunction() {
    val s: Any = "test"
    assertIs<String>(s)  // throws AssertionError mentioning the actual type of s if the assertion fails
    // can now print s.length because of contract in assertIs
    println("${s.length}")
}
```

  Because of type erasure, this assert function only checks whether the value is of the List type in the following example and doesn't check whether it's a list of the particular String element type: assertIs<List<String>>(value).

- Comparing the container content for arrays, sequences, and arbitrary iterables

  There is a new set of overloaded assertContentEquals() functions for comparing content for different collections that don't implement structural equality:

```
@Test
fun test() {
    val expectedArray = arrayOf(1, 2, 3)
    val actualArray = Array(3) { it + 1 }
    assertContentEquals(expectedArray, actualArray)
}
```

- New overloads to assertEquals() and assertNotEquals() for Double and Float numbers

  There are new overloads for the assertEquals() function that make it possible to compare two Double or Float numbers with absolute precision. The precision value is specified as the third parameter of the function:

```
@Test
fun test() {
    val x = sin(PI)

    // precision parameter
    val tolerance = 0.000001

    assertEquals(0.0, x, tolerance)
}
```

- New functions for checking the content of collections and elements

  You can now check whether the collection or element contains something with the assertContains() function. You can use it with Kotlin collections and elements that have the contains() operator, such as IntRange, String, and others:

```
@Test
fun test() {
    val sampleList = listOf<String>("sample", "sample2")
    val sampleString = "sample"
    assertContains(sampleList, sampleString)  // element in collection
    assertContains(sampleString, "amp")       // substring in string
}
```

- assertTrue(), assertFalse(), expect() functions are now inline

  From now on, you can use these as inline functions, so it's possible to call suspend functions inside a lambda expression:

```
@Test
fun test() = runBlocking<Unit> {
    val deferred = async { "Kotlin is nice" }
    assertTrue("Kotlin substring should be present") {
        deferred.await() .contains("Kotlin")
    }
}
```

kotlinx libraries

Along with Kotlin 1.5.0, we are releasing new versions of the kotlinx libraries:

- kotlinx.coroutines 1.5.0-RC
- kotlinx.serialization 1.2.1
- kotlinx-datetime 0.2.0

Coroutines 1.5.0-RC

kotlinx.coroutines 1.5.0-RC is here with:

- New channels API
- Stable reactive integrations
- And more

Starting with Kotlin 1.5.0, experimental coroutines are disabled and the -Xcoroutines=experimental flag is no longer supported.

Learn more in the changelog and the kotlinx.coroutines 1.5.0 release blog post.

Watch video online.

Serialization 1.2.1

kotlinx.serialization 1.2.1 is here with:

- Improvements to JSON serialization performance
- Support for multiple names in JSON serialization
- Experimental .proto schema generation from @Serializable classes
- And more

Learn more in the changelog and the kotlinx.serialization 1.2.1 release blog post.

Watch video online.

dateTime 0.2.0

kotlinx-datetime 0.2.0 is here with:

- @Serializable Datetime objects
- Normalized API of DateTimePeriod and DatePeriod
- And more

Learn more in the changelog and the kotlinx-datetime 0.2.0 release blog post.

Migrating to Kotlin 1.5.0

IntelliJ IDEA and Android Studio will suggest updating the Kotlin plugin to 1.5.0 once it is available.

To migrate existing projects to Kotlin 1.5.0, just change the Kotlin version to 1.5.0 and re-import your Gradle or Maven project. Learn how to update to Kotlin 1.5.0.

To start a new project with Kotlin 1.5.0, update the Kotlin plugin and run the Project Wizard from File | New | Project.

The new command-line compiler is available for downloading on the GitHub release page.

Kotlin 1.5.0 is a feature release and therefore can bring incompatible changes to the language. Find the detailed list of such changes in the Compatibility Guide for Kotlin 1.5.

What's new in Kotlin 1.4.30

Released: 3 February 2021

Kotlin 1.4.30 offers preview versions of new language features, promotes the new IR backend of the Kotlin/JVM compiler to Beta, and ships various performance and functional improvements.

You can also learn about new features in this blog post.

Language features

Kotlin 1.5.0 is going to deliver new language features – JVM records support, sealed interfaces, and Stable inline classes. In Kotlin 1.4.30, you can try these features and improvements in preview mode. We would be very grateful if you share your feedback with us in the corresponding YouTrack tickets, as that will allow us to address it before the release of 1.5.0.

- JVM records support
- Sealed interfaces and sealed class improvements
- Improved inline classes

To enable these language features and improvements in preview mode, you need to opt in by adding specific compiler options. See the sections below for details.

Learn more about the new features preview in this blog post.

JVM records support

The JVM records feature is Experimental. It may be dropped or changed at any time. Opt-in is required (see the details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

The JDK 16 release includes plans to stabilize a new Java class type called record. To provide all the benefits of Kotlin and maintain its interoperability with Java, Kotlin is introducing experimental record class support.

You can use record classes that are declared in Java just like classes with properties in Kotlin. No additional steps are required.

Starting with 1.4.30, you can declare the record class in Kotlin using the@JvmRecord annotation for a data class:

```
@JvmRecord
data class User(val name: String, val age: Int)
```

To try the preview version of JVM records, add the compiler options -Xjvm-enable-preview and -language-version 1.5.

We're continuing to work on JVM records support, and we would be very grateful if you would share your feedback with us using this YouTrack ticket.

Learn more about implementation, restrictions, and the syntax in KEEP.

Sealed interfaces

Sealed interfaces are Experimental. They may be dropped or changed at any time. Opt-in is required (see the details below), and you should use them only for evaluation purposes. We would appreciate your feedback on them in YouTrack.

In Kotlin 1.4.30, we're shipping the prototype of sealed interfaces. They complement sealed classes and make it possible to build more flexible restricted class hierarchies.

They can serve as "internal" interfaces that cannot be implemented outside the same module. You can rely on that fact, for example, to write exhaustive when expressions.

```
sealed interface Polygon

class Rectangle(): Polygon
class Triangle(): Polygon

// when() is exhaustive: no other polygon implementations can appear
// after the module is compiled
fun draw(polygon: Polygon) = when (polygon) {
    is Rectangle -> // ...
    is Triangle -> // ...
}
```

Another use-case: with sealed interfaces, you can inherit a class from two or more sealed superclasses.

```
sealed interface Fillable {
   fun fill()
}
sealed interface Polygon {
   val vertices: List<Point>
}

class Rectangle(override val vertices: List<Point>): Fillable, Polygon {
   override fun fill() { /*...*/ }
}
```

To try the preview version of sealed interfaces, add the compiler option -language-version 1.5. Once you switch to this version, you'll be able to use the sealed modifier on interfaces. We would be very grateful if you would share your feedback with us using this YouTrack ticket.

Learn more about sealed interfaces.

Package-wide sealed class hierarchies

Package-wide hierarchies of sealed classes are Experimental. They may be dropped or changed at any time. Opt-in is required (see the details below), and you should use them only for evaluation purposes. We would appreciate your feedback on them in YouTrack.

Sealed classes can now form more flexible hierarchies. They can have subclasses in all files of the same compilation unit and the same package. Previously, all subclasses had to appear in the same file.

Direct subclasses may be top-level or nested inside any number of other named classes, named interfaces, or named objects. The subclasses of a sealed class must have a name that is properly qualified – they cannot be local nor anonymous objects.

To try package-wide hierarchies of sealed classes, add the compiler option -language-version 1.5. We would be very grateful if you would share your feedback with us using this YouTrack ticket.

Learn more about package-wide hierarchies of sealed classes.

Improved inline classes

Inline value classes are in Beta. They are almost stable, but migration steps may be required in the future. We'll do our best to minimize any changes you have to make. We would appreciate your feedback on the inline classes feature in YouTrack.

Kotlin 1.4.30 promotes inline classes to Beta and brings the following features and improvements to them:

- Since inline classes are value-based, you can define them using the value modifier. The inline and value modifiers are now equivalent to each other. In future Kotlin versions, we're planning to deprecate the inline modifier.

  From now on, Kotlin requires the @JvmInline annotation before a class declaration for the JVM backend:

```kotlin
inline class Name(private val s: String)

value class Name(private val s: String)

// For JVM backends
@JvmInline
value class Name(private val s: String)
```

- Inline classes can have init blocks. You can add code to be executed right after the class is instantiated:

```kotlin
@JvmInline
value class Negative(val x: Int) {
  init {
      require(x < 0) { }
  }
}
```

- Calling functions with inline classes from Java code: before Kotlin 1.4.30, you couldn't call functions that accept inline classes from Java because of mangling. From now on, you can disable mangling manually. To call such functions from Java code, you should add the @JvmName annotation before the function declaration:

```kotlin
inline class UInt(val x: Int)

fun compute(x: Int) { }

@JvmName("computeUInt")
fun compute(x: UInt) { }
```

- In this release, we've changed the mangling scheme for functions to fix the incorrect behavior. These changes led to ABI changes.

  Starting with 1.4.30, the Kotlin compiler uses a new mangling scheme by default. Use the -Xuse-14-inline-classes-mangling-scheme compiler flag to force the compiler to use the old 1.4.0 mangling scheme and preserve binary compatibility.

Kotlin 1.4.30 promotes inline classes to Beta and we are planning to make them Stable in future releases. We'd be very grateful if you would share your feedback with us using this YouTrack ticket.

To try the preview version of inline classes, add the compiler option -Xinline-classes or -language-version 1.5.

Learn more about the mangling algorithm in KEEP.

Learn more about inline classes.

Kotlin/JVM

JVM IR compiler backend reaches Beta

The IR-based compiler backend for Kotlin/JVM, which was presented in 1.4.0 in Alpha, has reached Beta. This is the last pre-stable level before the IR backend becomes the default for the Kotlin/JVM compiler.

We're now dropping the restriction on consuming binaries produced by the IR compiler. Previously, you could use code compiled by the new JVM IR backend only if you had enabled the new backend. Starting from 1.4.30, there is no such limitation, so you can use the new backend to build components for third-party use, such as libraries. Try the Beta version of the new backend and share your feedback in our issue tracker.

To enable the new JVM IR backend, add the following lines to the project's configuration file:

- In Gradle:

Kotlin

```kotlin
tasks.withType(org.jetbrains.kotlin.gradle.dsl.KotlinJvmCompile::class) {
  kotlinOptions.useIR = true
}
```

Groovy

```
tasks.withType(org.jetbrains.kotlin.gradle.dsl.KotlinJvmCompile) {
  kotlinOptions.useIR = true
}
```

- In Maven:

```
<configuration>
    <args>
        <arg>-Xuse-ir</arg>
    </args>
</configuration>
```

Learn more about the changes that the JVM IR backend brings in this blog post.

Kotlin/Native

Performance improvements

Kotlin/Native has received a variety of performance improvements in 1.4.30, which has resulted in faster compilation times. For example, the time required to rebuild the framework in the Networking and data storage with Kotlin Multiplatform Mobile sample has decreased from 9.5 seconds (in 1.4.10) to 4.5 seconds (in 1.4.30).

Apple watchOS 64-bit simulator target

The x86 simulator target has been deprecated for watchOS since version 7.0. To keep up with the latest watchOS versions, Kotlin/Native has the new target watchosX64 for running the simulator on 64-bit architecture.

Support for Xcode 12.2 libraries

We have added support for the new libraries delivered with Xcode 12.2. You can now use them from Kotlin code.

Kotlin/JS

Lazy initialization of top-level properties

> Lazy initialization of top-level properties is Experimental. It may be dropped or changed at any time. Opt-in is required (see the details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

The IR backend for Kotlin/JS is receiving a prototype implementation of lazy initialization for top-level properties. This reduces the need to initialize all top-level properties when the application starts, and it should significantly improve application start-up times.

We'll keep working on the lazy initialization, and we ask you to try the current prototype and share your thoughts and results in this YouTrack ticket or the #javascript channel in the official Kotlin Slack (get an invite here).

To use the lazy initialization, add the -Xir-property-lazy-initialization compiler option when compiling the code with the JS IR compiler.

Gradle project improvements

Support the Gradle configuration cache

Starting with 1.4.30, the Kotlin Gradle plugin supports the configuration cache feature. It speeds up the build process: once you run the command, Gradle executes the configuration phase and calculates the task graph. Gradle caches the result and reuses it for subsequent builds.

To start using this feature, you can use the Gradle command or set up the IntelliJ based IDE.

Standard library

Locale-agnostic API for upper/lowercasing text

The locale-agnostic API feature is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

This release introduces the experimental locale-agnostic API for changing the case of strings and characters. The current toLowerCase(), toUpperCase(), capitalize(), decapitalize() API functions are locale-sensitive. This means that different platform locale settings can affect code behavior. For example, in the Turkish locale, when the string "kotlin" is converted using toUpperCase, the result is "KOTLİN", not "KOTLIN".

```
// current API
println("Needs to be capitalized".toUpperCase()) // NEEDS TO BE CAPITALIZED

// new API
println("Needs to be capitalized".uppercase()) // NEEDS TO BE CAPITALIZED
```

Kotlin 1.4.30 provides the following alternatives:

- For String functions:

Earlier versions	1.4.30 alternative
String.toUpperCase()	String.uppercase()
String.toLowerCase()	String.lowercase()
String.capitalize()	String.replaceFirstChar { it.uppercase() }
String.decapitalize()	String.replaceFirstChar { it.lowercase() }

- For Char functions:

Earlier versions	1.4.30 alternative
Char.toUpperCase()	Char.uppercaseChar(): Char Char.uppercase(): String
Char.toLowerCase()	Char.lowercaseChar(): Char Char.lowercase(): String
Char.toTitleCase()	Char.titlecaseChar(): Char Char.titlecase(): String

For Kotlin/JVM, there are also overloaded uppercase(), lowercase(), and titlecase() functions with an explicit Locale parameter.

See the full list of changes to the text processing functions in KEEP.

Clear Char-to-code and Char-to-digit conversions

The unambiguous API for the Char conversion feature is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

The current Char to numbers conversion functions, which return UTF-16 codes expressed in different numeric types, are often confused with the similar String-to-Int conversion, which returns the numeric value of a string:

```
"4".toInt() // returns 4
'4'.toInt() // returns 52
// and there was no common function that would return the numeric value 4 for Char '4'
```

To avoid this confusion we've decided to separate Char conversions into two following sets of clearly named functions:

- Functions to get the integer code of Char and to construct Char from the given code:

  ```
  fun Char(code: Int): Char
  fun Char(code: UShort): Char
  val Char.code: Int
  ```

- Functions to convert Char to the numeric value of the digit it represents:

  ```
  fun Char.digitToInt(radix: Int): Int
  fun Char.digitToIntOrNull(radix: Int): Int?
  ```

- An extension function for Int to convert the non-negative single digit it represents to the corresponding Char representation:

  ```
  fun Int.digitToChar(radix: Int): Char
  ```

See more details in KEEP.

Serialization updates

Along with Kotlin 1.4.30, we are releasing kotlinx.serialization 1.1.0-RC, which includes some new features:

- Inline classes serialization support
- Unsigned primitive type serialization support

Inline classes serialization support

Starting with Kotlin 1.4.30, you can make inline classes serializable:

```
@Serializable
inline class Color(val rgb: Int)
```

The feature requires the new 1.4.30 IR compiler.

The serialization framework does not box serializable inline classes when they are used in other serializable classes.

Learn more in the kotlinx.serialization docs.

Unsigned primitive type serialization support

Starting from 1.4.30, you can use standard JSON serializers of kotlinx.serialization for unsigned primitive types: UInt, ULong, UByte, and UShort:

```
@Serializable
class Counter(val counted: UByte, val description: String)
fun main() {
    val counted = 239.toUByte()
    println(Json.encodeToString(Counter(counted, "tries")))
}
```

Learn more in the kotlinx.serialization docs.

What's new in Kotlin 1.4.20

Released: 23 November 2020

Kotlin 1.4.20 offers a number of new experimental features and provides fixes and improvements for existing features, including those added in 1.4.0.

You can also learn about new features with more examples in this blog post.

Kotlin/JVM

Improvements of Kotlin/JVM are intended to keep it up with the features of modern Java versions:

- Java 15 target
- invokedynamic string concatenation

Java 15 target

Now Java 15 is available as a Kotlin/JVM target.

invokedynamic string concatenation

> invokedynamic string concatenation is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below). Use it only for evaluation purposes. We appreciate your feedback on it in YouTrack.

Kotlin 1.4.20 can compile string concatenations into dynamic invocations on JVM 9+ targets, therefore improving the performance.

Currently, this feature is experimental and covers the following cases:

- String.plus in the operator (a + b), explicit (a.plus(b)), and reference ((a::plus)(b)) form.
- toString on inline and data classes.
- string templates except for ones with a single non-constant argument (see KT-42457).

To enable invokedynamic string concatenation, add the -Xstring-concat compiler option with one of the following values:

- indy-with-constants to perform invokedynamic concatenation on strings with StringConcatFactory.makeConcatWithConstants().
- indy to perform invokedynamic concatenation on strings with StringConcatFactory.makeConcat().
- inline to switch back to the classic concatenation via StringBuilder.append().

Kotlin/JS

Kotlin/JS keeps evolving fast, and in 1.4.20 you can find a number experimental features and improvements:

- Gradle DSL changes

- New Wizard templates
- Ignoring compilation errors with IR compiler

Gradle DSL changes

The Gradle DSL for Kotlin/JS receives a number of updates which simplify project setup and customization. This includes webpack configuration adjustments, modifications to the auto-generated package.json file, and improved control over transitive dependencies.

Single point for webpack configuration

A new configuration block commonWebpackConfig is available for the browser target. Inside it, you can adjust common settings from a single point, instead of having to duplicate configurations for the webpackTask, runTask, and testTask.

To enable CSS support by default for all three tasks, add the following snippet in the build.gradle(.kts) of your project:

```
browser {
    commonWebpackConfig {
        cssSupport.enabled = true
    }
    binaries.executable()
}
```

Learn more about configuring webpack bundling.

package.json customization from Gradle

For more control over your Kotlin/JS package management and distribution, you can now add properties to the project file package.json via the Gradle DSL.

To add custom fields to your package.json, use the customField function in the compilation's packageJson block:

```
kotlin {
    js(BOTH) {
        compilations["main"].packageJson {
            customField("hello", mapOf("one" to 1, "two" to 2))
        }
    }
}
```

Learn more about package.json customization.

Selective yarn dependency resolutions

Support for selective yarn dependency resolutions is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We appreciate your feedback on it in YouTrack.

Kotlin 1.4.20 provides a way of configuring Yarn's selective dependency resolutions - the mechanism for overriding dependencies of the packages you depend on.

You can use it through the YarnRootExtension inside the YarnPlugin in Gradle. To affect the resolved version of a package for your project, use the resolution function passing in the package name selector (as specified by Yarn) and the version to which it should resolve.

```
rootProject.plugins.withType<YarnPlugin> {
    rootProject.the<YarnRootExtension>().apply {
        resolution("react", "16.0.0")
        resolution("processor/decamelize", "3.0.0")
    }
}
```

Here, all of your npm dependencies which require react will receive version 16.0.0, and processor will receive its dependency decamelize as version 3.0.0.

Disabling granular workspaces

Disabling granular workspaces is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We appreciate your feedback on it in YouTrack.

To speed up build times, the Kotlin/JS Gradle plugin only installs the dependencies which are required for a particular Gradle task. For example, the webpack-dev-server package is only installed when you execute one of the *Run tasks, and not when you execute the assemble task. Such behavior can potentially bring problems when you run multiple Gradle processes in parallel. When the dependency requirements clash, the two installations of npm packages can cause errors.

To resolve this issue, Kotlin 1.4.20 includes an option to disable these so-called granular workspaces. This feature is currently available through the YarnRootExtension inside the YarnPlugin in Gradle. To use it, add the following snippet to your build.gradle.kts file:

```
rootProject.plugins.withType<YarnPlugin> {
    rootProject.the<YarnRootExtension>().disableGranularWorkspaces()
}
```

New Wizard templates

To give you more convenient ways to customize your project during creation, the project wizard for Kotlin comes with new templates for Kotlin/JS applications:

- Browser Application - a minimal Kotlin/JS Gradle project that runs in the browser.
- React Application - a React app that uses the appropriate kotlin-wrappers. It provides options to enable integrations for style-sheets, navigational components, or state containers.
- Node.js Application - a minimal project for running in a Node.js runtime. It comes with the option to directly include the experimental kotlinx-nodejs package.

Ignoring compilation errors with IR compiler

Ignore compilation errors mode is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below). Use it only for evaluation purposes. We appreciate your feedback on it in YouTrack.

The IR compiler for Kotlin/JS comes with a new experimental mode - compilation with errors. In this mode, you can run you code even if it contains errors, for example, if you want to try certain things it when the whole application is not ready yet.

There are two tolerance policies for this mode:

- SEMANTIC: the compiler will accept code which is syntactically correct, but doesn't make sense semantically, such as val x: String = 3.
- SYNTAX: the compiler will accept any code, even if it contains syntax errors.

To allow compilation with errors, add the -Xerror-tolerance-policy= compiler option with one of the values listed above.

Learn more about Kotlin/JS IR compiler.

Kotlin/Native

Kotlin/Native's priorities in 1.4.20 are performance and polishing existing features. These are the notable improvements:

- Escape analysis
- Performance improvements and bug fixes
- Opt-in wrapping of Objective-C exceptions
- CocoaPods plugin improvements
- Support for Xcode 12 libraries

Escape analysis

The escape analysis mechanism is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We appreciate your feedback on it in YouTrack.

Kotlin/Native receives a prototype of the new escape analysis mechanism. It improves the runtime performance by allocating certain objects on the stack instead of the heap. This mechanism shows a 10% average performance increase on our benchmarks, and we continue improving it so that it speeds up the program even more.

The escape analysis runs in a separate compilation phase for the release builds (with the -opt compiler option).

If you want to disable the escape analysis phase, use the -Xdisable-phases=EscapeAnalysis compiler option.

Performance improvements and bug fixes

Kotlin/Native receives performance improvements and bug fixes in various components, including the ones added in 1.4.0, for example, the code sharing mechanism.

Opt-in wrapping of Objective-C exceptions

The Objective-C exception wrapping mechanism is Experimental. It may be dropped or changed at any time. Opt-in is required (see details below). Use it only for evaluation purposes. We appreciate your feedback on it in YouTrack.

Kotlin/Native now can handle exceptions thrown from Objective-C code in runtime to avoid program crashes.

You can opt in to wrap NSException's into Kotlin exceptions of type ForeignException. They hold the references to the original NSException's. This lets you get the information about the root cause and handle it properly.

To enable wrapping of Objective-C exceptions, specify the -Xforeign-exception-mode objc-wrap option in the cinterop call or add foreignExceptionMode = objc-wrap property to .def file. If you use CocoaPods integration, specify the option in the pod {} build script block of a dependency like this:

```
pod("foo") {
    extraOpts = listOf("-Xforeign-exception-mode", "objc-wrap")
}
```

The default behavior remains unchanged: the program terminates when an exception is thrown from the Objective-C code.

CocoaPods plugin improvements

Kotlin 1.4.20 continues the set of improvements in CocoaPods integration. Namely, you can try the following new features:

- Improved task execution
- Extended DSL
- Updated integration with Xcode

Improved task execution

CocoaPods plugin gets an improved task execution flow. For example, if you add a new CocoaPods dependency, existing dependencies are not rebuilt. Adding an extra target also doesn't affect rebuilding dependencies for existing ones.

Extended DSL

The DSL of adding CocoaPods dependencies to your Kotlin project receives new capabilites.

In addition to local Pods and Pods from the CocoaPods repository, you can add dependencies on the following types of libraries:

- A library from a custom spec repository.
- A remote library from a Git repository.

- A library from an archive (also available by arbitrary HTTP address).
- A static library.
- A library with custom cinterop options.

Learn more about adding CocoaPods dependencies in Kotlin projects. Find examples in the Kotlin with CocoaPods sample.

Updated integration with Xcode

To work correctly with Xcode, Kotlin requires some Podfile changes:

- If your Kotlin Pod has any Git, HTTP, or specRepo Pod dependency, you should also specify it in the Podfile.
- When you add a library from the custom spec, you also should specify the location of specs at the beginning of your Podfile.

Now integration errors have a detailed description in IDEA. So if you have problems with your Podfile, you will immediately know how to fix them.

Learn more about creating Kotlin pods.

Support for Xcode 12 libraries

We have added support for new libraries delivered with Xcode 12. Now you can use them from the Kotlin code.

Kotlin Multiplatform

Updated structure of multiplatform library publications

Starting from Kotlin 1.4.20, there is no longer a separate metadata publication. Metadata artifacts are now included in the root publication which stands for the whole library and is automatically resolved to the appropriate platform-specific artifacts when added as a dependency to the common source set.

Learn more about publishing a multiplatform library.

Compatibility with earlier versions

This change of structure breaks the compatibility between projects with hierarchical project structure. If a multiplatform project and a library it depends on both have the hierarchical project structure, then you need to update them to Kotlin 1.4.20 or higher simultaneously. Libraries published with Kotlin 1.4.20 are not available for using from project published with earlier versions.

Projects and libraries without the hierarchical project structure remain compatible.

Standard library

The standard library of Kotlin 1.4.20 offers new extensions for working with files and a better performance.

- Extensions for java.nio.file.Path
- Improved String.replace function performance

Extensions for java.nio.file.Path

> Extensions for java.nio.file.Path are Experimental. They may be dropped or changed at any time. Opt-in is required (see details below). Use them only for evaluation purposes. We appreciate your feedback on them in YouTrack.

Now the standard library provides experimental extensions for java.nio.file.Path. Working with the modern JVM file API in an idiomatic Kotlin way is now similar to working with java.io.File extensions from the kotlin.io package.

```
// construct path with the div (/) operator
val baseDir = Path("/base")
val subDir = baseDir / "subdirectory"

// list files in a directory
val kotlinFiles: List<Path> = Path("/home/user").listDirectoryEntries("*.kt")
```

The extensions are available in the kotlin.io.path package in the kotlin-stdlib-jdk7 module. To use the extensions, opt-in to the experimental annotation @ExperimentalPathApi.

Improved String.replace function performance

The new implementation of String.replace() speeds up the function execution. The case-sensitive variant uses a manual replacement loop based on indexOf, while the case-insensitive one uses regular expression matching.

Kotlin Android Extensions

In 1.4.20 the Kotlin Android Extensions plugin becomes deprecated and Parcelable implementation generator moves to a separate plugin.

- Deprecation of synthetic views
- New plugin for Parcelable implementation generator

Deprecation of synthetic views

Synthetic views were presented in the Kotlin Android Extensions plugin a while ago to simplify the interaction with UI elements and reduce boilerplate. Now Google offers a native mechanism that does the same - Android Jetpack's view bindings, and we're deprecating synthetic views in favor of those.

We extract the Parcelable implementations generator from kotlin-android-extensions and start the deprecation cycle for the rest of it - synthetic views. For now, they will keep working with a deprecation warning. In the future, you'll need to switch your project to another solution. Here are the guidelines that will help you migrate your Android project from synthetics to view bindings.

New plugin for Parcelable implementation generator

The Parcelable implementation generator is now available in the new kotlin-parcelize plugin. Apply this plugin instead of kotlin-android-extensions.

> kotlin-parcelize and kotlin-android-extensions can't be applied together in one module.

The @Parcelize annotation is moved to the kotlinx.parcelize package.

Learn more about Parcelable implementation generator in the Android documentation.

What's new in Kotlin 1.4.0

Released: 17 August 2020

In Kotlin 1.4.0, we ship a number of improvements in all of its components, with the focus on quality and performance. Below you will find the list of the most important changes in Kotlin 1.4.0.

Language features and improvements

Kotlin 1.4.0 comes with a variety of different language features and improvements. They include:

- SAM conversions for Kotlin interfaces
- Explicit API mode for library authors
- Mixing named and positional arguments
- Trailing comma

- Callable reference improvements
- break and continue inside when included in loops

SAM conversions for Kotlin interfaces

Before Kotlin 1.4.0, you could apply SAM (Single Abstract Method) conversions only when working with Java methods and Java interfaces from Kotlin. From now on, you can use SAM conversions for Kotlin interfaces as well. To do so, mark a Kotlin interface explicitly as functional with the fun modifier.

SAM conversion applies if you pass a lambda as an argument when an interface with only one single abstract method is expected as a parameter. In this case, the compiler automatically converts the lambda to an instance of the class that implements the abstract member function.

```
fun interface IntPredicate {
    fun accept(i: Int): Boolean
}

val isEven = IntPredicate { it % 2 == 0 }

fun main() {
    println("Is 7 even? - ${isEven.accept(7)}")
}
```

Learn more about Kotlin functional interfaces and SAM conversions.

Explicit API mode for library authors

Kotlin compiler offers explicit API mode for library authors. In this mode, the compiler performs additional checks that help make the library's API clearer and more consistent. It adds the following requirements for declarations exposed to the library's public API:

- Visibility modifiers are required for declarations if the default visibility exposes them to the public API. This helps ensure that no declarations are exposed to the public API unintentionally.
- Explicit type specifications are required for properties and functions that are exposed to the public API. This guarantees that API users are aware of the types of API members they use.

Depending on your configuration, these explicit APIs can produce errors (strict mode) or warnings (warning mode). Certain kinds of declarations are excluded from such checks for the sake of readability and common sense:

- primary constructors
- properties of data classes
- property getters and setters
- override methods

Explicit API mode analyzes only the production sources of a module.

To compile your module in the explicit API mode, add the following lines to your Gradle build script:

Kotlin

```
kotlin {
    // for strict mode
    explicitApi()
    // or
    explicitApi = ExplicitApiMode.Strict

    // for warning mode
    explicitApiWarning()
    // or
    explicitApi = ExplicitApiMode.Warning
}
```

Groovy

```
kotlin {
    // for strict mode
    explicitApi()
    // or
    explicitApi = 'strict'

    // for warning mode
    explicitApiWarning()
    // or
    explicitApi = 'warning'
}
```

When using the command-line compiler, switch to explicit API mode by adding the -Xexplicit-api compiler option with the value strict or warning.

```
-Xexplicit-api={strict|warning}
```

Find more details about the explicit API mode in the KEEP.

Mixing named and positional arguments

In Kotlin 1.3, when you called a function with named arguments, you had to place all the arguments without names (positional arguments) before the first named argument. For example, you could call f(1, y = 2), but you couldn't call f(x = 1, 2).

It was really annoying when all the arguments were in their correct positions but you wanted to specify a name for one argument in the middle. It was especially helpful for making absolutely clear which attribute a boolean or null value belongs to.

In Kotlin 1.4, there is no such limitation – you can now specify a name for an argument in the middle of a set of positional arguments. Moreover, you can mix positional and named arguments any way you like, as long as they remain in the correct order.

```
fun reformat(
    str: String,
    uppercaseFirstLetter: Boolean = true,
    wordSeparator: Char = ' '
) {
    // ...
}

//Function call with a named argument in the middle
reformat("This is a String!", uppercaseFirstLetter = false , '-')
```

Trailing comma

With Kotlin 1.4 you can now add a trailing comma in enumerations such as argument and parameter lists, when entries, and components of destructuring declarations. With a trailing comma, you can add new items and change their order without adding or removing commas.

This is especially helpful if you use multi-line syntax for parameters or values. After adding a trailing comma, you can then easily swap lines with parameters or values.

```
fun reformat(
    str: String,
    uppercaseFirstLetter: Boolean = true,
    wordSeparator: Character = ' ', //trailing comma
) {
    // ...
}
```

```
val colors = listOf(
    "red",
    "green",
    "blue", //trailing comma
)
```

Callable reference improvements

Kotlin 1.4 supports more cases for using callable references:

- References to functions with default argument values

- Function references in Unit-returning functions
- References that adapt based on the number of arguments in a function
- Suspend conversion on callable references

References to functions with default argument values

Now you can use callable references to functions with default argument values. If the callable reference to the function foo takes no arguments, the default value 0 is used.

```kotlin
fun foo(i: Int = 0): String = "$i!"

fun apply(func: () -> String): String = func()

fun main() {
    println(apply(::foo))
}
```

Previously, you had to write additional overloads for the function apply to use the default argument values.

```kotlin
// some new overload
fun applyInt(func: (Int) -> String): String = func(0)
```

Function references in Unit-returning functions

In Kotlin 1.4, you can use callable references to functions returning any type in Unit-returning functions. Before Kotlin 1.4, you could only use lambda arguments in this case. Now you can use both lambda arguments and callable references.

```kotlin
fun foo(f: () -> Unit) { }
fun returnsInt(): Int = 42

fun main() {
    foo { returnsInt() } // this was the only way to do it  before 1.4
    foo(::returnsInt) // starting from 1.4, this also works
}
```

References that adapt based on the number of arguments in a function

Now you can adapt callable references to functions when passing a variable number of arguments (vararg) . You can pass any number of parameters of the same type at the end of the list of passed arguments.

```kotlin
fun foo(x: Int, vararg y: String) {}

fun use0(f: (Int) -> Unit) {}
fun use1(f: (Int, String) -> Unit) {}
fun use2(f: (Int, String, String) -> Unit) {}

fun test() {
    use0(::foo)
    use1(::foo)
    use2(::foo)
}
```

Suspend conversion on callable references

In addition to suspend conversion on lambdas, Kotlin now supports suspend conversion on callable references starting from version 1.4.0.

```kotlin
fun call() {}
fun takeSuspend(f: suspend () -> Unit) {}

fun test() {
    takeSuspend { call() } // OK before 1.4
    takeSuspend(::call) // In Kotlin 1.4, it also works
}
```

Using break and continue inside when expressions included in loops

In Kotlin 1.3, you could not use unqualified break and continue inside when expressions included in loops. The reason was that these keywords were reserved for possible fall-through behavior in when expressions.

That's why if you wanted to use break and continue inside when expressions in loops, you had to label them, which became rather cumbersome.

```
fun test(xs: List<Int>) {
    LOOP@for (x in xs) {
        when (x) {
            2 -> continue@LOOP
            17 -> break@LOOP
            else -> println(x)
        }
    }
}
```

In Kotlin 1.4, you can use break and continue without labels inside when expressions included in loops. They behave as expected by terminating the nearest enclosing loop or proceeding to its next step.

```
fun test(xs: List<Int>) {
    for (x in xs) {
        when (x) {
            2 -> continue
            17 -> break
            else -> println(x)
        }
    }
}
```

The fall-through behavior inside when is subject to further design.

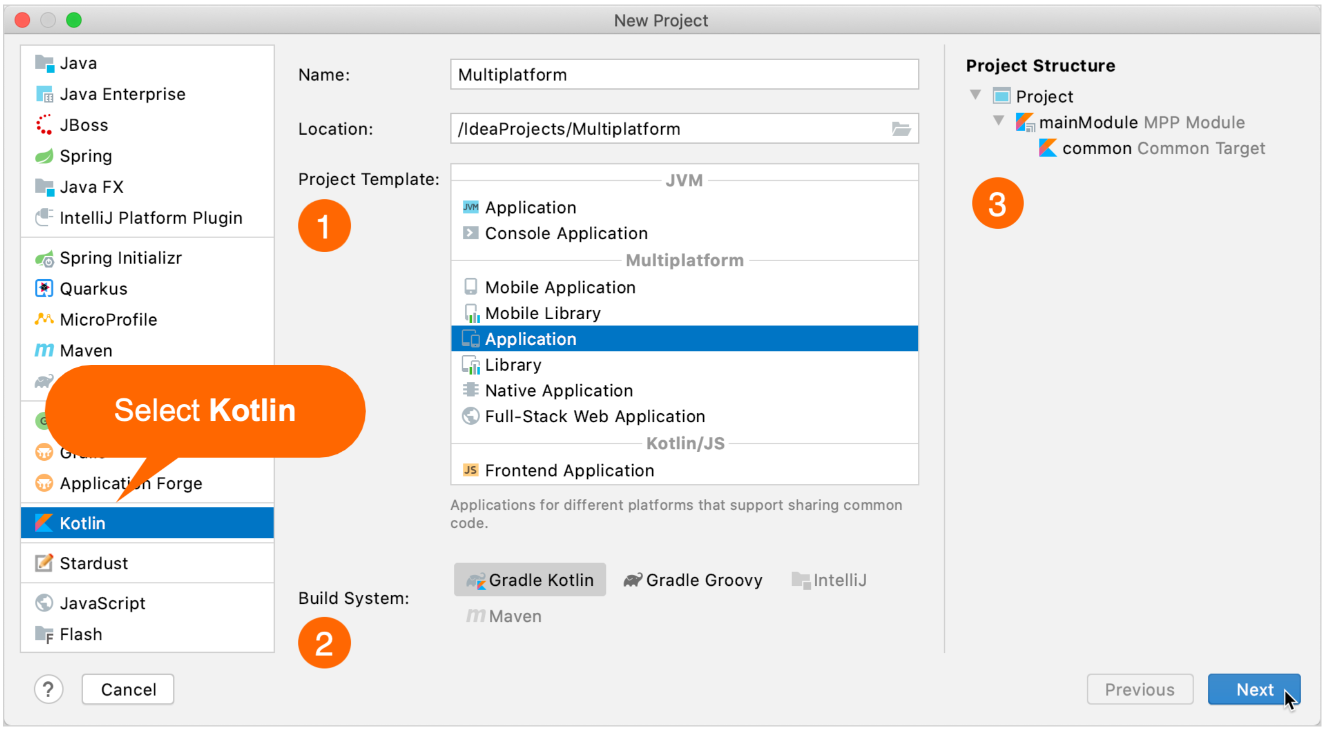
New tools in the IDE

With Kotlin 1.4, you can use the new tools in IntelliJ IDEA to simplify Kotlin development:

- New flexible Project Wizard
- Coroutine Debugger

New flexible Project Wizard

With the flexible new Kotlin Project Wizard, you have a place to easily create and configure different types of Kotlin projects, including multiplatform projects, which can be difficult to configure without a UI.



Kotlin Project Wizard – Multiplatform project

The new Kotlin Project Wizard is both simple and flexible:

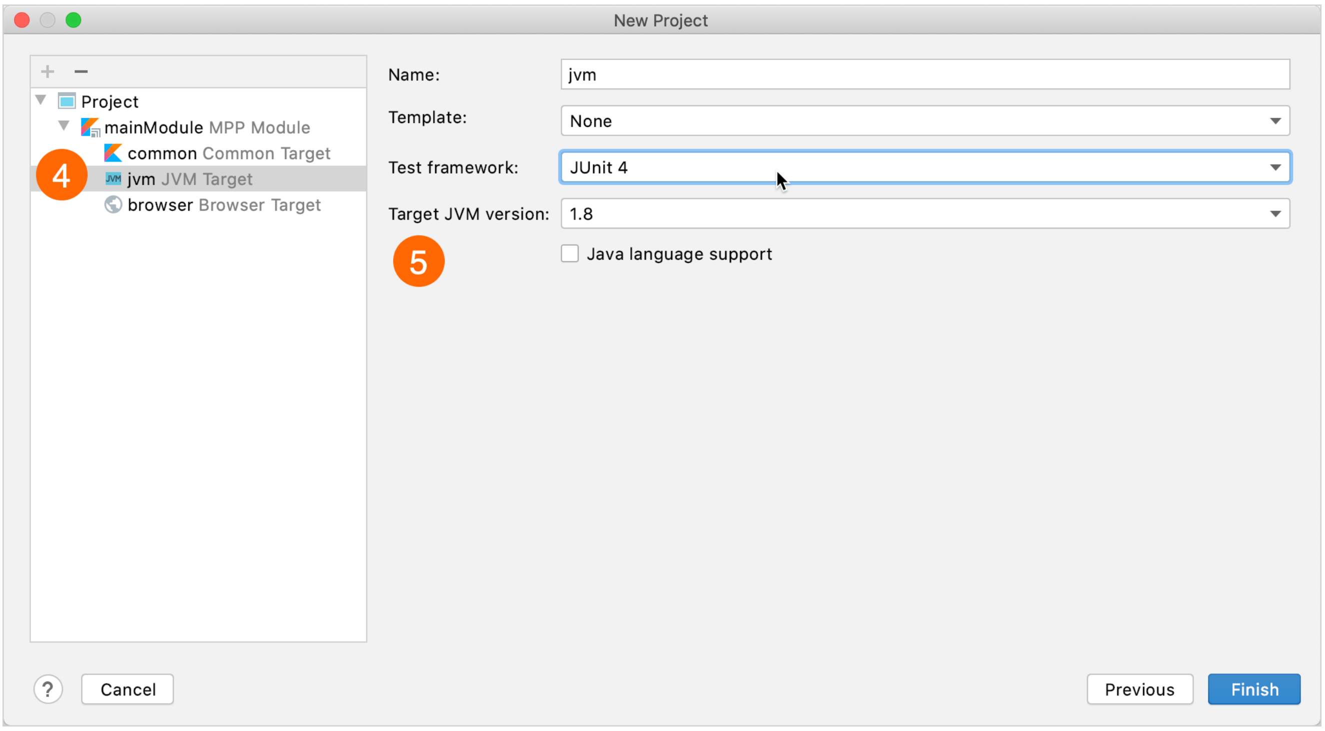
1. Select the project template, depending on what you're trying to do. More templates will be added in the future.
2. Select the build system – Gradle (Kotlin or Groovy DSL), Maven, or IntelliJ IDEA.

   The Kotlin Project Wizard will only show the build systems supported on the selected project template.

3. Preview the project structure directly on the main screen.

Then you can finish creating your project or, optionally, configure the project on the next screen:

4. Add/remove modules and targets supported for this project template.
5. Configure module and target settings, for example, the target JVM version, target template, and test framework.



Name: jvm
Template: None
Test framework: JUnit 4
Target JVM version: 1.8
Java language support [ ]

Kotlin Project Wizard - Configure targets

In the future, we are going to make the Kotlin Project Wizard even more flexible by adding more configuration options and templates.

You can try out the new Kotlin Project Wizard by working through these tutorials:

- Create a console application based on Kotlin/JVM
- Create a Kotlin/JS application for React
- Create a Kotlin/Native application

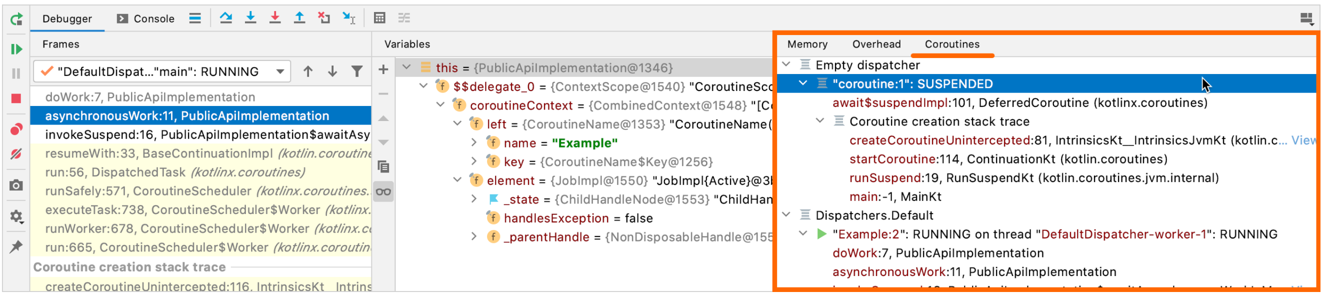
Coroutine Debugger

Many people already use coroutines for asynchronous programming. But when it came to debugging, working with coroutines before Kotlin 1.4, could be a real pain. Since coroutines jumped between threads, it was difficult to understand what a specific coroutine was doing and check its context. In some cases, tracking steps over breakpoints simply didn't work. As a result, you had to rely on logging or mental effort to debug code that used coroutines.

In Kotlin 1.4, debugging coroutines is now much more convenient with the new functionality shipped with the Kotlin plugin.

> Debugging works for versions 1.3.8 or later of kotlinx-coroutines-core.

The Debug Tool Window now contains a new Coroutines tab. In this tab, you can find information about both currently running and suspended coroutines. The coroutines are grouped by the dispatcher they are running on.



```
"DefaultDispat..."main": RUNNING
doWork:7, PublicApiImplementation
asynchronousWork:11, PublicApiImplementation
invokeSuspend:16, PublicApiImplementation$awaitAsy
resumeWith:33, BaseContinuationImpl (kotlin.coroutine
run:56, DispatchedTask (kotlinx.coroutines)
runSafely:571, CoroutineScheduler (kotlinx.coroutines.
executeTask:738, CoroutineScheduler$Worker (kotlinx.
runWorker:678, CoroutineScheduler$Worker (kotlinx.c
run:665, CoroutineScheduler$Worker (kotlinx.coroutin
Coroutine creation stack trace
createCoroutineUnintercepted:116, IntrinsicsKt__Intrins
```

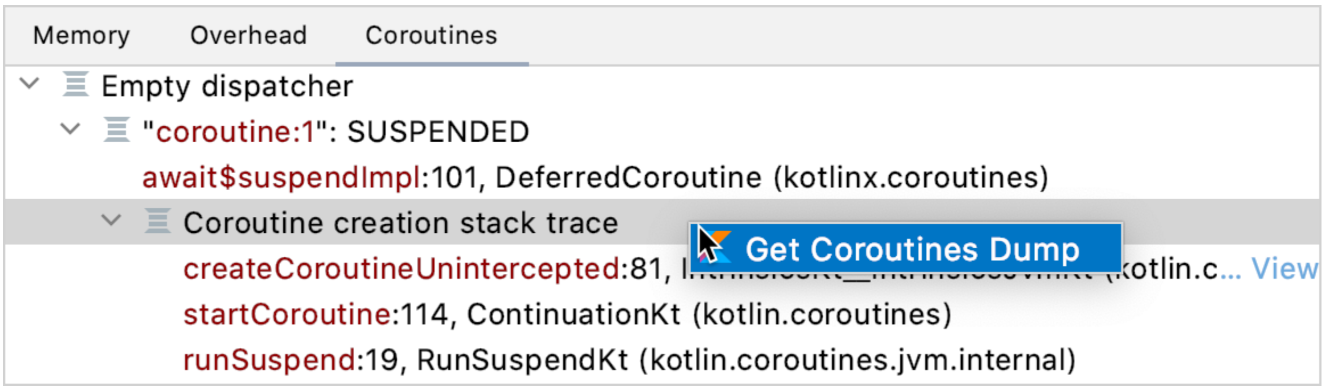
```
this = {PublicApiImplementation@1346}
  $$delegate_0 = {ContextScope@1540} "CoroutineSc
    coroutineContext = {CombinedContext@1548} "[C
      left = {CoroutineName@1353} "CoroutineName(
        name = "Example"
        key = {CoroutineName$Key@1256}
      element = {JobImpl@1550} "JobImpl{Active}@3
        _state = {ChildHandleNode@1553} "ChildHan
        handlesException = false
        _parentHandle = {NonDisposableHandle@155
```

```
Empty dispatcher
  "coroutine:1": SUSPENDED
    await$suspendImpl:101, DeferredCoroutine (kotlinx.coroutines)
    Coroutine creation stack trace
      createCoroutineUnintercepted:81, IntrinsicsKt__IntrinsicsJvmKt (kotlin.c... View
      startCoroutine:114, ContinuationKt (kotlin.coroutines)
      runSuspend:19, RunSuspendKt (kotlin.coroutines.jvm.internal)
      main:-1, MainKt
Dispatchers.Default
  "Example:2": RUNNING on thread "DefaultDispatcher-worker-1": RUNNING
    doWork:7, PublicApiImplementation
    asynchronousWork:11, PublicApiImplementation
```

Now you can:

- Easily check the state of each coroutine.
- See the values of local and captured variables for both running and suspended coroutines.
- See a full coroutine creation stack, as well as a call stack inside the coroutine. The stack includes all frames with variable values, even those that would be lost during standard debugging.

If you need a full report containing the state of each coroutine and its stack, right-click inside the Coroutines tab, and then click Get Coroutines Dump. Currently, the coroutines dump is rather simple, but we're going to make it more readable and helpful in future versions of Kotlin.



```
Empty dispatcher
  "coroutine:1": SUSPENDED
    await$suspendImpl:101, DeferredCoroutine (kotlinx.coroutines)
    Coroutine creation stack trace
      createCoroutineUnintercepted:81, I (kotlin.c... View
      startCoroutine:114, ContinuationKt (kotlin.coroutines)
      runSuspend:19, RunSuspendKt (kotlin.coroutines.jvm.internal)
```

Coroutines Dump

Learn more about debugging coroutines in this blog post and IntelliJ IDEA documentation.

New compiler

The new Kotlin compiler is going to be really fast; it will unify all the supported platforms and provide an API for compiler extensions. It's a long-term project, and we've already completed several steps in Kotlin 1.4.0:

- New, more powerful type inference algorithm is enabled by default.
- New JVM and JS IR backends. They will become the default once we stabilize them.

New more powerful type inference algorithm

Kotlin 1.4 uses a new, more powerful type inference algorithm. This new algorithm was already available to try in Kotlin 1.3 by specifying a compiler option, and now it's used by default. You can find the full list of issues fixed in the new algorithm in YouTrack. Here you can find some of the most noticeable improvements:

- More cases where type is inferred automatically
- Smart casts for a lambda's last expression
- Smart casts for callable references
- Better inference for delegated properties
- SAM conversion for Java interfaces with different arguments
- Java SAM interfaces in Kotlin

More cases where type is inferred automatically

The new inference algorithm infers types for many cases where the old algorithm required you to specify them explicitly. For instance, in the following example the type of the lambda parameter it is correctly inferred to String?:

```
val rulesMap: Map<String, (String?) -> Boolean> = mapOf(
    "weak" to { it != null },
    "medium" to { !it.isNullOrBlank() },
    "strong" to { it != null && "^[a-zA-Z0-9]+$".toRegex().matches(it) }
)

fun main() {
    println(rulesMap.getValue("weak")("abc!"))
    println(rulesMap.getValue("strong")("abc"))
    println(rulesMap.getValue("strong")("abc!"))
}
```

In Kotlin 1.3, you needed to introduce an explicit lambda parameter or replace to with a Pair constructor with explicit generic arguments to make it work.

Smart casts for a lambda's last expression

In Kotlin 1.3, the last expression inside a lambda wasn't smart cast unless you specified the expected type. Thus, in the following example, Kotlin 1.3 infers String? as the type of the result variable:

```
val result = run {
    var str = currentValue()
    if (str == null) {
        str = "test"
    }
    str // the Kotlin compiler knows that str is not null here
}
// The type of 'result' is String? in Kotlin 1.3 and String in Kotlin 1.4
```

In Kotlin 1.4, thanks to the new inference algorithm, the last expression inside a lambda gets smart cast, and this new, more precise type is used to infer the resulting lambda type. Thus, the type of the result variable becomes String.

In Kotlin 1.3, you often needed to add explicit casts (either !! or type casts like as String) to make such cases work, and now these casts have become unnecessary.

Smart casts for callable references

In Kotlin 1.3, you couldn't access a member reference of a smart cast type. Now in Kotlin 1.4 you can:

```
import kotlin.reflect.KFunction

sealed class Animal
class Cat : Animal() {
    fun meow() {
        println("meow")
    }
}

class Dog : Animal() {
    fun woof() {
        println("woof")
    }
}

fun perform(animal: Animal) {
    val kFunction: KFunction<*> = when (animal) {
        is Cat -> animal::meow
        is Dog -> animal::woof
    }
    kFunction.call()
}

fun main() {
    perform(Cat())
}
```

You can use different member references animal::meow and animal::woof after the animal variable has been smart cast to specific types Cat and Dog. After type checks, you can access member references corresponding to subtypes.

Better inference for delegated properties

The type of a delegated property wasn't taken into account while analyzing the delegate expression which follows the by keyword. For instance, the following code didn't compile before, but now the compiler correctly infers the types of the old and new parameters as String?:

```
import kotlin.properties.Delegates

fun main() {
    var prop: String? by Delegates.observable(null) { p, old, new ->
        println("$old → $new")
    }
    prop = "abc"
    prop = "xyz"
}
```

SAM conversion for Java interfaces with different arguments

Kotlin has supported SAM conversions for Java interfaces from the beginning, but there was one case that wasn't supported, which was sometimes annoying when working with existing Java libraries. If you called a Java method that took two SAM interfaces as parameters, both arguments needed to be either lambdas or regular objects. You couldn't pass one argument as a lambda and another as an object.

The new algorithm fixes this issue, and you can pass a lambda instead of a SAM interface in any case, which is the way you'd naturally expect it to work.

```
// FILE: A.java
public class A {
    public static void foo(Runnable r1, Runnable r2) {}
}
```

```
// FILE: test.kt
fun test(r1: Runnable) {
    A.foo(r1) {}  // Works in Kotlin 1.4
}
```

Java SAM interfaces in Kotlin

In Kotlin 1.4, you can use Java SAM interfaces in Kotlin and apply SAM conversions to them.

```
import java.lang.Runnable

fun foo(r: Runnable) {}

fun test() {
    foo { } // OK
}
```

In Kotlin 1.3, you would have had to declare the function foo above in Java code to perform a SAM conversion.

Unified backends and extensibility

In Kotlin, we have three backends that generate executables: Kotlin/JVM, Kotlin/JS, and Kotlin/Native. Kotlin/JVM and Kotlin/JS don't share much code since they were developed independently of each other. Kotlin/Native is based on a new infrastructure built around an intermediate representation (IR) for Kotlin code.

We are now migrating Kotlin/JVM and Kotlin/JS to the same IR. As a result, all three backends share a lot of logic and have a unified pipeline. This allows us to implement most features, optimizations, and bug fixes only once for all platforms. Both new IR-based back-ends are in Alpha.

A common backend infrastructure also opens the door for multiplatform compiler extensions. You will be able to plug into the pipeline and add custom processing and transformations that will automatically work for all platforms.

We encourage you to use our new JVM IR and JS IR backends, which are currently in Alpha, and share your feedback with us.

Kotlin/JVM

Kotlin 1.4.0 includes a number of JVM-specific improvements, such as:

- New JVM IR backend
- New modes for generating default methods in interfaces
- Unified exception type for null checks

- Type annotations in the JVM bytecode

New JVM IR backend

Along with Kotlin/JS, we are migrating Kotlin/JVM to the unified IR backend, which allows us to implement most features and bug fixes once for all platforms. You will also be able to benefit from this by creating multiplatform extensions that will work for all platforms.

Kotlin 1.4.0 does not provide a public API for such extensions yet, but we are working closely with our partners, including Jetpack Compose, who are already building their compiler plugins using our new backend.

We encourage you to try out the new Kotlin/JVM backend, which is currently in Alpha, and to file any issues and feature requests to our issue tracker. This will help us to unify the compiler pipelines and bring compiler extensions like Jetpack Compose to the Kotlin community more quickly.

To enable the new JVM IR backend, specify an additional compiler option in your Gradle build script:

```
kotlinOptions.useIR = true
```

> If you enable Jetpack Compose, you will automatically be opted in to the new JVM backend without needing to specify the compiler option in kotlinOptions.

When using the command-line compiler, add the compiler option -Xuse-ir.

> You can use code compiled by the new JVM IR backend only if you've enabled the new backend. Otherwise, you will get an error. Considering this, we don't recommend that library authors switch to the new backend in production.

New modes for generating default methods

When compiling Kotlin code to targets JVM 1.8 and above, you could compile non-abstract methods of Kotlin interfaces into Java's default methods. For this purpose, there was a mechanism that includes the @JvmDefault annotation for marking such methods and the -Xjvm-default compiler option that enables processing of this annotation.

In 1.4.0, we've added a new mode for generating default methods: -Xjvm-default=all compiles all non-abstract methods of Kotlin interfaces to default Java methods. For compatibility with the code that uses the interfaces compiled without default, we also added all-compatibility mode.

For more information about default methods in the Java interop, see the interoperability documentation and this blog post.

Unified exception type for null checks

Starting from Kotlin 1.4.0, all runtime null checks will throw a java.lang.NullPointerException instead of KotlinNullPointerException, IllegalStateException, IllegalArgumentException, and TypeCastException. This applies to: the !! operator, parameter null checks in the method preamble, platform-typed expression null checks, and the as operator with a non-nullable type. This doesn't apply to lateinit null checks and explicit library function calls like checkNotNull or requireNotNull.

This change increases the number of possible null check optimizations that can be performed either by the Kotlin compiler or by various kinds of bytecode processing tools, such as the Android R8 optimizer.

Note that from a developer's perspective, things won't change that much: the Kotlin code will throw exceptions with the same error messages as before. The type of exception changes, but the information passed stays the same.

Type annotations in the JVM bytecode

Kotlin can now generate type annotations in the JVM bytecode (target version 1.8+), so that they become available in Java reflection at runtime. To emit the type annotation in the bytecode, follow these steps:

1. Make sure that your declared annotation has a proper annotation target (Java's ElementType.TYPE_USE or Kotlin's AnnotationTarget.TYPE) and retention (AnnotationRetention.RUNTIME).
2. Compile the annotation class declaration to JVM bytecode target version 1.8+. You can specify it with -jvm-target=1.8 compiler option.
3. Compile the code that uses the annotation to JVM bytecode target version 1.8+ (-jvm-target=1.8) and add the -Xemit-jvm-type-annotations compiler option.

Note that the type annotations from the standard library aren't emitted in the bytecode for now because the standard library is compiled with the target version 1.6.

So far, only the basic cases are supported:

- Type annotations on method parameters, method return types and property types;
- Invariant projections of type arguments, such as Smth<@Ann Foo>, Array<@Ann Foo>.

In the following example, the @Foo annotation on the String type can be emitted to the bytecode and then used by the library code:

```
@Target(AnnotationTarget.TYPE)
annotation class Foo

class A {
    fun foo(): @Foo String = "OK"
}
```

Kotlin/JS

On the JS platform, Kotlin 1.4.0 provides the following improvements:

- New Gradle DSL
- New JS IR backend

New Gradle DSL

The kotlin.js Gradle plugin comes with an adjusted Gradle DSL, which provides a number of new configuration options and is more closely aligned to the DSL used by the kotlin-multiplatform plugin. Some of the most impactful changes include:

- Explicit toggles for the creation of executable files via binaries.executable(). Read more about the executing Kotlin/JS and its environment here.
- Configuration of webpack's CSS and style loaders from within the Gradle configuration via cssSupport. Read more about using CSS and style loaders here.
- Improved management for npm dependencies, with mandatory version numbers or semver version ranges, as well as support for development, peer, and optional npm dependencies using devNpm, optionalNpm and peerNpm. Read more about dependency management for npm packages directly from Gradle here.
- Stronger integrations for Dukat, the generator for Kotlin external declarations. External declarations can now be generated at build time, or can be manually generated via a Gradle task.

New JS IR backend

The IR backend for Kotlin/JS, which currently has Alpha stability, provides some new functionality specific to the Kotlin/JS target which is focused around the generated code size through dead code elimination, and improved interoperation with JavaScript and TypeScript, among others.

To enable the Kotlin/JS IR backend, set the key kotlin.js.compiler=ir in your gradle.properties, or pass the IR compiler type to the js function of your Gradle build script:

```
kotlin {
    js(IR) { // or: LEGACY, BOTH
        // ...
    }
    binaries.executable()
}
```

For more detailed information about how to configure the new backend, check out the Kotlin/JS IR compiler documentation.

With the new @JsExport annotation and the ability to generate TypeScript definitions from Kotlin code, the Kotlin/JS IR compiler backend improves JavaScript & TypeScript interoperability. This also makes it easier to integrate Kotlin/JS code with existing tooling, to create hybrid applications and leverage code-sharing functionality in multiplatform projects.

Learn more about the available features in the Kotlin/JS IR compiler backend.

Kotlin/Native

In 1.4.0, Kotlin/Native got a significant number of new features and improvements, including:

- Support for suspending functions in Swift and Objective-C
- Objective-C generics support by default
- Exception handling in Objective-C/Swift interop
- Generate release .dSYMs on Apple targets by default
- Performance improvements
- Simplified management of CocoaPods dependencies

Support for Kotlin's suspending functions in Swift and Objective-C

In 1.4.0, we add the basic support for suspending functions in Swift and Objective-C. Now, when you compile a Kotlin module into an Apple framework, suspending functions are available in it as functions with callbacks (completionHandler in the Swift/Objective-C terminology). When you have such functions in the generated framework's header, you can call them from your Swift or Objective-C code and even override them.

For example, if you write this Kotlin function:

```
suspend fun queryData(id: Int): String = ...
```

...then you can call it from Swift like so:

```
queryData(id: 17) { result, error in
   if let e = error {
       print("ERROR: \(e)")
   } else {
       print(result!)
   }
}
```

Learn more about using suspending functions in Swift and Objective-C.

Objective-C generics support by default

Previous versions of Kotlin provided experimental support for generics in Objective-C interop. Since 1.4.0, Kotlin/Native generates Apple frameworks with generics from Kotlin code by default. In some cases, this may break existing Objective-C or Swift code calling Kotlin frameworks. To have the framework header written without generics, add the -Xno-objc-generics compiler option.

```
kotlin {
    targets.withType<org.jetbrains.kotlin.gradle.plugin.mpp.KotlinNativeTarget> {
        binaries.all {
            freeCompilerArgs += "-Xno-objc-generics"
        }
    }
}
```

Please note that all specifics and limitations listed in the documentation on interoperability with Objective-C are still valid.

Exception handling in Objective-C/Swift interop

In 1.4.0, we slightly change the Swift API generated from Kotlin with respect to the way exceptions are translated. There is a fundamental difference in error handling between Kotlin and Swift. All Kotlin exceptions are unchecked, while Swift has only checked errors. Thus, to make Swift code aware of expected exceptions, Kotlin functions should be marked with a @Throws annotation specifying a list of potential exception classes.

When compiling to Swift or the Objective-C framework, functions that have or are inheriting @Throws annotation are represented as NSError*-producing methods in Objective-C and as throws methods in Swift.

Previously, any exceptions other than RuntimeException and Error were propagated as NSError. Now this behavior changes: now NSError is thrown only for exceptions that are instances of classes specified as parameters of @Throws annotation (or their subclasses). Other Kotlin exceptions that reach Swift/Objective-C are considered unhandled and cause program termination.

Generate release .dSYMs on Apple targets by default

Starting with 1.4.0, the Kotlin/Native compiler produces debug symbol files (.dSYMs) for release binaries on Darwin platforms by default. This can be disabled with the -Xadd-light-debug=disable compiler option. On other platforms, this option is disabled by default. To toggle this option in Gradle, use:

```
kotlin {
    targets.withType<org.jetbrains.kotlin.gradle.plugin.mpp.KotlinNativeTarget> {
        binaries.all {
            freeCompilerArgs += "-Xadd-light-debug={enable|disable}"
        }
    }
}
```

Learn more about crash report symbolication.

Performance improvements

Kotlin/Native has received a number of performance improvements that speed up both the development process and execution. Here are some examples:

- To improve the speed of object allocation, we now offer the mimalloc memory allocator as an alternative to the system allocator. mimalloc works up to two times faster on some benchmarks. Currently, the usage of mimalloc in Kotlin/Native is experimental; you can switch to it using the -Xallocator=mimalloc compiler option.
- We've reworked how C interop libraries are built. With the new tooling, Kotlin/Native produces interop libraries up to 4 times as fast as before, and artifacts are 25% to 30% the size they used to be.
- Overall runtime performance has improved because of optimizations in GC. This improvement will be especially apparent in projects with a large number of long-lived objects. HashMap and HashSet collections now work faster by escaping redundant boxing.
- In 1.3.70 we introduced two new features for improving the performance of Kotlin/Native compilation: caching project dependencies and running the compiler from the Gradle daemon. Since that time, we've managed to fix numerous issues and improve the overall stability of these features.

Simplified management of CocoaPods dependencies

Previously, once you integrated your project with the dependency manager CocoaPods, you could build an iOS, macOS, watchOS, or tvOS part of your project only in Xcode, separate from other parts of your multiplatform project. These other parts could be built in IntelliJ IDEA.

Moreover, every time you added a dependency on an Objective-C library stored in CocoaPods (Pod library), you had to switch from IntelliJ IDEA to Xcode, call pod install, and run the Xcode build there.

Now you can manage Pod dependencies right in IntelliJ IDEA while enjoying the benefits it provides for working with code, such as code highlighting and completion. You can also build the whole Kotlin project with Gradle, without having to switch to Xcode. This means you only have to go to Xcode when you need to write Swift/Objective-C code or run your application on a simulator or device.

Now you can also work with Pod libraries stored locally.

Depending on your needs, you can add dependencies between:

- A Kotlin project and Pod libraries stored remotely in the CocoaPods repository or stored locally on your machine.
- A Kotlin Pod (Kotlin project used as a CocoaPods dependency) and an Xcode project with one or more targets.

Complete the initial configuration, and when you add a new dependency to cocoapods, just re-import the project in IntelliJ IDEA. The new dependency will be added automatically. No additional steps are required.

Learn how to add dependencies.

Kotlin Multiplatform

Support for multiplatform projects is in Alpha. It may change incompatibly and require manual migration in the future. We appreciate your feedback on it in YouTrack.

Kotlin Multiplatform reduces time spent writing and maintaining the same code for different platforms while retaining the flexibility and benefits of native programming. We continue investing our effort in multiplatform features and improvements:

- Sharing code in several targets with the hierarchical project structure
- Leveraging native libs in the hierarchical structure
- Specifying kotlinx dependencies only once

Multiplatform projects require Gradle 6.0 or later.

Sharing code in several targets with the hierarchical project structure

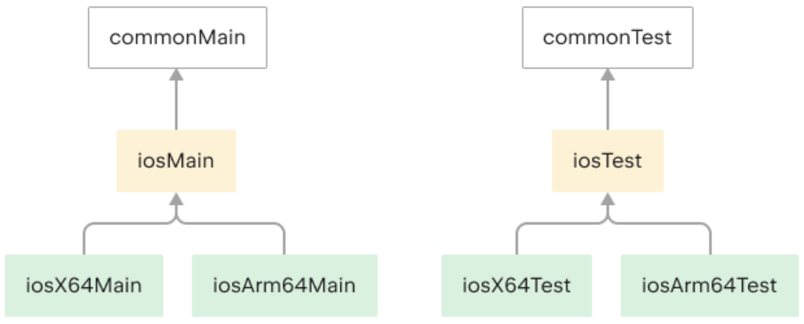
With the new hierarchical project structure support, you can share code among several platforms in a multiplatform project.

Previously, any code added to a multiplatform project could be placed either in a platform-specific source set, which is limited to one target and can't be reused by any other platform, or in a common source set, like commonMain or commonTest, which is shared across all the platforms in the project. In the common source set, you could only call a platform-specific API by using an expect declaration that needs platform-specific actual implementations.

This made it easy to share code on all platforms, but it was not so easy to share between only some of the targets, especially similar ones that could potentially reuse a lot of the common logic and third-party APIs.

For example, in a typical multiplatform project targeting iOS, there are two iOS-related targets: one for iOS ARM64 devices, and the other for the x64 simulator. They have separate platform-specific source sets, but in practice, there is rarely a need for different code for the device and simulator, and their dependencies are much alike. So iOS-specific code could be shared between them.

Apparently, in this setup, it would be desirable to have a shared source set for two iOS targets, with Kotlin/Native code that could still directly call any of the APIs that are common to both the iOS device and the simulator.



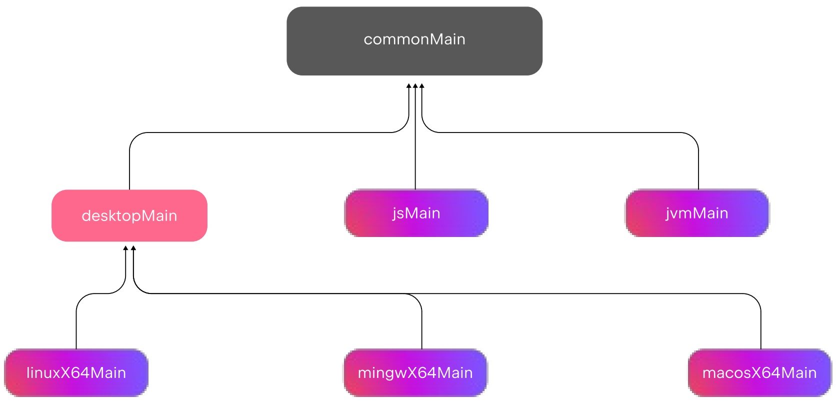
Code shared for iOS targets

Now you can do this with the hierarchical project structure support, which infers and adapts the API and language features available in each source set based on which targets consume them.

For common combinations of targets, you can create a hierarchical structure with target shortcuts. For example, create two iOS targets and the shared source set shown above with the ios() shortcut:

```
kotlin {
    ios() // iOS device and simulator targets; iosMain and iosTest source sets
}
```

For other combinations of targets, create a hierarchy manually by connecting the source sets with the dependsOn relation.



Hierarchical structure

Kotlin

```kotlin
kotlin{
    sourceSets {
        val desktopMain by creating {
            dependsOn(commonMain)
        }
        val linuxX64Main by getting {
            dependsOn(desktopMain)
        }
        val mingwX64Main by getting {
            dependsOn(desktopMain)
        }
        val macosX64Main by getting {
            dependsOn(desktopMain)
        }
    }
}
```

Groovy

```groovy
kotlin {
    sourceSets {
        desktopMain {
            dependsOn(commonMain)
        }
        linuxX64Main {
            dependsOn(desktopMain)
        }
        mingwX64Main {
            dependsOn(desktopMain)
        }
        macosX64Main {
            dependsOn(desktopMain)
        }
    }
}
```

Thanks to the hierarchical project structure, libraries can also provide common APIs for a subset of targets. Learn more about sharing code in libraries.

Leveraging native libs in the hierarchical structure

You can use platform-dependent libraries, such as Foundation, UIKit, and POSIX, in source sets shared among several native targets. This can help you share more native code without being limited by platform-specific dependencies.

No additional steps are required – everything is done automatically. IntelliJ IDEA will help you detect common declarations that you can use in the shared code.

Learn more about usage of platform-dependent libraries.

Specifying dependencies only once

From now on, instead of specifying dependencies on different variants of the same library in shared and platform-specific source sets where it is used, you should specify a dependency only once in the shared source set.

Kotlin

```kotlin
kotlin {
    sourceSets {
        val commonMain by getting {
            dependencies {
                implementation("org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2")
            }
        }
    }
}
```

Groovy

```groovy
kotlin {
    sourceSets {
        commonMain {
            dependencies {
                implementation 'org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2'
            }
        }
    }
}
```

Don't use kotlinx library artifact names with suffixes specifying the platform, such as -common, -native, or similar, as they are NOT supported anymore. Instead, use the library base artifact name, which in the example above is kotlinx-coroutines-core.

However, the change doesn't currently affect:

- The stdlib library – starting from Kotlin 1.4.0, the stdlib dependency is added automatically.
- The kotlin.test library – you should still use test-common and test-annotations-common. These dependencies will be addressed later.

If you need a dependency only for a specific platform, you can still use platform-specific variants of standard and kotlinx libraries with such suffixes as -jvm or-js, for example kotlinx-coroutines-core-jvm.

Learn more about configuring dependencies.

Gradle project improvements

Besides Gradle project features and improvements that are specific to Kotlin Multiplatform, Kotlin/JVM, Kotlin/Native, and Kotlin/JS, there are several changes applicable to all Kotlin Gradle projects:

- Dependency on the standard library is now added by default
- Kotlin projects require a recent version of Gradle
- Improved support for Kotlin Gradle DSL in the IDE

Dependency on the standard library added by default

You no longer need to declare a dependency on the stdlib library in any Kotlin Gradle project, including a multiplatform one. The dependency is added by default.

The automatically added standard library will be the same version of the Kotlin Gradle plugin, since they have the same versioning.

For platform-specific source sets, the corresponding platform-specific variant of the library is used, while a common standard library is added to the rest. The Kotlin Gradle plugin will select the appropriate JVM standard library depending on the kotlinOptions.jvmTarget compiler option of your Gradle build script.

Learn how to change the default behavior.

Minimum Gradle version for Kotlin projects

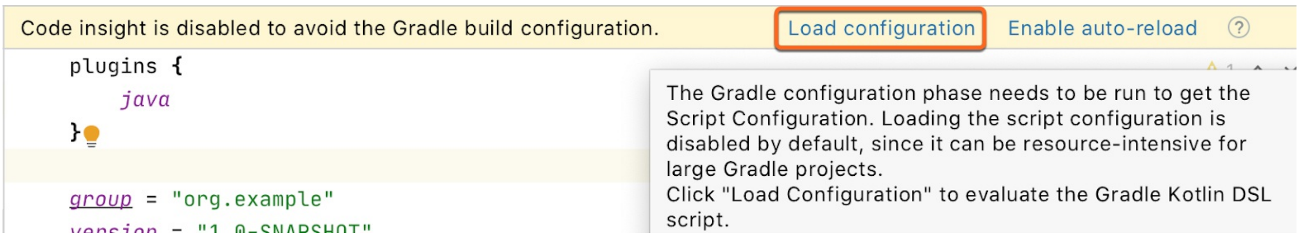
To enjoy the new features in your Kotlin projects, update Gradle to the latest version. Multiplatform projects require Gradle 6.0 or later, while other Kotlin projects work with Gradle 5.4 or later.

Improved *.gradle.kts support in the IDE

In 1.4.0, we continued improving the IDE support for Gradle Kotlin DSL scripts (*.gradle.kts files). Here is what the new version brings:

- Explicit loading of script configurations for better performance. Previously, the changes you make to the build script were loaded automatically in the background. To improve the performance, we've disabled the automatic loading of build script configuration in 1.4.0. Now the IDE loads the changes only when you explicitly apply them.

  In Gradle versions earlier than 6.0, you need to manually load the script configuration by clicking Load Configuration in the editor.



Code insight is disabled to avoid the Gradle build configuration.

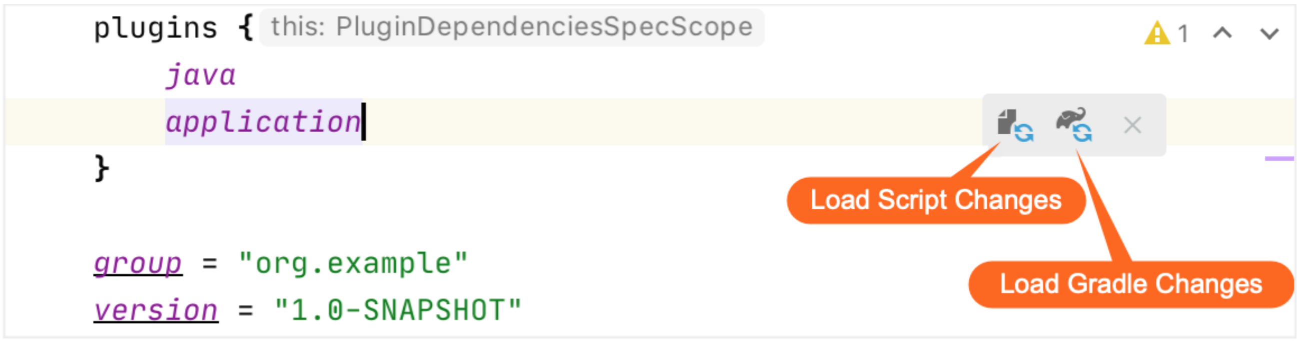
```
plugins {
    java
}

group = "org.example"
```

The Gradle configuration phase needs to be run to get the Script Configuration. Loading the script configuration is disabled by default, since it can be resource-intensive for large Gradle projects.
Click "Load Configuration" to evaluate the Gradle Kotlin DSL script.

*.gradle.kts – Load Configuration

In Gradle 6.0 and above, you can explicitly apply changes by clicking Load Gradle Changes or by reimporting the Gradle project.

We've added one more action in IntelliJ IDEA 2020.1 with Gradle 6.0 and above – Load Script Configurations, which loads changes to the script configurations without updating the whole project. This takes much less time than reimporting the whole project.



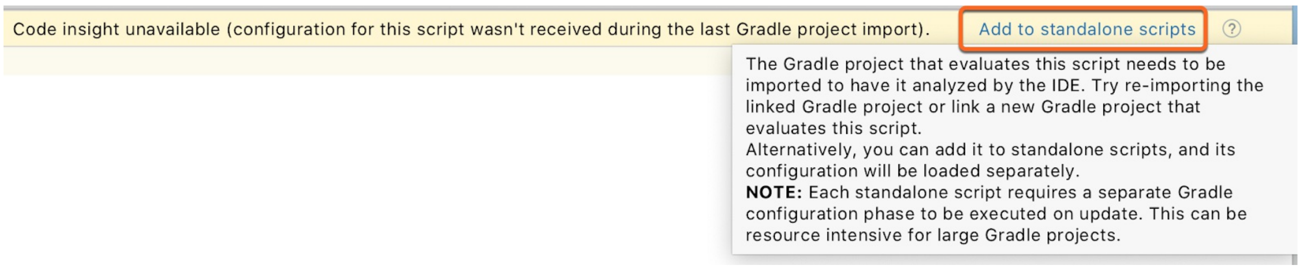
```
plugins { this: PluginDependenciesSpecScope
    java
    application
}

group = "org.example"
version = "1.0-SNAPSHOT"
```

*.gradle.kts – Load Script Changes and Load Gradle Changes

You should also Load Script Configurations for newly created scripts or when you open a project with new Kotlin plugin for the first time.

With Gradle 6.0 and above, you are now able to load all scripts at once as opposed to the previous implementation where they were loaded individually. Since each request requires the Gradle configuration phase to be executed, this could be resource-intensive for large Gradle projects.

Currently, such loading is limited to build.gradle.kts and settings.gradle.kts files (please vote for the related issue). To enable highlighting for init.gradle.kts or applied script plugins, use the old mechanism – adding them to standalone scripts. Configuration for that scripts will be loaded separately when you need it. You can also enable auto-reload for such scripts.



Code insight unavailable (configuration for this script wasn't received during the last Gradle project import).

The Gradle project that evaluates this script needs to be imported to have it analyzed by the IDE. Try re-importing the linked Gradle project or link a new Gradle project that evaluates this script.
Alternatively, you can add it to standalone scripts, and its configuration will be loaded separately.
NOTE: Each standalone script requires a separate Gradle configuration phase to be executed on update. This can be resource intensive for large Gradle projects.

*.gradle.kts – Add to standalone scripts

- Better error reporting. Previously you could only see errors from the Gradle Daemon in separate log files. Now the Gradle Daemon returns all the information about errors directly and shows it in the Build tool window. This saves you both time and effort.

Standard library

Here is the list of the most significant changes to the Kotlin standard library in 1.4.0:

- Common exception processing API
- New functions for arrays and collections
- Functions for string manipulations
- Bit operations
- Delegated properties improvements
- Converting from KType to Java Type
- Proguard configurations for Kotlin reflection
- Improving the existing API
- module-info descriptors for stdlib artifacts
- Deprecations
- Exclusion of the deprecated experimental coroutines

Common exception processing API

The following API elements have been moved to the common library:

- Throwable.stackTraceToString() extension function, which returns the detailed description of this throwable with its stack trace, and Throwable.printStackTrace(), which prints this description to the standard error output.
- Throwable.addSuppressed() function, which lets you specify the exceptions that were suppressed in order to deliver the exception, and the Throwable.suppressedExceptions property, which returns a list of all the suppressed exceptions.
- @Throws annotation, which lists exception types that will be checked when the function is compiled to a platform method (on JVM or native platforms).

New functions for arrays and collections

Collections

In 1.4.0, the standard library includes a number of useful functions for working with collections:

- setOfNotNull(), which makes a set consisting of all the non-null items among the provided arguments.

```
fun main() {
    val set = setOfNotNull(null, 1, 2, 0, null)
    println(set)
}
```

- shuffled() for sequences.

```
fun main() {
    val numbers = (0 until 50).asSequence()
    val result = numbers.map { it * 2 }.shuffled().take(5)
    println(result.toList()) //five random even numbers below 100
}
```

- *Indexed() counterparts for onEach() and flatMap(). The operation that they apply to the collection elements has the element index as a parameter.

```
fun main() {
    listOf("a", "b", "c", "d").onEachIndexed {
        index, item -> println(index.toString() + ":" + item)
    }

   val list = listOf("hello", "kot", "lin", "world")
          val kotlin = list.flatMapIndexed { index, item ->
              if (index in 1..2) item.toList() else emptyList()
          }
          println(kotlin)
}
```

- *OrNull() counterparts randomOrNull(), reduceOrNull(), and reduceIndexedOrNull(). They return null on empty collections.

```
fun main() {
     val empty = emptyList<Int>()
     empty.reduceOrNull { a, b -> a + b }
     //empty.reduce { a, b -> a + b } // Exception: Empty collection can't be reduced.
}
```

- runningFold(), its synonym scan(), and runningReduce() apply the given operation to the collection elements sequentially, similarly tofold() and reduce(); the difference is that these new functions return the whole sequence of intermediate results.

```
fun main() {
    val numbers = mutableListOf(0, 1, 2, 3, 4, 5)
    val runningReduceSum = numbers.runningReduce { sum, item -> sum + item }
    val runningFoldSum = numbers.runningFold(10) { sum, item -> sum + item }
    println(runningReduceSum.toString())
    println(runningFoldSum.toString())
}
```

- sumOf() takes a selector function and returns a sum of its values for all elements of a collection. sumOf() can produce sums of the types Int, Long, Double, UInt, and ULong. On the JVM, BigInteger and BigDecimal are also available.

```
data class OrderItem(val name: String, val price: Double, val count: Int)

fun main() {
    val order = listOf<OrderItem>(
        OrderItem("Cake", price = 10.0, count = 1),
        OrderItem("Coffee", price = 2.5, count = 3),
        OrderItem("Tea", price = 1.5, count = 2))

    val total = order.sumOf { it.price * it.count } // Double
    val count = order.sumOf { it.count } // Int
    println("You've ordered $count items that cost $total in total")
}
```

- The min() and max() functions have been renamed to minOrNull() and maxOrNull() to comply with the naming convention used across the Kotlin collections API. An *OrNull suffix in the function name means that it returns null if the receiver collection is empty. The same applies to minBy(), maxBy(), minWith(), maxWith() – in 1.4, they have *OrNull() synonyms.

- The new minOf() and maxOf() extension functions return the minimum and the maximum value of the given selector function on the collection items.

```
data class OrderItem(val name: String, val price: Double, val count: Int)

fun main() {
    val order = listOf<OrderItem>(
        OrderItem("Cake", price = 10.0, count = 1),
        OrderItem("Coffee", price = 2.5, count = 3),
        OrderItem("Tea", price = 1.5, count = 2))
    val highestPrice = order.maxOf { it.price }
    println("The most expensive item in the order costs $highestPrice")
}
```

There are also minOfWith() and maxOfWith(), which take a Comparator as an argument, and *OrNull() versions of all four functions that return null on empty collections.

- New overloads for flatMap and flatMapTo let you use transformations with return types that don't match the receiver type, namely:

  - Transformations to Sequence on Iterable, Array, and Map

- Transformations to Iterable on Sequence

  ```
  fun main() {
      val list = listOf("kot", "lin")
      val lettersList = list.flatMap { it.asSequence() }
      val lettersSeq = list.asSequence().flatMap { it.toList() }
      println(lettersList)
      println(lettersSeq.toList())
  }
  ```

- removeFirst() and removeLast() shortcuts for removing elements from mutable lists, and *orNull() counterparts of these functions.

Arrays

To provide a consistent experience when working with different container types, we've also added new functions for arrays:

- shuffle() puts the array elements in a random order.
- onEach() performs the given action on each array element and returns the array itself.
- associateWith() and associateWithTo() build maps with the array elements as keys.
- reverse() for array subranges reverses the order of the elements in the subrange.
- sortDescending() for array subranges sorts the elements in the subrange in descending order.
- sort() and sortWith() for array subranges are now available in the common library.

```
fun main() {
    var language = ""
    val letters = arrayOf("k", "o", "t", "l", "i", "n")
    val fileExt = letters.onEach { language += it }
       .filterNot { it in "aeuio" }.take(2)
       .joinToString(prefix = ".", separator = "")
    println(language) // "kotlin"
    println(fileExt) // ".kt"

    letters.shuffle()
    letters.reverse(0, 3)
    letters.sortDescending(2, 5)
    println(letters.contentToString()) // [k, o, t, l, i, n]
}
```

Additionally, there are new functions for conversions between CharArray/ByteArray and String:

- ByteArray.decodeToString() and String.encodeToByteArray()
- CharArray.concatToString() and String.toCharArray()

```
fun main() {
 val str = "kotlin"
    val array = str.toCharArray()
    println(array.concatToString())
}
```

ArrayDeque

We've also added the ArrayDeque class – an implementation of a double-ended queue. A double-ended queue lets you add or remove elements both at the beginning or end of the queue in an amortized constant time. You can use a double-ended queue by default when you need a queue or a stack in your code.

```
fun main() {
    val deque = ArrayDeque(listOf(1, 2, 3))

    deque.addFirst(0)
    deque.addLast(4)
    println(deque) // [0, 1, 2, 3, 4]

    println(deque.first()) // 0
    println(deque.last()) // 4
```

```
    deque.removeFirst()
    deque.removeLast()
    println(deque) // [1, 2, 3]
}
```

The ArrayDeque implementation uses a resizable array underneath: it stores the contents in a circular buffer, an Array, and resizes this Array only when it becomes full.

Functions for string manipulations

The standard library in 1.4.0 includes a number of improvements in the API for string manipulation:

- StringBuilder has useful new extension functions: set(), setRange(), deleteAt(), deleteRange(), appendRange(), and others.

```
fun main() {
            val sb = StringBuilder("Bye Kotlin 1.3.72")
        sb.deleteRange(0, 3)
        sb.insertRange(0, "Hello", 0 ,5)
        sb.set(15, '4')
        sb.setRange(17, 19, "0")
        print(sb.toString())
    //sampleEnd
    }
```

- Some existing functions of StringBuilder are available in the common library. Among them are append(), insert(), substring(), setLength(), and more.

- New functions Appendable.appendLine() and StringBuilder.appendLine() have been added to the common library. They replace the JVM-only appendln() functions of these classes.

```
fun main() {
    println(buildString {
        appendLine("Hello,")
        appendLine("world")
    })
}
```

Bit operations

New functions for bit manipulations:

- countOneBits()
- countLeadingZeroBits()
- countTrailingZeroBits()
- takeHighestOneBit()
- takeLowestOneBit()
- rotateLeft() and rotateRight() (experimental)

```
fun main() {
    val number = "1010000".toInt(radix = 2)
    println(number.countOneBits())
    println(number.countTrailingZeroBits())
    println(number.takeHighestOneBit().toString(2))
}
```

Delegated properties improvements

In 1.4.0, we have added new features to improve your experience with delegated properties in Kotlin:

- Now a property can be delegated to another property.
- A new interface PropertyDelegateProvider helps create delegate providers in a single declaration.

- ReadWriteProperty now extends ReadOnlyProperty so you can use both of them for read-only properties.

Aside from the new API, we've made some optimizations that reduce the resulting bytecode size. These optimizations are described in this blog post.

Learn more about delegated properties.

Converting from KType to Java Type

A new extension property KType.javaType (currently experimental) in the stdlib helps you obtain a java.lang.reflect.Type from a Kotlin type without using the whole kotlin-reflect dependency.

```
import kotlin.reflect.javaType
import kotlin.reflect.typeOf

@OptIn(ExperimentalStdlibApi::class)
inline fun <reified T> accessReifiedTypeArg() {
   val kType = typeOf<T>()
   println("Kotlin type: $kType")
   println("Java type: ${kType.javaType}")
}

@OptIn(ExperimentalStdlibApi::class)
fun main() {
   accessReifiedTypeArg<String>()
   // Kotlin type: kotlin.String
   // Java type: class java.lang.String

   accessReifiedTypeArg<List<String>>()
   // Kotlin type: kotlin.collections.List<kotlin.String>
   // Java type: java.util.List<java.lang.String>
}
```

Proguard configurations for Kotlin reflection

Starting from 1.4.0, we have embedded Proguard/R8 configurations for Kotlin Reflection in kotlin-reflect.jar. With this in place, most Android projects using R8 or Proguard should work with kotlin-reflect without needing any additional configuration. You no longer need to copy-paste the Proguard rules for kotlin-reflect internals. But note that you still need to explicitly list all the APIs you're going to reflect on.

Improving the existing API

- Several functions now work on null receivers, for example:
  - toBoolean() on strings
  - contentEquals(), contentHashcode(), contentToString() on arrays
- NaN, NEGATIVE_INFINITY, and POSITIVE_INFINITY in Double and Float are now defined as const, so you can use them as annotation arguments.
- New constants SIZE_BITS and SIZE_BYTES in Double and Float contain the number of bits and bytes used to represent an instance of the type in binary form.
- The maxOf() and minOf() top-level functions can accept a variable number of arguments (vararg).

module-info descriptors for stdlib artifacts

Kotlin 1.4.0 adds module-info.java module information to default standard library artifacts. This lets you use them with jlink tool, which generates custom Java runtime images containing only the platform modules that are required for your app. You could already use jlink with Kotlin standard library artifacts, but you had to use separate artifacts to do so – the ones with the "modular" classifier – and the whole setup wasn't straightforward.
In Android, make sure you use the Android Gradle plugin version 3.2 or higher, which can correctly process jar files with module-info.

Deprecations

toShort() and toByte() of Double and Float

We've deprecated the functions toShort() and toByte() on Double and Float because they could lead to unexpected results because of the narrow value range and smaller variable size.

To convert floating-point numbers to Byte or Short, use the two-step conversion: first, convert them to Int, and then convert them again to the target type.

contains(), indexOf(), and lastIndexOf() on floating-point arrays

We've deprecated the contains(), indexOf(), and lastIndexOf() extension functions of FloatArray and DoubleArray because they use the IEEE 754 standard equality, which contradicts the total order equality in some corner cases. See this issue for details.

min() and max() collection functions

We've deprecated the min() and max() collection functions in favor of minOrNull() and maxOrNull(), which more properly reflect their behavior – returning null on empty collections. See this issue for details.

Exclusion of the deprecated experimental coroutines

The kotlin.coroutines.experimental API was deprecated in favor of kotlin.coroutines in 1.3.0. In 1.4.0, we're completing the deprecation cycle for kotlin.coroutines.experimental by removing it from the standard library. For those who still use it on the JVM, we've provided a compatibility artifact kotlin-coroutines-experimental-compat.jar with all the experimental coroutines APIs. We've published it to Maven, and we include it in the Kotlin distribution alongside the standard library.

Stable JSON serialization

With Kotlin 1.4.0, we are shipping the first stable version of kotlinx.serialization - 1.0.0-RC. Now we are pleased to declare the JSON serialization API in kotlinx-serialization-core (previously known as kotlinx-serialization-runtime) stable. Libraries for other serialization formats remain experimental, along with some advanced parts of the core library.

We have significantly reworked the API for JSON serialization to make it more consistent and easier to use. From now on, we'll continue developing the JSON serialization API in a backward-compatible manner. However, if you have used previous versions of it, you'll need to rewrite some of your code when migrating to 1.0.0-RC. To help you with this, we also offer the Kotlin Serialization Guide – the complete set of documentation for kotlinx.serialization. It will guide you through the process of using the most important features and it can help you address any issues that you might face.

> Note: kotlinx-serialization 1.0.0-RC only works with Kotlin compiler 1.4. Earlier compiler versions are not compatible.

Scripting and REPL

In 1.4.0, scripting in Kotlin benefits from a number of functional and performance improvements along with other updates. Here are some of the key changes:

- New dependencies resolution API
- New REPL API
- Compiled scripts cache
- Artifacts renaming

To help you become more familiar with scripting in Kotlin, we've prepared a project with examples. It contains examples of the standard scripts (*.main.kts) and examples of uses of the Kotlin Scripting API and custom script definitions. Please give it a try and share your feedback using our issue tracker.

New dependencies resolution API

In 1.4.0, we've introduced a new API for resolving external dependencies (such as Maven artifacts), along with implementations for it. This API is published in the new artifacts kotlin-scripting-dependencies and kotlin-scripting-dependencies-maven. The previous dependency resolution functionality in kotlin-script-util library is now deprecated.

New REPL API

The new experimental REPL API is now a part of the Kotlin Scripting API. There are also several implementations of it in the published artifacts, and some have advanced functionality, such as code completion. We use this API in the Kotlin Jupyter kernel and now you can try it in your own custom shells and REPLs.

Compiled scripts cache

The Kotlin Scripting API now provides the ability to implement a compiled scripts cache, significantly speeding up subsequent executions of unchanged scripts. Our default advanced script implementation kotlin-main-kts already has its own cache.

Artifacts renaming

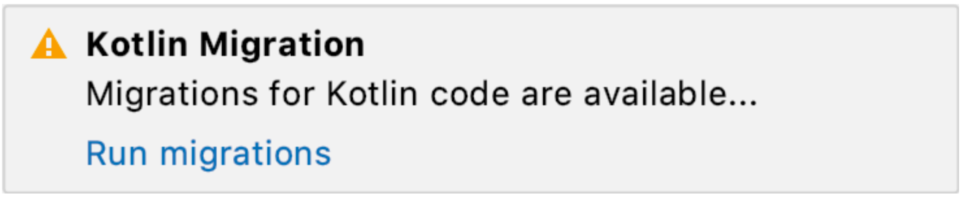
In order to avoid confusion about artifact names, we've renamed kotlin-scripting-jsr223-embeddable and kotlin-scripting-jvm-host-embeddable to just kotlin-scripting-jsr223 and kotlin-scripting-jvm-host. These artifacts depend on the kotlin-compiler-embeddable artifact, which shades the bundled third-party libraries to avoid usage conflicts. With this renaming, we're making the usage of kotlin-compiler-embeddable (which is safer in general) the default for scripting artifacts. If, for some reason, you need artifacts that depend on the unshaded kotlin-compiler, use the artifact versions with the -unshaded suffix, such as kotlin-scripting-jsr223-unshaded. Note that this renaming affects only the scripting artifacts that are supposed to be used directly; names of other artifacts remain unchanged.

Migrating to Kotlin 1.4.0

The Kotlin plugin's migration tools help you migrate your projects from earlier versions of Kotlin to 1.4.0.

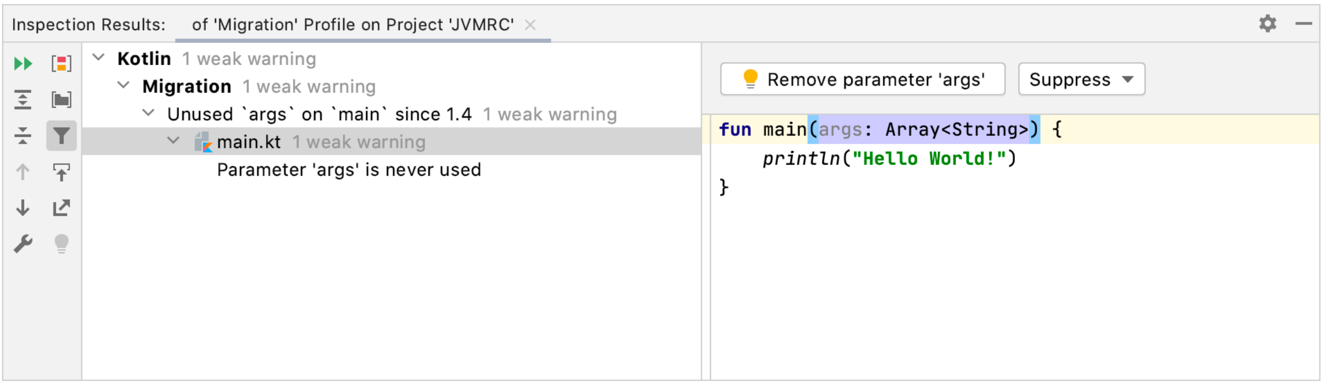
Just change the Kotlin version to 1.4.0 and re-import your Gradle or Maven project. The IDE will then ask you about migration.

If you agree, it will run migration code inspections that will check your code and suggest corrections for anything that doesn't work or that is not recommended in 1.4.0.


Kotlin Migration
Migrations for Kotlin code are available...
Run migrations

Run migration

Code inspections have different severity levels, to help you decide which suggestions to accept and which to ignore.


Inspection Results: of 'Migration' Profile on Project 'JVMRC'

Kotlin 1 weak warning
Migration 1 weak warning
Unused `args` on `main` since 1.4 1 weak warning
main.kt 1 weak warning
Parameter 'args' is never used

```
fun main(args: Array<String>) {
    println("Hello World!")
}
```

Migration inspections

Kotlin 1.4.0 is a feature release and therefore can bring incompatible changes to the language. Find the detailed list of such changes in the Compatibility Guide for Kotlin 1.4.

What's new in Kotlin 1.3

Released: 29 October 2018

Coroutines release

After some long and extensive battle testing, coroutines are now released! It means that from Kotlin 1.3 the language support and the API are fully stable. Check out the new coroutines overview page.

Kotlin 1.3 introduces callable references on suspend-functions and support of coroutines in the reflection API.

Kotlin/Native

Kotlin 1.3 continues to improve and polish the Native target. See the Kotlin/Native overview for details.

Multiplatform projects

In 1.3, we've completely reworked the model of multiplatform projects in order to improve expressiveness and flexibility, and to make sharing common code easier. Also, Kotlin/Native is now supported as one of the targets!

The key differences to the old model are:

- In the old model, common and platform-specific code needed to be placed in separate modules, linked by expectedBy dependencies. Now, common and platform-specific code is placed in different source roots of the same module, making projects easier to configure.
- There is now a large number of preset platform configurations for different supported platforms.
- The dependencies configuration has been changed; dependencies are now specified separately for each source root.
- Source sets can now be shared between an arbitrary subset of platforms (for example, in a module that targets JS, Android and iOS, you can have a source set that is shared only between Android and iOS).
- Publishing multiplatform libraries is now supported.

For more information, please refer to the multiplatform programming documentation.

Contracts

The Kotlin compiler does extensive static analysis to provide warnings and reduce boilerplate. One of the most notable features is smartcasts — with the ability to perform a cast automatically based on the performed type checks:

```
fun foo(s: String?) {
    if (s != null) s.length // Compiler automatically casts 's' to 'String'
}
```

However, as soon as these checks are extracted in a separate function, all the smartcasts immediately disappear:

```
fun String?.isNotNull(): Boolean = this != null

fun foo(s: String?) {
    if (s.isNotNull()) s.length // No smartcast :(
}
```

To improve the behavior in such cases, Kotlin 1.3 introduces experimental mechanism called contracts.

Contracts allow a function to explicitly describe its behavior in a way which is understood by the compiler. Currently, two wide classes of cases are supported:

- Improving smartcasts analysis by declaring the relation between a function's call outcome and the passed arguments values:

```
fun require(condition: Boolean) {
    // This is a syntax form which tells the compiler:
    // "if this function returns successfully, then the passed 'condition' is true"
    contract { returns() implies condition }
    if (!condition) throw IllegalArgumentException(...)
}

fun foo(s: String?) {
    require(s is String)
    // s is smartcast to 'String' here, because otherwise
    // 'require' would have thrown an exception
}
```

- Improving the variable initialization analysis in the presence of higher-order functions:

```
fun synchronize(lock: Any?, block: () -> Unit) {
    // It tells the compiler:
    // "This function will invoke 'block' here and now, and exactly one time"
    contract { callsInPlace(block, EXACTLY_ONCE) }
}

fun foo() {
    val x: Int
    synchronize(lock) {
        x = 42 // Compiler knows that lambda passed to 'synchronize' is called
               // exactly once, so no reassignment is reported
    }
    println(x) // Compiler knows that lambda will be definitely called, performing
               // initialization, so 'x' is considered to be initialized here
}
```

Contracts in stdlib

stdlib already makes use of contracts, which leads to improvements in the analyses described above. This part of contracts is stable, meaning that you can benefit from the improved analysis right now without any additional opt-ins:

```
fun bar(x: String?) {
    if (!x.isNullOrEmpty()) {
        println("length of '$x' is ${x.length}") // Yay, smartcast to not-null!
    }
}
fun main() {
    bar(null)
    bar("42")
}
```

Custom contracts

It is possible to declare contracts for your own functions, but this feature is experimental, as the current syntax is in a state of early prototype and will most probably be changed. Also please note that currently the Kotlin compiler does not verify contracts, so it's the responsibility of the programmer to write correct and sound contracts.

Custom contracts are introduced by a call to contract stdlib function, which provides DSL scope:

```
fun String?.isNullOrEmpty(): Boolean {
    contract {
        returns(false) implies (this@isNullOrEmpty != null)
    }
    return this == null || isEmpty()
}
```

See the details on the syntax as well as the compatibility notice in the KEEP.

Capturing when subject in a variable

In Kotlin 1.3, it is now possible to capture the when subject into a variable:

```
fun Request.getBody() =
        when (val response = executeRequest()) {
            is Success -> response.body
            is HttpError -> throw HttpException(response.status)
        }
```

While it was already possible to extract this variable just before when, val in when has its scope properly restricted to the body of when, and so preventing namespace pollution. See the full documentation on when here.

@JvmStatic and @JvmField in companions of interfaces

With Kotlin 1.3, it is possible to mark members of a companion object of interfaces with annotations @JvmStatic and @JvmField. In the classfile, such members will be lifted to the corresponding interface and marked as static.

For example, the following Kotlin code:

```
interface Foo {
    companion object {
        @JvmField
        val answer: Int = 42

        @JvmStatic
        fun sayHello() {
            println("Hello, world!")
        }
    }
}
```

It is equivalent to this Java code:

```
interface Foo {
    public static int answer = 42;
    public static void sayHello() {
        // ...
    }
}
```

Nested declarations in annotation classes

In Kotlin 1.3, it is possible for annotations to have nested classes, interfaces, objects, and companions:

```
annotation class Foo {
    enum class Direction { UP, DOWN, LEFT, RIGHT }

    annotation class Bar

    companion object {
        fun foo(): Int = 42
        val bar: Int = 42
    }
}
```

Parameterless main

By convention, the entry point of a Kotlin program is a function with a signature like main(args: Array<String>), where args represent the command-line arguments passed to the program. However, not every application supports command-line arguments, so this parameter often ends up not being used.

Kotlin 1.3 introduced a simpler form of main which takes no parameters. Now "Hello, World" in Kotlin is 19 characters shorter!

```
fun main() {
    println("Hello, world!")
}
```

Functions with big arity

In Kotlin, functional types are represented as generic classes taking a different number of parameters: Function0<R>, Function1<P0, R>, Function2<P0, P1, R>, ... This approach has a problem in that this list is finite, and it currently ends with Function22.

Kotlin 1.3 relaxes this limitation and adds support for functions with bigger arity:

```
fun trueEnterpriseComesToKotlin(block: (Any, Any, ... /* 42 more */, Any) -> Any) {
    block(Any(), Any(), ..., Any())
}
```

Progressive mode

Kotlin cares a lot about stability and backward compatibility of code: Kotlin compatibility policy says that breaking changes (e.g., a change which makes the code that used to compile fine, not compile anymore) can be introduced only in the major releases (1.2, 1.3, etc.).

We believe that a lot of users could use a much faster cycle where critical compiler bug fixes arrive immediately, making the code more safe and correct. So, Kotlin 1.3 introduces the progressive compiler mode, which can be enabled by passing the argument -progressive to the compiler.

In the progressive mode, some fixes in language semantics can arrive immediately. All these fixes have two important properties:

- They preserve backward compatibility of source code with older compilers, meaning that all the code which is compilable by the progressive compiler will be compiled fine by non-progressive one.
- They only make code safer in some sense — e.g., some unsound smartcast can be forbidden, behavior of the generated code may be changed to be more predictable/stable, and so on.

Enabling the progressive mode can require you to rewrite some of your code, but it shouldn't be too much — all the fixes enabled under progressive are carefully handpicked, reviewed, and provided with tooling migration assistance. We expect that the progressive mode will be a nice choice for any actively maintained codebases which are updated to the latest language versions quickly.

Inline classes

Inline classes are in Alpha. They may change incompatibly and require manual migration in the future. We appreciate your feedback on it in YouTrack. See details in the reference.

Kotlin 1.3 introduces a new kind of declaration — inline class. Inline classes can be viewed as a restricted version of the usual classes, in particular, inline classes must have exactly one property:

```
inline class Name(val s: String)
```

The Kotlin compiler will use this restriction to aggressively optimize runtime representation of inline classes and substitute their instances with the value of the underlying property where possible removing constructor calls, GC pressure, and enabling other optimizations:

```
inline class Name(val s: String)
fun main() {
    // In the next line no constructor call happens, and
    // at the runtime 'name' contains just string "Kotlin"
    val name = Name("Kotlin")
    println(name.s)
}
```

See reference for inline classes for details.

Unsigned integers

Unsigned integers are in Beta. Their implementation is almost stable, but migration steps may be required in the future. We'll do our best to minimize any changes you will have to make.

Kotlin 1.3 introduces unsigned integer types:

- kotlin.UByte: an unsigned 8-bit integer, ranges from 0 to 255
- kotlin.UShort: an unsigned 16-bit integer, ranges from 0 to 65535
- kotlin.UInt: an unsigned 32-bit integer, ranges from 0 to 2^32 - 1
- kotlin.ULong: an unsigned 64-bit integer, ranges from 0 to 2^64 - 1

Most of the functionality of signed types are supported for unsigned counterparts too:

```
fun main() {
// You can define unsigned types using literal suffixes
val uint = 42u
val ulong = 42uL
val ubyte: UByte = 255u

// You can convert signed types to unsigned and vice versa via stdlib extensions:
val int = uint.toInt()
val byte = ubyte.toByte()
val ulong2 = byte.toULong()

// Unsigned types support similar operators:
val x = 20u + 22u
val y = 1u shl 8
val z = "128".toUByte()
val range = 1u..5u
println("ubyte: $ubyte, byte: $byte, ulong2: $ulong2")
println("x: $x, y: $y, z: $z, range: $range")
}
```

See reference for details.

@JvmDefault

@JvmDefault is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We appreciate your feedback on it in YouTrack.

Kotlin targets a wide range of the Java versions, including Java 6 and Java 7, where default methods in the interfaces are not allowed. For your convenience, the Kotlin compiler works around that limitation, but this workaround isn't compatible with the default methods, introduced in Java 8.

This could be an issue for Java-interoperability, so Kotlin 1.3 introduces the @JvmDefault annotation. Methods annotated with this annotation will be generated as default methods for JVM:

```
interface Foo {
    // Will be generated as 'default' method
    @JvmDefault
    fun foo(): Int = 42
}
```

Warning! Annotating your API with @JvmDefault has serious implications on binary compatibility. Make sure to carefully read the reference page before using @JvmDefault in production.

Standard library

Multiplatform random

Prior to Kotlin 1.3, there was no uniform way to generate random numbers on all platforms — we had to resort to platform-specific solutions like java.util.Random on JVM. This release fixes this issue by introducing the class kotlin.random.Random, which is available on all platforms:

```
import kotlin.random.Random

fun main() {
    val number = Random.nextInt(42)  // number is in range [0, limit)
    println(number)
}
```

isNullOrEmpty and orEmpty extensions

isNullOrEmpty and orEmpty extensions for some types are already present in stdlib. The first one returns true if the receiver is null or empty, and the second one falls back to an empty instance if the receiver is null. Kotlin 1.3 provides similar extensions on collections, maps, and arrays of objects.

Copy elements between two existing arrays

The array.copyInto(targetArray, targetOffset, startIndex, endIndex) functions for the existing array types, including the unsigned arrays, make it easier to implement array-based containers in pure Kotlin.

```kotlin
fun main() {
    val sourceArr = arrayOf("k", "o", "t", "l", "i", "n")
    val targetArr = sourceArr.copyInto(arrayOfNulls<String>(6), 3, startIndex = 3, endIndex = 6)
    println(targetArr.contentToString())

    sourceArr.copyInto(targetArr, startIndex = 0, endIndex = 3)
    println(targetArr.contentToString())
}
```

associateWith

It is quite a common situation to have a list of keys and want to build a map by associating each of these keys with some value. It was possible to do it before with the associate { it to getValue(it) } function, but now we're introducing a more efficient and easy to explore alternative: keys.associateWith { getValue(it) }.

```kotlin
fun main() {
    val keys = 'a'..'f'
    val map = keys.associateWith { it.toString().repeat(5).capitalize() }
    map.forEach { println(it) }
}
```

ifEmpty and ifBlank functions

Collections, maps, object arrays, char sequences, and sequences now have an ifEmpty function, which allows specifying a fallback value that will be used instead of the receiver if it is empty:

```kotlin
fun main() {
    fun printAllUppercase(data: List<String>) {
        val result = data
        .filter { it.all { c -> c.isUpperCase() } }
            .ifEmpty { listOf("<no uppercase>") }
        result.forEach { println(it) }
    }

    printAllUppercase(listOf("foo", "Bar"))
    printAllUppercase(listOf("FOO", "BAR"))
}
```

Char sequences and strings in addition have an ifBlank extension that does the same thing as ifEmpty but checks for a string being all whitespace instead of empty.

```kotlin
fun main() {
    val s = "    \n"
    println(s.ifBlank { "<blank>" })
    println(s.ifBlank { null })
}
```

Sealed classes in reflection

We've added a new API to kotlin-reflect that can be used to enumerate all the direct subtypes of a sealed class, namely KClass.sealedSubclasses.

Smaller changes

- Boolean type now has companion.
- Any?.hashCode() extension that returns 0 for null.
- Char now provides MIN_VALUE and MAX_VALUE constants.
- SIZE_BYTES and SIZE_BITS constants in primitive type companions.

Tooling

Code style support in IDE

Kotlin 1.3 introduces support for the recommended code style in IntelliJ IDEA. Check out this page for the migration guidelines.

kotlinx.serialization

kotlinx.serialization is a library which provides multiplatform support for (de)serializing objects in Kotlin. Previously, it was a separate project, but since Kotlin 1.3, it ships with the Kotlin compiler distribution on par with the other compiler plugins. The main difference is that you don't need to manually watch out for the Serialization IDE Plugin being compatible with the Kotlin IDE plugin version you're using: now the Kotlin IDE plugin already includes serialization!

See here for details.

> Even though kotlinx.serialization now ships with the Kotlin Compiler distribution, it is still considered to be an experimental feature in Kotlin 1.3.

Scripting update

> Scripting is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We appreciate your feedback on it in YouTrack.

Kotlin 1.3 continues to evolve and improve scripting API, introducing some experimental support for scripts customization, such as adding external properties, providing static or dynamic dependencies, and so on.

For additional details, please consult the KEEP-75.

Scratches support

Kotlin 1.3 introduces support for runnable Kotlin scratch files. Scratch file is a kotlin script file with the .kts extension that you can run and get evaluation results directly in the editor.

Consult the general Scratches documentation for details.

What's new in Kotlin 1.2

Released: 28 November 2017

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Multiplatform projects (experimental)

Multiplatform projects are a new experimental feature in Kotlin 1.2, allowing you to reuse code between target platforms supported by Kotlin – JVM, JavaScript, and (in the future) Native. In a multiplatform project, you have three kinds of modules:

- A common module contains code that is not specific to any platform, as well as declarations without implementation of platform-dependent APIs.

- A platform module contains implementations of platform-dependent declarations in the common module for a specific platform, as well as other platform-dependent code.
- A regular module targets a specific platform and can either be a dependency of platform modules or depend on platform modules.

When you compile a multiplatform project for a specific platform, the code for both the common and platform-specific parts is generated.

A key feature of the multiplatform project support is the possibility to express dependencies of common code on platform-specific parts through expected and actual declarations. An expected declaration specifies an API (class, interface, annotation, top-level declaration etc.). An actual declaration is either a platform-dependent implementation of the API or a type alias referring to an existing implementation of the API in an external library. Here's an example:

In the common code:

```
// expected platform-specific API:
expect fun hello(world: String): String

fun greet() {
    // usage of the expected API:
    val greeting = hello("multiplatform world")
    println(greeting)
}

expect class URL(spec: String) {
    open fun getHost(): String
    open fun getPath(): String
}
```

In the JVM platform code:

```
actual fun hello(world: String): String =
    "Hello, $world, on the JVM platform!"

// using existing platform-specific implementation:
actual typealias URL = java.net.URL
```

See the multiplatform programming documentation for details and steps to build a multiplatform project.

Other language features

Array literals in annotations

Starting with Kotlin 1.2, array arguments for annotations can be passed with the new array literal syntax instead of the arrayOf function:

```
@CacheConfig(cacheNames = ["books", "default"])
public class BookRepositoryImpl {
    // ...
}
```

The array literal syntax is constrained to annotation arguments.

Lateinit top-level properties and local variables

The lateinit modifier can now be used on top-level properties and local variables. The latter can be used, for example, when a lambda passed as a constructor argument to one object refers to another object which has to be defined later:

```
class Node<T>(val value: T, val next: () -> Node<T>)

fun main(args: Array<String>) {
    // A cycle of three nodes:
    lateinit var third: Node<Int>

    val second = Node(2, next = { third })
    val first = Node(1, next = { second })

    third = Node(3, next = { first })

    val nodes = generateSequence(first) { it.next() }
    println("Values in the cycle: ${nodes.take(7).joinToString { it.value.toString() }}, ...")
}
```

Check whether a lateinit var is initialized

You can now check whether a lateinit var has been initialized using isInitialized on the property reference:

```
class Foo {
    lateinit var lateinitVar: String

    fun initializationLogic() {
        println("isInitialized before assignment: " + this::lateinitVar.isInitialized)
        lateinitVar = "value"
        println("isInitialized after assignment: " + this::lateinitVar.isInitialized)
    }
}

fun main(args: Array<String>) {
 Foo().initializationLogic()
}
```

Inline functions with default functional parameters

Inline functions are now allowed to have default values for their inlined functional parameters:

```
inline fun <E> Iterable<E>.strings(transform: (E) -> String = { it.toString() }) =
    map { transform(it) }

val defaultStrings = listOf(1, 2, 3).strings()
val customStrings = listOf(1, 2, 3).strings { "($it)" }

fun main(args: Array<String>) {
    println("defaultStrings = $defaultStrings")
    println("customStrings = $customStrings")
}
```

Information from explicit casts is used for type inference

The Kotlin compiler can now use information from type casts in type inference. If you're calling a generic method that returns a type parameter T and casting the return value to a specific type Foo, the compiler now understands that T for this call needs to be bound to the type Foo.

This is particularly important for Android developers, since the compiler can now correctly analyze generic findViewById calls in Android API level 26:

```
val button = findViewById(R.id.button) as Button
```

Smart cast improvements

When a variable is assigned from a safe call expression and checked for null, the smart cast is now applied to the safe call receiver as well:

```
fun countFirst(s: Any): Int {
    val firstChar = (s as? CharSequence)?.firstOrNull()
    if (firstChar != null)
    return s.count { it == firstChar } // s: Any is smart cast to CharSequence

    val firstItem = (s as? Iterable<*>)?.firstOrNull()
    if (firstItem != null)
    return s.count { it == firstItem } // s: Any is smart cast to Iterable<*>
    return -1
}

fun main(args: Array<String>) {
  val string = "abacaba"
  val countInString = countFirst(string)
  println("called on \"$string\": $countInString")

  val list = listOf(1, 2, 3, 1, 2)
  val countInList = countFirst(list)
  println("called on $list: $countInList")
}
```

Also, smart casts in a lambda are now allowed for local variables that are only modified before the lambda:

```
fun main(args: Array<String>) {
    val flag = args.size == 0
    var x: String? = null
    if (flag) x = "Yahoo!"

    run {
        if (x != null) {
            println(x.length) // x is smart cast to String
        }
    }
}
```

Support for ::foo as a shorthand for this::foo

A bound callable reference to a member of this can now be written without explicit receiver, ::foo instead of this::foo. This also makes callable references more convenient to use in lambdas where you refer to a member of the outer receiver.

Breaking change: sound smart casts after try blocks

Earlier, Kotlin used assignments made inside a try block for smart casts after the block, which could break type- and null-safety and lead to runtime failures. This release fixes this issue, making the smart casts more strict, but breaking some code that relied on such smart casts.

To switch to the old smart casts behavior, pass the fallback flag -Xlegacy-smart-cast-after-try as the compiler argument. It will become deprecated in Kotlin 1.3.

Deprecation: data classes overriding copy

When a data class derived from a type that already had the copy function with the same signature, the copy implementation generated for the data class used the defaults from the supertype, leading to counter-intuitive behavior, or failed at runtime if there were no default parameters in the supertype.

Inheritance that leads to a copy conflict has become deprecated with a warning in Kotlin 1.2 and will be an error in Kotlin 1.3.

Deprecation: nested types in enum entries

Inside enum entries, defining a nested type that is not an inner class has been deprecated due to issues in the initialization logic. This causes a warning in Kotlin 1.2 and will become an error in Kotlin 1.3.

Deprecation: single named argument for vararg

For consistency with array literals in annotations, passing a single item for a vararg parameter in the named form (foo(items = i)) has been deprecated. Please use the spread operator with the corresponding array factory functions:

```
foo(items = *arrayOf(1))
```

There is an optimization that removes redundant arrays creation in such cases, which prevents performance degradation. The single-argument form produces warnings in Kotlin 1.2 and is to be dropped in Kotlin 1.3.

Deprecation: inner classes of generic classes extending Throwable

Inner classes of generic types that inherit from Throwable could violate type-safety in a throw-catch scenario and thus have been deprecated, with a warning in Kotlin 1.2 and an error in Kotlin 1.3.

Deprecation: mutating backing field of a read-only property

Mutating the backing field of a read-only property by assigning field = ... in the custom getter has been deprecated, with a warning in Kotlin 1.2 and an error in Kotlin 1.3.

Standard library

Kotlin standard library artifacts and split packages

The Kotlin standard library is now fully compatible with the Java 9 module system, which forbids split packages (multiple jar files declaring classes in the same package). In order to support that, new artifacts kotlin-stdlib-jdk7 and kotlin-stdlib-jdk8 are introduced, which replace the old kotlin-stdlib-jre7 and kotlin-stdlib-jre8.

The declarations in the new artifacts are visible under the same package names from the Kotlin point of view, but have different package names for Java. Therefore, switching to the new artifacts will not require any changes to your source code.

Another change made to ensure compatibility with the new module system is removing the deprecated declarations in the kotlin.reflect package from the kotlin-reflect library. If you were using them, you need to switch to using the declarations in the kotlin.reflect.full package, which is supported since Kotlin 1.1.

windowed, chunked, zipWithNext

New extensions for Iterable<T>, Sequence<T>, and CharSequence cover such use cases as buffering or batch processing (chunked), sliding window and computing sliding average (windowed) , and processing pairs of subsequent items (zipWithNext):

```
fun main(args: Array<String>) {
    val items = (1..9).map { it * it }

    val chunkedIntoLists = items.chunked(4)
    val points3d = items.chunked(3) { (x, y, z) -> Triple(x, y, z) }
    val windowed = items.windowed(4)
    val slidingAverage = items.windowed(4) { it.average() }
    val pairwiseDifferences = items.zipWithNext { a, b -> b - a }

    println("items: $items\n")

    println("chunked into lists: $chunkedIntoLists")
    println("3D points: $points3d")
    println("windowed by 4: $windowed")
    println("sliding average by 4: $slidingAverage")
    println("pairwise differences: $pairwiseDifferences")
}
```

fill, replaceAll, shuffle/shuffled

A set of extension functions was added for manipulating lists: fill, replaceAll and shuffle for MutableList, and shuffled for read-only List:

```
fun main(args: Array<String>) {
    val items = (1..5).toMutableList()

    items.shuffle()
    println("Shuffled items: $items")

    items.replaceAll { it * 2 }
    println("Items doubled: $items")

    items.fill(5)
    println("Items filled with 5: $items")
}
```

Math operations in kotlin-stdlib

Satisfying the longstanding request, Kotlin 1.2 adds the kotlin.math API for math operations that is common for JVM and JS and contains the following:

- Constants: PI and E
- Trigonometric: cos, sin, tan and inverse of them: acos, asin, atan, atan2
- Hyperbolic: cosh, sinh, tanh and their inverse: acosh, asinh, atanh
- Exponentation: pow (an extension function), sqrt, hypot, exp, expm1
- Logarithms: log, log2, log10, ln, ln1p
- Rounding:

  - ceil, floor, truncate, round (half to even) functions
  - roundToInt, roundToLong (half to integer) extension functions
- Sign and absolute value:
  - abs and sign functions
  - absoluteValue and sign extension properties
  - withSign extension function
- max and min of two values
- Binary representation:
  - ulp extension property
  - nextUp, nextDown, nextTowards extension functions
  - toBits, toRawBits, Double.fromBits (these are in the kotlin package)

The same set of functions (but without constants) is also available for Float arguments.

Operators and conversions for BigInteger and BigDecimal

Kotlin 1.2 introduces a set of functions for operating with BigInteger and BigDecimal and creating them from other numeric types. These are:

- toBigInteger for Int and Long
- toBigDecimal for Int, Long, Float, Double, and BigInteger
- Arithmetic and bitwise operator functions:
  - Binary operators +, -, *, /, % and infix functions and, or, xor, shl, shr
  - Unary operators -, ++, --, and a function inv

Floating point to bits conversions

New functions were added for converting Double and Float to and from their bit representations:

- toBits and toRawBits returning Long for Double and Int for Float
- Double.fromBits and Float.fromBits for creating floating point numbers from the bit representation

Regex is now serializable

The kotlin.text.Regex class has become Serializable and can now be used in serializable hierarchies.

Closeable.use calls Throwable.addSuppressed if available

The Closeable.use function calls Throwable.addSuppressed when an exception is thrown during closing the resource after some other exception.

To enable this behavior you need to have kotlin-stdlib-jdk7 in your dependencies.

JVM backend

Constructor calls normalization

Ever since version 1.0, Kotlin supported expressions with complex control flow, such as try-catch expressions and inline function calls. Such code is valid according to the Java Virtual Machine specification. Unfortunately, some bytecode processing tools do not handle such code quite well when such expressions are present in the arguments of constructor calls.

To mitigate this problem for the users of such bytecode processing tools, we've added a command-line compiler option (-Xnormalize-constructor-calls=MODE) that tells the compiler to generate more Java-like bytecode for such constructs. Here MODE is one of:

- disable (default) – generate bytecode in the same way as in Kotlin 1.0 and 1.1.
- enable – generate Java-like bytecode for constructor calls. This can change the order in which the classes are loaded and initialized.
- preserve-class-initialization – generate Java-like bytecode for constructor calls, ensuring that the class initialization order is preserved. This can affect overall performance of your application; use it only if you have some complex state shared between multiple classes and updated on class initialization.

The "manual" workaround is to store the values of sub-expressions with control flow in variables, instead of evaluating them directly inside the call arguments. It's similar to -Xnormalize-constructor-calls=enable.

Java-default method calls

Before Kotlin 1.2, interface members overriding Java-default methods while targeting JVM 1.6 produced a warning on super calls: Super calls to Java default methods are deprecated in JVM target 1.6. Recompile with '-jvm-target 1.8'. In Kotlin 1.2, there's an error instead, thus requiring any such code to be compiled with JVM target 1.8.

Breaking change: consistent behavior of x.equals(null) for platform types

Calling x.equals(null) on a platform type that is mapped to a Java primitive (Int!, Boolean!, Short!, Long!, Float!, Double!, Char!) incorrectly returned true when x was null. Starting with Kotlin 1.2, calling x.equals(...) on a null value of a platform type throws an NPE (but x == ... does not).

To return to the pre-1.2 behavior, pass the flag -Xno-exception-on-explicit-equals-for-boxed-null to the compiler.

Breaking change: fix for platform null escaping through an inlined extension receiver

Inline extension functions that were called on a null value of a platform type did not check the receiver for null and would thus allow null to escape into the other code. Kotlin 1.2 forces this check at the call sites, throwing an exception if the receiver is null.

To switch to the old behavior, pass the fallback flag -Xno-receiver-assertions to the compiler.

JavaScript backend

TypedArrays support enabled by default

The JS typed arrays support that translates Kotlin primitive arrays, such as IntArray, DoubleArray, into JavaScript typed arrays, that was previously an opt-in feature, has been enabled by default.

Tools

Warnings as errors

The compiler now provides an option to treat all warnings as errors. Use -Werror on the command line, or the following Gradle snippet:

```
compileKotlin {
    kotlinOptions.allWarningsAsErrors = true
}
```

What's new in Kotlin 1.1

Released: 15 February 2016

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- Standard library
- JVM backend
- JavaScript backend

JavaScript

Starting with Kotlin 1.1, the JavaScript target is no longer considered experimental. All language features are supported, and there are many new tools for integration with the frontend development environment. See below for a more detailed list of changes.

Coroutines (experimental)

The key new feature in Kotlin 1.1 is coroutines, bringing the support of async/await, yield, and similar programming patterns. The key feature of Kotlin's design is that the implementation of coroutine execution is part of the libraries, not the language, so you aren't bound to any specific programming paradigm or concurrency library.

A coroutine is effectively a light-weight thread that can be suspended and resumed later. Coroutines are supported through suspending functions: a call to such a function can potentially suspend a coroutine, and to start a new coroutine we usually use an anonymous suspending functions (i.e. suspending lambdas).

Let's look at async/await which is implemented in an external library, kotlinx.coroutines:

```
// runs the code in the background thread pool
fun asyncOverlay() = async(CommonPool) {
    // start two async operations
    val original = asyncLoadImage("original")
    val overlay = asyncLoadImage("overlay")
    // and then apply overlay to both results
    applyOverlay(original.await(), overlay.await())
}

// launches new coroutine in UI context
launch(UI) {
    // wait for async overlay to complete
    val image = asyncOverlay().await()
    // and then show it in UI
    showImage(image)
}
```

Here, async { ... } starts a coroutine and, when we use await(), the execution of the coroutine is suspended while the operation being awaited is executed, and is resumed (possibly on a different thread) when the operation being awaited completes.

The standard library uses coroutines to support lazily generated sequences with yield and yieldAll functions. In such a sequence, the block of code that returns sequence elements is suspended after each element has been retrieved, and resumed when the next element is requested. Here's an example:

```
import kotlin.coroutines.experimental.*

fun main(args: Array<String>) {
    val seq = buildSequence {
      for (i in 1..5) {
          // yield a square of i
          yield(i * i)
      }
      // yield a range
      yieldAll(26..28)
    }

    // print the sequence
    println(seq.toList())
}
```

Run the code above to see the result. Feel free to edit it and run again!

For more information, please refer to the coroutines documentation and tutorial.

Note that coroutines are currently considered an experimental feature, meaning that the Kotlin team is not committing to supporting the backwards compatibility of this feature after the final 1.1 release.

Other language features

Type aliases

A type alias allows you to define an alternative name for an existing type. This is most useful for generic types such as collections, as well as for function types. Here is an example:

```
typealias OscarWinners = Map<String, String>

fun countLaLaLand(oscarWinners: OscarWinners) =
        oscarWinners.count { it.value.contains("La La Land") }

// Note that the type names (initial and the type alias) are interchangeable:
fun checkLaLaLandIsTheBestMovie(oscarWinners: Map<String, String>) =
        oscarWinners["Best picture"] == "La La Land"

fun oscarWinners(): OscarWinners {
    return mapOf(
            "Best song" to "City of Stars (La La Land)",
            "Best actress" to "Emma Stone (La La Land)",
            "Best picture" to "Moonlight" /* ... */)
}

fun main(args: Array<String>) {
    val oscarWinners = oscarWinners()

    val laLaLandAwards = countLaLaLand(oscarWinners)
    println("LaLaLandAwards = $laLaLandAwards (in our small example), but actually it's 6.")

    val laLaLandIsTheBestMovie = checkLaLaLandIsTheBestMovie(oscarWinners)
    println("LaLaLandIsTheBestMovie = $laLaLandIsTheBestMovie")
}
```

See the type aliases documentation and KEEP for more details.

Bound callable references

You can now use the :: operator to get a member reference pointing to a method or property of a specific object instance. Previously this could only be expressed with a lambda. Here's an example:

```
val numberRegex = "\\d+".toRegex()
val numbers = listOf("abc", "123", "456").filter(numberRegex::matches)

fun main(args: Array<String>) {
    println("Result is $numbers")
}
```

Read the documentation and KEEP for more details.

Sealed and data classes

Kotlin 1.1 removes some of the restrictions on sealed and data classes that were present in Kotlin 1.0. Now you can define subclasses of a top-level sealed class on the top level in the same file, and not just as nested classes of the sealed class. Data classes can now extend other classes. This can be used to define a hierarchy of expression classes nicely and cleanly:

```
sealed class Expr

data class Const(val number: Double) : Expr()
data class Sum(val e1: Expr, val e2: Expr) : Expr()
object NotANumber : Expr()

fun eval(expr: Expr): Double = when (expr) {
    is Const -> expr.number
    is Sum -> eval(expr.e1) + eval(expr.e2)
    NotANumber -> Double.NaN
}
val e = eval(Sum(Const(1.0), Const(2.0)))

fun main(args: Array<String>) {
    println("e is $e") // 3.0
}
```

Read the sealed classes documentation or KEEPs for sealed class and data class for more detail.

Destructuring in lambdas

You can now use the destructuring declaration syntax to unpack the arguments passed to a lambda. Here's an example:

```
fun main(args: Array<String>) {
    val map = mapOf(1 to "one", 2 to "two")
    // before
    println(map.mapValues { entry ->
      val (key, value) = entry
      "$key -> $value!"
    })
    // now
    println(map.mapValues { (key, value) -> "$key -> $value!" })
}
```

Read the destructuring declarations documentation and KEEP for more details.

Underscores for unused parameters

For a lambda with multiple parameters, you can use the _ character to replace the names of the parameters you don't use:

```
fun main(args: Array<String>) {
    val map = mapOf(1 to "one", 2 to "two")

    map.forEach { _, value -> println("$value!") }
}
```

This also works in destructuring declarations:

```
data class Result(val value: Any, val status: String)

fun getResult() = Result(42, "ok").also { println("getResult() returns $it") }

fun main(args: Array<String>) {
    val (_, status) = getResult()
    println("status is '$status'")
}
```

Read the KEEP for more details.

Underscores in numeric literals

Just as in Java 8, Kotlin now allows to use underscores in numeric literals to separate groups of digits:

```
val oneMillion = 1_000_000
val hexBytes = 0xFF_EC_DE_5E
val bytes = 0b11010010_01101001_10010100_10010010

fun main(args: Array<String>) {
    println(oneMillion)
    println(hexBytes.toString(16))
    println(bytes.toString(2))
}
```

Read the KEEP for more details.

Shorter syntax for properties

For properties with the getter defined as an expression body, the property type can now be omitted:

```
    data class Person(val name: String, val age: Int) {
    val isAdult get() = age >= 20 // Property type inferred to be 'Boolean'
```

```
}
fun main(args: Array<String>) {
    val akari = Person("Akari", 26)
    println("$akari.isAdult = ${akari.isAdult}")
}
```

Inline property accessors

You can now mark property accessors with the inline modifier if the properties don't have a backing field. Such accessors are compiled in the same way as inline functions.

```
public val <T> List<T>.lastIndex: Int
    inline get() = this.size - 1

fun main(args: Array<String>) {
    val list = listOf('a', 'b')
    // the getter will be inlined
    println("Last index of $list is ${list.lastIndex}")
}
```

You can also mark the entire property as inline - then the modifier is applied to both accessors.

Read the inline functions documentation and KEEP for more details.

Local delegated properties

You can now use the delegated property syntax with local variables. One possible use is defining a lazily evaluated local variable:

```
import java.util.Random

fun needAnswer() = Random().nextBoolean()

fun main(args: Array<String>) {
    val answer by lazy {
        println("Calculating the answer...")
        42
    }
    if (needAnswer()) {                     // returns the random value
        println("The answer is $answer.")   // answer is calculated at this point
    }
    else {
        println("Sometimes no answer is the answer...")
    }
}
```

Read the KEEP for more details.

Interception of delegated property binding

For delegated properties, it is now possible to intercept delegate to property binding using the provideDelegate operator. For example, if we want to check the property name before binding, we can write something like this:

```
class ResourceLoader<T>(id: ResourceID<T>) {
    operator fun provideDelegate(thisRef: MyUI, prop: KProperty<*>): ReadOnlyProperty<MyUI, T> {
        checkProperty(thisRef, prop.name)
        ... // property creation
    }

    private fun checkProperty(thisRef: MyUI, name: String) { ... }
}

fun <T> bindResource(id: ResourceID<T>): ResourceLoader<T> { ... }

class MyUI {
    val image by bindResource(ResourceID.image_id)
    val text by bindResource(ResourceID.text_id)
}
```

The provideDelegate method will be called for each property during the creation of a MyUI instance, and it can perform the necessary validation right away.

Read the delegated properties documentation for more details.

Generic enum value access

It is now possible to enumerate the values of an enum class in a generic way.

```
enum class RGB { RED, GREEN, BLUE }

inline fun <reified T : Enum<T>> printAllValues() {
    print(enumValues<T>().joinToString { it.name })
}

fun main(args: Array<String>) {
    printAllValues<RGB>() // prints RED, GREEN, BLUE
}
```

Scope control for implicit receivers in DSLs

The @DslMarker annotation allows to restrict the use of receivers from outer scopes in a DSL context. Consider the canonical HTML builder example:

```
table {
    tr {
        td { + "Text" }
    }
}
```

In Kotlin 1.0, code in the lambda passed to td has access to three implicit receivers: the one passed to table, to tr and to td. This allows you to call methods that make no sense in the context - for example to call tr inside td and thus to put a <tr> tag in a <td>.

In Kotlin 1.1, you can restrict that, so that only methods defined on the implicit receiver of td will be available inside the lambda passed to td. You do that by defining your annotation marked with the @DslMarker meta-annotation and applying it to the base class of the tag classes.

Read the type safe builders documentation and KEEP for more details.

rem operator

The mod operator is now deprecated, and rem is used instead. See this issue for motivation.

Standard library

String to number conversions

There is a bunch of new extensions on the String class to convert it to a number without throwing an exception on invalid number: String.toIntOrNull(): Int?, String.toDoubleOrNull(): Double? etc.

```
val port = System.getenv("PORT")?.toIntOrNull() ?: 80
```

Also integer conversion functions, like Int.toString(), String.toInt(), String.toIntOrNull(), each got an overload with radix parameter, which allows to specify the base of conversion (2 to 36).

onEach()

onEach is a small, but useful extension function for collections and sequences, which allows to perform some action, possibly with side-effects, on each element of the collection/sequence in a chain of operations. On iterables it behaves like forEach but also returns the iterable instance further. And on sequences it returns a wrapping sequence, which applies the given action lazily as the elements are being iterated.

```
inputDir.walk()
        .filter { it.isFile && it.name.endsWith(".txt") }
        .onEach { println("Moving $it to $outputDir") }
        .forEach { moveFile(it, File(outputDir, it.toRelativeString(inputDir))) }
```

also(), takeIf(), and takeUnless()

These are three general-purpose extension functions applicable to any receiver.

also is like apply: it takes the receiver, does some action on it, and returns that receiver. The difference is that in the block inside apply the receiver is available as this, while in the block inside also it's available as it (and you can give it another name if you want). This comes handy when you do not want to shadow this from the outer scope:

```
class Block {
    lateinit var content: String
}

fun Block.copy() = Block().also {
    it.content = this.content
}

// using 'apply' instead
fun Block.copy1() = Block().apply {
    this.content = this@copy1.content
}

fun main(args: Array<String>) {
    val block = Block().apply { content = "content" }
    val copy = block.copy()
    println("Testing the content was copied:")
    println(block.content == copy.content)
}
```

takeIf is like filter for a single value. It checks whether the receiver meets the predicate, and returns the receiver, if it does or null if it doesn't. Combined with an elvis operator (?:) and early returns it allows writing constructs like:

```
val outDirFile = File(outputDir.path).takeIf { it.exists() } ?: return false
// do something with existing outDirFile
```

```
fun main(args: Array<String>) {
    val input = "Kotlin"
    val keyword = "in"

    val index = input.indexOf(keyword).takeIf { it >= 0 } ?: error("keyword not found")
    // do something with index of keyword in input string, given that it's found

    println("'$keyword' was found in '$input'")
    println(input)
    println(" ".repeat(index) + "^")
}
```

takeUnless is the same as takeIf, but it takes the inverted predicate. It returns the receiver when it doesn't meet the predicate and null otherwise. So one of the examples above could be rewritten with takeUnless as following:

```
val index = input.indexOf(keyword).takeUnless { it < 0 } ?: error("keyword not found")
```

It is also convenient to use when you have a callable reference instead of the lambda:

```
private fun testTakeUnless(string: String) {
    val result = string.takeUnless(String::isEmpty)

    println("string = \"$string\"; result = \"$result\"")
}

fun main(args: Array<String>) {
    testTakeUnless("")
    testTakeUnless("abc")
}
```

groupingBy()

This API can be used to group a collection by key and fold each group simultaneously. For example, it can be used to count the number of words starting with each letter:

```
fun main(args: Array<String>) {
    val words = "one two three four five six seven eight nine ten".split(' ')
    val frequencies = words.groupingBy { it.first() }.eachCount()
    println("Counting first letters: $frequencies.")

    // The alternative way that uses 'groupBy' and 'mapValues' creates an intermediate map,
    // while 'groupingBy' way counts on the fly.
    val groupBy = words.groupBy { it.first() }.mapValues { (_, list) -> list.size }
    println("Comparing the result with using 'groupBy': ${groupBy == frequencies}.")
}
```

Map.toMap() and Map.toMutableMap()

These functions can be used for easy copying of maps:

```
class ImmutablePropertyBag(map: Map<String, Any>) {
    private val mapCopy = map.toMap()
}
```

Map.minus(key)

The operator plus provides a way to add key-value pair(s) to a read-only map producing a new map, however there was not a simple way to do the opposite: to remove a key from the map you have to resort to less straightforward ways to like Map.filter() or Map.filterKeys(). Now the operator minus fills this gap. There are 4 overloads available: for removing a single key, a collection of keys, a sequence of keys and an array of keys.

```
fun main(args: Array<String>) {
    val map = mapOf("key" to 42)
    val emptyMap = map - "key"

    println("map: $map")
    println("emptyMap: $emptyMap")
}
```

minOf() and maxOf()

These functions can be used to find the lowest and greatest of two or three given values, where values are primitive numbers or Comparable objects. There is also an overload of each function that take an additional Comparator instance if you want to compare objects that are not comparable themselves.

```
fun main(args: Array<String>) {
    val list1 = listOf("a", "b")
    val list2 = listOf("x", "y", "z")
    val minSize = minOf(list1.size, list2.size)
    val longestList = maxOf(list1, list2, compareBy { it.size })

    println("minSize = $minSize")
    println("longestList = $longestList")
}
```

Array-like List instantiation functions

Similar to the Array constructor, there are now functions that create List and MutableList instances and initialize each element by calling a lambda:

```
fun main(args: Array<String>) {
    val squares = List(10) { index -> index * index }
    val mutable = MutableList(10) { 0 }

    println("squares: $squares")
    println("mutable: $mutable")
}
```

Map.getValue()

This extension on Map returns an existing value corresponding to the given key or throws an exception, mentioning which key was not found. If the map was produced with withDefault, this function will return the default value instead of throwing an exception.

```
fun main(args: Array<String>) {
//sampleStart
    val map = mapOf("key" to 42)
    // returns non-nullable Int value 42
    val value: Int = map.getValue("key")

    val mapWithDefault = map.withDefault { k -> k.length }
    // returns 4
    val value2 = mapWithDefault.getValue("key2")

    // map.getValue("anotherKey") // <- this will throw NoSuchElementException

    println("value is $value")
    println("value2 is $value2")
}
```

Abstract collections

These abstract classes can be used as base classes when implementing Kotlin collection classes. For implementing read-only collections there are AbstractCollection, AbstractList, AbstractSet and AbstractMap, and for mutable collections there are AbstractMutableCollection, AbstractMutableList, AbstractMutableSet and AbstractMutableMap. On JVM, these abstract mutable collections inherit most of their functionality from JDK's abstract collections.

Array manipulation functions

The standard library now provides a set of functions for element-by-element operations on arrays: comparison (contentEquals and contentDeepEquals), hash code calculation (contentHashCode and contentDeepHashCode), and conversion to a string (contentToString and contentDeepToString). They're supported both for the JVM (where they act as aliases for the corresponding functions in java.util.Arrays) and for JS (where the implementation is provided in the Kotlin standard library).

```
fun main(args: Array<String>) {
    val array = arrayOf("a", "b", "c")
    println(array.toString())  // JVM implementation: type-and-hash gibberish
    println(array.contentToString())  // nicely formatted as list
}
```

JVM Backend

Java 8 bytecode support

Kotlin has now the option of generating Java 8 bytecode (-jvm-target 1.8 command line option or the corresponding options in Ant/Maven/Gradle). For now this doesn't change the semantics of the bytecode (in particular, default methods in interfaces and lambdas are generated exactly as in Kotlin 1.0), but we plan to make further use of this later.

Java 8 standard library support

There are now separate versions of the standard library supporting the new JDK APIs added in Java 7 and 8. If you need access to the new APIs, use kotlin-stdlib-jre7 and kotlin-stdlib-jre8 maven artifacts instead of the standard kotlin-stdlib. These artifacts are tiny extensions on top of kotlin-stdlib and they bring it to your project as a transitive dependency.

Parameter names in the bytecode

Kotlin now supports storing parameter names in the bytecode. This can be enabled using the -java-parameters command line option.

Constant inlining

The compiler now inlines values of const val properties into the locations where they are used.

Mutable closure variables

The box classes used for capturing mutable closure variables in lambdas no longer have volatile fields. This change improves performance, but can lead to new race conditions in some rare usage scenarios. If you're affected by this, you need to provide your own synchronization for accessing the variables.

javax.script support

Kotlin now integrates with the javax.script API (JSR-223). The API allows to evaluate snippets of code at runtime:

```
val engine = ScriptEngineManager().getEngineByExtension("kts")!!
engine.eval("val x = 3")
println(engine.eval("x + 2"))  // Prints out 5
```

See here for a larger example project using the API.

kotlin.reflect.full

To prepare for Java 9 support, the extension functions and properties in the kotlin-reflect.jar library have been moved to the package kotlin.reflect.full. The names in the old package (kotlin.reflect) are deprecated and will be removed in Kotlin 1.2. Note that the core reflection interfaces (such as KClass) are part of the Kotlin standard library, not kotlin-reflect, and are not affected by the move.

JavaScript backend

Unified standard library

A much larger part of the Kotlin standard library can now be used from code compiled to JavaScript. In particular, key classes such as collections (ArrayList, HashMap etc.), exceptions (IllegalArgumentException etc.) and a few others (StringBuilder, Comparator) are now defined under the kotlin package. On the JVM, the names are type aliases for the corresponding JDK classes, and on the JS, the classes are implemented in the Kotlin standard library.

Better code generation

JavaScript backend now generates more statically checkable code, which is friendlier to JS code processing tools, like minifiers, optimisers, linters, etc.

The external modifier

If you need to access a class implemented in JavaScript from Kotlin in a typesafe way, you can write a Kotlin declaration using the external modifier. (In Kotlin 1.0, the @native annotation was used instead.) Unlike the JVM target, the JS one permits to use external modifier with classes and properties. For example, here's how you can declare the DOM Node class:

```
external class Node {
    val firstChild: Node

    fun appendChild(child: Node): Node

    fun removeChild(child: Node): Node

    // etc
}
```

Improved import handling

You can now describe declarations which should be imported from JavaScript modules more precisely. If you add the @JsModule("<module-name>") annotation on an external declaration it will be properly imported to a module system (either CommonJS or AMD) during the compilation. For example, with CommonJS the declaration will be imported via require(...) function. Additionally, if you want to import a declaration either as a module or as a global JavaScript object, you can use the @JsNonModule annotation.

For example, here's how you can import JQuery into a Kotlin module:

```
external interface JQuery {
    fun toggle(duration: Int = definedExternally): JQuery
    fun click(handler: (Event) -> Unit): JQuery
}

@JsModule("jquery")
@JsNonModule
```

```kotlin
@JsName("$")
external fun jquery(selector: String): JQuery
```

In this case, JQuery will be imported as a module named jquery. Alternatively, it can be used as a $-object, depending on what module system Kotlin compiler is configured to use.

You can use these declarations in your application like this:

```kotlin
fun main(args: Array<String>) {
    jquery(".toggle-button").click {
        jquery(".toggle-panel").toggle(300)
    }
}
```

Kotlin roadmap

Last modified on	February 2025
Next update	August 2025

Welcome to the Kotlin roadmap! Get a sneak peek into the priorities of the JetBrains Team.

Key priorities

The goal of this roadmap is to give you the big picture. Here's a list of our key focus areas – the most important directions we are focused on delivering:

- Language evolution: more efficient data handling, increased abstraction, enhanced performance with clear code.
- Kotlin Multiplatform: release direct Kotlin to Swift Export, streamlined build setup, and simplified creation of multiplatform libraries.
- Experience of third-party ecosystem authors: simplified development and publication process for Kotlin libraries, tools, and frameworks.

Kotlin roadmap by subsystem

If you have any questions or feedback about the roadmap or the items on it, feel free to post them to YouTrack tickets or in the #kotlin-roadmap channel of Kotlin Slack (request an invite).

Subsystem	In focus now
Language	See the full list of Kotlin language features and proposals or follow the YouTrack issue for upcoming language features
Compiler	• Finalize JSpecify support • Deprecate K1 compiler • Promote Kotlin/Wasm (wasm-js target) to Beta • Kotlin/Wasm: Switch wasm-wasi target of libraries to WASI Preview 2 • Kotlin/Wasm: Support Component Model

Subsystem	In focus now
Multiplatform	• The first public release of Swift Export • Enable Concurrent Mark and Sweep (CMS) GC by default • Stabilize klib cross-compilation on different platforms • Implement the next generation distribution format of multiplatform libraries • Support declaring Kotlin Multiplatform dependencies at project-level • Unify inline semantics between all Kotlin targets • Enable incremental compilation of klib artifacts by default Kotlin Multiplatform development roadmap
Tooling	• Improve development experience for Kotlin/Wasm projects in IntelliJ IDEA • Improve performance of imports • Support resources in XCFrameworks • Kotlin Notebook: Smoother access and improved experience • IntelliJ IDEA K2 mode complete release • Design the Build Tools API • Kotlin Ecosystem Plugin supporting Declarative Gradle • Support Gradle project isolation • Improve integration of Kotlin/Native toolchain into Gradle • Improve Kotlin build reports • Expose stable compiler arguments in Gradle DSL • Improve Kotlin scripting and experience with .gradle.kts

Subsystem	In focus now
Library ecosystem	Library ecosystem roadmap items: • Refine the Dokka HTML output UI • Introduce default warnings/errors for Kotlin functions that return non-unit values that are unused • New multiplatform API for the standard library: Support for Unicode and codepoints • Stabilize the kotlinx-io library • Improve Kotlin distribution UX: add code coverage and binary compatibility validation • Promote kotlinx-datetime to Beta Ktor: • Add gRPC support to Ktor with a generator plugin and tutorial • Make project structuring for the backend applications simple • Publish CLI generator to SNAP • Create Kubernetes Generator Plugin • Make Dependency Injection Usage Simple • HTTP/3 Support Exposed: • Release 1.0.0 • Add R2DBC Support

- This roadmap is not an exhaustive list of all things the team is working on, only the biggest projects.
- There's no commitment to delivering specific features or fixes in specific versions.
- We will adjust our priorities as we go and update the roadmap approximately every six months.

What's changed since September 2024

Completed items

We've completed the following items from the previous roadmap:

- Compiler: Support debugging inline functions on Android
- Compiler: Improve the quality of compiler diagnostics
- Multiplatform: Support Xcode 16 in Kotlin
- Multiplatform: Publish publicly available API reference for Kotlin Gradle Plugin
- Tooling: Provide out-of-the-box debugging experience for Kotlin/Wasm targets
- Library ecosystem: Implement new Dokka Gradle plugin based on Dokkatoo
- Library ecosystem: New multiplatform API for the standard library: Atomics
- Library ecosystem: Expand Library authors' guidelines

New items

We've added the following items to the roadmap:

- Compiler: Finalize JSpecify support
- Compiler: Deprecate K1 compiler
- Compiler: Promote Kotlin/Wasm (wasm-js target) to Beta
- Tooling: Improve development experience for Kotlin/Wasm projects in IntelliJ IDEA
- Tooling: Improve performance of imports
- Tooling: Support resources in XCFrameworks
- Tooling: Smoother access and improved experience in Kotlin Notebook
- Ktor: Add gRPC support to Ktor with a generator plugin and tutorial
- Ktor: Make project structuring for the backend applications simple
- Ktor: Publish CLI generator to SNAP
- Ktor: Create Kubernetes Generator Plugin
- Ktor: Make Dependency Injection Usage Simple
- Ktor: HTTP/3 Support
- Exposed: Release 1.0.0
- Exposed: Add R2DBC Support

Items in progress

All other previously identified roadmap items are in progress. You can check their YouTrack tickets for updates.

Kotlin language features and proposals

JetBrains evolves the Kotlin language according to the Kotlin language evolution principles, guided by pragmatic design.

> Language feature proposals are listed from Kotlin 1.7.0.
>
> See the explanation of language feature statuses in the Kotlin evolution principles documentation.

All

Exploration and design

Rich Errors: Error union types

- KEEP proposal: Not defined
- YouTrack issue: KT-68296

Exploration and design

Name-based destructuring

- KEEP proposal: Not defined
- YouTrack issue: KT-19627

Exploration and design

Support immutability

- KEEP notes: immutability
- YouTrack issue: KT-77734

KEEP discussion	Kotlin statics and static extensions • KEEP proposal: statics.md • YouTrack issue: KT-11968
KEEP discussion	Collection literals • KEEP proposal: collection-literals.md • YouTrack issue: KT-43871
KEEP discussion	Explicit backing fields • KEEP proposal: explicit-backing-fields.md • YouTrack issue: KT-14663
KEEP discussion	Version overloading • KEEP proposal: version-overloading.md
KEEP discussion	Unused return value checker • KEEP proposal: unused-return-value-checker.md • YouTrack issue: KT-12719
KEEP discussion	Streamline KDoc ambiguity links • KEEP proposal: streamline-KDoc-ambiguity-references.md • GitHub issues: dokka/#3451, dokka/#3179, dokka/#3334
KEEP discussion	Resolution of links to extensions in KDoc • KEEP proposal: links-to-extensions.md • GitHub issue: dokka/#3555
In preview	Context parameters: support for context-dependent declarations • KEEP proposal: context-parameters.md • YouTrack issue: KT-14663 • Available since: 2.2.0
In preview	Improvements to annotation use-site targets on properties • KEEP proposal: Improvements to annotation use-site targets on properties • YouTrack issue: KT-19289 • Available since: 2.2.0
In preview	Nested (non-capturing) type aliases • KEEP proposal: Nested (non-capturing) type aliases • YouTrack issue: KT-45285 • Available since: 2.2.0

In preview	Context-sensitive resolution • KEEP proposal: context-sensitive-resolution.md • YouTrack issue: KT-16768 • Available since: 2.2.0
In preview	Expose boxed inline value classes in JVM • KEEP proposal: jvm-expose-boxed.md • YouTrack issue: KT-28135 • Available since: 2.2.0
In preview	kotlin.time.Instant • KEEP proposal: Instant and Clock • Available since: 2.1.0
In preview	Uuid • KEEP proposal: uuid.md • YouTrack issue: KT-31880 • Available since: 2.0.20
In preview	Common Atomics and Atomic Arrays • KEEP proposal: Common atomics • YouTrack issue: KT-62423 • Available since: 2.2.0
In preview	KMP Kotlin-to-Java direct actualization • KEEP proposal: kmp-kotlin-to-java-direct-actualization.md • YouTrack issue: KT-67202 • Available since: 2.1.0
Stable	Guard conditions in when-with-subject • KEEP proposal: guards.md • YouTrack issue: KT-13626 • Available since: 2.2.0
Stable	Multidollar interpolation: improved handling of $ in string literals • KEEP proposal: dollar-escape.md • YouTrack issue: KT-2425 • Available since: 2.2.0
Stable	Non-local break and continue • KEEP proposal: break-continue-in-inline-lambdas.md • YouTrack issue: KT-1436 • Available since: 2.2.0

Stable	Stabilized @SubclassOptInRequired • KEEP proposal: subclass-opt-in-required.md • YouTrack issue: KT-54617 • Available since: 2.1.0
Stable	Enum.entries: performant replacement of the Enum.values() • KEEP proposal: enum-entries.md • YouTrack issue: KT-48872 • Target version: 2.0.0
Stable	Data objects • KEEP proposal: data-objects.md • YouTrack issue: KT-4107 • Target version: 1.9.0
Stable	RangeUntil operator ..< • KEEP proposal: open-ended-ranges.md • YouTrack issue: KT-15613 • Target version: 1.7.20
Stable	Definitely non-nullable types • KEEP proposal: definitely-non-nullable-types.md • YouTrack issue: KT-26245 • Target version: 1.7.0
Revoked	Context receivers • KEEP proposal: context-receivers.md • YouTrack issue: KT-10468 • Replaced with context-parameters.md
Revoked	Java synthetic property references • KEEP proposal: references-to-java-synthetic-properties.md • YouTrack issue: KT-8575
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Revoked	Java synthetic property references • KEEP proposal: references-to-java-synthetic-properties.md • YouTrack issue: KT-8575

Kotlin evolution principles

Principles of pragmatic evolution

> Language design is cast in stone,
>
> but this stone is reasonably soft,
>
> and with some effort we can reshape it later.
>
> Kotlin Design Team

Kotlin is designed to be a pragmatic tool for programmers. When it comes to language evolution, its pragmatic nature is captured by the following principles:

- Keep the language modern over time.
- Maintain a continuous feedback loop with users.
- Make updating to new versions easy and comfortable for the users.

As this is key to understanding how Kotlin is moving forward, let's expand on these principles.

Keeping the Language Modern. We recognize that systems accumulate legacy over time. What was once been cutting-edge technology can become hopelessly outdated today. We have to evolve the language to keep it relevant to the needs of our users and up-to-date with their expectations. This includes not only adding new features, but also phasing out old ones that are no longer recommended for production use and have become legacy.

Comfortable Updates. Incompatible changes, such as removing things from a language, may lead to painful migration from one version to the next if carried out without proper care. We will always announce such changes well in advance, mark things as deprecated and provide automated migration tools before the change happens. By the time the language changes we want most of the code in the world to be already updated and thus have no issues migrating to the new version.

Feedback Loop. Going through deprecation cycles requires significant effort, so we want to minimize the number of incompatible changes we'll be making in the future. Apart from using our best judgement, we believe that trying things out in real life is the best way to validate a design. Before casting things in stone we want them battle-tested. This is why we use every opportunity to make early versions of our designs available in production versions of the language, but in one of the pre-stable statuses: Experimental, Alpha, or Beta. Such features are not stable, they can be changed at any time, and the users that opt into using them do so explicitly to indicate that they are ready to deal with the future migration issues. These users provide invaluable feedback that we gather to iterate on the design and make it rock-solid.

Incompatible changes

If, upon updating from one version to another, some code that used to work doesn't work anymore, it is an incompatible change in the language (sometimes referred to as a "breaking change"). There can be debates as to what "doesn't work anymore" means precisely in some cases, but it definitely includes the following:

- Code that compiled and ran fine is now rejected with an error (at compile or link time). This includes removing language constructs and adding new restrictions.
- Code that executed normally is now throwing an exception.

The less obvious cases that belong to the "gray area" include handling corner cases differently, throwing an exception of a different type than before, changing behavior observable only through reflection, modifying undocumented or undefined behavior, renaming binary artifacts, and others. Sometimes such changes are crucial and affect migration experience dramatically, sometimes they are insignificant.

Some examples of what definitely isn't an incompatible change include:

- Adding new warnings.
- Enabling new language constructs or relaxing limitations for existing ones.
- Changing private/internal APIs and other implementation details.

The principles of Keeping the Language Modern and Comfortable Updates suggest that incompatible changes are sometimes necessary, but they should be introduced carefully. Our goal is to make users aware of upcoming changes well in advance to let them migrate their code comfortably.

Ideally, every incompatible change should be announced through a compile-time warning reported in the problematic code (usually referred to as a deprecation warning) and accompanied by automated migration aids. So, the ideal migration workflow is as follows:

- Update to version A (where the change is announced)
  - See warnings about the upcoming change
  - Migrate the code with help from tools
- Update to version B (where the change happens)
  - See no issues at all

In practice, some changes can't be accurately detected at compile time, so no warnings can be reported, but at least the users will be notified through the release notes of version A that a change is coming in version B.

Dealing with compiler bugs

Compilers are complicated software, and despite the best efforts of their developers, they have bugs. The bugs that cause the compiler itself to fail or report spurious errors or generate obviously failing code, though annoying and often embarrassing, are easy to fix, because the fixes do not constitute incompatible changes. Other bugs may cause the compiler to generate incorrect code that does not fail: for example, by missing some errors in the source or simply generating the wrong instructions. Fixes for such bugs are technically incompatible changes (some code used to compile fine, but now it won't anymore), but we are inclined to fix them as soon as possible to prevent the bad code patterns from spreading across user code. In our opinion, this supports the principle of Comfortable Updates, because fewer users have a chance of encountering the issue. Of course, this applies only to bugs that are found soon after appearing in a released version.

Decision making

JetBrains, the original creator of Kotlin, is driving its progress with the help of the community and in collaboration with the Kotlin Foundation.

All changes to the Kotlin Programming Language are overseen by the Lead Language Designer (currently Michail Zarečenskij). The Lead Designer has the final say in all matters related to language evolution. Additionally, incompatible changes to fully stable components have to be approved by the Language Committee, designated under the Kotlin Foundation (currently comprising Jeffrey van Gogh, Werner Dietl, and Michail Zarečenskij).

The Language Committee makes final decisions on which incompatible changes will be made and what exact measures should be taken to make user updates as seamless as possible. In doing so, it relies on a set of Language committee guidelines.

Language and tooling releases

Stable releases with versions, such as 2.0.0, are usually considered to be language releases bringing major changes in the language. Normally, we publish tooling releases, numbered x.x. 20 in between language releases.

Tooling releases bring updates in the tooling (often including features), performance improvements, and bug fixes. We try to keep such versions compatible with each other, so changes to the compiler are mostly optimizations and warning additions/removals. Pre-stable features may be added, removed, or changed at any time.

Language releases often add new features and may remove or change previously deprecated ones. Feature graduation from pre-stable to stable also happens in language releases.

EAP builds

Before releasing stable versions of language and tooling releases, we publish a number of preview builds dubbed EAP (for "Early Access Preview") that let us iterate faster and gather feedback from the community. EAPs of language releases usually produce binaries that will be later rejected by the stable compiler to make sure that possible bugs in the binary format survive no longer than the preview period. Final Release Candidates normally do not bear this limitation.

Pre-stable features

According to the Feedback Loop principle described above, we iterate on our designs in the open and release versions of the language where some features have one of the pre-stable statuses and are supposed to change. Such features can be added, changed or removed at any point and without warning. We do our best to ensure that pre-stable features can't be used accidentally by an unsuspecting user. Such features usually require some sort of explicit opt-in either in the code or in the project configuration.

A Kotlin language feature can have one of the following statuses:

- Exploration and design. We are considering the introduction of a new feature to the language. This involves discussing how it would integrate with existing features, gathering use cases, and assessing its potential impact. We need feedback from users on the problems this feature would solve and the use cases it addresses. Whenever possible, we try to estimate how often these use cases and problems occur would also be beneficial. Typically, ideas are documented as YouTrack issues, where the discussion continues.
- KEEP discussion. We are fairly certain that the feature should be added to the language. We aim to provide a motivation, use-cases, design, and other important details in a document called a KEEP. We expect feedback from users to focus on discussing all the information provided in the KEEP.
- In preview. A feature prototype is ready, and you can enable it using a feature-specific compiler option. We seek feedback on your experience with the feature, including how easily it integrates into your codebase, how it interacts with existing code, and any IDE support issues or suggestions. The feature's design may change significantly, or it could be completely revoked based on feedback. When a feature is in preview, it has a stability level.
- Stable. The language feature is now a first-class citizen in the Kotlin language. We guarantee its backward compatibility and that we'll provide tooling support.
- Revoked. We have revoked the proposal and will not implement the feature in the Kotlin language. We may revoke a feature that is in preview if it is not a good fit for Kotlin.

See the full list of Kotlin language proposals and their statuses.

Status of different components

Learn more about the stability status of different components in Kotlin, such as Kotlin/JVM, JS, and Native compilers, and various libraries.

Libraries

A language is nothing without its ecosystem, so we pay extra attention to enable smooth library evolution.

Ideally, a new version of a library can be used as a "drop-in replacement" for an older version. This means that upgrading a binary dependency should not break anything, even if the application is not recompiled (this is possible under dynamic linking).

On the one hand, to achieve this, the compiler has to provide certain Application Binary Interface (ABI) stability guarantees under the constraints of separate compilation. This is why every change in the language is examined from a binary compatibility standpoint.

On the other hand, a lot depends on the library authors being careful about which changes are safe to make. Thus, it's crucial that library authors understand how source changes affect compatibility and follow certain best practices to keep both APIs and ABIs of their libraries stable. Here are some assumptions that we make when considering language changes from the library evolution standpoint:

- Library code should always specify return types of public/protected functions and properties explicitly, thus never relying on type inference for public API. Subtle changes in type inference may cause return types to change inadvertently, leading to binary compatibility issues.
- Overloaded functions and properties provided by the same library should do essentially the same thing. Changes in type inference may result in more precise static types to be known at call sites, causing changes in overload resolution.

Library authors can use the @Deprecated and @RequiresOptIn annotations to control the evolution of their API surface. Note that @Deprecated(level=HIDDEN) can be used to preserve binary compatibility even for declarations removed from the API.

Also, by convention, packages named "internal" are not considered public API. All API residing in packages named "experimental" is considered pre-stable and can change at any moment.

We evolve the Kotlin Standard Library (kotlin-stdlib) for stable platforms according to the principles stated above. Changes to the contracts for its API undergo the same procedures as changes in the language itself.

Compiler options

Command line options accepted by the compiler are also a kind of public API, and they are subject to the same considerations. Supported options (those that don't have the "-X" or "-XX" prefix) can be added only in language releases and should be properly deprecated before removing them. The "-X" and "-XX" options are experimental and can be added and removed at any time.

Compatibility tools

As legacy features get removed and bugs fixed, the source language changes, and old code that has not been properly migrated may not compile anymore. The normal deprecation cycle allows a comfortable period of time for migration, and even when it's over and the change ships in a stable version, there's still a way to compile non-migrated code.

Compatibility options

We provide the -language-version X.Y and -api-version X.Y options that make a new version emulate the behavior of an old one for compatibility purposes. To give you more time for migration, we support the three previous language and API versions in addition to the latest stable one.

Actively maintained code bases can benefit from getting bug fixes as soon as possible, without waiting for a full deprecation cycle to complete. Currently, such projects can enable the -progressive option and get such fixes enabled even in tooling releases.

All options are available in the command line as well as in Gradle and in Maven.

Evolving the binary format

Unlike sources that can be fixed by hand in the worst case, binaries are a lot harder to migrate, and this makes backwards compatibility crucial in the case of binaries. Incompatible changes to binaries can make updates very uncomfortable and thus should be introduced with even more care than those in the source language syntax.

For fully stable versions of the compiler, the default binary compatibility protocol is the following:

- All binaries are backwards compatible; that means a newer compiler can read older binaries (for example, 1.3 understands 1.0 through 1.2).
- Older compilers reject binaries that rely on new features (for example, the 1.0 compiler rejects binaries that use coroutines).
- Preferably (but we can't guarantee it), the binary format is mostly forwards compatible with the next language release, but not later ones (in the cases when new features are not used, for example, 1.9 can understand most binaries from 2.0, but not 2.1).

This protocol is designed for comfortable updates as no project can be blocked from updating its dependencies even if it's using a slightly outdated compiler.

Note that not all target platforms have reached this level of stability, but Kotlin/JVM has.

Kotlin klib binaries

Kotlin klib binaries have reached the Stable level in Kotlin 1.9.20. However, there are some compatibility details you need to keep in mind:

- klib binaries are backwards compatible starting with Kotlin 1.9.20. For example, the 2.0.x compiler can read binaries produced by the 1.9.2x compiler.
- Forward compatibility is not guaranteed. For example, the 2.0.x compiler is not guaranteed to read binaries produced by the 2.1.x compiler.

The Kotlin cinterop klib binaries are still in Beta. Currently, we cannot give specific compatibility guarantees between different Kotlin versions for cinterop klib binaries.

Stability of Kotlin components

The Kotlin language and toolset are divided into many components such as the compilers for the JVM, JS and Native targets, the Standard Library, various accompanying tools and so on. Many of these components were officially released as Stable, which means that they were evolved in a backward-compatible way following the principles of Comfortable Updates and Keeping the Language Modern.

Following the Feedback Loop principle, we release many things early for the community to try out, so a number of components are not yet released as Stable. Some of them are at a very early stage, some are more mature. We mark them as Experimental, Alpha or Beta depending on how quickly each component evolves and the level of risk users take on when adopting it.

Stability levels explained

Here's a quick guide to these stability levels and their meaning:

Experimental means "try it only in toy projects":

- We are just trying out an idea and want some users to play with it and give feedback. If it doesn't work out, we may drop it any minute.

Alpha means "use at your own risk, expect migration issues":

- We intend to productize this idea, but it hasn't reached its final shape yet.

Beta means "you can use it, we'll do our best to minimize migration issues for you":

- It's almost done, user feedback is especially important now.
- Still, it's not 100% finished, so changes are possible (including ones based on your own feedback).
- Watch for deprecation warnings in advance for the best update experience.

We collectively refer to Experimental, Alpha and Beta as pre-stable levels.

Stable means "use it even in most conservative scenarios":

- It's done. We will be evolving it according to our strict backward compatibility rules.

Please note that stability levels do not say anything about how soon a component will be released as Stable. Similarly, they do not indicate how much a component will be changed before release. They only say how fast a component is changing and how much risk of update issues users are running.

GitHub badges for Kotlin components

The Kotlin GitHub organization hosts different Kotlin-related projects. Some of them we develop full-time, while others are side projects.

Each Kotlin project has two GitHub badges describing its stability and support status:

- Stability status. This shows how quickly each project is evolving and how much risk the users are taking when adopting it. The stability status completely coincides with the stability level of the Kotlin language features and its components:
  - experimental stands for Experimental
  - alpha stands for Alpha
  - beta stands for Beta
  - stable stands for Stable
- Support status. This shows our commitment to maintaining a project and helping users to solve their problems. The level of support is unified for all JetBrains products.
  See the JetBrains Open Source document for details.

Stability of subcomponents

A stable component may have an experimental subcomponent, for example:

- a stable compiler may have an experimental feature;
- a stable API may include experimental classes or functions;
- a stable command-line tool may have experimental options.

We make sure to document precisely which subcomponents are not Stable. We also do our best to warn users where possible and ask to opt them in explicitly to avoid the accidental use of features that have not been released as stable.

Current stability of Kotlin components

By default, all new components have Experimental status.

Kotlin compiler

Component	Status	Status since version	Comments
Kotlin/JVM	Stable	1.0.0	
Kotlin/Native	Stable	1.9.0	
Kotlin/JS	Stable	1.3.0	
Kotlin/Wasm	Alpha	1.9.20	
Analysis API	Stable		

Core compiler plugins

Component	Status	Status since version	Comments
All-open	Stable	1.3.0	
No-arg	Stable	1.3.0	
SAM-with-receiver	Stable	1.3.0	
kapt	Stable	1.3.0	
Lombok	Experimental	1.5.20	
Power-assert	Experimental	2.0.0	

Kotlin libraries

Component	Status	Status since version	Comments
kotlin-stdlib (JVM)	Stable	1.0.0	

Component	Status	Status since version	Comments
kotlinx-coroutines	Stable	1.3.0	
kotlinx-serialization	Stable	1.0.0	
kotlin-metadata-jvm	Stable	2.0.0	
kotlin-reflect (JVM)	Beta	1.0.0	
kotlinx-datetime	Alpha	0.2.0	
kotlinx-io	Alpha	0.2.0	

Kotlin Multiplatform

Component	Status	Status since version	Comments
Kotlin Multiplatform	Stable	1.9.20	
Kotlin Multiplatform plugin for Android Studio	Beta	0.8.0	Versioned separately from the language

Kotlin/Native

Component	Status	Status since version	Comments
Kotlin/Native Runtime	Stable	1.9.20	
Kotlin/Native interop with C and Objective-C	Beta	1.3.0	
klib binaries	Stable	1.9.20	Not including cinterop klibs, see below
cinterop klib binaries	Beta	1.3.0	
CocoaPods integration	Stable	1.9.20	

For details about Kotlin/Native targets support, see Kotlin/Native target support.

Language tools

Component	Status	Status since version	Comments
Scripting syntax and semantics	Alpha	1.2.0	
Scripting embedding and extension API	Beta	1.5.0	
Scripting IDE support	Beta		Available since IntelliJ IDEA 2023.1 and later
CLI scripting	Alpha	1.2.0	

Language features and design proposals

For language features and new design proposals, see Kotlin language features and proposals.

Kotlin releases

Since Kotlin 2.0.0, we ship the following types of releases:

- Language releases (2. x. 0) that bring major changes in the language and include tooling updates. Released once in 6 months.
- Tooling releases (2. x. 20) that are shipped between language releases and include updates in the tooling, performance improvements, and bug fixes. Released in 3 months after corresponding language release.
- Bug fix releases (2. x. yz) that include bug fixes for tooling releases. There is no exact release schedule for these releases.

For each language and tooling release, we also ship several preview (EAP) versions for you to try new features before they are released. See Early Access Preview for details.

If you want to be notified about new Kotlin releases, subscribe to the Kotlin newsletter, follow Kotlin on X, or enable the Watch | Custom | Releases option on the Kotlin GitHub repository.

Update to a new Kotlin version

To upgrade your project to a new release, you need to update your build script file. For example, to update to Kotlin 2.2.0, change the version of the Kotlin Gradle plugin in your build.gradle(.kts) file:

Kotlin

```kotlin
plugins {
    // Replace `<...>` with the plugin name appropriate for your target environment
    kotlin("<...>") version "2.2.0"
    // For example, if your target environment is JVM:
    // kotlin("jvm") version "2.2.0"
    // If your target is Kotlin Multiplatform:
    // kotlin("multiplatform") version "2.2.0"
}
```

Groovy

```groovy
plugins {
    // Replace `<...>` with the plugin name appropriate for your target environment
    id 'org.jetbrains.kotlin.<...>' version '2.2.0'
    // For example, if your target environment is JVM:
    // id 'org.jetbrains.kotlin.jvm' version '2.2.0'
    // If your target is Kotlin Multiplatform:
    // id 'org.jetbrains.kotlin.multiplatform' version '2.2.0'
}
```

If you have projects created with earlier Kotlin versions, change the Kotlin version in your projects and update kotlinx libraries if necessary.

If you are migrating to the new language release, Kotlin plugin's migration tools will help you with the migration.

IDE support

Kotlin has full out-of-the-box support in IntelliJ IDEA and Android Studio with an official Kotlin plugin developed by JetBrains.

K2 mode in IntelliJ IDEA and Android Studio uses the K2 compiler to improve code analysis, code completion, and highlighting.

Starting with IntelliJ IDEA 2025.1, K2 mode is enabled by default.

In Android Studio, you can enable K2 mode starting with 2024.1 by following these steps:

1. Go to Settings | Languages & Frameworks | Kotlin.
2. Select the Enable K2 mode option.

Learn more about K2 mode in our blog.

Kotlin release compatibility

Learn more about types of Kotlin releases and their compatibility

Release details

The following table lists details of the latest Kotlin releases:

> You can also try Early Access Preview (EAP) versions of Kotlin.

Build info	Build highlights
2.2.0 Released: June 23, 2025 Release on GitHub	A language release including both new and stable language features, tooling updates, performance improvements for different platforms, and important fixes. For more details, please refer to the changelog.
2.1.21 Released: May 13, 2025 Release on GitHub	A bug fix release for Kotlin 2.1.20. For more details, please refer to the changelog.

Build info	Build highlights
2.1.20 Released: March 20, 2025 Release on GitHub	A tooling release for Kotlin 2.1.0 containing new experimental features, performance improvements, and bug fixes. Learn more about Kotlin 2.1.20 in What's new in Kotlin 2.1.20.
2.1.10 Released: January 27, 2025 Release on GitHub	A bug fix release for Kotlin 2.1.0 For more details, please refer to the changelog.
2.1.0 Released: November 27, 2024 Release on GitHub	A language release introducing new language features. Learn more about Kotlin 2.1.0 in What's new in Kotlin 2.1.0.
2.0.21 Released: October 10, 2024 Release on GitHub	A bug fix release for Kotlin 2.0.20 For more details, please refer to the changelog.
2.0.20 Released: August 22, 2024 Release on GitHub	A tooling release for Kotlin 2.0.0 containing performance improvements and bug fixes. Features also include concurrent marking in Kotlin/Native's garbage collector, UUID support in Kotlin common standard library, Compose compiler updates, and support up to Gradle 8.8. Learn more about Kotlin 2.0.20 in What's new in Kotlin 2.0.20.
2.0.10 Released: August 6, 2024 Release on GitHub	A bug fix release for Kotlin 2.0.0. Learn more about Kotlin 2.0.0 in What's new in Kotlin 2.0.0.

Build info	Build highlights
2.0.0 Released: May 21, 2024 Release on GitHub	A language release with the Stable Kotlin K2 compiler. Learn more about Kotlin 2.0.0 in What's new in Kotlin 2.0.0.
1.9.25 Released: July 19, 2024 Release on GitHub	A bug fix release for Kotlin 1.9.20, 1.9.21, 1.9.22, 1.9.23, and 1.9.24. Learn more about Kotlin 1.9.20 in What's new in Kotlin 1.9.20.
1.9.24 Released: May 7, 2024 Release on GitHub	A bug fix release for Kotlin 1.9.20, 1.9.21, 1.9.22, and 1.9.23. Learn more about Kotlin 1.9.20 in What's new in Kotlin 1.9.20.
1.9.23 Released: March 7, 2024 Release on GitHub	A bug fix release for Kotlin 1.9.20, 1.9.21, and 1.9.22. Learn more about Kotlin 1.9.20 in What's new in Kotlin 1.9.20.
1.9.22 Released: December 21, 2023 Release on GitHub	A bug fix release for Kotlin 1.9.20 and 1.9.21. Learn more about Kotlin 1.9.20 in What's new in Kotlin 1.9.20.
1.9.21 Released: November 23, 2023 Release on GitHub	A bug fix release for Kotlin 1.9.20. Learn more about Kotlin 1.9.20 in What's new in Kotlin 1.9.20.

Build info	Build highlights
1.9.20 Released: November 1, 2023 Release on GitHub	A feature release with Kotlin K2 compiler in Beta and Stable Kotlin Multiplatform. Learn more in: • What's new in Kotlin 1.9.20
1.9.10 Released: August 23, 2023 Release on GitHub	A bug fix release for Kotlin 1.9.0. Learn more about Kotlin 1.9.0 in What's new in Kotlin 1.9.0. For Android Studio Giraffe and Hedgehog, the Kotlin plugin 1.9.10 will be delivered with upcoming Android Studios updates.
1.9.0 Released: July 6, 2023 Release on GitHub	A feature release with Kotlin K2 compiler updates, new enum class values function, new operator for open-ended ranges, preview of Gradle configuration cache in Kotlin Multiplatform, changes to Android target support in Kotlin Multiplatform, preview of custom memory allocator in Kotlin/Native. Learn more in: • What's new in Kotlin 1.9.0 • What's new in Kotlin YouTube video
1.8.22 Released: June 8, 2023 Release on GitHub	A bug fix release for Kotlin 1.8.20. Learn more about Kotlin 1.8.20 in What's new in Kotlin 1.8.20.
1.8.21 Released: April 25, 2023 Release on GitHub	A bug fix release for Kotlin 1.8.20. Learn more about Kotlin 1.8.20 in What's new in Kotlin 1.8.20. For Android Studio Flamingo and Giraffe, the Kotlin plugin 1.8.21 will be delivered with upcoming Android Studios updates.
1.8.20 Released: April 3, 2023 Release on GitHub	A feature release with Kotlin K2 compiler updates, AutoCloseable interface and Base64 encoding in stdlib, new JVM incremental compilation enabled by default, new Kotlin/Wasm compiler backend. Learn more in: • What's new in Kotlin 1.8.20 • What's new in Kotlin YouTube video

Build info	Build highlights
1.8.10 Released: February 2, 2023 Release on GitHub	A bug fix release for Kotlin 1.8.0. Learn more about Kotlin 1.8.0. For Android Studio Electric Eel and Flamingo, the Kotlin plugin 1.8.10 will be delivered with upcoming Android Studios updates.
1.8.0 Released: December 28, 2022 Release on GitHub	A feature release with improved kotlin-reflect performance, new recursively copy or delete directory content experimental functions for JVM, improved Objective-C/Swift interoperability. Learn more in: • What's new in Kotlin 1.8.0 • Compatibility guide for Kotlin 1.8.0
1.7.21 Released: November 9, 2022 Release on GitHub	A bug fix release for Kotlin 1.7.20. Learn more about Kotlin 1.7.20 in What's new in Kotlin 1.7.20. For Android Studio Dolphin, Electric Eel, and Flamingo, the Kotlin plugin 1.7.21 will be delivered with upcoming Android Studios updates.
1.7.20 Released: September 29, 2022 Release on GitHub	An incremental release with new language features, the support for several compiler plugins in the Kotlin K2 compiler, the new Kotlin/Native memory manager enabled by default, and the support for Gradle 7.1. Learn more in: • What's new in Kotlin 1.7.20 • What's new in Kotlin YouTube video • Compatibility guide for Kotlin 1.7.20 Learn more about Kotlin 1.7.20.
1.7.10 Released: July 7, 2022 Release on GitHub	A bug fix release for Kotlin 1.7.0. Learn more about Kotlin 1.7.0. For Android Studio Dolphin (213) and Android Studio Electric Eel (221), the Kotlin plugin 1.7.10 will be delivered with upcoming Android Studios updates.

Build info	Build highlights
1.7.0 Released: June 9, 2022 Release on GitHub	A feature release with Kotlin K2 compiler in Alpha for JVM, stabilized language features, performance improvements, and evolutionary changes such as stabilizing experimental APIs. Learn more in: • What's new in Kotlin 1.7.0 • What's new in Kotlin YouTube video • Compatibility guide for Kotlin 1.7.0
1.6.21 Released: April 20, 2022 Release on GitHub	A bug fix release for Kotlin 1.6.20. Learn more about Kotlin 1.6.20.
1.6.20 Released: April 4, 2022 Release on GitHub	An incremental release with various improvements such as: • Prototype of context receivers • Callable references to functional interface constructors • Kotlin/Native: performance improvements for the new memory manager • Multiplatform: hierarchical project structure by default • Kotlin/JS: IR compiler improvements • Gradle: compiler execution strategies Learn more about Kotlin 1.6.20.
1.6.10 Released: December 14, 2021 Release on GitHub	A bug fix release for Kotlin 1.6.0. Learn more about Kotlin 1.6.0.
1.6.0 Released: November 16, 2021 Release on GitHub	A feature release with new language features, performance improvements, and evolutionary changes such as stabilizing experimental APIs. Learn more in: • Release blog post • What's new in Kotlin 1.6.0 • Compatibility guide

Build info	Build highlights
1.5.32 Released: November 29, 2021 Release on GitHub	A bug fix release for Kotlin 1.5.31. Learn more about Kotlin 1.5.30.
1.5.31 Released: September 20, 2021 Release on GitHub	A bug fix release for Kotlin 1.5.30. Learn more about Kotlin 1.5.30.
1.5.30 Released: August 23, 2021 Release on GitHub	An incremental release with various improvements such as: • Instantiation of annotation classes on JVM • Improved opt-in requirement mechanism and type inference • Kotlin/JS IR backend in Beta • Support for Apple Silicon targets • Improved CocoaPods support • Gradle: Java toolchain support and improved daemon configuration Learn more in: • Release blog post • What's new in Kotlin 1.5.30
1.5.21 Released: July 13, 2021 Release on GitHub	A bug fix release for Kotlin 1.5.20. Learn more about Kotlin 1.5.20.

Build info	Build highlights
1.5.20 Released: June 24, 2021 Release on GitHub	An incremental release with various improvements such as: • String concatenation via invokedynamic on JVM by default • Improved support for Lombok and support for JSpecify • Kotlin/Native: KDoc export to Objective-C headers and faster Array.copyInto() inside one array • Gradle: caching of annotation processors' classloaders and support for the --parallel Gradle property • Aligned behavior of stdlib functions across platforms Learn more in: • Release blog post • What's new in Kotlin 1.5.20
1.5.10 Released: May 24, 2021 Release on GitHub	A bug fix release for Kotlin 1.5.0. Learn more about Kotlin 1.5.0.
1.5.0 Released: May 5, 2021 Release on GitHub	A feature release with new language features, performance improvements, and evolutionary changes such as stabilizing experimental APIs. Learn more in: • Release blog post • What's new in Kotlin 1.5.0 • Compatibility guide
1.4.32 Released: March 22, 2021 Release on GitHub	A bug fix release for Kotlin 1.4.30. Learn more about Kotlin 1.4.30.
1.4.31 Released: February 25, 2021 Release on GitHub	A bug fix release for Kotlin 1.4.30 Learn more about Kotlin 1.4.30.

Build info	Build highlights
1.4.30 Released: February 3, 2021 Release on GitHub	An incremental release with various improvements such as: • New JVM backend, now in Beta • Preview of new language features • Improved Kotlin/Native performance • Standard library API improvements Learn more in: • Release blog post • What's new in Kotlin 1.4.30
1.4.21 Released: December 7, 2020 Release on GitHub	A bug fix release for Kotlin 1.4.20 Learn more about Kotlin 1.4.20.
1.4.20 Released: November 23, 2020 Release on GitHub	An incremental release with various improvements such as: • Supporting new JVM features, like string concatenation via invokedynamic • Improved performance and exception handling for Kotlin Multiplatform Mobile projects • Extensions for JDK Path: Path("dir") / "file.txt" Learn more in: • Release blog post • What's new in Kotlin 1.4.20
1.4.10 Released: September 7, 2020 Release on GitHub	A bug fix release for Kotlin 1.4.0. Learn more about Kotlin 1.4.0.
1.4.0 Released: August 17, 2020 Release on GitHub	A feature release with many features and improvements that mostly focus on quality and performance. Learn more in: • Release blog post • What's new in Kotlin 1.4.0 • Compatibility guide • Migrating to Kotlin 1.4.0

Build info	Build highlights
1.3.72 Released: April 15, 2020 Release on GitHub	A bug fix release for Kotlin 1.3.70. Learn more about Kotlin 1.3.70.

Basic syntax

This is a collection of basic syntax elements with examples. At the end of every section, you'll find a link to a detailed description of the related topic.

You can also learn all the Kotlin essentials with the free Kotlin Core track by JetBrains Academy.

Package definition and imports

Package specification should be at the top of the source file:

```
package my.demo

import kotlin.text.*

// ...
```

It is not required to match directories and packages: source files can be placed arbitrarily in the file system.

See Packages.

Program entry point

An entry point of a Kotlin application is the main function:

```
fun main() {
    println("Hello world!")
}
```

Another form of main accepts a variable number of String arguments:

```
fun main(args: Array<String>) {
    println(args.contentToString())
}
```

Print to the standard output

print prints its argument to the standard output:

```
fun main() {
    print("Hello ")
    print("world!")
}
```

println prints its arguments and adds a line break, so that the next thing you print appears on the next line:

```
fun main() {
    println("Hello world!")
    println(42)
}
```

Read from the standard input

The readln() function reads from the standard input. This function reads the entire line the user enters as a string.

You can use the println(), readln(), and print() functions together to print messages requesting and showing user input:

```
// Prints a message to request input
println("Enter any word: ")

// Reads and stores the user input. For example: Happiness
val yourWord = readln()

// Prints a message with the input
print("You entered the word: ")
print(yourWord)
// You entered the word: Happiness
```

For more information, see Read standard input.

Functions

A function with two Int parameters and Int return type:

```
fun sum(a: Int, b: Int): Int {
    return a + b
}

fun main() {
    print("sum of 3 and 5 is ")
    println(sum(3, 5))
}
```

A function body can be an expression. Its return type is inferred:

```
fun sum(a: Int, b: Int) = a + b

fun main() {
    println("sum of 19 and 23 is ${sum(19, 23)}")
}
```

A function that returns no meaningful value:

```
fun printSum(a: Int, b: Int): Unit {
    println("sum of $a and $b is ${a + b}")
}

fun main() {
    printSum(-1, 8)
}
```

Unit return type can be omitted:

```
fun printSum(a: Int, b: Int) {
    println("sum of $a and $b is ${a + b}")
}

fun main() {
    printSum(-1, 8)
}
```

See Functions.

Variables

In Kotlin, you declare a variable starting with a keyword, val or var, followed by the name of the variable.

Use the val keyword to declare variables that are assigned a value only once. These are immutable, read-only local variables that can’t be reassigned a different value after initialization:

```kotlin
fun main() {
    // Declares the variable x and initializes it with the value of 5
    val x: Int = 5
    // 5
    println(x)
}
```

Use the var keyword to declare variables that can be reassigned. These are mutable variables, and you can change their values after initialization:

```kotlin
fun main() {
    // Declares the variable x and initializes it with the value of 5
    var x: Int = 5
    // Reassigns a new value of 6 to the variable x
    x += 1
    // 6
    println(x)
}
```

Kotlin supports type inference and automatically identifies the data type of a declared variable. When declaring a variable, you can omit the type after the variable name:

```kotlin
fun main() {
    // Declares the variable x with the value of 5;`Int` type is inferred
    val x = 5
    // 5
    println(x)
}
```

You can use variables only after initializing them. You can either initialize a variable at the moment of declaration or declare a variable first and initialize it later. In the second case, you must specify the data type:

```kotlin
fun main() {
    // Initializes the variable x at the moment of declaration; type is not required
    val x = 5
    // Declares the variable c without initialization; type is required
    val c: Int
    // Initializes the variable c after declaration
    c = 3
    // 5
    // 3
    println(x)
    println(c)
}
```

You can declare variables at the top level:

```kotlin
val PI = 3.14
var x = 0

fun incrementX() {
    x += 1
}
// x = 0; PI = 3.14
// incrementX()
// x = 1; PI = 3.14

fun main() {
    println("x = $x; PI = $PI")
    incrementX()
    println("incrementX()")
    println("x = $x; PI = $PI")
}
```

For information about declaring properties, see Properties.

Creating classes and instances

To define a class, use the class keyword:

```kotlin
class Shape
```

Properties of a class can be listed in its declaration or body:

```kotlin
class Rectangle(val height: Double, val length: Double) {
    val perimeter = (height + length) * 2
}
```

The default constructor with parameters listed in the class declaration is available automatically:

```kotlin
class Rectangle(val height: Double, val length: Double) {
    val perimeter = (height + length) * 2
}
fun main() {
    val rectangle = Rectangle(5.0, 2.0)
    println("The perimeter is ${rectangle.perimeter}")
}
```

Inheritance between classes is declared by a colon (:). Classes are final by default; to make a class inheritable, mark it as open:

```kotlin
open class Shape

class Rectangle(val height: Double, val length: Double): Shape() {
    val perimeter = (height + length) * 2
}
```

For more information about constructors and inheritance, see Classes and Objects and instances.

Comments

Just like most modern languages, Kotlin supports single-line (or end-of-line) and multi-line (block) comments:

```kotlin
// This is an end-of-line comment

/* This is a block comment
   on multiple lines. */
```

Block comments in Kotlin can be nested:

```kotlin
/* The comment starts here
/* contains a nested comment */
and ends here. */
```

See Documenting Kotlin Code for information on the documentation comment syntax.

String templates

```kotlin
fun main() {
    var a = 1
    // simple name in template:
    val s1 = "a is $a"

    a = 2
    // arbitrary expression in template:
    val s2 = "${s1.replace("is", "was")}, but now is $a"
    println(s2)
}
```

See String templates for details.

Conditional expressions

```
fun maxOf(a: Int, b: Int): Int {
    if (a > b) {
        return a
    } else {
        return b
    }
}

fun main() {
    println("max of 0 and 42 is ${maxOf(0, 42)}")
}
```

In Kotlin, if can also be used as an expression:

```
fun maxOf(a: Int, b: Int) = if (a > b) a else b

fun main() {
    println("max of 0 and 42 is ${maxOf(0, 42)}")
}
```

See if-expressions.

for loop

```
fun main() {
    val items = listOf("apple", "banana", "kiwifruit")
    for (item in items) {
        println(item)
    }
}
```

or:

```
fun main() {
    val items = listOf("apple", "banana", "kiwifruit")
    for (index in items.indices) {
        println("item at $index is ${items[index]}")
    }
}
```

See for loop.

while loop

```
fun main() {
    val items = listOf("apple", "banana", "kiwifruit")
    var index = 0
    while (index < items.size) {
        println("item at $index is ${items[index]}")
        index++
    }
}
```

See while loop.

when expression

```
fun describe(obj: Any): String =
    when (obj) {
        1          -> "One"
        "Hello"    -> "Greeting"
        is Long    -> "Long"
        !is String -> "Not a string"
        else       -> "Unknown"
    }

fun main() {
    println(describe(1))
    println(describe("Hello"))
    println(describe(1000L))
    println(describe(2))
    println(describe("other"))
}
```

See when expressions and statements.

Ranges

Check if a number is within a range using in operator:

```
fun main() {
    val x = 10
    val y = 9
    if (x in 1..y+1) {
        println("fits in range")
    }
}
```

Check if a number is out of range:

```
fun main() {
    val list = listOf("a", "b", "c")

    if (-1 !in 0..list.lastIndex) {
        println("-1 is out of range")
    }
    if (list.size !in list.indices) {
        println("list size is out of valid list indices range, too")
    }
}
```

Iterate over a range:

```
fun main() {
    for (x in 1..5) {
        print(x)
    }
}
```

Or over a progression:

```
fun main() {
    for (x in 1..10 step 2) {
        print(x)
    }
    println()
    for (x in 9 downTo 0 step 3) {
        print(x)
    }
}
```

See Ranges and progressions.

Collections

Iterate over a collection:

```
fun main() {
    val items = listOf("apple", "banana", "kiwifruit")
    for (item in items) {
        println(item)
    }
}
```

Check if a collection contains an object using in operator:

```
fun main() {
    val items = setOf("apple", "banana", "kiwifruit")
    when {
        "orange" in items -> println("juicy")
        "apple" in items -> println("apple is fine too")
    }
}
```

Use lambda expressions to filter and map collections:

```
fun main() {
    val fruits = listOf("banana", "avocado", "apple", "kiwifruit")
    fruits
      .filter { it.startsWith("a") }
      .sortedBy { it }
      .map { it.uppercase() }
      .forEach { println(it) }
}
```

See Collections overview.

Nullable values and null checks

A reference must be explicitly marked as nullable when null value is possible. Nullable type names have ? at the end.

Return null if str does not hold an integer:

```
fun parseInt(str: String): Int? {
    // ...
}
```

Use a function returning nullable value:

```
fun parseInt(str: String): Int? {
    return str.toIntOrNull()
}

fun printProduct(arg1: String, arg2: String) {
    val x = parseInt(arg1)
    val y = parseInt(arg2)

    // Using `x * y` yields error because they may hold nulls.
    if (x != null && y != null) {
        // x and y are automatically cast to non-nullable after null check
        println(x * y)
    }
    else {
        println("'$arg1' or '$arg2' is not a number")
    }
}

fun main() {
    printProduct("6", "7")
    printProduct("a", "7")
    printProduct("a", "b")
}
```

or:

```
fun parseInt(str: String): Int? {
    return str.toIntOrNull()
}

fun printProduct(arg1: String, arg2: String) {
    val x = parseInt(arg1)
    val y = parseInt(arg2)

    // ...
    if (x == null) {
        println("Wrong number format in arg1: '$arg1'")
        return
    }
    if (y == null) {
        println("Wrong number format in arg2: '$arg2'")
        return
    }

    // x and y are automatically cast to non-nullable after null check
    println(x * y)
}

fun main() {
    printProduct("6", "7")
    printProduct("a", "7")
    printProduct("99", "b")
}
```

See Null-safety.

Type checks and automatic casts

The is operator checks if an expression is an instance of a type. If an immutable local variable or property is checked for a specific type, there's no need to cast it explicitly:

```
fun getStringLength(obj: Any): Int? {
    if (obj is String) {
        // `obj` is automatically cast to `String` in this branch
        return obj.length
    }

    // `obj` is still of type `Any` outside of the type-checked branch
    return null
}

fun main() {
    fun printLength(obj: Any) {
        println("Getting the length of '$obj'. Result: ${getStringLength(obj) ?: "Error: The object is not a string"} ")
    }
    printLength("Incomprehensibilities")
    printLength(1000)
    printLength(listOf(Any()))
}
```

or:

```
fun getStringLength(obj: Any): Int? {
    if (obj !is String) return null

    // `obj` is automatically cast to `String` in this branch
    return obj.length
}

fun main() {
    fun printLength(obj: Any) {
        println("Getting the length of '$obj'. Result: ${getStringLength(obj) ?: "Error: The object is not a string"} ")
    }
    printLength("Incomprehensibilities")
    printLength(1000)
    printLength(listOf(Any()))
}
```

or even:

```
fun getStringLength(obj: Any): Int? {
    // `obj` is automatically cast to `String` on the right-hand side of `&&`
    if (obj is String && obj.length > 0) {
        return obj.length
    }
    return null
}

fun main() {
    fun printLength(obj: Any) {
        println("Getting the length of '$obj'. Result: ${getStringLength(obj) ?: "Error: The object is not a string"} ")
    }
    printLength("Incomprehensibilities")
    printLength("")
    printLength(1000)
}
```

See Classes and Type casts.

Idioms

A collection of random and frequently used idioms in Kotlin. If you have a favorite idiom, contribute it by sending a pull request.

Create DTOs (POJOs/POCOs)

```
data class Customer(val name: String, val email: String)
```

provides a Customer class with the following functionality:

- getters (and setters in case of vars) for all properties
- equals()
- hashCode()
- toString()
- copy()
- component1(), component2(), ..., for all properties (see Data classes)

Default values for function parameters

```
fun foo(a: Int = 0, b: String = "") { ... }
```

Filter a list

```
val positives = list.filter { x -> x > 0 }
```

Or alternatively, even shorter:

```
val positives = list.filter { it > 0 }
```

Learn the difference between Java and Kotlin filtering.

Check the presence of an element in a collection

```
if ("john@example.com" in emailsList) { ... }

if ("jane@example.com" !in emailsList) { ... }
```

String interpolation

```
println("Name $name")
```

Learn the difference between Java and Kotlin string concatenation.

Read standard input safely

```
// Reads a string and returns null if the input can't be converted into an integer. For example: Hi there!
val wrongInt = readln().toIntOrNull()
println(wrongInt)
// null

// Reads a string that can be converted into an integer and returns an integer. For example: 13
val correctInt = readln().toIntOrNull()
println(correctInt)
// 13
```

For more information, see Read standard input.

Instance checks

```
when (x) {
    is Foo -> ...
    is Bar -> ...
    else   -> ...
}
```

Read-only list

```
val list = listOf("a", "b", "c")
```

Read-only map

```
val map = mapOf("a" to 1, "b" to 2, "c" to 3)
```

Access a map entry

```
println(map["key"])
map["key"] = value
```

Traverse a map or a list of pairs

```
for ((k, v) in map) {
    println("$k -> $v")
}
```

k and v can be any convenient names, such as name and age.

Iterate over a range

```
for (i in 1..100) { ... }  // closed-ended range: includes 100
for (i in 1..<100) { ... } // open-ended range: does not include 100
for (x in 2..10 step 2) { ... }
for (x in 10 downTo 1) { ... }
(1..10).forEach { ... }
```

Lazy property

```
val p: String by lazy { // the value is computed only on first access
    // compute the string
}
```

Extension functions

```
fun String.spaceToCamelCase() { ... }

"Convert this to camelcase".spaceToCamelCase()
```

Create a singleton

```
object Resource {
    val name = "Name"
}
```

Use inline value classes for type-safe values

```
@JvmInline
value class EmployeeId(private val id: String)

@JvmInline
value class CustomerId(private val id: String)
```

If you accidentally mix up EmployeeId and CustomerId, a compilation error is triggered.

The @JvmInline annotation is only needed for JVM backends.

Instantiate an abstract class

```
abstract class MyAbstractClass {
    abstract fun doSomething()
    abstract fun sleep()
}

fun main() {
    val myObject = object : MyAbstractClass() {
        override fun doSomething() {
            // ...
        }

        override fun sleep() { // ...
        }
    }
    myObject.doSomething()
}
```

If-not-null shorthand

```kotlin
val files = File("Test").listFiles()

println(files?.size) // size is printed if files is not null
```

If-not-null-else shorthand

```kotlin
val files = File("Test").listFiles()

// For simple fallback values:
println(files?.size ?: "empty") // if files is null, this prints "empty"

// To calculate a more complicated fallback value in a code block, use `run`
val filesSize = files?.size ?: run {
    val someSize = getSomeSize()
    someSize * 2
}
println(filesSize)
```

Execute a statement if null

```kotlin
val values = ...
val email = values["email"] ?: throw IllegalStateException("Email is missing!")
```

Get first item of a possibly empty collection

```kotlin
val emails = ... // might be empty
val mainEmail = emails.firstOrNull() ?: ""
```

Learn the difference between Java and Kotlin first item getting.

Execute if not null

```kotlin
val value = ...

value?.let {
    ... // execute this block if not null
}
```

Map nullable value if not null

```kotlin
val value = ...

val mapped = value?.let { transformValue(it) } ?: defaultValue
// defaultValue is returned if the value or the transform result is null.
```

Return on when statement

```kotlin
fun transform(color: String): Int {
    return when (color) {
        "Red" -> 0
        "Green" -> 1
        "Blue" -> 2
        else -> throw IllegalArgumentException("Invalid color param value")
    }
}
```

try-catch expression

```
fun test() {
    val result = try {
        count()
    } catch (e: ArithmeticException) {
        throw IllegalStateException(e)
    }

    // Working with result
}
```

if expression

```
val y = if (x == 1) {
    "one"
} else if (x == 2) {
    "two"
} else {
    "other"
}
```

Builder-style usage of methods that return Unit

```
fun arrayOfMinusOnes(size: Int): IntArray {
    return IntArray(size).apply { fill(-1) }
}
```

Single-expression functions

```
fun theAnswer() = 42
```

This is equivalent to

```
fun theAnswer(): Int {
    return 42
}
```

This can be effectively combined with other idioms, leading to shorter code. For example, with the when expression:

```
fun transform(color: String): Int = when (color) {
    "Red" -> 0
    "Green" -> 1
    "Blue" -> 2
    else -> throw IllegalArgumentException("Invalid color param value")
}
```

Call multiple methods on an object instance (with)

```
class Turtle {
    fun penDown()
    fun penUp()
    fun turn(degrees: Double)
    fun forward(pixels: Double)
}
```

```
val myTurtle = Turtle()
with(myTurtle) { //draw a 100 pix square
    penDown()
    for (i in 1..4) {
        forward(100.0)
        turn(90.0)
    }
    penUp()
}
```

Configure properties of an object (apply)

```
val myRectangle = Rectangle().apply {
    length = 4
    breadth = 5
    color = 0xFAFAFA
}
```

This is useful for configuring properties that aren't present in the object constructor.

Java 7's try-with-resources

```
val stream = Files.newInputStream(Paths.get("/some/file.txt"))
stream.buffered().reader().use { reader ->
    println(reader.readText())
}
```

Generic function that requires the generic type information

```
//  public final class Gson {
//     ...
//     public <T> T fromJson(JsonElement json, Class<T> classOfT) throws JsonSyntaxException {
//     ...

inline fun <reified T: Any> Gson.fromJson(json: JsonElement): T = this.fromJson(json, T::class.java)
```

Swap two variables

```
var a = 1
var b = 2
a = b.also { b = a }
```

Mark code as incomplete (TODO)

Kotlin's standard library has a TODO() function that will always throw a NotImplementedError. Its return type is Nothing so it can be used regardless of expected type. There's also an overload that accepts a reason parameter:

```
fun calcTaxes(): BigDecimal = TODO("Waiting for feedback from accounting")
```

IntelliJ IDEA's kotlin plugin understands the semantics of TODO() and automatically adds a code pointer in the TODO tool window.

What's next?

- Solve Advent of Code puzzles using the idiomatic Kotlin style.
- Learn how to perform typical tasks with strings in Java and Kotlin.

- Learn how to perform typical tasks with collections in Java and Kotlin.
- Learn how to handle nullability in Java and Kotlin.

Coding conventions

Commonly known and easy-to-follow coding conventions are vital for any programming language. Here we provide guidelines on the code style and code organization for projects that use Kotlin.

Configure style in IDE

Two most popular IDEs for Kotlin - IntelliJ IDEA and Android Studio provide powerful support for code styling. You can configure them to automatically format your code in consistence with the given code style.

Apply the style guide

1. Go to Settings/Preferences | Editor | Code Style | Kotlin.
2. Click Set from....
3. Select Kotlin style guide.

Verify that your code follows the style guide

1. Go to Settings/Preferences | Editor | Inspections | General.
2. Switch on Incorrect formatting inspection. Additional inspections that verify other issues described in the style guide (such as naming conventions) are enabled by default.

Source code organization

Directory structure

In pure Kotlin projects, the recommended directory structure follows the package structure with the common root package omitted. For example, if all the code in the project is in the org.example.kotlin package and its subpackages, files with the org.example.kotlin package should be placed directly under the source root, and files in org.example.kotlin.network.socket should be in the network/socket subdirectory of the source root.

> On JVM: In projects where Kotlin is used together with Java, Kotlin source files should reside in the same source root as the Java source files, and follow the same directory structure: each file should be stored in the directory corresponding to each package statement.

Source file names

If a Kotlin file contains a single class or interface (potentially with related top-level declarations), its name should be the same as the name of the class, with the .kt extension appended. It applies to all types of classes and interfaces. If a file contains multiple classes, or only top-level declarations, choose a name describing what the file contains, and name the file accordingly. Use upper camel case, where the first letter of each word is capitalized. For example, ProcessDeclarations.kt.

The name of the file should describe what the code in the file does. Therefore, you should avoid using meaningless words such as Util in file names.

Multiplatform projects

In multiplatform projects, files with top-level declarations in platform-specific source sets should have a suffix associated with the name of the source set. For example:

- jvmMain/kotlin/Platform. jvm .kt
- androidMain/kotlin/Platform. android .kt

- iosMain/kotlin/Platform. ios .kt

As for the common source set, files with top-level declarations should not have a suffix. For example, commonMain/kotlin/Platform.kt.

Technical details

We recommend following this file naming scheme in multiplatform projects due to JVM limitations: it doesn't allow top-level members (functions, properties).

To work around this, the Kotlin JVM compiler creates wrapper classes (so-called "file facades") that contain top-level member declarations. File facades have an internal name derived from the file name.

In turn, JVM doesn't allow several classes with the same fully qualified name (FQN). This might lead to situations when a Kotlin project cannot be compiled to JVM:

```
root
|- commonMain/kotlin/myPackage/Platform.kt // contains 'fun count() { }'
|- jvmMain/kotlin/myPackage/Platform.kt // contains 'fun multiply() { }'
```

Here both Platform.kt files are in the same package, so the Kotlin JVM compiler produces two file facades, both of which have FQN myPackage.PlatformKt. This produces the "Duplicate JVM classes" error.

The simplest way to avoid that is renaming one of the files according to the guideline above. This naming scheme helps avoid clashes while retaining code readability.

> There are two scenarios where these recommendations may seem redundant, but we still advise to follow them:
>
> - Non-JVM platforms don't have issues with duplicating file facades. However, this naming scheme can help you keep file naming consistent.
> - On JVM, if source files don't have top-level declarations, the file facades aren't generated, and you won't face naming clashes.
>
>   However, this naming scheme can help you avoid situations when a simple refactoring or an addition could include a top-level function and result in the same "Duplicate JVM classes" error.

Source file organization

Placing multiple declarations (classes, top-level functions or properties) in the same Kotlin source file is encouraged as long as these declarations are closely related to each other semantically, and the file size remains reasonable (not exceeding a few hundred lines).

In particular, when defining extension functions for a class which are relevant for all clients of this class, put them in the same file with the class itself. When defining extension functions that make sense only for a specific client, put them next to the code of that client. Avoid creating files just to hold all extensions of some class.

Class layout

The contents of a class should go in the following order:

1. Property declarations and initializer blocks
2. Secondary constructors
3. Method declarations
4. Companion object

Do not sort the method declarations alphabetically or by visibility, and do not separate regular methods from extension methods. Instead, put related stuff together, so that someone reading the class from top to bottom can follow the logic of what's happening. Choose an order (either higher-level stuff first, or vice versa) and stick to it.

Put nested classes next to the code that uses those classes. If the classes are intended to be used externally and aren't referenced inside the class, put them in the end, after the companion object.

Interface implementation layout

When implementing an interface, keep the implementing members in the same order as members of the interface (if necessary, interspersed with additional private methods used for the implementation).

Overload layout

Always put overloads next to each other in a class.

Naming rules

Package and class naming rules in Kotlin are quite simple:

- Names of packages are always lowercase and do not use underscores (org.example.project). Using multi-word names is generally discouraged, but if you do need to use multiple words, you can either just concatenate them together or use camel case (org.example.myProject).
- Names of classes and objects use upper camel case:

```
open class DeclarationProcessor { /*...*/ }

object EmptyDeclarationProcessor : DeclarationProcessor() { /*...*/ }
```

Function names

Names of functions, properties and local variables start with a lowercase letter and use camel case with no underscores:

```
fun processDeclarations() { /*...*/ }
var declarationCount = 1
```

Exception: factory functions used to create instances of classes can have the same name as the abstract return type:

```
interface Foo { /*...*/ }

class FooImpl : Foo { /*...*/ }

fun Foo(): Foo { return FooImpl() }
```

Names for test methods

In tests (and only in tests), you can use method names with spaces enclosed in backticks. Note that such method names are only supported by Android runtime from API level 30. Underscores in method names are also allowed in test code.

```
class MyTestCase {
     @Test fun `ensure everything works`() { /*...*/ }

     @Test fun ensureEverythingWorks_onAndroid() { /*...*/ }
}
```

Property names

Names of constants (properties marked with const, or top-level or object val properties with no custom get function that hold deeply immutable data) should use all uppercase, underscore-separated names following the screaming snake case convention:

```
const val MAX_COUNT = 8
val USER_NAME_FIELD = "UserName"
```

Names of top-level or object properties which hold objects with behavior or mutable data should use camel case names:

```
val mutableCollection: MutableSet<String> = HashSet()
```

Names of properties holding references to singleton objects can use the same naming style as object declarations:

```
val PersonComparator: Comparator<Person> = /*...*/
```

For enum constants, it's OK to use either all uppercase, underscore-separated (screaming snake case) names (enum class Color { RED, GREEN }) or upper camel case names, depending on the usage.

Names for backing properties

If a class has two properties which are conceptually the same but one is part of a public API and another is an implementation detail, use an underscore as the prefix for the name of the private property:

```
class C {
    private val _elementList = mutableListOf<Element>()

    val elementList: List<Element>
         get() = _elementList
}
```

Choose good names

The name of a class is usually a noun or a noun phrase explaining what the class is: List, PersonReader.

The name of a method is usually a verb or a verb phrase saying what the method does: close, readPersons. The name should also suggest if the method is mutating the object or returning a new one. For instance sort is sorting a collection in place, while sorted is returning a sorted copy of the collection.

The names should make it clear what the purpose of the entity is, so it's best to avoid using meaningless words (Manager, Wrapper) in names.

When using an acronym as part of a declaration name, follow these rules:

- For two-letter acronyms, use uppercase for both letters. For example, IOStream.
- For acronyms longer than two letters, capitalize only the first letter. For example, XmlFormatter or HttpInputStream.

Formatting

Indentation

Use four spaces for indentation. Do not use tabs.

For curly braces, put the opening brace at the end of the line where the construct begins, and the closing brace on a separate line aligned horizontally with the opening construct.

```
if (elements != null) {
    for (element in elements) {
        // ...
    }
}
```

In Kotlin, semicolons are optional, and therefore line breaks are significant. The language design assumes Java-style braces, and you may encounter surprising behavior if you try to use a different formatting style.

Horizontal whitespace

- Put spaces around binary operators (a + b). Exception: don't put spaces around the "range to" operator (0..i).
- Do not put spaces around unary operators (a++).
- Put spaces between control flow keywords (if, when, for, and while) and the corresponding opening parenthesis.
- Do not put a space before an opening parenthesis in a primary constructor declaration, method declaration or method call.

```
class A(val x: Int)

fun foo(x: Int) { ... }

fun bar() {
    foo(1)
}
```

- Never put a space after (, [, or before],).
- Never put a space around . or ?.: foo.bar().filter { it > 2 }.joinToString(), foo?.bar().
- Put a space after //: // This is a comment.
- Do not put spaces around angle brackets used to specify type parameters: class Map<K, V> { ... }.
- Do not put spaces around ::: Foo::class, String::length.
- Do not put a space before ? used to mark a nullable type: String?.

As a general rule, avoid horizontal alignment of any kind. Renaming an identifier to a name with a different length should not affect the formatting of either the declaration or any of the usages.

Colon

Put a space before : in the following scenarios:

- When it's used to separate a type and a supertype.
- When delegating to a superclass constructor or a different constructor of the same class.
- After the object keyword.

Don't put a space before : when it separates a declaration and its type.

Always put a space after :.

```
abstract class Foo<out T : Any> : IFoo {
    abstract fun foo(a: Int): T
}

class FooImpl : Foo() {
    constructor(x: String) : this(x) { /*...*/ }

    val x = object : IFoo { /*...*/ }
}
```

Class headers

Classes with a few primary constructor parameters can be written in a single line:

```
class Person(id: Int, name: String)
```

Classes with longer headers should be formatted so that each primary constructor parameter is in a separate line with indentation. Also, the closing parenthesis should be on a new line. If you use inheritance, the superclass constructor call, or the list of implemented interfaces should be located on the same line as the parenthesis:

```
class Person(
    id: Int,
    name: String,
    surname: String
) : Human(id, name) { /*...*/ }
```

For multiple interfaces, the superclass constructor call should be located first and then each interface should be located in a different line:

```
class Person(
    id: Int,
    name: String,
    surname: String
) : Human(id, name),
    KotlinMaker { /*...*/ }
```

For classes with a long supertype list, put a line break after the colon and align all supertype names horizontally:

```
class MyFavouriteVeryLongClassHolder :
    MyLongHolder<MyFavouriteVeryLongClass>(),
    SomeOtherInterface,
    AndAnotherOne {

    fun foo() { /*...*/ }
}
```

To clearly separate the class header and body when the class header is long, either put a blank line following the class header (as in the example above), or put the opening curly brace on a separate line:

```
class MyFavouriteVeryLongClassHolder :
    MyLongHolder<MyFavouriteVeryLongClass>(),
    SomeOtherInterface,
    AndAnotherOne
{
    fun foo() { /*...*/ }
}
```

Use regular indent (four spaces) for constructor parameters. This ensures that properties declared in the primary constructor have the same indentation as properties declared in the body of a class.

Modifiers order

If a declaration has multiple modifiers, always put them in the following order:

```
public / protected / private / internal
expect / actual
final / open / abstract / sealed / const
external
override
lateinit
tailrec
vararg
suspend
inner
enum / annotation / fun // as a modifier in `fun interface`
companion
inline / value
infix
operator
data
```

Place all annotations before modifiers:

```
@Named("Foo")
private val foo: Foo
```

Unless you're working on a library, omit redundant modifiers (for example, public).

Annotations

Place annotations on separate lines before the declaration to which they are attached, and with the same indentation:

```
@Target(AnnotationTarget.PROPERTY)
annotation class JsonExclude
```

Annotations without arguments may be placed on the same line:

```
@JsonExclude @JvmField
var x: String
```

A single annotation without arguments may be placed on the same line as the corresponding declaration:

```
@Test fun foo() { /*...*/ }
```

File annotations

File annotations are placed after the file comment (if any), before the package statement, and are separated from package with a blank line (to emphasize the fact that they target the file and not the package).

```
/** License, copyright and whatever */
@file:JvmName("FooBar")

package foo.bar
```

Functions

If the function signature doesn't fit on a single line, use the following syntax:

```
fun longMethodName(
    argument: ArgumentType = defaultValue,
    argument2: AnotherArgumentType,
): ReturnType {
    // body
}
```

Use regular indent (four spaces) for function parameters. It helps ensure consistency with constructor parameters.

Prefer using an expression body for functions with the body consisting of a single expression.

```
fun foo(): Int {     // bad
    return 1
}

fun foo() = 1        // good
```

Expression bodies

If the function has an expression body whose first line doesn't fit on the same line as the declaration, put the = sign on the first line and indent the expression body by four spaces.

```
fun f(x: String, y: String, z: String) =
    veryLongFunctionCallWithManyWords(andLongParametersToo(), x, y, z)
```

Properties

For very simple read-only properties, consider one-line formatting:

```
val isEmpty: Boolean get() = size == 0
```

For more complex properties, always put get and set keywords on separate lines:

```
val foo: String
    get() { /*...*/ }
```

For properties with an initializer, if the initializer is long, add a line break after the = sign and indent the initializer by four spaces:

```
private val defaultCharset: Charset? =
    EncodingRegistry.getInstance().getDefaultCharsetForPropertiesFiles(file)
```

Control flow statements

If the condition of an if or when statement is multiline, always use curly braces around the body of the statement. Indent each subsequent line of the condition by four spaces relative to the statement start. Put the closing parentheses of the condition together with the opening curly brace on a separate line:

```
if (!component.isSyncing &&
    !hasAnyKotlinRuntimeInScope(module)
) {
    return createKotlinNotConfiguredPanel(module)
}
```

This helps align the condition and statement bodies.

Put the else, catch, finally keywords, as well as the while keyword of a do-while loop, on the same line as the preceding curly brace:

```
if (condition) {
    // body
} else {
    // else part
}

try {
    // body
} finally {
    // cleanup
}
```

In a when statement, if a branch is more than a single line, consider separating it from adjacent case blocks with a blank line:

```
private fun parsePropertyValue(propName: String, token: Token) {
    when (token) {
        is Token.ValueToken ->
            callback.visitValue(propName, token.value)

        Token.LBRACE -> { // ...
        }
    }
}
```

Put short branches on the same line as the condition, without braces.

```
when (foo) {
    true -> bar() // good
    false -> { baz() } // bad
}
```

Method calls

In long argument lists, put a line break after the opening parenthesis. Indent arguments by four spaces. Group multiple closely related arguments on the same line.

```
drawSquare(
    x = 10, y = 10,
    width = 100, height = 100,
    fill = true
)
```

Put spaces around the = sign separating the argument name and value.

Wrap chained calls

When wrapping chained calls, put the . character or the ?. operator on the next line, with a single indent:

```
val anchor = owner
    ?.firstChild!!
    .siblings(forward = true)
    .dropWhile { it is PsiComment || it is PsiWhiteSpace }
```

The first call in the chain should usually have a line break before it, but it's OK to omit it if the code makes more sense that way.

Lambdas

In lambda expressions, spaces should be used around the curly braces, as well as around the arrow which separates the parameters from the body. If a call takes a single lambda, pass it outside parentheses whenever possible.

```
list.filter { it > 10 }
```

If assigning a label for a lambda, do not put a space between the label and the opening curly brace:

```
fun foo() {
    ints.forEach lit@{
        // ...
    }
}
```

When declaring parameter names in a multiline lambda, put the names on the first line, followed by the arrow and the newline:

```
appendCommaSeparated(properties) { prop ->
    val propertyValue = prop.get(obj)  // ...
}
```

If the parameter list is too long to fit on a line, put the arrow on a separate line:

```
foo {
   context: Context,
   environment: Env
   ->
   context.configureEnv(environment)
}
```

Trailing commas

A trailing comma is a comma symbol after the last item in a series of elements:

```
class Person(
    val firstName: String,
    val lastName: String,
    val age: Int, // trailing comma
)
```

Using trailing commas has several benefits:

- It makes version-control diffs cleaner – as all the focus is on the changed value.
- It makes it easy to add and reorder elements – there is no need to add or delete the comma if you manipulate elements.
- It simplifies code generation, for example, for object initializers. The last element can also have a comma.

Trailing commas are entirely optional – your code will still work without them. The Kotlin style guide encourages the use of trailing commas at the declaration site and leaves it at your discretion for the call site.

To enable trailing commas in the IntelliJ IDEA formatter, go to Settings/Preferences | Editor | Code Style | Kotlin, open the Other tab and select the Use trailing comma option.

Enumerations

```
enum class Direction {
    NORTH,
    SOUTH,
    WEST,
    EAST, // trailing comma
}
```

Value arguments

```
fun shift(x: Int, y: Int) { /*...*/ }
shift(
    25,
    20, // trailing comma
)
val colors = listOf(
    "red",
    "green",
    "blue", // trailing comma
)
```

Class properties and parameters

```
class Customer(
    val name: String,
    val lastName: String, // trailing comma
)
class Customer(
    val name: String,
    lastName: String, // trailing comma
)
```

Function value parameters

```
fun powerOf(
    number: Int,
    exponent: Int, // trailing comma
) { /*...*/ }
constructor(
    x: Comparable<Number>,
    y: Iterable<Number>, // trailing comma
) {}
fun print(
    vararg quantity: Int,
    description: String, // trailing comma
) {}
```

Parameters with optional type (including setters)

```
val sum: (Int, Int, Int) -> Int = fun(
    x,
    y,
    z, // trailing comma
): Int {
    return x + y + x
}
println(sum(8, 8, 8))
```

Indexing suffix

```
class Surface {
    operator fun get(x: Int, y: Int) = 2 * x + 4 * y - 10
}
fun getZValue(mySurface: Surface, xValue: Int, yValue: Int) =
    mySurface[
        xValue,
        yValue, // trailing comma
    ]
```

Parameters in lambdas

```
fun main() {
    val x = {
            x: Comparable<Number>,
            y: Iterable<Number>, // trailing comma
        ->
        println("1")
    }
    println(x)
}
```

when entry

```
fun isReferenceApplicable(myReference: KClass<*>) = when (myReference) {
    Comparable::class,
    Iterable::class,
    String::class, // trailing comma
        -> true
    else -> false
}
```

Collection literals (in annotations)

```
annotation class ApplicableFor(val services: Array<String>)
@ApplicableFor([
    "serializer",
    "balancer",
    "database",
    "inMemoryCache", // trailing comma
])
fun run() {}
```

Type arguments

```
fun <T1, T2> foo() {}
fun main() {
    foo<
            Comparable<Number>,
            Iterable<Number>, // trailing comma
            >()
}
```

Type parameters

```
class MyMap<
        MyKey,
        MyValue, // trailing comma
        > {}
```

Destructuring declarations

```
data class Car(val manufacturer: String, val model: String, val year: Int)
val myCar = Car("Tesla", "Y", 2019)
val (
    manufacturer,
    model,
    year, // trailing comma
) = myCar
val cars = listOf<Car>()
fun printMeanValue() {
    var meanValue: Int = 0
    for ((
        _,
        _,
        year, // trailing comma
    ) in cars) {
        meanValue += year
    }
    println(meanValue/cars.size)
}
printMeanValue()
```

Documentation comments

For longer documentation comments, place the opening /** on a separate line and begin each subsequent line with an asterisk:

```
/**
 * This is a documentation comment
 * on multiple lines.
 */
```

Short comments can be placed on a single line:

```
/** This is a short documentation comment. */
```

Generally, avoid using @param and @return tags. Instead, incorporate the description of parameters and return values directly into the documentation comment, and add links to parameters wherever they are mentioned. Use @param and @return only when a lengthy description is required which doesn't fit into the flow of the main text.

```
// Avoid doing this:

/**
 * Returns the absolute value of the given number.
 * @param number The number to return the absolute value for.
 * @return The absolute value.
 */
fun abs(number: Int): Int { /*...*/ }

// Do this instead:

/**
 * Returns the absolute value of the given [number].
 */
fun abs(number: Int): Int { /*...*/ }
```

Avoid redundant constructs

In general, if a certain syntactic construction in Kotlin is optional and highlighted by the IDE as redundant, you should omit it in your code. Do not leave unnecessary syntactic elements in code just "for clarity".

Unit return type

If a function returns Unit, the return type should be omitted:

```
fun foo() { // ": Unit" is omitted here

}
```

Semicolons

Omit semicolons whenever possible.

String templates

Don't use curly braces when inserting a simple variable into a string template. Use curly braces only for longer expressions.

```
println("$name has ${children.size} children")
```

Idiomatic use of language features

Immutability

Prefer using immutable data to mutable. Always declare local variables and properties as val rather than var if they are not modified after initialization.

Always use immutable collection interfaces (Collection, List, Set, Map) to declare collections which are not mutated. When using factory functions to create collection instances, always use functions that return immutable collection types when possible:

```
// Bad: use of a mutable collection type for value which will not be mutated
fun validateValue(actualValue: String, allowedValues: HashSet<String>) { ... }

// Good: immutable collection type used instead
fun validateValue(actualValue: String, allowedValues: Set<String>) { ... }

// Bad: arrayListOf() returns ArrayList<T>, which is a mutable collection type
val allowedValues = arrayListOf("a", "b", "c")

// Good: listOf() returns List<T>
val allowedValues = listOf("a", "b", "c")
```

Default parameter values

Prefer declaring functions with default parameter values to declaring overloaded functions.

```
// Bad
fun foo() = foo("a")
fun foo(a: String) { /*...*/ }

// Good
fun foo(a: String = "a") { /*...*/ }
```

Type aliases

If you have a functional type or a type with type parameters which is used multiple times in a codebase, prefer defining a type alias for it:

```
typealias MouseClickHandler = (Any, MouseEvent) -> Unit
typealias PersonIndex = Map<String, Person>
```

If you use a private or internal type alias for avoiding name collision, prefer the import ... as ... mentioned in Packages and Imports.

Lambda parameters

In lambdas which are short and not nested, it's recommended to use the it convention instead of declaring the parameter explicitly. In nested lambdas with parameters, always declare parameters explicitly.

Returns in a lambda

Avoid using multiple labeled returns in a lambda. Consider restructuring the lambda so that it will have a single exit point. If that's not possible or not clear enough, consider converting the lambda into an anonymous function.

Do not use a labeled return for the last statement in a lambda.

Named arguments

Use the named argument syntax when a method takes multiple parameters of the same primitive type, or for parameters of Boolean type, unless the meaning of all parameters is absolutely clear from context.

```
drawSquare(x = 10, y = 10, width = 100, height = 100, fill = true)
```

Conditional statements

Prefer using the expression form of try, if, and when.

```
return if (x) foo() else bar()
return when(x) {
    0 -> "zero"
    else -> "nonzero"
}
```

The above is preferable to:

```
if (x)
    return foo()
else
    return bar()
```

```
when(x) {
    0 -> return "zero"
    else -> return "nonzero"
}
```

if versus when

Prefer using if for binary conditions instead of when. For example, use this syntax with if:

```
if (x == null) ... else ...
```

Instead of this one with when:

```
when (x) {
    null -> // ...
    else -> // ...
}
```

Prefer using when if there are three or more options.

Guard conditions in when expression

Use parentheses when combining multiple boolean expressions in when expressions or statements with guard conditions:

```
when (status) {
    is Status.Ok if (status.info.isEmpty() || status.info.id == null) -> "no information"
}
```

Instead of:

```
when (status) {
    is Status.Ok if status.info.isEmpty() || status.info.id == null -> "no information"
}
```

Nullable Boolean values in conditions

If you need to use a nullable Boolean in a conditional statement, use if (value == true) or if (value == false) checks.

Loops

Prefer using higher-order functions (filter, map etc.) to loops. Exception: forEach (prefer using a regular for loop instead, unless the receiver of forEach is nullable or forEach is used as part of a longer call chain).

When making a choice between a complex expression using multiple higher-order functions and a loop, understand the cost of the operations being performed in each case and keep performance considerations in mind.

Loops on ranges

Use the ..< operator to loop over an open-ended range:

```
for (i in 0..n - 1) { /*...*/ }  // bad
for (i in 0..<n) { /*...*/ }  // good
```

Strings

Prefer string templates to string concatenation.

Prefer multiline strings to embedding \n escape sequences into regular string literals.

To maintain indentation in multiline strings, use trimIndent when the resulting string does not require any internal indentation, or trimMargin when internal indentation is required:

```
fun main() {
   println("""
    Not
    trimmed
    text
    """
   )

   println("""
    Trimmed
    text
    """.trimIndent()
   )

   println()

   val a = """Trimmed to margin text:
          |if(a > 1) {
          |    return a
          |}""".trimMargin()

   println(a)
}
```

Learn the difference between Java and Kotlin multiline strings.

Functions vs properties

In some scenarios, functions with no arguments might be interchangeable with read-only properties. Although the semantics are similar, there are some stylistic conventions on when to prefer one to another.

Prefer a property over a function when the underlying algorithm:

- Does not throw.
- Is cheap to calculate (or cached on the first run).
- Returns the same result over invocations if the object state hasn't changed.

Extension functions

Use extension functions liberally. Every time you have a function that works primarily on an object, consider making it an extension function accepting that object as a receiver. To minimize API pollution, restrict the visibility of extension functions as much as it makes sense. As necessary, use local extension functions, member extension functions, or top-level extension functions with private visibility.

Infix functions

Declare a function as infix only when it works on two objects which play a similar role. Good examples: and, to, zip. Bad example: add.

Do not declare a method as infix if it mutates the receiver object.

Factory functions

If you declare a factory function for a class, avoid giving it the same name as the class itself. Prefer using a distinct name, making it clear why the behavior of the factory function is special. Only if there is really no special semantics, you can use the same name as the class.

```
class Point(val x: Double, val y: Double) {
    companion object {
        fun fromPolar(angle: Double, radius: Double) = Point(...)
    }
}
```

If you have an object with multiple overloaded constructors that don't call different superclass constructors and can't be reduced to a single constructor with default argument values, prefer to replace the overloaded constructors with factory functions.

Platform types

A public function/method returning an expression of a platform type must declare its Kotlin type explicitly:

```
fun apiCall(): String = MyJavaApi.getProperty("name")
```

Any property (package-level or class-level) initialized with an expression of a platform type must declare its Kotlin type explicitly:

```
class Person {
    val name: String = MyJavaApi.getProperty("name")
}
```

A local value initialized with an expression of a platform type may or may not have a type declaration:

```
fun main() {
    val name = MyJavaApi.getProperty("name")
    println(name)
}
```

Scope functions apply/with/run/also/let

Kotlin provides a set of functions to execute a block of code in the context of a given object: let, run, with, apply, and also. For the guidance on choosing the right scope function for your case, refer to Scope Functions.

Coding conventions for libraries

When writing libraries, it's recommended to follow an additional set of rules to ensure API stability:

- Always explicitly specify member visibility (to avoid accidentally exposing declarations as public API).
- Always explicitly specify function return types and property types (to avoid accidentally changing the return type when the implementation changes).
- Provide KDoc comments for all public members, except for overrides that do not require any new documentation (to support generating documentation for the library).

Learn more about best practices and ideas to consider when writing an API for your library in the Library authors' guidelines.

Basic types

In Kotlin, everything is an object in the sense that you can call member functions and properties on any variable. While certain types have an optimized internal representation as primitive values at runtime (such as numbers, characters, booleans and others), they appear and behave like regular classes to you.

This section describes the basic types used in Kotlin:

- Numbers and their unsigned counterparts
- Booleans
- Characters

* Strings
* Arrays

Learn how to perform type checks and casts in Kotlin.

To learn about other Kotlin types, such as Nothing, Any, and Unit, look through the Kotlin API reference:

* Any
* Nothing
* Unit

Numbers

Integer types

Kotlin provides a set of built-in types that represent numbers.
For integer numbers, there are four types with different sizes and value ranges:

Type	Size (bits)	Min value	Max value
Byte	8	-128	127
Short	16	-32768	32767
Int	32	-2,147,483,648 (-231)	2,147,483,647 (231 - 1)
Long	64	-9,223,372,036,854,775,808 (-263)	9,223,372,036,854,775,807 (263 - 1)

In addition to signed integer types, Kotlin also provides unsigned integer types. As unsigned integers are aimed at a different set of use cases, they are covered separately. See Unsigned integer types.

When you initialize a variable with no explicit type specification, the compiler automatically infers the type with the smallest range enough to represent the value starting from Int. If it doesn't exceed the range of Int, the type is Int. If it does exceed that range, the type is Long. To specify the Long value explicitly, append the suffix L to the value. To use the Byte or Short type, specify it explicitly in the declaration. Explicit type specification triggers the compiler to check that the value doesn't exceed the range of the specified type.

```kotlin
val one = 1 // Int
val threeBillion = 3000000000 // Long
val oneLong = 1L // Long
val oneByte: Byte = 1
```

Floating-point types

For real numbers, Kotlin provides floating-point types Float and Double that adhere to the IEEE 754 standard. Float reflects the IEEE 754 single precision, while Double reflects double precision.

These types differ in their size and provide storage for floating-point numbers with different precision:

Type	Size (bits)	Significant bits	Exponent bits	Decimal digits
Float	32	24	8	6-7
Double	64	53	11	15-16

You can initialize Double and Float variables only with numbers that have a fractional part. Separate the fractional part from the integer part by a period (.)

For variables initialized with fractional numbers, the compiler infers the Double type:

```kotlin
val pi = 3.14          // Double

val one: Double = 1    // Int is inferred
// Initializer type mismatch

val oneDouble = 1.0    // Double
```

To explicitly specify the Float type for a value, add the suffix f or F. If a value provided in this way contains more than 7 decimal digits, it is rounded:

```kotlin
val e = 2.7182818284          // Double
val eFloat = 2.7182818284f    // Float, actual value is 2.7182817
```

Unlike in some other languages, there are no implicit widening conversions for numbers in Kotlin. For example, a function with a Double parameter can be called only on Double values, but not Float, Int, or other numeric values:

```kotlin
fun main() {
    fun printDouble(x: Double) { print(x) }

    val x = 1.0
    val xInt = 1
    val xFloat = 1.0f

    printDouble(x)

    printDouble(xInt)
    // Argument type mismatch

    printDouble(xFloat)
    // Argument type mismatch
}
```

To convert numeric values to different types, use explicit conversions.

Literal constants for numbers

There are several kinds of literal constants for integral values:

- Decimals: 123
- Longs, ending with the capital L: 123L
- Hexadecimals: 0x0F
- Binaries: 0b00001011

Octal literals are not supported in Kotlin.

Kotlin also supports conventional notation for floating-point numbers:

- Doubles (default when the fractional part does not end with a letter): 123.5, 123.5e10
- Floats, ending with the letter f or F: 123.5f

You can use underscores to make number constants more readable:

```
val oneMillion = 1_000_000
val creditCardNumber = 1234_5678_9012_3456L
val socialSecurityNumber = 999_99_9999L
val hexBytes = 0xFF_EC_DE_5E
val bytes = 0b11010010_01101001_10010100_10010010
val bigFractional = 1_234_567.7182818284
```

> There are also special suffixes for unsigned integer literals.
> Read more about literals for unsigned integer types.

Boxing and caching numbers on the Java Virtual Machine

The way the JVM stores numbers can make your code behave counterintuitively because of the cache used by default for small (byte-sized) numbers.

The JVM stores numbers as primitive types: int, double, and so on. When you use generic types or create a nullable number reference such as Int?, numbers are boxed in Java classes such as Integer or Double.

The JVM applies a memory optimization technique to Integer and other objects that represent numbers between −128 and 127. All nullable references to such objects refer to the same cached object. For example, nullable objects in the following code are referentially equal:

```
fun main() {
    val a: Int = 100
    val boxedA: Int? = a
    val anotherBoxedA: Int? = a

    println(boxedA === anotherBoxedA) // true
}
```

For numbers outside this range, the nullable objects are different but structurally equal:

```
fun main() {
    val b: Int = 10000
    val boxedB: Int? = b
    val anotherBoxedB: Int? = b

    println(boxedB === anotherBoxedB) // false
    println(boxedB == anotherBoxedB) // true
}
```

For this reason, Kotlin warns about using referential equality with boxable numbers and literals with the following message: "Identity equality for arguments of types ... and ... is prohibited." When comparing Int, Short, Long, and Byte types (as well as Char and Boolean), use structural equality checks to get consistent results.

Explicit number conversions

Due to different representations, number types are not subtypes of each other. As a consequence, smaller types are not implicitly converted to bigger types and vice versa. For example, assigning a value of type Byte to an Int variable requires an explicit conversion:

```
fun main() {
    val byte: Byte = 1
    // OK, literals are checked statically

    val intAssignedByte: Int = byte
    // Initializer type mismatch

    val intConvertedByte: Int = byte.toInt()

    println(intConvertedByte)
}
```

All number types support conversions to other types:

- toByte(): Byte (deprecated for Float and Double)

- toShort(): Short
- toInt(): Int
- toLong(): Long
- toFloat(): Float
- toDouble(): Double

In many cases, there is no need for explicit conversion because the type is inferred from the context, and arithmetical operators are overloaded to handle conversions automatically. For example:

```
fun main() {
    val l = 1L + 3       // Long + Int => Long
    println(l is Long)   // true
}
```

Reasoning against implicit conversions

Kotlin doesn't support implicit conversions because they can lead to unexpected behavior.

If numbers of different types were converted implicitly, we could sometimes lose equality and identity silently. For example, imagine if Int was a subtype of Long:

```
// Hypothetical code, does not actually compile:
val a: Int? = 1    // A boxed Int (java.lang.Integer)
val b: Long? = a   // Implicit conversion yields a boxed Long (java.lang.Long)
print(b == a)      // Prints "false" as Long.equals() checks not only the value but whether the other number is Long as well
```

Operations on numbers

Kotlin supports the standard set of arithmetical operations over numbers: +, -, *, /, %. They are declared as members of appropriate classes:

```
fun main() {
    println(1 + 2)
    println(2_500_000_000L - 1L)
    println(3.14 * 2.71)
    println(10.0 / 3)
}
```

You can override these operators in custom number classes. See Operator overloading for details.

Division of integers

Division between integer numbers always returns an integer number. Any fractional part is discarded.

```
fun main() {
    val x = 5 / 2
    println(x == 2.5)
    // Operator '==' cannot be applied to 'Int' and 'Double'

    println(x == 2)
    // true
}
```

This is true for a division between any two integer types:

```
fun main() {
    val x = 5L / 2
    println (x == 2)
    // Error, as Long (x) cannot be compared to Int (2)

    println(x == 2L)
    // true
}
```

To return a division result with the fractional part, explicitly convert one of the arguments to a floating-point type:

```
fun main() {
    val x = 5 / 2.toDouble()
    println(x == 2.5)
}
```

Bitwise operations

Kotlin provides a set of bitwise operations on integer numbers. They operate on the binary level directly with bits of the numbers' representation. Bitwise operations are represented by functions that can be called in infix form. They can be applied only to Int and Long:

```
fun main() {
    val x = 1
    val xShiftedLeft = (x shl 2)
    println(xShiftedLeft)
    // 4

    val xAnd = x and 0x000FF000
    println(xAnd)
    // 0
}
```

The complete list of bitwise operations:

- shl(bits) – signed shift left
- shr(bits) – signed shift right
- ushr(bits) – unsigned shift right
- and(bits) – bitwise AND
- or(bits) – bitwise OR
- xor(bits) – bitwise XOR
- inv() – bitwise inversion

Floating-point numbers comparison

The operations on floating-point numbers discussed in this section are:

- Equality checks: a == b and a != b
- Comparison operators: a < b, a > b, a <= b, a >= b
- Range instantiation and range checks: a..b, x in a..b, x !in a..b

When the operands a and b are statically known to be Float or Double or their nullable counterparts (the type is declared or inferred or is a result of a smart cast), the operations on the numbers and the range that they form follow the IEEE 754 Standard for Floating-Point Arithmetic.

However, to support generic use cases and provide total ordering, the behavior is different for operands that are not statically typed as floating-point numbers. For example, Any, Comparable<...>, or Collection<T> types. In this case, the operations use the equals and compareTo implementations for Float and Double. As a result:

- NaN is considered equal to itself
- NaN is considered greater than any other element including POSITIVE_INFINITY
- -0.0 is considered less than 0.0

Here is an example that shows the difference in behavior between operands statically typed as floating-point numbers (Double.NaN) and operands not statically typed as floating-point numbers (listOf(T)).

```
fun main() {
        // Operand statically typed as floating-point number
    println(Double.NaN == Double.NaN)                 // false
    // Operand NOT statically typed as floating-point number
    // So NaN is equal to itself
    println(listOf(Double.NaN) == listOf(Double.NaN)) // true

    // Operand statically typed as floating-point number
    println(0.0 == -0.0)                              // true

    // Operand NOT statically typed as floating-point number
    // So -0.0 is less than 0.0
    println(listOf(0.0) == listOf(-0.0))              // false

    println(listOf(Double.NaN, Double.POSITIVE_INFINITY, 0.0, -0.0).sorted())
    // [-0.0, 0.0, Infinity, NaN]
    //sampleEnd
}
```

Unsigned integer types

In addition to integer types, Kotlin provides the following types for unsigned integer numbers:

Type	Size (bits)	Min value	Max value
UByte	8	0	255
UShort	16	0	65,535
UInt	32	0	4,294,967,295 (232 - 1)
ULong	64	0	18,446,744,073,709,551,615 (264 - 1)

Unsigned types support most of the operations of their signed counterparts.

> Unsigned numbers are implemented as inline classes with a single storage property that contains the corresponding signed counterpart type of the same width. If you want to convert between unsigned and signed integer types, make sure you update your code so that any function calls and operations support the new type.

Unsigned arrays and ranges

> Unsigned arrays and operations on them are in Beta. They can be changed incompatibly at any time. Opt-in is required (see the details below).

Same as for primitives, each unsigned type has a corresponding type that represents arrays of that type:

- UByteArray: an array of unsigned bytes.
- UShortArray: an array of unsigned shorts.
- UIntArray: an array of unsigned ints.
- ULongArray: an array of unsigned longs.

Same as for signed integer arrays, they provide a similar API to the Array class without boxing overhead.

When you use unsigned arrays, you receive a warning that indicates that this feature is not stable yet. To remove the warning, opt-in with the @ExperimentalUnsignedTypes annotation. It's up to you to decide if your clients have to explicitly opt-in into usage of your API, but keep in mind that unsigned arrays are not a stable feature, so an API that uses them can be broken by changes in the language. Learn more about opt-in requirements.

Ranges and progressions are supported for UInt and ULong by classes UIntRange, UIntProgression, ULongRange, and ULongProgression. Together with the unsigned integer types, these classes are stable.

Unsigned integers literals

To make unsigned integers easier to use, you can append a suffix to an integer literal
indicating a specific unsigned type (similarly to F for Float or L for Long):

- u and U letters signify unsigned literals without specifying the exact type. If no expected type is provided, the compiler uses UInt or ULong depending on the size of the literal:

```
val b: UByte = 1u  // UByte, expected type provided
val s: UShort = 1u // UShort, expected type provided
val l: ULong = 1u  // ULong, expected type provided

val a1 = 42u // UInt: no expected type provided, constant fits in UInt
val a2 = 0xFFFF_FFFF_FFFFu // ULong: no expected type provided, constant doesn't fit in UInt
```

- uL and UL explicitly specify that literal should be an unsigned long:

```
val a = 1UL // ULong, even though no expected type provided and the constant fits into UInt
```

Use cases

The main use case of unsigned numbers is utilizing the full bit range of an integer to represent positive values.
For example, to represent hexadecimal constants that do not fit in signed types such as color in 32-bit AARRGGBB format:

```
data class Color(val representation: UInt)

val yellow = Color(0xFFCC00CCu)
```

You can use unsigned numbers to initialize byte arrays without explicit toByte() literal casts:

```
val byteOrderMarkUtf8 = ubyteArrayOf(0xEFu, 0xBBu, 0xBFu)
```

Another use case is interoperability with native APIs. Kotlin allows representing native declarations that contain unsigned types in the signature. The mapping won't substitute unsigned integers with signed ones keeping the semantics unaltered.

Non-goals

While unsigned integers can only represent positive numbers and zero, it's not a goal to use them where application domain requires non-negative integers. For example, as a type of collection size or collection index value.

There are a couple of reasons:

- Using signed integers can help to detect accidental overflows and signal error conditions, such as List.lastIndex being -1 for an empty list.
- Unsigned integers cannot be treated as a range-limited version of signed ones because their range of values is not a subset of the signed integers range. Neither signed, nor unsigned integers are subtypes of each other.

Booleans

The type Boolean represents boolean objects that can have two values: true and false. Boolean has a nullable counterpart declared as Boolean?.

On the JVM, booleans stored as the primitive boolean type typically use 8 bits.

Built-in operations on booleans include:

- || – disjunction (logical OR)
- && – conjunction (logical AND)
- ! – negation (logical NOT)

For example:

```
fun main() {
    val myTrue: Boolean = true
    val myFalse: Boolean = false
    val boolNull: Boolean? = null

    println(myTrue || myFalse)
    // true
    println(myTrue && myFalse)
    // false
    println(!myTrue)
    // false
    println(boolNull)
    // null
}
```

The || and && operators work lazily, which means:

- If the first operand is true, the || operator does not evaluate the second operand.
- If the first operand is false, the && operator does not evaluate the second operand.

On the JVM, nullable references to boolean objects are boxed in Java classes, just like with numbers.

Characters

Characters are represented by the type Char. Character literals go in single quotes: '1'.

On the JVM, a character stored as primitive type: char, represents a 16-bit Unicode character.

Special characters start from an escaping backslash \. The following escape sequences are supported:

- \t – tab
- \b – backspace
- \n – new line (LF)
- \r – carriage return (CR)
- \' – single quotation mark
- \" – double quotation mark
- \\ – backslash
- \$ – dollar sign

To encode any other character, use the Unicode escape sequence syntax: '\uFF00'.

```
fun main() {
    val aChar: Char = 'a'

    println(aChar)
    println('\n') // Prints an extra newline character
    println('\uFF00')
}
```

If a value of character variable is a digit, you can explicitly convert it to an Int number using the digitToInt() function.

On the JVM, characters are boxed in Java classes when a nullable reference is needed, just like with numbers. Identity is not preserved by the boxing operation.

Strings

Strings in Kotlin are represented by the type String.

On the JVM, an object of String type in UTF-16 encoding uses approximately 2 bytes per character.

Generally, a string value is a sequence of characters in double quotes ("):

```
val str = "abcd 123"
```

Elements of a string are characters that you can access via the indexing operation: s[i]. You can iterate over these characters with a for loop:

```
fun main() {
    val str = "abcd"
    for (c in str) {
        println(c)
    }
}
```

Strings are immutable. Once you initialize a string, you can't change its value or assign a new value to it. All operations that transform strings return their results in a new String object, leaving the original string unchanged:

```
fun main() {
    val str = "abcd"

    // Creates and prints a new String object
    println(str.uppercase())
    // ABCD

    // The original string remains the same
    println(str)
    // abcd
}
```

To concatenate strings, use the + operator. This also works for concatenating strings with values of other types, as long as the first element in the expression is a string:

```
fun main() {
    val s = "abc" + 1
    println(s + "def")
    // abc1def
}
```

In most cases using string templates or multiline strings is preferable to string concatenation.

String literals

Kotlin has two types of string literals:

- Escaped strings
- Multiline strings

Escaped strings

Escaped strings can contain escaped characters.

Here's an example of an escaped string:

```
val s = "Hello, world!\n"
```

Escaping is done in the conventional way, with a backslash (\).
See Characters page for the list of supported escape sequences.

Multiline strings

Multiline strings can contain newlines and arbitrary text. It is delimited by a triple quote ("""), contains no escaping and can contain newlines and any other characters:

```
val text = """
    for (c in "foo")
        print(c)
    """
```

To remove leading whitespace from multiline strings, use the trimMargin() function:

```
val text = """
    |Tell me and I forget.
    |Teach me and I remember.
    |Involve me and I learn.
    |(Benjamin Franklin)
    """.trimMargin()
```

By default, a pipe symbol | is used as margin prefix, but you can choose another character and pass it as a parameter, like trimMargin(">").

String templates

String literals may contain template expressions – pieces of code that are evaluated and whose results are concatenated into a string. When a template expression is processed, Kotlin automatically calls the .toString() function on the expression's result to convert it into a string. A template expression starts with a dollar sign ($) and consists of either a variable name:

```
fun main() {
    val i = 10
    println("i = $i")
    // i = 10

    val letters = listOf("a","b","c","d","e")
    println("Letters: $letters")
    // Letters: [a, b, c, d, e]

}
```

or an expression in curly braces:

```
fun main() {
    val s = "abc"
    println("$s.length is ${s.length}")
    // abc.length is 3
}
```

You can use templates both in multiline and escaped strings. However, multiline strings don't support backslash escaping. To insert the dollar sign $ in a multiline string before any symbol allowed at the beginning of an identifier, use the following syntax:

```
val price = """
${'$'}_9.99
"""
```

> To avoid ${'$'} sequences in strings, you can use the Experimental multi-dollar string interpolation feature.

Multi-dollar string interpolation

The multi-dollar string interpolation is Experimental and opt-in is required (see details below).

It may be changed at any time. We would appreciate your feedback in YouTrack.

Multi-dollar string interpolation allows you to specify how many consecutive dollar signs are required to trigger interpolation. Interpolation is the process of embedding variables or expressions directly into a string.

While you can escape literals for single-line strings, multiline strings in Kotlin don't support backslash escaping. To include dollar signs ($) as literal characters, you must use the ${'$'} construct to prevent string interpolation. This approach can make code harder to read, especially when strings contain multiple dollar signs.

Multi-dollar string interpolation simplifies this by letting you treat dollar signs as literal characters in both single-line and multiline strings. For example:

```
val KClass<*>.jsonSchema : String
    get() = $$"""
    {
      "$schema": "https://json-schema.org/draft/2020-12/schema",
      "$id": "https://example.com/product.schema.json",
      "$dynamicAnchor": "meta"
      "title": "$${simpleName ?: qualifiedName ?: "unknown"}",
      "type": "object"
    }
    """
```

Here, the $$ prefix specifies that two consecutive dollar signs are required to trigger string interpolation. Single dollar signs remain as literal characters.

You can adjust how many dollar signs trigger interpolation. For example, using three consecutive dollar signs ($$$) allows $ and $$ to remain as literals while enabling interpolation with $$$:

```
val productName = "carrot"
val requestedData =
    $$$"""{
      "currency": "$",
      "enteredAmount": "42.45 $$",
      "$$serviceField": "none",
      "product": "$$$productName"
    }
    """

println(requestedData)
//{
//    "currency": "$",
//    "enteredAmount": "42.45 $$",
//    "$$serviceField": "none",
//    "product": "carrot"
//}
```

Here, the $$$ prefix allows the string to include $ and $$ without requiring the ${'$'} construct for escaping.

To enable the feature, use the following compiler option in the command line:

```
kotlinc -Xmulti-dollar-interpolation main.kt
```

Alternatively, update the compilerOptions {} block of your Gradle build file:

```
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xmulti-dollar-interpolation")
    }
}
```

This feature doesn't affect existing code that uses single-dollar string interpolation. You can continue using a single $ as before and apply multi-dollar signs when you need to handle literal dollar signs in strings.

String formatting

String formatting with the String.format() function is only available in Kotlin/JVM.

To format a string to your specific requirements, use the String.format() function.

The String.format() function accepts a format string and one or more arguments. The format string contains one placeholder (indicated by %) for a given argument, followed by format specifiers. Format specifiers are formatting instructions for the respective argument, consisting of flags, width, precision, and conversion type. Collectively, format specifiers shape the output's formatting. Common format specifiers include %d for integers, %f for floating-point numbers, and %s for strings. You can also use the argument_index$ syntax to reference the same argument multiple times within the format string in different formats.

For a detailed understanding and an extensive list of format specifiers, see Java's Class Formatter documentation.

Let's look at an example:

```kotlin
fun main() {
    // Formats an integer, adding leading zeroes to reach a length of seven characters
    val integerNumber = String.format("%07d", 31416)
    println(integerNumber)
    // 0031416

    // Formats a floating-point number to display with a + sign and four decimal places
    val floatNumber = String.format("%+.4f", 3.141592)
    println(floatNumber)
    // +3.1416

    // Formats two strings to uppercase, each taking one placeholder
    val helloString = String.format("%S %S", "hello", "world")
    println(helloString)
    // HELLO WORLD

    // Formats a negative number to be enclosed in parentheses, then repeats the same number in a different format (without
parentheses) using `argument_index$`.
    val negativeNumberInParentheses = String.format("%(d means %1\$d", -31416)
    println(negativeNumberInParentheses)
    //(31416) means -31416
}
```

The String.format() function provides similar functionality to string templates. However, the String.format() function is more versatile because there are more formatting options available.

In addition, you can assign the format string from a variable. This can be useful when the format string changes, for example, in localization cases that depend on the user locale.

Be careful when using the String.format() function because it can be easy to mismatch the number or position of the arguments with their corresponding placeholders.

Arrays

An array is a data structure that holds a fixed number of values of the same type or its subtypes. The most common type of array in Kotlin is the object-type array, represented by the Array class.

If you use primitives in an object-type array, this has a performance impact because your primitives are boxed into objects. To avoid boxing overhead, use primitive-type arrays instead.

When to use arrays

Use arrays in Kotlin when you have specialized low-level requirements that you need to meet. For example, if you have performance requirements beyond what is needed for regular applications, or you need to build custom data structures. If you don't have these sorts of restrictions, use collections instead.

Collections have the following benefits compared to arrays:

- Collections can be read-only, which gives you more control and allows you to write robust code that has a clear intent.
- It is easy to add or remove elements from collections. In comparison, arrays are fixed in size. The only way to add or remove elements from an array is to create a new array each time, which is very inefficient:

```kotlin
fun main() {
    var riversArray = arrayOf("Nile", "Amazon", "Yangtze")

    // Using the += assignment operation creates a new riversArray,
    // copies over the original elements and adds "Mississippi"
    riversArray += "Mississippi"
    println(riversArray.joinToString())
    // Nile, Amazon, Yangtze, Mississippi
}
```

- You can use the equality operator (==) to check if collections are structurally equal. You can't use this operator for arrays. Instead, you have to use a special function, which you can read more about in Compare arrays.

For more information about collections, see Collections overview.

Create arrays

To create arrays in Kotlin, you can use:

- functions, such as arrayOf(), arrayOfNulls() or emptyArray().
- the Array constructor.

This example uses the arrayOf() function and passes item values to it:

```kotlin
fun main() {
    // Creates an array with values [1, 2, 3]
    val simpleArray = arrayOf(1, 2, 3)
    println(simpleArray.joinToString())
    // 1, 2, 3
}
```

This example uses the arrayOfNulls() function to create an array of a given size filled with null elements:

```kotlin
fun main() {
    // Creates an array with values [null, null, null]
    val nullArray: Array<Int?> = arrayOfNulls(3)
    println(nullArray.joinToString())
    // null, null, null
}
```

This example uses the emptyArray() function to create an empty array :

```kotlin
var exampleArray = emptyArray<String>()
```

You can specify the type of the empty array on the left-hand or right-hand side of the assignment due to Kotlin's type inference.

For example:

```kotlin
var exampleArray = emptyArray<String>()

var exampleArray: Array<String> = emptyArray()
```

The Array constructor takes the array size and a function that returns values for array elements given its index:

```kotlin
fun main() {
    // Creates an Array<Int> that initializes with zeros [0, 0, 0]
    val initArray = Array<Int>(3) { 0 }
    println(initArray.joinToString())
    // 0, 0, 0

    // Creates an Array<String> with values ["0", "1", "4", "9", "16"]
    val asc = Array(5) { i -> (i * i).toString() }
    asc.forEach { print(it) }
    // 014916
}
```

Like in most programming languages, indices start from 0 in Kotlin.

Nested arrays

Arrays can be nested within each other to create multidimensional arrays:

```
fun main() {
    // Creates a two-dimensional array
    val twoDArray = Array(2) { Array<Int>(2) { 0 } }
    println(twoDArray.contentDeepToString())
    // [[0, 0], [0, 0]]

    // Creates a three-dimensional array
    val threeDArray = Array(3) { Array(3) { Array<Int>(3) { 0 } } }
    println(threeDArray.contentDeepToString())
    // [[[0, 0, 0], [0, 0, 0], [0, 0, 0]], [[0, 0, 0], [0, 0, 0], [0, 0, 0]], [[0, 0, 0], [0, 0, 0], [0, 0, 0]]]
}
```

Nested arrays don't have to be the same type or the same size.

Access and modify elements

Arrays are always mutable. To access and modify elements in an array, use the indexed access operator[]:

```
fun main() {
    val simpleArray = arrayOf(1, 2, 3)
    val twoDArray = Array(2) { Array<Int>(2) { 0 } }

    // Accesses the element and modifies it
    simpleArray[0] = 10
    twoDArray[0][0] = 2

    // Prints the modified element
    println(simpleArray[0].toString()) // 10
    println(twoDArray[0][0].toString()) // 2
}
```

Arrays in Kotlin are invariant. This means that Kotlin doesn't allow you to assign an Array<String> to an Array<Any> to prevent a possible runtime failure. Instead, you can use Array<out Any>. For more information, see Type Projections.

Work with arrays

In Kotlin, you can work with arrays by using them to pass a variable number of arguments to a function or perform operations on the arrays themselves. For example, comparing arrays, transforming their contents or converting them to collections.

Pass variable number of arguments to a function

In Kotlin, you can pass a variable number of arguments to a function via the vararg parameter. This is useful when you don't know the number of arguments in advance, like when formatting a message or creating an SQL query.

To pass an array containing a variable number of arguments to a function, use the spread operator (*). The spread operator passes each element of the array as individual arguments to your chosen function:

```
fun main() {
    val lettersArray = arrayOf("c", "d")
    printAllStrings("a", "b", *lettersArray)
    // abcd
}

fun printAllStrings(vararg strings: String) {
    for (string in strings) {
        print(string)
    }
}
```

For more information, see Variable number of arguments (varargs).

Compare arrays

To compare whether two arrays have the same elements in the same order, use the .contentEquals() and .contentDeepEquals() functions:

```
fun main() {
    val simpleArray = arrayOf(1, 2, 3)
    val anotherArray = arrayOf(1, 2, 3)

    // Compares contents of arrays
    println(simpleArray.contentEquals(anotherArray))
    // true

    // Using infix notation, compares contents of arrays after an element
    // is changed
    simpleArray[0] = 10
    println(simpleArray contentEquals anotherArray)
    // false
}
```

Don't use equality (==) and inequality (!=) operators to compare the contents of arrays. These operators check whether the assigned variables point to the same object.

To learn more about why arrays in Kotlin behave this way, see our blog post.

Transform arrays

Kotlin has many useful functions to transform arrays. This document highlights a few but this isn't an exhaustive list. For the full list of functions, see our API reference.

Sum

To return the sum of all elements in an array, use the .sum() function:

```
fun main() {
    val sumArray = arrayOf(1, 2, 3)

    // Sums array elements
    println(sumArray.sum())
    // 6
}
```

The .sum() function can only be used with arrays of numeric data types, such as Int.

Shuffle

To randomly shuffle the elements in an array, use the .shuffle() function:

```
fun main() {
    val simpleArray = arrayOf(1, 2, 3)

    // Shuffles elements [3, 2, 1]
    simpleArray.shuffle()
    println(simpleArray.joinToString())

    // Shuffles elements again [2, 3, 1]
    simpleArray.shuffle()
    println(simpleArray.joinToString())
}
```

Convert arrays to collections

If you work with different APIs where some use arrays and some use collections, then you can convert your arrays tocollections and vice versa.

Convert to List or Set

To convert an array to a List or Set, use the .toList() and .toSet() functions.

```
fun main() {
    val simpleArray = arrayOf("a", "b", "c", "c")

    // Converts to a Set
    println(simpleArray.toSet())
    // [a, b, c]

    // Converts to a List
    println(simpleArray.toList())
    // [a, b, c, c]
}
```

Convert to Map

To convert an array to a Map, use the .toMap() function.

Only an array of Pair<K,V> can be converted to a Map. The first value of a Pair instance becomes a key, and the second becomes a value. This example uses the infix notation to call the to function to create tuples of Pair:

```
fun main() {
    val pairArray = arrayOf("apple" to 120, "banana" to 150, "cherry" to 90, "apple" to 140)

    // Converts to a Map
    // The keys are fruits and the values are their number of calories
    // Note how keys must be unique, so the latest value of "apple"
    // overwrites the first
    println(pairArray.toMap())
    // {apple=140, banana=150, cherry=90}

}
```

Primitive-type arrays

If you use the Array class with primitive values, these values are boxed into objects. As an alternative, you can use primitive-type arrays, which allow you to store primitives in an array without the side effect of boxing overhead:

Primitive-type array	Equivalent in Java
BooleanArray	boolean[]
ByteArray	byte[]

Primitive-type array	Equivalent in Java
CharArray	char[]
DoubleArray	double[]
FloatArray	float[]
IntArray	int[]
LongArray	long[]
ShortArray	short[]

These classes have no inheritance relation to the Array class, but they have the same set of functions and properties.

This example creates an instance of the IntArray class:

```
fun main() {
    // Creates an array of Int of size 5 with the values initialized to zero
    val exampleArray = IntArray(5)
    println(exampleArray.joinToString())
    // 0, 0, 0, 0, 0
}
```

To convert primitive-type arrays to object-type arrays, use the .toTypedArray() function.

To convert object-type arrays to primitive-type arrays, use .toBooleanArray(), .toByteArray(), .toCharArray(), and so on.

What's next?

- To learn more about why we recommend using collections for most use cases, read our Collections overview.
- Learn about other basic types.
- If you are a Java developer, read our Java to Kotlin migration guide for Collections.

Type checks and casts

In Kotlin, you can perform type checks to check the type of an object at runtime. Type casts enable you to convert objects to a different type.

To learn specifically about generics type checks and casts, for example List<T>, Map<K,V>, see Generics type checks and casts.

is and !is operators

To perform a runtime check that identifies whether an object conforms to a given type, use the is operator or its negated form !is:

```
if (obj is String) {
    print(obj.length)
}
```

```kotlin
if (obj !is String) { // Same as !(obj is String)
    print("Not a String")
} else {
    print(obj.length)
}
```

Smart casts

In most cases, you don't need to use explicit cast operators because the compiler automatically casts objects for you. This is called smart-casting. The compiler tracks the type checks and explicit casts for immutable values and inserts implicit (safe) casts automatically when necessary:

```kotlin
fun demo(x: Any) {
    if (x is String) {
        print(x.length) // x is automatically cast to String
    }
}
```

The compiler is even smart enough to know that a cast is safe if a negative check leads to a return:

```kotlin
if (x !is String) return

print(x.length) // x is automatically cast to String
```

Control flow

Smart casts work not only for if conditional expressions but also for when expressions and while loops:

```kotlin
when (x) {
    is Int -> print(x + 1)
    is String -> print(x.length + 1)
    is IntArray -> print(x.sum())
}
```

If you declare a variable of Boolean type before using it in your if, when, or while condition, then any information collected by the compiler about the variable will be accessible in the corresponding block for smart-casting.

This can be useful when you want to do things like extract boolean conditions into variables. Then, you can give the variable a meaningful name, which will improve your code readability and make it possible to reuse the variable later in your code. For example:

```kotlin
class Cat {
    fun purr() {
        println("Purr purr")
    }
}

fun petAnimal(animal: Any) {
    val isCat = animal is Cat
    if (isCat) {
        // The compiler can access information about
        // isCat, so it knows that animal was smart-cast
        // to the type Cat.
        // Therefore, the purr() function can be called.
        animal.purr()
    }
}

fun main(){
    val kitty = Cat()
    petAnimal(kitty)
    // Purr purr
}
```

Logical operators

The compiler can perform smart casts on the right-hand side of && or || operators if there is a type check (regular or negative) on the left-hand side:

```
// x is automatically cast to String on the right-hand side of `||`
if (x !is String || x.length == 0) return

// x is automatically cast to String on the right-hand side of `&&`
if (x is String && x.length > 0) {
    print(x.length) // x is automatically cast to String
}
```

If you combine type checks for objects with an or operator (||), a smart cast is made to their closest common supertype:

```
interface Status {
    fun signal() {}
}

interface Ok : Status
interface Postponed : Status
interface Declined : Status

fun signalCheck(signalStatus: Any) {
    if (signalStatus is Postponed || signalStatus is Declined) {
        // signalStatus is smart-cast to a common supertype Status
        signalStatus.signal()
    }
}
```

The common supertype is an approximation of a union type. Union types are not currently supported in Kotlin.

Inline functions

The compiler can smart-cast variables captured within lambda functions that are passed to inline functions.

Inline functions are treated as having an implicit callsInPlace contract. This means that any lambda functions passed to an inline function are called in place. Since lambda functions are called in place, the compiler knows that a lambda function can't leak references to any variables contained within its function body.

The compiler uses this knowledge, along with other analyses to decide whether it's safe to smart-cast any of the captured variables. For example:

```
interface Processor {
    fun process()
}

inline fun inlineAction(f: () -> Unit) = f()

fun nextProcessor(): Processor? = null

fun runProcessor(): Processor? {
    var processor: Processor? = null
    inlineAction {
        // The compiler knows that processor is a local variable and inlineAction()
        // is an inline function, so references to processor can't be leaked.
        // Therefore, it's safe to smart-cast processor.

        // If processor isn't null, processor is smart-cast
        if (processor != null) {
            // The compiler knows that processor isn't null, so no safe call
            // is needed
            processor.process()
        }

        processor = nextProcessor()
    }

    return processor
}
```

Exception handling

Smart cast information is passed on to catch and finally blocks. This makes your code safer as the compiler tracks whether your object has a nullable type. For example:

```
fun testString() {
    var stringInput: String? = null
    // stringInput is smart-cast to String type
    stringInput = ""
    try {
        // The compiler knows that stringInput isn't null
        println(stringInput.length)
        // 0

        // The compiler rejects previous smart cast information for
        // stringInput. Now stringInput has the String? type.
        stringInput = null

        // Trigger an exception
        if (2 > 1) throw Exception()
        stringInput = ""
    } catch (exception: Exception) {
        // The compiler knows stringInput can be null
        // so stringInput stays nullable.
        println(stringInput?.length)
        // null
    }
}
fun main() {
    testString()
}
```

Smart cast prerequisites

Note that smart casts work only when the compiler can guarantee that the variable won't change between the check and its usage.

Smart casts can be used in the following conditions:

val local variables	Always, except local delegated properties.
val properties	If the property is private, internal, or if the check is performed in the same module where the property is declared. Smart casts can't be used on open properties or properties that have custom getters.
var local variables	If the variable is not modified between the check and its usage, is not captured in a lambda that modifies it, and is not a local delegated property.
var properties	Never, because the variable can be modified at any time by other code.

"Unsafe" cast operator

To explicitly cast an object to a non-nullable type, use the unsafe cast operator as:

```
val x: String = y as String
```

If the cast isn't possible, the compiler throws an exception. This is why it's called unsafe.

In the previous example, if y is null, the code above also throws an exception. This is because null can't be cast to String, as String isn't nullable. To make the example work for possible null values, use a nullable type on the right-hand side of the cast:

```
val x: String? = y as String?
```

"Safe" (nullable) cast operator

To avoid exceptions, use the safe cast operator as?, which returns null on failure.

```
val x: String? = y as? String
```

Note that despite the fact that the right-hand side of as? is a non-nullable type String, the result of the cast is nullable.

Conditions and loops

If expression

In Kotlin, if is an expression: it returns a value. Therefore, there is no ternary operator (condition ? then : else) because ordinary if works fine in this role.

```
fun main() {
    val a = 2
    val b = 3

        var max = a
    if (a < b) max = b

    // With else
    if (a > b) {
      max = a
    } else {
      max = b
    }

    // As expression
    max = if (a > b) a else b

    // You can also use `else if` in expressions:
    val maxLimit = 1
    val maxOrLimit = if (maxLimit > a) maxLimit else if (a > b) a else b

    println("max is $max")
    // max is 3
    println("maxOrLimit is $maxOrLimit")
    // maxOrLimit is 3
    //sampleEnd
}
```

Branches of an if expression can be blocks. In this case, the last expression is the value of a block:

```
val max = if (a > b) {
    print("Choose a")
    a
} else {
    print("Choose b")
    b
}
```

If you're using if as an expression, for example, for returning its value or assigning it to a variable, the else branch is mandatory.

When expressions and statements

when is a conditional expression that runs code based on multiple possible values or conditions. It is similar to the switch statement in Java, C, and similar languages. For example:

```
fun main() {
        val x = 2
    when (x) {
        1 -> print("x == 1")
        2 -> print("x == 2")
        else -> print("x is neither 1 nor 2")
    }
    // x == 2
    //sampleEnd
}
```

when matches its argument against all branches sequentially until some branch condition is satisfied.

You can use when in a few different ways. Firstly, you can use when either as an expression or as a statement. As an expression, when returns a value for later use in your code. As a statement, when completes an action without returning anything of further use:

Expression	Statement

```
// Returns a string assigned to the
// text variable
val text = when (x) {
    1 -> "x == 1"
    2 -> "x == 2"
    else -> "x is neither 1 nor 2"
}
```
	```
	// Returns nothing but triggers a
	// print statement
	when (x) {
	    1 -> print("x == 1")
	    2 -> print("x == 2")
	    else -> print("x is neither 1 nor 2")
	}
	```

Secondly, you can use when with or without a subject. Whether you use a subject with when or not, your expression or statement behaves the same. We recommend using when with a subject when possible, as it makes your code easier to read and maintain by clearly showing what you're checking.

With subject x	Without subject
`when(x) { ... }`	`when { ... }`

Depending on how you use when, there are different requirements for whether you need to cover all possible cases in your branches.

If you use when as a statement, you don't have to cover all possible cases. In this example, some cases aren't covered, so nothing happens. However, no error occurs:

```
fun main() {
        val x = 3
    when (x) {
        // Not all cases are covered
        1 -> print("x == 1")
        2 -> print("x == 2")
    }
    //sampleEnd
}
```

In a when statement, the values of individual branches are ignored. Just like with if, each branch can be a block, and its value is the value of the last expression in the block.

If you use when as an expression, you have to cover all possible cases. In other words, it must be exhaustive. The value of the first matching branch becomes the value of the overall expression. If you don't cover all cases, the compiler throws an error.

If your when expression has a subject, you can use an else branch to make sure that all possible cases are covered, but it isn't mandatory. For example, if your subject is a Boolean, enum class, sealed class, or one of their nullable counterparts, you can cover all cases without an else branch:

```
enum class Bit {
    ZERO, ONE
}

val numericValue = when (getRandomBit()) {
    // No else branch is needed because all cases are covered
    Bit.ZERO -> 0
    Bit.ONE -> 1
}
```

To simplify when expressions and reduce repetition, try out context-sensitive resolution (currently in preview). This feature allows you to omit the type name when using enum entries or sealed class members in when expressions if the expected type is known.

For more information, see Preview of context-sensitive resolution or the related KEEP proposal.

If your when expression doesn't have a subject, you must have an else branch or the compiler throws an error. The else branch is evaluated when none of the other branch conditions are satisfied:

```
val message = when {
    a > b -> "a is greater than b"
    a < b -> "a is less than b"
    else -> "a is equal to b"
}
```

when expressions and statements offer different ways to simplify your code, handle multiple conditions, and perform type checks.

You can define a common behavior for multiple cases by combining their conditions in a single line with a comma:

```
when (x) {
    0, 1 -> print("x == 0 or x == 1")
    else -> print("otherwise")
}
```

You can use arbitrary expressions (not only constants) as branch conditions:

```
when (x) {
    s.toInt() -> print("s encodes x")
    else -> print("s does not encode x")
}
```

You can also check whether a value is or isn't contained in a range or collection via the in or !in keywords:

```
when (x) {
    in 1..10 -> print("x is in the range")
    in validNumbers -> print("x is valid")
    !in 10..20 -> print("x is outside the range")
    else -> print("none of the above")
}
```

Additionally, you can check that a value is or isn't a particular type via the is or !is keywords. Note that, due to smart casts, you can access the member functions and properties of the type without any additional checks.

```
fun hasPrefix(x: Any) = when(x) {
    is String -> x.startsWith("prefix")
    else -> false
}
```

You can use when as a replacement for an if-else if chain. If there's no subject, the branch conditions are simply boolean expressions. The first branch with a true condition runs:

```
when {
    x.isOdd() -> print("x is odd")
    y.isEven() -> print("y is even")
    else -> print("x+y is odd")
}
```

You can capture the subject in a variable by using the following syntax:

```
fun Request.getBody() =
    when (val response = executeRequest()) {
        is Success -> response.body
        is HttpError -> throw HttpException(response.status)
    }
```

The scope of a variable introduced as the subject is restricted to the body of the when expression or statement.

Guard conditions in when expressions

Guard conditions allow you to include more than one condition to the branches of a when expression, making complex control flow more explicit and concise. You can use guard conditions in when expressions or statements with a subject.

To include a guard condition in a branch, place it after the primary condition, separated by if:

```
sealed interface Animal {
    data class Cat(val mouseHunter: Boolean) : Animal
    data class Dog(val breed: String) : Animal
}

fun feedAnimal(animal: Animal) {
    when (animal) {
        // Branch with only primary condition. Calls `feedDog()` when `animal` is `Dog`
        is Animal.Dog -> feedDog()
        // Branch with both primary and guard conditions. Calls `feedCat()` when `animal` is `Cat` and not `mouseHunter`
        is Animal.Cat if !animal.mouseHunter -> feedCat()
        // Prints "Unknown animal" if none of the above conditions match
        else -> println("Unknown animal")
    }
}
```

In a single when expression, you can combine branches with and without guard conditions. The code in a branch with a guard condition runs only if both the primary condition and the guard condition evaluate to true. If the primary condition does not match, the guard condition is not evaluated.

If you use guard conditions in when statements without an else branch, and none of the conditions matches, none of the branches is executed.

Otherwise, if you use guard conditions in when expressions without an else branch, the compiler requires you to declare all the possible cases to avoid runtime errors.

Additionally, guard conditions support else if:

```
when (animal) {
    // Checks if `animal` is `Dog`
    is Animal.Dog -> feedDog()
    // Guard condition that checks if `animal` is `Cat` and not `mouseHunter`
    is Animal.Cat if !animal.mouseHunter -> feedCat()
    // Calls giveLettuce() if none of the above conditions match and animal.eatsPlants is true
    else if animal.eatsPlants -> giveLettuce()
    // Prints "Unknown animal" if none of the above conditions match
    else -> println("Unknown animal")
}
```

Combine multiple guard conditions within a single branch using the boolean operators && (AND) or || (OR). Use parentheses around the boolean expressions to avoid confusion:

```
when (animal) {
    is Animal.Cat if (!animal.mouseHunter && animal.hungry) -> feedCat()
}
```

You can use guard conditions in any when expression or statement with a subject, except the case when you have multiple conditions separated by a comma. For example, 0, 1 -> print("x == 0 or x == 1").

For loops

The for loop iterates through anything that provides an iterator. This is equivalent to the foreach loop in languages like C#. The syntax of for is the following:

```
for (item in collection) print(item)
```

The body of for can be a block.

```
for (item: Int in ints) {
    // ...
}
```

As mentioned before, for iterates through anything that provides an iterator. This means that it:

- has a member or an extension function iterator() that returns Iterator<>, which:
  - has a member or an extension function next()
  - has a member or an extension function hasNext() that returns Boolean.

All of these three functions need to be marked as operator.

To iterate over a range of numbers, use a range expression:

```
fun main() {
    for (i in 1..3) {
        print(i)
    }
    for (i in 6 downTo 0 step 2) {
        print(i)
    }
    // 1236420
}
```

A for loop over a range or an array is compiled to an index-based loop that does not create an iterator object.

If you want to iterate through an array or a list with an index, you can do it this way:

```
fun main() {
val array = arrayOf("a", "b", "c")
    for (i in array.indices) {
        print(array[i])
    }
    // abc
}
```

Alternatively, you can use the withIndex library function:

```
fun main() {
    val array = arrayOf("a", "b", "c")
    for ((index, value) in array.withIndex()) {
        println("the element at $index is $value")
    }
    // the element at 0 is a
    // the element at 1 is b
    // the element at 2 is c
}
```

While loops

while and do-while loops process their body continuously while their condition is satisfied. The difference between them is the condition checking time:

- while checks the condition and, if it's satisfied, processes the body and then returns to the condition check.
- do-while processes the body and then checks the condition. If it's satisfied, the loop repeats. So, the body of do-while runs at least once regardless of the condition.

```
while (x > 0) {
    x--
}

do {
    val y = retrieveData()
} while (y != null) // y is visible here!
```

Break and continue in loops

Kotlin supports traditional break and continue operators in loops. See Returns and jumps.

Returns and jumps

Kotlin has three structural jump expressions:

- return by default returns from the nearest enclosing function or anonymous function.
- break terminates the nearest enclosing loop.
- continue proceeds to the next step of the nearest enclosing loop.

All of these expressions can be used as part of larger expressions:

```
val s = person.name ?: return
```

The type of these expressions is the Nothing type.

Break and continue labels

Any expression in Kotlin may be marked with a label. Labels have the form of an identifier followed by the @ sign, such as abc@ or fooBar@. To label an expression, just add a label in front of it.

```
loop@ for (i in 1..100) {
    // ...
}
```

Now, you can qualify a break or a continue with a label:

```
loop@ for (i in 1..100) {
    for (j in 1..100) {
        if (...) break@loop
    }
}
```

A break qualified with a label jumps to the execution point right after the loop marked with that label. A continue proceeds to the next iteration of that loop.

In some cases, you can apply break and continue non-locally without explicitly defining labels. Such non-local usages are valid in lambda expressions used in enclosing inline functions.

Return to labels

In Kotlin, functions can be nested using function literals, local functions, and object expressions. A qualified return allows you to return from an outer function.

The most important use case is returning from a lambda expression. To return from a lambda expression, label it and qualify the return:

```
fun foo() {
    listOf(1, 2, 3, 4, 5).forEach lit@{
        if (it == 3) return@lit // local return to the caller of the lambda - the forEach loop
        print(it)
    }
    print(" done with explicit label")
}

fun main() {
    foo()
}
```

Now, it returns only from the lambda expression. Often it is more convenient to use implicit labels, because such a label has the same name as the function to which the lambda is passed.

```
fun foo() {
    listOf(1, 2, 3, 4, 5).forEach {
        if (it == 3) return@forEach // local return to the caller of the lambda - the forEach loop
        print(it)
    }
    print(" done with implicit label")
}

fun main() {
    foo()
}
```

Alternatively, you can replace the lambda expression with an anonymous function. A return statement in an anonymous function will return from the anonymous function itself.

```
fun foo() {
    listOf(1, 2, 3, 4, 5).forEach(fun(value: Int) {
        if (value == 3) return  // local return to the caller of the anonymous function - the forEach loop
        print(value)
    })
    print(" done with anonymous function")
}

fun main() {
    foo()
}
```

Note that the use of local returns in the previous three examples is similar to the use of continue in regular loops.

There is no direct equivalent for break, but it can be simulated by adding another nesting lambda and non-locally returning from it:

```
fun foo() {
    run loop@{
        listOf(1, 2, 3, 4, 5).forEach {
            if (it == 3) return@loop // non-local return from the lambda passed to run
            print(it)
        }
    }
    print(" done with nested loop")
}

fun main() {
    foo()
}
```

When returning a value, the parser gives preference to the qualified return:

```
return@a 1
```

This means "return 1 at label @a " rather than "return a labeled expression (@a 1) ".

> In some cases, you can return from a lambda expression without using labels. Such non-local returns are located in a lambda but exit the enclosing inline function.

Exceptions

Exceptions help your code run more predictably, even when runtime errors occur that could disrupt program execution. Kotlin treats all exceptions as unchecked by default. Unchecked exceptions simplify the exception handling process: you can catch exceptions, but you don't need to explicitly handle or declare them.

> Learn more about how Kotlin handles exceptions when interacting with Java, Swift, and Objective-C in the Exception interoperability with Java, Swift, and Objective-C section.

Working with exceptions consists of two primary actions:

- Throwing exceptions: indicate when a problem occurs.
- Catching exceptions: handle the unexpected exception manually by resolving the issue or notifying the developer or application user.

Exceptions are represented by subclasses of the Exception class, which is a subclass of the Throwable class. For more information about the hierarchy, see the Exception hierarchy section. Since Exception is an open class, you can create custom exceptions to suit your application's specific needs.

Throw exceptions

You can manually throw exceptions with the throw keyword. Throwing an exception indicates that an unexpected runtime error has occurred in the code. Exceptions are objects, and throwing one creates an instance of an exception class.

You can throw an exception without any parameters:

```
throw IllegalArgumentException()
```

To better understand the source of the problem, include additional information, such as a custom message and the original cause:

```
val cause = IllegalStateException("Original cause: illegal state")

// Throws an IllegalArgumentException if userInput is negative
// Additionally, it shows the original cause, represented by the cause IllegalStateException
if (userInput < 0) {
    throw IllegalArgumentException("Input must be non-negative", cause)
}
```

In this example, an IllegalArgumentException is thrown when the user inputs a negative value. You can create custom error messages and keep the original cause (cause) of the exception, which will be included in the stack trace.

Throw exceptions with precondition functions

Kotlin offers additional ways to automatically throw exceptions using precondition functions. Precondition functions include:

Precondition function	Use case	Exception thrown
require()	Checks user input validity	IllegalArgumentException
check()	Checks object or variable state validity	IllegalStateException
error()	Indicates an illegal state or condition	IllegalStateException

These functions are suitable for situations where the program's flow cannot continue if specific conditions aren't met. This streamlines your code and makes handling these checks efficient.

require() function

Use the require() function to validate input arguments when they are crucial for the function's operation, and the function can't proceed if these arguments are invalid.

If the condition in require() is not met, it throws an IllegalArgumentException:

```
fun getIndices(count: Int): List<Int> {
    require(count >= 0) { "Count must be non-negative. You set count to $count." }
    return List(count) { it + 1 }
}

fun main() {
    // This fails with an IllegalArgumentException
    println(getIndices(-1))

    // Uncomment the line below to see a working example
    // println(getIndices(3))
    // [1, 2, 3]
}
```

The require() function allows the compiler to perform smart casting. After a successful check, the variable is automatically cast to a non-nullable type. These functions are often used for nullability checks to ensure that the variable is not null before proceeding. For example:

```
fun printNonNullString(str: String?) {
    // Nullability check
    require(str != null)
    // After this successful check, 'str' is guaranteed to be
    // non-null and is automatically smart cast to non-nullable String
    println(str.length)
}
```

check() function

Use the check() function to validate the state of an object or variable. If the check fails, it indicates a logic error that needs to be addressed.

If the condition specified in the check() function is false, it throws an IllegalStateException:

```
fun main() {
    var someState: String? = null

    fun getStateValue(): String {

        val state = checkNotNull(someState) { "State must be set beforehand!" }
        check(state.isNotEmpty()) { "State must be non-empty!" }
        return state
    }
    // If you uncomment the line below then the program fails with IllegalStateException
    // getStateValue()

    someState = ""

    // If you uncomment the line below then the program fails with IllegalStateException
    // getStateValue()
    someState = "non-empty-state"

    // This prints "non-empty-state"
    println(getStateValue())
}
```

The check() function allows the compiler to perform smart casting. After a successful check, the variable is automatically cast to a non-nullable type. These functions are often used for nullability checks to ensure that the variable is not null before proceeding. For example:

```
fun printNonNullString(str: String?) {
    // Nullability check
    check(str != null)
    // After this successful check, 'str' is guaranteed to be
    // non-null and is automatically smart cast to non-nullable String
    println(str.length)
}
```

error() function

The error() function is used to signal an illegal state or a condition in the code that logically should not occur. It's suitable for scenarios when you want to throw an exception intentionally in your code, such as when the code encounters an unexpected state. This function is particularly useful in when expressions, providing a clear way to handle cases that shouldn't logically happen.

In the following example, the error() function is used to handle an undefined user role. If the role is not one of the predefined ones, an IllegalStateException is thrown:

```
class User(val name: String, val role: String)

fun processUserRole(user: User) {
    when (user.role) {
        "admin" -> println("${user.name} is an admin.")
        "editor" -> println("${user.name} is an editor.")
        "viewer" -> println("${user.name} is a viewer.")
        else -> error("Undefined role: ${user.role}")
    }
}

fun main() {
    // This works as expected
    val user1 = User("Alice", "admin")
    processUserRole(user1)
    // Alice is an admin.

    // This throws an IllegalStateException
    val user2 = User("Bob", "guest")
    processUserRole(user2)
}
```

Handle exceptions using try-catch blocks

When an exception is thrown, it interrupts the normal execution of the program. You can handle exceptions gracefully with the try and catch keywords to keep your program stable. The try block contains the code that might throw an exception, while the catch block catches and handles the exception if it occurs. The exception is caught by the first catch block that matches its specific type or a superclass of the exception.

Here's how you can use the try and catch keywords together:

```
try {
    // Code that may throw an exception
} catch (e: SomeException) {
    // Code for handling the exception
}
```

It's a common approach to use try-catch as an expression, so it can return a value from either the try block or the catch block:

```
fun main() {
    val num: Int = try {

        // If count() completes successfully, its return value is assigned to num
        count()

    } catch (e: ArithmeticException) {

        // If count() throws an exception, the catch block returns -1,
        // which is assigned to num
        -1
    }
    println("Result: $num")
}

// Simulates a function that might throw ArithmeticException
fun count(): Int {

    // Change this value to return a different value to num
    val a = 0

    return 10 / a
}
```

You can use multiple catch handlers for the same try block. You can add as many catch blocks as needed to handle different exceptions distinctively. When you have multiple catch blocks, it's important to order them from the most specific to the least specific exception, following a top-to-bottom order in your code. This ordering aligns with the program's execution flow.

Consider this example with custom exceptions:

```
open class WithdrawalException(message: String) : Exception(message)
class InsufficientFundsException(message: String) : WithdrawalException(message)

fun processWithdrawal(amount: Double, availableFunds: Double) {
    if (amount > availableFunds) {
        throw InsufficientFundsException("Insufficient funds for the withdrawal.")
    }
    if (amount < 1 || amount % 1 != 0.0) {
        throw WithdrawalException("Invalid withdrawal amount.")
    }
    println("Withdrawal processed")
}

fun main() {
    val availableFunds = 500.0

    // Change this value to test different scenarios
    val withdrawalAmount = 500.5

    try {
        processWithdrawal(withdrawalAmount.toDouble(), availableFunds)

    // The order of catch blocks is important!
    } catch (e: InsufficientFundsException) {
        println("Caught an InsufficientFundsException: ${e.message}")
    } catch (e: WithdrawalException) {
        println("Caught a WithdrawalException: ${e.message}")
    }
}
```

A general catch block handling WithdrawalException, catches all exceptions of its type, including specific ones like InsufficientFundsException, unless they are caught earlier by a more specific catch block.

The finally block

The finally block contains code that always executes, regardless of whether the try block completes successfully or throws an exception. With the finally block you can clean up code after the execution of try and catch blocks. This is especially important when working with resources like files or network connections, as finally guarantees they are properly closed or released.

Here is how you would typically use the try-catch-finally blocks together:

```
try {
    // Code that may throw an exception
}
catch (e: YourException) {
    // Exception handler
}
finally {
    // Code that is always executed
}
```

The returned value of a try expression is determined by the last executed expression in either the try or catch block. If no exceptions occur, the result comes from the try block; if an exception is handled, it comes from the catch block. The finally block is always executed, but it doesn't change the result of the try-catch block.

Let's look at an example to demonstrate:

```
fun divideOrNull(a: Int): Int {

    // The try block is always executed
    // An exception here (division by zero) causes an immediate jump to the catch block
    try {
        val b = 44 / a
        println("try block: Executing division: $b")
        return b
    }

    // The catch block is executed due to the ArithmeticException (division by zero if a ==0)
    catch (e: ArithmeticException) {
        println("catch block: Encountered ArithmeticException $e")
        return -1
    }
    finally {
        println("finally block: The finally block is always executed")
    }
}

fun main() {

    // Change this value to get a different result. An ArithmeticException will return: -1
    divideOrNull(0)
}
```

In Kotlin, the idiomatic way to manage resources that implement the AutoClosable interface, such as file streams like FileInputStream or FileOutputStream, is to use the .use() function. This function automatically closes the resource when the block of code completes, regardless of whether an exception is thrown, thereby eliminating the need for a finally block. Consequently, Kotlin does not require a special syntax like Java's try-with-resources for resource management.

```
FileWriter("test.txt").use { writer ->
writer.write("some text")
// After this block, the .use function automatically calls writer.close(), similar to a finally block
}
```

If your code requires resource cleanup without handling exceptions, you can also use try with the finally block without catch blocks:

```
class MockResource {
    fun use() {
        println("Resource being used")
        // Simulate a resource being used
        // This throws an ArithmeticException if division by zero occurs
        val result = 100 / 0

        // This line is not executed if an exception is thrown
        println("Result: $result")
    }

    fun close() {
        println("Resource closed")
    }
}

fun main() {
    val resource = MockResource()
//sampleStart
    try {

        // Attempts to use the resource
        resource.use()

    } finally {

        // Ensures that the resource is always closed, even if an exception occurs
        resource.close()
    }

    // This line is not printed if an exception is thrown
    println("End of the program")
}
```

As you can see, the finally block guarantees that the resource is closed, regardless of whether an exception occurs.

In Kotlin, you have the flexibility to use only a catch block, only a finally block, or both, depending on your specific needs, but a try block must always be accompanied by at least one catch block or a finally block.

Create custom exceptions

In Kotlin, you can define custom exceptions by creating classes that extend the built-in Exception class. This allows you to create more specific error types tailored to your application's needs.

To create one, you can define a class that extends Exception:

```
class MyException: Exception("My message")
```

In this example, there is a default error message, "My message", but you can leave it blank if you want.

Exceptions in Kotlin are stateful objects, carrying information specific to the context of their creation, referred to as the stack trace. Avoid creating exceptions using object declarations. Instead, create a new instance of the exception every time you need one. This way, you can ensure the exception's state accurately reflects the specific context.

Custom exceptions can also be a subclass of any pre-existent exception subclass, like the ArithmeticException subclass:

```
class NumberTooLargeException: ArithmeticException("My message")
```

If you want to create subclasses of custom exceptions, you must declare the parent class as open because classes are final by default and cannot be subclassed otherwise.

For example:

```
// Declares a custom exception as an open class, making it subclassable
open class MyCustomException(message: String): Exception(message)

// Creates a subclass of the custom exception
class SpecificCustomException: MyCustomException("Specific error message")
```

Custom exceptions behave just like built-in exceptions. You can throw them using the throw keyword, and handle them with try-catch-finally blocks. Let's look at an example to demonstrate:

```
class NegativeNumberException: Exception("Parameter is less than zero.")
class NonNegativeNumberException: Exception("Parameter is a non-negative number.")

fun myFunction(number: Int) {
    if (number < 0) throw NegativeNumberException()
    else if (number >= 0) throw NonNegativeNumberException()
}

fun main() {

    // Change the value in this function to a get a different exception
    myFunction(1)
}
```

In applications with diverse error scenarios, creating a hierarchy of exceptions can help making the code clearer and more specific. You can achieve this by using an abstract class or a sealed class as a base for common exception features and creating specific subclasses for detailed exception types. Additionally, custom exceptions with optional parameters offer flexibility, allowing initialization with varied messages, which enables more granular error handling.

Let's look at an example using the sealed class AccountException as the base for an exception hierarchy, and class APIKeyExpiredException, a subclass, which showcases the use of optional parameters for improved exception detail:

```
// Creates a sealed class as the base for an exception hierarchy for account-related errors
sealed class AccountException(message: String, cause: Throwable? = null):
Exception(message, cause)

// Creates a subclass of AccountException
class InvalidAccountCredentialsException : AccountException("Invalid account credentials detected")

// Creates a subclass of AccountException, which allows the addition of custom messages and causes
class APIKeyExpiredException(message: String = "API key expired", cause: Throwable? = null) : AccountException(message, cause)

// Change values of placeholder functions to get different results
fun areCredentialsValid(): Boolean = true
fun isAPIKeyExpired(): Boolean = true

// Validates account credentials and API key
fun validateAccount() {
    if (!areCredentialsValid()) throw InvalidAccountCredentialsException()
    if (isAPIKeyExpired()) {
        // Example of throwing APIKeyExpiredException with a specific cause
        val cause = RuntimeException("API key validation failed due to network error")
        throw APIKeyExpiredException(cause = cause)
    }
}

fun main() {
    try {
        validateAccount()
        println("Operation successful: Account credentials and API key are valid.")
    } catch (e: AccountException) {
        println("Error: ${e.message}")
        e.cause?.let { println("Caused by: ${it.message}") }
    }
}
```

The Nothing type

In Kotlin, every expression has a type. The type of the expression throw IllegalArgumentException() is Nothing, a built-in type that is a subtype of all other types, also known as the bottom type. This means Nothing can be used as a return type or generic type where any other type is expected, without causing type errors.

Nothing is a special type in Kotlin used to represent functions or expressions that never complete successfully, either because they always throw an exception or enter an endless execution path like an infinite loop. You can use Nothing to mark functions that are not yet implemented or are designed to always throw an exception, clearly indicating your intentions to both the compiler and code readers. If the compiler infers a Nothing type in a function signature, it will warn you. Explicitly defining Nothing as the return type can eliminate this warning.

This Kotlin code demonstrates the use of the Nothing type, where the compiler marks the code following the function call as unreachable:

```kotlin
class Person(val name: String?)

fun fail(message: String): Nothing {
    throw IllegalArgumentException(message)
    // This function will never return successfully.
    // It will always throw an exception.
}

fun main() {
    // Creates an instance of Person with 'name' as null
    val person = Person(name = null)

    val s: String = person.name ?: fail("Name required")

    // 's' is guaranteed to be initialized at this point
    println(s)
}
```

Kotlin's TODO() function, which also uses the Nothing type, serves as a placeholder to highlight areas of the code that need future implementation:

```kotlin
fun notImplementedFunction(): Int {
    TODO("This function is not yet implemented")
}

fun main() {
    val result = notImplementedFunction()
    // This throws a NotImplementedError
    println(result)
}
```

As you can see, the TODO() function always throws a NotImplementedError exception.

Exception classes

Let's explore some common exception types found in Kotlin, which are all subclasses of the RuntimeException class:

- ArithmeticException: This exception occurs when an arithmetic operation is impossible to perform, like division by zero.

  ```kotlin
  val example = 2 / 0 // throws ArithmeticException
  ```

- IndexOutOfBoundsException: This exception is thrown to indicate that an index of some sort, such as an array or string is out of range.

  ```kotlin
  val myList = mutableListOf(1, 2, 3)
  myList.removeAt(3)  // throws IndexOutOfBoundsException
  ```

To avoid this exception, use a safer alternative, such as the getOrNull() function:

```kotlin
val myList = listOf(1, 2, 3)
// Returns null, instead of IndexOutOfBoundsException
val element = myList.getOrNull(3)
println("Element at index 3: $element")
```

- NoSuchElementException: This exception is thrown when an element that does not exist in a particular collection is accessed. It occurs when using methods that expect a specific element, such as first() or last().

```kotlin
val emptyList = listOf<Int>()
val firstElement = emptyList.first()  // throws NoSuchElementException
```

To avoid this exception, use a safer alternative, such as the firstOrNull() function:

```kotlin
val emptyList = listOf<Int>()
// Returns null, instead of NoSuchElementException
val firstElement = emptyList.firstOrNull()
println("First element in empty list: $firstElement")
```

- NumberFormatException: This exception occurs when attempting to convert a string to a numeric type, but the string doesn't have an appropriate format.

```kotlin
val string = "This is not a number"
val number = string.toInt() // throws NumberFormatException
```

To avoid this exception, use a safer alternative, such as the toIntOrNull() function:

```kotlin
val nonNumericString = "not a number"
// Returns null, instead of NumberFormatException
val number = nonNumericString.toIntOrNull()
println("Converted number: $number")
```

- NullPointerException: This exception is thrown when an application attempts to use an object reference that has the null value. Even though Kotlin's null safety features significantly reduce the risk of NullPointerExceptions, they can still occur either through deliberate use of the !! operator or when interacting with Java, which lacks Kotlin's null safety.

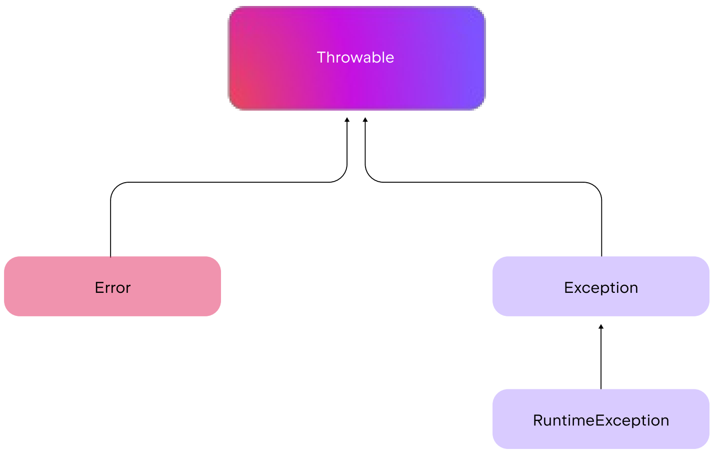
```kotlin
val text: String? = null
println(text!!.length)  // throws a NullPointerException
```

While all exceptions are unchecked in Kotlin, and you don't have to catch them explicitly, you still have the flexibility to catch them if desired.

Exception hierarchy

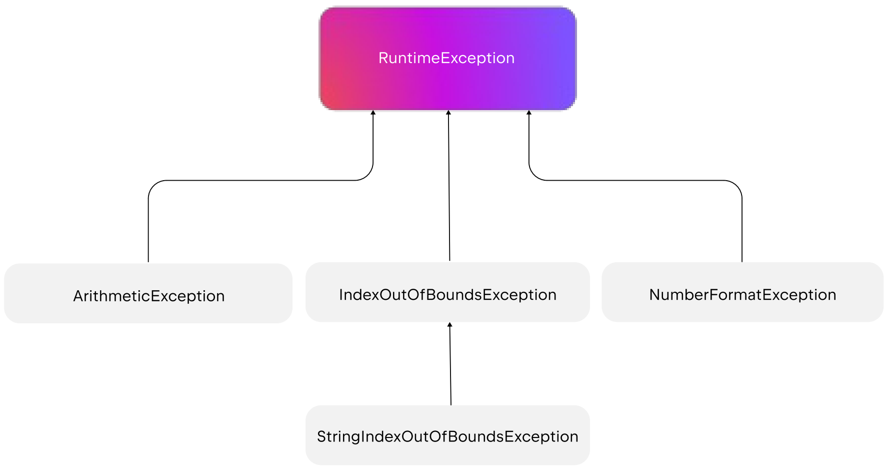
The root of the Kotlin exception hierarchy is the Throwable class. It has two direct subclasses, Error and Exception:

- The Error subclass represents serious fundamental problems that an application might not be able to recover from by itself. These are problems that you generally would not attempt to handle, such as OutOfMemoryError or StackOverflowError.
- The Exception subclass is used for conditions that you might want to handle. Subtypes of the Exception type, such as the RuntimeException and IOException (Input/Output Exception), deal with exceptional events in applications.



Exception hierarchy - the Throwable class

RuntimeException is usually caused by insufficient checks in the program code and can be prevented programmatically. Kotlin helps prevent common RuntimeExceptions like NullPointerException and provides compile-time warnings for potential runtime errors, such as division by zero. The following picture demonstrates a hierarchy of subtypes descended from RuntimeException:



Hierarchy of RuntimeExceptions

Stack trace

The stack trace is a report generated by the runtime environment, used for debugging. It shows the sequence of function calls leading to a specific point in the program, especially where an error or exception occurred.

Let's see an example where the stack trace is automatically printed because of an exception in a JVM environment:

```
fun main() {
//sampleStart
    throw ArithmeticException("This is an arithmetic exception!")
}
```

Running this code in a JVM environment produces the following output:

```
Exception in thread "main" java.lang.ArithmeticException: This is an arithmetic exception!
    at MainKt.main(Main.kt:3)
    at MainKt.main(Main.kt)
```

The first line is the exception description, which includes:

- Exception type: java.lang.ArithmeticException
- Thread: main
- Exception message: "This is an arithmetic exception!"

Each other line that starts with an at after the exception description is the stack trace. A single line is called a stack trace element or a stack frame:

- at MainKt.main (Main.kt:3): This shows the method name (MainKt.main) and the source file and line number where the method was called (Main.kt:3).
- at MainKt.main (Main.kt): This shows that the exception occurs in the main() function of the Main.kt file.

Exception interoperability with Java, Swift, and Objective-C

Since Kotlin treats all exceptions as unchecked, it can lead to complications when such exceptions are called from languages that distinguish between checked and unchecked exceptions. To address this disparity in exception handling between Kotlin and languages like Java, Swift, and Objective-C, you can use the @Throws annotation. This annotation alerts callers about possible exceptions. For more information, see Calling Kotlin from Java and Interoperability with Swift/Objective-C.

Packages and imports

A source file may start with a package declaration:

```
package org.example

fun printMessage() { /*...*/ }
class Message { /*...*/ }

// ...
```

All the contents, such as classes and functions, of the source file are included in this package. So, in the example above, the full name of printMessage() is org.example.printMessage, and the full name of Message is org.example.Message.

If the package is not specified, the contents of such a file belong to the default package with no name.

Default imports

A number of packages are imported into every Kotlin file by default:

- kotlin.*
- kotlin.annotation.*
- kotlin.collections.*
- kotlin.comparisons.*
- kotlin.io.*
- kotlin.ranges.*
- kotlin.sequences.*
- kotlin.text.*

Additional packages are imported depending on the target platform:

- JVM:
  - java.lang.*
  - kotlin.jvm.*
- JS:
  - kotlin.js.*

Imports

Apart from the default imports, each file may contain its own import directives.

You can import either a single name:

```
import org.example.Message // Message is now accessible without qualification
```

or all the accessible contents of a scope: package, class, object, and so on:

```
import org.example.* // everything in 'org.example' becomes accessible
```

If there is a name clash, you can disambiguate by using as keyword to locally rename the clashing entity:

```
import org.example.Message // Message is accessible
import org.test.Message as TestMessage // TestMessage stands for 'org.test.Message'
```

The import keyword is not restricted to importing classes; you can also use it to import other declarations:

- top-level functions and properties
- functions and properties declared in object declarations
- enum constants

Visibility of top-level declarations

If a top-level declaration is marked private, it is private to the file it's declared in (see Visibility modifiers).

Classes

Classes in Kotlin are declared using the keyword class:

```
class Person { /*...*/ }
```

The class declaration consists of the class name, the class header (specifying its type parameters, the primary constructor, and some other things), and the class body surrounded by curly braces. Both the header and the body are optional; if the class has no body, the curly braces can be omitted.

```
class Empty
```

Constructors

A class in Kotlin has a primary constructor and possibly one or more secondary constructors. The primary constructor is declared in the class header, and it goes after the class name and optional type parameters.

```
class Person constructor(firstName: String) { /*...*/ }
```

If the primary constructor does not have any annotations or visibility modifiers, the constructor keyword can be omitted:

```
class Person(firstName: String) { /*...*/ }
```

The primary constructor initializes a class instance and its properties in the class header. The class header can't contain any runnable code. If you want to run some code during object creation, use initializer blocks inside the class body. Initializer blocks are declared with the init keyword followed by curly braces. Write any code that you want to run within the curly braces.

During the initialization of an instance, the initializer blocks are executed in the same order as they appear in the class body, interleaved with the property initializers:

```
class InitOrderDemo(name: String) {
    val firstProperty = "First property: $name".also(::println)

    init {
        println("First initializer block that prints $name")
    }

    val secondProperty = "Second property: ${name.length}".also(::println)

    init {
        println("Second initializer block that prints ${name.length}")
    }
}

fun main() {
    InitOrderDemo("hello")
}
```

Primary constructor parameters can be used in the initializer blocks. They can also be used in property initializers declared in the class body:

```
class Customer(name: String) {
    val customerKey = name.uppercase()
}
```

Kotlin has a concise syntax for declaring properties and initializing them from the primary constructor:

```
class Person(val firstName: String, val lastName: String, var age: Int)
```

Such declarations can also include default values of the class properties:

```
class Person(val firstName: String, val lastName: String, var isEmployed: Boolean = true)
```

You can use a trailing comma when you declare class properties:

```
class Person(
    val firstName: String,
    val lastName: String,
    var age: Int, // trailing comma
) { /*...*/ }
```

Much like regular properties, properties declared in the primary constructor can be mutable (var) or read-only (val).

If the constructor has annotations or visibility modifiers, the constructor keyword is required and the modifiers go before it:

```
class Customer public @Inject constructor(name: String) { /*...*/ }
```

Learn more about visibility modifiers.

Secondary constructors

A class can also declare secondary constructors, which are prefixed with constructor:

```
class Person(val pets: MutableList<Pet> = mutableListOf())

class Pet {
    constructor(owner: Person) {
        owner.pets.add(this) // adds this pet to the list of its owner's pets
    }
}
```

If the class has a primary constructor, each secondary constructor needs to delegate to the primary constructor, either directly or indirectly through another secondary constructor(s). Delegation to another constructor of the same class is done using the this keyword:

```
class Person(val name: String) {
    val children: MutableList<Person> = mutableListOf()
    constructor(name: String, parent: Person) : this(name) {
        parent.children.add(this)
    }
}
```

Code in initializer blocks effectively becomes part of the primary constructor. Delegation to the primary constructor happens at the moment of access to the first statement of a secondary constructor, so the code in all initializer blocks and property initializers is executed before the body of the secondary constructor.

Even if the class has no primary constructor, the delegation still happens implicitly, and the initializer blocks are still executed:

```
class Constructors {
    init {
        println("Init block")
    }

    constructor(i: Int) {
        println("Constructor $i")
    }
}

fun main() {
    Constructors(1)
}
```

If a non-abstract class does not declare any constructors (primary or secondary), it will have a generated primary constructor with no arguments. The visibility of the constructor will be public.

If you don't want your class to have a public constructor, declare an empty primary constructor with non-default visibility:

```
class DontCreateMe private constructor() { /*...*/ }
```

On the JVM, if all of the primary constructor parameters have default values, the compiler will generate an additional parameterless constructor which will use the default values. This makes it easier to use Kotlin with libraries such as Jackson or JPA that create class instances through parameterless constructors.

```
class Customer(val customerName: String = "")
```

Creating instances of classes

To create an instance of a class, call the constructor as if it were a regular function. You can assign the created instance to a variable:

```
val invoice = Invoice()

val customer = Customer("Joe Smith")
```

Kotlin does not have a new keyword.

The process of creating instances of nested, inner, and anonymous inner classes is described in Nested classes.

Class members

Classes can contain:

- Constructors and initializer blocks
- Functions
- Properties
- Nested and inner classes
- Object declarations

Inheritance

Classes can be derived from each other and form inheritance hierarchies. Learn more about inheritance in Kotlin.

Abstract classes

A class may be declared abstract, along with some or all of its members. An abstract member does not have an implementation in its class. You don't need to annotate abstract classes or functions with open.

```
abstract class Polygon {
    abstract fun draw()
}

class Rectangle : Polygon() {
    override fun draw() {
        // draw the rectangle
    }
}
```

You can override a non-abstract open member with an abstract one.

```
open class Polygon {
    open fun draw() {
        // some default polygon drawing method
    }
}

abstract class WildShape : Polygon() {
    // Classes that inherit WildShape need to provide their own
    // draw method instead of using the default on Polygon
    abstract override fun draw()
}
```

Companion objects

If you need to write a function that can be called without having a class instance but that needs access to the internals of a class (such as a factory method), you can write it as a member of an object declaration inside that class.

Even more specifically, if you declare a companion object inside your class, you can access its members using only the class name as a qualifier.

Inheritance

All classes in Kotlin have a common superclass, Any, which is the default superclass for a class with no supertypes declared:

```
class Example // Implicitly inherits from Any
```

Any has three methods: equals(), hashCode(), and toString(). Thus, these methods are defined for all Kotlin classes.

By default, Kotlin classes are final – they can't be inherited. To make a class inheritable, mark it with the open keyword:

```
open class Base // Class is open for inheritance
```

To declare an explicit supertype, place the type after a colon in the class header:

```
open class Base(p: Int)

class Derived(p: Int) : Base(p)
```

If the derived class has a primary constructor, the base class can (and must) be initialized in that primary constructor according to its parameters.

If the derived class has no primary constructor, then each secondary constructor has to initialize the base type using the super keyword or it has to delegate to another constructor which does. Note that in this case different secondary constructors can call different constructors of the base type:

```
class MyView : View {
    constructor(ctx: Context) : super(ctx)

    constructor(ctx: Context, attrs: AttributeSet) : super(ctx, attrs)
}
```

Overriding methods

Kotlin requires explicit modifiers for overridable members and overrides:

```
open class Shape {
    open fun draw() { /*...*/ }
    fun fill() { /*...*/ }
}

class Circle() : Shape() {
    override fun draw() { /*...*/ }
}
```

The override modifier is required for Circle.draw(). If it's missing, the compiler will complain. If there is no open modifier on a function, like Shape.fill(), declaring a method with the same signature in a subclass is not allowed, either with override or without it. The open modifier has no effect when added to members of a final class – a class without an open modifier.

A member marked override is itself open, so it may be overridden in subclasses. If you want to prohibit re-overriding, use final:

```
open class Rectangle() : Shape() {
    final override fun draw() { /*...*/ }
}
```

Overriding properties

The overriding mechanism works on properties in the same way that it does on methods. Properties declared on a superclass that are then redeclared on a derived class must be prefaced with override, and they must have a compatible type. Each declared property can be overridden by a property with an initializer or by a property with a get method:

```
open class Shape {
    open val vertexCount: Int = 0
}

class Rectangle : Shape() {
    override val vertexCount = 4
}
```

You can also override a val property with a var property, but not vice versa. This is allowed because a val property essentially declares a get method, and overriding it as a var additionally declares a set method in the derived class.

Note that you can use the override keyword as part of the property declaration in a primary constructor:

```
interface Shape {
    val vertexCount: Int
}

class Rectangle(override val vertexCount: Int = 4) : Shape // Always has 4 vertices

class Polygon : Shape {
    override var vertexCount: Int = 0  // Can be set to any number later
}
```

Derived class initialization order

During the construction of a new instance of a derived class, the base class initialization is done as the first step (preceded only by evaluation of the arguments for the base class constructor), which means that it happens before the initialization logic of the derived class is run.

```
open class Base(val name: String) {

    init { println("Initializing a base class") }

    open val size: Int =
        name.length.also { println("Initializing size in the base class: $it") }
}

class Derived(
    name: String,
    val lastName: String,
) : Base(name.replaceFirstChar { it.uppercase() }.also { println("Argument for the base class: $it") }) {

    init { println("Initializing a derived class") }

    override val size: Int =
        (super.size + lastName.length).also { println("Initializing size in the derived class: $it") }
}

fun main() {
    println("Constructing the derived class(\"hello\", \"world\")")
    Derived("hello", "world")
}
```

This means that when the base class constructor is executed, the properties declared or overridden in the derived class have not yet been initialized. Using any of those properties in the base class initialization logic (either directly or indirectly through another overridden open member implementation) may lead to incorrect behavior or a runtime failure. When designing a base class, you should therefore avoid using open members in the constructors, property initializers, or init blocks.

Calling the superclass implementation

Code in a derived class can call its superclass functions and property accessor implementations using the super keyword:

```
open class Rectangle {
    open fun draw() { println("Drawing a rectangle") }
    val borderColor: String get() = "black"
}

class FilledRectangle : Rectangle() {
    override fun draw() {
        super.draw()
        println("Filling the rectangle")
    }

    val fillColor: String get() = super.borderColor
}
```

Inside an inner class, accessing the superclass of the outer class is done using the super keyword qualified with the outer class name: super@Outer:

```
open class Rectangle {
    open fun draw() { println("Drawing a rectangle") }
    val borderColor: String get() = "black"
}

class FilledRectangle: Rectangle() {
    override fun draw() {
        val filler = Filler()
        filler.drawAndFill()
    }

    inner class Filler {
        fun fill() { println("Filling") }
        fun drawAndFill() {
            super@FilledRectangle.draw() // Calls Rectangle's implementation of draw()
            fill()
            println("Drawn a filled rectangle with color ${super@FilledRectangle.borderColor}") // Uses Rectangle's implementation
of borderColor's get()
        }
    }
}

fun main() {
    val fr = FilledRectangle()
        fr.draw()
}
```

Overriding rules

In Kotlin, implementation inheritance is regulated by the following rule: if a class inherits multiple implementations of the same member from its immediate superclasses, it must override this member and provide its own implementation (perhaps, using one of the inherited ones).

To denote the supertype from which the inherited implementation is taken, use super qualified by the supertype name in angle brackets, such as super<Base>:

```
open class Rectangle {
    open fun draw() { /* ... */ }
}

interface Polygon {
    fun draw() { /* ... */ } // interface members are 'open' by default
}

class Square() : Rectangle(), Polygon {
    // The compiler requires draw() to be overridden:
    override fun draw() {
        super<Rectangle>.draw() // call to Rectangle.draw()
        super<Polygon>.draw() // call to Polygon.draw()
    }
}
```

It's fine to inherit from both Rectangle and Polygon, but both of them have their implementations of draw(), so you need to override draw() in Square and provide a separate implementation for it to eliminate the ambiguity.

Properties

Declaring properties

Properties in Kotlin classes can be declared either as mutable, using the var keyword, or as read-only, using the val keyword.

```
class Address {
    var name: String = "Holmes, Sherlock"
    var street: String = "Baker"
    var city: String = "London"
    var state: String? = null
    var zip: String = "123456"
}
```

To use a property, simply refer to it by its name:

```
fun copyAddress(address: Address): Address {
    val result = Address() // there's no 'new' keyword in Kotlin
    result.name = address.name // accessors are called
    result.street = address.street
    // ...
    return result
}
```

Getters and setters

The full syntax for declaring a property is as follows:

```
var <propertyName>[: <PropertyType>] [= <property_initializer>]
    [<getter>]
    [<setter>]
```

The initializer, getter, and setter are optional. The property type is optional if it can be inferred from the initializer or the getter's return type, as shown below:

```
var initialized = 1 // has type Int, default getter and setter
// var allByDefault // ERROR: explicit initializer required, default getter and setter implied
```

The full syntax of a read-only property declaration differs from a mutable one in two ways: it starts with val instead of var and does not allow a setter:

```
val simple: Int? // has type Int, default getter, must be initialized in constructor
val inferredType = 1 // has type Int and a default getter
```

You can define custom accessors for a property. If you define a custom getter, it will be called every time you access the property (this way you can implement a computed property). Here's an example of a custom getter:

```
class Rectangle(val width: Int, val height: Int) {
    val area: Int // property type is optional since it can be inferred from the getter's return type
        get() = this.width * this.height
}
fun main() {
    val rectangle = Rectangle(3, 4)
    println("Width=${rectangle.width}, height=${rectangle.height}, area=${rectangle.area}")
}
```

You can omit the property type if it can be inferred from the getter:

```
val area get() = this.width * this.height
```

If you define a custom setter, it will be called every time you assign a value to the property, except its initialization. A custom setter looks like this:

```
var stringRepresentation: String
    get() = this.toString()
    set(value) {
        setDataFromString(value) // parses the string and assigns values to other properties
    }
```

By convention, the name of the setter parameter is value, but you can choose a different name if you prefer.

If you need to annotate an accessor or change its visibility, but you don't want to change the default implementation, you can define the accessor without defining its body:

```
var setterVisibility: String = "abc"
    private set // the setter is private and has the default implementation

var setterWithAnnotation: Any? = null
    @Inject set // annotate the setter with Inject
```

Backing fields

In Kotlin, a field is only used as a part of a property to hold its value in memory. Fields cannot be declared directly. However, when a property needs a backing field, Kotlin provides it automatically. This backing field can be referenced in the accessors using the field identifier:

```
var counter = 0 // the initializer assigns the backing field directly
    set(value) {
        if (value >= 0)
            field = value
            // counter = value // ERROR StackOverflow: Using actual name 'counter' would make setter recursive
    }
```

The field identifier can only be used in the accessors of the property.

A backing field will be generated for a property if it uses the default implementation of at least one of the accessors, or if a custom accessor references it through the field identifier.

For example, there would be no backing field in the following case:

```
val isEmpty: Boolean
    get() = this.size == 0
```

Backing properties

If you want to do something that does not fit into this implicit backing field scheme, you can always fall back to having a backing property:

```
private var _table: Map<String, Int>? = null
public val table: Map<String, Int>
    get() {
        if (_table == null) {
            _table = HashMap() // Type parameters are inferred
        }
        return _table ?: throw AssertionError("Set to null by another thread")
    }
```

On the JVM: Access to private properties with default getters and setters is optimized to avoid function call overhead.

Compile-time constants

If the value of a read-only property is known at compile time, mark it as a compile time constant using the const modifier. Such a property needs to fulfill the following requirements:

- It must be a top-level property, or a member of an object declaration or a companion object.
- It must be initialized with a value of type String or a primitive type
- It cannot be a custom getter

The compiler will inline usages of the constant, replacing the reference to the constant with its actual value. However, the field will not be removed and therefore can be interacted with using reflection.

Such properties can also be used in annotations:

```
const val SUBSYSTEM_DEPRECATED: String = "This subsystem is deprecated"

@Deprecated(SUBSYSTEM_DEPRECATED) fun foo() { ... }
```

Late-initialized properties and variables

Normally, properties declared as having a non-nullable type must be initialized in the constructor. However, it is often the case that doing so is not convenient. For example, properties can be initialized through dependency injection, or in the setup method of a unit test. In these cases, you cannot supply a non-nullable initializer in the constructor, but you still want to avoid null checks when referencing the property inside the body of a class.

To handle such cases, you can mark the property with the lateinit modifier:

```
public class MyTest {
    lateinit var subject: TestSubject

    @SetUp fun setup() {
        subject = TestSubject()
    }

    @Test fun test() {
        subject.method()  // dereference directly
    }
}
```

This modifier can be used on var properties declared inside the body of a class (not in the primary constructor, and only when the property does not have a custom getter or setter), as well as for top-level properties and local variables. The type of the property or variable must be non-nullable, and it must not be a primitive type.

Accessing a lateinit property before it has been initialized throws a special exception that clearly identifies the property being accessed and the fact that it hasn't been initialized.

Checking whether a lateinit var is initialized

To check whether a lateinit var has already been initialized, use .isInitialized on the reference to that property:

```
if (foo::bar.isInitialized) {
    println(foo.bar)
}
```

This check is only available for properties that are lexically accessible when declared in the same type, in one of the outer types, or at top level in the same file.

Overriding properties

See Overriding properties

Delegated properties

The most common kind of property simply reads from (and maybe writes to) a backing field, but custom getters and setters allow you to use properties so one can implement any sort of behavior of a property. Somewhere in between the simplicity of the first kind and variety of the second, there are common patterns for what properties can do. A few examples: lazy values, reading from a map by a given key, accessing a database, notifying a listener on access.

Such common behaviors can be implemented as libraries using delegated properties.

Interfaces

Interfaces in Kotlin can contain declarations of abstract methods, as well as method implementations. What makes them different from abstract classes is that interfaces cannot store state. They can have properties, but these need to be abstract or provide accessor implementations.

An interface is defined using the keyword interface:

```
interface MyInterface {
    fun bar()
    fun foo() {
      // optional body
    }
}
```

Implementing interfaces

A class or object can implement one or more interfaces:

```
class Child : MyInterface {
    override fun bar() {
        // body
    }
}
```

Properties in interfaces

You can declare properties in interfaces. A property declared in an interface can either be abstract or provide implementations for accessors. Properties declared in interfaces can't have backing fields, and therefore accessors declared in interfaces can't reference them:

```
interface MyInterface {
    val prop: Int // abstract

    val propertyWithImplementation: String
        get() = "foo"

    fun foo() {
        print(prop)
    }
}

class Child : MyInterface {
    override val prop: Int = 29
}
```

Interfaces Inheritance

An interface can derive from other interfaces, meaning it can both provide implementations for their members and declare new functions and properties. Quite naturally, classes implementing such an interface are only required to define the missing implementations:

```
interface Named {
    val name: String
}

interface Person : Named {
    val firstName: String
    val lastName: String

    override val name: String get() = "$firstName $lastName"
}

data class Employee(
    // implementing 'name' is not required
    override val firstName: String,
    override val lastName: String,
    val position: Position
) : Person
```

Resolving overriding conflicts

When you declare many types in your supertype list, you may inherit more than one implementation of the same method:

```
interface A {
    fun foo() { print("A") }
    fun bar()
}

interface B {
    fun foo() { print("B") }
    fun bar() { print("bar") }
}

class C : A {
    override fun bar() { print("bar") }
}

class D : A, B {
    override fun foo() {
        super<A>.foo()
        super<B>.foo()
    }

    override fun bar() {
        super<B>.bar()
    }
}
```

Interfaces A and B both declare functions foo() and bar(). Both of them implement foo(), but only B implements bar() (bar() is not marked as abstract in A, because this is the default for interfaces if the function has no body). Now, if you derive a concrete class C from A, you have to override bar() and provide an implementation.

However, if you derive D from A and B, you need to implement all the methods that you have inherited from multiple interfaces, and you need to specify how exactly D should implement them. This rule applies both to methods for which you've inherited a single implementation (bar()) and to those for which you've inherited multiple implementations (foo()).

JVM default method generation for interface functions

On the JVM, functions declared in interfaces are compiled to default methods. You can control this behavior using the -jvm-default compiler option with the following values:

- enable (default): generates default implementations in interfaces and includes bridge functions in subclasses and DefaultImpls classes. Use this mode to maintain binary compatibility with older Kotlin versions.
- no-compatibility: generates only default implementations in interfaces. This mode skips compatibility bridges and DefaultImpls classes, making it suitable for new Kotlin code.
- disable: skips default methods and generates only compatibility bridges and DefaultImpls classes.

To configure the -jvm-default compiler option, set the jvmDefault property in your Gradle Kotlin DSL:

```
kotlin {
    compilerOptions {
        jvmDefault = JvmDefaultMode.NO_COMPATIBILITY
    }
}
```

Functional (SAM) interfaces

An interface with only one abstract member function is called a functional interface, or a Single Abstract Method (SAM) interface. The functional interface can have several non-abstract member functions but only one abstract member function.

To declare a functional interface in Kotlin, use the fun modifier.

```
fun interface KRunnable {
   fun invoke()
}
```

SAM conversions

For functional interfaces, you can use SAM conversions that help make your code more concise and readable by using lambda expressions.

Instead of creating a class that implements a functional interface manually, you can use a lambda expression. With a SAM conversion, Kotlin can convert any lambda expression whose signature matches the signature of the interface's single method into the code, which dynamically instantiates the interface implementation.

For example, consider the following Kotlin functional interface:

```
fun interface IntPredicate {
   fun accept(i: Int): Boolean
}
```

If you don't use a SAM conversion, you will need to write code like this:

```
// Creating an instance of a class
val isEven = object : IntPredicate {
   override fun accept(i: Int): Boolean {
       return i % 2 == 0
   }
}
```

By leveraging Kotlin's SAM conversion, you can write the following equivalent code instead:

```
// Creating an instance using lambda
val isEven = IntPredicate { it % 2 == 0 }
```

A short lambda expression replaces all the unnecessary code.

```
fun interface IntPredicate {
   fun accept(i: Int): Boolean
}

val isEven = IntPredicate { it % 2 == 0 }

fun main() {
   println("Is 7 even? - ${isEven.accept(7)}")
}
```

You can also use SAM conversions for Java interfaces.

Migration from an interface with constructor function to a functional interface

Starting from 1.6.20, Kotlin supports callable references to functional interface constructors, which adds a source-compatible way to migrate from an interface with a constructor function to a functional interface. Consider the following code:

```
interface Printer {
    fun print()
}

fun Printer(block: () -> Unit): Printer = object : Printer { override fun print() = block() }
```

With callable references to functional interface constructors enabled, this code can be replaced with just a functional interface declaration:

```
fun interface Printer {
    fun print()
}
```

Its constructor will be created implicitly, and any code using the ::Printer function reference will compile. For example:

```
documentsStorage.addPrinter(::Printer)
```

Preserve the binary compatibility by marking the legacy function Printer with the @Deprecated annotation with DeprecationLevel.HIDDEN:

```
@Deprecated(message = "Your message about the deprecation", level = DeprecationLevel.HIDDEN)
fun Printer(...) {...}
```

Functional interfaces vs. type aliases

You can also simply rewrite the above using a type alias for a functional type:

```
typealias IntPredicate = (i: Int) -> Boolean

val isEven: IntPredicate = { it % 2 == 0 }

fun main() {
   println("Is 7 even? - ${isEven(7)}")
}
```

However, functional interfaces and type aliases serve different purposes. Type aliases are just names for existing types – they don't create a new type, while functional interfaces do. You can provide extensions that are specific to a particular functional interface to be inapplicable for plain functions or their type aliases.

Type aliases can have only one member, while functional interfaces can have multiple non-abstract member functions and one abstract member function.

Functional interfaces can also implement and extend other interfaces.

Functional interfaces are more flexible and provide more capabilities than type aliases, but they can be more costly both syntactically and at runtime because they can require conversions to a specific interface. When you choose which one to use in your code, consider your needs:

- If your API needs to accept a function (any function) with some specific parameter and return types – use a simple functional type or define a type alias to give a shorter name to the corresponding functional type.
- If your API accepts a more complex entity than a function – for example, it has non-trivial contracts and/or operations on it that can't be expressed in a functional type's signature – declare a separate functional interface for it.

Visibility modifiers

Classes, objects, interfaces, constructors, and functions, as well as properties and their setters, can have visibility modifiers. Getters always have the same visibility as their properties.

There are four visibility modifiers in Kotlin: private, protected, internal, and public. The default visibility is public.

On this page, you'll learn how the modifiers apply to different types of declaring scopes.

Packages

Functions, properties, classes, objects, and interfaces can be declared at the "top-level" directly inside a package:

```
// file name: example.kt
package foo

fun baz() { ... }
class Bar { ... }
```

- If you don't use a visibility modifier, public is used by default, which means that your declarations will be visible everywhere.
- If you mark a declaration as private, it will only be visible inside the file that contains the declaration.
- If you mark it as internal, it will be visible everywhere in the same module.
- The protected modifier is not available for top-level declarations.

To use a visible top-level declaration from another package, you should import it.

Examples:

```
// file name: example.kt
package foo

private fun foo() { ... } // visible inside example.kt

public var bar: Int = 5 // property is visible everywhere
    private set         // setter is visible only in example.kt

internal val baz = 6    // visible inside the same module
```

Class members

For members declared inside a class:

- private means that the member is visible inside this class only (including all its members).
- protected means that the member has the same visibility as one marked as private, but that it is also visible in subclasses.
- internal means that any client inside this module who sees the declaring class sees its internal members.

- public means that any client who sees the declaring class sees its public members.

In Kotlin, an outer class does not see private members of its inner classes.

If you override a protected or an internal member and do not specify the visibility explicitly, the overriding member will also have the same visibility as the original.

Examples:

```kotlin
open class Outer {
    private val a = 1
    protected open val b = 2
    internal open val c = 3
    val d = 4  // public by default

    protected class Nested {
        public val e: Int = 5
    }
}

class Subclass : Outer() {
    // a is not visible
    // b, c and d are visible
    // Nested and e are visible

    override val b = 5   // 'b' is protected
    override val c = 7   // 'c' is internal
}

class Unrelated(o: Outer) {
    // o.a, o.b are not visible
    // o.c and o.d are visible (same module)
    // Outer.Nested is not visible, and Nested::e is not visible either
}
```

Constructors

Use the following syntax to specify the visibility of the primary constructor of a class:

You need to add an explicit constructor keyword.

```kotlin
class C private constructor(a: Int) { ... }
```

Here the constructor is private. By default, all constructors are public, which effectively amounts to them being visible everywhere the class is visible (this means that a constructor of an internal class is only visible within the same module).

For sealed classes, constructors are protected by default. For more information, see Sealed classes.

Local declarations

Local variables, functions, and classes can't have visibility modifiers.

Modules

The internal visibility modifier means that the member is visible within the same module. More specifically, a module is a set of Kotlin files compiled together, for example:

- An IntelliJ IDEA module.
- A Maven project.
- A Gradle source set (with the exception that the test source set can access the internal declarations of main).
- A set of files compiled with one invocation of the <kotlinc> Ant task.

Extensions

Kotlin provides the ability to extend a class or an interface with new functionality without having to inherit from the class or use design patterns such as Decorator. This is done via special declarations called extensions.

For example, you can write new functions for a class or an interface from a third-party library that you can't modify. Such functions can be called in the usual way, as if they were methods of the original class. This mechanism is called an extension function. There are also extension properties that let you define new properties for existing classes.

Extension functions

To declare an extension function, prefix its name with a receiver type, which refers to the type being extended. The following adds a swap function to MutableList<Int>:

```
fun MutableList<Int>.swap(index1: Int, index2: Int) {
    val tmp = this[index1] // 'this' corresponds to the list
    this[index1] = this[index2]
    this[index2] = tmp
}
```

The this keyword inside an extension function corresponds to the receiver object (the one that is passed before the dot). Now, you can call such a function on any MutableList<Int>:

```
val list = mutableListOf(1, 2, 3)
list.swap(0, 2) // 'this' inside 'swap()' will hold the value of 'list'
```

This function makes sense for any MutableList<T>, and you can make it generic:

```
fun <T> MutableList<T>.swap(index1: Int, index2: Int) {
    val tmp = this[index1] // 'this' corresponds to the list
    this[index1] = this[index2]
    this[index2] = tmp
}
```

You need to declare the generic type parameter before the function name to make it available in the receiver type expression. For more information about generics, see generic functions.

Extensions are resolved statically

Extensions do not actually modify the classes they extend. By defining an extension, you are not inserting new members into a class, only making new functions callable with the dot-notation on variables of this type.

Extension functions are dispatched statically. So which extension function is called is already known at compile time based on the receiver type. For example:

```
fun main() {
    open class Shape
    class Rectangle: Shape()

    fun Shape.getName() = "Shape"
    fun Rectangle.getName() = "Rectangle"

    fun printClassName(s: Shape) {
        println(s.getName())
    }

    printClassName(Rectangle())
}
```

This example prints Shape, because the extension function called depends only on the declared type of the parameter s, which is the Shape class.

If a class has a member function, and an extension function is defined which has the same receiver type, the same name, and is applicable to given arguments, the member always wins. For example:

```
fun main() {
    class Example {
        fun printFunctionType() { println("Class method") }
    }

    fun Example.printFunctionType() { println("Extension function") }

    Example().printFunctionType()
}
```

This code prints Class method.

However, it's perfectly OK for extension functions to overload member functions that have the same name but a different signature:

```
fun main() {
    class Example {
        fun printFunctionType() { println("Class method") }
    }

    fun Example.printFunctionType(i: Int) { println("Extension function #$i") }

    Example().printFunctionType(1)
}
```

Nullable receiver

Note that extensions can be defined with a nullable receiver type. These extensions can be called on an object variable even if its value is null. If the receiver is null, then this is also null. So when defining an extension with a nullable receiver type, we recommend performing a this == null check inside the function body to avoid compiler errors.

You can call toString() in Kotlin without checking for null, as the check already happens inside the extension function:

```
fun Any?.toString(): String {
    if (this == null) return "null"
    // After the null check, 'this' is autocast to a non-nullable type, so the toString() below
    // resolves to the member function of the Any class
    return toString()
}
```

Extension properties

Kotlin supports extension properties much like it supports functions:

```
val <T> List<T>.lastIndex: Int
    get() = size - 1
```

Since extensions do not actually insert members into classes, there's no efficient way for an extension property to have a backing field. This is why initializers are not allowed for extension properties. Their behavior can only be defined by explicitly providing getters/setters.

Example:

```
val House.number = 1 // error: initializers are not allowed for extension properties
```

Companion object extensions

If a class has a companion object defined, you can also define extension functions and properties for the companion object. Just like regular members of the companion object, they can be called using only the class name as the qualifier:

```
class MyClass {
    companion object { }  // will be called "Companion"
}

fun MyClass.Companion.printCompanion() { println("companion") }

fun main() {
    MyClass.printCompanion()
}
```

Scope of extensions

In most cases, you define extensions on the top level, directly under packages:

```
package org.example.declarations

fun List<String>.getLongestString() { /*...*/}
```

To use an extension outside its declaring package, import it at the call site:

```
package org.example.usage

import org.example.declarations.getLongestString

fun main() {
    val list = listOf("red", "green", "blue")
    list.getLongestString()
}
```

See Imports for more information.

Declaring extensions as members

You can declare extensions for one class inside another class. Inside such an extension, there are multiple implicit receivers - objects whose members can be accessed without a qualifier. An instance of a class in which the extension is declared is called a dispatch receiver, and an instance of the receiver type of the extension method is called an extension receiver.

```
class Host(val hostname: String) {
    fun printHostname() { print(hostname) }
}

class Connection(val host: Host, val port: Int) {
    fun printPort() { print(port) }

    fun Host.printConnectionString() {
        printHostname()   // calls Host.printHostname()
        print(":")
        printPort()   // calls Connection.printPort()
    }

    fun connect() {
        /*...*/
        host.printConnectionString()   // calls the extension function
    }
}

fun main() {
    Connection(Host("kotl.in"), 443).connect()
    //Host("kotl.in").printConnectionString()  // error, the extension function is unavailable outside Connection
}
```

In the event of a name conflict between the members of a dispatch receiver and an extension receiver, the extension receiver takes precedence. To refer to the member of the dispatch receiver, you can use the qualified this syntax.

```
class Connection {
    fun Host.getConnectionString() {
        toString()         // calls Host.toString()
        this@Connection.toString()  // calls Connection.toString()
    }
}
```

Extensions declared as members can be declared as open and overridden in subclasses. This means that the dispatch of such functions is virtual with regard to the dispatch receiver type, but static with regard to the extension receiver type.

```
open class Base { }

class Derived : Base() { }

open class BaseCaller {
    open fun Base.printFunctionInfo() {
        println("Base extension function in BaseCaller")
    }

    open fun Derived.printFunctionInfo() {
        println("Derived extension function in BaseCaller")
    }

    fun call(b: Base) {
        b.printFunctionInfo()   // call the extension function
    }
}

class DerivedCaller: BaseCaller() {
    override fun Base.printFunctionInfo() {
        println("Base extension function in DerivedCaller")
    }

    override fun Derived.printFunctionInfo() {
        println("Derived extension function in DerivedCaller")
    }
}

fun main() {
    BaseCaller().call(Base())   // "Base extension function in BaseCaller"
    DerivedCaller().call(Base())  // "Base extension function in DerivedCaller" - dispatch receiver is resolved virtually
    DerivedCaller().call(Derived())  // "Base extension function in DerivedCaller" - extension receiver is resolved statically
}
```

Note on visibility

Extensions utilize the same visibility modifiers as regular functions declared in the same scope would. For example:

- An extension declared at the top level of a file has access to the other private top-level declarations in the same file.
- If an extension is declared outside its receiver type, it cannot access the receiver's private or protected members.

Data classes

Data classes in Kotlin are primarily used to hold data. For each data class, the compiler automatically generates additional member functions that allow you to print an instance to readable output, compare instances, copy instances, and more. Data classes are marked with data:

```
data class User(val name: String, val age: Int)
```

The compiler automatically derives the following members from all properties declared in the primary constructor:

- equals()/hashCode() pair.
- toString() of the form "User(name=John, age=42)".
- componentN() functions corresponding to the properties in their order of declaration.
- copy() function (see below).

To ensure consistency and meaningful behavior of the generated code, data classes have to fulfill the following requirements:

- The primary constructor must have at least one parameter.
- All primary constructor parameters must be marked as val or var.
- Data classes can't be abstract, open, sealed, or inner.

Additionally, the generation of data class members follows these rules with regard to the members' inheritance:

- If there are explicit implementations of equals(), hashCode(), or toString() in the data class body or final implementations in a superclass, then these functions are not generated, and the existing implementations are used.
- If a supertype has componentN() functions that are open and return compatible types, the corresponding functions are generated for the data class and override those of the supertype. If the functions of the supertype cannot be overridden due to incompatible signatures or due to their being final, an error is reported.
- Providing explicit implementations for the componentN() and copy() functions is not allowed.

Data classes may extend other classes (see Sealed classes for examples).

> On the JVM, if the generated class needs to have a parameterless constructor, default values for the properties have to be specified (see Constructors):
>
> ```
> data class User(val name: String = "", val age: Int = 0)
> ```

Properties declared in the class body

The compiler only uses the properties defined inside the primary constructor for the automatically generated functions. To exclude a property from the generated implementations, declare it inside the class body:

```
data class Person(val name: String) {
    var age: Int = 0
}
```

In the example below, only the name property is used by default inside the toString(), equals(), hashCode(), and copy() implementations, and there is only one component function, component1(). The age property is declared inside the class body and is excluded. Therefore, two Person objects with the same name but different age values are considered equal since equals() only evaluates properties from the primary constructor:

```
data class Person(val name: String) {
    var age: Int = 0
}
fun main() {
    val person1 = Person("John")
    val person2 = Person("John")
    person1.age = 10
    person2.age = 20

    println("person1 == person2: ${person1 == person2}")
    // person1 == person2: true

    println("person1 with age ${person1.age}: ${person1}")
    // person1 with age 10: Person(name=John)

    println("person2 with age ${person2.age}: ${person2}")
    // person2 with age 20: Person(name=John)
}
```

Copying

Use the copy() function to copy an object, allowing you to alter some of its properties while keeping the rest unchanged. The implementation of this function for the User class above would be as follows:

```
fun copy(name: String = this.name, age: Int = this.age) = User(name, age)
```

You can then write the following:

```
val jack = User(name = "Jack", age = 1)
val olderJack = jack.copy(age = 2)
```

Data classes and destructuring declarations

Component functions generated for data classes make it possible to use them in destructuring declarations:

```kotlin
val jane = User("Jane", 35)
val (name, age) = jane
println("$name, $age years of age")
// Jane, 35 years of age
```

Standard data classes

The standard library provides the Pair and Triple classes. In most cases, though, named data classes are a better design choice because they make the code easier to read by providing meaningful names for the properties.

Sealed classes and interfaces

Sealed classes and interfaces provide controlled inheritance of your class hierarchies. All direct subclasses of a sealed class are known at compile time. No other subclasses may appear outside the module and package within which the sealed class is defined. The same logic applies to sealed interfaces and their implementations: once a module with a sealed interface is compiled, no new implementations can be created.

> Direct subclasses are classes that immediately inherit from their superclass.
>
> Indirect subclasses are classes that inherit from more than one level down from their superclass.

When you combine sealed classes and interfaces with the when expression, you can cover the behavior of all possible subclasses and ensure that no new subclasses are created to affect your code adversely.

Sealed classes are best used for scenarios when:

- Limited class inheritance is desired: You have a predefined, finite set of subclasses that extend a class, all of which are known at compile time.
- Type-safe design is required: Safety and pattern matching are crucial in your project. Particularly for state management or handling complex conditional logic. For an example, check out Use sealed classes with when expressions.
- Working with closed APIs: You want robust and maintainable public APIs for libraries that ensure that third-party clients use the APIs as intended.

For more detailed practical applications, see Use case scenarios.

> Java 15 introduced a similar concept, where sealed classes use the sealed keyword along with the permits clause to define restricted hierarchies.

Declare a sealed class or interface

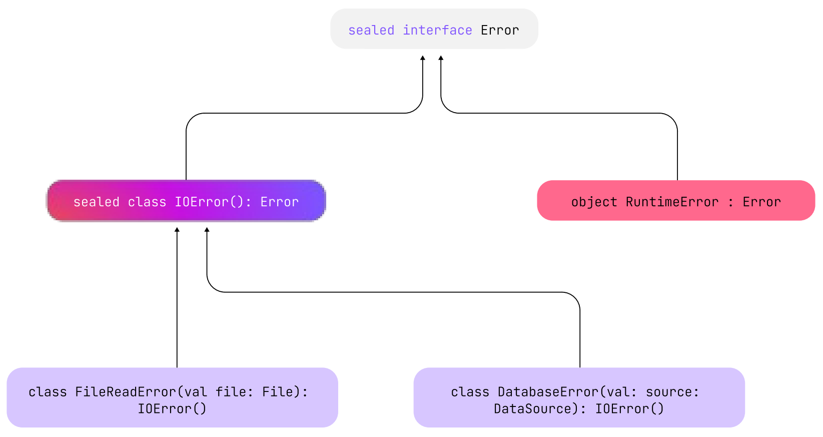
To declare a sealed class or interface, use the sealed modifier:

```kotlin
// Create a sealed interface
sealed interface Error

// Create a sealed class that implements sealed interface Error
sealed class IOError(): Error

// Define subclasses that extend sealed class 'IOError'
class FileReadError(val file: File): IOError()
class DatabaseError(val source: DataSource): IOError()

// Create a singleton object implementing the 'Error' sealed interface
object RuntimeError : Error
```

This example could represent a library's API that contains error classes to let library users handle errors that it can throw. If the hierarchy of such error classes includes interfaces or abstract classes visible in the public API, then nothing prevents other developers from implementing or extending them in the client code.

Since the library doesn't know about errors declared outside of it, it can't treat them consistently with its own classes. However, with a sealed hierarchy of error classes, library authors can be sure that they know all the possible error types and that other error types can't appear later.

The hierarchy of the example looks like this:


sealed interface Error
sealed class IOError(): Error
object RuntimeError : Error
class FileReadError(val file: File): IOError()
class DatabaseError(val: source: DataSource): IOError()

Hierarchy illustration of sealed classes and interfaces

Constructors

A sealed class itself is always an abstract class, and as a result, can't be instantiated directly. However, it may contain or inherit constructors. These constructors aren't for creating instances of the sealed class itself but for its subclasses. Consider the following example with a sealed class called Error and its several subclasses, which we instantiate:

```kotlin
sealed class Error(val message: String) {
    class NetworkError : Error("Network failure")
    class DatabaseError : Error("Database cannot be reached")
    class UnknownError : Error("An unknown error has occurred")
}

fun main() {
    val errors = listOf(Error.NetworkError(), Error.DatabaseError(), Error.UnknownError())
    errors.forEach { println(it.message) }
}
// Network failure
// Database cannot be reached
// An unknown error has occurred
```

You can use enum classes within your sealed classes to use enum constants to represent states and provide additional detail. Each enum constant exists only as a single instance, while subclasses of a sealed class may have multiple instances. In the example, the sealed class Error along with its several subclasses, employs an enum to denote error severity. Each subclass constructor initializes the severity and can alter its state:

```kotlin
enum class ErrorSeverity { MINOR, MAJOR, CRITICAL }

sealed class Error(val severity: ErrorSeverity) {
    class FileReadError(val file: File): Error(ErrorSeverity.MAJOR)
    class DatabaseError(val source: DataSource): Error(ErrorSeverity.CRITICAL)
    object RuntimeError : Error(ErrorSeverity.CRITICAL)
    // Additional error types can be added here
}
```

Constructors of sealed classes can have one of two visibilities: protected (by default) or private:

```kotlin
sealed class IOError {
    // A sealed class constructor has protected visibility by default. It's visible inside this class and its subclasses
    constructor() { /*...*/ }
    // Private constructor, visible inside this class only.
    // Using a private constructor in a sealed class allows for even stricter control over instantiation, enabling specific
initialization procedures within the class.
    private constructor(description: String): this() { /*...*/ }

    // This will raise an error because public and internal constructors are not allowed in sealed classes
    // public constructor(code: Int): this() {}
}
```

Inheritance

Direct subclasses of sealed classes and interfaces must be declared in the same package. They may be top-level or nested inside any number of other named classes, named interfaces, or named objects. Subclasses can have any visibility as long as they are compatible with normal inheritance rules in Kotlin.

Subclasses of sealed classes must have a properly qualified name. They can't be local or anonymous objects.

enum classes can't extend a sealed class, or any other class. However, they can implement sealed interfaces:

```
sealed interface Error

// enum class extending the sealed interface Error
enum class ErrorType : Error {
    FILE_ERROR, DATABASE_ERROR
}
```

These restrictions don't apply to indirect subclasses. If a direct subclass of a sealed class is not marked as sealed, it can be extended in any way that its modifiers allow:

```
// Sealed interface 'Error' has implementations only in the same package and module
sealed interface Error

// Sealed class 'IOError' extends 'Error' and is extendable only within the same package
sealed class IOError(): Error

// Open class 'CustomError' extends 'Error' and can be extended anywhere it's visible
open class CustomError(): Error
```

Inheritance in multiplatform projects

There is one more inheritance restriction in multiplatform projects: direct subclasses of sealed classes must reside in the same source set. It applies to sealed classes without the expected and actual modifiers.

If a sealed class is declared as expect in a common source set and have actual implementations in platform source sets, both expect and actual versions can have subclasses in their source sets. Moreover, if you use a hierarchical structure, you can create subclasses in any source set between the expect and actual declarations.

Learn more about the hierarchical structure of multiplatform projects.

Use sealed classes with when expression

The key benefit of using sealed classes comes into play when you use them in a when expression. The when expression, used with a sealed class, allows the Kotlin compiler to check exhaustively that all possible cases are covered. In such cases, you don't need to add an else clause:

```
// Sealed class and its subclasses
sealed class Error {
    class FileReadError(val file: String): Error()
    class DatabaseError(val source: String): Error()
    object RuntimeError : Error()
}

// Function to log errors
fun log(e: Error) = when(e) {
    is Error.FileReadError -> println("Error while reading file ${e.file}")
    is Error.DatabaseError -> println("Error while reading from database ${e.source}")
    Error.RuntimeError -> println("Runtime error")
    // No `else` clause is required because all the cases are covered
}

// List all errors
fun main() {
    val errors = listOf(
        Error.FileReadError("example.txt"),
        Error.DatabaseError("usersDatabase"),
        Error.RuntimeError
    )

    errors.forEach { log(it) }
}
```

To reduce repetition in when expressions, try out context-sensitive resolution (currently in preview). This feature allows you to omit the type name when matching sealed class members if the expected type is known.

For more information, see Preview of context-sensitive resolution or the related KEEP proposal.

When using sealed classes with when expressions, you can also add guard conditions to include additional checks in a single branch. For more information, see Guard conditions in when expressions.

In multiplatform projects, if you have a sealed class with a when expression as an expected declaration in your common code, you still need an else branch. This is because subclasses of actual platform implementations may extend sealed classes that aren't known in the common code.

Use case scenarios

Let's explore some practical scenarios where sealed classes and interfaces can be particularly useful.

State management in UI applications

You can use sealed classes to represent different UI states in an application. This approach allows for structured and safe handling of UI changes. This example demonstrates how to manage various UI states:

```
sealed class UIState {
    data object Loading : UIState()
    data class Success(val data: String) : UIState()
    data class Error(val exception: Exception) : UIState()
}

fun updateUI(state: UIState) {
    when (state) {
        is UIState.Loading -> showLoadingIndicator()
        is UIState.Success -> showData(state.data)
        is UIState.Error -> showError(state.exception)
    }
}
```

Payment method handling

In practical business applications, handling various payment methods efficiently is a common requirement. You can use sealed classes with when expressions to implement such business logic. By representing different payment methods as subclasses of a sealed class, it establishes a clear and manageable structure for processing transactions:

```
sealed class Payment {
    data class CreditCard(val number: String, val expiryDate: String) : Payment()
    data class PayPal(val email: String) : Payment()
    data object Cash : Payment()
}

fun processPayment(payment: Payment) {
    when (payment) {
        is Payment.CreditCard -> processCreditCardPayment(payment.number, payment.expiryDate)
        is Payment.PayPal -> processPayPalPayment(payment.email)
        is Payment.Cash -> processCashPayment()
    }
}
```

Payment is a sealed class that represents different payment methods in an e-commerce system: CreditCard, PayPal, and Cash. Each subclass can have its specific properties, like number and expiryDate for CreditCard, and email for PayPal.

The processPayment() function demonstrates how to handle different payment methods. This approach ensures that all possible payment types are considered, and the system remains flexible for new payment methods to be added in the future.

API request-response handling

You can use sealed classes and sealed interfaces to implement a user authentication system that handles API requests and responses. The user authentication system has login and logout functionalities. The ApiRequest sealed interface defines specific request types: LoginRequest for login, and LogoutRequest for logout operations. The sealed class, ApiResponse, encapsulates different response scenarios: UserSuccess with user data, UserNotFound for absent users, and Error for any failures. The handleRequest function processes these requests in a type-safe manner using a when expression, while getUserById simulates user retrieval:

```
// Import necessary modules
import io.ktor.server.application.*
import io.ktor.server.resources.*

import kotlinx.serialization.*

// Define the sealed interface for API requests using Ktor resources
@Resource("api")
sealed interface ApiRequest

@Serializable
@Resource("login")
data class LoginRequest(val username: String, val password: String) : ApiRequest


@Serializable
@Resource("logout")
object LogoutRequest : ApiRequest

// Define the ApiResponse sealed class with detailed response types
sealed class ApiResponse {
    data class UserSuccess(val user: UserData) : ApiResponse()
    data object UserNotFound : ApiResponse()
    data class Error(val message: String) : ApiResponse()
}

// User data class to be used in the success response
data class UserData(val userId: String, val name: String, val email: String)

// Function to validate user credentials (for demonstration purposes)
fun isValidUser(username: String, password: String): Boolean {
    // Some validation logic (this is just a placeholder)
    return username == "validUser" && password == "validPass"
}

// Function to handle API requests with detailed responses
fun handleRequest(request: ApiRequest): ApiResponse {
    return when (request) {
        is LoginRequest -> {
            if (isValidUser(request.username, request.password)) {
                ApiResponse.UserSuccess(UserData("userId", "userName", "userEmail"))
            } else {
                ApiResponse.Error("Invalid username or password")
            }
        }
        is LogoutRequest -> {
            // Assuming logout operation always succeeds for this example
            ApiResponse.UserSuccess(UserData("userId", "userName", "userEmail")) // For demonstration
        }
    }
}

// Function to simulate a getUserById call
fun getUserById(userId: String): ApiResponse {
    return if (userId == "validUserId") {
        ApiResponse.UserSuccess(UserData("validUserId", "John Doe", "john@example.com"))
    } else {
        ApiResponse.UserNotFound
    }
    // Error handling would also result in an Error response.
}

// Main function to demonstrate the usage
fun main() {
    val loginResponse = handleRequest(LoginRequest("user", "pass"))
    println(loginResponse)

    val logoutResponse = handleRequest(LogoutRequest)
    println(logoutResponse)

    val userResponse = getUserById("validUserId")
    println(userResponse)

    val userNotFoundResponse = getUserById("invalidId")
    println(userNotFoundResponse)
}
```

Generics: in, out, where

Classes in Kotlin can have type parameters, just like in Java:

```kotlin
class Box<T>(t: T) {
    var value = t
}
```

To create an instance of such a class, simply provide the type arguments:

```kotlin
val box: Box<Int> = Box<Int>(1)
```

But if the parameters can be inferred, for example, from the constructor arguments, you can omit the type arguments:

```kotlin
val box = Box(1) // 1 has type Int, so the compiler figures out that it is Box<Int>
```

Variance

One of the trickiest aspects of Java's type system is the wildcard types (see Java Generics FAQ). Kotlin doesn't have these. Instead, Kotlin has declaration-site variance and type projections.

Variance and wildcards in Java

Let's think about why Java needs these mysterious wildcards. First, generic types in Java are invariant, meaning that List<String> is not a subtype of List<Object>. If List were not invariant, it would have been no better than Java's arrays, as the following code would have compiled but caused an exception at runtime:

```java
// Java
List<String> strs = new ArrayList<String>();

// Java reports a type mismatch here at compile-time.
List<Object> objs = strs;

// What if it didn't?
// We would be able to put an Integer into a list of Strings.
objs.add(1);

// And then at runtime, Java would throw
// a ClassCastException: Integer cannot be cast to String
String s = strs.get(0);
```

Java prohibits such things to guarantee runtime safety. But this has implications. For example, consider the addAll() method from the Collection interface. What's the signature of this method? Intuitively, you'd write it this way:

```java
// Java
interface Collection<E> ... {
    void addAll(Collection<E> items);
}
```

But then, you would not be able to do the following (which is perfectly safe):

```
// Java

// The following would not compile with the naive declaration of addAll:
// Collection<String> is not a subtype of Collection<Object>
void copyAll(Collection<Object> to, Collection<String> from) {
    to.addAll(from);
}
```

That's why the actual signature of addAll() is the following:

```
// Java
interface Collection<E> ... {
    void addAll(Collection<? extends E> items);
}
```

The wildcard type argument ? extends E indicates that this method accepts a collection of objects of E or a subtype of E, not just E itself. This means that you can safely read E's from items (elements of this collection are instances of a subclass of E), but cannot write to it as you don't know what objects comply with that unknown subtype of E. In return for this limitation, you get the desired behavior: Collection<String> is a subtype of Collection<? extends Object>. In other words, the wildcard with an extends-bound (upper bound) makes the type covariant.

The key to understanding why this works is rather simple: if you can only take items from a collection, then using a collection of Strings and reading Objects from it is fine. Conversely, if you can only put items into the collection, it's okay to take a collection of Objects and put Strings into it: in Java there is List<? super String>, which accepts Strings or any of its supertypes.

The latter is called contravariance, and you can only call methods that take String as an argument on List<? super String> (for example, you can call add(String) or set(int, String)). If you call something that returns T in List<T>, you don't get a String, but rather an Object.

Joshua Bloch, in his book Effective Java, 3rd Edition, explains the problem well (Item 31: "Use bounded wildcards to increase API flexibility"). He gives the name Producers to objects you only read from and Consumers to those you only write to. He recommends:

> "For maximum flexibility, use wildcard types on input parameters that represent producers or consumers."

He then proposes the following mnemonic: PECS stands for Producer-Extends, Consumer-Super.

> If you use a producer-object, say, List<? extends Foo>, you are not allowed to call add() or set() on this object, but this does not mean that it is immutable: for example, nothing prevents you from calling clear() to remove all the items from the list, since clear() does not take any parameters at all.
>
> The only thing guaranteed by wildcards (or other types of variance) is type safety. Immutability is a completely different story.

Declaration-site variance

Let's suppose that there is a generic interface Source<T> that does not have any methods that take T as a parameter, only methods that return T:

```
// Java
interface Source<T> {
    T nextT();
}
```

Then, it would be perfectly safe to store a reference to an instance of Source<String> in a variable of type Source<Object> - there are no consumer-methods to call. But Java does not know this, and still prohibits it:

```
// Java
void demo(Source<String> strs) {
    Source<Object> objects = strs; // !!! Not allowed in Java
    // ...
}
```

To fix this, you should declare objects of type Source<? extends Object>. Doing so is meaningless, because you can call all the same methods on such a variable as before, so there's no value added by the more complex type. But the compiler does not know that.

In Kotlin, there is a way to explain this sort of thing to the compiler. This is called declaration-site variance: you can annotate the type parameter T of Source to make sure that it is only returned (produced) from members of Source<T>, and never consumed. To do this, use the out modifier:

```
interface Source<out T> {
    fun nextT(): T
}

fun demo(strs: Source<String>) {
    val objects: Source<Any> = strs // This is OK, since T is an out-parameter
    // ...
}
```

The general rule is this: when a type parameter T of a class C is declared out, it may occur only in the out-position in the members of C, but in return C<Base> can safely be a supertype of C<Derived>.

In other words, you can say that the class C is covariant in the parameter T, or that T is a covariant type parameter. You can think of C as being a producer of T's, and NOT a consumer of T's.

The out modifier is called a variance annotation, and since it is provided at the type parameter declaration site, it provides declaration-site variance. This is in contrast with Java's use-site variance where wildcards in the type usages make the types covariant.

In addition to out, Kotlin provides a complementary variance annotation: in. It makes a type parameter contravariant, meaning it can only be consumed and never produced. A good example of a contravariant type is Comparable:

```
interface Comparable<in T> {
    operator fun compareTo(other: T): Int
}

fun demo(x: Comparable<Number>) {
    x.compareTo(1.0) // 1.0 has type Double, which is a subtype of Number
    // Thus, you can assign x to a variable of type Comparable<Double>
    val y: Comparable<Double> = x // OK!
}
```

The words in and out seem to be self-explanatory (as they've already been used successfully in C# for quite some time), and so the mnemonic mentioned above is not really needed. It can in fact be rephrased at a higher level of abstraction:

The Existential Transformation: Consumer in, Producer out!:-)

Type projections

Use-site variance: type projections

It is very easy to declare a type parameter T as out and avoid trouble with subtyping on the use site, but some classes can't actually be restricted to only return T's! A good example of this is Array:

```
class Array<T>(val size: Int) {
    operator fun get(index: Int): T { ... }
    operator fun set(index: Int, value: T) { ... }
}
```

This class can be neither co- nor contravariant in T. And this imposes certain inflexibilities. Consider the following function:

```
fun copy(from: Array<Any>, to: Array<Any>) {
    assert(from.size == to.size)
    for (i in from.indices)
        to[i] = from[i]
}
```

This function is supposed to copy items from one array to another. Let's try to apply it in practice:

```
val ints: Array<Int> = arrayOf(1, 2, 3)
val any = Array<Any>(3) { "" }
```

```
copy(ints, any)
//   ^ type is Array<Int> but Array<Any> was expected
```

Here you run into the same familiar problem: Array<T> is invariant in T, and so neither Array<Int> nor Array<Any> is a subtype of the other. Why not? Again, this is because copy could have an unexpected behavior, for example, it may attempt to write a String to from, and if you actually pass an array of Int there, a ClassCastException will be thrown later.

To prohibit the copy function from writing to from, you can do the following:

```
fun copy(from: Array<out Any>, to: Array<Any>) { ... }
```

This is type projection, which means that from is not a simple array, but is rather a restricted (projected) one. You can only call methods that return the type parameter T, which in this case means that you can only call get(). This is our approach to use-site variance, and it corresponds to Java's Array<? extends Object> while being slightly simpler.

You can project a type with in as well:

```
fun fill(dest: Array<in String>, value: String) { ... }
```

Array<in String> corresponds to Java's Array<? super String>. This means that you can pass an array of String, CharSequence, or Object to the fill() function.

Star-projections

Sometimes you want to say that you know nothing about the type argument, but you still want to use it in a safe way. The safe way here is to define such a projection of the generic type, that every concrete instantiation of that generic type will be a subtype of that projection.

Kotlin provides so-called star-projection syntax for this:

- For Foo<out T : TUpper>, where T is a covariant type parameter with the upper bound TUpper, Foo<*> is equivalent to Foo<out TUpper>. This means that when the T is unknown you can safely read values of TUpper from Foo<*>.
- For Foo<in T>, where T is a contravariant type parameter, Foo<*> is equivalent to Foo<in Nothing>. This means there is nothing you can write to Foo<*> in a safe way when T is unknown.
- For Foo<T : TUpper>, where T is an invariant type parameter with the upper bound TUpper, Foo<*> is equivalent to Foo<out TUpper> for reading values and to Foo<in Nothing> for writing values.

If a generic type has several type parameters, each of them can be projected independently. For example, if the type is declared as interface Function<in T, out U> you could use the following star-projections:

- Function<*, String> means Function<in Nothing, String>.
- Function<Int, *> means Function<Int, out Any?>.
- Function<*, *> means Function<in Nothing, out Any?>.

> Star-projections are very much like Java's raw types, but safe.

Generic functions

Classes aren't the only declarations that can have type parameters. Functions can, too. Type parameters are placed before the name of the function:

```
fun <T> singletonList(item: T): List<T> {
    // ...
}

fun <T> T.basicToString(): String { // extension function
    // ...
}
```

To call a generic function, specify the type arguments at the call site after the name of the function:

```
val l = singletonList<Int>(1)
```

Type arguments can be omitted if they can be inferred from the context, so the following example works as well:

```
val l = singletonList(1)
```

Generic constraints

The set of all possible types that can be substituted for a given type parameter may be restricted by generic constraints.

Upper bounds

The most common type of constraint is an upper bound, which corresponds to Java's extends keyword:

```
fun <T : Comparable<T>> sort(list: List<T>) {  ... }
```

The type specified after a colon is the upper bound, indicating that only a subtype of Comparable<T> can be substituted for T. For example:

```
sort(listOf(1, 2, 3)) // OK. Int is a subtype of Comparable<Int>
sort(listOf(HashMap<Int, String>())) // Error: HashMap<Int, String> is not a subtype of Comparable<HashMap<Int, String>>
```

The default upper bound (if there was none specified) is Any?. Only one upper bound can be specified inside the angle brackets. If the same type parameter needs more than one upper bound, you need a separate where-clause:

```
fun <T> copyWhenGreater(list: List<T>, threshold: T): List<String>
    where T : CharSequence,
          T : Comparable<T> {
    return list.filter { it > threshold }.map { it.toString() }
}
```

The passed type must satisfy all conditions of the where clause simultaneously. In the above example, the T type must implement both CharSequence and Comparable.

Definitely non-nullable types

To make interoperability with generic Java classes and interfaces easier, Kotlin supports declaring a generic type parameter as definitely non-nullable.

To declare a generic type T as definitely non-nullable, declare the type with & Any. For example: T & Any.

A definitely non-nullable type must have a nullable upper bound.

The most common use case for declaring definitely non-nullable types is when you want to override a Java method that contains @NotNull as an argument. For example, consider the load() method:

```
import org.jetbrains.annotations.*;

public interface Game<T> {
    public T save(T x) {}
    @NotNull
    public T load(@NotNull T x) {}
}
```

To override the load() method in Kotlin successfully, you need T1 to be declared as definitely non-nullable:

```
interface ArcadeGame<T1> : Game<T1> {
    override fun save(x: T1): T1
    // T1 is definitely non-nullable
    override fun load(x: T1 & Any): T1 & Any
}
```

When working only with Kotlin, it's unlikely that you will need to declare definitely non-nullable types explicitly because Kotlin's type inference takes care of this for you.

Type erasure

The type safety checks that Kotlin performs for generic declaration usages are done at compile time. At runtime, the instances of generic types do not hold any information about their actual type arguments. The type information is said to be erased. For example, the instances of Foo<Bar> and Foo<Baz?> are erased to just Foo<*>.

Generics type checks and casts

Due to the type erasure, there is no general way to check whether an instance of a generic type was created with certain type arguments at runtime, and the compiler prohibits such is-checks such as ints is List<Int> or list is T (type parameter). However, you can check an instance against a star-projected type:

```
if (something is List<*>) {
    something.forEach { println(it) } // The items are typed as `Any?`
}
```

Similarly, when you already have the type arguments of an instance checked statically (at compile time), you can make an is-check or a cast that involves the non-generic part of the type. Note that angle brackets are omitted in this case:

```
fun handleStrings(list: MutableList<String>) {
    if (list is ArrayList) {
        // `list` is smart-cast to `ArrayList<String>`
    }
}
```

The same syntax but with the type arguments omitted can be used for casts that do not take type arguments into account: list as ArrayList.

The type arguments of generic function calls are also only checked at compile time. Inside the function bodies, the type parameters cannot be used for type checks, and type casts to type parameters (foo as T) are unchecked. The only exclusion is inline functions with reified type parameters, which have their actual type arguments inlined at each call site. This enables type checks and casts for the type parameters. However, the restrictions described above still apply for instances of generic types used inside checks or casts. For example, in the type check arg is T, if arg is an instance of a generic type itself, its type arguments are still erased.

```
inline fun <reified A, reified B> Pair<*, *>.asPairOf(): Pair<A, B>? {
    if (first !is A || second !is B) return null
    return first as A to second as B
}

val somePair: Pair<Any?, Any?> = "items" to listOf(1, 2, 3)


val stringToSomething = somePair.asPairOf<String, Any>()
val stringToInt = somePair.asPairOf<String, Int>()
val stringToList = somePair.asPairOf<String, List<*>>()
val stringToStringList = somePair.asPairOf<String, List<String>>() // Compiles but breaks type safety!
// Expand the sample for more details


fun main() {
    println("stringToSomething = " + stringToSomething)
    println("stringToInt = " + stringToInt)
    println("stringToList = " + stringToList)
    println("stringToStringList = " + stringToStringList)
    //println(stringToStringList?.second?.forEach() {it.length}) // This will throw ClassCastException as list items are not String
}
```

Unchecked casts

Type casts to generic types with concrete type arguments such as foo as List<String> cannot be checked at runtime.
These unchecked casts can be used when type safety is implied by the high-level program logic but cannot be inferred directly by the compiler. See the example below.

```
fun readDictionary(file: File): Map<String, *> = file.inputStream().use {
    TODO("Read a mapping of strings to arbitrary elements.")
}

// We saved a map with `Int`s into this file
val intsFile = File("ints.dictionary")

// Warning: Unchecked cast: `Map<String, *>` to `Map<String, Int>`
```

```kotlin
val intsDictionary: Map<String, Int> = readDictionary(intsFile) as Map<String, Int>
```

A warning appears for the cast in the last line. The compiler can't fully check it at runtime and provides no guarantee that the values in the map are Int.

To avoid unchecked casts, you can redesign the program structure. In the example above, you could use the DictionaryReader<T> and DictionaryWriter<T> interfaces with type-safe implementations for different types. You can introduce reasonable abstractions to move unchecked casts from the call site to the implementation details. Proper use of generic variance can also help.

For generic functions, using reified type parameters makes casts like arg as T checked, unless arg's type has its own type arguments that are erased.

An unchecked cast warning can be suppressed by annotating the statement or the declaration where it occurs with @Suppress("UNCHECKED_CAST"):

```kotlin
inline fun <reified T> List<*>.asListOfType(): List<T>? =
    if (all { it is T })
        @Suppress("UNCHECKED_CAST")
        this as List<T> else
        null
```

> On the JVM: array types (Array<Foo>) retain information about the erased type of their elements, and type casts to an array type are partially checked: the nullability and actual type arguments of the element type are still erased. For example, the cast foo as Array<List<String>?> will succeed if foo is an array holding any List<*>, whether it is nullable or not.

Underscore operator for type arguments

The underscore operator _ can be used for type arguments. Use it to automatically infer a type of the argument when other types are explicitly specified:

```kotlin
abstract class SomeClass<T> {
    abstract fun execute() : T
}

class SomeImplementation : SomeClass<String>() {
    override fun execute(): String = "Test"
}

class OtherImplementation : SomeClass<Int>() {
    override fun execute(): Int = 42
}

object Runner {
    inline fun <reified S: SomeClass<T>, T> run() : T {
        return S::class.java.getDeclaredConstructor().newInstance().execute()
    }
}

fun main() {
    // T is inferred as String because SomeImplementation derives from SomeClass<String>
    val s = Runner.run<SomeImplementation, _>()
    assert(s == "Test")

    // T is inferred as Int because OtherImplementation derives from SomeClass<Int>
    val n = Runner.run<OtherImplementation, _>()
    assert(n == 42)
}
```

Nested and inner classes

Classes can be nested in other classes:

```kotlin
class Outer {
    private val bar: Int = 1
    class Nested {
        fun foo() = 2
    }
}

val demo = Outer.Nested().foo() // == 2
```

You can also use interfaces with nesting. All combinations of classes and interfaces are possible: You can nest interfaces in classes, classes in interfaces, and interfaces in interfaces.

```
interface OuterInterface {
    class InnerClass
    interface InnerInterface
}

class OuterClass {
    class InnerClass
    interface InnerInterface
}
```

Inner classes

A nested class marked as inner can access the members of its outer class. Inner classes carry a reference to an object of an outer class:

```
class Outer {
    private val bar: Int = 1
    inner class Inner {
        fun foo() = bar
    }
}

val demo = Outer().Inner().foo() // == 1
```

See Qualified this expressions to learn about disambiguation of this in inner classes.

Anonymous inner classes

Anonymous inner class instances are created using an object expression:

```
window.addMouseListener(object : MouseAdapter() {

    override fun mouseClicked(e: MouseEvent) { ... }

    override fun mouseEntered(e: MouseEvent) { ... }
})
```

On the JVM, if the object is an instance of a functional Java interface (that means a Java interface with a single abstract method), you can create it using a lambda expression prefixed with the type of the interface:

```
val listener = ActionListener { println("clicked") }
```

Enum classes

The most basic use case for enum classes is the implementation of type-safe enums:

```
enum class Direction {
    NORTH, SOUTH, WEST, EAST
}
```

Each enum constant is an object. Enum constants are separated by commas.

Since each enum is an instance of the enum class, it can be initialized as:

```
enum class Color(val rgb: Int) {
    RED(0xFF0000),
    GREEN(0x00FF00),
    BLUE(0x0000FF)
}
```

Anonymous classes

Enum constants can declare their own anonymous classes with their corresponding methods, as well as with overriding base methods.

```
enum class ProtocolState {
    WAITING {
        override fun signal() = TALKING
    },

    TALKING {
        override fun signal() = WAITING
    };

    abstract fun signal(): ProtocolState
}
```

If the enum class defines any members, separate the constant definitions from the member definitions with a semicolon.

Implementing interfaces in enum classes

An enum class can implement an interface (but it cannot derive from a class), providing either a common implementation of interface members for all the entries, or separate implementations for each entry within its anonymous class. This is done by adding the interfaces you want to implement to the enum class declaration as follows:

```
import java.util.function.BinaryOperator
import java.util.function.IntBinaryOperator

enum class IntArithmetics : BinaryOperator<Int>, IntBinaryOperator {
    PLUS {
        override fun apply(t: Int, u: Int): Int = t + u
    },
    TIMES {
        override fun apply(t: Int, u: Int): Int = t * u
    };

    override fun applyAsInt(t: Int, u: Int) = apply(t, u)
}

fun main() {
    val a = 13
    val b = 31
    for (f in IntArithmetics.entries) {
        println("$f($a, $b) = ${f.apply(a, b)}")
    }
}
```

All enum classes implement the Comparable interface by default. Constants in the enum class are defined in the natural order. For more information, see Ordering.

Working with enum constants

Enum classes in Kotlin have synthetic properties and methods for listing the defined enum constants and getting an enum constant by its name. The signatures of these methods are as follows (assuming the name of the enum class is EnumClass):

```
EnumClass.valueOf(value: String): EnumClass
EnumClass.entries: EnumEntries<EnumClass> // specialized List<EnumClass>
```

Below is an example of them in action:

```
enum class RGB { RED, GREEN, BLUE }

fun main() {
    for (color in RGB.entries) println(color.toString()) // prints RED, GREEN, BLUE
    println("The first color is: ${RGB.valueOf("RED")}") // prints "The first color is: RED"
}
```

The valueOf() method throws an IllegalArgumentException if the specified name does not match any of the enum constants defined in the class.

Prior to the introduction of entries in Kotlin 1.9.0, the values() function was used to retrieve an array of enum constants.

Every enum constant also has properties: name and ordinal, for obtaining its name and position (starting from 0) in the enum class declaration:

```
enum class RGB { RED, GREEN, BLUE }

fun main() {
        println(RGB.RED.name)    // prints RED
    println(RGB.RED.ordinal) // prints 0
    //sampleEnd
}
```

> To reduce repetition when working with enum entries, try out context-sensitive resolution (currently in preview). This feature allows you to omit the enum class name when the expected type is known, such as in when expressions or when assigning to a typed variable.
>
> For more information, see Preview of context-sensitive resolution or the related KEEP proposal.

You can access the constants in an enum class in a generic way using the enumValues<T>() and enumValueOf<T>() functions. In Kotlin 2.0.0, the enumEntries<T>() function is introduced as a replacement for the enumValues<T>() function. The enumEntries<T>() function returns a list of all enum entries for the given enum type T.

The enumValues<T>() function is still supported, but we recommend that you use the enumEntries<T>() function instead because it has less performance impact. Every time you call enumValues<T>() a new array is created, whereas whenever you call enumEntries<T>() the same list is returned each time, which is far more efficient.

For example:

```
enum class RGB { RED, GREEN, BLUE }

inline fun <reified T : Enum<T>> printAllValues() {
    println(enumEntries<T>().joinToString { it.name })
}

printAllValues<RGB>()
// RED, GREEN, BLUE
```

> For more information about inline functions and reified type parameters, see Inline functions.

Inline value classes

Sometimes it is useful to wrap a value in a class to create a more domain-specific type. However, it introduces runtime overhead due to additional heap allocations. Moreover, if the wrapped type is primitive, the performance hit is significant, because primitive types are usually heavily optimized by the runtime, while their wrappers don't get any special treatment.

To solve such issues, Kotlin introduces a special kind of class called an inline class. Inline classes are a subset of value-based classes. They don't have an identity and can only hold values.

To declare an inline class, use the value modifier before the name of the class:

```
value class Password(private val s: String)
```

To declare an inline class for the JVM backend, use the value modifier along with the @JvmInline annotation before the class declaration:

```
// For JVM backends
@JvmInline
value class Password(private val s: String)
```

An inline class must have a single property initialized in the primary constructor. At runtime, instances of the inline class will be represented using this single property (see details about runtime representation below):

```
// No actual instantiation of class 'Password' happens
// At runtime 'securePassword' contains just 'String'
val securePassword = Password("Don't try this in production")
```

This is the main feature of inline classes, which inspired the name inline: data of the class is inlined into its usages (similar to how content of inline functions is inlined to call sites).

Members

Inline classes support some functionality of regular classes. In particular, they are allowed to declare properties and functions, have an init block and secondary constructors:

```
@JvmInline
value class Person(private val fullName: String) {
    init {
        require(fullName.isNotEmpty()) {
            "Full name shouldn't be empty"
        }
    }

    constructor(firstName: String, lastName: String) : this("$firstName $lastName") {
        require(lastName.isNotBlank()) {
            "Last name shouldn't be empty"
        }
    }

    val length: Int
        get() = fullName.length

    fun greet() {
        println("Hello, $fullName")
    }
}

fun main() {
    val name1 = Person("Kotlin", "Mascot")
    val name2 = Person("Kodee")
    name1.greet() // the `greet()` function is called as a static method
    println(name2.length) // property getter is called as a static method
}
```

Inline class properties cannot have backing fields. They can only have simple computable properties (no lateinit /delegated properties).

Inheritance

Inline classes are allowed to inherit from interfaces:

```
interface Printable {
    fun prettyPrint(): String
}

@JvmInline
value class Name(val s: String) : Printable {
    override fun prettyPrint(): String = "Let's $s!"
}

fun main() {
    val name = Name("Kotlin")
    println(name.prettyPrint()) // Still called as a static method
}
```

It is forbidden for inline classes to participate in a class hierarchy. This means that inline classes cannot extend other classes and are always final.

Representation

In generated code, the Kotlin compiler keeps a wrapper for each inline class. Inline class instances can be represented at runtime either as wrappers or as the underlying type. This is similar to how Int can be represented either as a primitive int or as the wrapper Integer.

The Kotlin compiler will prefer using underlying types instead of wrappers to produce the most performant and optimized code. However, sometimes it is necessary to keep wrappers around. As a rule of thumb, inline classes are boxed whenever they are used as another type.

```
interface I

@JvmInline
value class Foo(val i: Int) : I

fun asInline(f: Foo) {}
fun <T> asGeneric(x: T) {}
fun asInterface(i: I) {}
fun asNullable(i: Foo?) {}

fun <T> id(x: T): T = x

fun main() {
    val f = Foo(42)

    asInline(f)    // unboxed: used as Foo itself
    asGeneric(f)   // boxed: used as generic type T
    asInterface(f) // boxed: used as type I
    asNullable(f)  // boxed: used as Foo?, which is different from Foo

    // below, 'f' first is boxed (while being passed to 'id') and then unboxed (when returned from 'id')
    // In the end, 'c' contains unboxed representation (just '42'), as 'f'
    val c = id(f)
}
```

Because inline classes may be represented both as the underlying value and as a wrapper, referential equality is pointless for them and is therefore prohibited.

Inline classes can also have a generic type parameter as the underlying type. In this case, the compiler maps it to Any? or, generally, to the upper bound of the type parameter.

```
@JvmInline
value class UserId<T>(val value: T)

fun compute(s: UserId<String>) {} // compiler generates fun compute-<hashcode>(s: Any?)
```

Mangling

Since inline classes are compiled to their underlying type, it may lead to various obscure errors, for example unexpected platform signature clashes:

```
@JvmInline
value class UInt(val x: Int)

// Represented as 'public final void compute(int x)' on the JVM
fun compute(x: Int) { }

// Also represented as 'public final void compute(int x)' on the JVM!
fun compute(x: UInt) { }
```

To mitigate such issues, functions using inline classes are mangled by adding some stable hashcode to the function name. Therefore, fun compute(x: UInt) will be represented as public final void compute-<hashcode>(int x), which solves the clash problem.

Calling from Java code

You can call functions that accept inline classes from Java code. To do so, you should manually disable mangling: add the @JvmName annotation before the function declaration:

```
@JvmInline
value class UInt(val x: Int)

fun compute(x: Int) { }

@JvmName("computeUInt")
fun compute(x: UInt) { }
```

By default, Kotlin compiles inline classes using unboxed representations, which makes them difficult to access from Java. To learn how to compile inline classes into boxed representations that are accessible from Java, see the guide to Calling Kotlin from Java.

Inline classes vs type aliases

At first sight, inline classes seem very similar to type aliases. Indeed, both seem to introduce a new type and both will be represented as the underlying type at runtime.

However, the crucial difference is that type aliases are assignment-compatible with their underlying type (and with other type aliases with the same underlying type), while inline classes are not.

In other words, inline classes introduce a truly new type, contrary to type aliases which only introduce an alternative name (alias) for an existing type:

```
typealias NameTypeAlias = String

@JvmInline
value class NameInlineClass(val s: String)

fun acceptString(s: String) {}
fun acceptNameTypeAlias(n: NameTypeAlias) {}
fun acceptNameInlineClass(p: NameInlineClass) {}

fun main() {
    val nameAlias: NameTypeAlias = ""
    val nameInlineClass: NameInlineClass = NameInlineClass("")
    val string: String = ""

    acceptString(nameAlias) // OK: pass alias instead of underlying type
    acceptString(nameInlineClass) // Not OK: can't pass inline class instead of underlying type

    // And vice versa:
    acceptNameTypeAlias(string) // OK: pass underlying type instead of alias
    acceptNameInlineClass(string) // Not OK: can't pass underlying type instead of inline class
}
```

Inline classes and delegation

Implementation by delegation to inlined value of inlined class is allowed with interfaces:

```
interface MyInterface {
    fun bar()
    fun foo() = "foo"
}

@JvmInline
value class MyInterfaceWrapper(val myInterface: MyInterface) : MyInterface by myInterface

fun main() {
    val my = MyInterfaceWrapper(object : MyInterface {
        override fun bar() {
            // body
        }
    })
    println(my.foo()) // prints "foo"
}
```

Object declarations and expressions

In Kotlin, objects allow you to define a class and create an instance of it in a single step. This is useful when you need either a reusable singleton instance or a one-time object. To handle these scenarios, Kotlin provides two key approaches: object declarations for creating singletons and object expressions for creating anonymous, one-time objects.

> A singleton ensures that a class has only one instance and provides a global point of access to it.

Object declarations and object expressions are best used for scenarios when:

- Using singletons for shared resources: You need to ensure that only one instance of a class exists throughout the application. For example, managing a database connection pool.
- Creating factory methods: You need a convenient way to create instances efficiently. Companion objects allow you to define class-level functions and properties tied to a class, simplifying the creation and management of these instances.
- Modifying existing class behavior temporarily: You want to modify the behavior of an existing class without the need to create a new subclass. For example, adding temporary functionality to an object for a specific operation.
- Type-safe design is required: You require one-time implementations of interfaces or abstract classes using object expressions. This can be useful for scenarios like a button click handler.

Object declarations

You can create single instances of objects in Kotlin using object declarations, which always have a name following the object keyword. This allows you to define a class and create an instance of it in a single step, which is useful for implementing singletons:

```
// Declares a Singleton object to manage data providers
object DataProviderManager {
    private val providers = mutableListOf<DataProvider>()

    // Registers a new data provider
    fun registerDataProvider(provider: DataProvider) {
        providers.add(provider)
    }

    // Retrieves all registered data providers
    val allDataProviders: Collection<DataProvider>
        get() = providers
}

// Example data provider interface
interface DataProvider {
    fun provideData(): String
}

// Example data provider implementation
class ExampleDataProvider : DataProvider {
    override fun provideData(): String {
        return "Example data"
    }
}

fun main() {
    // Creates an instance of ExampleDataProvider
    val exampleProvider = ExampleDataProvider()

    // To refer to the object, use its name directly
    DataProviderManager.registerDataProvider(exampleProvider)

    // Retrieves and prints all data providers
    println(DataProviderManager.allDataProviders.map { it.provideData() })
    // [Example data]
}
```

> The initialization of an object declaration is thread-safe and done on first access.

To refer to the object, use its name directly:

```
DataProviderManager.registerDataProvider(exampleProvider)
```

Object declarations can also have supertypes, similar to how anonymous objects can inherit from existing classes or implement interfaces:

```
object DefaultListener : MouseAdapter() {
    override fun mouseClicked(e: MouseEvent) { ... }

    override fun mouseEntered(e: MouseEvent) { ... }
}
```

Like variable declarations, object declarations are not expressions, so they cannot be used on the right-hand side of an assignment statement:

```
// Syntax error: An object expression cannot bind a name.
val myObject = object MySingleton {
    val name = "Singleton"
}
```

Object declarations cannot be local, which means they cannot be nested directly inside a function. However, they can be nested within other object declarations or non-inner classes.

Data objects

When printing a plain object declaration in Kotlin, the string representation contains both its name and the hash of the object:

```
object MyObject

fun main() {
    println(MyObject)
    // MyObject@hashcode
}
```

However, by marking an object declaration with the data modifier, you can instruct the compiler to return the actual name of the object when calling toString(), the same way it works for data classes:

```
data object MyDataObject {
    val number: Int = 3
}

fun main() {
    println(MyDataObject)
    // MyDataObject
}
```

Additionally, the compiler generates several functions for your data object:

- toString() returns the name of the data object
- equals()/hashCode() enables equality checks and hash-based collections

> You can't provide a custom equals or hashCode implementation for a data object.

The equals() function for a data object ensures that all objects that have the type of your data object are considered equal. In most cases, you will only have a single instance of your data object at runtime, since a data object declares a singleton. However, in the edge case where another object of the same type is generated at runtime (for example, by using platform reflection with java.lang.reflect or a JVM serialization library that uses this API under the hood), this ensures that the objects are treated as being equal.

> Make sure that you only compare data objects structurally (using the == operator) and never by reference (using the === operator). This helps you to avoid pitfalls when more than one instance of a data object exists at runtime.

```
import java.lang.reflect.Constructor

data object MySingleton

fun main() {
    val evilTwin = createInstanceViaReflection()

    println(MySingleton)
    // MySingleton

    println(evilTwin)
    // MySingleton
    // Even when a library forcefully creates a second instance of MySingleton,
    // its equals() function returns true:
    println(MySingleton == evilTwin)
    // true

    // Don't compare data objects using ===
    println(MySingleton === evilTwin)
    // false
}

fun createInstanceViaReflection(): MySingleton {
    // Kotlin reflection does not permit the instantiation of data objects.
    // This creates a new MySingleton instance "by force" (using Java platform reflection)
    // Don't do this yourself!
    return (MySingleton.javaClass.declaredConstructors[0].apply { isAccessible = true } as Constructor<MySingleton>).newInstance()
}
```

The generated hashCode() function has a behavior that is consistent with the equals() function, so that all runtime instances of a data object have the same hash code.

Differences between data objects and data classes

While data object and data class declarations are often used together and have some similarities, there are some functions that are not generated for a data object:

- No copy() function. Because a data object declaration is intended to be used as singletons, no copy() function is generated. Singletons restrict the instantiation of a class to a single instance, which would be violated by allowing copies of the instance to be created.
- No componentN() function. Unlike a data class, a data object does not have any data properties. Since attempting to destructure such an object without data properties wouldn't make sense, no componentN() functions are generated.

Use data objects with sealed hierarchies

Data object declarations are particularly useful for sealed hierarchies like sealed classes or sealed interfaces. They allow you to maintain symmetry with any data classes you may have defined alongside the object.

In this example, declaring EndOfFile as a data object instead of a plain object means that it will get the toString() function without the need to override it manually:

```
sealed interface ReadResult
data class Number(val number: Int) : ReadResult
data class Text(val text: String) : ReadResult
data object EndOfFile : ReadResult

fun main() {
    println(Number(7))
    // Number(number=7)
    println(EndOfFile)
    // EndOfFile
}
```

Companion objects

Companion objects allow you to define class-level functions and properties. This makes it easy to create factory methods, hold constants, and access shared utilities.

An object declaration inside a class can be marked with the companion keyword:

```
class MyClass {
    companion object Factory {
        fun create(): MyClass = MyClass()
    }
}
```

Members of the companion object can be called simply by using the class name as the qualifier:

```
class User(val name: String) {
    // Defines a companion object that acts as a factory for creating User instances
    companion object Factory {
        fun create(name: String): User = User(name)
    }
}

fun main(){
    // Calls the companion object's factory method using the class name as the qualifier.
    // Creates a new User instance
    val userInstance = User.create("John Doe")
    println(userInstance.name)
    // John Doe
}
```

The name of the companion object can be omitted, in which case the name Companion is used:

```
class User(val name: String) {
    // Defines a companion object without a name
    companion object { }
}

// Accesses the companion object
val companionUser = User.Companion
```

Class members can access private members of their corresponding companion object:

```
class User(val name: String) {
    companion object {
        private val defaultGreeting = "Hello"
    }

    fun sayHi() {
        println(defaultGreeting)
    }
}
User("Nick").sayHi()
// Hello
```

When a class name is used by itself, it acts as a reference to the companion object of the class, regardless of whether the companion object is named or not:

```
class User1 {
    // Defines a named companion object
    companion object Named {
        fun show(): String = "User1's Named Companion Object"
    }
}

// References the companion object of User1 using the class name
val reference1 = User1

class User2 {
    // Defines an unnamed companion object
    companion object {
        fun show(): String = "User2's Companion Object"
    }
}

// References the companion object of User2 using the class name
val reference2 = User2

fun main() {
    // Calls the show() function from the companion object of User1
    println(reference1.show())
    // User1's Named Companion Object

    // Calls the show() function from the companion object of User2
    println(reference2.show())
    // User2's Companion Object
}
```

Although members of companion objects in Kotlin look like static members from other languages, they are actually instance members of the companion object, meaning they belong to the object itself. This allows companion objects to implement interfaces:

```
interface Factory<T> {
    fun create(name: String): T
}

class User(val name: String) {
    // Defines a companion object that implements the Factory interface
    companion object : Factory<User> {
        override fun create(name: String): User = User(name)
    }
}

fun main() {
    // Uses the companion object as a Factory
    val userFactory: Factory<User> = User
    val newUser = userFactory.create("Example User")
    println(newUser.name)
    // Example User
}
```

However, on the JVM, you can have members of companion objects generated as real static methods and fields if you use the @JvmStatic annotation. See the Java interoperability section for more detail.

Object expressions

Object expressions declare a class and create an instance of that class, but without naming either of them. These classes are useful for one-time use. They can either be created from scratch, inherit from existing classes, or implement interfaces. Instances of these classes are also called anonymous objects because they are defined by an expression, not a name.

Create anonymous objects from scratch

Object expressions start with the object keyword.

If the object doesn't extend any classes or implement interfaces, you can define an object's members directly inside curly braces after the object keyword:

```
fun main() {
    val helloWorld = object {
        val hello = "Hello"
        val world = "World"
        // Object expressions extend the Any class, which already has a toString() function,
        // so it must be overridden
        override fun toString() = "$hello $world"
    }

    print(helloWorld)
    // Hello World
}
```

Inherit anonymous objects from supertypes

To create an anonymous object that inherits from some type (or types), specify this type after object and a colon :. Then implement or override the members of this class as if you were inheriting from it:

```
window.addMouseListener(object : MouseAdapter() {
    override fun mouseClicked(e: MouseEvent) { /*...*/ }

    override fun mouseEntered(e: MouseEvent) { /*...*/ }
})
```

If a supertype has a constructor, pass the appropriate constructor parameters to it. Multiple supertypes can be specified, separated by commas, after the colon:

```
// Creates an open class BankAccount with a balance property
open class BankAccount(initialBalance: Int) {
    open val balance: Int = initialBalance
}

// Defines an interface Transaction with an execute() function
interface Transaction {
    fun execute()
}

// A function to perform a special transaction on a BankAccount
fun specialTransaction(account: BankAccount) {
    // Creates an anonymous object that inherits from the BankAccount class and implements the Transaction interface
    // The balance of the provided account is passed to the BankAccount superclass constructor
    val temporaryAccount = object : BankAccount(account.balance), Transaction {
```

```kotlin
        override val balance = account.balance + 500  // Temporary bonus

        // Implements the execute() function from the Transaction interface
        override fun execute() {
            println("Executing special transaction. New balance is $balance.")
        }
    }
    // Executes the transaction
    temporaryAccount.execute()
}
fun main() {
    // Creates a BankAccount with an initial balance of 1000
    val myAccount = BankAccount(1000)
    // Performs a special transaction on the created account
    specialTransaction(myAccount)
    // Executing special transaction. New balance is 1500.
}
```

Use anonymous objects as return and value types

When you return an anonymous object from a local or private function or property, all the members of that anonymous object are accessible through that function or property:

```kotlin
class UserPreferences {
    private fun getPreferences() = object {
        val theme: String = "Dark"
        val fontSize: Int = 14
    }

    fun printPreferences() {
        val preferences = getPreferences()
        println("Theme: ${preferences.theme}, Font Size: ${preferences.fontSize}")
    }
}

fun main() {
    val userPreferences = UserPreferences()
    userPreferences.printPreferences()
    // Theme: Dark, Font Size: 14
}
```

This allows you to return an anonymous object with specific properties, offering a simple way to encapsulate data or behavior without creating a separate class.

If a function or property that returns an anonymous object has public, protected, or internal visibility, its actual type is:

- Any if the anonymous object doesn't have a declared supertype.
- The declared supertype of the anonymous object, if there is exactly one such type.
- The explicitly declared type if there is more than one declared supertype.

In all these cases, members added in the anonymous object are not accessible. Overridden members are accessible if they are declared in the actual type of the function or property. For example:

```kotlin
interface Notification {
    // Declares notifyUser() in the Notification interface
    fun notifyUser()
}

interface DetailedNotification

class NotificationManager {
    // The return type is Any. The message property is not accessible.
    // When the return type is Any, only members of the Any class are accessible.
    fun getNotification() = object {
        val message: String = "General notification"
    }

    // The return type is Notification because the anonymous object implements only one interface
    // The notifyUser() function is accessible because it is part of the Notification interface
    // The message property is not accessible because it is not declared in the Notification interface
    fun getEmailNotification() = object : Notification {
        override fun notifyUser() {
            println("Sending email notification")
        }
        val message: String = "You've got mail!"
    }

    // The return type is DetailedNotification. The notifyUser() function and the message property are not accessible
    // Only members declared in the DetailedNotification interface are accessible
    fun getDetailedNotification(): DetailedNotification = object : Notification, DetailedNotification {
        override fun notifyUser() {
            println("Sending detailed notification")
        }
        val message: String = "Detailed message content"
    }
}
fun main() {
    // This produces no output
    val notificationManager = NotificationManager()

    // The message property is not accessible here because the return type is Any
    // This produces no output
    val notification = notificationManager.getNotification()

    // The notifyUser() function is accessible
    // The message property is not accessible here because the return type is Notification
    val emailNotification = notificationManager.getEmailNotification()
    emailNotification.notifyUser()
    // Sending email notification

    // The notifyUser() function and message property are not accessible here because the return type is DetailedNotification
    // This produces no output
    val detailedNotification = notificationManager.getDetailedNotification()
}
```

Access variables from anonymous objects

Code within the body of object expressions can access variables from the enclosing scope:

```
import java.awt.event.MouseAdapter
import java.awt.event.MouseEvent

fun countClicks(window: JComponent) {
    var clickCount = 0
    var enterCount = 0

    // MouseAdapter provides default implementations for mouse event functions
    // Simulates MouseAdapter handling mouse events
    window.addMouseListener(object : MouseAdapter() {
        override fun mouseClicked(e: MouseEvent) {
            clickCount++
        }

        override fun mouseEntered(e: MouseEvent) {
            enterCount++
        }
    })
    // The clickCount and enterCount variables are accessible within the object expression
}
```

Behavior difference between object declarations and expressions

There are differences in the initialization behavior between object declarations and object expressions:

- Object expressions are executed (and initialized) immediately, where they are used.
- Object declarations are initialized lazily, when accessed for the first time.
- A companion object is initialized when the corresponding class is loaded (resolved) that matches the semantics of a Java static initializer.

Delegation

The Delegation pattern has proven to be a good alternative to implementation inheritance, and Kotlin supports it natively requiring zero boilerplate code.

A class Derived can implement an interface Base by delegating all of its public members to a specified object:

```kotlin
interface Base {
    fun print()
}

class BaseImpl(val x: Int) : Base {
    override fun print() { print(x) }
}

class Derived(b: Base) : Base by b

fun main() {
    val base = BaseImpl(10)
    Derived(base).print()
}
```

The by-clause in the supertype list for Derived indicates that b will be stored internally in objects of Derived and the compiler will generate all the methods of Base that forward to b.

Overriding a member of an interface implemented by delegation

Overrides work as you expect: the compiler will use your override implementations instead of those in the delegate object. If you want to add override fun printMessage() { print("abc") } to Derived, the program would print abc instead of 10 when printMessage is called:

```kotlin
interface Base {
    fun printMessage()
    fun printMessageLine()
}

class BaseImpl(val x: Int) : Base {
    override fun printMessage() { print(x) }
    override fun printMessageLine() { println(x) }
}

class Derived(b: Base) : Base by b {
    override fun printMessage() { print("abc") }
}

fun main() {
    val base = BaseImpl(10)
    Derived(base).printMessage()
    Derived(base).printMessageLine()
}
```

Note, however, that members overridden in this way do not get called from the members of the delegate object, which can only access its own implementations of the interface members:

```kotlin
interface Base {
    val message: String
    fun print()
}

class BaseImpl(x: Int) : Base {
    override val message = "BaseImpl: x = $x"
    override fun print() { println(message) }
}

class Derived(b: Base) : Base by b {
    // This property is not accessed from b's implementation of `print`
    override val message = "Message of Derived"
}

fun main() {
    val b = BaseImpl(10)
    val derived = Derived(b)
    derived.print()
    println(derived.message)
}
```

Learn more about delegated properties.

Delegated properties

With some common kinds of properties, even though you can implement them manually every time you need them, it is more helpful to implement them once, add them to a library, and reuse them later. For example:

- Lazy properties: the value is computed only on first access.
- Observable properties: listeners are notified about changes to this property.
- Storing properties in a map instead of a separate field for each property.

To cover these (and other) cases, Kotlin supports delegated properties:

```
class Example {
    var p: String by Delegate()
}
```

The syntax is: val/var <property name>: <Type> by <expression>. The expression after by is a delegate, because the get() (and set()) that correspond to the property will be delegated to its getValue() and setValue() methods. Property delegates don't have to implement an interface, but they have to provide a getValue() function (and setValue() for vars).

For example:

```
import kotlin.reflect.KProperty

class Delegate {
    operator fun getValue(thisRef: Any?, property: KProperty<*>): String {
        return "$thisRef, thank you for delegating '${property.name}' to me!"
    }

    operator fun setValue(thisRef: Any?, property: KProperty<*>, value: String) {
        println("$value has been assigned to '${property.name}' in $thisRef.")
    }
}
```

When you read from p, which delegates to an instance of Delegate, the getValue() function from Delegate is called. Its first parameter is the object you read p from, and the second parameter holds a description of p itself (for example, you can take its name).

```
val e = Example()
println(e.p)
```

This prints:

```
Example@33a17727, thank you for delegating 'p' to me!
```

Similarly, when you assign to p, the setValue() function is called. The first two parameters are the same, and the third holds the value being assigned:

```
e.p = "NEW"
```

This prints:

```
NEW has been assigned to 'p' in Example@33a17727.
```

The specification of the requirements for the delegated object can be found below.

You can declare a delegated property inside a function or code block; it doesn't have to be a member of a class. Below you can find an example.

Standard delegates

The Kotlin standard library provides factory methods for several useful kinds of delegates.

Lazy properties

lazy() is a function that takes a lambda and returns an instance of Lazy<T>, which can serve as a delegate for implementing a lazy property. The first call to get() executes the lambda passed to lazy() and remembers the result. Subsequent calls to get() simply return the remembered result.

```
val lazyValue: String by lazy {
    println("computed!")
    "Hello"
}

fun main() {
    println(lazyValue)
    println(lazyValue)
}
```

By default, the evaluation of lazy properties is synchronized: the value is computed only in one thread, but all threads will see the same value. If the synchronization of the initialization delegate is not required to allow multiple threads to execute it simultaneously, pass LazyThreadSafetyMode.PUBLICATION as a parameter to lazy().

If you're sure that the initialization will always happen in the same thread as the one where you use the property, you can use LazyThreadSafetyMode.NONE. It doesn't incur any thread-safety guarantees and related overhead.

Observable properties

Delegates.observable() takes two arguments: the initial value and a handler for modifications.

The handler is called every time you assign to the property (after the assignment has been performed). It has three parameters: the property being assigned to, the old value, and the new value:

```
import kotlin.properties.Delegates

class User {
    var name: String by Delegates.observable("<no name>") {
        prop, old, new ->
        println("$old -> $new")
    }
}

fun main() {
    val user = User()
    user.name = "first"
    user.name = "second"
}
```

If you want to intercept assignments and veto them, use vetoable() instead of observable(). The handler passed to vetoable will be called before the assignment of a new property value.

Delegating to another property

A property can delegate its getter and setter to another property. Such delegation is available for both top-level and class properties (member and extension). The delegate property can be:

- A top-level property
- A member or an extension property of the same class
- A member or an extension property of another class

To delegate a property to another property, use the :: qualifier in the delegate name, for example, this::delegate or MyClass::delegate.

```
var topLevelInt: Int = 0
class ClassWithDelegate(val anotherClassInt: Int)

class MyClass(var memberInt: Int, val anotherClassInstance: ClassWithDelegate) {
    var delegatedToMember: Int by this::memberInt
    var delegatedToTopLevel: Int by ::topLevelInt

    val delegatedToAnotherClass: Int by anotherClassInstance::anotherClassInt
}
var MyClass.extDelegated: Int by ::topLevelInt
```

This may be useful, for example, when you want to rename a property in a backward-compatible way: introduce a new property, annotate the old one with the @Deprecated annotation, and delegate its implementation.

```
class MyClass {
   var newName: Int = 0
   @Deprecated("Use 'newName' instead", ReplaceWith("newName"))
   var oldName: Int by this::newName
}
fun main() {
   val myClass = MyClass()
   // Notification: 'oldName: Int' is deprecated.
   // Use 'newName' instead
   myClass.oldName = 42
   println(myClass.newName) // 42
}
```

Storing properties in a map

One common use case is storing the values of properties in a map. This comes up often in applications for things like parsing JSON or performing other dynamic tasks. In this case, you can use the map instance itself as the delegate for a delegated property.

```
class User(val map: Map<String, Any?>) {
    val name: String by map
    val age: Int     by map
}
```

In this example, the constructor takes a map:

```
val user = User(mapOf(
    "name" to "John Doe",
    "age"  to 25
))
```

Delegated properties take values from this map through string keys, which are associated with the names of properties:

```
class User(val map: Map<String, Any?>) {
    val name: String by map
    val age: Int     by map
}

fun main() {
    val user = User(mapOf(
        "name" to "John Doe",
        "age"  to 25
    ))
    println(user.name) // Prints "John Doe"
    println(user.age)  // Prints 25
}
```

This also works for var's properties if you use a MutableMap instead of a read-only Map:

```
class MutableUser(val map: MutableMap<String, Any?>) {
    var name: String by map
    var age: Int     by map
}
```

Local delegated properties

You can declare local variables as delegated properties. For example, you can make a local variable lazy:

```
fun example(computeFoo: () -> Foo) {
    val memoizedFoo by lazy(computeFoo)

    if (someCondition && memoizedFoo.isValid()) {
        memoizedFoo.doSomething()
    }
}
```

The memoizedFoo variable will be computed on first access only. If someCondition fails, the variable won't be computed at all.

Property delegate requirements

For a read-only property (val), a delegate should provide an operator function getValue() with the following parameters:

- thisRef must be the same type as, or a supertype of, the property owner (for extension properties, it should be the type being extended).
- property must be of type KProperty<*> or its supertype.

getValue() must return the same type as the property (or its subtype).

```kotlin
class Resource

class Owner {
    val valResource: Resource by ResourceDelegate()
}

class ResourceDelegate {
    operator fun getValue(thisRef: Owner, property: KProperty<*>): Resource {
        return Resource()
    }
}
```

For a mutable property (var), a delegate has to additionally provide an operator function setValue() with the following parameters:

- thisRef must be the same type as, or a supertype of, the property owner (for extension properties, it should be the type being extended).
- property must be of type KProperty<*> or its supertype.
- value must be of the same type as the property (or its supertype).

```kotlin
class Resource

class Owner {
    var varResource: Resource by ResourceDelegate()
}

class ResourceDelegate(private var resource: Resource = Resource()) {
    operator fun getValue(thisRef: Owner, property: KProperty<*>): Resource {
        return resource
    }
    operator fun setValue(thisRef: Owner, property: KProperty<*>, value: Any?) {
        if (value is Resource) {
            resource = value
        }
    }
}
```

getValue() and/or setValue() functions can be provided either as member functions of the delegate class or as extension functions. The latter is handy when you need to delegate a property to an object that doesn't originally provide these functions. Both of the functions need to be marked with the operator keyword.

You can create delegates as anonymous objects without creating new classes, by using the interfaces ReadOnlyProperty and ReadWriteProperty from the Kotlin standard library. They provide the required methods: getValue() is declared in ReadOnlyProperty; ReadWriteProperty extends it and adds setValue(). This means you can pass a ReadWriteProperty whenever a ReadOnlyProperty is expected.

```kotlin
fun resourceDelegate(resource: Resource = Resource()): ReadWriteProperty<Any?, Resource> =
    object : ReadWriteProperty<Any?, Resource> {
        var curValue = resource
        override fun getValue(thisRef: Any?, property: KProperty<*>): Resource = curValue
        override fun setValue(thisRef: Any?, property: KProperty<*>, value: Resource) {
            curValue = value
        }
    }

val readOnlyResource: Resource by resourceDelegate()  // ReadWriteProperty as val
var readWriteResource: Resource by resourceDelegate()
```

Translation rules for delegated properties

Under the hood, the Kotlin compiler generates auxiliary properties for some kinds of delegated properties and then delegates to them.

> For optimization purposes, the compiler does not generate auxiliary properties in several cases. Learn about the optimization on the example of delegating to another property.

For example, for the property prop it generates the hidden property prop$delegate, and the code of the accessors simply delegates to this additional property:

```
class C {
    var prop: Type by MyDelegate()
}

// this code is generated by the compiler instead:
class C {
    private val prop$delegate = MyDelegate()
    var prop: Type
        get() = prop$delegate.getValue(this, this::prop)
        set(value: Type) = prop$delegate.setValue(this, this::prop, value)
}
```

The Kotlin compiler provides all the necessary information about prop in the arguments: the first argument this refers to an instance of the outer class C, and this::prop is a reflection object of the KProperty type describing prop itself.

Optimized cases for delegated properties

The $delegate field will be omitted if a delegate is:

- A referenced property:

```
class C<Type> {
    private var impl: Type = ...
    var prop: Type by ::impl
}
```

- A named object:

```
object NamedObject {
    operator fun getValue(thisRef: Any?, property: KProperty<*>): String = ...
}

val s: String by NamedObject
```

- A final val property with a backing field and a default getter in the same module:

```
val impl: ReadOnlyProperty<Any?, String> = ...

class A {
    val s: String by impl
}
```

- A constant expression, enum entry, this, null. The example of this:

```
class A {
    operator fun getValue(thisRef: Any?, property: KProperty<*>) ...

    val s by this
}
```

Translation rules when delegating to another property

When delegating to another property, the Kotlin compiler generates immediate access to the referenced property. This means that the compiler doesn't generate the field prop$delegate. This optimization helps save memory.

Take the following code, for example:

```
class C<Type> {
    private var impl: Type = ...
    var prop: Type by ::impl
}
```

Property accessors of the prop variable invoke the impl variable directly, skipping the delegated property's getValueand setValue operators, and thus the KProperty reference object is not needed.

For the code above, the compiler generates the following code:

```
class C<Type> {
    private var impl: Type = ...

    var prop: Type
        get() = impl
        set(value) {
            impl = value
        }

    fun getProp$delegate(): Type = impl // This method is needed only for reflection
}
```

Providing a delegate

By defining the provideDelegate operator, you can extend the logic for creating the object to which the property implementation is delegated. If the object used on the right-hand side of by defines provideDelegate as a member or extension function, that function will be called to create the property delegate instance.

One of the possible use cases of provideDelegate is to check the consistency of the property upon its initialization.

For example, to check the property name before binding, you can write something like this:

```
class ResourceDelegate<T> : ReadOnlyProperty<MyUI, T> {
    override fun getValue(thisRef: MyUI, property: KProperty<*>): T { ... }
}

class ResourceLoader<T>(id: ResourceID<T>) {
    operator fun provideDelegate(
            thisRef: MyUI,
            prop: KProperty<*>
    ): ReadOnlyProperty<MyUI, T> {
        checkProperty(thisRef, prop.name)
        // create delegate
        return ResourceDelegate()
    }

    private fun checkProperty(thisRef: MyUI, name: String) { ... }
}

class MyUI {
    fun <T> bindResource(id: ResourceID<T>): ResourceLoader<T> { ... }

    val image by bindResource(ResourceID.image_id)
    val text by bindResource(ResourceID.text_id)
}
```

The parameters of provideDelegate are the same as those of getValue:

- thisRef must be the same type as, or a supertype of, the property owner (for extension properties, it should be the type being extended);
- property must be of type KProperty<*> or its supertype.

The provideDelegate method is called for each property during the creation of the MyUI instance, and it performs the necessary validation right away.

Without this ability to intercept the binding between the property and its delegate, to achieve the same functionality you'd have to pass the property name explicitly, which isn't very convenient:

```
// Checking the property name without "provideDelegate" functionality
class MyUI {
    val image by bindResource(ResourceID.image_id, "image")
    val text by bindResource(ResourceID.text_id, "text")
}

fun <T> MyUI.bindResource(
        id: ResourceID<T>,
        propertyName: String
): ReadOnlyProperty<MyUI, T> {
    checkProperty(this, propertyName)
    // create delegate
}
```

In the generated code, the provideDelegate method is called to initialize the auxiliary prop$delegate property. Compare the generated code for the property declaration val prop: Type by MyDelegate() with the generated code above (when the provideDelegate method is not present):

```
class C {
    var prop: Type by MyDelegate()
}

// this code is generated by the compiler
// when the 'provideDelegate' function is available:
class C {
    // calling "provideDelegate" to create the additional "delegate" property
    private val prop$delegate = MyDelegate().provideDelegate(this, this::prop)
    var prop: Type
        get() = prop$delegate.getValue(this, this::prop)
        set(value: Type) = prop$delegate.setValue(this, this::prop, value)
}
```

Note that the provideDelegate method affects only the creation of the auxiliary property and doesn't affect the code generated for the getter or the setter.

With the PropertyDelegateProvider interface from the standard library, you can create delegate providers without creating new classes.

```
val provider = PropertyDelegateProvider { thisRef: Any?, property ->
    ReadOnlyProperty<Any?, Int> {_, property -> 42 }
}
val delegate: Int by provider
```

Type aliases

Type aliases provide alternative names for existing types. If the type name is too long you can introduce a different shorter name and use the new one instead.

It's useful to shorten long generic types. For instance, it's often tempting to shrink collection types:

```
typealias NodeSet = Set<Network.Node>

typealias FileTable<K> = MutableMap<K, MutableList<File>>
```

You can provide different aliases for function types:

```
typealias MyHandler = (Int, String, Any) -> Unit

typealias Predicate<T> = (T) -> Boolean
```

You can have new names for inner and nested classes:

```
class A {
    inner class Inner
}
class B {
    inner class Inner
}

typealias AInner = A.Inner
typealias BInner = B.Inner
```

Type aliases do not introduce new types. They are equivalent to the corresponding underlying types. When you add typealias Predicate<T> and use Predicate<Int> in your code, the Kotlin compiler always expands it to (Int) -> Boolean. Thus you can pass a variable of your type whenever a general function type is required and vice versa:

```
typealias Predicate<T> = (T) -> Boolean

fun foo(p: Predicate<Int>) = p(42)

fun main() {
    val f: (Int) -> Boolean = { it > 0 }
    println(foo(f)) // prints "true"

    val p: Predicate<Int> = { it > 0 }
    println(listOf(1, -2).filter(p)) // prints "[1]"
}
```

Nested type aliases

In Kotlin, you can define type aliases inside other declarations, as long as they don't capture type parameters from their outer class:

```
class Dijkstra {
   typealias VisitedNodes = Set<Node>

   private fun step(visited: VisitedNodes, ...) = ...
}
```

Capturing means that the type alias refers to a type parameter defined in the outer class:

```
class Graph<Node> {
    // Incorrect because captures Node
    typealias Path = List<Node>
}
```

To fix this issue, declare the type parameter directly in the type alias:

```
class Graph<Node> {
    // Correct because Node is a type alias parameter
    typealias Path<Node> = List<Node>
}
```

Nested type aliases allow for cleaner, more maintainable code by improving encapsulation, reducing package-level clutter, and simplifying internal implementations.

Rules for nested type aliases

Nested type aliases follow specific rules to ensure clear and consistent behavior:

- Nested type aliases must follow all existing type alias rules.
- In terms of visibility, the alias can't expose more than its referenced types allow.
- Their scope is the same as nested classes. You can define them inside classes, and they hide any parent type aliases with the same name as they don't override.
- Nested type aliases can be marked as internal or private to limit their visibility.
- Nested type aliases are not supported in Kotlin Multiplatform's expect/actual declarations.

How to enable nested type aliases

To enable nested type aliases in your project, use the following compiler option in the command line:

```
-Xnested-type-aliases
```

Or add it to the compilerOptions {} block of your Gradle build file:

```
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xnested-type-aliases")
    }
}
```

Functions

Kotlin functions are declared using the fun keyword:

```
fun double(x: Int): Int {
    return 2 * x
}
```

Function usage

Functions are called using the standard approach:

```
val result = double(2)
```

Calling member functions uses dot notation:

```
Stream().read() // create instance of class Stream and call read()
```

Parameters

Function parameters are defined using Pascal notation - name: type. Parameters are separated using commas, and each parameter must be explicitly typed:

```
fun powerOf(number: Int, exponent: Int): Int { /*...*/ }
```

You can use a trailing comma when you declare function parameters:

```
fun powerOf(
    number: Int,
    exponent: Int, // trailing comma
) { /*...*/ }
```

Default arguments

Function parameters can have default values, which are used when you skip the corresponding argument. This reduces the number of overloads:

```
fun read(
    b: ByteArray,
    off: Int = 0,
    len: Int = b.size,
) { /*...*/ }
```

A default value is set by appending = to the type.

Overriding methods always use the base method's default parameter values. When overriding a method that has default parameter values, the default parameter values must be omitted from the signature:

```
open class A {
    open fun foo(i: Int = 10) { /*...*/ }
}

class B : A() {
    override fun foo(i: Int) { /*...*/ }  // No default value is allowed.
}
```

If a default parameter precedes a parameter with no default value, the default value can only be used by calling the function with named arguments:

```
fun foo(
    bar: Int = 0,
    baz: Int,
) { /*...*/ }

foo(baz = 1) // The default value bar = 0 is used
```

If the last argument after default parameters is a lambda, you can pass it either as a named argument or outside the parentheses:

```
fun foo(
    bar: Int = 0,
    baz: Int = 1,
    qux: () -> Unit,
) { /*...*/ }

foo(1) { println("hello") }     // Uses the default value baz = 1
foo(qux = { println("hello") }) // Uses both default values bar = 0 and baz = 1
foo { println("hello") }        // Uses both default values bar = 0 and baz = 1
```

Named arguments

You can name one or more of a function's arguments when calling it. This can be helpful when a function has many arguments and it's difficult to associate a value with an argument, especially if it's a boolean or null value.

When you use named arguments in a function call, you can freely change the order that they are listed in. If you want to use their default values, you can just leave these arguments out altogether.

Consider the reformat() function, which has 4 arguments with default values.

```
fun reformat(
    str: String,
    normalizeCase: Boolean = true,
    upperCaseFirstLetter: Boolean = true,
    divideByCamelHumps: Boolean = false,
    wordSeparator: Char = ' ',
) { /*...*/ }
```

When calling this function, you don't have to name all its arguments:

```
reformat(
    "String!",
    false,
    upperCaseFirstLetter = false,
    divideByCamelHumps = true,
    '_'
)
```

You can skip all the ones with default values:

```
reformat("This is a long String!")
```

You are also able to skip specific arguments with default values, rather than omitting them all. However, after the first skipped argument, you must name all subsequent arguments:

```
reformat("This is a short String!", upperCaseFirstLetter = false, wordSeparator = '_')
```

You can pass a variable number of arguments (vararg) with names using the spread operator (prefix the array with *):

```
fun foo(vararg strings: String) { /*...*/ }

foo(strings = *arrayOf("a", "b", "c"))
```

When calling Java functions on the JVM, you can't use the named argument syntax because Java bytecode does not always preserve the names of function parameters.

Unit-returning functions

If a function does not return a useful value, its return type is Unit. Unit is a type with only one value - Unit. This value does not have to be returned explicitly:

```
fun printHello(name: String?): Unit {
    if (name != null)
        println("Hello $name")
    else
        println("Hi there!")
    // `return Unit` or `return` is optional
}
```

The Unit return type declaration is also optional. The above code is equivalent to:

```
fun printHello(name: String?) { ... }
```

Single-expression functions

When the function body consists of a single expression, the curly braces can be omitted and the body specified after an = symbol:

```
fun double(x: Int): Int = x * 2
```

Explicitly declaring the return type is optional when this can be inferred by the compiler:

```
fun double(x: Int) = x * 2
```

Explicit return types

Functions with block body must always specify return types explicitly, unless it's intended for them to return Unit, in which case specifying the return type is optional.

Kotlin does not infer return types for functions with block bodies because such functions may have complex control flow in the body, and the return type will be non-obvious to the reader (and sometimes even for the compiler).

Variable number of arguments (varargs)

You can mark a parameter of a function (usually the last one) with the vararg modifier:

```
fun <T> asList(vararg ts: T): List<T> {
    val result = ArrayList<T>()
    for (t in ts) // ts is an Array
        result.add(t)
    return result
}
```

In this case, you can pass a variable number of arguments to the function:

```
val list = asList(1, 2, 3)
```

Inside a function, a vararg-parameter of type T is visible as an array of T, as in the example above, where the ts variable has type Array<out T>.

Only one parameter can be marked as vararg. If a vararg parameter is not the last one in the list, values for the subsequent parameters must be passed using named argument syntax, or, if the parameter has a function type, by passing a lambda outside the parentheses.

When you call a vararg-function, you can pass arguments individually, for example asList(1, 2, 3). If you already have an array and want to pass its contents to the function, use the spread operator (prefix the array with *):

```
val a = arrayOf(1, 2, 3)
val list = asList(-1, 0, *a, 4)
```

If you want to pass a primitive type array into vararg, you need to convert it to a regular (typed) array using the toTypedArray() function:

```
val a = intArrayOf(1, 2, 3) // IntArray is a primitive type array
val list = asList(-1, 0, *a.toTypedArray(), 4)
```

Infix notation

Functions marked with the infix keyword can also be called using the infix notation (omitting the dot and the parentheses for the call). Infix functions must meet the following requirements:

- They must be member functions or extension functions.
- They must have a single parameter.
- The parameter must not accept variable number of arguments and must have no default value.

```
infix fun Int.shl(x: Int): Int { ... }

// calling the function using the infix notation
1 shl 2

// is the same as
1.shl(2)
```

> Infix function calls have lower precedence than arithmetic operators, type casts, and the rangeTo operator. The following expressions are equivalent:
>
> - 1 shl 2 + 3 is equivalent to 1 shl (2 + 3)
> - 0 until n * 2 is equivalent to 0 until (n * 2)
> - xs union ys as Set<*> is equivalent to xs union (ys as Set<*>)
>
> On the other hand, an infix function call's precedence is higher than that of the boolean operators && and ||, is - and in-checks, and some other operators. These expressions are equivalent as well:
>
> - a && b xor c is equivalent to a && (b xor c)
> - a xor b in c is equivalent to (a xor b) in c

Note that infix functions always require both the receiver and the parameter to be specified. When you're calling a method on the current receiver using the infix notation, use this explicitly. This is required to ensure unambiguous parsing.

```
class MyStringCollection {
    infix fun add(s: String) { /*...*/ }

    fun build() {
        this add "abc"   // Correct
        add("abc")       // Correct
        //add "abc"        // Incorrect: the receiver must be specified
    }
}
```

Function scope

Kotlin functions can be declared at the top level in a file, meaning you do not need to create a class to hold a function, which you are required to do in languages such as Java, C#, and Scala (top level definition is available since Scala 3). In addition to top level functions, Kotlin functions can also be declared locally as member functions and extension functions.

Local functions

Kotlin supports local functions, which are functions inside other functions:

```
fun dfs(graph: Graph) {
    fun dfs(current: Vertex, visited: MutableSet<Vertex>) {
        if (!visited.add(current)) return
        for (v in current.neighbors)
            dfs(v, visited)
    }

    dfs(graph.vertices[0], HashSet())
}
```

A local function can access local variables of outer functions (the closure). In the case above, visited can be a local variable:

```
fun dfs(graph: Graph) {
    val visited = HashSet<Vertex>()
    fun dfs(current: Vertex) {
        if (!visited.add(current)) return
        for (v in current.neighbors)
            dfs(v)
    }

    dfs(graph.vertices[0])
}
```

Member functions

A member function is a function that is defined inside a class or object:

```
class Sample {
    fun foo() { print("Foo") }
}
```

Member functions are called with dot notation:

```
Sample().foo() // creates instance of class Sample and calls foo
```

For more information on classes and overriding members see Classes and Inheritance.

Generic functions

Functions can have generic parameters, which are specified using angle brackets before the function name:

```
fun <T> singletonList(item: T): List<T> { /*...*/ }
```

For more information on generic functions, see Generics.

Tail recursive functions

Kotlin supports a style of functional programming known as tail recursion. For some algorithms that would normally use loops, you can use a recursive function instead without the risk of stack overflow. When a function is marked with the tailrec modifier and meets the required formal conditions, the compiler optimizes out the recursion, leaving behind a fast and efficient loop based version instead:

```
val eps = 1E-10 // "good enough", could be 10^-15

tailrec fun findFixPoint(x: Double = 1.0): Double =
    if (Math.abs(x - Math.cos(x)) < eps) x else findFixPoint(Math.cos(x))
```

This code calculates the fixpoint of cosine, which is a mathematical constant. It simply calls Math.cos repeatedly starting at 1.0 until the result no longer changes, yielding a result of 0.7390851332151611 for the specified eps precision. The resulting code is equivalent to this more traditional style:

```
val eps = 1E-10 // "good enough", could be 10^-15
```

```
private fun findFixPoint(): Double {
    var x = 1.0
    while (true) {
        val y = Math.cos(x)
        if (Math.abs(x - y) < eps) return x
        x = Math.cos(x)
    }
}
```

To be eligible for the tailrec modifier, a function must call itself as the last operation it performs. You cannot use tail recursion when there is more code after the recursive call, within try/catch/finally blocks, or on open functions. Currently, tail recursion is supported by Kotlin for the JVM and Kotlin/Native.

See also:

- Inline functions
- Extension functions
- Higher-order functions and lambdas

Higher-order functions and lambdas

Kotlin functions are first-class, which means they can be stored in variables and data structures, and can be passed as arguments to and returned from other higher-order functions. You can perform any operations on functions that are possible for other non-function values.

To facilitate this, Kotlin, as a statically typed programming language, uses a family of function types to represent functions, and provides a set of specialized language constructs, such as lambda expressions.

Higher-order functions

A higher-order function is a function that takes functions as parameters, or returns a function.

A good example of a higher-order function is the functional programming idiom fold for collections. It takes an initial accumulator value and a combining function and builds its return value by consecutively combining the current accumulator value with each collection element, replacing the accumulator value each time:

```
fun <T, R> Collection<T>.fold(
    initial: R,
    combine: (acc: R, nextElement: T) -> R
): R {
    var accumulator: R = initial
    for (element: T in this) {
        accumulator = combine(accumulator, element)
    }
    return accumulator
}
```

In the code above, the combine parameter has the function type (R, T) -> R, so it accepts a function that takes two arguments of types R and T and returns a value of type R. It is invoked inside the for loop, and the return value is then assigned to accumulator.

To call fold, you need to pass an instance of the function type to it as an argument, and lambda expressions (described in more detail below) are widely used for this purpose at higher-order function call sites:

```
fun main() {
        val items = listOf(1, 2, 3, 4, 5)

    // Lambdas are code blocks enclosed in curly braces.
    items.fold(0, {
        // When a lambda has parameters, they go first, followed by '->'
        acc: Int, i: Int ->
        print("acc = $acc, i = $i, ")
        val result = acc + i
        println("result = $result")
        // The last expression in a lambda is considered the return value:
        result
    })

    // Parameter types in a lambda are optional if they can be inferred:
    val joinedToString = items.fold("Elements:", { acc, i -> acc + " " + i })
    // Function references can also be used for higher-order function calls:
    val product = items.fold(1, Int::times)
    //sampleEnd
    println("joinedToString = $joinedToString")
    println("product = $product")
}
```

Function types

Kotlin uses function types, such as (Int) -> String, for declarations that deal with functions: val onClick: () -> Unit = ...

These types have a special notation that corresponds to the signatures of the functions - their parameters and return values:

- All function types have a parenthesized list of parameter types and a return type: (A, B) -> C denotes a type that represents functions that take two arguments of types A and B and return a value of type C. The list of parameter types may be empty, as in () -> A. The Unit return type cannot be omitted.
- Function types can optionally have an additional receiver type, which is specified before the dot in the notation: the type A.(B) -> C represents functions that can be called on a receiver object A with a parameter B and return a value C. Function literals with receiver are often used along with these types.
- Suspending functions belong to a special kind of function type that have a suspend modifier in their notation, such as suspend () -> Unit or suspend A.(B) -> C.

The function type notation can optionally include names for the function parameters: (x: Int, y: Int) -> Point. These names can be used for documenting the meaning of the parameters.

To specify that a function type is nullable, use parentheses as follows: ((Int, Int) -> Int)?.

Function types can also be combined using parentheses: (Int) -> ((Int) -> Unit).

The arrow notation is right-associative, (Int) -> (Int) -> Unit is equivalent to the previous example, but not to ((Int) -> (Int)) -> Unit.

You can also give a function type an alternative name by using a type alias:

```
typealias ClickHandler = (Button, ClickEvent) -> Unit
```

Instantiating a function type

There are several ways to obtain an instance of a function type:

- Use a code block within a function literal, in one of the following forms:
  - a lambda expression: { a, b -> a + b },
  - an anonymous function: fun(s: String): Int { return s.toIntOrNull() ?: 0 }

  Function literals with receiver can be used as values of function types with receiver.
- Use a callable reference to an existing declaration:
  - a top-level, local, member, or extension function: ::isOdd, String::toInt,
  - a top-level, member, or extension property: List<Int>::size,
  - a constructor: ::Regex

  These include bound callable references that point to a member of a particular instance: foo::toString.
- Use instances of a custom class that implements a function type as an interface:

```
class IntTransformer: (Int) -> Int {
    override operator fun invoke(x: Int): Int = TODO()
}

val intFunction: (Int) -> Int = IntTransformer()
```

The compiler can infer the function types for variables if there is enough information:

```
val a = { i: Int -> i + 1 } // The inferred type is (Int) -> Int
```

Non-literal values of function types with and without a receiver are interchangeable, so the receiver can stand in for the first parameter, and vice versa. For instance, a value of type (A, B) -> C can be passed or assigned where a value of type A.(B) -> C is expected, and the other way around:

```
fun main() {
        val repeatFun: String.(Int) -> String = { times -> this.repeat(times) }
    val twoParameters: (String, Int) -> String = repeatFun // OK

    fun runTransformation(f: (String, Int) -> String): String {
        return f("hello", 3)
    }
    val result = runTransformation(repeatFun) // OK
    //sampleEnd
    println("result = $result")
}
```

A function type with no receiver is inferred by default, even if a variable is initialized with a reference to an extension function. To alter that, specify the variable type explicitly.

Invoking a function type instance

A value of a function type can be invoked by using its invoke(...) operator: f.invoke(x) or just f(x).

If the value has a receiver type, the receiver object should be passed as the first argument. Another way to invoke a value of a function type with receiver is to prepend it with the receiver object, as if the value were an extension function: 1.foo(2).

Example:

```
fun main() {
        val stringPlus: (String, String) -> String = String::plus
    val intPlus: Int.(Int) -> Int = Int::plus

    println(stringPlus.invoke("<-", "->"))
    println(stringPlus("Hello, ", "world!"))

    println(intPlus.invoke(1, 1))
    println(intPlus(1, 2))
    println(2.intPlus(3)) // extension-like call
    //sampleEnd
}
```

Inline functions

Sometimes it is beneficial to use inline functions, which provide flexible control flow, for higher-order functions.

Lambda expressions and anonymous functions

Lambda expressions and anonymous functions are function literals. Function literals are functions that are not declared but are passed immediately as an expression. Consider the following example:

```
max(strings, { a, b -> a.length < b.length })
```

The function max is a higher-order function, as it takes a function value as its second argument. This second argument is an expression that is itself a function, called a function literal, which is equivalent to the following named function:

```
fun compare(a: String, b: String): Boolean = a.length < b.length
```

Lambda expression syntax

The full syntactic form of lambda expressions is as follows:

```
val sum: (Int, Int) -> Int = { x: Int, y: Int -> x + y }
```

- A lambda expression is always surrounded by curly braces.
- Parameter declarations in the full syntactic form go inside curly braces and have optional type annotations.
- The body goes after the ->.
- If the inferred return type of the lambda is not Unit, the last (or possibly single) expression inside the lambda body is treated as the return value.

If you leave all the optional annotations out, what's left looks like this:

```
val sum = { x: Int, y: Int -> x + y }
```

Passing trailing lambdas

According to Kotlin convention, if the last parameter of a function is a function, then a lambda expression passed as the corresponding argument can be placed outside the parentheses:

```
val product = items.fold(1) { acc, e -> acc * e }
```

Such syntax is also known as trailing lambda.

If the lambda is the only argument in that call, the parentheses can be omitted entirely:

```
run { println("...") }
```

it: implicit name of a single parameter

It's very common for a lambda expression to have only one parameter.

If the compiler can parse the signature without any parameters, the parameter does not need to be declared and -> can be omitted. The parameter will be implicitly declared under the name it:

```
ints.filter { it > 0 } // this literal is of type '(it: Int) -> Boolean'
```

Returning a value from a lambda expression

You can explicitly return a value from the lambda using the qualified return syntax. Otherwise, the value of the last expression is implicitly returned.

Therefore, the two following snippets are equivalent:

```
ints.filter {
    val shouldFilter = it > 0
    shouldFilter
}

ints.filter {
    val shouldFilter = it > 0
    return@filter shouldFilter
}
```

This convention, along with passing a lambda expression outside of parentheses, allows for LINQ-style code:

```
strings.filter { it.length == 5 }.sortedBy { it }.map { it.uppercase() }
```

Underscore for unused variables

If the lambda parameter is unused, you can place an underscore instead of its name:

```
map.forEach { (_, value) -> println("$value!") }
```

Destructuring in lambdas

Destructuring in lambdas is described as a part of destructuring declarations.

Anonymous functions

The lambda expression syntax above is missing one thing – the ability to specify the function's return type. In most cases, this is unnecessary because the return type can be inferred automatically. However, if you do need to specify it explicitly, you can use an alternative syntax: an anonymous function.

```
fun(x: Int, y: Int): Int = x + y
```

An anonymous function looks very much like a regular function declaration, except its name is omitted. Its body can be either an expression (as shown above) or a block:

```
fun(x: Int, y: Int): Int {
    return x + y
}
```

The parameters and the return type are specified in the same way as for regular functions, except the parameter types can be omitted if they can be inferred from the context:

```
ints.filter(fun(item) = item > 0)
```

The return type inference for anonymous functions works just like for normal functions: the return type is inferred automatically for anonymous functions with an expression body, but it has to be specified explicitly (or is assumed to be Unit) for anonymous functions with a block body.

When passing anonymous functions as parameters, place them inside the parentheses. The shorthand syntax that allows you to leave the function outside the parentheses works only for lambda expressions.

Another difference between lambda expressions and anonymous functions is the behavior of non-local returns. A return statement without a label always returns from the function declared with the fun keyword. This means that a return inside a lambda expression will return from the enclosing function, whereas a return inside an anonymous function will return from the anonymous function itself.

Closures

A lambda expression or anonymous function (as well as a local function and an object expression) can access its closure, which includes the variables declared in the outer scope. The variables captured in the closure can be modified in the lambda:

```
var sum = 0
ints.filter { it > 0 }.forEach {
    sum += it
}
print(sum)
```

Function literals with receiver

Function types with receiver, such as A.(B) -> C, can be instantiated with a special form of function literals – function literals with receiver.

As mentioned above, Kotlin provides the ability to call an instance of a function type with receiver while providing the receiver object.

Inside the body of the function literal, the receiver object passed to a call becomes an implicit this, so that you can access the members of that receiver object without any additional qualifiers, or access the receiver object using a this expression.

This behavior is similar to that of extension functions, which also allow you to access the members of the receiver object inside the function body.

Here is an example of a function literal with receiver along with its type, where plus is called on the receiver object:

```
val sum: Int.(Int) -> Int = { other -> plus(other) }
```

The anonymous function syntax allows you to specify the receiver type of a function literal directly. This can be useful if you need to declare a variable of a function type with receiver, and then to use it later.

```
val sum = fun Int.(other: Int): Int = this + other
```

Lambda expressions can be used as function literals with receiver when the receiver type can be inferred from the context. One of the most important examples of their usage is type-safe builders:

```
class HTML {
    fun body() { ... }
}

fun html(init: HTML.() -> Unit): HTML {
    val html = HTML()  // create the receiver object
    html.init()        // pass the receiver object to the lambda
    return html
}

html {       // lambda with receiver begins here
    body()   // calling a method on the receiver object
}
```

Inline functions

Using higher-order functions imposes certain runtime penalties: each function is an object, and it captures a closure. A closure is a scope of variables that can be accessed in the body of the function. Memory allocations (both for function objects and classes) and virtual calls introduce runtime overhead.

But it appears that in many cases this kind of overhead can be eliminated by inlining the lambda expressions. The functions shown below are good examples of this situation. The lock() function could be easily inlined at call-sites. Consider the following case:

```
lock(l) { foo() }
```

Instead of creating a function object for the parameter and generating a call, the compiler could emit the following code:

```
l.lock()
try {
    foo()
} finally {
    l.unlock()
}
```

To make the compiler do this, mark the lock() function with the inline modifier:

```
inline fun <T> lock(lock: Lock, body: () -> T): T { ... }
```

The inline modifier affects both the function itself and the lambdas passed to it: all of those will be inlined into the call site.

Inlining may cause the generated code to grow. However, if you do it in a reasonable way (avoiding inlining large functions), it will pay off in performance, especially at "megamorphic" call-sites inside loops.

noinline

If you don't want all of the lambdas passed to an inline function to be inlined, mark some of your function parameters with the noinline modifier:

```
inline fun foo(inlined: () -> Unit, noinline notInlined: () -> Unit) { ... }
```

Inlinable lambdas can only be called inside inline functions or passed as inlinable arguments. noinline lambdas, however, can be manipulated in any way you like, including being stored in fields or passed around.

> If an inline function has no inlinable function parameters and no reified type parameters, the compiler will issue a warning, since inlining such functions is very unlikely to be beneficial (you can use the @Suppress("NOTHING_TO_INLINE") annotation to suppress the warning if you are sure the inlining is needed).

Non-local jump expressions

Returns

In Kotlin, you can only use a normal, unqualified return to exit a named function or an anonymous function. To exit a lambda, use a label. A bare return is forbidden inside a lambda because a lambda cannot make the enclosing function return:

```kotlin
fun ordinaryFunction(block: () -> Unit) {
    println("hi!")
}
fun foo() {
    ordinaryFunction {
        return // ERROR: cannot make `foo` return here
    }
}
fun main() {
    foo()
}
```

But if the function the lambda is passed to is inlined, the return can be inlined, as well. So it is allowed:

```kotlin
inline fun inlined(block: () -> Unit) {
    println("hi!")
}
fun foo() {
    inlined {
        return // OK: the lambda is inlined
    }
}
fun main() {
    foo()
}
```

Such returns (located in a lambda, but exiting the enclosing function) are called non-local returns. This sort of construct usually occurs in loops, which inline functions often enclose:

```kotlin
fun hasZeros(ints: List<Int>): Boolean {
    ints.forEach {
        if (it == 0) return true // returns from hasZeros
    }
    return false
}
```

Note that some inline functions may call the lambdas passed to them as parameters not directly from the function body, but from another execution context, such as a local object or a nested function. In such cases, non-local control flow is also not allowed in the lambdas. To indicate that the lambda parameter of the inline function cannot use non-local returns, mark the lambda parameter with the crossinline modifier:

```kotlin
inline fun f(crossinline body: () -> Unit) {
    val f = object: Runnable {
        override fun run() = body()
    }
    // ...
}
```

Break and continue

Similar to non-local return, you can apply break and continue jump expressions in lambdas passed as arguments to an inline function that encloses a loop:

```
fun processList(elements: List<Int>): Boolean {
    for (element in elements) {
        val variable = element.nullableMethod() ?: run {
            log.warning("Element is null or invalid, continuing...")
            continue
        }
        if (variable == 0) return true
    }
    return false
}
```

Reified type parameters

Sometimes you need to access a type passed as a parameter:

```
fun <T> TreeNode.findParentOfType(clazz: Class<T>): T? {
    var p = parent
    while (p != null && !clazz.isInstance(p)) {
        p = p.parent
    }
    @Suppress("UNCHECKED_CAST")
    return p as T?
}
```

Here, you walk up a tree and use reflection to check whether a node has a certain type. It's all fine, but the call site is not very pretty:

```
treeNode.findParentOfType(MyTreeNode::class.java)
```

A better solution would be to simply pass a type to this function. You can call it as follows:

```
treeNode.findParentOfType<MyTreeNode>()
```

To enable this, inline functions support reified type parameters, so you can write something like this:

```
inline fun <reified T> TreeNode.findParentOfType(): T? {
    var p = parent
    while (p != null && p !is T) {
        p = p.parent
    }
    return p as T?
}
```

The code above qualifies the type parameter with the reified modifier to make it accessible inside the function, almost as if it were a normal class. Since the function is inlined, no reflection is needed and normal operators like !is and as are now available for you to use. Also, you can call the function as shown above: myTree.findParentOfType<MyTreeNodeType>().

Though reflection may not be needed in many cases, you can still use it with a reified type parameter:

```
inline fun <reified T> membersOf() = T::class.members

fun main(s: Array<String>) {
    println(membersOf<StringBuilder>().joinToString("\n"))
}
```

Normal functions (not marked as inline) cannot have reified parameters. A type that does not have a run-time representation (for example, a non-reified type parameter or a fictitious type like Nothing) cannot be used as an argument for a reified type parameter.

Inline properties

The inline modifier can be used on accessors of properties that don't have backing fields. You can annotate individual property accessors:

```
val foo: Foo
    inline get() = Foo()
```

```
var bar: Bar
    get() = ...
    inline set(v) { ... }
```

You can also annotate an entire property, which marks both of its accessors as inline:

```
inline var bar: Bar
    get() = ...
    set(v) { ... }
```

At the call site, inline accessors are inlined as regular inline functions.

Restrictions for public API inline functions

When an inline function is public or protected but is not a part of a private or internal declaration, it is considered a module's public API. It can be called in other modules and is inlined at such call sites as well.

This imposes certain risks of binary incompatibility caused by changes in the module that declares an inline function in case the calling module is not re-compiled after the change.

To eliminate the risk of such incompatibility being introduced by a change in a non-public API of a module, public API inline functions are not allowed to use non-public-API declarations, i.e. private and internal declarations and their parts, in their bodies.

An internal declaration can be annotated with @PublishedApi, which allows its use in public API inline functions. When an internal inline function is marked as @PublishedApi, its body is checked too, as if it were public.

Operator overloading

Kotlin allows you to provide custom implementations for the predefined set of operators on types. These operators have predefined symbolic representation (like + or *) and precedence. To implement an operator, provide a member function or an extension function with a specific name for the corresponding type. This type becomes the left-hand side type for binary operations and the argument type for the unary ones.

To overload an operator, mark the corresponding function with the operator modifier:

```
interface IndexedContainer {
    operator fun get(index: Int)
}
```

When overriding your operator overloads, you can omit operator:

```
class OrdersList: IndexedContainer {
    override fun get(index: Int) { /*...*/ }
}
```

Unary operations

Unary prefix operators

Expression	Translated to
+a	a.unaryPlus()
-a	a.unaryMinus()

Expression	Translated to
!a	a.not()

This table says that when the compiler processes, for example, an expression +a, it performs the following steps:

- Determines the type of a, let it be T.
- Looks up a function unaryPlus() with the operator modifier and no parameters for the receiver T, that means a member function or an extension function.
- If the function is absent or ambiguous, it is a compilation error.
- If the function is present and its return type is R, the expression +a has type R.

> These operations, as well as all the others, are optimized for basic types and do not introduce overhead of function calls for them.

As an example, here's how you can overload the unary minus operator:

```
data class Point(val x: Int, val y: Int)

operator fun Point.unaryMinus() = Point(-x, -y)

val point = Point(10, 20)

fun main() {
   println(-point)  // prints "Point(x=-10, y=-20)"
}
```

Increments and decrements

Expression	Translated to
a++	a.inc() + see below
a--	a.dec() + see below

The inc() and dec() functions must return a value, which will be assigned to the variable on which the ++ or -- operation was used. They shouldn't mutate the object on which the inc or dec was invoked.

The compiler performs the following steps for resolution of an operator in the postfix form, for example a++:

- Determines the type of a, let it be T.
- Looks up a function inc() with the operator modifier and no parameters, applicable to the receiver of type T.
- Checks that the return type of the function is a subtype of T.

The effect of computing the expression is:

- Store the initial value of a to a temporary storage a0.
- Assign the result of a0.inc() to a.
- Return a0 as the result of the expression.

For a-- the steps are completely analogous.

For the prefix forms ++a and --a resolution works the same way, and the effect is:

- Assign the result of a.inc() to a.
- Return the new value of a as a result of the expression.

Binary operations

Arithmetic operators

Expression	Translated to
a + b	a.plus(b)
a - b	a.minus(b)
a * b	a.times(b)
a / b	a.div(b)
a % b	a.rem(b)
a..b	a.rangeTo(b)
a..<b	a.rangeUntil(b)

For the operations in this table, the compiler just resolves the expression in the Translated to column.

Below is an example Counter class that starts at a given value and can be incremented using the overloaded + operator:

```
data class Counter(val dayIndex: Int) {
    operator fun plus(increment: Int): Counter {
        return Counter(dayIndex + increment)
    }
}
```

in operator

Expression	Translated to
a in b	b.contains(a)
a !in b	!b.contains(a)

For in and !in the procedure is the same, but the order of arguments is reversed.

Indexed access operator

Expression	Translated to
a[i]	a.get(i)
a[i, j]	a.get(i, j)
a[i_1, ..., i_n]	a.get(i_1, ..., i_n)
a[i] = b	a.set(i, b)
a[i, j] = b	a.set(i, j, b)
a[i_1, ..., i_n] = b	a.set(i_1, ..., i_n, b)

Square brackets are translated to calls to get and set with appropriate numbers of arguments.

invoke operator

Expression	Translated to
a()	a.invoke()
a(i)	a.invoke(i)
a(i, j)	a.invoke(i, j)
a(i_1, ..., i_n)	a.invoke(i_1, ..., i_n)

Parentheses are translated to calls to invoke with appropriate number of arguments.

Augmented assignments

Expression	Translated to
a += b	a.plusAssign(b)
a -= b	a.minusAssign(b)
a *= b	a.timesAssign(b)
a /= b	a.divAssign(b)

Expression	Translated to
a %= b	a.remAssign(b)

For the assignment operations, for example a += b, the compiler performs the following steps:

- If the function from the right column is available:
  - If the corresponding binary function (that means plus() for plusAssign()) is available too, a is a mutable variable, and the return type of plus is a subtype of the type of a, report an error (ambiguity).
  - Make sure its return type is Unit, and report an error otherwise.
  - Generate code for a.plusAssign(b).
- Otherwise, try to generate code for a = a + b (this includes a type check: the type of a + b must be a subtype of a).

> Assignments are NOT expressions in Kotlin.

Equality and inequality operators

Expression	Translated to
a == b	a?.equals(b) ?: (b === null)
a != b	!(a?.equals(b) ?: (b === null))

These operators only work with the function equals(other: Any?): Boolean, which can be overridden to provide custom equality check implementation. Any other function with the same name (like equals(other: Foo)) will not be called.

> === and !== (identity checks) are not overloadable, so no conventions exist for them.

The == operation is special: it is translated to a complex expression that screens for null's. null == null is always true, and x == null for a non-null x is always false and won't invoke x.equals().

Comparison operators

Expression	Translated to
a > b	a.compareTo(b) > 0
a < b	a.compareTo(b) < 0
a >= b	a.compareTo(b) >= 0
a <= b	a.compareTo(b) <= 0

All comparisons are translated into calls to compareTo, that is required to return Int.

)

Property delegation operators

provideDelegate, getValue and setValue operator functions are described in Delegated properties.

Infix calls for named functions

You can simulate custom infix operations by using infix function calls.

Type-safe builders

By using well-named functions as builders in combination with function literals with receiver it is possible to create type-safe, statically-typed builders in Kotlin.

Type-safe builders allow creating Kotlin-based domain-specific languages (DSLs) suitable for building complex hierarchical data structures in a semi-declarative way. Sample use cases for the builders are:

- Generating markup with Kotlin code, such as HTML or XML
- Configuring routes for a web server: Ktor

Consider the following code:

```
import com.example.html.* // see declarations below

fun result() =
    html {
        head {
            title {+"XML encoding with Kotlin"}
        }
        body {
            h1 {+"XML encoding with Kotlin"}
            p  {+"this format can be used as an alternative markup to XML"}

            // an element with attributes and text content
            a(href = "https://kotlinlang.org") {+"Kotlin"}

            // mixed content
            p {
                +"This is some"
                b {+"mixed"}
                +"text. For more see the"
                a(href = "https://kotlinlang.org") {+"Kotlin"}
                +"project"
            }
            p {+"some text"}

            // content generated by
            p {
                for (arg in args)
                    +arg
            }
        }
    }
```

This is completely legitimate Kotlin code. You can play with this code online (modify it and run in the browser) here.

How it works

Assume that you need to implement a type-safe builder in Kotlin. First of all, define the model you want to build. In this case you need to model HTML tags. It is easily done with a bunch of classes. For example, HTML is a class that describes the <html> tag defining children like <head> and <body>. (See its declaration below.)

Now, let's recall why you can say something like this in the code:

```
html {
 // ...
}
```

html is actually a function call that takes a lambda expression as an argument. This function is defined as follows:

```
fun html(init: HTML.() -> Unit): HTML {
    val html = HTML()
    html.init()
    return html
}
```

This function takes one parameter named init, which is itself a function. The type of the function is HTML.() -> Unit, which is a function type with receiver. This means that you need to pass an instance of type HTML (a receiver) to the function, and you can call members of that instance inside the function.

The receiver can be accessed through the this keyword:

```
html {
    this.head { ... }
    this.body { ... }
}
```

(head and body are member functions of HTML.)

Now, this can be omitted, as usual, and you get something that looks very much like a builder already:

```
html {
    head { ... }
    body { ... }
}
```

So, what does this call do? Let's look at the body of html function as defined above. It creates a new instance of HTML, then it initializes it by calling the function that is passed as an argument (in this example this boils down to calling head and body on the HTML instance), and then it returns this instance. This is exactly what a builder should do.

The head and body functions in the HTML class are defined similarly to html. The only difference is that they add the built instances to the children collection of the enclosing HTML instance:

```
fun head(init: Head.() -> Unit): Head {
    val head = Head()
    head.init()
    children.add(head)
    return head
}

fun body(init: Body.() -> Unit): Body {
    val body = Body()
    body.init()
    children.add(body)
    return body
}
```

Actually these two functions do just the same thing, so you can have a generic version, initTag:

```
protected fun <T : Element> initTag(tag: T, init: T.() -> Unit): T {
    tag.init()
    children.add(tag)
    return tag
}
```

So, now your functions are very simple:

```
fun head(init: Head.() -> Unit) = initTag(Head(), init)

fun body(init: Body.() -> Unit) = initTag(Body(), init)
```

And you can use them to build <head> and <body> tags.

One other thing to be discussed here is how you add text to tag bodies. In the example above you say something like:

```
html {
    head {
        title {+"XML encoding with Kotlin"}
    }
    // ...
}
```

So basically, you just put a string inside a tag body, but there is this little + in front of it, so it is a function call that invokes a prefix unaryPlus() operation. That operation is actually defined by an extension function unaryPlus() that is a member of the TagWithText abstract class (a parent of Title):

```
operator fun String.unaryPlus() {
    children.add(TextElement(this))
}
```

So, what the prefix + does here is wrapping a string into an instance of TextElement and adding it to the children collection, so that it becomes a proper part of the tag tree.

All this is defined in a package com.example.html that is imported at the top of the builder example above. In the last section you can read through the full definition of this package.

Scope control: @DslMarker

When using DSLs, one might have come across the problem that too many functions can be called in the context. You can call methods of every available implicit receiver inside a lambda and therefore get an inconsistent result, like the tag head inside another head:

```
html {
    head {
        head {} // should be forbidden
    }
    // ...
}
```

In this example only members of the nearest implicit receiver this@head must be available; head() is a member of the outer receiver this@html, so it must be illegal to call it.

To address this problem, there is a special mechanism to control receiver scope.

To make the compiler start controlling scopes you only have to annotate the types of all receivers used in the DSL with the same marker annotation. For instance, for HTML Builders you declare an annotation @HTMLTagMarker:

```
@DslMarker
annotation class HtmlTagMarker
```

An annotation class is called a DSL marker if it is annotated with the @DslMarker annotation.

In our DSL all the tag classes extend the same superclass Tag. It's enough to annotate only the superclass with @HtmlTagMarker and after that the Kotlin compiler will treat all the inherited classes as annotated:

```
@HtmlTagMarker
abstract class Tag(val name: String) { ... }
```

You don't have to annotate the HTML or Head classes with @HtmlTagMarker because their superclass is already annotated:

```
class HTML() : Tag("html") { ... }

class Head() : Tag("head") { ... }
```

After you've added this annotation, the Kotlin compiler knows which implicit receivers are part of the same DSL and allows to call members of the nearest receivers only:

```
html {
    head {
        head { } // error: a member of outer receiver
    }
    // ...
}
```

Note that it's still possible to call the members of the outer receiver, but to do that you have to specify this receiver explicitly:

```
html {
    head {
        this@html.head { } // possible
    }
    // ...
}
```

You can also apply the @DslMarker annotation directly to function types. Simply annotate the @DslMarker annotation with @Target(AnnotationTarget.TYPE):

```
@Target(AnnotationTarget.TYPE)
@DslMarker
annotation class HtmlTagMarker
```

As a result, the @DslMarker annotation can be applied to function types, most commonly to lambdas with receivers. For example:

```
fun html(init: @HtmlTagMarker HTML.() -> Unit): HTML { ... }

fun HTML.head(init: @HtmlTagMarker Head.() -> Unit): Head { ... }

fun Head.title(init: @HtmlTagMarker Title.() -> Unit): Title { ... }
```

When you call these functions, the @DslMarker annotation restricts access to outer receivers in the body of a lambda marked with it unless you specify them explicitly:

```
html {
    head {
        title {
            // Access to title, head or other functions of outer receivers is restricted here.
        }
    }
}
```

Only the nearest receiver's members and extensions are accessible within a lambda, preventing unintended interactions between nested scopes.

Full definition of the com.example.html package

This is how the package com.example.html is defined (only the elements used in the example above). It builds an HTML tree. It makes heavy use of extension functions and lambdas with receiver.

```
package com.example.html

interface Element {
    fun render(builder: StringBuilder, indent: String)
}

class TextElement(val text: String) : Element {
    override fun render(builder: StringBuilder, indent: String) {
        builder.append("$indent$text\n")
    }
}

@DslMarker
annotation class HtmlTagMarker

@HtmlTagMarker
abstract class Tag(val name: String) : Element {
    val children = arrayListOf<Element>()
    val attributes = hashMapOf<String, String>()

    protected fun <T : Element> initTag(tag: T, init: T.() -> Unit): T {
        tag.init()
        children.add(tag)
        return tag
    }

    override fun render(builder: StringBuilder, indent: String) {
        builder.append("$indent<$name${renderAttributes()}>\n")
        for (c in children) {
            c.render(builder, indent + "  ")
        }
        builder.append("$indent</$name>\n")
    }

    private fun renderAttributes(): String {
        val builder = StringBuilder()
        for ((attr, value) in attributes) {
            builder.append(" $attr=\"$value\"")
        }
        return builder.toString()
    }

    override fun toString(): String {
        val builder = StringBuilder()
        render(builder, "")
        return builder.toString()
    }
}

abstract class TagWithText(name: String) : Tag(name) {
    operator fun String.unaryPlus() {
        children.add(TextElement(this))
    }
}

class HTML : TagWithText("html") {
    fun head(init: Head.() -> Unit) = initTag(Head(), init)

    fun body(init: Body.() -> Unit) = initTag(Body(), init)
}

class Head : TagWithText("head") {
    fun title(init: Title.() -> Unit) = initTag(Title(), init)
}

class Title : TagWithText("title")

abstract class BodyTag(name: String) : TagWithText(name) {
    fun b(init: B.() -> Unit) = initTag(B(), init)
    fun p(init: P.() -> Unit) = initTag(P(), init)
    fun h1(init: H1.() -> Unit) = initTag(H1(), init)
    fun a(href: String, init: A.() -> Unit) {
        val a = initTag(A(), init)
        a.href = href
    }
}

class Body : BodyTag("body")
class B : BodyTag("b")
class P : BodyTag("p")
class H1 : BodyTag("h1")

class A : BodyTag("a") {
    var href: String
        get() = attributes["href"]!!
        set(value) {
            attributes["href"] = value
        }
}

fun html(init: HTML.() -> Unit): HTML {
    val html = HTML()
    html.init()
    return html
}
```

Using builders with builder type inference

Kotlin supports builder type inference (or builder inference), which can come in useful when you are working with generic builders. It helps the compiler infer the type arguments of a builder call based on the type information about other calls inside its lambda argument.

Consider this example of buildMap() usage:

```
fun addEntryToMap(baseMap: Map<String, Number>, additionalEntry: Pair<String, Int>?) {
   val myMap = buildMap {
       putAll(baseMap)
```

```
        if (additionalEntry != null) {
            put(additionalEntry.first, additionalEntry.second)
        }
    }
}
```

There is not enough type information here to infer type arguments in a regular way, but builder inference can analyze the calls inside the lambda argument. Based on the type information about putAll() and put() calls, the compiler can automatically infer type arguments of the buildMap() call into String and Number. Builder inference allows to omit type arguments while using generic builders.

Writing your own builders

Requirements for enabling builder inference

Before Kotlin 1.7.0, enabling builder inference for a builder function required -Xenable-builder-inference compiler option. In 1.7.0 the option is enabled by default.

To let builder inference work for your own builder, make sure its declaration has a builder lambda parameter of a function type with a receiver. There are also two requirements for the receiver type:

1. It should use the type arguments that builder inference is supposed to infer. For example:

   ```
   fun <V> buildList(builder: MutableList<V>.() -> Unit) { ... }
   ```

   Note that passing the type parameter's type directly like fun <T> myBuilder(builder: T.() -> Unit) is not yet supported.

2. It should provide public members or extensions that contain the corresponding type parameters in their signature. For example:

   ```
   class ItemHolder<T> {
       private val items = mutableListOf<T>()

       fun addItem(x: T) {
           items.add(x)
       }

       fun getLastItem(): T? = items.lastOrNull()
   }

   fun <T> ItemHolder<T>.addAllItems(xs: List<T>) {
       xs.forEach { addItem(it) }
   }

   fun <T> itemHolderBuilder(builder: ItemHolder<T>.() -> Unit): ItemHolder<T> =
       ItemHolder<T>().apply(builder)

   fun test(s: String) {
       val itemHolder1 = itemHolderBuilder { // Type of itemHolder1 is ItemHolder<String>
           addItem(s)
       }
       val itemHolder2 = itemHolderBuilder { // Type of itemHolder2 is ItemHolder<String>
           addAllItems(listOf(s))
       }
       val itemHolder3 = itemHolderBuilder { // Type of itemHolder3 is ItemHolder<String?>
           val lastItem: String? = getLastItem()
           // ...
       }
   }
   ```

Supported features

Builder inference supports:

- Inferring several type arguments

```
fun <K, V> myBuilder(builder: MutableMap<K, V>.() -> Unit): Map<K, V> { ... }
```

- Inferring type arguments of several builder lambdas within one call including interdependent ones

```
fun <K, V> myBuilder(
    listBuilder: MutableList<V>.() -> Unit,
    mapBuilder: MutableMap<K, V>.() -> Unit
): Pair<List<V>, Map<K, V>> =
    mutableListOf<V>().apply(listBuilder) to mutableMapOf<K, V>().apply(mapBuilder)

fun main() {
    val result = myBuilder(
        { add(1) },
        { put("key", 2) }
    )
    // result has Pair<List<Int>, Map<String, Int>> type
}
```

- Inferring type arguments whose type parameters are lambda's parameter or return types

```
fun <K, V> myBuilder1(
    mapBuilder: MutableMap<K, V>.() -> K
): Map<K, V> = mutableMapOf<K, V>().apply { mapBuilder() }

fun <K, V> myBuilder2(
    mapBuilder: MutableMap<K, V>.(K) -> Unit
): Map<K, V> = mutableMapOf<K, V>().apply { mapBuilder(2 as K) }

fun main() {
    // result1 has the Map<Long, String> type inferred
    val result1 = myBuilder1 {
        put(1L, "value")
        2
    }
    val result2 = myBuilder2 {
        put(1, "value 1")
        // You can use `it` as "postponed type variable" type
        // See the details in the section below
        put(it, "value 2")
    }
}
```

How builder inference works

Postponed type variables

Builder inference works in terms of postponed type variables, which appear inside the builder lambda during builder inference analysis. A postponed type variable is a type argument's type, which is in the process of inferring. The compiler uses it to collect type information about the type argument.

Consider the example with buildList():

```
val result = buildList {
    val x = get(0)
}
```

Here x has a type of postponed type variable: the get() call returns a value of type E, but E itself is not yet fixed. At this moment, a concrete type for E is unknown.

When a value of a postponed type variable gets associated with a concrete type, builder inference collects this information to infer the resulting type of the corresponding type argument at the end of the builder inference analysis. For example:

```
val result = buildList {
    val x = get(0)
    val y: String = x
} // result has the List<String> type inferred
```

After the postponed type variable gets assigned to a variable of the String type, builder inference gets the information that x is a subtype of String. This assignment is the last statement in the builder lambda, so the builder inference analysis ends with the result of inferring the type argument E into String.

Note that you can always call equals(), hashCode(), and toString() functions with a postponed type variable as a receiver.

Contributing to builder inference results

Builder inference can collect different varieties of type information that contribute to the analysis result. It considers:

- Calling methods on a lambda's receiver that use the type parameter's type

```
val result = buildList {
    // Type argument is inferred into String based on the passed "value" argument
    add("value")
} // result has the List<String> type inferred
```

- Specifying the expected type for calls that return the type parameter's type

```
val result = buildList {
    // Type argument is inferred into Float based on the expected type
    val x: Float = get(0)
} // result has the List<Float> type
```

```
class Foo<T> {
    val items = mutableListOf<T>()
}

fun <K> myBuilder(builder: Foo<K>.() -> Unit): Foo<K> = Foo<K>().apply(builder)

fun main() {
    val result = myBuilder {
        val x: List<CharSequence> = items
        // ...
    } // result has the Foo<CharSequence> type
}
```

- Passing postponed type variables' types into methods that expect concrete types

```
fun takeMyLong(x: Long) { ... }

fun String.isMoreThat3() = length > 3

fun takeListOfStrings(x: List<String>) { ... }

fun main() {
    val result1 = buildList {
        val x = get(0)
        takeMyLong(x)
    } // result1 has the List<Long> type

    val result2 = buildList {
        val x = get(0)
        val isLong = x.isMoreThat3()
    // ...
    } // result2 has the List<String> type

    val result3 = buildList {
        takeListOfStrings(this)
    } // result3 has the List<String> type
}
```

- Taking a callable reference to the lambda receiver's member

```
fun main() {
    val result = buildList {
        val x: KFunction1<Int, Float> = ::get
    } // result has the List<Float> type
}
```

```
fun takeFunction(x: KFunction1<Int, Float>) { ... }

fun main() {
    val result = buildList {
        takeFunction(::get)
    } // result has the List<Float> type
}
```

At the end of the analysis, builder inference considers all collected type information and tries to merge it into the resulting type. See the example.

```
val result = buildList { // Inferring postponed type variable E
    // Considering E is Number or a subtype of Number
    val n: Number? = getOrNull(0)
    // Considering E is Int or a supertype of Int
    add(1)
    // E gets inferred into Int
} // result has the List<Int> type
```

The resulting type is the most specific type that corresponds to the type information collected during the analysis. If the given type information is contradictory and cannot be merged, the compiler reports an error.

Note that the Kotlin compiler uses builder inference only if regular type inference cannot infer a type argument. This means you can contribute type information outside a builder lambda, and then builder inference analysis is not required. Consider the example:

```
fun someMap() = mutableMapOf<CharSequence, String>()

fun <E> MutableMap<E, String>.f(x: MutableMap<E, String>) { ... }

fun main() {
    val x: Map<in String, String> = buildMap {
        put("", "")
        f(someMap()) // Type mismatch (required String, found CharSequence)
    }
}
```

Here a type mismatch appears because the expected type of the map is specified outside the builder lambda. The compiler analyzes all the statements inside with the fixed receiver type Map<in String, String>.

Context parameters

Context parameters replace an older experimental feature called context receivers. You can find their main differences in the design document for context parameters. To migrate from context receivers to context parameters, you can use assisted support in IntelliJ IDEA, as described in the related blog post.

Context parameters allow functions and properties to declare dependencies that are implicitly available in the surrounding context.

With context parameters, you don't need to manually pass around values, such as services or dependencies, that are shared and rarely change across sets of function calls.

To declare context parameters for properties and functions, use the context keyword followed by a list of parameters, with each parameter declared as name: Type. Here is an example with a dependency on the UserService interface:

```
// UserService defines the dependency required in context
interface UserService {
    fun log(message: String)
    fun findUserById(id: Int): String
}

// Declares a function with a context parameter
context(users: UserService)
fun outputMessage(message: String) {
    // Uses log from the context
    users.log("Log: $message")
}

// Declares a property with a context parameter
context(users: UserService)
val firstUser: String
    // Uses findUserById from the context
    get() = users.findUserById(1)
```

You can use _ as a context parameter name. In this case, the parameter's value is available for resolution but is not accessible by name inside the block:

```
// Uses "_" as context parameter name
context(_: UserService)
fun logWelcome() {
    // Resolution still finds the appropriate log function from UserService
    outputMessage("Welcome!")
}
```

Context parameters resolution

Kotlin resolves context parameters at the call site by searching for matching context values in the current scope. Kotlin matches them by their type. If multiple compatible values exist at the same scope level, the compiler reports an ambiguity:

```
// UserService defines the dependency required in context
interface UserService {
    fun log(message: String)
}

// Declares a function with a context parameter
context(users: UserService)
fun outputMessage(message: String) {
    users.log("Log: $message")
}

fun main() {
    // Implements UserService
    val serviceA = object : UserService {
        override fun log(message: String) = println("A: $message")
    }

    // Implements UserService
    val serviceB = object : UserService {
        override fun log(message: String) = println("B: $message")
    }

    // Both serviceA and serviceB match the expected UserService type at the call site
    context(serviceA, serviceB) {
        // This results in an ambiguity error
        outputMessage("This will not compile")
    }
}
```

Restrictions

Context parameters are in continuous improvement, and some of the current restrictions include:

- Constructors can't declare context parameters.
- Properties with context parameters can't have backing fields or initializers.
- Properties with context parameters can't use delegation.

Despite these restrictions, context parameters simplify managing dependencies through simplified dependency injection, improved DSL design, and scoped operations.

How to enable context parameters

To enable context parameters in your project, use the following compiler option in the command line:

```
-Xcontext-parameters
```

Or add it to the compilerOptions {} block of your Gradle build file:

```
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xcontext-parameters")
    }
}
```

Specifying both -Xcontext-receivers and -Xcontext-parameters compiler options simultaneously leads to an error.

This feature is planned to be stabilized and improved in future Kotlin releases. We would appreciate your feedback in our issue tracker YouTrack.

Null safety

Null safety is a Kotlin feature designed to significantly reduce the risk of null references, also known as The Billion-Dollar Mistake.

One of the most common pitfalls in many programming languages, including Java, is that accessing a member of a null reference results in a null reference exception. In Java, this would be the equivalent of a NullPointerException, or an NPE for short.

Kotlin explicitly supports nullability as part of its type system, meaning you can explicitly declare which variables or properties are allowed to be null. Also, when you declare non-null variables, the compiler enforces that these variables cannot hold a null value, preventing an NPE.

Kotlin's null safety ensures safer code by catching potential null-related issues at compile time rather than runtime. This feature improves code robustness, readability, and maintainability by explicitly expressing null values, making the code easier to understand and manage.

The only possible causes of an NPE in Kotlin are:

- An explicit call to throw NullPointerException().
- Usage of the not-null assertion operator !!.
- Data inconsistency during initialization, such as when:
  - An uninitialized this available in a constructor is used somewhere else (a "leaking this ").
  - A superclass constructor calling an open member whose implementation in the derived class uses an uninitialized state.
- Java interoperation:
  - Attempts to access a member of a null reference of a platform type.
  - Nullability issues with generic types. For example, a piece of Java code adding null into a Kotlin MutableList<String>, which would require MutableList<String?> to handle it properly.
  - Other issues caused by external Java code.

Besides NPE, another exception related to null safety is UninitializedPropertyAccessException. Kotlin throws this exception when you try to access a property that has not been initialized, ensuring that non-nullable properties are not used until they are ready. This typically happens with lateinit properties.

Nullable types and non-nullable types

In Kotlin, the type system distinguishes between types that can hold null (nullable types) and those that cannot (non-nullable types). For example, a regular variable of type String cannot hold null:

```
fun main() {
    // Assigns a non-null string to a variable
    var a: String = "abc"
    // Attempts to re-assign null to the non-nullable variable
    a = null
    print(a)
    // Null can not be a value of a non-null type String
}
```

You can safely call a method or access a property on a. It's guaranteed not to cause an NPE because a is a non-nullable variable. The compiler ensures that a always holds a valid String value, so there's no risk of accessing its properties or methods when it's null:

```
fun main() {
    // Assigns a non-null string to a variable
    val a: String = "abc"
    // Returns the length of a non-nullable variable
    val l = a.length
    print(l)
    // 3
}
```

To allow null values, declare a variable with a ? sign right after the variable type. For example, you can declare a nullable string by writing String?. This expression makes String a type that can accept null:

```
fun main() {
    // Assigns a nullable string to a variable
    var b: String? = "abc"
    // Successfully re-assigns null to the nullable variable
    b = null
    print(b)
    // null
}
```

If you try accessing length directly on b, the compiler reports an error. This is because b is declared as a nullable variable and can hold null values. Attempting to access properties on nullables directly leads to an NPE:

```
fun main() {
    // Assigns a nullable string to a variable
    var b: String? = "abc"
    // Re-assigns null to the nullable variable
    b = null
    // Tries to directly return the length of a nullable variable
    val l = b.length
    print(l)
    // Only safe (?.) or non-null asserted (!!.) calls are allowed on a nullable receiver of type String?
}
```

In the example above, the compiler requires you to use safe calls to check for nullability before accessing properties or performing operations. There are several ways to handle nullables:

- Check for null with the if conditional
- Safe call operator ?.
- Elvis operator ?:
- Not-null assertion operator !!
- Nullable receiver
- let function
- Safe casts as?
- Collections of a nullable type

Read the next sections for details and examples of null handling tools and techniques.

Check for null with the if conditional

When working with nullable types, you need to handle nullability safely to avoid an NPE. One way to handle this is checking for nullability explicitly with the if conditional expression.

For example, check whether b is null and then access b.length:

```
fun main() {
    // Assigns null to a nullable variable
    val b: String? = null
    // Checks for nullability first and then accesses length
    val l = if (b != null) b.length else -1
    print(l)
    // -1
}
```

In the example above, the compiler performs a smart cast to change the type from nullable String? to non-nullable String. It also tracks the information about the check you performed and allows the call to length inside the if conditional.

More complex conditions are supported as well:

```kotlin
fun main() {
    // Assigns a nullable string to a variable
    val b: String? = "Kotlin"

    // Checks for nullability first and then accesses length
    if (b != null && b.length > 0) {
        print("String of length ${b.length}")
        // String of length 6
    } else {
        // Provides alternative if the condition is not met
        print("Empty string")
    }
}
```

Note that the example above only works when the compiler can guarantee that b doesn't change between the check and its usage, same as the smart cast prerequisites.

Safe call operator

The safe call operator ?. allows you to handle nullability safely in a shorter form. Instead of throwing an NPE, if the object is null, the ?. operator simply returns null:

```kotlin
fun main() {
    // Assigns a nullable string to a variable
    val a: String? = "Kotlin"
    // Assigns null to a nullable variable
    val b: String? = null

    // Checks for nullability and returns length or null
    println(a?.length)
    // 6
    println(b?.length)
    // null
}
```

The b?.length expression checks for nullability and returns b.length if b is non-null, or null otherwise. The type of this expression is Int?.

You can use the ?. operator with both var and val variables in Kotlin:

- A nullable var can hold a null (for example, var nullableValue: String? = null) or a non-null value (for example, var nullableValue: String? = "Kotlin"). If it's a non-null value, you can change it to null at any point.
- A nullable val can hold a null (for example, val nullableValue: String? = null) or a non-null value (for example, val nullableValue: String? = "Kotlin"). If it's a non-null value, you cannot change it to null subsequently.

Safe calls are useful in chains. For example, Bob is an employee who may be assigned to a department (or not). That department may, in turn, have another employee as a department head. To obtain the name of Bob's department head (if there is one), you write the following:

```kotlin
bob?.department?.head?.name
```

This chain returns null if any of its properties are null.

You can also place a safe call on the left side of an assignment:

```kotlin
person?.department?.head = managersPool.getManager()
```

In the example above, if one of the receivers in the safe call chain is null, the assignment is skipped, and the expression on the right is not evaluated at all. For example, if either person or person.department is null, the function is not called. Here's the equivalent of the same safe call but with the if conditional:

```kotlin
if (person != null && person.department != null) {
    person.department.head = managersPool.getManager()
}
```

Elvis operator

When working with nullable types, you can check for null and provide an alternative value. For example, if b is not null, access b.length. Otherwise, return an alternative value:

```
fun main() {
    // Assigns null to a nullable variable
    val b: String? = null
    // Checks for nullability. If not null, returns length. If null, returns 0
    val l: Int = if (b != null) b.length else 0
    println(l)
    // 0
}
```

Instead of writing the complete if expression, you can handle this in a more concise way with the Elvis operator ?::

```
fun main() {
    // Assigns null to a nullable variable
    val b: String? = null
    // Checks for nullability. If not null, returns length. If null, returns a non-null value
    val l = b?.length ?: 0
    println(l)
    // 0
}
```

If the expression to the left of ?: is not null, the Elvis operator returns it. Otherwise, the Elvis operator returns the expression to the right. The expression on the right-hand side is evaluated only if the left-hand side is null.

Since throw and return are expressions in Kotlin, you can also use them on the right-hand side of the Elvis operator. This can be handy, for example, when checking function arguments:

```
fun foo(node: Node): String? {
    // Checks for getParent(). If not null, it's assigned to parent. If null, returns null
    val parent = node.getParent() ?: return null
    // Checks for getName(). If not null, it's assigned to name. If null, throws exception
    val name = node.getName() ?: throw IllegalArgumentException("name expected")
    // ...
}
```

Not-null assertion operator

The not-null assertion operator !! converts any value to a non-nullable type.

When you apply the !! operator to a variable whose value is not null, it's safely handled as a non-nullable type, and the code executes normally. However, if the value is null, the !! operator forces it to be treated as non-nullable, which results in an NPE.

When b is not null and the !! operator makes it return its non-null value (which is a String in this example), it accesses length correctly:

```
fun main() {
    // Assigns a nullable string to a variable
    val b: String? = "Kotlin"
    // Treats b as non-null and accesses its length
    val l = b!!.length
    println(l)
    // 6
}
```

When b is null and the !! operator makes it return its non-null value, and an NPE occurs:

```
fun main() {
    // Assigns null to a nullable variable
    val b: String? = null
    // Treats b as non-null and tries to access its length
    val l = b!!.length
    println(l)
    // Exception in thread "main" java.lang.NullPointerException
}
```

The !! operator is particularly useful when you are confident that a value is not null and there's no chance of getting an NPE, but the compiler cannot guarantee this due to certain rules. In such cases, you can use the !! operator to explicitly tell the compiler that the value is not null.

Nullable receiver

You can use extension functions with a nullable receiver type, allowing these functions to be called on variables that might be null.

By defining an extension function on a nullable receiver type, you can handle null values within the function itself instead of checking for null at every place where you call the function.

For example, the .toString() extension function can be called on a nullable receiver. When invoked on a null value, it safely returns the string "null" without throwing an exception:

```kotlin
fun main() {
    // Assigns null to a nullable Person object stored in the person variable
    val person: Person? = null

    // Applies .toString to the nullable person variable and prints a string
    println(person.toString())
    // null
}

// Defines a simple Person class
data class Person(val name: String)
```

In the example above, even though person is null, the .toString() function safely returns the string "null". This can be helpful for debugging and logging.

If you expect the .toString() function to return a nullable string (either a string representation or null), use the safe-call operator ?.. The ?. operator calls .toString() only if the object is not null, otherwise it returns null:

```kotlin
fun main() {
    // Assigns a nullable Person object to a variable
    val person1: Person? = null
    val person2: Person? = Person("Alice")

    // Prints "null" if person is null; otherwise prints the result of person.toString()
    println(person1?.toString())
    // null
    println(person2?.toString())
    // Person(name=Alice)
}

// Defines a Person class
data class Person(val name: String)
```

The ?. operator allows you to safely handle potential null values while still accessing properties or functions of objects that might be null.

Let function

To handle null values and perform operations only on non-null types, you can use the safe call operator ?. together with the let function.

This combination is useful for evaluating an expression, check the result for null, and execute code only if it's not null, avoiding manual null checks:

```kotlin
fun main() {
    // Declares a list of nullable strings
    val listWithNulls: List<String?> = listOf("Kotlin", null)

    // Iterates over each item in the list
    for (item in listWithNulls) {
        // Checks if the item is null and only prints non-null values
        item?.let { println(it) }
        //Kotlin
    }
}
```

Safe casts

The regular Kotlin operator for type casts is the as operator. However, regular casts can result in an exception if the object is not of the target type.

You can use the as? operator for safe casts. It tries to cast a value to the specified type and returns null if the value is not of that type:

```
fun main() {
    // Declares a variable of type Any, which can hold any type of value
    val a: Any = "Hello, Kotlin!"

    // Safe casts to Int using the 'as?' operator
    val aInt: Int? = a as? Int
    // Safe casts to String using the 'as?' operator
    val aString: String? = a as? String

    println(aInt)
    // null
    println(aString)
    // "Hello, Kotlin!"
}
```

The code above prints null because a is not an Int, so the cast fails safely. It also prints "Hello, Kotlin!" because it matches the String? type, so the safe cast succeeds.

Collections of a nullable type

If you have a collection of nullable elements and want to keep only the non-null ones, use the filterNotNull() function:

```
fun main() {
    // Declares a list containing some null and non-null integer values
    val nullableList: List<Int?> = listOf(1, 2, null, 4)

    // Filters out null values, resulting in a list of non-null integers
    val intList: List<Int> = nullableList.filterNotNull()

    println(intList)
    // [1, 2, 4]
}
```

What's next?

- Learn how to handle nullability in Java and Kotlin.
- Learn about generic types that are definitely non-nullable.

Equality

In Kotlin, there are two types of equality:

- Structural equality (==) - a check for the equals() function
- Referential equality (===) - a check for two references pointing to the same object

Structural equality

Structural equality verifies if two objects have the same content or structure. Structural equality is checked by the == operation and its negated counterpart !=. By convention, an expression like a == b is translated to:

```
a?.equals(b) ?: (b === null)
```

If a is not null, it calls the equals(Any?) function. Otherwise (a is null), it checks that b is referentially equal to null:

```
fun main() {
    var a = "hello"
    var b = "hello"
    var c = null
    var d = null
    var e = d

    println(a == b)
    // true
    println(a == c)
    // false
    println(c == e)
    // true
}
```

Note that there's no point in optimizing your code when comparing to null explicitly: a == null will be automatically translated to a === null.

In Kotlin, the equals() function is inherited by all classes from the Any class. By default, the equals() function implements referential equality. However, classes in Kotlin can override the equals() function to provide a custom equality logic and, in this way, implement structural equality.

Value classes and data classes are two specific Kotlin types that automatically override the equals() function. That's why they implement structural equality by default.

However, in the case of data classes, if the equals() function is marked as final in the parent class, its behavior remains unchanged.

Distinctly, non-data classes (those not declared with the data modifier) do not override the equals() function by default. Instead, non-data classes implement referential equality behavior inherited from the Any class. To implement structural equality, non-data classes require a custom equality logic to override the equals() function.

To provide a custom equals check implementation, override the equals(other: Any?): Boolean function:

```
class Point(val x: Int, val y: Int) {
    override fun equals(other: Any?): Boolean {
        if (this === other) return true
        if (other !is Point) return false

        // Compares properties for structural equality
        return this.x == other.x && this.y == other.y
    }
}
```

When overriding the equals() function, you should also override the hashCode() function to keep consistency between equality and hashing and ensure a proper behavior of these functions.

Functions with the same name and other signatures (like equals(other: Foo)) don't affect equality checks with the operators == and !=.

Structural equality has nothing to do with comparison defined by the Comparable<...> interface, so only a custom equals(Any?) implementation may affect the behavior of the operator.

Referential equality

Referential equality verifies the memory addresses of two objects to determine if they are the same instance.

Referential equality is checked by the === operation and its negated counterpart !==. a === b evaluates to true if and only if a and b point to the same object:

```
fun main() {
    var a = "Hello"
    var b = a
    var c = "world"
    var d = "world"

    println(a === b)
    // true
    println(a === c)
    // false
    println(c === d)
    // true
}
```

For values represented by primitive types at runtime (for example, Int), the === equality check is equivalent to the == check.

> The referential equality is implemented differently in Kotlin/JS. For more information about equality, see the Kotlin/JS documentation.

Floating-point numbers equality

When the operands of an equality check are statically known to be Float or Double (nullable or not), the check follows the IEEE 754 Standard for Floating-Point Arithmetic.

The behavior is different for operands that are not statically typed as floating-point numbers. In these cases, structural equality is implemented. As a result, checks with operands not statically typed as floating-point numbers differ from the IEEE standard. In this scenario:

- NaN is equal to itself
- NaN is greater than any other element (including POSITIVE_INFINITY)
- -0.0 is not equal to 0.0

For more information, see Floating-point numbers comparison.

Array equality

To compare whether two arrays have the same elements in the same order, use contentEquals().

For more information, see Compare arrays.

This expressions

To denote the current receiver, you use this expressions:

- In a member of a class, this refers to the current object of that class.
- In an extension function or a function literal with receiver this denotes the receiver parameter that is passed on the left-hand side of a dot.

If this has no qualifiers, it refers to the innermost enclosing scope. To refer to this in other scopes, label qualifiers are used:

Qualified this

To access this from an outer scope (a class, extension function, or labeled function literal with receiver) you write this@label, where @label is a label on the scope this is meant to be from:

```
class A { // implicit label @A
    inner class B { // implicit label @B
        fun Int.foo() { // implicit label @foo
            val a = this@A // A's this
            val b = this@B // B's this

            val c = this // foo()'s receiver, an Int
            val c1 = this@foo // foo()'s receiver, an Int

            val funLit = lambda@ fun String.() {
                val d = this // funLit's receiver, a String
            }

            val funLit2 = { s: String ->
                // foo()'s receiver, since enclosing lambda expression
                // doesn't have any receiver
                val d1 = this
            }
        }
    }
}
```

Implicit this

When you call a member function on this, you can skip the this. part. If you have a non-member function with the same name, use this with caution because in some cases it can be called instead:

```
fun main() {
    fun printLine() { println("Local function") }

    class A {
        fun printLine() { println("Member function") }

        fun invokePrintLine(omitThis: Boolean = false) {
            if (omitThis) printLine()
            else this.printLine()
        }
    }

    A().invokePrintLine() // Member function
    A().invokePrintLine(omitThis = true) // Local function
}
```

Asynchronous programming techniques

For decades, as developers we are confronted with a problem to solve - how to prevent our applications from blocking. Whether we're developing desktop, mobile, or even server-side applications, we want to avoid having the user wait or what's worse cause bottlenecks that would prevent an application from scaling.

There have been many approaches to solving this problem, including:

- Threading
- Callbacks
- Futures, promises, and others
- Reactive Extensions
- Coroutines

Before explaining what coroutines are, let's briefly review some of the other solutions.

Threading

Threads are by far probably the most well-known approach to avoid applications from blocking.

```
fun postItem(item: Item) {
    val token = preparePost()
    val post = submitPost(token, item)
    processPost(post)
}

fun preparePost(): Token {
    // makes a request and consequently blocks the main thread
    return token
}
```

Let's assume in the code above that preparePost is a long-running process and consequently would block the user interface. What we can do is launch it in a separate thread. This would then allow us to avoid the UI from blocking. This is a very common technique, but has a series of drawbacks:

- Threads aren't cheap. Threads require context switches which are costly.
- Threads aren't infinite. The number of threads that can be launched is limited by the underlying operating system. In server-side applications, this could cause a major bottleneck.

- Threads aren't always available. Some platforms, such as JavaScript do not even support threads.
- Threads aren't easy. Debugging threads and avoiding race conditions are common problems we suffer in multi-threaded programming.

Callbacks

With callbacks, the idea is to pass one function as a parameter to another function, and have this one invoked once the process has completed.

```
fun postItem(item: Item) {
    preparePostAsync { token ->
        submitPostAsync(token, item) { post ->
            processPost(post)
        }
    }
}

fun preparePostAsync(callback: (Token) -> Unit) {
    // make request and return immediately
    // arrange callback to be invoked later
}
```

This in principle feels like a much more elegant solution, but once again has several issues:

- Difficulty of nested callbacks. Usually a function that is used as a callback, often ends up needing its own callback. This leads to a series of nested callbacks which lead to incomprehensible code. The pattern is often referred to as callback hell, or the pyramid of doom due to the triangular shape that indentations from these deeply nested callbacks create.
- Error handling is complicated. The nesting model makes error handling and propagation of these somewhat more complicated.

Callbacks are quite common in event-loop architectures such as JavaScript, but even there, generally people have moved away to using other approaches such as promises or reactive extensions.

Futures, promises, and others

The idea behind futures or promises (other terms may be used depending on the language or platform), is that when we make a call, we're promised that at some point the call will return a Promise object, which we can then operate on.

```
fun postItem(item: Item) {
    preparePostAsync()
        .thenCompose { token ->
            submitPostAsync(token, item)
        }
        .thenAccept { post ->
            processPost(post)
        }

}

fun preparePostAsync(): Promise<Token> {
    // makes request and returns a promise that is completed later
    return promise
}
```

This approach requires a series of changes in how we program, in particular:

- Different programming model. Similar to callbacks, the programming model moves away from a top-down imperative approach to a compositional model with chained calls. Traditional program structures such as loops, exception handling, etc. usually are no longer valid in this model.
- Different APIs. Usually there's a need to learn a completely new API such as thenCompose or thenAccept, which can also vary across platforms.
- Specific return type. The return type moves away from the actual data that we need and instead returns a new type Promise which has to be introspected.
- Error handling can be complicated. The propagation and chaining of errors aren't always straightforward.

Reactive extensions

Reactive Extensions (Rx) were introduced to C# by Erik Meijer. While it was definitely used on the .NET platform it really didn't reach mainstream adoption until

Netflix ported it over to Java, naming it RxJava. From then on, numerous ports have been provided for a variety of platforms including JavaScript (RxJS).

The idea behind Rx is to move towards what's called observable streams whereby we now think of data as streams (infinite amounts of data) and these streams can be observed. In practical terms, Rx is simply the Observer Pattern with a series of extensions which allow us to operate on the data.

In approach it's quite similar to Futures, but one can think of a Future as returning a discrete element, whereas Rx returns a stream. However, similar to the previous, it also introduces a complete new way of thinking about our programming model, famously phrased as

```
"everything is a stream, and it's observable"
```

This implies a different way to approach problems and quite a significant shift from what we're used to when writing synchronous code. One benefit as opposed to Futures is that given it's ported to so many platforms, generally we can find a consistent API experience no matter what we use, be it C#, Java, JavaScript, or any other language where Rx is available.

In addition, Rx does introduce a somewhat nicer approach to error handling.

Coroutines

Kotlin's approach to working with asynchronous code is using coroutines, which is the idea of suspendable computations, i.e. the idea that a function can suspend its execution at some point and resume later on.

One of the benefits however of coroutines is that when it comes to the developer, writing non-blocking code is essentially the same as writing blocking code. The programming model in itself doesn't really change.

Take for instance the following code:

```kotlin
fun postItem(item: Item) {
    launch {
        val token = preparePost()
        val post = submitPost(token, item)
        processPost(post)
    }
}

suspend fun preparePost(): Token {
    // makes a request and suspends the coroutine
    return suspendCoroutine { /* ... */ }
}
```

This code will launch a long-running operation without blocking the main thread. The preparePost is what's called a suspendable function, thus the keyword suspend prefixing it. What this means as stated above, is that the function will execute, pause execution and resume at some point in time.

- The function signature remains exactly the same. The only difference is suspend being added to it. The return type however is the type we want to be returned.
- The code is still written as if we were writing synchronous code, top-down, without the need of any special syntax, beyond the use of a function called launch which essentially kicks off the coroutine (covered in other tutorials).
- The programming model and APIs remain the same. We can continue to use loops, exception handling, etc. and there's no need to learn a complete set of new APIs.
- It is platform independent. Whether we're targeting JVM, JavaScript or any other platform, the code we write is the same. Under the covers the compiler takes care of adapting it to each platform.

Coroutines are not a new concept, let alone invented by Kotlin. They've been around for decades and are popular in some other programming languages such as Go. What is important to note though is that the way they're implemented in Kotlin, most of the functionality is delegated to libraries. In fact, beyond the suspend keyword, no other keywords are added to the language. This is somewhat different from languages such as C# that have async and await as part of the syntax. With Kotlin, these are just library functions.

For more information, see the Coroutines reference.

Coroutines

Applications often need to perform multiple tasks at the same time, such as responding to user input, loading data, or updating the screen. To support this, they rely on concurrency, which allows operations to run independently without blocking each other.

The most common way to run tasks concurrently is by using threads, which are independent paths of execution managed by the operating system. However, threads are relatively heavy, and creating many of them can lead to performance issues.

To support efficient concurrency, Kotlin uses asynchronous programming built around coroutines, which let you write asynchronous code in a natural, sequential style using suspending functions. Coroutines are lightweight alternatives to threads. They can suspend without blocking system resources and are resource-friendly, making them better suited for fine-grained concurrency.

Most coroutine features are provided by the kotlinx.coroutines library, which includes tools for launching coroutines, handling concurrency, working with asynchronous streams, and more.

If you're new to coroutines in Kotlin, start with the Coroutine basics guide before diving into more complex topics. This guide introduces the key concepts of suspending functions, coroutine builders, and structured concurrency through simple examples:

Get started with Kotlin coroutines→

Get started with coroutines

> Check out the KotlinConf app for a sample project to see how coroutines are used in practice.

Coroutine concepts

The kotlinx.coroutines library provides the core building blocks for running tasks concurrently, structuring coroutine execution, and managing shared state.

Suspending functions and coroutine builders

Coroutines in Kotlin are built on suspending functions, which allow code to pause and resume without blocking a thread. The suspend keyword marks functions that can perform long-running operations asynchronously.

To launch new coroutines, use coroutine builders like .launch() and .async(). These builders are extension functions on CoroutineScope, which defines the coroutine's lifecycle and provides the coroutine context.

You can learn more about these builders in Coroutine basics and Composing suspend functions.

Coroutine context and behavior

Launching a coroutine from a CoroutineScope creates a context that governs its execution. Builder functions like .launch() and .async() automatically create a set of elements that define how the coroutine behaves:

- The Job interface tracks the coroutine's lifecycle and enables structured concurrency.
- CoroutineDispatcher controls where the coroutine runs, such as on a background thread or the main thread in UI applications.
- CoroutineExceptionHandler handles uncaught exceptions.

These, along with other possible elements, make up the coroutine context, which is inherited by default from the coroutine's parent. This context forms a hierarchy that enables structured concurrency, where related coroutines can be canceled together or handle exceptions as a group.

Asynchronous flow and shared mutable state

Kotlin provides several ways for coroutines to communicate. Use one of the following options based on how you want to share values between coroutines:

- Flow produces values only when a coroutine actively collects them.
- Channel allows multiple coroutines to send and receive values, with each value delivered to exactly one coroutine.
- SharedFlow continuously shares every value with all active collecting coroutines.

When multiple coroutines need to access or update the same data, they share mutable state. Without coordination, this can lead to race conditions, where operations interfere with each other in unpredictable ways. To safely manage shared mutable state, use StateFlow to wrap the shared data. Then, you can update it from one coroutine and collect its latest value from others.

For more information, see Asynchronous flow, Channels, and the Coroutines and channels tutorial.

What's next

- Learn the fundamentals of coroutines, suspending functions, and builders in the Coroutine basics guide.
- Explore how to combine suspending functions and build coroutine pipelines in Composing suspending functions.
- Learn how to debug coroutines using built-in tools in IntelliJ IDEA.
- For flow-specific debugging, see the Debug Kotlin Flow using IntelliJ IDEA tutorial.
- Read the Guide to UI programming with coroutines to learn about coroutine-based UI development.
- Review best practices for using coroutines in Android.
- Check out the kotlinx.coroutines API reference.

Annotations

Annotations are a means of attaching metadata to code. To declare an annotation, put the annotation modifier in front of a class:

```
annotation class Fancy
```

Additional attributes of the annotation can be specified by annotating the annotation class with meta-annotations:

- @Target specifies the possible kinds of elements which can be annotated with the annotation (such as classes, functions, properties, and expressions);
- @Retention specifies whether the annotation is stored in the compiled class files and whether it's visible through reflection at runtime (by default, both are true);
- @Repeatable allows using the same annotation on a single element multiple times;
- @MustBeDocumented specifies that the annotation is part of the public API and should be included in the class or method signature shown in the generated API documentation.

```
@Target(AnnotationTarget.CLASS, AnnotationTarget.FUNCTION,
        AnnotationTarget.TYPE_PARAMETER, AnnotationTarget.VALUE_PARAMETER,
        AnnotationTarget.EXPRESSION)
@Retention(AnnotationRetention.SOURCE)
@MustBeDocumented
annotation class Fancy
```

Usage

```
@Fancy class Foo {
    @Fancy fun baz(@Fancy foo: Int): Int {
        return (@Fancy 1)
    }
}
```

If you need to annotate the primary constructor of a class, you need to add the constructor keyword to the constructor declaration, and add the annotations before it:

```
class Foo @Inject constructor(dependency: MyDependency) { ... }
```

You can also annotate property accessors:

```
class Foo {
    var x: MyDependency? = null
        @Inject set
}
```

Constructors

Annotations can have constructors that take parameters.

```
annotation class Special(val why: String)

@Special("example") class Foo {}
```

Allowed parameter types are:

- Types that correspond to Java primitive types (Int, Long etc.)
- Strings
- Classes (Foo::class)
- Enums
- Other annotations
- Arrays of the types listed above

Annotation parameters cannot have nullable types, because the JVM does not support storing null as a value of an annotation attribute.

If an annotation is used as a parameter of another annotation, its name is not prefixed with the @ character:

```
annotation class ReplaceWith(val expression: String)

annotation class Deprecated(
        val message: String,
        val replaceWith: ReplaceWith = ReplaceWith(""))

@Deprecated("This function is deprecated, use === instead", ReplaceWith("this === other"))
```

If you need to specify a class as an argument of an annotation, use a Kotlin class (KClass). The Kotlin compiler will automatically convert it to a Java class, so that the Java code can access the annotations and arguments normally.

```
import kotlin.reflect.KClass

annotation class Ann(val arg1: KClass<*>, val arg2: KClass<out Any>)

@Ann(String::class, Int::class) class MyClass
```

Instantiation

In Java, an annotation type is a form of an interface, so you can implement it and use an instance. As an alternative to this mechanism, Kotlin lets you call a constructor of an annotation class in arbitrary code and similarly use the resulting instance.

```
annotation class InfoMarker(val info: String)

fun processInfo(marker: InfoMarker): Unit = TODO()

fun main(args: Array<String>) {
    if (args.isNotEmpty())
        processInfo(getAnnotationReflective(args))
    else
        processInfo(InfoMarker("default"))
}
```

Learn more about instantiation of annotation classes in this KEEP.

Lambdas

Annotations can also be used on lambdas. They will be applied to the invoke() method into which the body of the lambda is generated. This is useful for frameworks like Quasar, which uses annotations for concurrency control.

```
annotation class Suspendable

val f = @Suspendable { Fiber.sleep(10) }
```

Annotation use-site targets

When you're annotating a property or a primary constructor parameter, there are multiple Java elements that are generated from the corresponding Kotlin element, and therefore multiple possible locations for the annotation in the generated Java bytecode. To specify how exactly the annotation should be generated, use the following syntax:

```
class Example(@field:Ann val foo,    // annotate only the Java field
              @get:Ann val bar,      // annotate only the Java getter
              @param:Ann val quux)   // annotate only the Java constructor parameter
```

The same syntax can be used to annotate the entire file. To do this, put an annotation with the target file at the top level of a file, before the package directive or before all imports if the file is in the default package:

```
@file:JvmName("Foo")

package org.jetbrains.demo
```

If you have multiple annotations with the same target, you can avoid repeating the target by adding brackets after the target and putting all the annotations inside the brackets (except for the all meta-target):

```
class Example {
     @set:[Inject VisibleForTesting]
     var collaborator: Collaborator
}
```

The full list of supported use-site targets is:

- file
- field
- property (annotations with this target are not visible to Java)
- get (property getter)
- set (property setter)
- all (an experimental meta-target for properties, see below for its purpose and usage)
- receiver (receiver parameter of an extension function or property)

  To annotate the receiver parameter of an extension function, use the following syntax:

  ```
  fun @receiver:Fancy String.myExtension() { ... }
  ```

- param (constructor parameter)
- setparam (property setter parameter)
- delegate (the field storing the delegate instance for a delegated property)

Defaults when no use-site targets are specified

If you don't specify a use-site target, the target is chosen according to the @Target annotation of the annotation being used. If there are multiple applicable targets, the first applicable target from the following list is used:

- param
- property
- field

Let's use the @Email annotation from Jakarta Bean Validation:

```
@Target(value={METHOD,FIELD,ANNOTATION_TYPE,CONSTRUCTOR,PARAMETER,TYPE_USE})
public @interface Email { }
```

With this annotation, consider the following example:

```
data class User(val username: String,
                // @Email is equivalent to @param:Email
                @Email val email: String) {
    // @Email is equivalent to @field:Email
    @Email val secondaryEmail: String? = null
}
```

Kotlin 2.2.0 introduced an experimental defaulting rule which should make propagating annotations to parameters, fields, and properties more predictable.

With the new rule, if there are multiple applicable targets, one or more is chosen as follows:

- If the constructor parameter target (param) is applicable, it is used.
- If the property target (property) is applicable, it is used.
- If the field target (field) is applicable while property isn't, field is used.

Using the same example:

```
data class User(val username: String,
                // @Email is now equivalent to @param:Email @field:Email
                @Email val email: String) {
    // @Email is still equivalent to @field:Email
    @Email val secondaryEmail: String? = null
}
```

If there are multiple targets, and none of param, property, or field are applicable, the annotation is invalid.

To enable the new defaulting rule, use the following line in your Gradle configuration:

```
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xannotation-default-target=param-property")
    }
}
```

Whenever you'd like to use the old behavior, you can:

- In a specific case, specify the necessary target explicitly, for example, using @param:Annotation instead of @Annotation.
- For a whole project, use this flag in your Gradle build file:

  ```
  // build.gradle.kts
  kotlin {
      compilerOptions {
          freeCompilerArgs.add("-Xannotation-default-target=first-only")
      }
  }
  ```

all meta-target

The all target makes it easier to apply the same annotation not only to the parameter and the property or field, but also to the corresponding getter and setter.

Specifically, the annotation marked with all is propagated, if applicable:

- To the constructor parameter (param) if the property is defined in the primary constructor.
- To the property itself (property).
- To the backing field (field) if the property has one.

- To the getter (get).
- To the setter parameter (setparam) if the property is defined as var.
- To the Java-only target RECORD_COMPONENT if the class has the @JvmRecord annotation.

Let's use the @Email annotation from Jakarta Bean Validation, which is defined as follows:

```
@Target(value={METHOD,FIELD,ANNOTATION_TYPE,CONSTRUCTOR,PARAMETER,TYPE_USE})
public @interface Email { }
```

In the example below, this @Email annotation is applied to all relevant targets:

```
data class User(
    val username: String,
    // Applies `@Email` to `param`, `field` and `get`
    @all:Email val email: String,
    // Applies `@Email` to `param`, `field`, `get`, and `set_param`
    @all:Email var name: String,
) {
    // Applies `@Email` to `field` and `getter` (no `param` since it's not in the constructor)
    @all:Email val secondaryEmail: String? = null
}
```

You can use the all meta-target with any property, both inside and outside the primary constructor.

Limitations

The all target comes with some limitations:

- It does not propagate an annotation to types, potential extension receivers, or context receivers or parameters.
- It cannot be used with multiple annotations:

  ```
  @all:[A B] // forbidden, use `@all:A @all:B`
  val x: Int = 5
  ```

- It cannot be used with delegated properties.

How to enable

To enable the all meta-target in your project, use the following compiler option in the command line:

```
-Xannotation-target-all
```

Or add it to the compilerOptions {} block of your Gradle build file:

```
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xannotation-target-all")
    }
}
```

Java annotations

Java annotations are 100% compatible with Kotlin:

```
import org.junit.Test
import org.junit.Assert.*
import org.junit.Rule
import org.junit.rules.*

class Tests {
    // apply @Rule annotation to property getter
```

```
    @get:Rule val tempFolder = TemporaryFolder()

    @Test fun simple() {
        val f = tempFolder.newFile()
        assertEquals(42, getTheAnswer())
    }
}
```

Since the order of parameters for an annotation written in Java is not defined, you can't use a regular function call syntax for passing the arguments. Instead, you need to use the named argument syntax:

```
// Java
public @interface Ann {
    int intValue();
    String stringValue();
}
```

```
// Kotlin
@Ann(intValue = 1, stringValue = "abc") class C
```

Just like in Java, a special case is the value parameter; its value can be specified without an explicit name:

```
// Java
public @interface AnnWithValue {
    String value();
}
```

```
// Kotlin
@AnnWithValue("abc") class C
```

Arrays as annotation parameters

If the value argument in Java has an array type, it becomes a vararg parameter in Kotlin:

```
// Java
public @interface AnnWithArrayValue {
    String[] value();
}
```

```
// Kotlin
@AnnWithArrayValue("abc", "foo", "bar") class C
```

For other arguments that have an array type, you need to use the array literal syntax or arrayOf(...):

```
// Java
public @interface AnnWithArrayMethod {
    String[] names();
}
```

```
@AnnWithArrayMethod(names = ["abc", "foo", "bar"])
class C
```

Accessing properties of an annotation instance

Values of an annotation instance are exposed as properties to Kotlin code:

```
// Java
public @interface Ann {
    int value();
}
```

```
// Kotlin
fun foo(ann: Ann) {
    val i = ann.value
}
```

Ability to not generate JVM 1.8+ annotation targets

If a Kotlin annotation has TYPE among its Kotlin targets, the annotation maps to java.lang.annotation.ElementType.TYPE_USE in its list of Java annotation targets. This is just like how the TYPE_PARAMETER Kotlin target maps to the java.lang.annotation.ElementType.TYPE_PARAMETER Java target. This is an issue for Android clients with API levels less than 26, which don't have these targets in the API.

To avoid generating the TYPE_USE and TYPE_PARAMETER annotation targets, use the new compiler argument -Xno-new-java-annotation-targets.

Repeatable annotations

Just like in Java, Kotlin has repeatable annotations, which can be applied to a single code element multiple times. To make your annotation repeatable, mark its declaration with the @kotlin.annotation.Repeatable meta-annotation. This will make it repeatable both in Kotlin and Java. Java repeatable annotations are also supported from the Kotlin side.

The main difference with the scheme used in Java is the absence of a containing annotation, which the Kotlin compiler generates automatically with a predefined name. For an annotation in the example below, it will generate the containing annotation @Tag.Container:

```
@Repeatable
annotation class Tag(val name: String)

// The compiler generates the @Tag.Container containing annotation
```

You can set a custom name for a containing annotation by applying the @kotlin.jvm.JvmRepeatable meta-annotation and passing an explicitly declared containing annotation class as an argument:

```
@JvmRepeatable(Tags::class)
annotation class Tag(val name: String)

annotation class Tags(val value: Array<Tag>)
```

To extract Kotlin or Java repeatable annotations via reflection, use the KAnnotatedElement.findAnnotations() function.

Learn more about Kotlin repeatable annotations in this KEEP.

Destructuring declarations

Sometimes it is convenient to destructure an object into a number of variables, for example:

```
val (name, age) = person
```

This syntax is called a destructuring declaration. A destructuring declaration creates multiple variables at once. You have declared two new variables: name and age, and can use them independently:

```
println(name)
println(age)
```

A destructuring declaration is compiled down to the following code:

```
val name = person.component1()
val age = person.component2()
```

The component1() and component2() functions are another example of the principle of conventions widely used in Kotlin (see operators like + and *, for-loops as an example). Anything can be on the right-hand side of a destructuring declaration, as long as the required number of component functions can be called on it. And, of course, there can be component3() and component4() and so on.

The componentN() functions need to be marked with the operator keyword to allow using them in a destructuring declaration.

Destructuring declarations also work in for-loops:

```
for ((a, b) in collection) { ... }
```

Variables a and b get the values returned by component1() and component2() called on elements of the collection.

Example: returning two values from a function

Assume that you need to return two things from a function - for example, a result object and a status of some sort. A compact way of doing this in Kotlin is to declare a data class and return its instance:

```
data class Result(val result: Int, val status: Status)
fun function(...): Result {
    // computations

    return Result(result, status)
}

// Now, to use this function:
val (result, status) = function(...)
```

Since data classes automatically declare componentN() functions, destructuring declarations work here.

You could also use the standard class Pair and have function() return Pair<Int, Status>, but it's often better to have your data named properly.

Example: destructuring declarations and maps

Probably the nicest way to traverse a map is this:

```
for ((key, value) in map) {
   // do something with the key and the value
}
```

To make this work, you should

- Present the map as a sequence of values by providing an iterator() function.
- Present each of the elements as a pair by providing functions component1() and component2().

And indeed, the standard library provides such extensions:

```
operator fun <K, V> Map<K, V>.iterator(): Iterator<Map.Entry<K, V>> = entrySet().iterator()
operator fun <K, V> Map.Entry<K, V>.component1() = getKey()
operator fun <K, V> Map.Entry<K, V>.component2() = getValue()
```

So you can freely use destructuring declarations in for-loops with maps (as well as collections of data class instances or similar).

Underscore for unused variables

If you don't need a variable in the destructuring declaration, you can place an underscore instead of its name:

```
val (_, status) = getResult()
```

The componentN() operator functions are not called for the components that are skipped in this way.

Destructuring in lambdas

You can use the destructuring declarations syntax for lambda parameters. If a lambda has a parameter of the Pair type (or Map.Entry, or any other type that has the appropriate componentN functions), you can introduce several new parameters instead of one by putting them in parentheses:

```
map.mapValues { entry -> "${entry.value}!" }
map.mapValues { (key, value) -> "$value!" }
```

Note the difference between declaring two parameters and declaring a destructuring pair instead of a parameter:

```
{ a -> ... } // one parameter
{ a, b -> ... } // two parameters
{ (a, b) -> ... } // a destructured pair
{ (a, b), c -> ... } // a destructured pair and another parameter
```

If a component of the destructured parameter is unused, you can replace it with the underscore to avoid inventing its name:

```
map.mapValues { (_, value) -> "$value!" }
```

You can specify the type for the whole destructured parameter or for a specific component separately:

```
map.mapValues { (_, value): Map.Entry<Int, String> -> "$value!" }

map.mapValues { (_, value: String) -> "$value!" }
```

Reflection

Reflection is a set of language and library features that allows you to introspect the structure of your program at runtime. Functions and properties are first-class citizens in Kotlin, and the ability to introspect them (for example, learning the name or the type of a property or function at runtime) is essential when using a functional or reactive style.

Kotlin/JS provides limited support for reflection features. Learn more about reflection in Kotlin/JS.

JVM dependency

On the JVM platform, the Kotlin compiler distribution includes the runtime component required for using the reflection features as a separate artifact, kotlin-reflect.jar. This is done to reduce the required size of the runtime library for applications that do not use reflection features.

To use reflection in a Gradle or Maven project, add the dependency on kotlin-reflect:

- In Gradle:

  Kotlin

  ```
  dependencies {
      implementation(kotlin("reflect"))
  }
  ```

  Groovy

  ```
  dependencies {
      implementation "org.jetbrains.kotlin:kotlin-reflect:2.2.0"
  }
  ```

- In Maven:

```xml
<dependencies>
    <dependency>
        <groupId>org.jetbrains.kotlin</groupId>
        <artifactId>kotlin-reflect</artifactId>
    </dependency>
</dependencies>
```

If you don't use Gradle or Maven, make sure you have kotlin-reflect.jar in the classpath of your project. In other supported cases (IntelliJ IDEA projects that use the command-line compiler or Ant), it is added by default. In the command-line compiler and Ant, you can use the -no-reflect compiler option to exclude kotlin-reflect.jar from the classpath.

Class references

The most basic reflection feature is getting the runtime reference to a Kotlin class. To obtain the reference to a statically known Kotlin class, you can use the class literal syntax:

```kotlin
val c = MyClass::class
```

The reference is a KClass type value.

On JVM: a Kotlin class reference is not the same as a Java class reference. To obtain a Java class reference, use the .java property on a KClass instance.

Bound class references

You can get the reference to the class of a specific object with the same ::class syntax by using the object as a receiver:

```kotlin
val widget: Widget = ...
assert(widget is GoodWidget) { "Bad widget: ${widget::class.qualifiedName}" }
```

You will obtain the reference to the exact class of an object, for example, GoodWidget or BadWidget, regardless of the type of the receiver expression (Widget).

Callable references

References to functions, properties, and constructors can also be called or used as instances of function types.

The common supertype for all callable references is KCallable<out R>, where R is the return value type. It is the property type for properties, and the constructed type for constructors.

Function references

When you have a named function declared as below, you can call it directly (isOdd(5)):

```kotlin
fun isOdd(x: Int) = x % 2 != 0
```

Alternatively, you can use the function as a function type value, that is, pass it to another function. To do so, use the :: operator:

```kotlin
fun isOdd(x: Int) = x % 2 != 0

fun main() {
    val numbers = listOf(1, 2, 3)
    println(numbers.filter(::isOdd))
}
```

Here ::isOdd is a value of function type (Int) -> Boolean.

Function references belong to one of the KFunction<out R> subtypes, depending on the parameter count. For instance, KFunction3<T1, T2, T3, R>.

:: can be used with overloaded functions when the expected type is known from the context. For example:

```
fun main() {
    fun isOdd(x: Int) = x % 2 != 0
    fun isOdd(s: String) = s == "brillig" || s == "slithy" || s == "tove"

    val numbers = listOf(1, 2, 3)
    println(numbers.filter(::isOdd)) // refers to isOdd(x: Int)
}
```

Alternatively, you can provide the necessary context by storing the method reference in a variable with an explicitly specified type:

```
val predicate: (String) -> Boolean = ::isOdd   // refers to isOdd(x: String)
```

If you need to use a member of a class or an extension function, it needs to be qualified: String::toCharArray.

Even if you initialize a variable with a reference to an extension function, the inferred function type will have no receiver, but it will have an additional parameter accepting a receiver object. To have a function type with a receiver instead, specify the type explicitly:

```
val isEmptyStringList: List<String>.() -> Boolean = List<String>::isEmpty
```

Example: function composition

Consider the following function:

```
fun <A, B, C> compose(f: (B) -> C, g: (A) -> B): (A) -> C {
    return { x -> f(g(x)) }
}
```

It returns a composition of two functions passed to it: compose(f, g) = f(g(*)). You can apply this function to callable references:

```
fun <A, B, C> compose(f: (B) -> C, g: (A) -> B): (A) -> C {
    return { x -> f(g(x)) }
}

fun isOdd(x: Int) = x % 2 != 0

fun main() {
    fun length(s: String) = s.length

    val oddLength = compose(::isOdd, ::length)
    val strings = listOf("a", "ab", "abc")

    println(strings.filter(oddLength))
}
```

Property references

To access properties as first-class objects in Kotlin, use the :: operator:

```
val x = 1

fun main() {
    println(::x.get())
    println(::x.name)
}
```

The expression ::x evaluates to a KProperty0<Int> type property object. You can read its value using get() or retrieve the property name using the name property. For more information, see the docs on the KProperty class.

For a mutable property such as var y = 1, ::y returns a value with the KMutableProperty0<Int> type which has a set() method:

```
var y = 1

fun main() {
    ::y.set(2)
    println(y)
}
```

A property reference can be used where a function with a single generic parameter is expected:

```
fun main() {
    val strs = listOf("a", "bc", "def")
    println(strs.map(String::length))
}
```

To access a property that is a member of a class, qualify it as follows:

```
fun main() {
    class A(val p: Int)
    val prop = A::p
    println(prop.get(A(1)))
}
```

For an extension property:

```
val String.lastChar: Char
    get() = this[length - 1]

fun main() {
    println(String::lastChar.get("abc"))
}
```

Interoperability with Java reflection

On the JVM platform, the standard library contains extensions for reflection classes that provide a mapping to and from Java reflection objects (see package kotlin.reflect.jvm). For example, to find a backing field or a Java method that serves as a getter for a Kotlin property, you can write something like this:

```
import kotlin.reflect.jvm.*

class A(val p: Int)

fun main() {
    println(A::p.javaGetter) // prints "public final int A.getP()"
    println(A::p.javaField)  // prints "private final int A.p"
}
```

To get the Kotlin class that corresponds to a Java class, use the .kotlin extension property:

```
fun getKClass(o: Any): KClass<Any> = o.javaClass.kotlin
```

Constructor references

Constructors can be referenced just like methods and properties. You can use them wherever the program expects a function type object that takes the same parameters as the constructor and returns an object of the appropriate type. Constructors are referenced by using the :: operator and adding the class name. Consider the following function that expects a function parameter with no parameters and return type Foo:

```
class Foo

fun function(factory: () -> Foo) {
    val x: Foo = factory()
}
```

Using ::Foo, the zero-argument constructor of the class Foo, you can call it like this:

```
function(::Foo)
```

Callable references to constructors are typed as one of the KFunction<out R> subtypes depending on the parameter count.

Bound function and property references

You can refer to an instance method of a particular object:

```
fun main() {
    val numberRegex = "\\d+".toRegex()
    println(numberRegex.matches("29"))

    val isNumber = numberRegex::matches
    println(isNumber("29"))
}
```

Instead of calling the method matches directly, the example uses a reference to it. Such a reference is bound to its receiver. It can be called directly (like in the example above) or used whenever a function type expression is expected:

```
fun main() {
    val numberRegex = "\\d+".toRegex()
    val strings = listOf("abc", "124", "a70")
    println(strings.filter(numberRegex::matches))
}
```

Compare the types of the bound and the unbound references. The bound callable reference has its receiver "attached" to it, so the type of the receiver is no longer a parameter:

```
val isNumber: (CharSequence) -> Boolean = numberRegex::matches

val matches: (Regex, CharSequence) -> Boolean = Regex::matches
```

A property reference can be bound as well:

```
fun main() {
    val prop = "abc"::length
    println(prop.get())
}
```

You don't need to specify this as the receiver: this::foo and ::foo are equivalent.

Bound constructor references

A bound callable reference to a constructor of an inner class can be obtained by providing an instance of the outer class:

```
class Outer {
    inner class Inner
}

val o = Outer()
val boundInnerCtor = o::Inner
```

Get started with Kotlin Notebook

Kotlin Notebook is an interactive tool that lets you mix code, visuals, and markdown in one document. You can use notebooks to write and execute code in sections known as code cells, see the results instantly, and write down your thoughts. This setup makes it an excellent tool for rapid prototyping, analytics, and data science.

Get to know Kotlin Notebook by completing these steps:

1 Set up an environment for working with Kotlin Notebook

2 Create your first notebook and perform some simple operations

3 Add dependencies to your Kotlin Notebook

Next step

Start by setting up an environment for working with Kotlin Notebook:

Proceed to the next part

Set up an environment

Before you create your first Kotlin Notebook, you need to set up an environment.

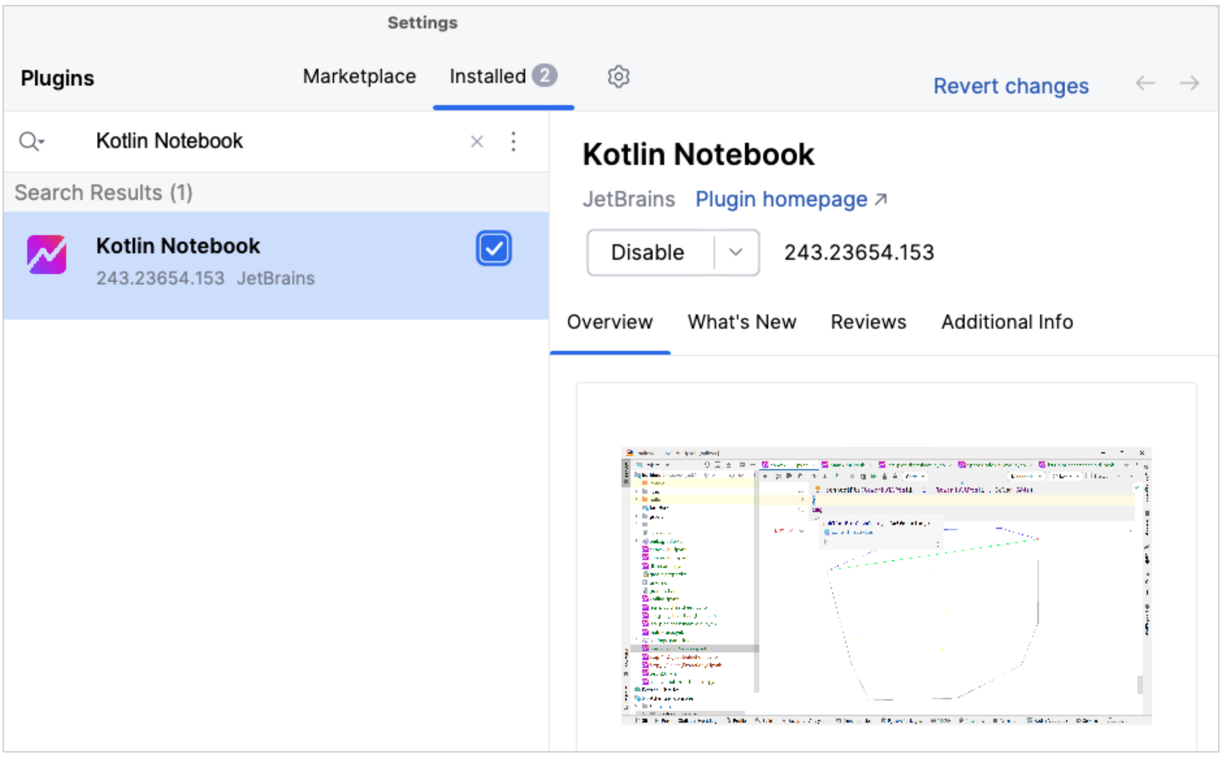
Set up the environment

Kotlin Notebook relies on the Kotlin Notebook plugin, which is bundled and enabled in IntelliJ IDEA by default.

To use Kotlin Notebook, download and install the latest version of IntelliJ IDEA.

If the Kotlin Notebook features are not available, ensure the plugin is enabled:

1. In IntelliJ IDEA, select IntelliJ IDEA | Settings | Plugins.
2. In the Installed tab, find the Kotlin Notebook plugin, and select the checkbox next to the plugin name.



Install Kotlin Notebook

3. Click OK to apply the changes and restart your IDE if prompted.

Next step

In the next part of the tutorial, you will learn how to create a Kotlin Notebook.

Proceed to the next chapter

Create your first Kotlin Notebook

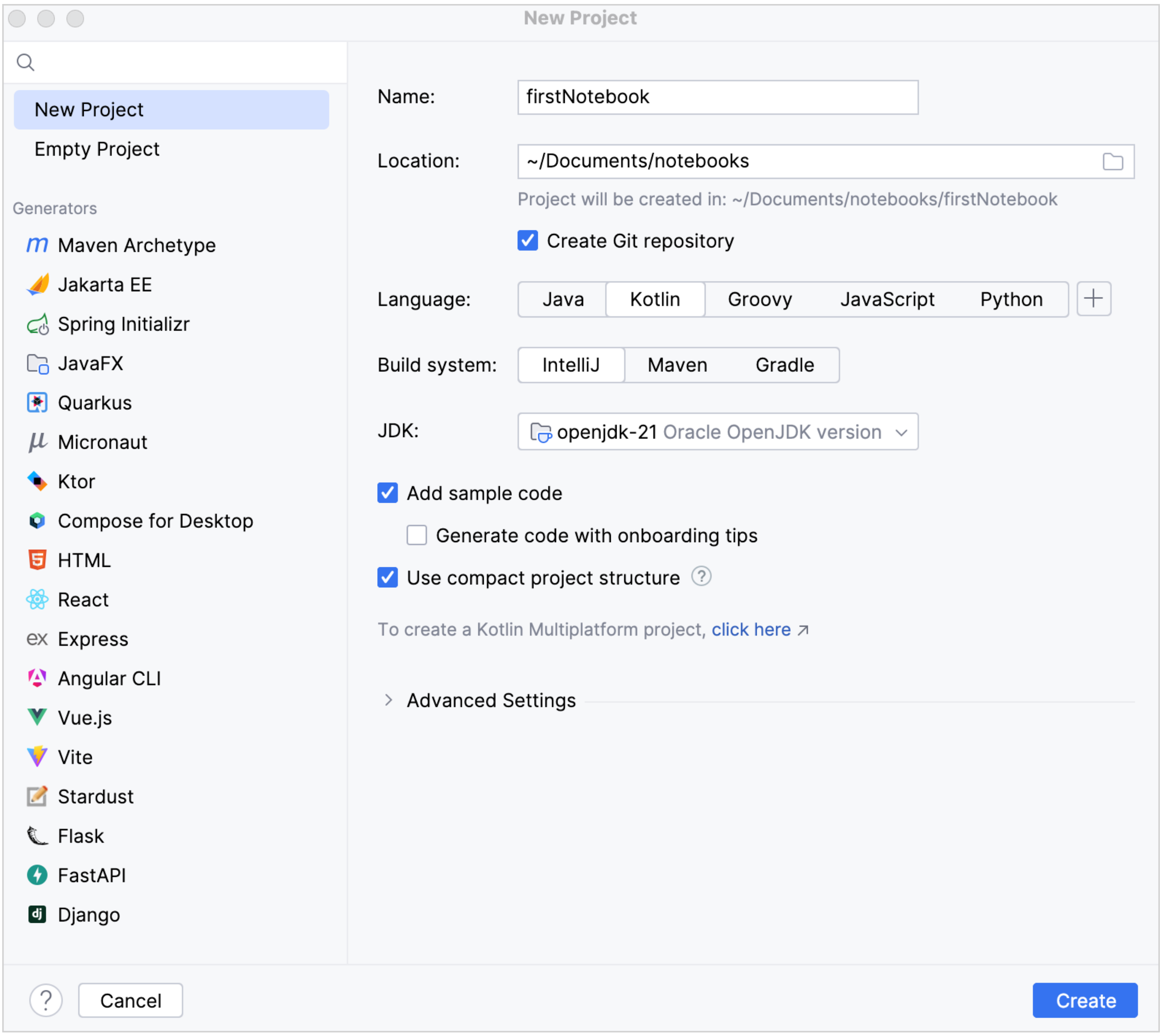
Here, you will learn how to create your first Kotlin Notebook, perform simple operations, and run code cells.

Create an empty project

1. In IntelliJ IDEA, select File | New | Project.
2. In the panel on the left, select New Project.
3. Name the new project and change its location if necessary.

> Select the Create Git repository checkbox to place the new project under version control. You will be able to do it later at any time.

4. From the Language list, select Kotlin.



Name: firstNotebook

Location: ~/Documents/notebooks

Project will be created in: ~/Documents/notebooks/firstNotebook

☑ Create Git repository

Language: Java [✓ Kotlin] Groovy JavaScript Python

Build system: [✓ IntelliJ] Maven Gradle

JDK: openjdk-21 Oracle OpenJDK version

☑ Add sample code

☐ Generate code with onboarding tips

☑ Use compact project structure

To create a Kotlin Multiplatform project, click here ↗

Advanced Settings

Create a new Kotlin Notebook project

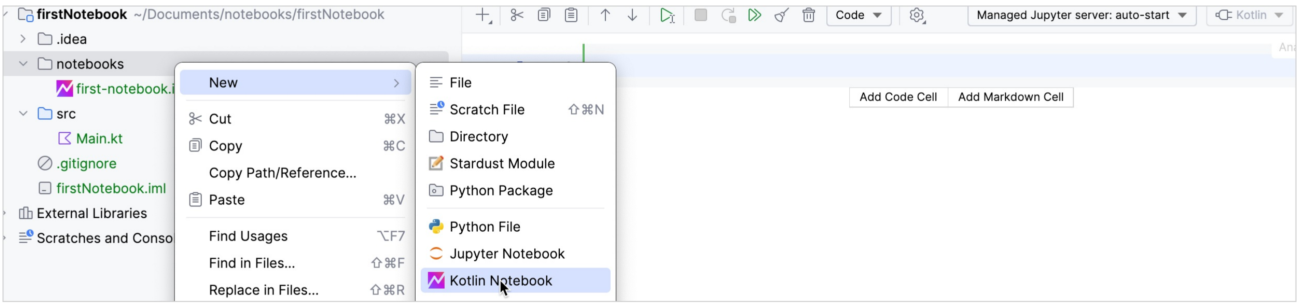
5. Select the IntelliJ build system.
6. From the JDK list, select the JDK that you want to use in your project.
7. Enable the Add sample code option to create a file with a sample "Hello World!" application.

You can also enable the Generate code with onboarding tips option to add some additional useful comments to your sample code.

8. Click Create.

Create a Kotlin Notebook

1. To create a new notebook, select File | New | Kotlin Notebook, or right-click on a folder and select New | Kotlin Notebook.



Create a new Kotlin Notebook

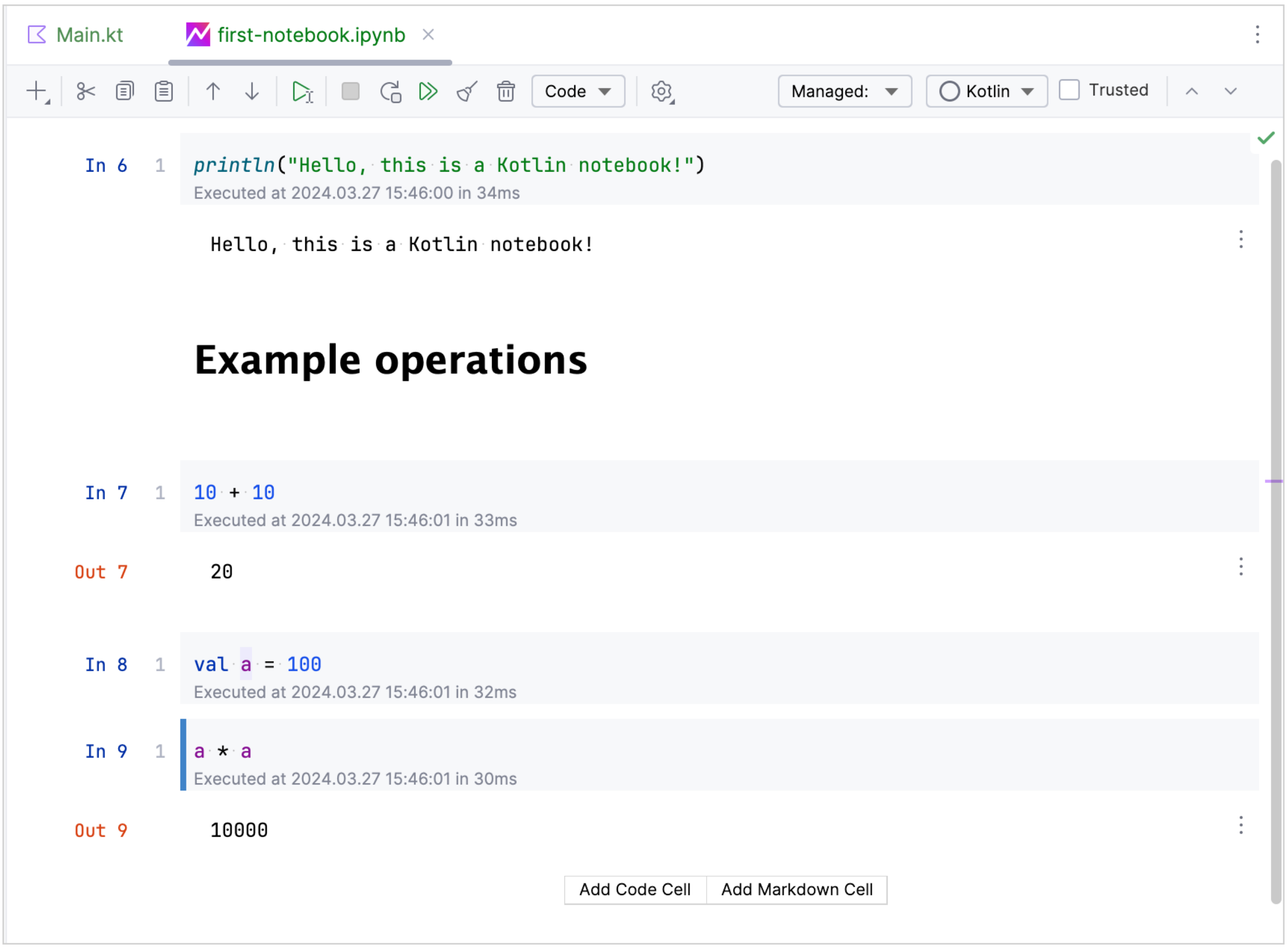
2. Set the name of the new notebook, for example, first-notebook, and press Enter. A new tab with a Kotlin Notebook first-notebook.ipynb will open.
3. In the open tab, type the following code in the code cell:

```kotlin
println("Hello, this is a Kotlin Notebook!")
```

4. To run a code cell, click the Run Cell and Select Below button or press Shift + Return.
5. Add a markdown cell by clicking on the Add Markdown Cell button.
6. Type # Example operations in the cell, and run it the same way you run code cells to render it.
7. In a new code cell, type 10 + 10 and run it.
8. Define a variable in a code cell. For example, val a = 100.

Once you run a code cell with defined variables, those variables become accessible in all other code cells.

9. Create a new code cell and add println(a * a).
0. Run all code and markdown cells in the notebook using the Run All button.



```
In 6    println("Hello, this is a Kotlin notebook!")
        Executed at 2024.03.27 15:46:00 in 34ms

        Hello, this is a Kotlin notebook!
```

Example operations

```
In 7    10 + 10
        Executed at 2024.03.27 15:46:01 in 33ms

Out 7   20

In 8    val a = 100
        Executed at 2024.03.27 15:46:01 in 32ms

In 9    a * a
        Executed at 2024.03.27 15:46:01 in 30ms

Out 9   10000
```

First notebook

Congratulations! You have just created your first Kotlin Notebook.

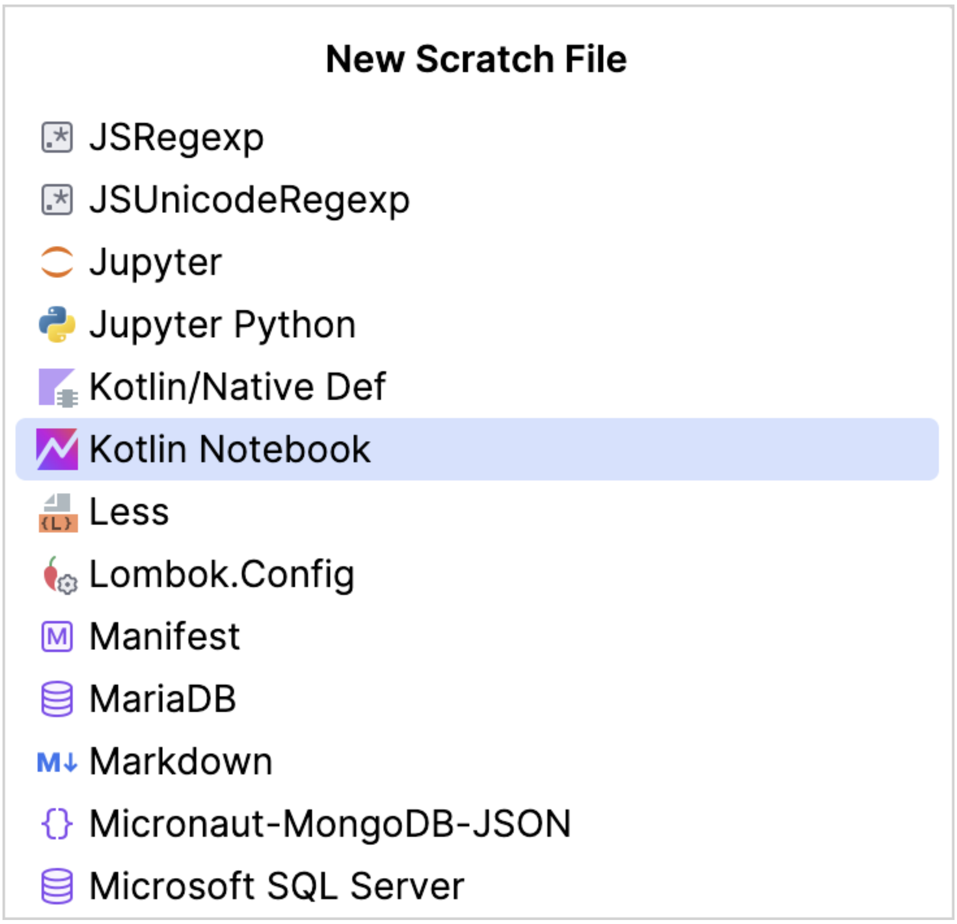
Create a scratch Kotlin Notebook

Starting from IntelliJ IDEA 2024.1.1, you can also create a Kotlin Notebook as a scratch file.

Scratch files allow you to test small pieces of code without creating a new project or modifying an existing one.

To create a scratch Kotlin Notebook:

1. Click File | New | Scratch File.
2. Select Kotlin Notebook from the New Scratch File list.



Scratch notebook

Next step

In the next part of the tutorial, you will learn how to add dependencies to a Kotlin Notebook.

Proceed to the next chapter

Add dependencies to your Kotlin Notebook

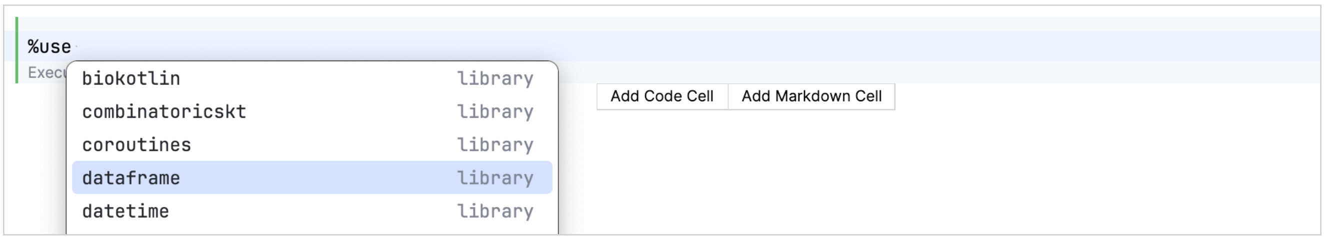
You've already created your first Kotlin Notebook! Now let's learn how to add dependencies to libraries, which is necessary to unlock advanced features.

> The Kotlin standard library can be used out of the box, so you don't have to import it.

You can load any library from the Maven repository by specifying its coordinates using Gradle-style syntax in any code cell. However, Kotlin Notebook has a simplified method to load popular libraries in the form of the %use statement:

```
// Replace libraryName with the library dependency you want to add
%use libraryName
```

You can also use the autocompletion feature in Kotlin Notebook to quickly access available libraries:


```
%use
Execu biokotlin         library
      combinatoricskt   library
      coroutines        library
      dataframe         library
      datetime          library
```

Autocompletion feature in Kotlin Notebook

Add Kotlin DataFrame and Kandy libraries to your Kotlin Notebook

Let's add two popular Kotlin library dependencies to your Kotlin Notebook:

- The Kotlin DataFrame library gives you the power to manipulate data in your Kotlin projects. You can use it to retrieve data from APIs, SQL databases, and various file formats, such as CSV or JSON.
- The Kandy library provides a powerful and flexible DSL for creating charts.

To add these libraries:

1. Click Add Code Cell to create a new code cell.
2. Enter the following code in the code cell:

```
// Ensures that the latest available library versions are used
%useLatestDescriptors

// Imports the Kotlin DataFrame library
%use dataframe

// Imports the Kotlin Kandy library
%use kandy
```

3. Run the code cell.

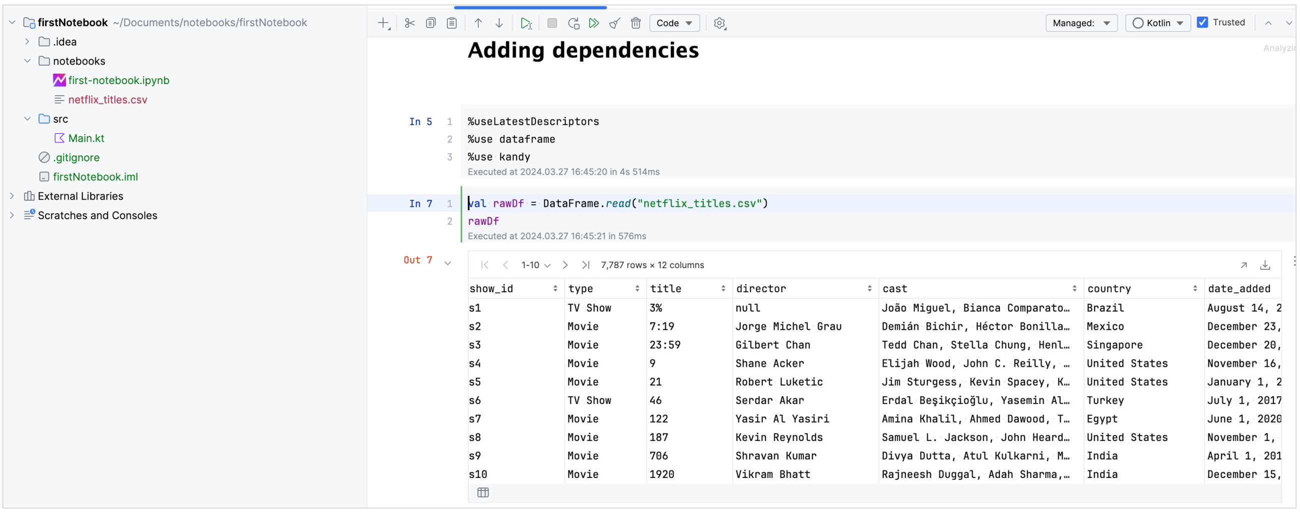
   When a %use statement is executed, it downloads the library dependencies and adds the default imports to your notebook.

   Make sure to run the code cell with the %use libraryName line before you run any other code cells that rely on the library.

4. To import data from a CSV file using the Kotlin DataFrame library, use the .read() function in a new code cell:

```
// Creates a DataFrame by importing data from the "netflix_titles.csv" file.
val rawDf = DataFrame.read("netflix_titles.csv")

// Displays the raw DataFrame data
rawDf
```

   You can download this example CSV from the Kotlin DataFrame examples GitHub repository. Add it to your project directory.



Adding dependencies

In 5
```
%useLatestDescriptors
%use dataframe
%use kandy
```
Executed at 2024.03.27 16:45:20 in 4s 514ms

In 7
```
val rawDf = DataFrame.read("netflix_titles.csv")
rawDf
```
Executed at 2024.03.27 16:45:21 in 576ms

Out 7

1-10 7,787 rows × 12 columns

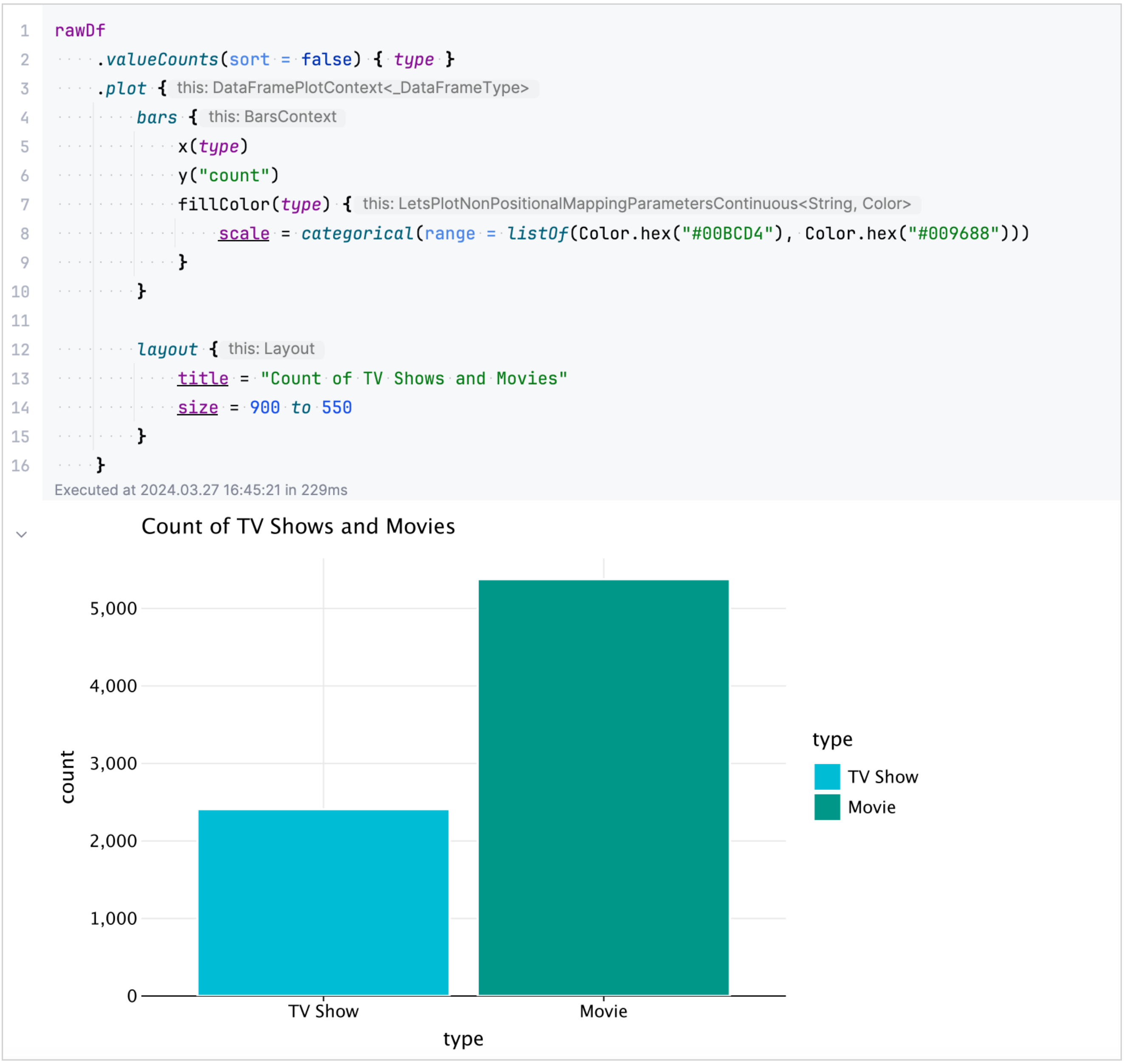
show_id	type	title	director	cast	country	date_added
s1	TV Show	3%	null	João Miguel, Bianca Comparato…	Brazil	August 14, 2
s2	Movie	7:19	Jorge Michel Grau	Demián Bichir, Héctor Bonilla…	Mexico	December 23,
s3	Movie	23:59	Gilbert Chan	Tedd Chan, Stella Chung, Henl…	Singapore	December 20,
s4	Movie	9	Shane Acker	Elijah Wood, John C. Reilly, …	United States	November 16,
s5	Movie	21	Robert Luketic	Jim Sturgess, Kevin Spacey, K…	United States	January 1, 2
s6	TV Show	46	Serdar Akar	Erdal Beşikçioğlu, Yasemin Al…	Turkey	July 1, 2017
s7	Movie	122	Yasir Al Yasiri	Amina Khalil, Ahmed Dawood, T…	Egypt	June 1, 2020
s8	Movie	187	Kevin Reynolds	Samuel L. Jackson, John Heard…	United States	November 1,
s9	Movie	706	Shravan Kumar	Divya Dutta, Atul Kulkarni, M…	India	April 1, 201
s10	Movie	1920	Vikram Bhatt	Rajneesh Duggal, Adah Sharma,…	India	December 15,

Using DataFrame to display data

5. In a new code cell, use the .plot method to visually represent the distribution of TV shows and Movies in your DataFrame:

```
rawDf
    // Counts the occurrences of each unique value in the column named "type"
    .valueCounts(sort = false) { type }
    // Visualizes data in a bar chart specifying the colors
    .plot {
        bars {
            x(type)
            y("count")
            fillColor(type) {
                scale = categorical(range = listOf(Color.hex("#00BCD4"), Color.hex("#009688")))
            }
        }

        // Configures the layout of the chart and sets the title
        layout {
            title = "Count of TV Shows and Movies"
            size = 900 to 550
        }
    }
```

The resulting chart:



```
rawDf
    .valueCounts(sort = false) { type }
    .plot { this: DataFramePlotContext<_DataFrameType>
        bars { this: BarsContext
            x(type)
            y("count")
            fillColor(type) { this: LetsPlotNonPositionalMappingParametersContinuous<String, Color>
                scale = categorical(range = listOf(Color.hex("#00BCD4"), Color.hex("#009688")))
            }
        }

        layout { this: Layout
            title = "Count of TV Shows and Movies"
            size = 900 to 550
        }
    }
```

Executed at 2024.03.27 16:45:21 in 229ms

Visualization using the Kandy library

Congratulations on adding and utilizing these libraries in your Kotlin Notebook! This is just a glimpse into what you can achieve with Kotlin Notebook and its supported libraries.

What's next

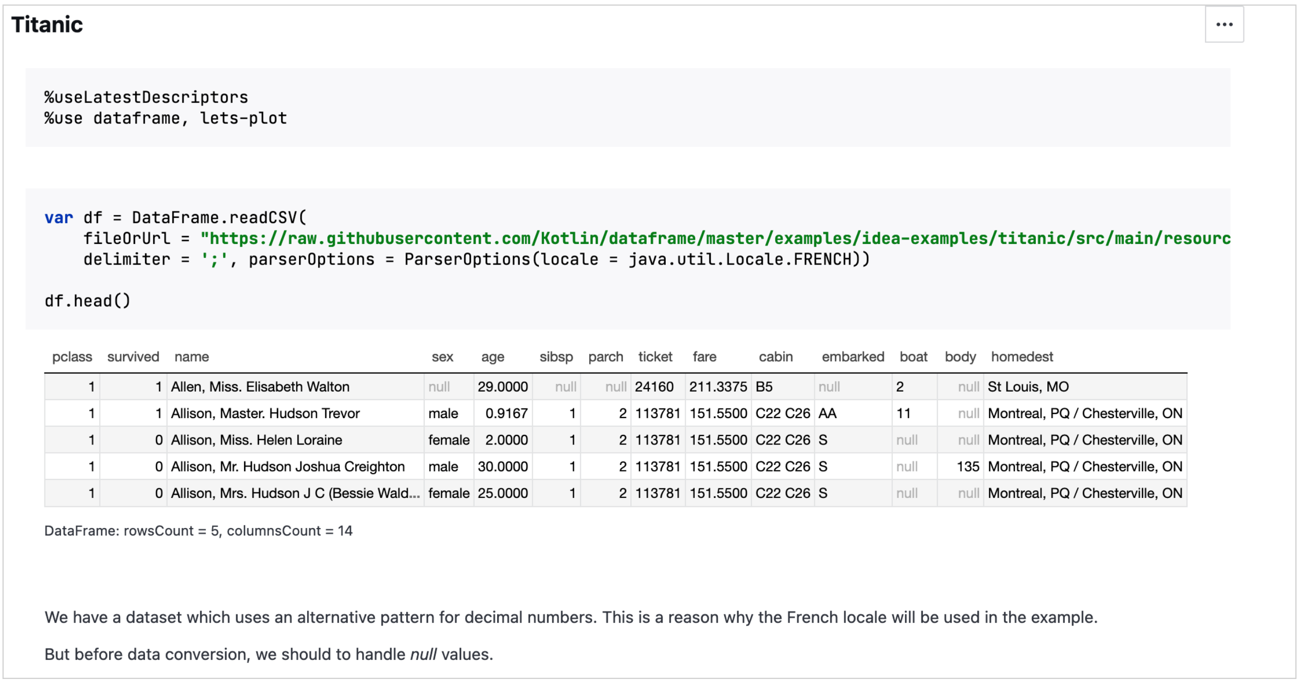
- Learn how to share your Kotlin Notebook
- See more details about adding dependencies to your Kotlin Notebook
- For a more extensive guide using the Kotlin DataFrame library, see Retrieve data from files
- For an extensive overview of tools and resources available for data science and analysis in Kotlin, see Kotlin and Java libraries for data analysis

Share your Kotlin Notebook

To share a Kotlin Notebook, you can just upload it to any notebook web viewer because Kotlin notebooks follow the universal Jupyter format.

We recommend the following platforms to share Kotlin notebooks:

* JetBrains Datalore: This platform not only facilitates the sharing of Kotlin notebooks but also improves their usability. Datalore allows you to execute and edit notebooks, and incorporates advanced features, such as creating interactive reports and scheduling notebook runs. To see it in action, see Kotlin Datalore example using DataFrame.



Titanic

```
%useLatestDescriptors
%use dataframe, lets-plot
```

```
var df = DataFrame.readCSV(
    fileOrUrl = "https://raw.githubusercontent.com/Kotlin/dataframe/master/examples/idea-examples/titanic/src/main/resourc
    delimiter = ';', parserOptions = ParserOptions(locale = java.util.Locale.FRENCH))

df.head()
```

pclass	survived	name	sex	age	sibsp	parch	ticket	fare	cabin	embarked	boat	body	homedest
1	1	Allen, Miss. Elisabeth Walton	null	29.0000	null	null	24160	211.3375	B5	null	2	null	St Louis, MO
1	1	Allison, Master. Hudson Trevor	male	0.9167	1	2	113781	151.5500	C22 C26	AA	11	null	Montreal, PQ / Chesterville, ON
1	0	Allison, Miss. Helen Loraine	female	2.0000	1	2	113781	151.5500	C22 C26	S	null	null	Montreal, PQ / Chesterville, ON
1	0	Allison, Mr. Hudson Joshua Creighton	male	30.0000	1	2	113781	151.5500	C22 C26	S	null	135	Montreal, PQ / Chesterville, ON
1	0	Allison, Mrs. Hudson J C (Bessie Wald...	female	25.0000	1	2	113781	151.5500	C22 C26	S	null	null	Montreal, PQ / Chesterville, ON

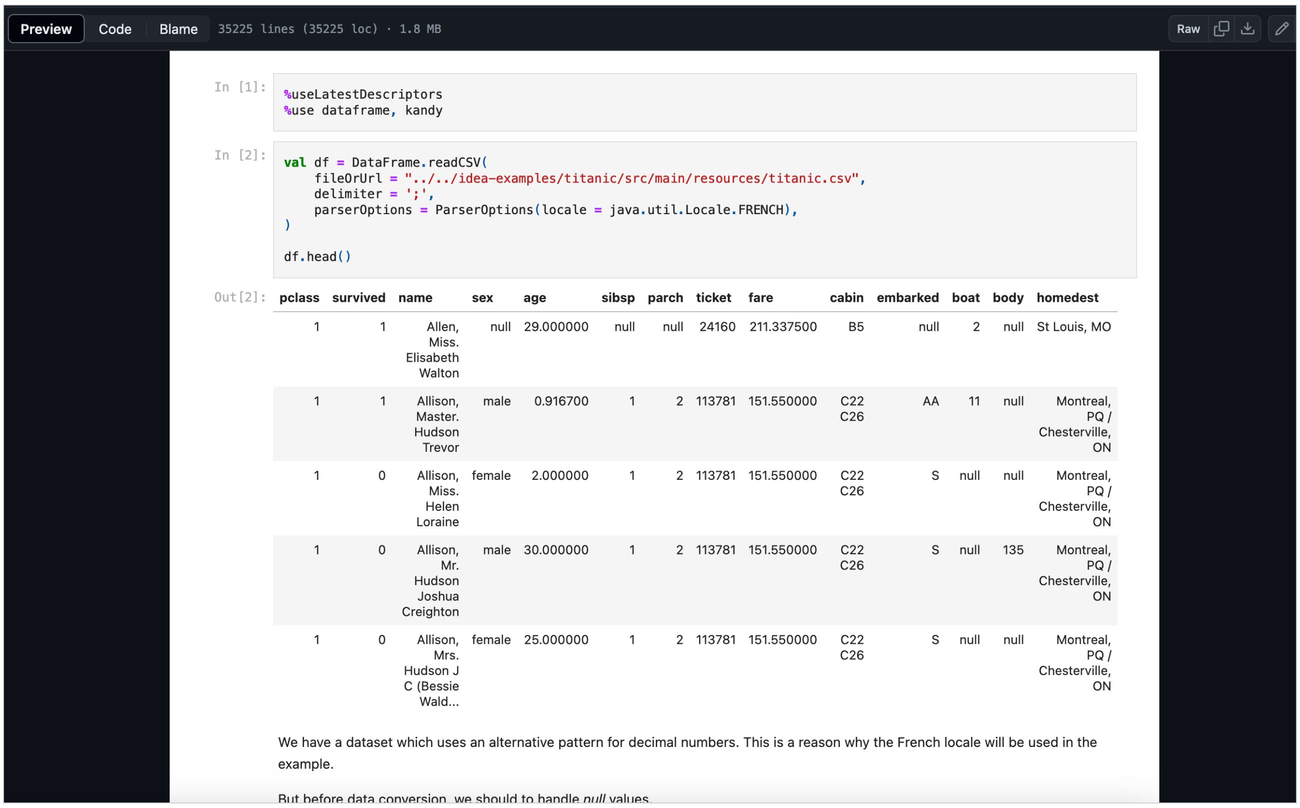
```
DataFrame: rowsCount = 5, columnsCount = 14
```

We have a dataset which uses an alternative pattern for decimal numbers. This is a reason why the French locale will be used in the example.

But before data conversion, we should to handle *null* values.

Datalore Notebook example

* GitHub: GitHub natively renders Kotlin notebooks, allowing for straightforward sharing and collaboration. For an example, see the Examples of Kotlin DataFrame GitHub repository.



In [1]:

```
%useLatestDescriptors
%use dataframe, kandy
```

In [2]:

```
val df = DataFrame.readCSV(
    fileOrUrl = "../../idea-examples/titanic/src/main/resources/titanic.csv",
    delimiter = ';',
    parserOptions = ParserOptions(locale = java.util.Locale.FRENCH),
)

df.head()
```

Out[2]:

pclass	survived	name	sex	age	sibsp	parch	ticket	fare	cabin	embarked	boat	body	homedest
1	1	Allen, Miss. Elisabeth Walton	null	29.000000	null	null	24160	211.337500	B5	null	2	null	St Louis, MO
1	1	Allison, Master. Hudson Trevor	male	0.916700	1	2	113781	151.550000	C22 C26	AA	11	null	Montreal, PQ / Chesterville, ON
1	0	Allison, Miss. Helen Loraine	female	2.000000	1	2	113781	151.550000	C22 C26	S	null	null	Montreal, PQ / Chesterville, ON
1	0	Allison, Mr. Hudson Joshua Creighton	male	30.000000	1	2	113781	151.550000	C22 C26	S	null	135	Montreal, PQ / Chesterville, ON
1	0	Allison, Mrs. Hudson J C (Bessie Wald...	female	25.000000	1	2	113781	151.550000	C22 C26	S	null	null	Montreal, PQ / Chesterville, ON

We have a dataset which uses an alternative pattern for decimal numbers. This is a reason why the French locale will be used in the example.

But before data conversion, we should to handle *null* values.

GitHub Notebook example

What's next

- Explore data visualization using the Kandy library
- Learn about retrieving data from files, web sources, or databases in Working with data sources
- For an extensive overview of tools and resources available for data science and analysis in Kotlin, see Kotlin and Java libraries for data analysis

Output formats supported by Kotlin Notebook

Kotlin Notebook supports a variety of output types, including text, HTML, and images. With the help of external libraries, you can expand your output options and visualize your data with charts, spreadsheets, and more.

Each output is a JSON object that maps the Jupiter MIME type to some data. From this map, Kotlin Notebook selects the supported MIME type with the highest priority among other types and renders it like this:

- Text uses the text/plain MIME type.
- The BufferedImage class uses the image/png MIME type that is mapped to a Base64 string.
- The Image class, as well as the LaTeX format, use the text/html MIME type with the img tag inside.
- Kotlin DataFrame tables and Kandy plots use their own internal MIME types, which are backed by static HTML or images. This way, you can display them on GitHub.

You can set up the mapping manually, for example, to use Markdown as a cell output:

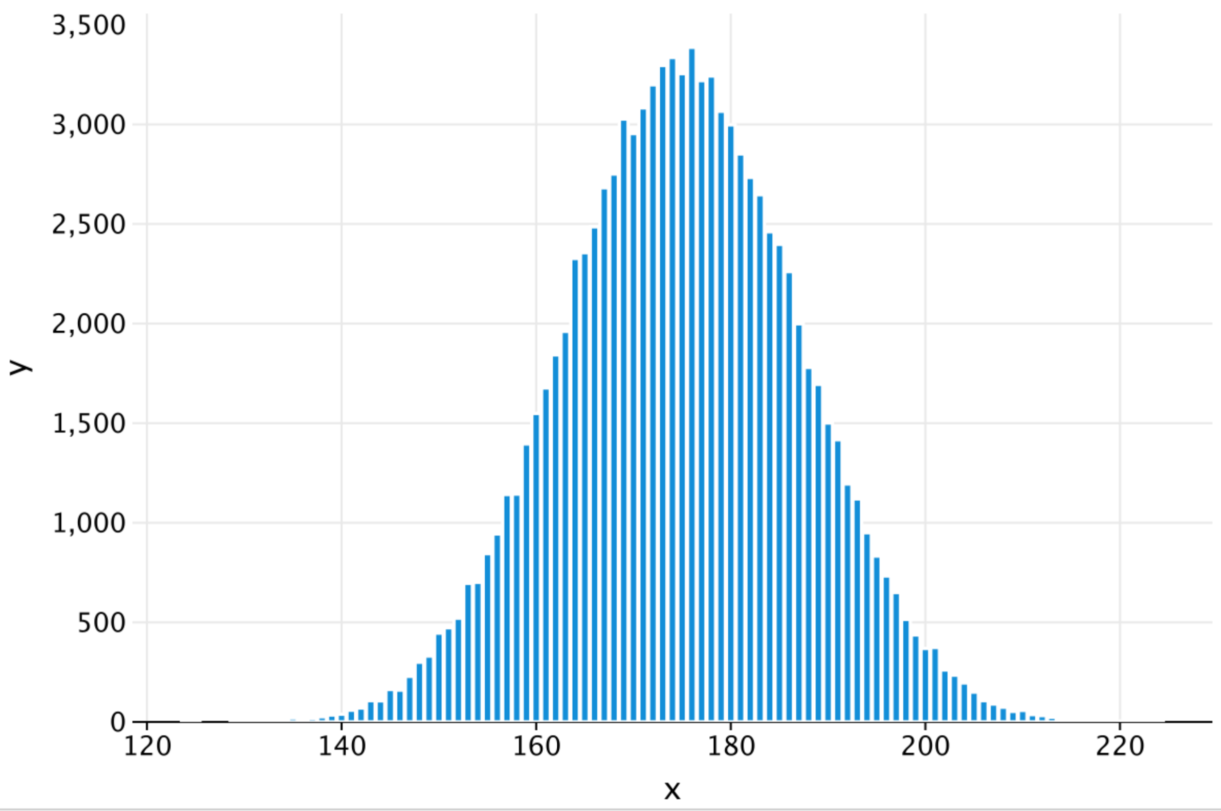
```
MimeTypedResult(
    mapOf(
        "text/plain" to "123",
        "text/markdown" to "# HEADER",
        //other mime:value pairs
    )
)
```

To display any kind of output, use the DISPLAY() function. It also enables the combination of several outputs:

```
DISPLAY(HTML("<h2>Gaussian distribution</h2>"))
DISPLAY(LATEX("f(x) = \\frac{1}{\\sigma \\sqrt{2\\pi}} \\cdot e^{-\\frac{(x - \\mu)^2}{2\\sigma^2}}"))

val experimentX = experimentData.map { it.key }
val experimentY = experimentData.map { it.value }

DISPLAY(plot {
    bars {
        x(experimentX)
        y(experimentY)
    }
})
```

Gaussian distribution

$$f(x) = \frac{1}{\sigma \sqrt{2\pi}} \cdot e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$



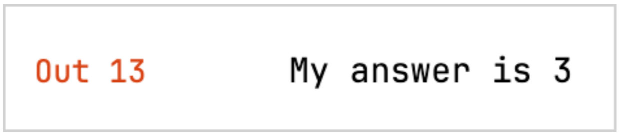
Different outputs for Gaussian distribution

Texts

Plain text

The simplest output type is plain text. It's used in printed statements, variable values, or any text-based output from your code:

```kotlin
val a1: Int = 1
val a2: Int = 2
var a3: Int? = a1 + a2

"My answer is $a3"
```



```
Out 13          My answer is 3
```

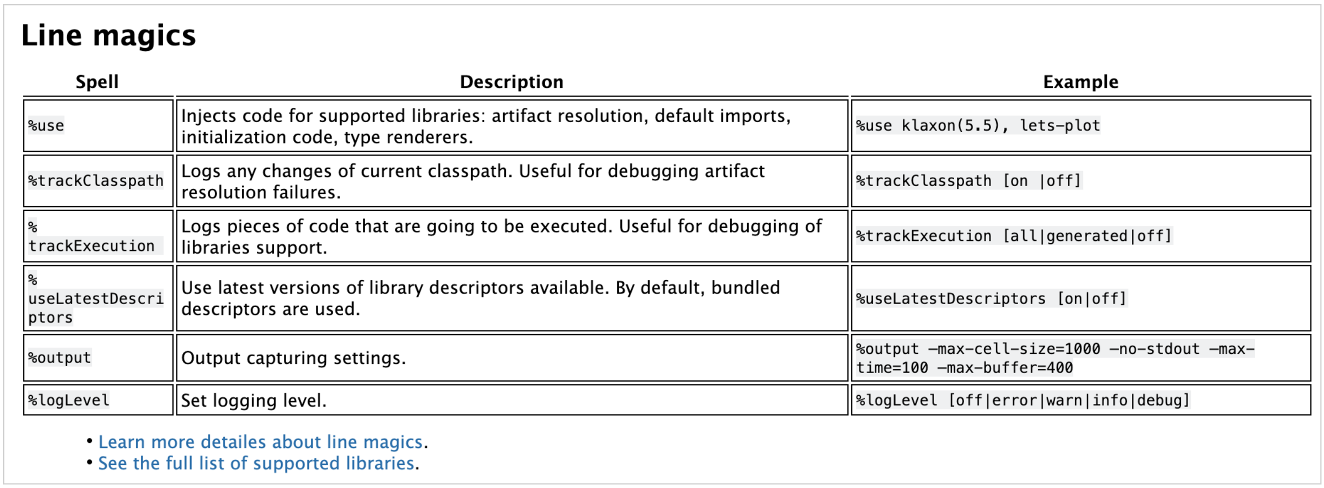
Plain text code output

- If a cell's result cannot be rendered and displayed as any of the output types, it will be printed as plain text using the toString() function.
- If your code contains errors, Kotlin Notebook displays an error message and a traceback, providing insights for debugging.

Rich text

Choose cells of the Markdown type to use rich text. This way, you can format the content with Markdown and HTML markup, using lists, tables, font styles, code blocks, and more. HTML can contain CSS styles and JavaScript.

```
## Line magics

| Spell                              | Description
| Example                                                                                      |
|------------------------------------|-------------------------------------------------------------------------------------------
------------------------|-------------------------------------------------------------------------------------|
| <code>%use</code>                  | Injects code for supported libraries: artifact resolution, default imports, initialization
code, type renderers. | <code>%use klaxon(5.5), lets-plot</code>                                        |
| <code>%trackClasspath</code>       | Logs any changes of current classpath. Useful for debugging artifact resolution failures.
| <code>%trackClasspath [on |off]</code>                                                       |
| <code>%trackExecution</code>       | Logs pieces of code that are going to be executed. Useful for debugging of libraries support.
| <code>%trackExecution [all|generated|off]</code>                                             |
| <code>%useLatestDescriptors</code> | Use latest versions of library descriptors available. By default, bundled descriptors are
used.                  | <code>%useLatestDescriptors [on|off]</code>                                           |
| <code>%output</code>               | Output capturing settings.
| <code>%output --max-cell-size=1000 --no-stdout --max-time=100 --max-buffer=400</code> |
| <code>%logLevel</code>             | Set logging level.
| <code>%logLevel [off|error|warn|info|debug]</code>                                           |

<ul><li><a href="https://github.com/Kotlin/kotlin-jupyter/blob/master/docs/magics.md">Learn more detailes about line magics</a>.</li>
<li><a href="https://github.com/Kotlin/kotlin-jupyter/blob/master/docs/magics.md">See the full list of supported libraries</a>.</li>
</ul>
```



Line magics

Spell	Description	Example
`%use`	Injects code for supported libraries: artifact resolution, default imports, initialization code, type renderers.	`%use klaxon(5.5), lets-plot`
`%trackClasspath`	Logs any changes of current classpath. Useful for debugging artifact resolution failures.	`%trackClasspath [on |off]`
`%trackExecution`	Logs pieces of code that are going to be executed. Useful for debugging of libraries support.	`%trackExecution [all|generated|off]`
`%useLatestDescriptors`	Use latest versions of library descriptors available. By default, bundled descriptors are used.	`%useLatestDescriptors [on|off]`
`%output`	Output capturing settings.	`%output –max-cell-size=1000 –no-stdout –max-time=100 –max-buffer=400`
`%logLevel`	Set logging level.	`%logLevel [off|error|warn|info|debug]`

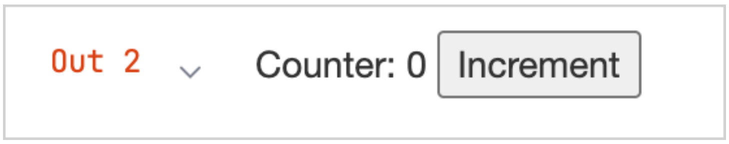
- Learn more detailes about line magics.
- See the full list of supported libraries.

Rich text in Markdown cells

HTML

Kotlin Notebook can render HTML directly, executing scripts or even embedding websites:

```
HTML("""
<p>Counter: <span id="ctr">0</span> <button onclick="inc()">Increment</button></p>
<script>
    function inc() {
        let counter = document.getElementById("ctr")
        counter.innerHTML = parseInt(counter.innerHTML) + 1;
}
</script>
""")
```



Using HTML script

Mark your notebook as Trusted at the top of the file to be able to execute scripts.

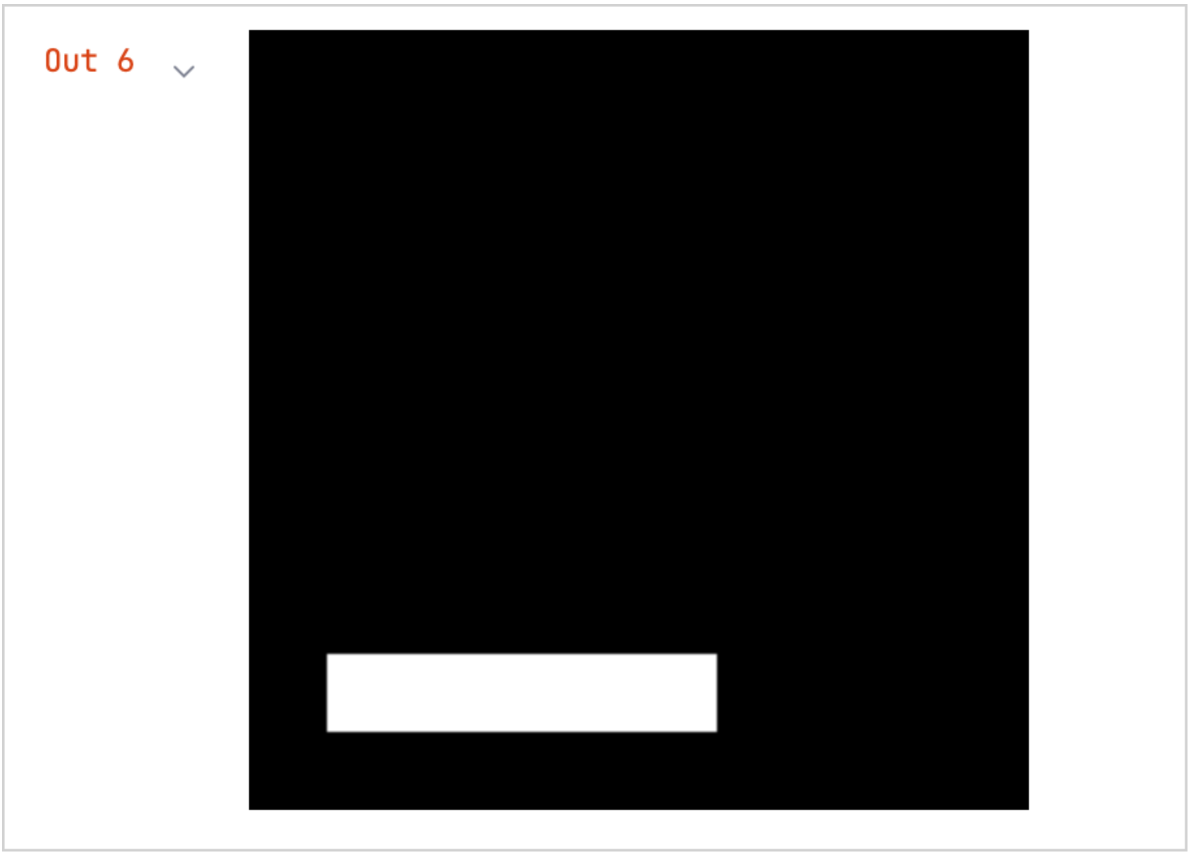
Images

With Kotlin Notebook, you can display images from files, generated graphs, or any other visual media. Static images can be displayed in formats such as .png, jpeg, and .svg.

Buffered images

By default, you can use BufferedImage class to display images:

```
import java.awt.Color
import java.awt.image.BufferedImage

val width = 300
val height = width

val image = BufferedImage(width, height, BufferedImage.TYPE_INT_ARGB)

val graphics = image.createGraphics()
graphics.background = Color.BLACK
graphics.clearRect(0, 0, width, height)
graphics.setRenderingHint(
    java.awt.RenderingHints.KEY_ANTIALIASING,
    java.awt.RenderingHints.VALUE_ANTIALIAS_ON
)
graphics.color = Color.WHITE
graphics.fillRect(width / 10, height * 8 / 10, width * 10 / 20, height / 10)
graphics.dispose()
```



Using default BufferedImage to display images

Loaded images

With the help of the lib-ext library, you can extend the standard Jupyter functionality and display images loaded from the network:

```
%use lib-ext(0.11.0-398)
```

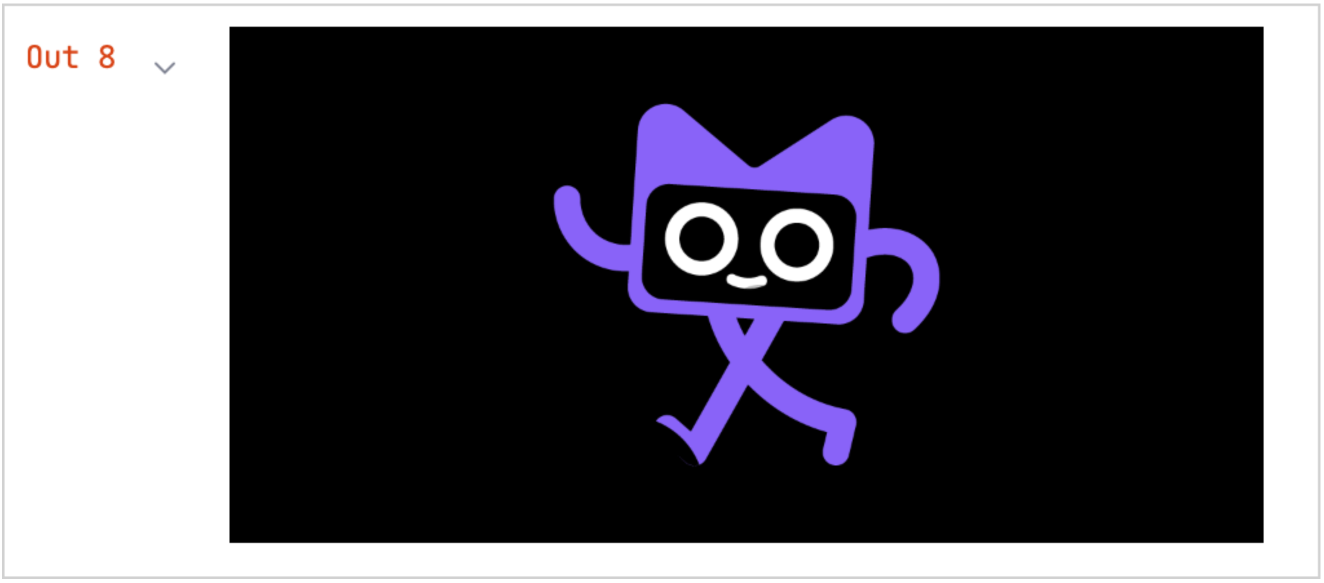
```
Image("https://kotlinlang.org/docs/images/kotlin-logo.png", embed = false).withWidth(300)
```

Using external image links

Embedded images

A disadvantage of images loaded from the network is that the image disappears if the link breaks or if you lose the network connection. To work around that, use embedded images, for example:

```
val kotlinMascot = Image("https://blog.jetbrains.com/wp-content/uploads/2023/04/DSGN-16174-Blog-post-banner-and-promo-materials-for-
post-about-Kotlin-mascot_3.png", embed = true).withWidth(400)
kotlinMascot
```



Using embedded images

Math formulas and equations

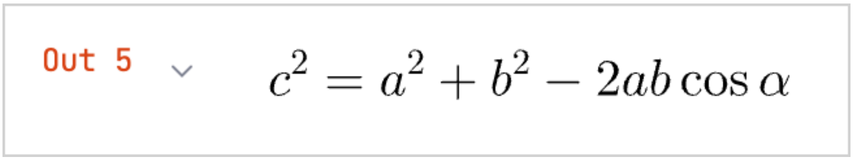
You can render mathematical formulas and equations using the LaTeX format, a typesetting system widely used in academia:

1. Add the lib-ext library that extends the functionality of the Jupyter kernel to your notebook:

```
%use lib-ext(0.11.0-398)
```

2. In the new cell, run your formula:

```
LATEX("c^2 = a^2 + b^2 - 2 a b \\cos\\alpha")
```



$$c^2 = a^2 + b^2 - 2ab\cos\alpha$$

Using LaTeX to render mathematical formulas

Data frames

With Kotlin Notebook, you can visualize structured data with data frames:

1. Add the Kotlin DataFrame library to your notebook:

```
%use dataframe
```

2. Create the data frame and run it in the new cell:

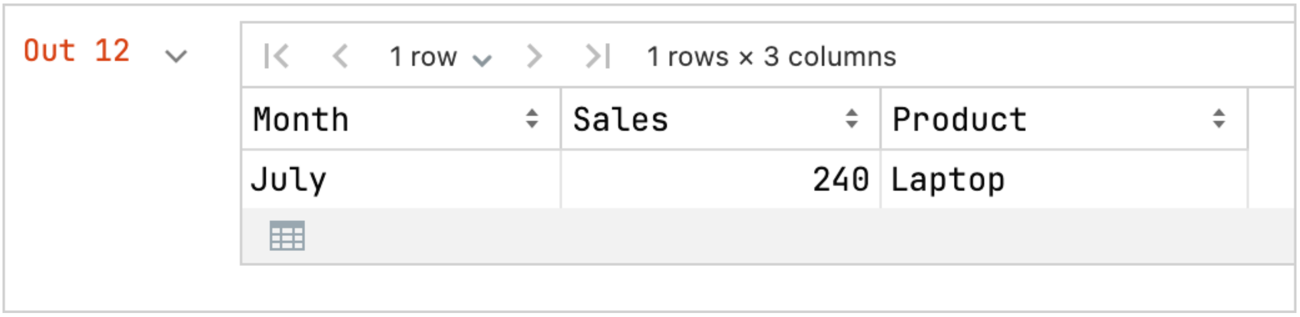
```
val months = listOf(
    "January", "February",
    "March", "April", "May",
    "June", "July", "August",
    "September", "October", "November",
    "December"
)
```

```
// Sales data for different products and months:
val salesLaptop = listOf(120, 130, 150, 180, 200, 220, 240, 230, 210, 190, 160, 140)
val salesSmartphone = listOf(90, 100, 110, 130, 150, 170, 190, 180, 160, 140, 120, 100)
val salesTablet = listOf(60, 70, 80, 90, 100, 110, 120, 110, 100, 90, 80, 70)

// A data frame with columns for Month, Sales, and Product
val dfSales = dataFrameOf(
    "Month" to months + months + months,
    "Sales" to salesLaptop + salesSmartphone + salesTablet,
    "Product" to List(12) { "Laptop" } + List(12) { "Smartphone" } + List(12) { "Tablet" },
)
```

The data frame uses the dataFrameOf() function and includes the number of products (laptops, smartphones, and tablets) sold in a 12-month period.

3. Explore the data in your frame, for example, by finding the product and month with the highest sales:

```
dfSales.maxBy("Sales")
```



Out 12

1 row 1 rows × 3 columns

Month	Sales	Product
July	240	Laptop

Using DataFrame to visualize data

4. You can also export your data frame as a CSV file:

```
// Export your data to CSV format
dfSales.writeCSV("sales-stats.csv")
```

Charts

You can create various charts directly in your Kotlin Notebook to visualize your data:

1. Add the Kandy plotting library to your notebook:

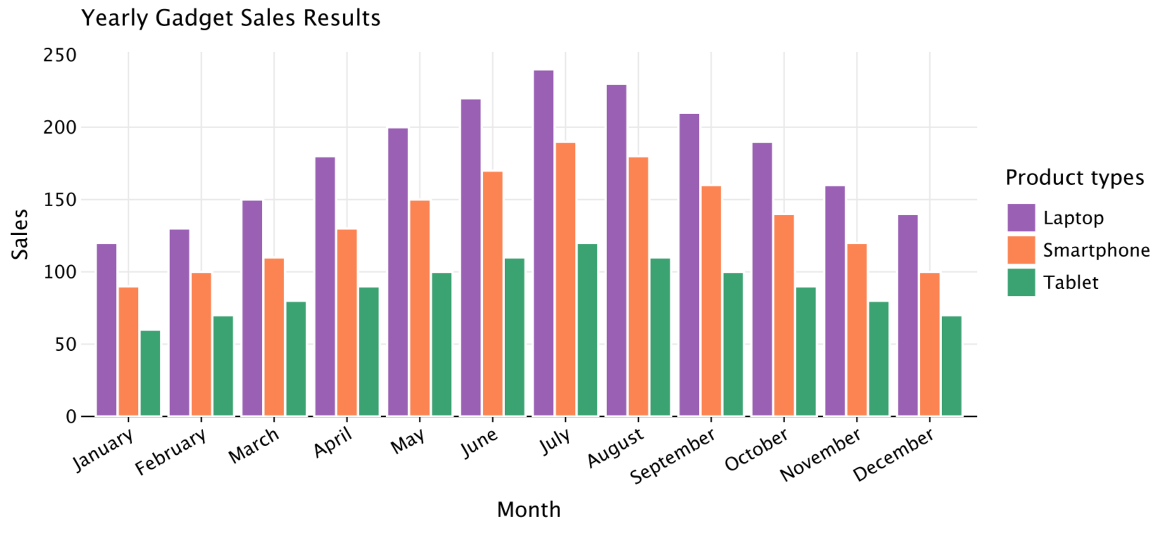
```
%use kandy
```

2. Use the same data frame and run the plot() function in the new cell:

```
val salesPlot = dfSales.groupBy { Product }.plot {
    bars {
        // Access the data frame's columns used for the X and Y axes
        x(Month)
        y(Sales)
        // Access the data frame's column used for categories and sets colors for these categories
        fillColor(Product) {
            scale = categorical(
                "Laptop" to Color.PURPLE,
                "Smartphone" to Color.ORANGE,
                "Tablet" to Color.GREEN
            )
            legend.name = "Product types"
        }
    }
    // Customize the chart's appearance
    layout.size = 1000 to 450
    layout.title = "Yearly Gadget Sales Results"
}
```

```
salesPlot
```

Out 9



Using Kandy to render visualize data

3. You can also export your plot in the .png, jpeg, .html, or .svg format:

```
// Specify the output format for the plot file:
salesPlot.save("sales-chart.svg")
```

What's next

- Visualize data using the DataFrame and Kandy libraries
- Learn more about rendering and displaying rich output in Kotlin Notebook
- Retrieve data from the CSV and JSON files
- Check out the list of recommended libraries

Retrieve data from files

Kotlin Notebook, coupled with the Kotlin DataFrame library, enables you to work with both non-structured and structured data. This combination offers the flexibility to transform non-structured data, such as data found in TXT files, into structured datasets.

For data transformations, you can use such methods as add, split, convert, and parse. Additionally, this toolset enables the retrieval and manipulation of data from various structured file formats, including CSV, JSON, XLS, XLSX, and Apache Arrow.

In this guide, you can learn how to retrieve, refine, and handle data through multiple examples.

Before you start

Kotlin Notebook relies on the Kotlin Notebook plugin, which is bundled and enabled in IntelliJ IDEA by default.

If the Kotlin Notebook features are not available, ensure the plugin is enabled. For more information, see Set up an environment.

Create a new Kotlin Notebook:

1. Select File | New | Kotlin Notebook.
2. In the Kotlin Notebook, import the Kotlin DataFrame library by running the following command:

```
%use dataframe
```

Retrieve data from a file

To retrieve data from a file in Kotlin Notebook:

1. Open your Kotlin Notebook file (.ipynb).
2. Import the Kotlin DataFrame library by adding %use dataframe in a code cell at the start of your notebook.

> Make sure to run the code cell with the %use dataframe line before you run any other code cells that rely on the Kotlin DataFrame library.

3. Use the .read() function from the Kotlin DataFrame library to retrieve data. For example, to read a CSV file, use: DataFrame.read("example.csv").

The .read() function automatically detects the input format based on the file extension and content. You can also add other arguments to customize the function, such as specifying the delimiter with delimiter = ';'.

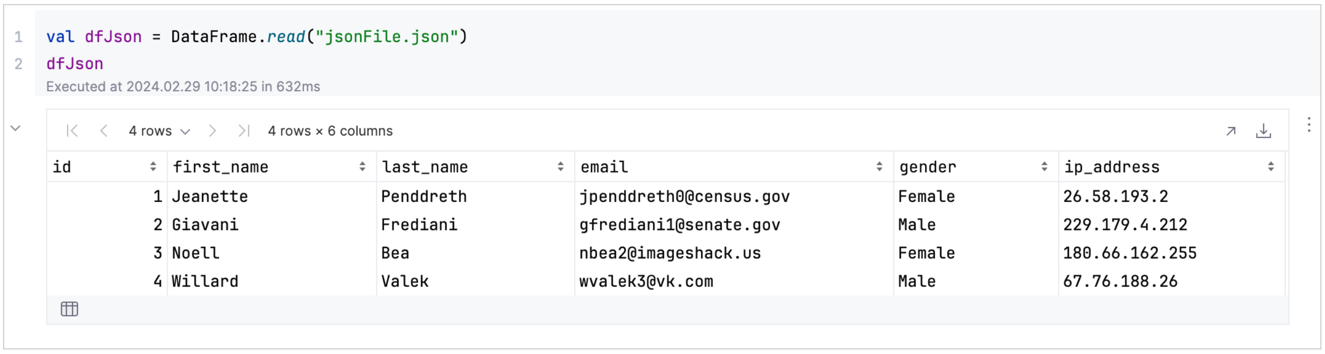
> For a comprehensive overview of additional file formats and a variety of read functions, see the Kotlin DataFrame library documentation.

Display data

Once you have the data in your notebook, you can easily store it in a variable and access it by running the following in a code cell:

```
val dfJson = DataFrame.read("jsonFile.json")
dfJson
```

This code displays the data from the file of your choice, such as CSV, JSON, XLS, XLSX, or Apache Arrow.



```
val dfJson = DataFrame.read("jsonFile.json")
dfJson
```

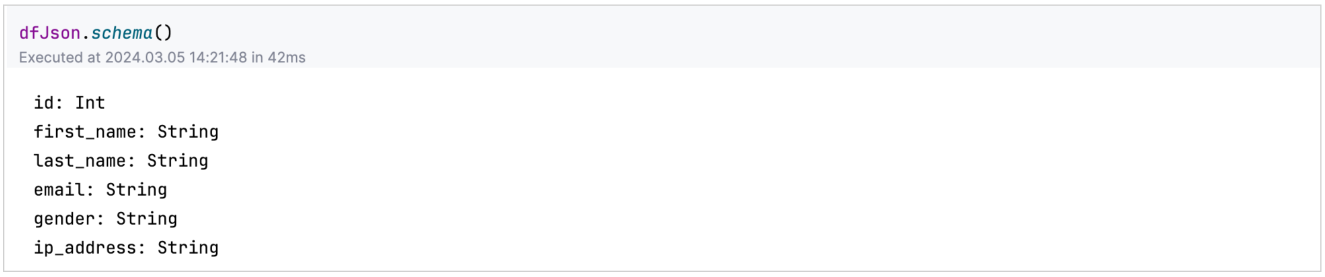
Executed at 2024.02.29 10:18:25 in 632ms

4 rows × 6 columns

id	first_name	last_name	email	gender	ip_address
1	Jeanette	Penddreth	jpenddreth0@census.gov	Female	26.58.193.2
2	Giavani	Frediani	gfrediani1@senate.gov	Male	229.179.4.212
3	Noell	Bea	nbea2@imageshack.us	Female	180.66.162.255
4	Willard	Valek	wvalek3@vk.com	Male	67.76.188.26

Display data

To gain insights into the structure or schema of your data, apply the .schema() function on your DataFrame variable. For example, dfJson.schema() lists the type of each column in your JSON dataset.



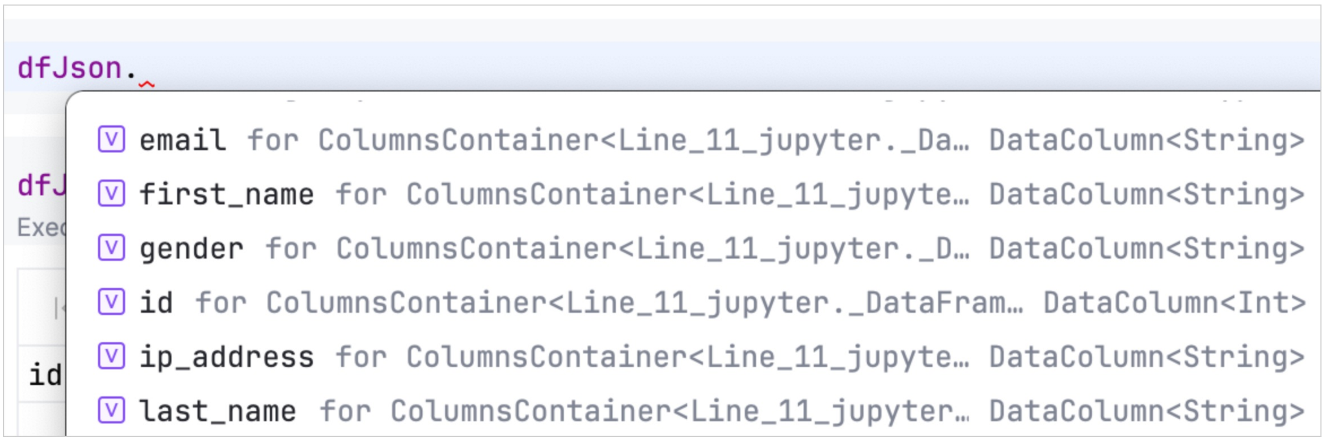
```
dfJson.schema()
```

Executed at 2024.03.05 14:21:48 in 42ms

```
id: Int
first_name: String
last_name: String
email: String
gender: String
ip_address: String
```

Schema example

You can also use the autocompletion feature in Kotlin Notebook to quickly access and manipulate the properties of your DataFrame. After loading your data, simply type the DataFrame variable followed by a dot to see a list of available columns and their types.



```
dfJson.
email for ColumnsContainer<Line_11_jupyter._Da… DataColumn<String>
first_name for ColumnsContainer<Line_11_jupyte… DataColumn<String>
gender for ColumnsContainer<Line_11_jupyter._D… DataColumn<String>
id for ColumnsContainer<Line_11_jupyter._DataFram… DataColumn<Int>
ip_address for ColumnsContainer<Line_11_jupyte… DataColumn<String>
last_name for ColumnsContainer<Line_11_jupyter… DataColumn<String>
```

Available properties

Refine data

Among the various operations available in the Kotlin DataFrame library for refining your dataset, key examples include grouping, filtering, updating, and adding new columns. These functions are essential for data analysis, allowing you to organize, clean, and transform your data effectively.

Let's look at an example where the data includes movie titles and their corresponding release year in the same cell. The goal is to refine this dataset for easier analysis:

1. Load your data into the notebook using the .read() function. This example involves reading data from a CSV file named movies.csv and creating a DataFrame called movies:

```kotlin
val movies = DataFrame.read("movies.csv")
```

2. Extract the release year from the movie titles using regex and add it as a new column:

```kotlin
val moviesWithYear = movies
    .add("year") {
        "\\d{4}".toRegex()
            .findAll(title)
            .lastOrNull()
            ?.value
            ?.toInt()
            ?: -1
    }
```

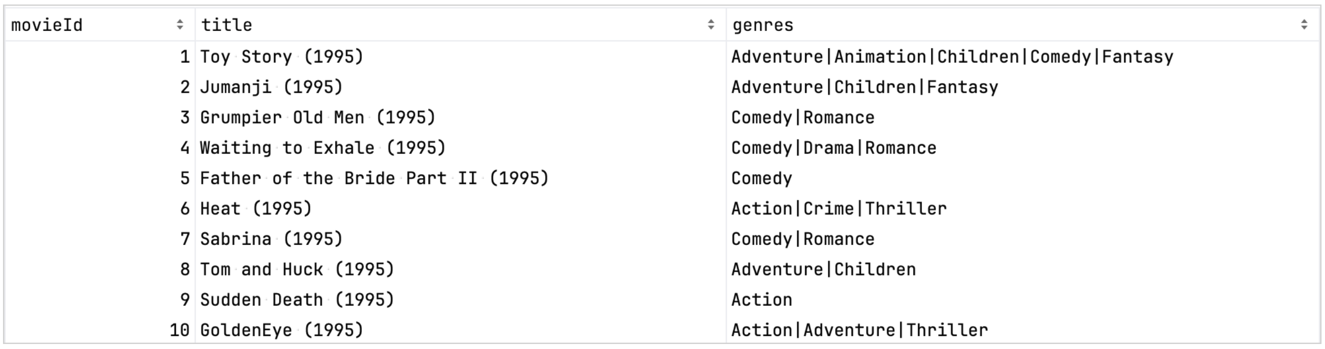
3. Modify the movie titles by removing the release year from each title. This cleans up the titles for consistency:

```kotlin
val moviesTitle = moviesWithYear
    .update("title") {
        "\\s*\\(\\d{4}\\)\\s*$".toRegex().replace(title, "")
    }
```

4. Use the filter method to focus on specific data. In this case, the dataset is filtered to focus on movies that were released after the year 1996:

```kotlin
val moviesNew = moviesWithYear.filter { year >= 1996 }
moviesNew
```

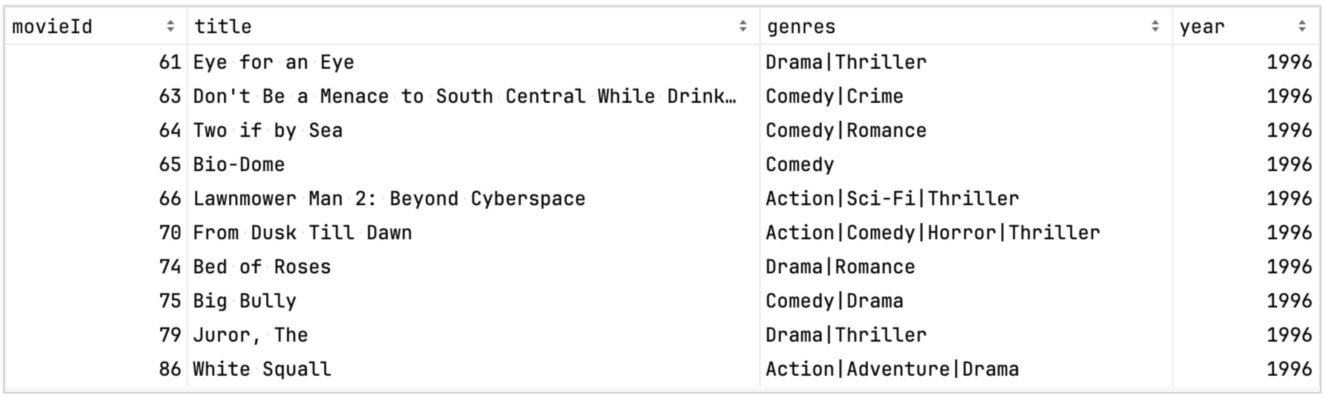
For comparison, here is the dataset before refinement:



movieId	title	genres
1	Toy Story (1995)	Adventure|Animation|Children|Comedy|Fantasy
2	Jumanji (1995)	Adventure|Children|Fantasy
3	Grumpier Old Men (1995)	Comedy|Romance
4	Waiting to Exhale (1995)	Comedy|Drama|Romance
5	Father of the Bride Part II (1995)	Comedy
6	Heat (1995)	Action|Crime|Thriller
7	Sabrina (1995)	Comedy|Romance
8	Tom and Huck (1995)	Adventure|Children
9	Sudden Death (1995)	Action
10	GoldenEye (1995)	Action|Adventure|Thriller

Original dataset

The refined dataset:



movieId	title	genres	year
61	Eye for an Eye	Drama|Thriller	1996
63	Don't Be a Menace to South Central While Drink…	Comedy|Crime	1996
64	Two if by Sea	Comedy|Romance	1996
65	Bio-Dome	Comedy	1996
66	Lawnmower Man 2: Beyond Cyberspace	Action|Sci-Fi|Thriller	1996
70	From Dusk Till Dawn	Action|Comedy|Horror|Thriller	1996
74	Bed of Roses	Drama|Romance	1996
75	Big Bully	Comedy|Drama	1996
79	Juror, The	Drama|Thriller	1996
86	White Squall	Action|Adventure|Drama	1996

Data refinement result

This is a practical demonstration of how you can use the Kotlin DataFrame library's methods, like add, update, and filter to effectively refine and analyze data in Kotlin.

> For additional use cases and detailed examples, see Examples of Kotlin Dataframe.

Save DataFrame

After refining data in Kotlin Notebook using the Kotlin DataFrame library, you can easily export your processed data. You can utilize a variety of .write() functions for this purpose, which support saving in multiple formats, including CSV, JSON, XLS, XLSX, Apache Arrow, and even HTML tables. This can be particularly useful for sharing your findings, creating reports, or making your data available for further analysis.

Here's how you can filter a DataFrame, remove a column, save the refined data to a JSON file, and open an HTML table in your browser:

1. In Kotlin Notebook, use the .read() function to load a file named movies.csv into a DataFrame named moviesDf:

```
val moviesDf = DataFrame.read("movies.csv")
```

2. Filter the DataFrame to only include movies that belong to the "Action" genre using the .filter method:

```
val actionMoviesDf = moviesDf.filter { genres.equals("Action") }
```

3. Remove the movieId column from the DataFrame using .remove:

```
val refinedMoviesDf = actionMoviesDf.remove { movieId }
refinedMoviesDf
```

4. The Kotlin DataFrame library offers various write functions to save data in different formats. In this example, the .writeJson() function is used to save the modified movies.csv as a JSON file:

```
refinedMoviesDf.writeJson("movies.json")
```

5. Use the .toStandaloneHTML() function to convert the DataFrame into a standalone HTML table and open it in your default web browser:

```
refinedMoviesDf.toStandaloneHTML(DisplayConfiguration(rowsLimit = null)).openInBrowser()
```

What's next

- Explore data visualization using the Kandy library
- Find additional information about data visualization in Data visualization in Kotlin Notebook with Kandy
- For an extensive overview of tools and resources available for data science and analysis in Kotlin, see Kotlin and Java libraries for data analysis

Retrieve data from web sources and APIs

Kotlin Notebook provides a powerful platform for accessing and manipulating data from various web sources and APIs. It simplifies data extraction and analysis tasks by offering an iterative environment where every step can be visualized for clarity. This makes it particularly useful when exploring APIs you are not familiar with.

When used in conjunction with the Kotlin DataFrame library, Kotlin Notebook not only enables you to connect to and fetch JSON data from APIs but also assists in reshaping this data for comprehensive analysis and visualization.

For Kotlin Notebook examples, see DataFrame examples on GitHub.

Before you start

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Create a new Kotlin Notebook:

1. Select File | New | Kotlin Notebook.
2. In the Kotlin Notebook, import the Kotlin DataFrame library by running the following command:

```
%use dataframe
```

Fetch data from an API

Fetching data from APIs using the Kotlin Notebook with the Kotlin DataFrame library is achieved through the .read() function, which is similar to retrieving data from files, such as CSV or JSON. However, when working with web-based sources, you might require additional formatting to transform the raw API data into a structured format.

Let's look at an example of fetching data from the YouTube Data API:

1. Open your Kotlin Notebook file (.ipynb).
2. Import the Kotlin DataFrame library, which is essential for data manipulation tasks. This is done by running the following command in a code cell:

```
%use dataframe
```

3. Securely add your API key in a new code cell, which is necessary for authenticating requests to the YouTube Data API. You can obtain your API key from the

credentials tab:

```
val apiKey = "YOUR-API_KEY"
```

4. Create a load function that takes a path as a string and uses the DataFrame's .read() function to fetch data from the YouTube Data API:

```
fun load(path: String): AnyRow = DataRow.read("https://www.googleapis.com/youtube/v3/$path&key=$apiKey")
```

5. Organize the fetched data into rows and handle the YouTube API's pagination through the nextPageToken. This ensures you gather data across multiple pages:

```
fun load(path: String, maxPages: Int): AnyFrame {

    // Initializes a mutable list to store rows of data.
    val rows = mutableListOf<AnyRow>()

    // Sets the initial page path for data loading.
    var pagePath = path
    do {

        // Loads data from the current page path.
        val row = load(pagePath)
        // Adds the loaded data as a row to the list.
        rows.add(row)

        // Retrieves the token for the next page, if available.
        val next = row.getValueOrNull<String>("nextPageToken")
        // Updates the page path for the next iteration, including the new token.
        pagePath = path + "&pageToken=" + next

        // Continues loading pages until there's no next page.
    } while (next != null && rows.size < maxPages)

    // Concatenates and returns all loaded rows as a DataFrame.
    return rows.concat()
}
```

6. Use the previously defined load() function to fetch data and create a DataFrame in a new code cell. This example fetches data, or in this case, videos related to Kotlin, with a maximum of 50 results per page, up to a maximum of 5 pages. The result is stored in the df variable:

```
val df = load("search?q=kotlin&maxResults=50&part=snippet", 5)
df
```

7. Finally, extract and concatenate items from the DataFrame:

```
val items = df.items.concat()
items
```

Clean and refine data

Cleaning and refining data are crucial steps in preparing your dataset for analysis. The Kotlin DataFrame library offers powerful functionalities for these tasks. Methods like move, concat, select, parse, and join are instrumental in organizing and transforming your data.

Let's explore an example where the data is already fetched using YouTube's data API. The goal is to clean and restructure the dataset to prepare for in-depth analysis:

1. You can start by reorganizing and cleaning your data. This involves moving certain columns under new headers and removing unnecessary ones for clarity:

```
val videos = items.dropNulls { id.videoId }
    .select { id.videoId named "id" and snippet }
    .distinct()
videos
```

2. Chunk IDs from the cleaned data and load corresponding video statistics. This involves breaking the data into smaller batches and fetching additional details:

```
val statPages = clean.id.chunked(50).map {
    val ids = it.joinToString("%2C")
```

```kotlin
    load("videos?part=statistics&id=$ids")
}
statPages
```

3. Concatenate the fetched statistics and select relevant columns:

```kotlin
val stats = statPages.items.concat().select { id and statistics.all() }.parse()
stats
```

4. Join the existing cleaned data with the newly fetched statistics. This merges two sets of data into a comprehensive DataFrame:

```kotlin
val joined = clean.join(stats)
joined
```

This example demonstrates how to clean, reorganize, and enhance your dataset using Kotlin DataFrame's various functions. Each step is designed to refine the data, making it more suitable for in-depth analysis.

Analyze data in Kotlin Notebook

After you've successfully fetched and cleaned and refined your data using functions from the Kotlin DataFrame library, the next step is to analyze this prepared dataset to extract meaningful insights.

Methods such as groupBy for categorizing data, sum and maxBy for summary statistics, and sortBy for ordering data are particularly useful. These tools allow you to perform complex data analysis tasks efficiently.

Let's look at an example, using groupBy to categorize videos by channel, sum to calculate total views per category, and maxBy to find the latest or most viewed video in each group:

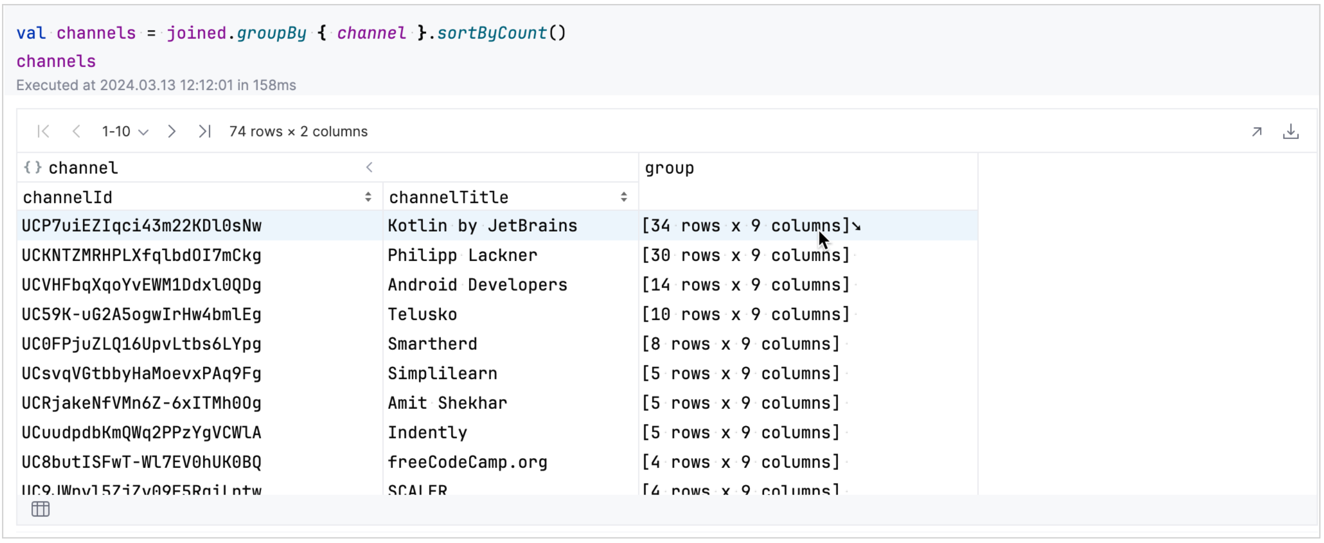
1. Simplify the access to specific columns by setting up references:

```kotlin
val view by column<Int>()
```

2. Use the groupBy method to group the data by the channel column and sort it.

```kotlin
val channels = joined.groupBy { channel }.sortByCount()
```

In the resulting table, you can interactively explore the data. Clicking on the group field of a row corresponding to a channel expands that row to reveal more details about that channel's videos.



```kotlin
val channels = joined.groupBy { channel }.sortByCount()
channels
```

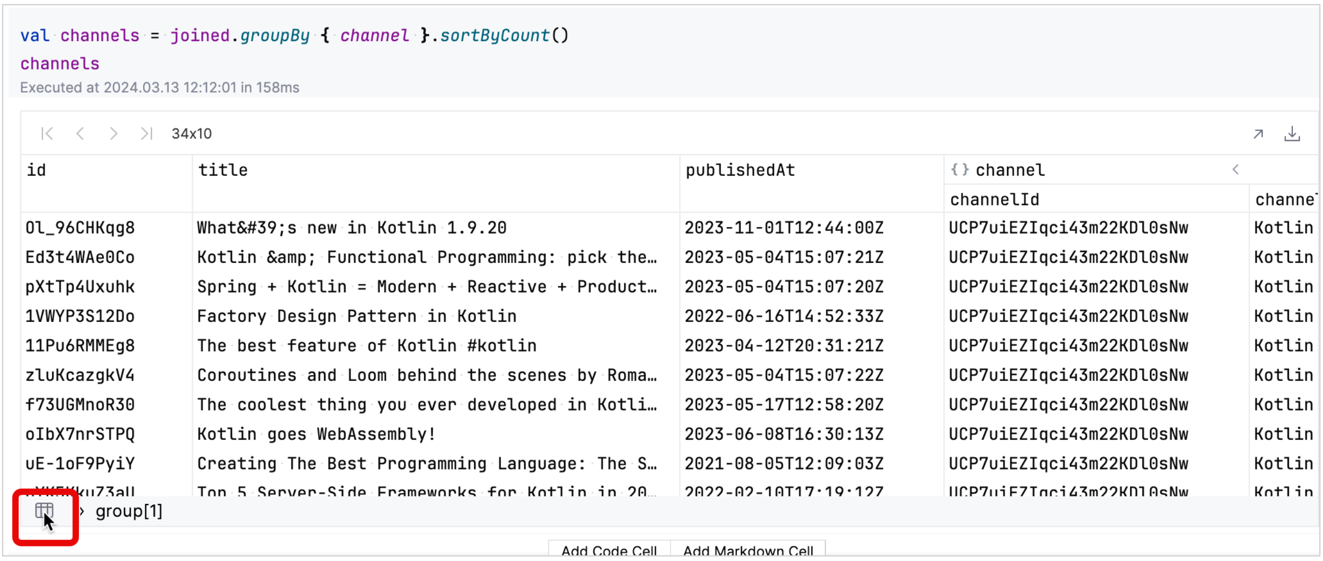
Executed at 2024.03.13 12:12:01 in 158ms

1-10 74 rows × 2 columns

channel		group
channelId	channelTitle	
UCP7uiEZIqci43m22KDl0sNw	Kotlin by JetBrains	[34 rows x 9 columns]
UCKNTZMRHPLXfqlbdOI7mCkg	Philipp Lackner	[30 rows x 9 columns]
UCVHFbqXqoYvEWM1Ddxl0QDg	Android Developers	[14 rows x 9 columns]
UC59K-uG2A5ogwIrHw4bmlEg	Telusko	[10 rows x 9 columns]
UC0FPjuZLQ16UpvLtbs6LYpg	Smartherd	[8 rows x 9 columns]
UCsvqVGtbbyHaMoevxPAq9Fg	Simplilearn	[5 rows x 9 columns]
UCRjakeNfVMn6Z-6xITMh0Og	Amit Shekhar	[5 rows x 9 columns]
UCuudpdbKmQWq2PPzYgVCWlA	Indently	[5 rows x 9 columns]
UC8butISFwT-Wl7EV0hUK0BQ	freeCodeCamp.org	[4 rows x 9 columns]
UC9JWnvl57i7v09F5RqiLntw	SCALER	[4 rows x 9 columns]

Expanding a row to reveal more details

You can click the table icon in the bottom left to return to the grouped dataset.



```
val channels = joined.groupBy { channel }.sortByCount()
channels
```

Executed at 2024.03.13 12:12:01 in 158ms

34x10

id	title	publishedAt	channel	
			channelId	channe
0l_96CHKqg8	What&#39;s new in Kotlin 1.9.20	2023-11-01T12:44:00Z	UCP7uiEZIqci43m22KDl0sNw	Kotlin
Ed3t4WAe0Co	Kotlin &amp; Functional Programming: pick the…	2023-05-04T15:07:21Z	UCP7uiEZIqci43m22KDl0sNw	Kotlin
pXtTp4Uxuhk	Spring + Kotlin = Modern + Reactive + Product…	2023-05-04T15:07:20Z	UCP7uiEZIqci43m22KDl0sNw	Kotlin
1VWYP3S12Do	Factory Design Pattern in Kotlin	2022-06-16T14:52:33Z	UCP7uiEZIqci43m22KDl0sNw	Kotlin
11Pu6RMMEg8	The best feature of Kotlin #kotlin	2023-04-12T20:31:21Z	UCP7uiEZIqci43m22KDl0sNw	Kotlin
zluKcazgkV4	Coroutines and Loom behind the scenes by Roma…	2023-05-04T15:07:22Z	UCP7uiEZIqci43m22KDl0sNw	Kotlin
f73UGMnoR30	The coolest thing you ever developed in Kotli…	2023-05-17T12:58:20Z	UCP7uiEZIqci43m22KDl0sNw	Kotlin
oIbX7nrSTPQ	Kotlin goes WebAssembly!	2023-06-08T16:30:13Z	UCP7uiEZIqci43m22KDl0sNw	Kotlin
uE-1oF9PyiY	Creating The Best Programming Language: The S…	2021-08-05T12:09:03Z	UCP7uiEZIqci43m22KDl0sNw	Kotlin
[illegible]ku73all	Top 5 Server-Side Frameworks for Kotlin in 20…	2022-02-10T17:19:12Z	UCP7uiEZIqci43m22KDl0sNw	Kotlin

› group[1]

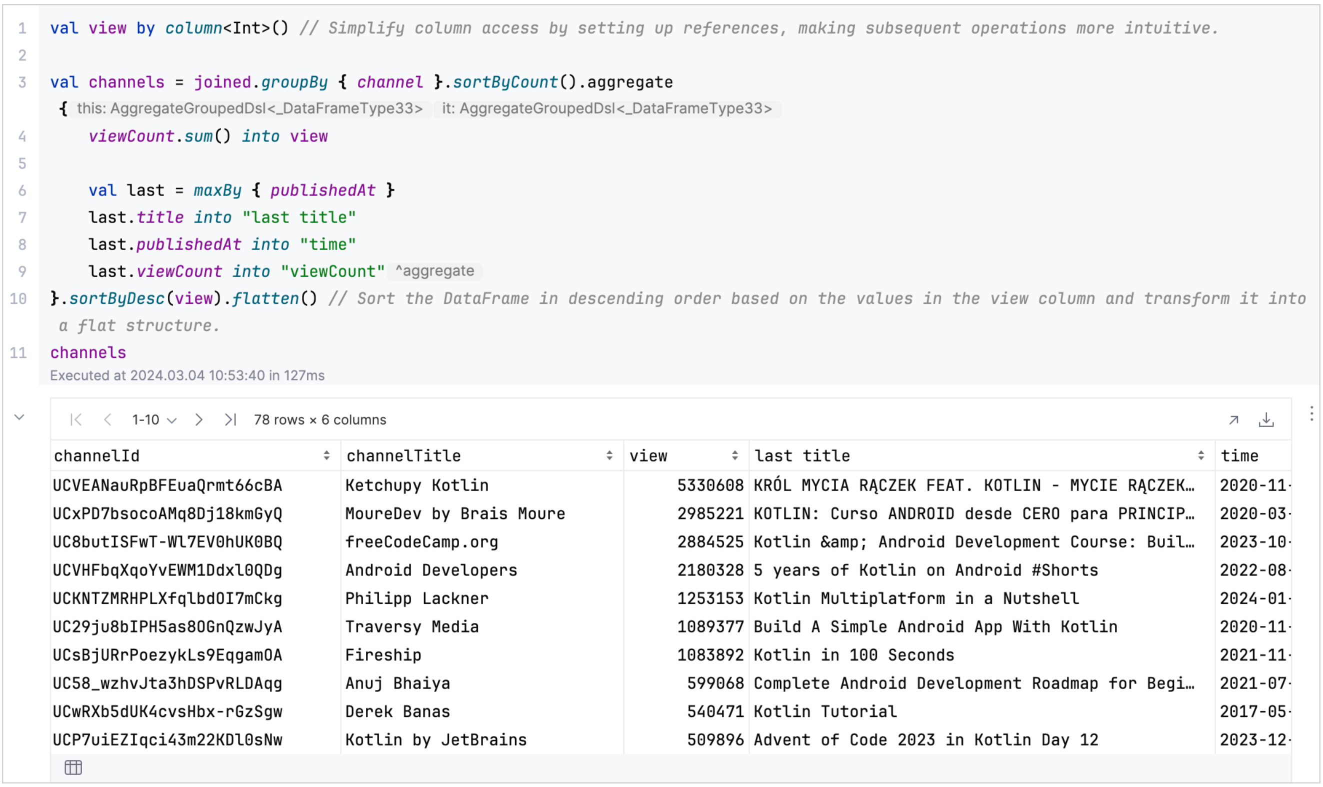
Click on the table icon in the bottom left to return

3. Use aggregate, sum, maxBy, and flatten to create a DataFrame summarizing each channel's total views and details of its latest or most viewed video:

```
val aggregated = channels.aggregate {
    viewCount.sum() into view

    val last = maxBy { publishedAt }
    last.title into "last title"
    last.publishedAt into "time"
    last.viewCount into "viewCount"
    // Sorts the DataFrame in descending order by view count and transform it into a flat structure.
}.sortByDesc(view).flatten()
aggregated
```

The results of the analysis:



```kotlin
val view by column<Int>() // Simplify column access by setting up references, making subsequent operations more intuitive.

val channels = joined.groupBy { channel }.sortByCount().aggregate
 { this: AggregateGroupedDsl<_DataFrameType33>  it: AggregateGroupedDsl<_DataFrameType33>
    viewCount.sum() into view

    val last = maxBy { publishedAt }
    last.title into "last title"
    last.publishedAt into "time"
    last.viewCount into "viewCount" ^aggregate
}.sortByDesc(view).flatten() // Sort the DataFrame in descending order based on the values in the view column and transform it into
 a flat structure.
channels
```

Executed at 2024.03.04 10:53:40 in 127ms

1-10 78 rows × 6 columns

channelId	channelTitle	view	last title	time
UCVEANauRpBFEuaQrmt66cBA	Ketchupy Kotlin	5330608	KRÓL MYCIA RĄCZEK FEAT. KOTLIN - MYCIE RĄCZEK…	2020-11-
UCxPD7bsocoAMq8Dj18kmGyQ	MoureDev by Brais Moure	2985221	KOTLIN: Curso ANDROID desde CERO para PRINCIP…	2020-03-
UC8butISFwT-Wl7EV0hUK0BQ	freeCodeCamp.org	2884525	Kotlin &amp; Android Development Course: Buil…	2023-10-
UCVHFbqXqoYvEWM1Ddxl0QDg	Android Developers	2180328	5 years of Kotlin on Android #Shorts	2022-08-
UCKNTZMRHPLXfqlbdOI7mCkg	Philipp Lackner	1253153	Kotlin Multiplatform in a Nutshell	2024-01-
UC29ju8bIPH5as8OGnQzwJyA	Traversy Media	1089377	Build A Simple Android App With Kotlin	2020-11-
UCsBjURrPoezykLs9EqgamOA	Fireship	1083892	Kotlin in 100 Seconds	2021-11-
UC58_wzhvJta3hDSPvRLDAqg	Anuj Bhaiya	599068	Complete Android Development Roadmap for Begi…	2021-07-
UCwRXb5dUK4cvsHbx-rGzSgw	Derek Banas	540471	Kotlin Tutorial	2017-05-
UCP7uiEZIqci43m22KDl0sNw	Kotlin by JetBrains	509896	Advent of Code 2023 in Kotlin Day 12	2023-12-

Analysis results

For more advanced techniques, see the Kotlin DataFrame documentation.

What's next

- Explore data visualization using the Kandy library
- Find additional information about data visualization in Data visualization in Kotlin Notebook with Kandy
- For an extensive overview of tools and resources available for data science and analysis in Kotlin, see Kotlin and Java libraries for data analysis

Connect and retrieve data from databases

Kotlin Notebook offers capabilities for connecting to and retrieving data from various types of SQL databases, such as MariaDB, PostgreSQL, MySQL, and SQLite. Utilizing the Kotlin DataFrame library, Kotlin Notebook can establish connections to databases, execute SQL queries, and import the results for further operations.

For a detailed example, see the Notebook in the KotlinDataFrame SQL Examples GitHub repository.

Before you start

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If the Kotlin Notebook features are not available, ensure the plugin is enabled. For more information, see Set up an environment.

Create a new Kotlin Notebook:

1. Select File | New | Kotlin Notebook.
2. Ensure you have access to an SQL database, such as MariaDB or MySQL.

Connect to database

You can connect to and interact with an SQL database using specific functions from the Kotlin DataFrame library. You can use DatabaseConfiguration to establish a connection to your database and getSchemaForAllSqlTables() to retrieve the schema of all tables within it.

Let's look at an example:

1. Open your Kotlin Notebook file (.ipynb).
2. Add a dependency for a JDBC (Java Database Connectivity) driver, and specify the JDBC driver version. This example uses MariaDB:

```
USE {
   dependencies("org.mariadb.jdbc:mariadb-java-client:$version")
}
```

3. Import the Kotlin DataFrame library, which is essential for data manipulation tasks, along with the necessary Java libraries for SQL connectivity and utility functions:

```
%use dataframe
import java.sql.DriverManager
import java.util.*
```

4. Use the DatabaseConfiguration class to define your database's connection parameters, including the URL, username, and password:

```
val URL = "YOUR_URL"
val USER_NAME = "YOUR_USERNAME"
val PASSWORD = "YOUR_PASSWORD"

val dbConfig = DatabaseConfiguration(URL, USER_NAME, PASSWORD)
```

5. Once connected, use the getSchemaForAllSqlTables() function to fetch and display the schema information for each table in the database:

```
val dataschemas = DataFrame.getSchemaForAllSqlTables(dbConfig)

dataschemas.forEach {
    println("---Yet another table schema---")
    println(it)
    println()
}
```

For more information on connecting to SQL databases, see Read from SQL databases in the Kotlin DataFrame documentation.

Retrieve and manipulate data

After establishing a connection to an SQL database, you can retrieve and manipulate data in Kotlin Notebook, utilizing the Kotlin DataFrame library. You can use the readSqlTable() function to retrieve data. To manipulate data, you can use methods, such as filter, groupBy, and convert.

Let's look at an example of connecting to an IMDB database and retrieving data about movies directed by Quentin Tarantino:

1. Use the readSqlTable() function to retrieve data from the "movies" table, setting limit to restrict the query to the first 100 records for efficiency:

```
val dfs = DataFrame.readSqlTable(dbConfig, tableName = "movies", limit = 100)
```

2. Use an SQL query to retrieve a specific dataset related to movies directed by Quentin Tarantino. This query selects movie details and combines genres for each movie:

```
val props = Properties()
props.setProperty("user", USER_NAME)
props.setProperty("password", PASSWORD)

val TARANTINO_FILMS_SQL_QUERY = """
    SELECT name, year, rank, GROUP_CONCAT(genre) as "genres"
    FROM movies JOIN movies_directors ON movie_id = movies.id
    JOIN directors ON directors.id=director_id LEFT JOIN movies_genres ON movies.id = movies_genres.movie_id
    WHERE directors.first_name = "Quentin" AND directors.last_name = "Tarantino"
    GROUP BY name, year, rank
    ORDER BY year
    """

// Retrieves a list of Quentin Tarantino's movies, including their name, year, rank, and a concatenated string of all genres.
// The results are grouped by name, year, rank, and sorted by year.

var dfTarantinoMovies: DataFrame<*>

DriverManager.getConnection(URL, props).use { connection ->
   connection.createStatement().use { st ->
      st.executeQuery(TARANTINO_FILMS_SQL_QUERY).use { rs ->
         val dfTarantinoFilmsSchema = DataFrame.getSchemaForResultSet(rs, connection)
         dfTarantinoFilmsSchema.print()

         dfTarantinoMovies = DataFrame.readResultSet(rs, connection)
         dfTarantinoMovies
      }
   }
}
```

3. After fetching the Tarantino movies dataset, you can further manipulate and filter the data.

```
val df = dfTarantinoMovies
    // Replaces any missing values in the 'year' column with 0.
    .fillNA { year }.with { 0 }

    // Converts the 'year' column to integers.
    .convert { year }.toInt()

    // Filters the data to include only movies released after the year 2000.
    .filter { year > 2000 }
df
```

The resulting output is a DataFrame where missing values in the year column are replaced with 0 using the fillNA method. The year column is converted to integer values with the convert method, and the data is filtered to include only rows from the year 2000 onwards using the filter method.

Analyze data in Kotlin Notebook

After establishing a connection to an SQL database, you can use Kotlin Notebook for in-depth data analysis utilizing the Kotlin DataFrame library. This includes functions for grouping, sorting, and aggregating data, helping you to uncover and understand patterns within your data.

Let's dive into an example that involves analyzing actor data from a movie database, focusing on the most frequently occurring first names of actors:

1. Extract data from the "actors" table using the readSqlTable() function:

```
val actorDf = DataFrame.readSqlTable(dbConfig, "actors", 10000)
```

2. Process the retrieved data to identify the top 20 most common actor first names. This analysis involves several DataFrame methods:

```
val top20ActorNames = actorDf
    // Groups the data by the first_name column to organize it based on actor first names.
   .groupBy { first_name }

    // Counts the occurrences of each unique first name, providing a frequency distribution.
   .count()

    // Sorts the results in descending order of count to identify the most common names.
   .sortByDesc("count")

    // Selects the top 20 most frequent names for analysis.
   .take(20)
top20ActorNames
```

What's next

- Explore data visualization using the Kandy library

- Find additional information about data visualization in Data visualization in Kotlin Notebook with Kandy
- For an extensive overview of tools and resources available for data science and analysis in Kotlin, see Kotlin and Java libraries for data analysis

Data visualization in Kotlin Notebook with Kandy

Kotlin offers an all-in-one-place solution for powerful and flexible data visualization, providing an intuitive way to present and explore data before diving into complex models.

This tutorial demonstrates how to create different chart types in IntelliJ IDEA using Kotlin Notebook with the Kandy and Kotlin DataFrame libraries.

Before you start

Kotlin Notebook relies on the Kotlin Notebook plugin, which is bundled and enabled in IntelliJ IDEA by default.

If the Kotlin Notebook features are not available, ensure the plugin is enabled. For more information, see Set up an environment.

Create a new Kotlin Notebook:

1. Select File | New | Kotlin Notebook.
2. In your notebook, import the Kandy and Kotlin DataFrame libraries by running the following command:

   ```
   %use kandy
   %use dataframe
   ```

Create the DataFrame

Start by creating the DataFrame containing the records to visualize. This DataFrame stores simulated numbers of the monthly average temperature in three cities: Berlin, Madrid, and Caracas.

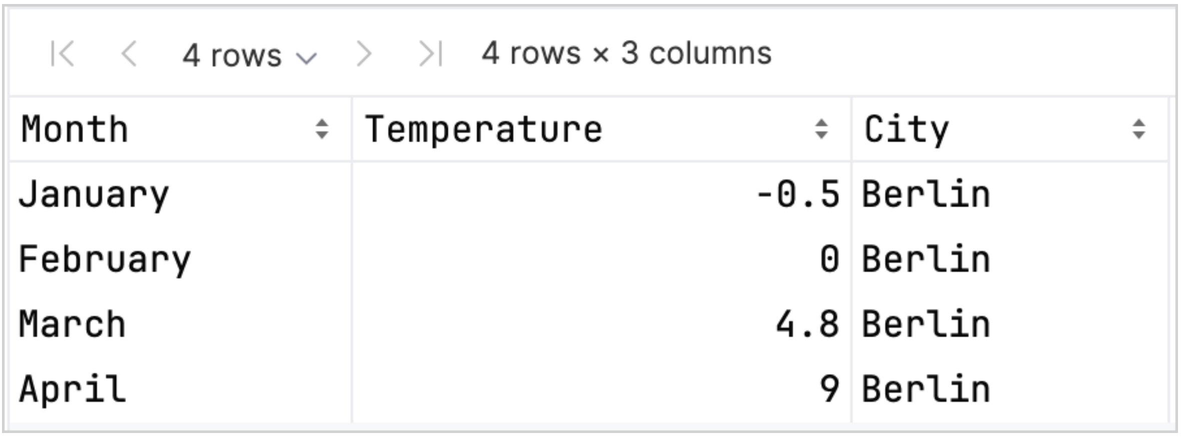
Use the dataFrameOf() function from the Kotlin DataFrame library to generate the DataFrame. Run the following code snippet in Kotlin Notebook:

```
// The months variable stores a list with the 12 months of the year
val months = listOf(
    "January", "February",
    "March", "April", "May",
    "June", "July", "August",
    "September", "October", "November",
    "December"
)
// The tempBerlin, tempMadrid, and tempCaracas variables store a list with temperature values for each month
val tempBerlin =
    listOf(-0.5, 0.0, 4.8, 9.0, 14.3, 17.5, 19.2, 18.9, 14.5, 9.7, 4.7, 1.0)
val tempMadrid =
    listOf(6.3, 7.9, 11.2, 12.9, 16.7, 21.1, 24.7, 24.2, 20.3, 15.4, 9.9, 6.6)
val tempCaracas =
    listOf(27.5, 28.9, 29.6, 30.9, 31.7, 35.1, 33.8, 32.2, 31.3, 29.4, 28.9, 27.6)

// The df variable stores a DataFrame of three columns, including records of months, temperature, and cities
val df = dataFrameOf(
    "Month" to months + months + months,
    "Temperature" to tempBerlin + tempMadrid + tempCaracas,
    "City" to List(12) { "Berlin" } + List(12) { "Madrid" } + List(12) { "Caracas" }
)
```

Explore the structure of the new DataFrame by looking into the first four rows:

```
df.head(4)
```

You can see that the DataFrame has three columns: Month, Temperature, and City. The first four rows of the DataFrame contain records of the temperature in Berlin from January to April:


4 rows 4 rows × 3 columns

Month	Temperature	City
January	-0.5	Berlin
February	0	Berlin
March	4.8	Berlin
April	9	Berlin

Dataframe exploration

There are different options to access a column's records that can help you increase type safety when working with the Kandy and Kotlin DataFrame libraries together. For more information, see Access APIs.

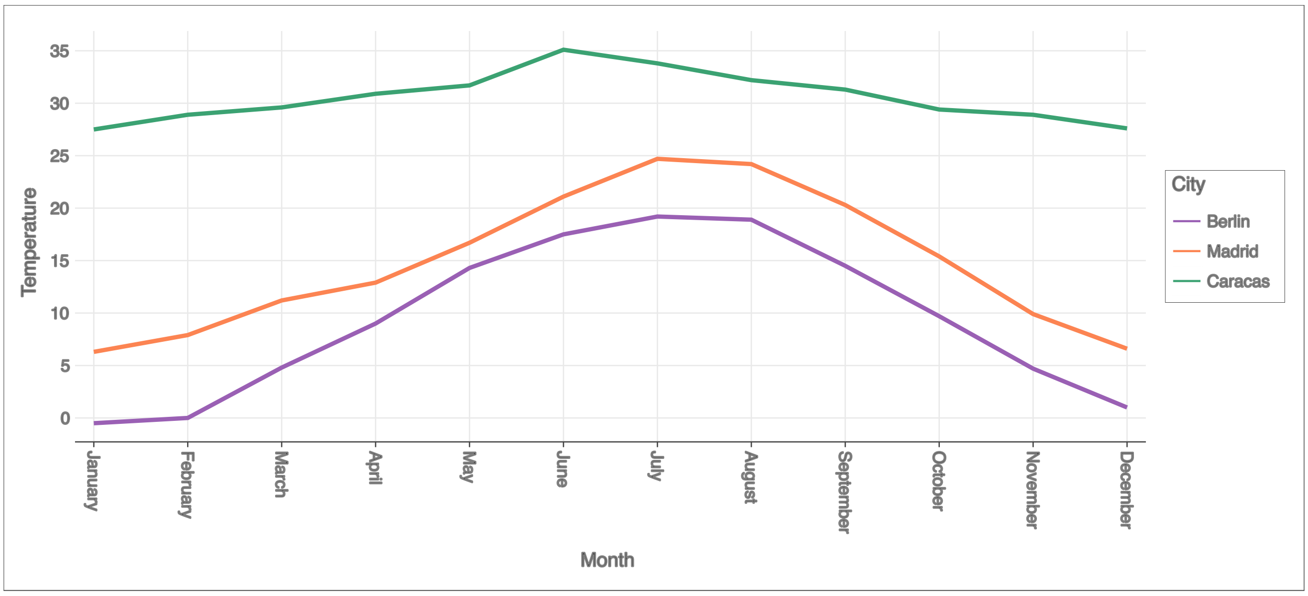
Create a line chart

Let's create a line chart in Kotlin Notebook using the df DataFrame from the previous section.

Use the plot() function from the Kandy library. Within the plot() function, specify the type of chart (in this case, it's line) and the values for the X and Y axes. You can customize colors and sizes:

```
df.plot {
    line {
        // Accesses the DataFrame's columns used for the X and Y axes
        x(Month)
        y(Temperature)
        // Accesses the DataFrame's column used for categories and sets colors for these categories
        color(City) {
            scale = categorical("Berlin" to Color.PURPLE, "Madrid" to Color.ORANGE, "Caracas" to Color.GREEN)
        }
        // Customizes the line's size
        width = 1.5
    }
    // Customizes the chart's layout size
    layout.size = 1000 to 450
}
```

Here's the result:



Line chart

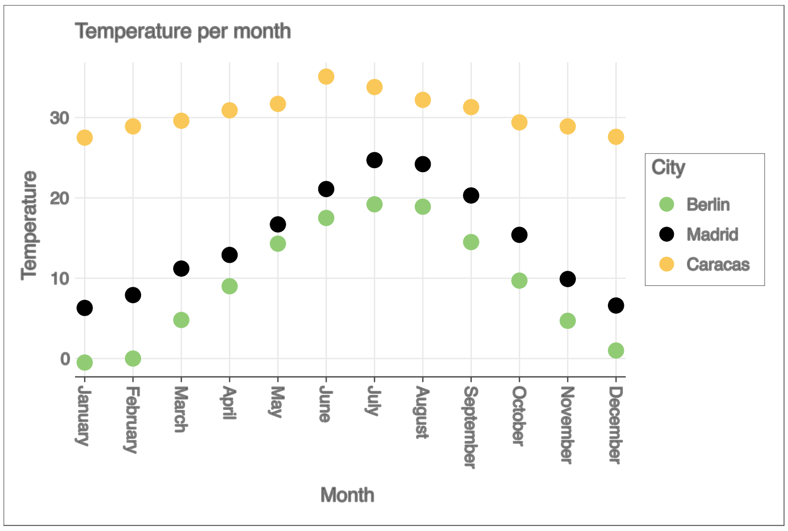
Create a points chart

Now, let's visualize the df DataFrame in a points (scatter) chart.

Within the plot() function, specify the points chart type. Add the X and Y axes' values and the categorical values from the df columns. You can also include a heading to your chart:

```
df.plot {
    points {
        // Accesses the DataFrame's columns used for the X and Y axes
        x(Month) { axis.name = "Month" }
        y(Temperature) { axis.name = "Temperature" }
        // Customizes the point's size
        size = 5.5
        // Accesses the DataFrame's column used for categories and sets colors for these categories
        color(City) {
            scale = categorical("Berlin" to Color.LIGHT_GREEN, "Madrid" to Color.BLACK, "Caracas" to Color.YELLOW)
        }
    }
    // Adds a chart heading
    layout.title = "Temperature per month"
}
```

Here's the result:



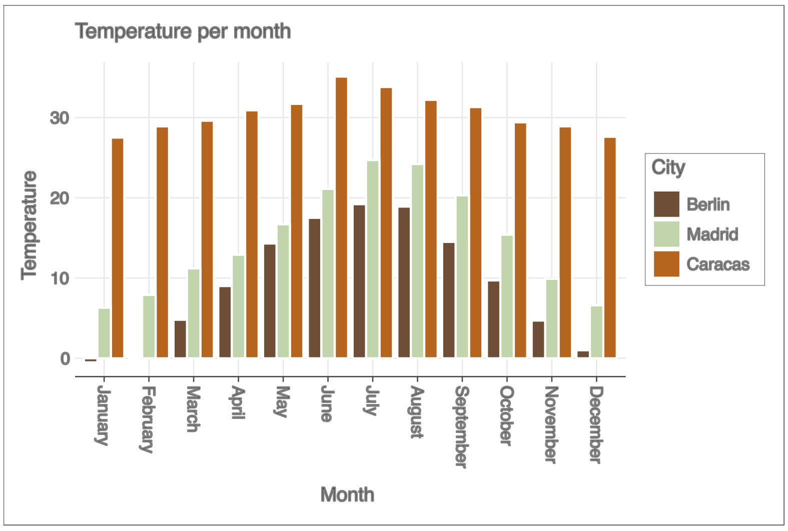
Points chart

Create a bar chart

Finally, let's create a bar chart grouped by city using the same data as in the previous charts. For colors, you can also use hexadecimal codes:

```
// Groups by cities
df.groupBy { City }.plot {
    // Adds a chart heading
    layout.title = "Temperature per month"
    bars {
        // Accesses the DataFrame's columns used for the X and Y axes
        x(Month)
        y(Temperature)
        // Accesses the DataFrame's column used for categories and sets colors for these categories
        fillColor(City) {
            scale = categorical(
                "Berlin" to Color.hex("#6F4E37"),
                "Madrid" to Color.hex("#C2D4AB"),
                "Caracas" to Color.hex("#B5651D")
            )
        }
    }
}
```

Here's the result:



Bar chart

What's next

- Explore more chart examples in the Kandy library documentation
- Explore more advanced plotting options in the Lets-Plot library documentation
- Find additional information about creating, exploring, and managing data frames in the Kotlin DataFrame library documentation
- Learn more about data visualization in Kotlin Notebook in this YouTube video

Kotlin and Java libraries for data analysis

From data collection to model building, Kotlin offers robust libraries facilitating different tasks in the data pipeline.

In addition to its own libraries, Kotlin is 100% interoperable with Java. This interoperability helps to leverage the entire ecosystem of tried-and-true Java libraries with excellent performance. With this perk, you can easily use either Kotlin or Java libraries when working on Kotlin data projects.

Kotlin libraries

Library	Purpose	Features
Kotlin DataFrame	• Data collection • Data cleaning and processing	• Operations for creating, sorting, and cleaning data frames, feature engineering, and more • Processing of structured data • Support for CSV, JSON, and other input formats • Reading from SQL databases • Connecting with different APIs to access data and increase type safety
Kandy	• Data exploration and visualization	• Powerful, readable, and typesafe DSL for plotting charts of various types • Open-source library written in Kotlin for the JVM • Support for Kotlin Notebook, Datalore, and Jupyter Notebook • Seamless integration with Kotlin DataFrame
KotlinDL	• Model building	• Deep learning API written in Kotlin and inspired by Keras • Training deep learning models from scratch or importing existing Keras and ONNX models for inference • Transferring learning for tailoring existing pre-trained models to your tasks • Support for the Android platform
Multik	• Data cleaning and processing • Model building	• Mathematical operations over multidimensional arrays (linear algebra, statistics, arithmetics, and other calculations) • Creating, copying, indexing, slicing, and other array operations • Kotlin-idiomatic library with benefits such as type and dimension safety and swappable computational engines, running on the JVM or as native code

Library	Purpose	Features
Kotlin for Apache Spark	• Data collection • Data cleaning and processing • Data exploration and visualization • Model building	• Layer of compatibility between Apache Spark and Kotlin • Apache Spark data transformation operations in Kotlin-idiomatic code • Simple usage of Kotlin features, such as data classes and lambda expressions, in curly braces or method reference
Lets-Plot	• Data exploration and visualization	• Plotting statistical data written in Kotlin • Support for Kotlin Notebook, Datalore, and Jupyter with Kotlin Kernel • Compatible with the JVM, JS, and Python • Embedding charts in Compose Multiplatform applications
KMath	• Data cleaning and processing • Data exploration and visualization • Model building	• Modular library to work with mathematical abstractions in Kotlin Multiplatform (JVM, JS, Native, and Wasm) • APIs for algebraic structures, mathematical expressions, histograms, and streaming operations • Interchangeable wrappers over existing Java and Kotlin libraries, including ND4J, Apache Commons Math, and Multik • Inspired by Python's NumPy but with other additional features like type safety
kravis	• Data exploration and visualization	• Visualization of tabular data • Inspired by R's ggplot • Support for Jupyter with Kotlin Kernel

Java libraries

Since Kotlin provides first-class interoperability with Java, you can use Java libraries for data tasks in your Kotlin code. Here are some examples of such libraries:

Library	Purpose	Features
Tablesaw	• Data collection • Data cleaning and processing • Data exploration and visualization	• Tools for loading, cleaning, transforming, filtering, and summarizing data • Inspired by Plot.ly
CoreNLP	• Data cleaning and processing	• Natural language processing toolkit • Linguistic annotations for text, such as sentiment and quote attributions • Support for eight languages

Library	Purpose	Features
Smile	• Data cleaning and processing • Data exploration and visualization • Model building	• Ready-made algorithms for machine learning and natural language processing • Linear algebra, graph, interpolation, and visualization tools • Provides functional Kotlin API, Scala API, Clojure API, and more
Smile-NLP-kt	• Data cleaning and processing	• Kotlin rewrite of the Scala implicits for the natural language processing part of Smile • Operations in the format of Kotlin extension functions and interfaces • Sentence breaking, stemming, bag of words, and other tasks
ND4J	• Data cleaning and processing • Model building	• Matrix mathematics library for the JVM • Over 500 mathematical, linear algebra, and deep learning operations
Apache Commons Math	• Data cleaning and processing • Model building	• Mathematics and statistics operations for Java • Correlations, distributions, linear algebra, geometry, and other operations • Machine learning models
NM Dev	• Data cleaning and processing • Model building	• Java math library of numerical algorithms • Object-oriented numerical methods • Linear algebra, optimization, statistics, calculus, and more operations
Apache OpenNLP	• Data cleaning and processing • Model building	• Machine-learning-based toolkit for the processing of natural language text • Tokenization, sentence segmentation, part-of-speech tagging, and other tasks • Built-in tools for data modeling and model validation
Charts	• Data exploration and visualization	• JavaFX library for scientific charts • Complex charts, such as logarithmic, heatmap, and force-directed graph
DeepLearning4J	• Model building	• Deep learning library for Java • Importing and retraining models (Pytorch, Tensorflow, Keras) • Deploying in JVM microservice environments, mobile devices, IoT, and Apache Spark
Timefold	• Model building	• Solver utility for optimization planning problems • Compatible with object-oriented and functional programming

Get started with Kotlin/JVM

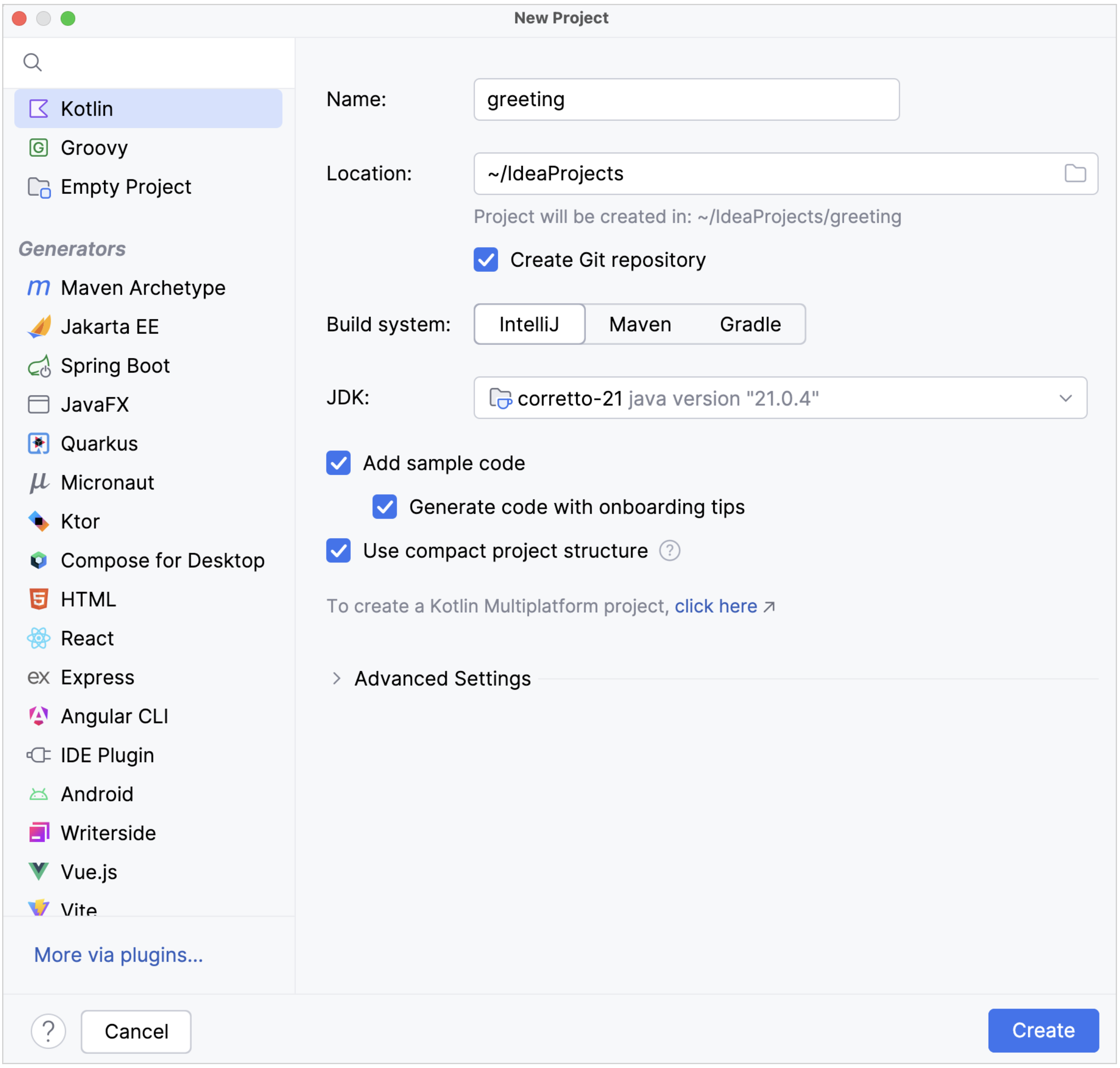
This tutorial demonstrates how to use IntelliJ IDEA for creating a console application.

To get started, first download and install the latest version of IntelliJ IDEA.

Create a project

1. In IntelliJ IDEA, select File | New | Project.
2. In the list on the left, select Kotlin.
3. Name the new project and change its location if necessary.

> Select the Create Git repository checkbox to place the new project under version control. You will be able to do it later at any time.



Name: greeting

Location: ~/IdeaProjects

Project will be created in: ~/IdeaProjects/greeting

✓ Create Git repository

Build system: IntelliJ Maven Gradle

JDK: corretto-21 java version "21.0.4"

✓ Add sample code

✓ Generate code with onboarding tips

✓ Use compact project structure

To create a Kotlin Multiplatform project, click here ↗

Advanced Settings

Create a console application

4. Select the IntelliJ build system. It's a native builder that doesn't require downloading additional artifacts.

   If you want to create a more complex project that needs further configuration, select Maven or Gradle. For Gradle, choose a language for the build script: Kotlin or Groovy.

5. From the JDK list, select the JDK that you want to use in your project.

   - If the JDK is installed on your computer, but not defined in the IDE, select Add JDK and specify the path to the JDK home directory.

* If you don't have the necessary JDK on your computer, select Download JDK.

6. Enable the Add sample code option to create a file with a sample "Hello World!" application.

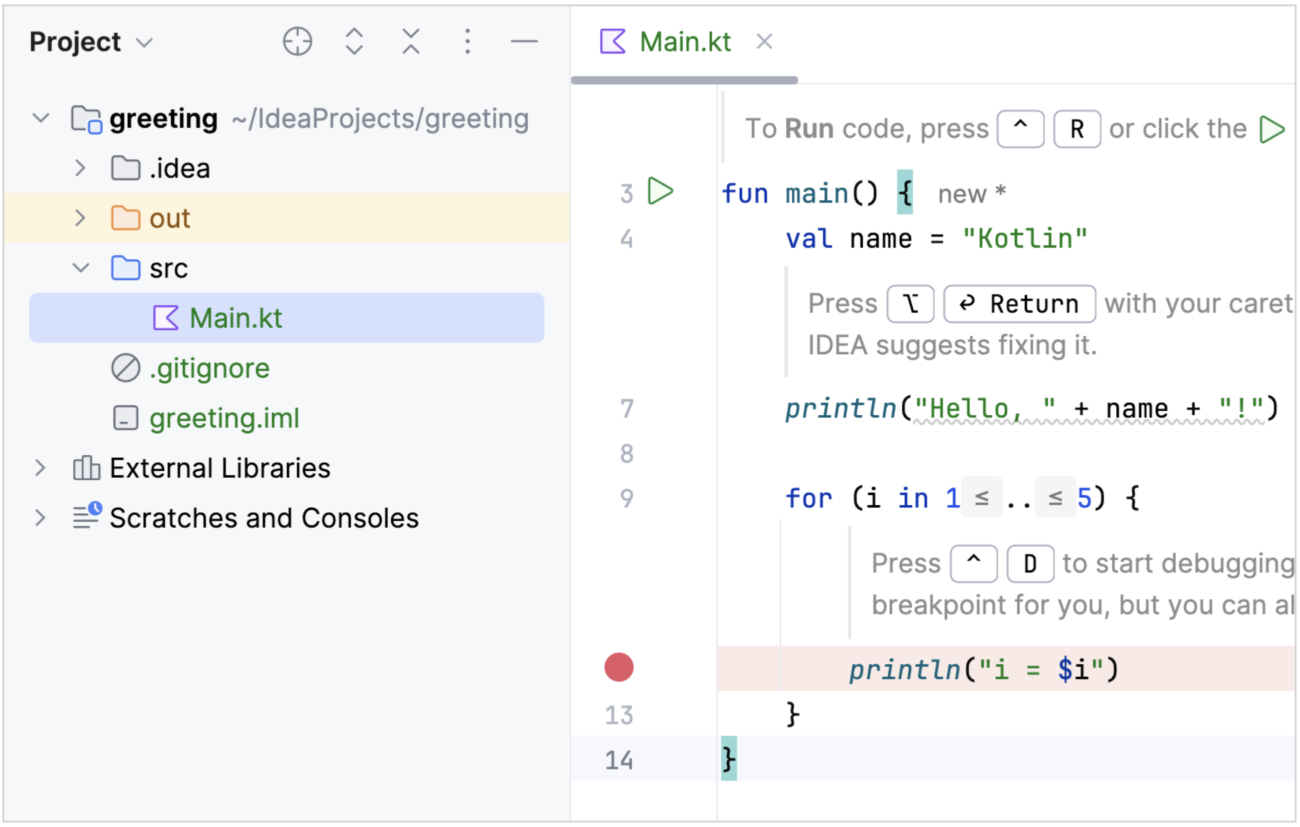
> You can also enable the Generate code with onboarding tips option to add some additional useful comments to your sample code.

7. Click Create.

> If you chose the Gradle build system, you have in your project a build script file: build.gradle(.kts). It includes the kotlin("jvm") plugin and dependencies required for your console application. Make sure that you use the latest version of the plugin:
>
> ```
> plugins {
>     kotlin("jvm") version "2.2.0"
>     application
> }
> ```

Create an application

1. Open the Main.kt file in src/main/kotlin.
   The src directory contains Kotlin source files and resources. The Main.kt file contains sample code that will print Hello, Kotlin! as well as several lines with values of the cycle iterator.



```
To Run code, press ^ R or click the
fun main() {  new *
    val name = "Kotlin"
    Press ⌥ ↩ Return with your caret
    IDEA suggests fixing it.
    println("Hello, " + name + "!")

    for (i in 1 ≤ .. ≤ 5) {
        Press ^ D to start debugging
        breakpoint for you, but you can al
        println("i = $i")
    }
}
```

Main.kt with main fun

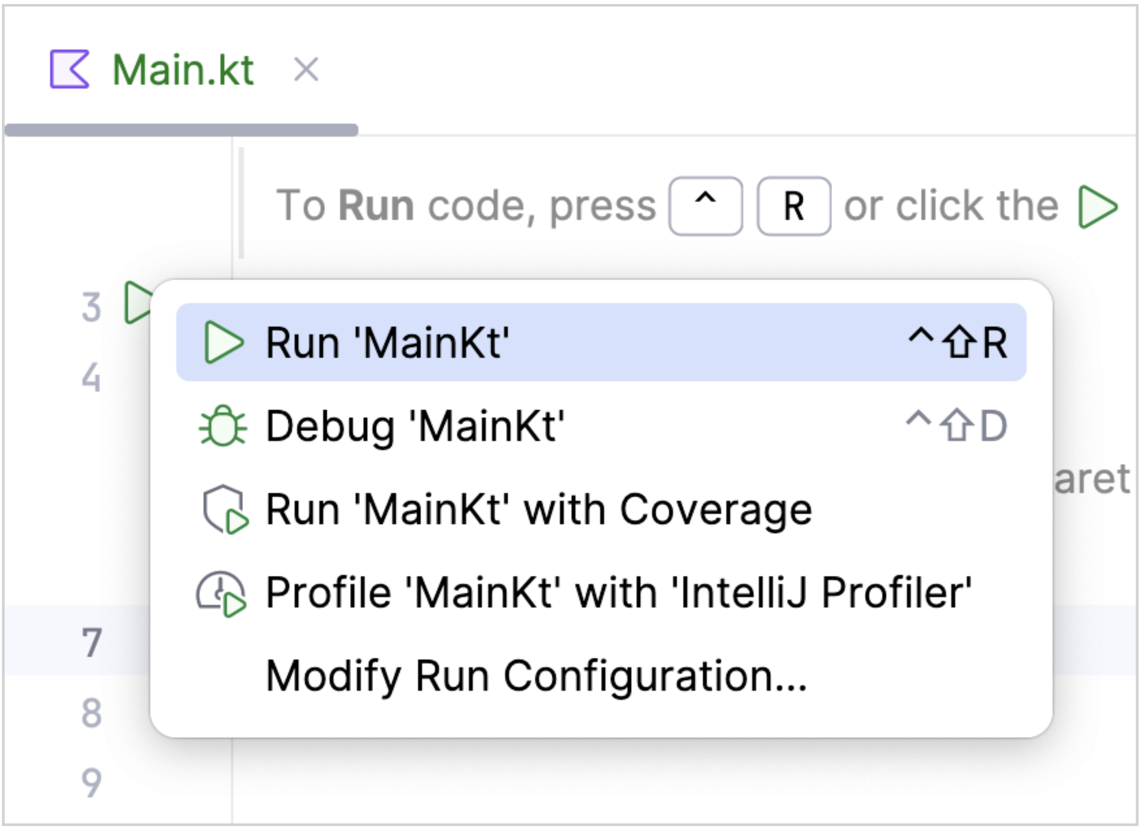
2. Modify the code so that it requests your name and says Hello to you:

   * Create an input prompt and assign to the name variable the value returned by the readln() function.
   * Let's use a string template instead of concatenation by adding a dollar sign $ before the variable name directly in the text output like this – $name.

```
fun main() {
    println("What's your name?")
    val name = readln()
    println("Hello, $name!")

    // ...
}
```

Run the application

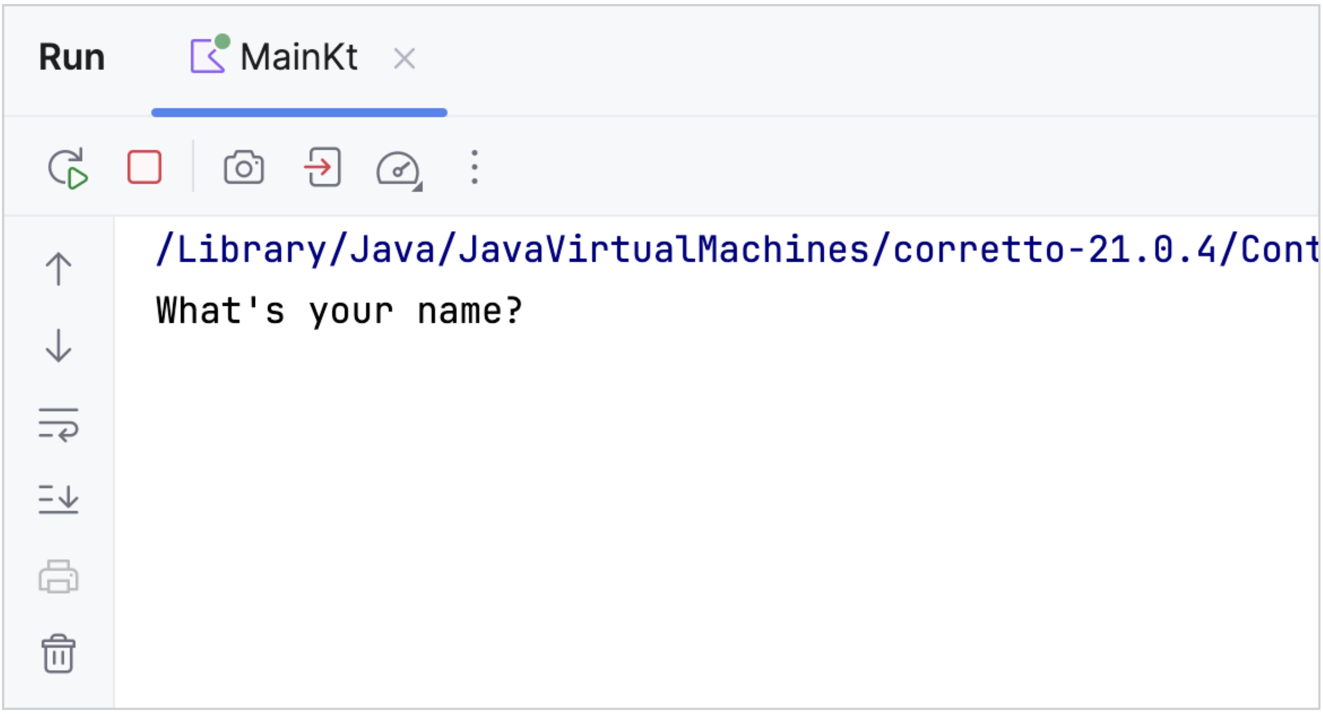
Now the application is ready to run. The easiest way to do this is to click the green Run icon in the gutter and select Run 'MainKt'.



Main.kt
To Run code, press ^ R or click the
Run 'MainKt' ^⇧R
Debug 'MainKt' ^⇧D
Run 'MainKt' with Coverage
Profile 'MainKt' with 'IntelliJ Profiler'
Modify Run Configuration...
aret

Running a console app

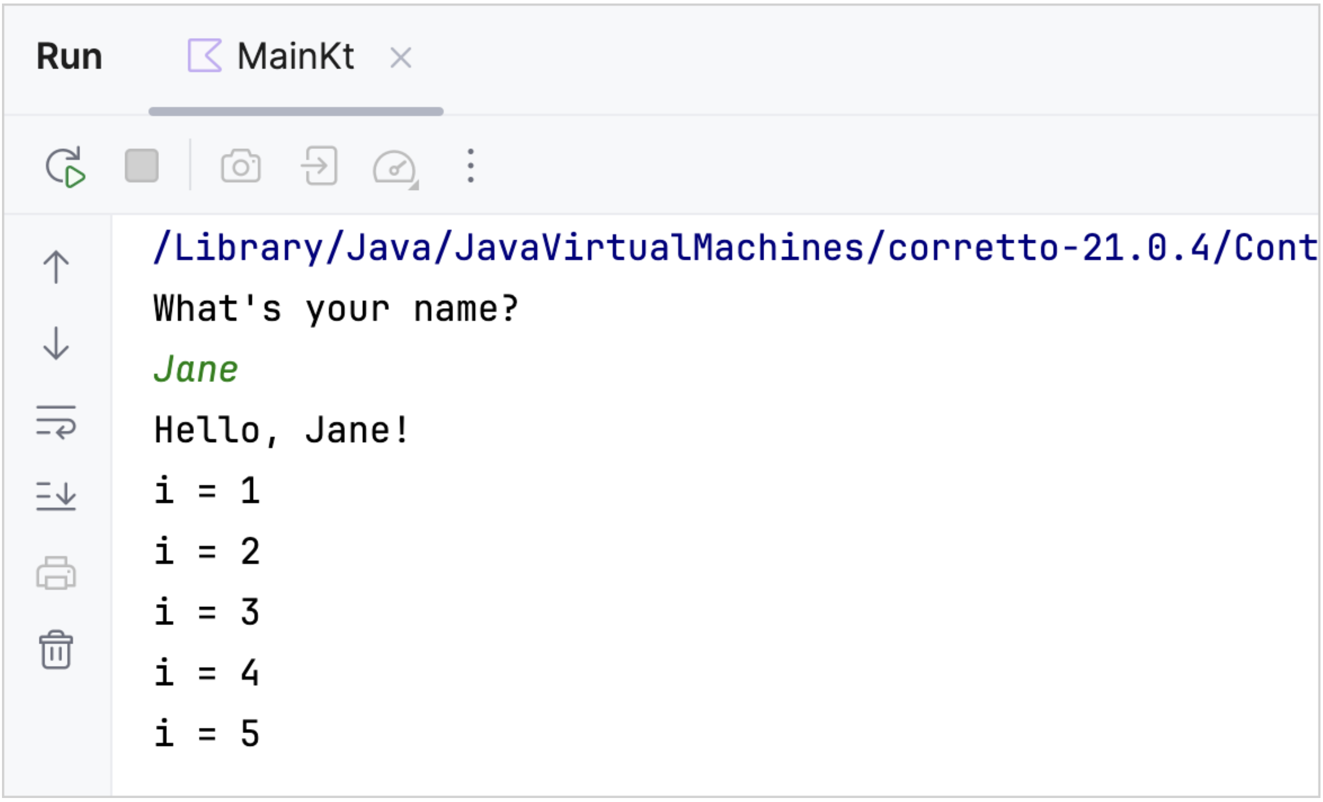
You can see the result in the Run tool window.



```
/Library/Java/JavaVirtualMachines/corretto-21.0.4/Cont
What's your name?
```

Kotlin run output

Enter your name and accept the greetings from your application!



```
/Library/Java/JavaVirtualMachines/corretto-21.0.4/Cont
What's your name?
Jane
Hello, Jane!
i = 1
i = 2
i = 3
i = 4
i = 5
```

Kotlin run output

Congratulations! You have just run your first Kotlin application.

What's next?

Once you've created this application, you can start to dive deeper into Kotlin syntax:

- Add sample code from Kotlin examples
- Install the JetBrains Academy plugin for IDEA and complete exercises from the Kotlin Koans course

Comparison to Java

Some Java issues addressed in Kotlin

Kotlin fixes a series of issues that Java suffers from:

- Null references are controlled by the type system.
- No raw types
- Arrays in Kotlin are invariant
- Kotlin has proper function types, as opposed to Java's SAM-conversions
- Use-site variance without wildcards
- Kotlin does not have checked exceptions
- Separate interfaces for read-only and mutable collections

What Java has that Kotlin does not

- Checked exceptions
- Primitive types that are not classes. The byte-code uses primitives where possible, but they are not explicitly available.
- Static members are replaced with companion objects, top-level functions, extension functions, or @JvmStatic.
- Wildcard-types are replaced with declaration-site variance and type projections.
- Ternary-operator a ? b : c is replaced with if expression.
- Records
- Pattern Matching
- package-private visibility modifier

What Kotlin has that Java does not

- Lambda expressions + Inline functions = performant custom control structures
- Extension functions
- Null-safety
- Smart casts (Java 16: Pattern Matching for instanceof)
- String templates (Java 21: String Templates (Preview))
- Properties
- Primary constructors
- First-class delegation
- Type inference for variable and property types (Java 10: Local-Variable Type Inference)

* Singletons
* Declaration-site variance & Type projections
* Range expressions
* Operator overloading
* Companion objects
* Data classes
* Coroutines
* Top-level functions
* Default arguments
* Named parameters
* Infix functions
* Expect and actual declarations
* Explicit API mode and better control of API surface

What's next?

Learn how to:

* Perform typical tasks with strings in Java and Kotlin.
* Perform typical tasks with collections in Java and Kotlin.
* Handle nullability in Java and Kotlin.

Calling Java from Kotlin

Kotlin is designed with Java interoperability in mind. Existing Java code can be called from Kotlin in a natural way, and Kotlin code can be used from Java rather smoothly as well. In this section, we describe some details about calling Java code from Kotlin.

Pretty much all Java code can be used without any issues:

```
import java.util.*

fun demo(source: List<Int>) {
    val list = ArrayList<Int>()
    // 'for'-loops work for Java collections:
    for (item in source) {
        list.add(item)
    }
    // Operator conventions work as well:
    for (i in 0..source.size - 1) {
        list[i] = source[i] // get and set are called
    }
}
```

Getters and setters

Methods that follow the Java conventions for getters and setters (no-argument methods with names starting with get and single-argument methods with names starting with set) are represented as properties in Kotlin. Such properties are also called synthetic properties. Boolean accessor methods (where the name of the getter starts with is and the name of the setter starts with set) are represented as properties which have the same name as the getter method.

```
import java.util.Calendar

fun calendarDemo() {
    val calendar = Calendar.getInstance()
    if (calendar.firstDayOfWeek == Calendar.SUNDAY) { // call getFirstDayOfWeek()
        calendar.firstDayOfWeek = Calendar.MONDAY // call setFirstDayOfWeek()
    }
    if (!calendar.isLenient) { // call isLenient()
        calendar.isLenient = true // call setLenient()
    }
}
```

calendar.firstDayOfWeek above is an example of a synthetic property.

Note that, if the Java class only has a setter, it isn't visible as a property in Kotlin because Kotlin doesn't support set-only properties.

Java synthetic property references

This feature is Experimental. It may be dropped or changed at any time. We recommend that you use it only for evaluation purposes.

Starting from Kotlin 1.8.20, you can create references to Java synthetic properties. Consider the following Java code:

```
public class Person {
    private String name;
    private int age;

    public Person(String name, int age) {
        this.name = name;
        this.age = age;
    }

    public String getName() {
        return name;
    }

    public int getAge() {
        return age;
    }
}
```

Kotlin has always allowed you to write person.age, where age is a synthetic property. Now, you can also create references to Person::age and person::age. The same applies for name, as well.

```
val persons = listOf(Person("Jack", 11), Person("Sofie", 12), Person("Peter", 11))
    persons
         // Call a reference to Java synthetic property:
        .sortedBy(Person::age)
         // Call Java getter via the Kotlin property syntax:
        .forEach { person -> println(person.name) }
```

How to enable Java synthetic property references

To enable this feature, set the -language-version 2.1 compiler option. In a Gradle project, you can do so by adding the following to your build.gradle(.kts):

Kotlin

```
tasks
    .withType<org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask<*>>()
    .configureEach {
        compilerOptions
            .languageVersion
            .set(
                org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_2_1
            )
    }
```

Groovy

```
tasks
    .withType(org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask.class)
    .configureEach {
        compilerOptions.languageVersion
            = org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_2_1
}
```

Prior to Kotlin 1.9.0, to enable this feature you had to set the -language-version 1.9 compiler option.

Methods returning void

If a Java method returns void, it will return Unit when called from Kotlin. If by any chance someone uses that return value, it will be assigned at the call site by the Kotlin compiler since the value itself is known in advance (being Unit).

Escaping for Java identifiers that are keywords in Kotlin

Some of the Kotlin keywords are valid identifiers in Java: in, object, is, and other. If a Java library uses a Kotlin keyword for a method, you can still call the method escaping it with the backtick (`) character:

```
foo.`is`(bar)
```

Null-safety and platform types

Any reference in Java may be null, which makes Kotlin's requirements of strict null-safety impractical for objects coming from Java. Types of Java declarations are treated in Kotlin in a specific manner and called platform types. Null-checks are relaxed for such types, so that safety guarantees for them are the same as in Java (see more below).

Consider the following examples:

```
val list = ArrayList<String>() // non-null (constructor result)
list.add("Item")
val size = list.size // non-null (primitive int)
val item = list[0] // platform type inferred (ordinary Java object)
```

When you call methods on variables of platform types, Kotlin does not issue nullability errors at compile time, but the call may fail at runtime, because of a null-pointer exception or an assertion that Kotlin generates to prevent nulls from propagating:

```
item.substring(1) // allowed, throws an exception if item == null
```

Platform types are non-denotable, meaning that you can't write them down explicitly in the language. When a platform value is assigned to a Kotlin variable, you can rely on the type inference (the variable will have an inferred platform type then, as item has in the example above), or you can choose the type you expect (both nullable and non-nullable types are allowed):

```
val nullable: String? = item // allowed, always works
val notNull: String = item // allowed, may fail at runtime
```

If you choose a non-nullable type, the compiler will emit an assertion upon assignment. This prevents Kotlin's non-nullable variables from holding nulls. Assertions are also emitted when you pass platform values to Kotlin functions expecting non-null values and in other cases. Overall, the compiler does its best to prevent nulls from propagating far through the program although sometimes this is impossible to eliminate entirely, because of generics.

Notation for platform types

As mentioned above, platform types can't be mentioned explicitly in the program, so there's no syntax for them in the language. Nevertheless, the compiler and IDE need to display them sometimes (for example, in error messages or parameter info), so there is a mnemonic notation for them:

- T! means " T or T? ",

* (Mutable)Collection<T>! means "Java collection of T may be mutable or not, may be nullable or not",
* Array<(out) T>! means "Java array of T (or a subtype of T), nullable or not"

Nullability annotations

Java types that have nullability annotations are represented not as platform types, but as actual nullable or non-nullable Kotlin types. The compiler supports several flavors of nullability annotations, including:

* JetBrains (@Nullable and @NotNull from the org.jetbrains.annotations package)
* JSpecify (org.jspecify.annotations)
* Android (com.android.annotations and android.support.annotations)
* JSR-305 (javax.annotation, more details below)
* FindBugs (edu.umd.cs.findbugs.annotations)
* Eclipse (org.eclipse.jdt.annotation)
* Lombok (lombok.NonNull)
* RxJava 3 (io.reactivex.rxjava3.annotations)

You can specify whether the compiler reports a nullability mismatch based on the information from specific types of nullability annotations. Use the compiler option -Xnullability-annotations=@<package-name>:<report-level>. In the argument, specify the fully qualified nullability annotations package and one of these report levels:

* ignore to ignore nullability mismatches
* warn to report warnings
* strict to report errors.

See the full list of supported nullability annotations in the Kotlin compiler source code.

Annotating type arguments and type parameters

You can annotate the type arguments and type parameters of generic types to provide nullability information for them as well.

All examples in the section use JetBrains nullability annotations from the org.jetbrains.annotations package.

Type arguments

Consider these annotations on a Java declaration:

```
@NotNull
Set<@NotNull String> toSet(@NotNull Collection<@NotNull String> elements) { ... }
```

They result in the following signature in Kotlin:

```
fun toSet(elements: (Mutable)Collection<String>) : (Mutable)Set<String> { ... }
```

When the @NotNull annotation is missing from a type argument, you get a platform type instead:

```
fun toSet(elements: (Mutable)Collection<String!>) : (Mutable)Set<String!> { ... }
```

Kotlin also takes into account nullability annotations on type arguments of base classes and interfaces. For example, there are two Java classes with the signatures provided below:

```
public class Base<T> {}
public class Derived extends Base<@Nullable String> {}
```

In the Kotlin code, passing the instance of Derived where the Base<String> is assumed produces the warning.

```
fun takeBaseOfNotNullStrings(x: Base<String>) {}

fun main() {
    takeBaseOfNotNullStrings(Derived()) // warning: nullability mismatch
}
```

The upper bound of Derived is set to Base<String?>, which is different from Base<String>.

Learn more about Java generics in Kotlin.

Type parameters

By default, the nullability of plain type parameters in both Kotlin and Java is undefined. In Java, you can specify it using nullability annotations. Let's annotate the type parameter of the Base class:

```
public class Base<@NotNull T> {}
```

When inheriting from Base, Kotlin expects a non-nullable type argument or type parameter. Thus, the following Kotlin code produces a warning:

```
class Derived<K> : Base<K> {} // warning: K has undefined nullability
```

You can fix it by specifying the upper bound K : Any.

Kotlin also supports nullability annotations on the bounds of Java type parameters. Let's add bounds to Base:

```
public class BaseWithBound<T extends @NotNull Number> {}
```

Kotlin translates this just as follows:

```
class BaseWithBound<T : Number> {}
```

So passing nullable type as a type argument or type parameter produces a warning.

Annotating type arguments and type parameters works with the Java 8 target or higher. The feature requires that the nullability annotations support the TYPE_USE target (org.jetbrains.annotations supports this in version 15 and above).

> If a nullability annotation supports other targets that are applicable to a type in addition to the TYPE_USE target, TYPE_USE takes priority. For example, if @Nullable has both TYPE_USE and METHOD targets, the Java method signature @Nullable String[] f() becomes fun f(): Array<String?>! in Kotlin.

JSR-305 support

The @Nonnull annotation defined in JSR-305 is supported for denoting nullability of Java types.

If the @Nonnull(when = ...) value is When.ALWAYS, the annotated type is treated as non-nullable; When.MAYBE and When.NEVER denote a nullable type; and When.UNKNOWN forces the type to be platform one.

A library can be compiled against the JSR-305 annotations, but there's no need to make the annotations artifact (e.g. jsr305.jar) a compile dependency for the library consumers. The Kotlin compiler can read the JSR-305 annotations from a library without the annotations present on the classpath.

Custom nullability qualifiers (KEEP-79) are also supported (see below).

Type qualifier nicknames

If an annotation type is annotated with both @TypeQualifierNickname and JSR-305 @Nonnull (or its another nickname, such as @CheckForNull), then the annotation type is itself used for retrieving precise nullability and has the same meaning as that nullability annotation:

```
@TypeQualifierNickname
@Nonnull(when = When.ALWAYS)
@Retention(RetentionPolicy.RUNTIME)
public @interface MyNonnull {
}

@TypeQualifierNickname
@CheckForNull // a nickname to another type qualifier nickname
@Retention(RetentionPolicy.RUNTIME)
public @interface MyNullable {
}

interface A {
    @MyNullable String foo(@MyNonnull String x);
    // in Kotlin (strict mode): `fun foo(x: String): String?`

    String bar(List<@MyNonnull String> x);
    // in Kotlin (strict mode): `fun bar(x: List<String>!): String!`
}
```

Type qualifier defaults

@TypeQualifierDefault allows introducing annotations that, when being applied, define the default nullability within the scope of the annotated element.

Such annotation type should itself be annotated with both @Nonnull (or its nickname) and @TypeQualifierDefault(...) with one or more ElementType values:

- ElementType.METHOD for return types of methods
- ElementType.PARAMETER for value parameters
- ElementType.FIELD for fields
- ElementType.TYPE_USE for any type including type arguments, upper bounds of type parameters and wildcard types

The default nullability is used when a type itself is not annotated by a nullability annotation, and the default is determined by the innermost enclosing element annotated with a type qualifier default annotation with the ElementType matching the type usage.

```
@Nonnull
@TypeQualifierDefault({ElementType.METHOD, ElementType.PARAMETER})
public @interface NonNullApi {
}

@Nonnull(when = When.MAYBE)
@TypeQualifierDefault({ElementType.METHOD, ElementType.PARAMETER, ElementType.TYPE_USE})
public @interface NullableApi {
}

@NullableApi
interface A {
    String foo(String x); // fun foo(x: String?): String?

    @NotNullApi // overriding default from the interface
    String bar(String x, @Nullable String y); // fun bar(x: String, y: String?): String

    // The List<String> type argument is seen as nullable because of `@NullableApi`
    // having the `TYPE_USE` element type:
    String baz(List<String> x); // fun baz(List<String?>?): String?

    // The type of `x` parameter remains platform because there's an explicit
    // UNKNOWN-marked nullability annotation:
    String qux(@Nonnull(when = When.UNKNOWN) String x); // fun baz(x: String!): String?
}
```

The types in this example only take place with the strict mode enabled; otherwise, the platform types remain. See the @UnderMigration annotation and Compiler configuration sections.

Package-level default nullability is also supported:

```
// FILE: test/package-info.java
@NonNullApi // declaring all types in package 'test' as non-nullable by default
package test;
```

@UnderMigration annotation

The @UnderMigration annotation (provided in a separate artifact kotlin-annotations-jvm) can be used by library maintainers to define the migration status for the nullability type qualifiers.

The status value in @UnderMigration(status = ...) specifies how the compiler treats inappropriate usages of the annotated types in Kotlin (e.g. using a @MyNullable-annotated type value as non-null):

- MigrationStatus.STRICT makes annotation work as any plain nullability annotation, i.e. report errors for the inappropriate usages and affect the types in the annotated declarations as they are seen in Kotlin
- MigrationStatus.WARN: the inappropriate usages are reported as compilation warnings instead of errors, but the types in the annotated declarations remain platform
- MigrationStatus.IGNORE makes the compiler ignore the nullability annotation completely

A library maintainer can add @UnderMigration status to both type qualifier nicknames and type qualifier defaults:

```
@Nonnull(when = When.ALWAYS)
@TypeQualifierDefault({ElementType.METHOD, ElementType.PARAMETER})
@UnderMigration(status = MigrationStatus.WARN)
public @interface NonNullApi {
}

// The types in the class are non-nullable, but only warnings are reported
// because `@NonNullApi` is annotated `@UnderMigration(status = MigrationStatus.WARN)`
@NonNullApi
public class Test {}
```

The migration status of a nullability annotation is not inherited by its type qualifier nicknames but is applied to its usages in default type qualifiers.

If a default type qualifier uses a type qualifier nickname and they are both @UnderMigration, the status from the default type qualifier is used.

Compiler configuration

The JSR-305 checks can be configured by adding the -Xjsr305 compiler flag with the following options (and their combination):

- -Xjsr305={strict|warn|ignore} to set up the behavior for non-@UnderMigration annotations. Custom nullability qualifiers, especially @TypeQualifierDefault, are already spread among many well-known libraries, and users may need to migrate smoothly when updating to the Kotlin version containing JSR-305 support. Since Kotlin 1.1.60, this flag only affects non-@UnderMigration annotations.
- -Xjsr305=under-migration:{strict|warn|ignore} to override the behavior for the @UnderMigration annotations. Users may have different view on the migration status for the libraries: they may want to have errors while the official migration status is WARN, or vice versa, they may wish to postpone errors reporting for some until they complete their migration.
- -Xjsr305=@<fq.name>:{strict|warn|ignore} to override the behavior for a single annotation, where <fq.name> is the fully qualified class name of the annotation. May appear several times for different annotations. This is useful for managing the migration state for a particular library.

The strict, warn and ignore values have the same meaning as those of MigrationStatus, and only the strict mode affects the types in the annotated declarations as they are seen in Kotlin.

Note: the built-in JSR-305 annotations @Nonnull, @Nullable and @CheckForNull are always enabled and affect the types of the annotated declarations in Kotlin, regardless of compiler configuration with the -Xjsr305 flag.

For example, adding -Xjsr305=ignore -Xjsr305=under-migration:ignore -Xjsr305=@org.library.MyNullable:warn to the compiler arguments makes the compiler generate warnings for inappropriate usages of types annotated by @org.library.MyNullable and ignore all other JSR-305 annotations.

The default behavior is the same to -Xjsr305=warn. The strict value should be considered experimental (more checks may be added to it in the future).

Mapped types

Kotlin treats some Java types specifically. Such types are not loaded from Java "as is", but are mapped to corresponding Kotlin types. The mapping only matters at compile time, the runtime representation remains unchanged. Java's primitive types are mapped to corresponding Kotlin types (keeping platform types in mind):

Java type	Kotlin type
byte	kotlin.Byte
short	kotlin.Short
int	kotlin.Int
long	kotlin.Long
char	kotlin.Char
float	kotlin.Float
double	kotlin.Double
boolean	kotlin.Boolean

Some non-primitive built-in classes are also mapped:

Java type	Kotlin type
java.lang.Object	kotlin.Any!
java.lang.Cloneable	kotlin.Cloneable!
java.lang.Comparable	kotlin.Comparable!
java.lang.Enum	kotlin.Enum!
java.lang.annotation.Annotation	kotlin.Annotation!
java.lang.CharSequence	kotlin.CharSequence!
java.lang.String	kotlin.String!
java.lang.Number	kotlin.Number!
java.lang.Throwable	kotlin.Throwable!

Java's boxed primitive types are mapped to nullable Kotlin types:

Java type	Kotlin type
java.lang.Byte	kotlin.Byte?
java.lang.Short	kotlin.Short?
java.lang.Integer	kotlin.Int?
java.lang.Long	kotlin.Long?
java.lang.Character	kotlin.Char?
java.lang.Float	kotlin.Float?
java.lang.Double	kotlin.Double?
java.lang.Boolean	kotlin.Boolean?

Note that a boxed primitive type used as a type parameter is mapped to a platform type: for example, List<java.lang.Integer> becomes a List<Int!> in Kotlin.

Collection types may be read-only or mutable in Kotlin, so Java's collections are mapped as follows (all Kotlin types in this table reside in the package kotlin.collections):

Java type	Kotlin read-only type	Kotlin mutable type	Loaded platform type
Iterator<T>	Iterator<T>	MutableIterator<T>	(Mutable)Iterator<T>!
Iterable<T>	Iterable<T>	MutableIterable<T>	(Mutable)Iterable<T>!
Collection<T>	Collection<T>	MutableCollection<T>	(Mutable)Collection<T>!
Set<T>	Set<T>	MutableSet<T>	(Mutable)Set<T>!
List<T>	List<T>	MutableList<T>	(Mutable)List<T>!
ListIterator<T>	ListIterator<T>	MutableListIterator<T>	(Mutable)ListIterator<T>!
Map<K, V>	Map<K, V>	MutableMap<K, V>	(Mutable)Map<K, V>!
Map.Entry<K, V>	Map.Entry<K, V>	MutableMap.MutableEntry<K,V>	(Mutable)Map.(Mutable)Entry<K, V>!

Java's arrays are mapped as mentioned below:

Java type	Kotlin type
int[]	kotlin.IntArray!
String[]	kotlin.Array<(out) String!>!

> The static members of these Java types are not directly accessible on the companion objects of the Kotlin types. To call them, use the full qualified names of the Java types, e.g. java.lang.Integer.toHexString(foo).

Java generics in Kotlin

Kotlin's generics are a little different from Java's (see Generics). When importing Java types to Kotlin, the following conversions are done:

- Java's wildcards are converted into type projections:
  - Foo<? extends Bar> becomes Foo<out Bar!>!
  - Foo<? super Bar> becomes Foo<in Bar!>!
- Java's raw types are converted into star projections:
  - List becomes List<*>! that is List<out Any?>!

Like Java's, Kotlin's generics are not retained at runtime: objects do not carry information about actual type arguments passed to their constructors. For example, ArrayList<Integer>() is indistinguishable from ArrayList<Character>(). This makes it impossible to perform is-checks that take generics into account. Kotlin only allows is-checks for star-projected generic types:

```
if (a is List<Int>) // Error: cannot check if it is really a List of Ints
// but
if (a is List<*>) // OK: no guarantees about the contents of the list
```

Java arrays

Arrays in Kotlin are invariant, unlike Java. This means that Kotlin won't let you assign an Array<String> to an Array<Any>, which prevents a possible runtime failure. Passing an array of a subclass as an array of superclass to a Kotlin method is also prohibited, but for Java methods this is allowed through platform types of the form Array<(out) String>!.

Arrays are used with primitive datatypes on the Java platform to avoid the cost of boxing/unboxing operations. As Kotlin hides those implementation details, a workaround is required to interface with Java code. There are specialized classes for every type of primitive array (IntArray, DoubleArray, CharArray, and so on) to handle this case. They are not related to the Array class and are compiled down to Java's primitive arrays for maximum performance.

Suppose there is a Java method that accepts an int array of indices:

```
public class JavaArrayExample {
    public void removeIndices(int[] indices) {
        // code here...
    }
}
```

To pass an array of primitive values, you can do the following in Kotlin:

```
val javaObj = JavaArrayExample()
val array = intArrayOf(0, 1, 2, 3)
javaObj.removeIndices(array)  // passes int[] to method
```

When compiling to the JVM bytecode, the compiler optimizes access to arrays so that there's no overhead introduced:

```
val array = arrayOf(1, 2, 3, 4)
array[1] = array[1] * 2 // no actual calls to get() and set() generated
for (x in array) { // no iterator created
    print(x)
}
```

Even when you navigate with an index, it does not introduce any overhead:

```
for (i in array.indices) { // no iterator created
    array[i] += 2
}
```

Finally, in-checks have no overhead either:

```
if (i in array.indices) { // same as (i >= 0 && i < array.size)
    print(array[i])
}
```

Java varargs

Java classes sometimes use a method declaration for the indices with a variable number of arguments (varargs):

```
public class JavaArrayExample {

    public void removeIndicesVarArg(int... indices) {
        // code here...
    }
}
```

In that case you need to use the spread operator * to pass the IntArray:

```
val javaObj = JavaArrayExample()
val array = intArrayOf(0, 1, 2, 3)
javaObj.removeIndicesVarArg(*array)
```

Operators

Since Java has no way of marking methods for which it makes sense to use the operator syntax, Kotlin allows using any Java methods with the right name and signature as operator overloads and other conventions (invoke() etc.) Calling Java methods using the infix call syntax is not allowed.

Checked exceptions

In Kotlin, all exceptions are unchecked, meaning that the compiler does not force you to catch any of them. So, when you call a Java method that declares a checked exception, Kotlin does not force you to do anything:

```
fun render(list: List<*>, to: Appendable) {
    for (item in list) {
        to.append(item.toString()) // Java would require us to catch IOException here
    }
}
```

Object methods

When Java types are imported into Kotlin, all the references of the type java.lang.Object are turned into Any. Since Any is not platform-specific, it only declares toString(), hashCode() and equals() as its members, so to make other members of java.lang.Object available, Kotlin uses extension functions.

wait()/notify()

Methods wait() and notify() are not available on references of type Any. Their usage is generally discouraged in favor of java.util.concurrent. If you really need to call these methods, you can cast to java.lang.Object:

```
(foo as java.lang.Object).wait()
```

getClass()

To retrieve the Java class of an object, use the java extension property on a class reference:

```
val fooClass = foo::class.java
```

The code above uses a bound class reference. You can also use the javaClass extension property:

```
val fooClass = foo.javaClass
```

clone()

To override clone(), your class needs to extend kotlin.Cloneable:

```
class Example : Cloneable {
    override fun clone(): Any { ... }
}
```

Don't forget about Effective Java, 3rd Edition, Item 13: Override clone judiciously.

finalize()

To override finalize(), all you need to do is simply declare it, without using the override keyword:

```
class C {
    protected fun finalize() {
        // finalization logic
    }
}
```

According to Java's rules, finalize() must not be private.

Inheritance from Java classes

At most one Java class (and as many Java interfaces as you like) can be a supertype for a class in Kotlin.

Accessing static members

Static members of Java classes form "companion objects" for these classes. You can't pass such a "companion object" around as a value but can access the members explicitly, for example:

```
if (Character.isLetter(a)) { ... }
```

To access static members of a Java type that is mapped to a Kotlin type, use the full qualified name of the Java type: java.lang.Integer.bitCount(foo).

Java reflection

Java reflection works on Kotlin classes and vice versa. As mentioned above, you can use instance::class.java, ClassName::class.java or instance.javaClass to enter Java reflection through java.lang.Class. Do not use ClassName.javaClass for this purpose because it refers to ClassName's companion object class, which is the same as ClassName.Companion::class.java and not ClassName::class.java.

For each primitive type, there are two different Java classes, and Kotlin provides ways to get both. For example, Int::class.java will return the class instance representing the primitive type itself, corresponding to Integer.TYPE in Java. To get the class of the corresponding wrapper type, use Int::class.javaObjectType, which is equivalent of Java's Integer.class.

Other supported cases include acquiring a Java getter/setter method or a backing field for a Kotlin property, a KProperty for a Java field, a Java method or constructor for a KFunction and vice versa.

SAM conversions

Kotlin supports SAM conversions for both Java and Kotlin interfaces. This support for Java means that Kotlin function literals can be automatically converted into implementations of Java interfaces with a single non-default method, as long as the parameter types of the interface method match the parameter types of the Kotlin function.

You can use this for creating instances of SAM interfaces:

```
val runnable = Runnable { println("This runs in a runnable") }
```

...and in method calls:

```
val executor = ThreadPoolExecutor()
// Java signature: void execute(Runnable command)
executor.execute { println("This runs in a thread pool") }
```

If the Java class has multiple methods taking functional interfaces, you can choose the one you need to call by using an adapter function that converts a lambda to a specific SAM type. Those adapter functions are also generated by the compiler when needed:

```
executor.execute(Runnable { println("This runs in a thread pool") })
```

SAM conversions only work for interfaces, not for abstract classes, even if those also have just a single abstract method.

Using JNI with Kotlin

To declare a function that is implemented in native (C or C++) code, you need to mark it with the external modifier:

```
external fun foo(x: Int): Double
```

The rest of the procedure works in exactly the same way as in Java.

You can also mark property getters and setters as external:

```
var myProperty: String
    external get
    external set
```

Behind the scenes, this will create two functions getMyProperty and setMyProperty, both marked as external.

Using Lombok-generated declarations in Kotlin

You can use Java's Lombok-generated declarations in Kotlin code. If you need to generate and use these declarations in the same mixed Java/Kotlin module, you can learn how to do this on the Lombok compiler plugin's page. If you call such declarations from another module, then you don't need to use this plugin to compile that module.

Calling Kotlin from Java

Kotlin code can be easily called from Java. For example, instances of a Kotlin class can be seamlessly created and operated in Java methods. However, there are certain differences between Java and Kotlin that require attention when integrating Kotlin code into Java. On this page, we'll describe the ways to tailor the interop of your Kotlin code with its Java clients.

Properties

A Kotlin property is compiled to the following Java elements:

- a getter method, with the name calculated by prepending the get prefix.
- a setter method, with the name calculated by prepending the set prefix (only for var properties).
- a private field, with the same name as the property name (only for properties with backing fields).

For example, var firstName: String compiles to the following Java declarations:

```
private String firstName;

public String getFirstName() {
    return firstName;
}

public void setFirstName(String firstName) {
    this.firstName = firstName;
}
```

If the name of the property starts with is, a different name mapping rule is used: the name of the getter is the same as the property name, and the name of the setter is obtained by replacing is with set. For example, for a property isOpen, the getter is called isOpen() and the setter is called setOpen(). This rule applies for properties of any type, not just Boolean.

Package-level functions

All the functions and properties declared in a file app.kt inside a package org.example, including extension functions, are compiled into static methods of a Java class named org.example.AppKt.

```
// app.kt
package org.example

class Util

fun getTime() { /*...*/ }
```

```
// Java
new org.example.Util();
org.example.AppKt.getTime();
```

To set a custom name to the generated Java class, use the @JvmName annotation:

```
@file:JvmName("DemoUtils")

package org.example

class Util

fun getTime() { /*...*/ }
```

```
// Java
new org.example.Util();
org.example.DemoUtils.getTime();
```

Having multiple files with the same generated Java class name (the same package and the same name or the same @JvmName annotation) is normally an error. However, the compiler can generate a single Java facade class which has the specified name and contains all the declarations from all the files which have that name. To enable the generation of such a facade, use the @JvmMultifileClass annotation in all such files.

```
// oldutils.kt
```

```
@file:JvmName("Utils")
@file:JvmMultifileClass

package org.example

fun getTime() { /*...*/ }
```

```
// newutils.kt
@file:JvmName("Utils")
@file:JvmMultifileClass

package org.example

fun getDate() { /*...*/ }
```

```
// Java
org.example.Utils.getTime();
org.example.Utils.getDate();
```

Instance fields

If you need to expose a Kotlin property as a field in Java, annotate it with the @JvmField annotation. The field has the same visibility as the underlying property. You can annotate a property with @JvmField if it:

- has a backing field
- is not private
- does not have open, override or const modifiers
- is not a delegated property

```
class User(id: String) {
    @JvmField val ID = id
}
```

```
// Java
class JavaClient {
    public String getID(User user) {
        return user.ID;
    }
}
```

Late-Initialized properties are also exposed as fields. The visibility of the field is the same as the visibility of the lateinit property setter.

Static fields

Kotlin properties declared in a named object or a companion object have static backing fields either in that named object or in the class containing the companion object.

Usually these fields are private, but they can be exposed in one of the following ways:

- @JvmField annotation
- lateinit modifier
- const modifier

Annotating such a property with @JvmField makes it a static field with the same visibility as the property itself.

```
class Key(val value: Int) {
    companion object {
        @JvmField
        val COMPARATOR: Comparator<Key> = compareBy<Key> { it.value }
    }
}
```

```
// Java
Key.COMPARATOR.compare(key1, key2);
// public static final field in Key class
```

A late-initialized property in an object or a companion object has a static backing field with the same visibility as the property setter.

```
object Singleton {
    lateinit var provider: Provider
}
```

```
// Java
Singleton.provider = new Provider();
// public static non-final field in Singleton class
```

Properties declared as const (in classes as well as at the top level) are turned into static fields in Java:

```
// file example.kt

object Obj {
    const val CONST = 1
}

class C {
    companion object {
        const val VERSION = 9
    }
}

const val MAX = 239
```

In Java:

```
int constant = Obj.CONST;
int max = ExampleKt.MAX;
int version = C.VERSION;
```

Static methods

As mentioned above, Kotlin represents package-level functions as static methods. Kotlin can also generate static methods for functions defined in named objects or companion objects if you annotate those functions as @JvmStatic. If you use this annotation, the compiler generates both a static method in the enclosing class of the object and an instance method in the object itself. For example:

```
class C {
    companion object {
        @JvmStatic fun callStatic() {}
        fun callNonStatic() {}
    }
}
```

Now, callStatic() is static in Java while callNonStatic() is not:

```
C.callStatic(); // works fine
C.callNonStatic(); // error: not a static method
C.Companion.callStatic(); // instance method remains
C.Companion.callNonStatic(); // the only way it works
```

Similarly, for named objects:

```
object Obj {
    @JvmStatic fun callStatic() {}
    fun callNonStatic() {}
}
```

In Java:

```
Obj.callStatic(); // works fine
Obj.callNonStatic(); // error
Obj.INSTANCE.callNonStatic(); // works, a call through the singleton instance
Obj.INSTANCE.callStatic(); // works too
```

Starting from Kotlin 1.3, @JvmStatic applies to functions defined in companion objects of interfaces as well. Such functions compile to static methods in interfaces. Note that static method in interfaces were introduced in Java 1.8, so be sure to use the corresponding targets.

```
interface ChatBot {
    companion object {
        @JvmStatic fun greet(username: String) {
            println("Hello, $username")
        }
    }
}
```

You can also apply @JvmStatic annotation to the property of an object or a companion object making its getter and setter methods static members in that object or the class containing the companion object.

Default methods in interfaces

When targeting the JVM, Kotlin compiles functions declared in interfaces to default methods unless configured otherwise. These are concrete methods in interfaces that Java classes can inherit directly, without reimplementation.

Here is an example of a Kotlin interface with a default method:

```
interface Robot {
    fun move() { println("~walking~") }  // will be default in the Java interface
    fun speak(): Unit
}
```

The default implementation is available for Java classes implementing the interface.

```
//Java implementation
public class C3PO implements Robot {
    // move() implementation from Robot is available implicitly
    @Override
    public void speak() {
        System.out.println("I beg your pardon, sir");
    }
}
```

```
C3PO c3po = new C3PO();
c3po.move(); // default implementation from the Robot interface
c3po.speak();
```

Implementations of the interface can override default methods.

```
//Java
public class BB8 implements Robot {
    //own implementation of the default method
    @Override
    public void move() {
        System.out.println("~rolling~");
    }

    @Override
    public void speak() {
        System.out.println("Beep-beep");
    }
}
```

Compatibility modes for default methods

Kotlin provides three modes for controlling how functions in interfaces are compiled to JVM default methods. These modes determine whether the compiler generates compatibility bridges and static methods in DefaultImpls classes.

You can control this behavior using the -jvm-default compiler option:

> The -jvm-default compiler option replaces the deprecated -Xjvm-default option.

Learn more about compatibility modes:

enable

Default behavior. Generates default implementations in interfaces and includes compatibility bridges and DefaultImpls classes. This mode maintains compatibility with older compiled Kotlin code.

no-compatibility

Generates only default implementations in interfaces. Skips compatibility bridges and DefaultImpls classes. Use this mode for new codebases that don't interact with code that relies on DefaultImpls classes. This can break binary compatibility with older Kotlin code.

> If interface delegation is used, all interface methods are delegated.

disable

Disables default implementations in interfaces. Only compatibility bridges and DefaultImpls classes are generated.

Visibility

The Kotlin visibility modifiers map to Java in the following way:

- private members are compiled to private members.
- private top-level declarations are compiled to private top-level declarations. Package-private accessors are also included, if accessed from within a class.
- protected remains protected. (Note that Java allows accessing protected members from other classes in the same package and Kotlin doesn't, so Java classes will have broader access to the code.)
- internal declarations become public in Java. Members of internal classes go through name mangling, to make. it harder to accidentally use them from Java and to allow overloading for members with the same signature that don't see each other according to Kotlin rules.
- public remains public.

KClass

Sometimes you need to call a Kotlin method with a parameter of type KClass. There is no automatic conversion from Class to KClass, so you have to do it manually by invoking the equivalent of the Class<T>.kotlin extension property:

```
kotlin.jvm.JvmClassMappingKt.getKotlinClass(MainView.class)
```

Handling signature clashes with @JvmName

Sometimes we have a named function in Kotlin, for which we need a different JVM name in bytecode. The most prominent example happens due to type erasure:

```
fun List<String>.filterValid(): List<String>
fun List<Int>.filterValid(): List<Int>
```

These two functions can not be defined side-by-side, because their JVM signatures are the same: filterValid(Ljava/util/List;)Ljava/util/List;. If we really want them to have the same name in Kotlin, we can annotate one (or both) of them with @JvmName and specify a different name as an argument:

```
fun List<String>.filterValid(): List<String>

@JvmName("filterValidInt")
fun List<Int>.filterValid(): List<Int>
```

From Kotlin, they are accessible by the same name filterValid, but from Java it is filterValid and filterValidInt.

The same trick applies when we need to have a property x along with a function getX():

```
val x: Int
    @JvmName("getX_prop")
    get() = 15

fun getX() = 10
```

To change the names of generated accessor methods for properties without explicitly implemented getters and setters, you can use @get:JvmName and @set:JvmName:

```
@get:JvmName("x")
@set:JvmName("changeX")
var x: Int = 23
```

Overloads generation

Normally, if you write a Kotlin function with default parameter values, it is visible in Java only as a full signature, with all parameters present. If you wish to expose multiple overloads to Java callers, you can use the @JvmOverloads annotation.

The annotation also works for constructors, static methods, and so on. It can't be used on abstract methods, including methods defined in interfaces.

```
class Circle @JvmOverloads constructor(centerX: Int, centerY: Int, radius: Double = 1.0) {
    @JvmOverloads fun draw(label: String, lineWidth: Int = 1, color: String = "red") { /*...*/ }
}
```

For every parameter with a default value, this generates one additional overload, which has this parameter and all parameters to the right of it in the parameter list removed. In this example, the following is generated:

```
// Constructors:
Circle(int centerX, int centerY, double radius)
Circle(int centerX, int centerY)

// Methods
void draw(String label, int lineWidth, String color) { }
void draw(String label, int lineWidth) { }
void draw(String label) { }
```

Note that, as described in Secondary constructors, if a class has default values for all constructor parameters, a public constructor with no arguments is generated for it. This works even if the @JvmOverloads annotation is not specified.

Checked exceptions

Kotlin does not have checked exceptions. So, normally the Java signatures of Kotlin functions do not declare exceptions thrown. Thus, if you have a function in Kotlin like this:

```
// example.kt
package demo

fun writeToFile() {
    /*...*/
    throw IOException()
}
```

And you want to call it from Java and catch the exception:

```
// Java
try {
    demo.Example.writeToFile();
} catch (IOException e) {
    // error: writeToFile() does not declare IOException in the throws list
    // ...
}
```

You get an error message from the Java compiler, because writeToFile() does not declare IOException. To work around this problem, use the @Throws annotation in Kotlin:

```
@Throws(IOException::class)
fun writeToFile() {
    /*...*/
    throw IOException()
}
```

Null-safety

When calling Kotlin functions from Java, nobody prevents us from passing null as a non-nullable parameter. That's why Kotlin generates runtime checks for all public functions that expect non-nulls. This way we get a NullPointerException in the Java code immediately.

Variant generics

When Kotlin classes make use of declaration-site variance, there are two options of how their usages are seen from the Java code. For example, imagine you have the following class and two functions that use it:

```
class Box<out T>(val value: T)

interface Base
class Derived : Base

fun boxDerived(value: Derived): Box<Derived> = Box(value)
fun unboxBase(box: Box<Base>): Base = box.value
```

A naive way of translating these functions into Java would be this:

```
Box<Derived> boxDerived(Derived value) { ... }
Base unboxBase(Box<Base> box) { ... }
```

The problem is that in Kotlin you can write unboxBase(boxDerived(Derived())) but in Java that would be impossible because in Java the class Box is invariant in its parameter T, and thus Box<Derived> is not a subtype of Box<Base>. To make this work in Java, you would have to define unboxBase as follows:

```
Base unboxBase(Box<? extends Base> box) { ... }
```

This declaration uses Java's wildcards types (? extends Base) to emulate declaration-site variance through use-site variance, because it is all Java has.

To make Kotlin APIs work in Java, the compiler generates Box<Super> as Box<? extends Super> for covariantly defined Box (or Foo<? super Bar> for contravariantly defined Foo) when it appears as a parameter. When it's a return value, wildcards are not generated, because otherwise Java clients will have to deal with them (and it's against the common Java coding style). Therefore, the functions from our example are actually translated as follows:

```
// return type - no wildcards
Box<Derived> boxDerived(Derived value) { ... }

// parameter - wildcards
Base unboxBase(Box<? extends Base> box) { ... }
```

When the argument type is final, there's usually no point in generating the wildcard, so Box<String> is always Box<String>, no matter what position it takes.

If you need wildcards where they are not generated by default, use the @JvmWildcard annotation:

```
fun boxDerived(value: Derived): Box<@JvmWildcard Derived> = Box(value)
// is translated to
// Box<? extends Derived> boxDerived(Derived value) { ... }
```

In the opposite case, if you don't need wildcards where they are generated, use @JvmSuppressWildcards:

```
fun unboxBase(box: Box<@JvmSuppressWildcards Base>): Base = box.value
// is translated to
// Base unboxBase(Box<Base> box) { ... }
```

> @JvmSuppressWildcards can be used not only on individual type arguments, but on entire declarations, such as functions or classes, causing all wildcards inside them to be suppressed.

Translation of type Nothing

The type Nothing is special, because it has no natural counterpart in Java. Indeed, every Java reference type, including java.lang.Void, accepts null as a value, and Nothing doesn't accept even that. So, this type cannot be accurately represented in the Java world. This is why Kotlin generates a raw type where an argument of type Nothing is used:

```
fun emptyList(): List<Nothing> = listOf()
// is translated to
// List emptyList() { ... }
```

Inline value classes

If you want Java code to work smoothly with Kotlin's inline value classes, you can use the @JvmExposeBoxed annotation or the -Xjvm-expose-boxed compiler option. These approaches ensure Kotlin generates the necessary boxed representations for Java interoperability.

By default, Kotlin compiles inline value classes to use unboxed representations, which are often inaccessible from Java. For example, you can't call the constructor for the MyInt class from Java:

```
@JvmInline
value class MyInt(val value: Int)
```

So the following Java code fails:

```
MyInt input = new MyInt(5);
```

You can use the @JvmExposeBoxed annotation so that Kotlin generates a public constructor that you can call from Java directly. You can apply the annotation at the following levels to ensure fine-grained control over what's exposed to Java:

- Class
- Constructor
- Function

Before using the @JvmExposeBoxed annotation in your code, you must opt in by using @OptIn(ExperimentalStdlibApi::class). For example:

```
@OptIn(ExperimentalStdlibApi::class)
@JvmExposeBoxed
@JvmInline
value class MyInt(val value: Int)

@OptIn(ExperimentalStdlibApi::class)
@JvmExposeBoxed
fun MyInt.timesTwoBoxed(): MyInt = MyInt(this.value * 2)
```

With these annotations, Kotlin generates a Java-accessible constructor for the MyInt class and a variant for the extension function that uses the boxed form of the value class. So the following Java code runs successfully:

```
MyInt input = new MyInt(5);
MyInt output = ExampleKt.timesTwoBoxed(input);
```

To apply this behavior to all inline value classes and the functions that use them within a module, compile it with the -Xjvm-expose-boxed option. Compiling with this option has the same effect as if every declaration in the module has the @JvmExposeBoxed annotation.

Get started with Spring Boot and Kotlin

Get started with Spring Boot and Kotlin by completing this tutorial: it walks you through the process of creating a simple application with Spring Boot and adding a database to store the information.

Going through these four steps, you'll learn a lot of essential features of the Kotlin language:

1. Create a Spring Boot project
2. Add a data class to Spring Boot project
3. Add database support for the Spring Boot project
4. Use Spring Data CrudRepository for database access

Next step

Start by creating a Spring Boot project with Kotlin using IntelliJ IDEA.

See also

Look through our Java to Kotlin (J2K) interop and migration guides:

- Calling Java from Kotlin and Calling Kotlin from Java
- Collections in Java and Kotlin
- Strings in Java and Kotlin

Join the community

- Kotlin slack: get an invitation and join the #spring and #server channels
- Stack Overflow: subscribe to the "kotlin", "spring-kotlin", or "ktor" tags
- Kotlin YouTube channel: subscribe and watch videos about Kotlin with Spring

Create a Spring Boot project with Kotlin

The first part of the tutorial shows how to create a Spring Boot project with Gradle in IntelliJ IDEA using the Project Wizard.

> This tutorial doesn't require using Gradle as the build system. You can follow the same steps if you use Maven.

Before you start

Download and install the latest version of IntelliJ IDEA Ultimate Edition.

> If you use IntelliJ IDEA Community Edition or another IDE, you can generate a Spring Boot project using a web-based project generator.

Create a Spring Boot project

Create a new Spring Boot project with Kotlin by using the Project Wizard in IntelliJ IDEA Ultimate Edition:

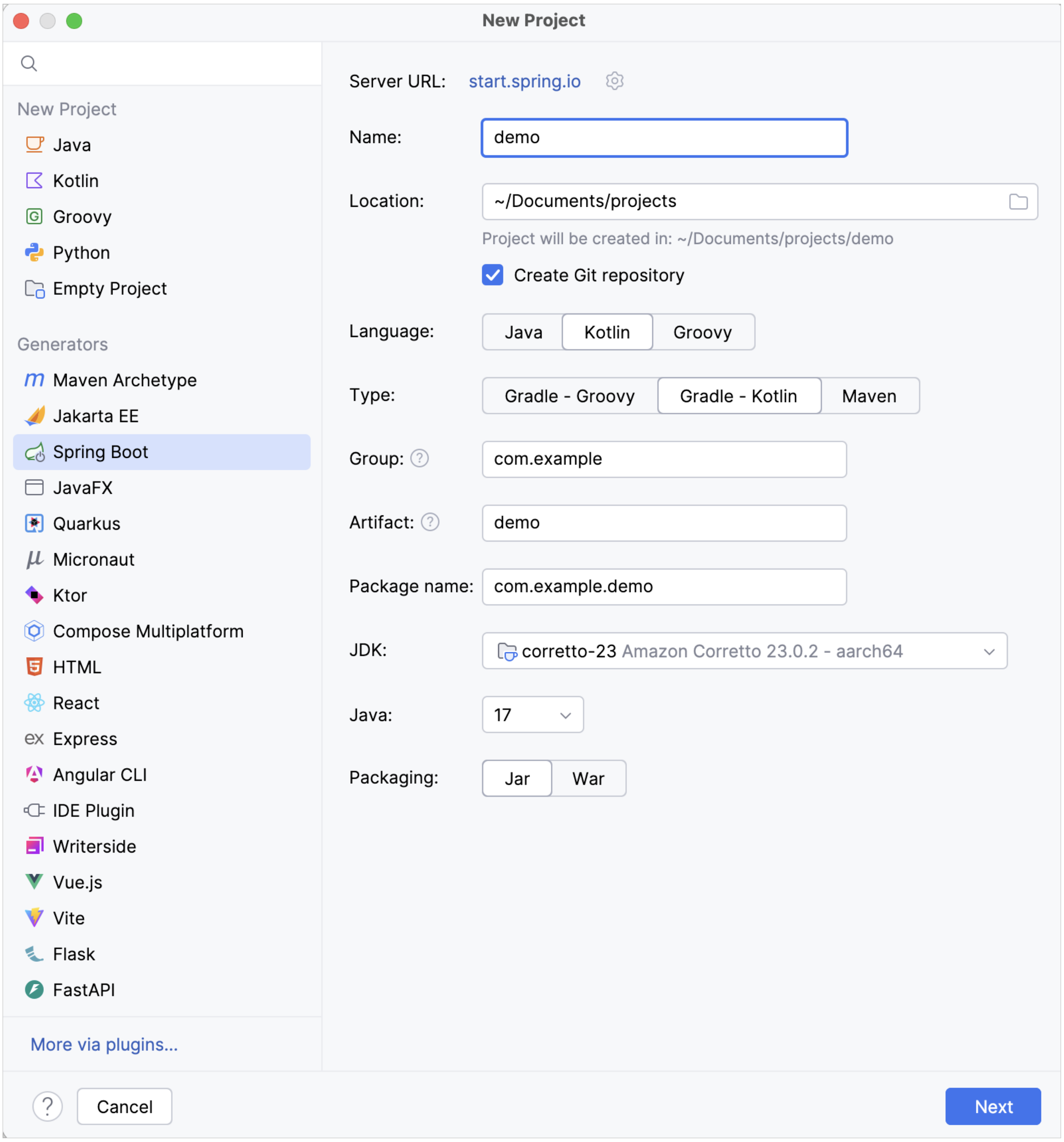
1. In IntelliJ IDEA, select File | New | Project.
2. In the panel on the left, select New Project | Spring Boot.
3. Specify the following fields and options in the New Project window:
   - Name: demo
   - Language: Kotlin
   - Type: Gradle - Kotlin

     > This option specifies the build system and the DSL.

   - Package name: com.example.demo
   - JDK: Java JDK

     > This tutorial uses Amazon Corretto version 23. If you don't have a JDK installed, you can download it from the dropdown list.

   - Java: 17



Server URL: start.spring.io

Name: demo

Location: ~/Documents/projects

Project will be created in: ~/Documents/projects/demo

[✓] Create Git repository

Language: Java [✓ Kotlin] Groovy

Type: Gradle - Groovy [✓ Gradle - Kotlin] Maven

Group: com.example

Artifact: demo

Package name: com.example.demo

JDK: corretto-23 Amazon Corretto 23.0.2 - aarch64

Java: 17

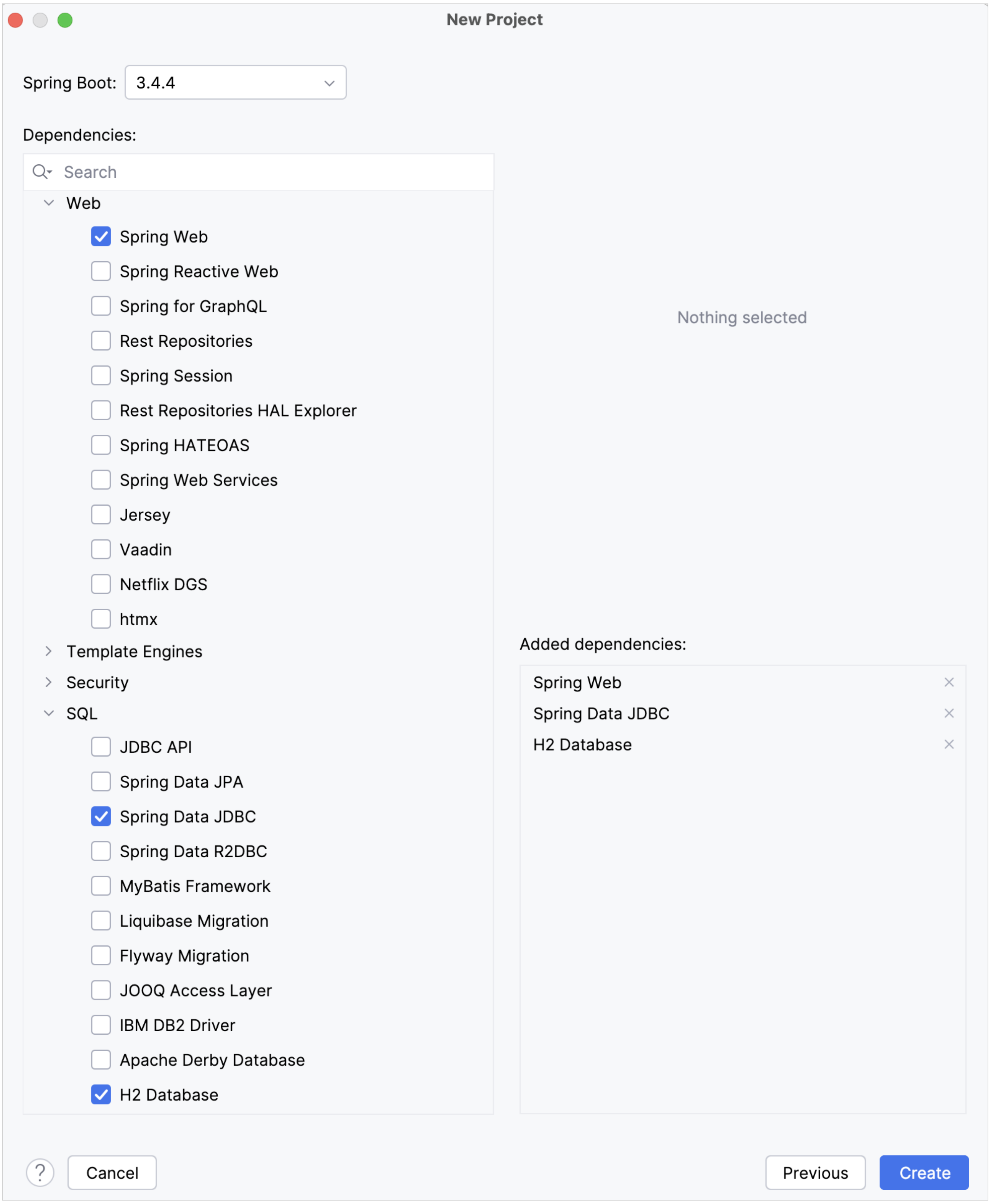
Packaging: [✓ Jar] War

Create Spring Boot project

4. Ensure that you have specified all the fields and click Next.

5. Select the following dependencies that will be required for the tutorial:

- Web | Spring Web
- SQL | Spring Data JDBC
- SQL | H2 Database



Spring Boot: 3.4.4

Dependencies:

Search

Web

- [✓] Spring Web
- [ ] Spring Reactive Web
- [ ] Spring for GraphQL
- [ ] Rest Repositories
- [ ] Spring Session
- [ ] Rest Repositories HAL Explorer
- [ ] Spring HATEOAS
- [ ] Spring Web Services
- [ ] Jersey
- [ ] Vaadin
- [ ] Netflix DGS
- [ ] htmx

Template Engines

Security

SQL

- [ ] JDBC API
- [ ] Spring Data JPA
- [✓] Spring Data JDBC
- [ ] Spring Data R2DBC
- [ ] MyBatis Framework
- [ ] Liquibase Migration
- [ ] Flyway Migration
- [ ] JOOQ Access Layer
- [ ] IBM DB2 Driver
- [ ] Apache Derby Database
- [✓] H2 Database

Nothing selected

Added dependencies:

Spring Web

Spring Data JDBC

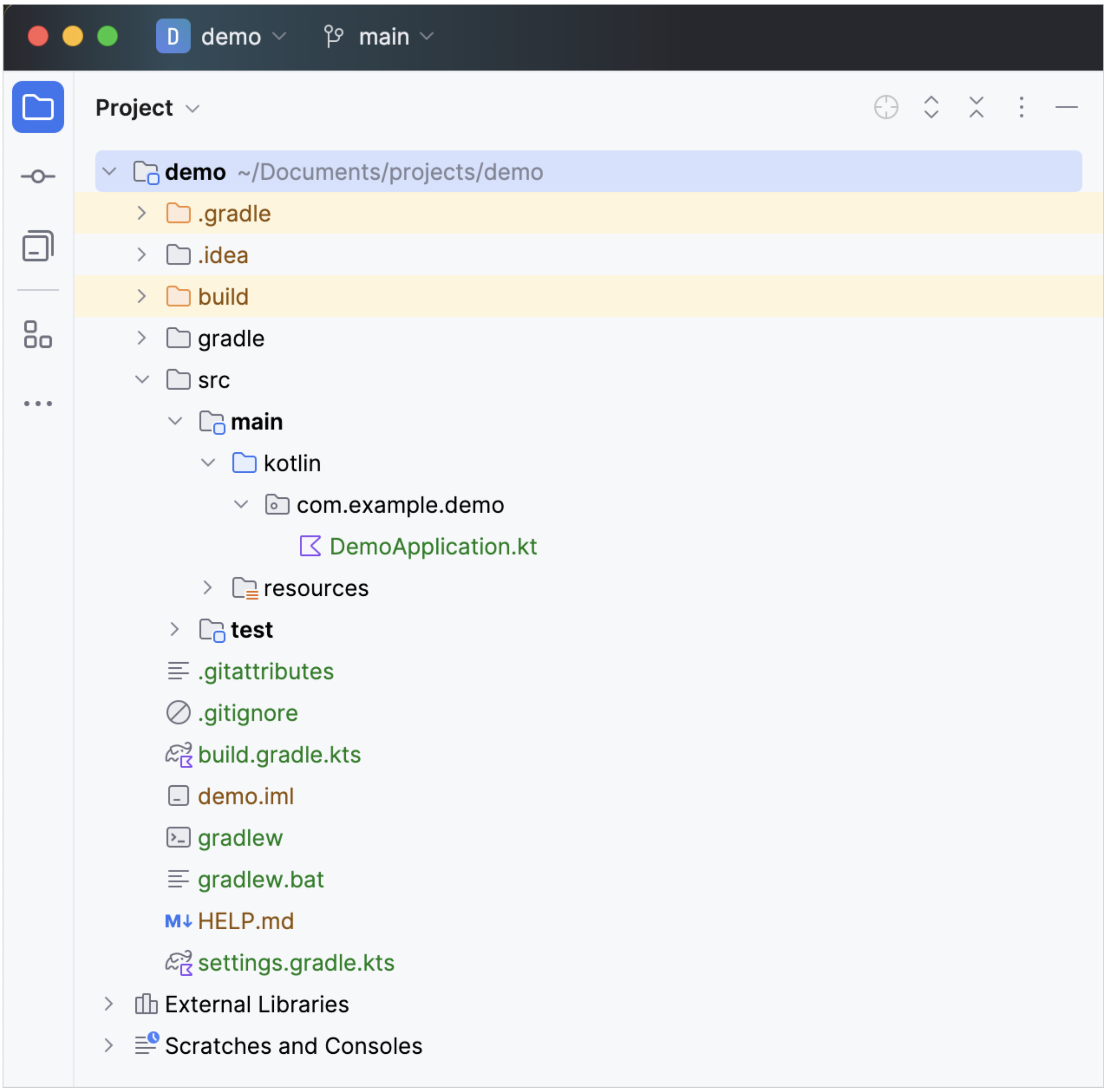
H2 Database

Set up Spring Boot project

6. Click Create to generate and set up the project.

> The IDE will generate and open a new project. It may take some time to download and import the project dependencies.

7. After this, you can observe the following structure in the Project view:



Set up Spring Boot project

The generated Gradle project corresponds to the Maven's standard directory layout:

- There are packages and classes under the main/kotlin folder that belong to the application.
- The entry point to the application is the main() method of the DemoApplication.kt file.

Explore the project Gradle build file

Open the build.gradle.kts file: it is the Gradle Kotlin build script, which contains a list of the dependencies required for the application.

The Gradle file is standard for Spring Boot, but it also contains necessary Kotlin dependencies, including the kotlin-spring Gradle plugin – kotlin("plugin.spring").

Here is the full script with the explanation of all parts and dependencies:

```
// build.gradle.kts
plugins {
    kotlin("jvm") version "1.9.25" // The version of Kotlin to use
    kotlin("plugin.spring") version "1.9.25" // The Kotlin Spring plugin
    id("org.springframework.boot") version "3.4.5"
    id("io.spring.dependency-management") version "1.1.7"
}

group = "com.example"
version = "0.0.1-SNAPSHOT"

java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(17)
    }
}

repositories {
    mavenCentral()
}

dependencies {
    implementation("org.springframework.boot:spring-boot-starter-data-jdbc")
    implementation("org.springframework.boot:spring-boot-starter-web")
    implementation("com.fasterxml.jackson.module:jackson-module-kotlin") // Jackson extensions for Kotlin for working with JSON
    implementation("org.jetbrains.kotlin:kotlin-reflect") // Kotlin reflection library, required for working with Spring
    runtimeOnly("com.h2database:h2")
    testImplementation("org.springframework.boot:spring-boot-starter-test")
    testImplementation("org.jetbrains.kotlin:kotlin-test-junit5")
    testRuntimeOnly("org.junit.platform:junit-platform-launcher")
}

kotlin {
    compilerOptions {
        freeCompilerArgs.addAll("-Xjsr305=strict") // `-Xjsr305=strict` enables the strict mode for JSR-305 annotations
    }
}

tasks.withType<Test> {
    useJUnitPlatform()
}
```

As you can see, there are a few Kotlin-related artifacts added to the Gradle build file:

1. In the plugins block, there are two Kotlin artifacts:
   - kotlin("jvm") – the plugin defines the version of Kotlin to be used in the project
   - kotlin("plugin.spring") – Kotlin Spring compiler plugin for adding the open modifier to Kotlin classes in order to make them compatible with Spring Framework features
2. In the dependencies block, a few Kotlin-related modules listed:
   - com.fasterxml.jackson.module:jackson-module-kotlin – the module adds support for serialization and deserialization of Kotlin classes and data classes
   - org.jetbrains.kotlin:kotlin-reflect – Kotlin reflection library
3. After the dependencies section, you can see the kotlin plugin configuration block. This is where you can add extra arguments to the compiler to enable or disable various language features.

Learn more about the Kotlin compiler options in Compiler options in the Kotlin Gradle plugin.

Explore the generated Spring Boot application

Open the DemoApplication.kt file:

```
// DemoApplication.kt
package com.example.demo

import org.springframework.boot.autoconfigure.SpringBootApplication
import org.springframework.boot.runApplication

@SpringBootApplication
class DemoApplication

fun main(args: Array<String>) {
    runApplication<DemoApplication>(*args)
}
```

Declaring classes – class DemoApplication

Right after package declaration and import statements you can see the first class declaration, class DemoApplication.

In Kotlin, if a class doesn't include any members (properties or functions), you can omit the class body ({}) for good.

@SpringBootApplication annotation

@SpringBootApplication annotation is a convenience annotation in a Spring Boot application. It enables Spring Boot's auto-configuration, component scan, and be able to define an extra configuration on their "application class".

Program entry point – main()

The main() function is the entry point to the application.

It is declared as a top-level function outside the DemoApplication class. The main() function invokes the Spring's runApplication(*args) function to start the application with the Spring Framework.

Variable arguments – args: Array<String>

If you check the declaration of the runApplication() function, you will see that the parameter of the function is marked with vararg modifier: vararg args: String. This means that you can pass a variable number of String arguments to the function.

The spread operator – (*args)

The args is a parameter to the main() function declared as an array of Strings. Since there is an array of strings, and you want to pass its content to the function, use the spread operator (prefix the array with a star sign *).

Create a controller

The application is ready to run, but let's update its logic first.

In the Spring application, a controller is used to handle the web requests. In the same package, next to the DemoApplication.kt file, create the MessageController.kt file with the MessageController class as follows:

```kotlin
// MessageController.kt
package com.example.demo

import org.springframework.web.bind.annotation.GetMapping
import org.springframework.web.bind.annotation.RequestParam
import org.springframework.web.bind.annotation.RestController

@RestController
class MessageController {
    @GetMapping("/")
    fun index(@RequestParam("name") name: String) = "Hello, $name!"
}
```

@RestController annotation

You need to tell Spring that MessageController is a REST Controller, so you should mark it with the @RestController annotation.

This annotation means this class will be picked up by the component scan because it's in the same package as our DemoApplication class.

@GetMapping annotation

@GetMapping marks the functions of the REST controller that implement the endpoints corresponding to HTTP GET calls:

```kotlin
@GetMapping("/")
      fun index(@RequestParam("name") name: String) = "Hello, $name!"
```

@RequestParam annotation

The function parameter name is marked with @RequestParam annotation. This annotation indicates that a method parameter should be bound to a web request parameter.

Hence, if you access the application at the root and supply a request parameter called "name", like /?name=<your-value>, the parameter value will be used as an argument for invoking the index() function.

Single-expression functions – index()

Since the index() function contains only one statement you can declare it as a single-expression function.

This means the curly braces can be omitted and the body is specified after the equals sign =.

Type inference for function return types

The index() function does not declare the return type explicitly. Instead, the compiler infers the return type by looking at the result of the statement on the right-hand side from the equals sign =.

The type of Hello, $name! expression is String, hence the return type of the function is also String.

String templates – $name

Hello, $name! expression is called a String template in Kotlin.

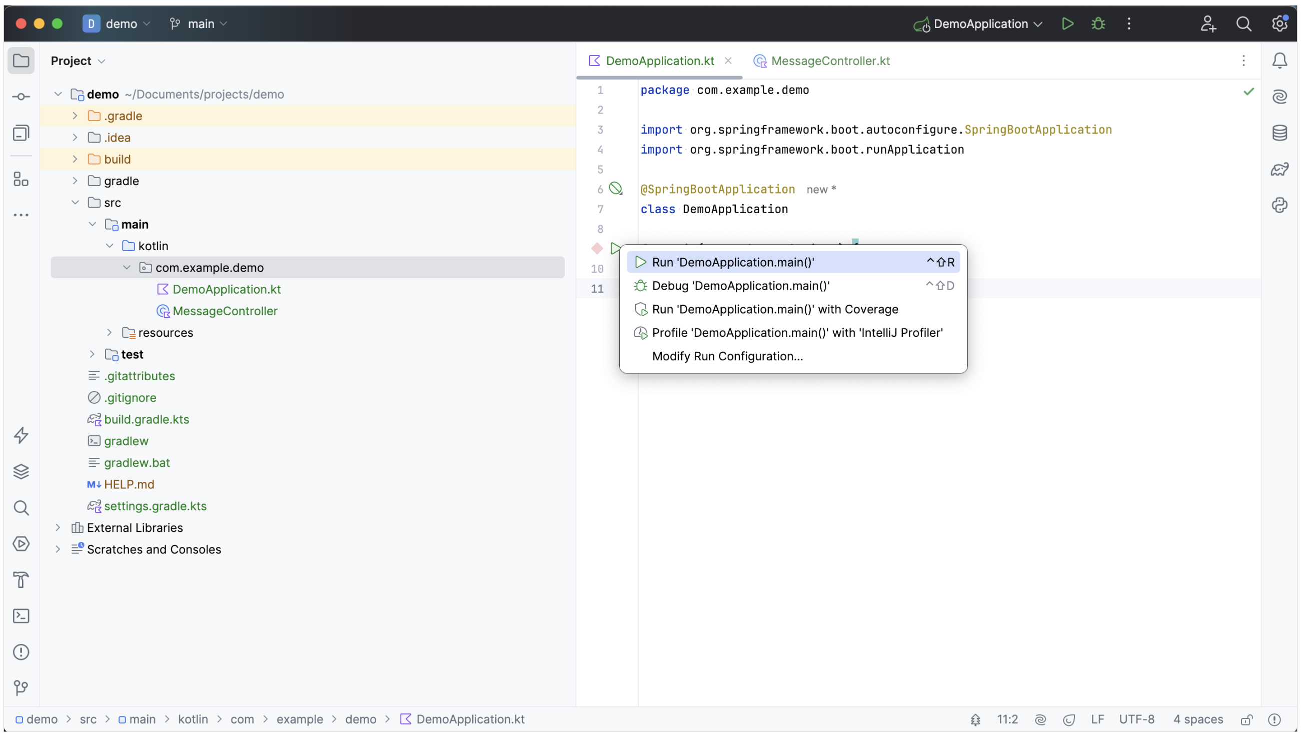
String templates are String literals that contain embedded expressions.

This is a convenient replacement for String concatenation operations.

Run the application

The Spring application is now ready to run:

1. In the DemoApplication.kt file, click the green Run icon in the gutter beside the main() method:



```
package com.example.demo

import org.springframework.boot.autoconfigure.SpringBootApplication
import org.springframework.boot.runApplication

@SpringBootApplication
class DemoApplication
```

Run Spring Boot application

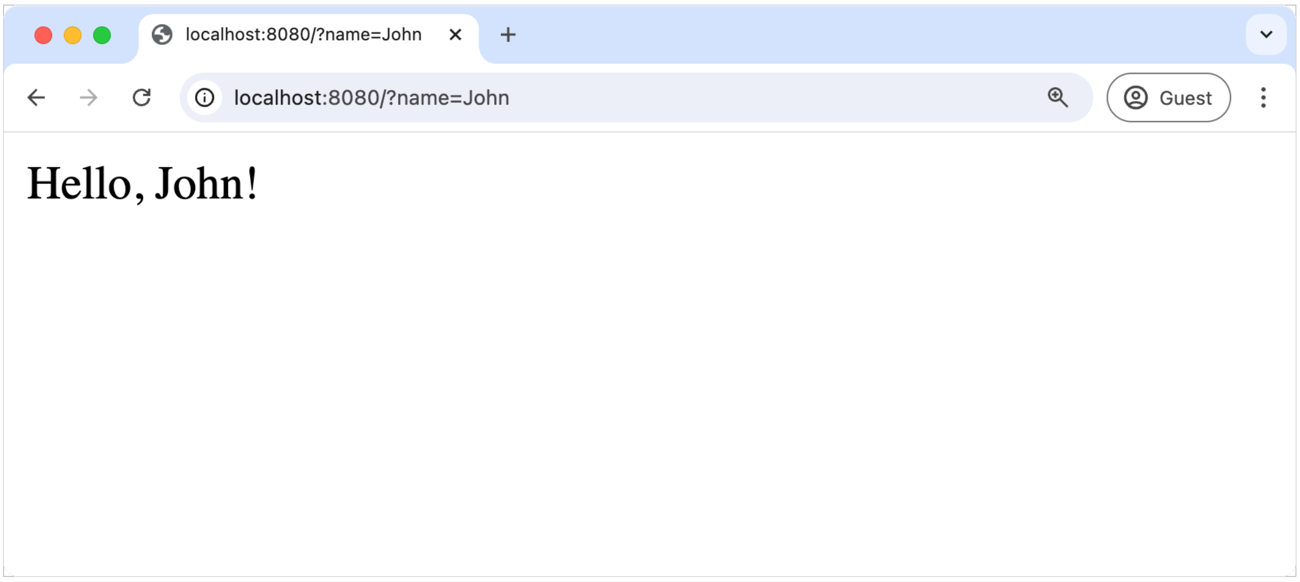
> You can also run the ./gradlew bootRun command in the terminal.

This starts the local server on your computer.

2. Once the application starts, open the following URL:

```
http://localhost:8080?name=John
```

You should see "Hello, John!" printed as a response:



Hello, John!

Spring Application response

Next step

In the next part of the tutorial, you'll learn about Kotlin data classes and how you can use them in your application.

Proceed to the next chapter

Add a data class to Spring Boot project

In this part of the tutorial, you'll add some more functionality to the application and discover more Kotlin language features, such as data classes. It requires changing the MessageController class to respond with a JSON document containing a collection of serialized objects.

Update your application

1. In the same package, next to the DemoApplication.kt file, create a Message.kt file.

2. In the Message.kt file, create a data class with two properties: id and text:

```
// Message.kt
package com.example.demo

data class Message(val id: String?, val text: String)
```

Message class will be used for data transfer: a list of serialized Message objects will make up the JSON document that the controller is going to respond to the browser request.

Data classes – data class Message
The main purpose of data classes in Kotlin is to hold data. Such classes are marked with the data keyword, and some standard functionality and some utility functions are often mechanically derivable from the class structure.

In this example, you declared Message as a data class as its main purpose is to store the data.

val and var properties
Properties in Kotlin classes can be declared either as:

- mutable, using the var keyword
- read-only, using the val keyword

The Message class declares two properties using val keyword, the id and text. The compiler will automatically generate the getters for both of these properties. It will not be possible to reassign the values of these properties after an instance of the Message class is created.

Nullable types – String?
Kotlin provides built-in support for nullable types. In Kotlin, the type system distinguishes between references that can hold null (nullable references) and those that cannot (non-nullable references).
For example, a regular variable of type String cannot hold null. To allow nulls, you can declare a variable as a nullable string by writing String?.

The id property of the Message class is declared as a nullable type this time. Hence, it is possible to create an instance of Message class by passing null as a value for id:

```
Message(null, "Hello!")
```

3. In the MessageController.kt file, instead of the index() function, create the listMessages() function returning a list of Message objects:

```
// MessageController.kt
package com.example.demo

import org.springframework.web.bind.annotation.GetMapping
import org.springframework.web.bind.annotation.RequestMapping
import org.springframework.web.bind.annotation.RestController

@RestController
@RequestMapping("/")
class MessageController {
    @GetMapping
    fun listMessages() = listOf(
        Message("1", "Hello!"),
        Message("2", "Bonjour!"),
        Message("3", "Privet!"),
    )
}
```

Collections – listOf()
The Kotlin Standard Library provides implementations for basic collection types: sets, lists, and maps.
Each collection type can be read-only or mutable:

- A read-only collection comes with operations for accessing collection elements.
- A mutable collection comes also with write operations for adding, removing, and updating its elements.

The corresponding factory functions are also provided by the Kotlin Standard Library to create instances of such collections.

In this tutorial, you use the listOf() function to create a list of Message objects. This is the factory function to create a read-only list of objects: you can't add or remove elements from the list.
If it is required to perform write operations on the list, call the mutableListOf() function to create a mutable list instance.

Trailing comma
A trailing comma is a comma symbol after the last item of a series of elements:

```
Message("3", "Privet!"),
```

This is a convenient feature of Kotlin syntax and is entirely optional – your code will still work without them.

In the example above, creating a list of Message objects includes the trailing comma after the last listOf() function argument.

The response from MessageController will now be a JSON document containing a collection of Message objects.

> Any controller in the Spring application renders JSON response by default if Jackson library is on the classpath. As you specified the spring-boot-starter-web dependency in the build.gradle.kts file, you received Jackson as a transitive dependency. Hence, the application responds with a JSON document if the endpoint returns a data structure that can be serialized to JSON.

Here is a complete code of the DemoApplication.kt, MessageController.kt, and Message.kt files:

```
// DemoApplication.kt
package com.example.demo
```

```kotlin
import org.springframework.boot.autoconfigure.SpringBootApplication
import org.springframework.boot.runApplication

@SpringBootApplication
class DemoApplication

fun main(args: Array<String>) {
    runApplication<DemoApplication>(*args)
}
```

```kotlin
// MessageController.kt
package com.example.demo

import org.springframework.web.bind.annotation.GetMapping
import org.springframework.web.bind.annotation.RequestMapping
import org.springframework.web.bind.annotation.RestController

@RestController
@RequestMapping("/")
class MessageController {
    @GetMapping
    fun listMessages() = listOf(
        Message("1", "Hello!"),
        Message("2", "Bonjour!"),
        Message("3", "Privet!"),
    )
}
```

```kotlin
// Message.kt
package com.example.demo

data class Message(val id: String?, val text: String)
```

Run the application

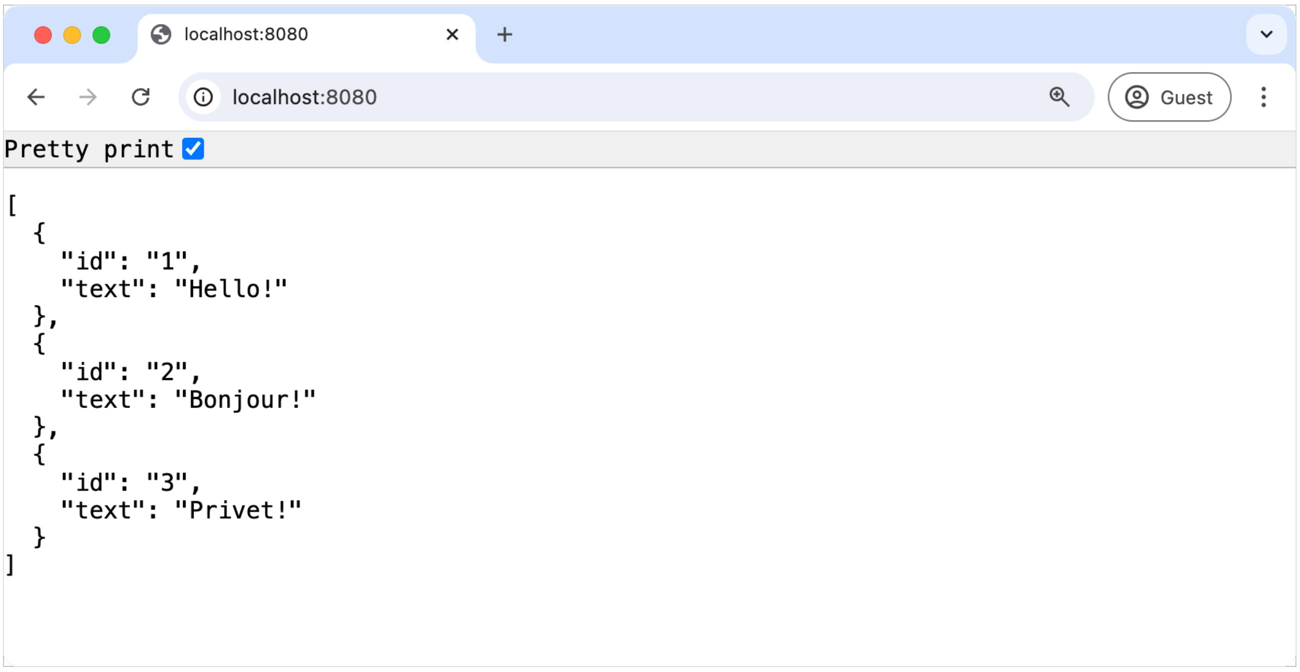
The Spring application is ready to run:

1. Run the application again.

2. Once the application starts, open the following URL:

   ```
   http://localhost:8080
   ```

   You will see a page with a collection of messages in JSON format:



```
[
  {
    "id": "1",
    "text": "Hello!"
  },
  {
    "id": "2",
    "text": "Bonjour!"
  },
  {
    "id": "3",
    "text": "Privet!"
  }
]
```

Run the application

Next step

In the next part of the tutorial, you'll add and configure a database to your project, and make HTTP requests.

Proceed to the next chapter

Add database support for Spring Boot project

In this part of the tutorial, you'll add and configure a database to your project using Java Database Connectivity (JDBC). In JVM applications, you use JDBC to interact with databases. For convenience, the Spring Framework provides the JdbcTemplate class that simplifies the use of JDBC and helps to avoid common errors.

Add database support

The common practice in Spring Framework based applications is to implement the database access logic within the so-called service layer – this is where business logic lives. In Spring, you should mark classes with the @Service annotation to imply that the class belongs to the service layer of the application. In this application, you will create the MessageService class for this purpose.

In the same package, create the MessageService.kt file and the MessageService class as follows:

```
// MessageService.kt
package com.example.demo

import org.springframework.stereotype.Service
import org.springframework.jdbc.core.JdbcTemplate
import java.util.*

@Service
class MessageService(private val db: JdbcTemplate) {
    fun findMessages(): List<Message> = db.query("select * from messages") { response, _ ->
        Message(response.getString("id"), response.getString("text"))
    }

    fun save(message: Message): Message {
        db.update(
            "insert into messages values ( ?, ? )",
            message.id, message.text
        )
        return message
    }
}
```

Constructor argument and dependency injection – (private val db: JdbcTemplate)

A class in Kotlin has a primary constructor. It can also have one or more secondary constructors. The primary constructor is a part of the class header, and it goes after the class name and optional type parameters. In our case, the constructor is (val db: JdbcTemplate).

val db: JdbcTemplate is the constructor's argument:

```
@Service
      class MessageService(private val db: JdbcTemplate)
```

Trailing lambda and SAM conversion

The findMessages() function calls the query() function of the JdbcTemplate class. The query() function takes two arguments: an SQL query as a String instance, and a callback that will map one object per row:

```
db.query("...", RowMapper { ... } )
```

The RowMapper interface declares only one method, so it is possible to implement it via lambda expression by omitting the name of the interface. The Kotlin compiler knows the interface that the lambda expression needs to be converted to because you use it as a parameter for the function call. This is known as SAM conversion in Kotlin:

```
db.query("...", { ... } )
```

After the SAM conversion, the query function ends up with two arguments: a String at the first position, and a lambda expression at the last position. According to the Kotlin convention, if the last parameter of a function is a function, then a lambda expression passed as the corresponding argument can be placed outside the parentheses. Such syntax is also known as trailing lambda:

```
db.query("...") { ... }
```

Underscore for unused lambda argument

For a lambda with multiple parameters, you can use the underscore _ character to replace the names of the parameters you don't use.

Hence, the final syntax for query function call looks like this:

```
db.query("select * from messages") { response, _ ->
         Message(response.getString("id"), response.getString("text"))
      }
```

Update the MessageController class

Update MessageController.kt to use the new MessageService class:

```
// MessageController.kt
package com.example.demo

import org.springframework.http.ResponseEntity
import org.springframework.web.bind.annotation.GetMapping
import org.springframework.web.bind.annotation.PostMapping
import org.springframework.web.bind.annotation.RequestBody
import org.springframework.web.bind.annotation.RequestMapping
import org.springframework.web.bind.annotation.RestController
import java.net.URI

@RestController
@RequestMapping("/")
class MessageController(private val service: MessageService) {
    @GetMapping
    fun listMessages() = service.findMessages()

    @PostMapping
    fun post(@RequestBody message: Message): ResponseEntity<Message> {
        val savedMessage = service.save(message)
        return ResponseEntity.created(URI("/${savedMessage.id}")).body(savedMessage)
    }
}
```

@PostMapping annotation
The method responsible for handling HTTP POST requests needs to be annotated with @PostMapping annotation. To be able to convert the JSON sent as HTTP Body content into an object, you need to use the @RequestBody annotation for the method argument. Thanks to having Jackson library in the classpath of the application, the conversion happens automatically.

ResponseEntity
ResponseEntity represents the whole HTTP response: status code, headers, and body.

Using the created() method you configure the response status code (201) and set the location header indicating the context path for the created resource.

Update the MessageService class

The id for Message class was declared as a nullable String:

```
data class Message(val id: String?, val text: String)
```

It would not be correct to store the null as an id value in the database though: you need to handle this situation gracefully.

Update your code of the MessageService.kt file to generate a new value when the id is null while storing the messages in the database:

```
// MessageService.kt
package com.example.demo

import org.springframework.stereotype.Service
import org.springframework.jdbc.core.JdbcTemplate
import org.springframework.jdbc.core.query
import java.util.UUID

@Service
class MessageService(private val db: JdbcTemplate) {
    fun findMessages(): List<Message> = db.query("select * from messages") { response, _ ->
        Message(response.getString("id"), response.getString("text"))
    }

    fun save(message: Message): Message {
        val id = message.id ?: UUID.randomUUID().toString() // Generate new id if it is null
        db.update(
            "insert into messages values ( ?, ? )",
            id, message.text
        )
        return message.copy(id = id) // Return a copy of the message with the new id
    }
}
```

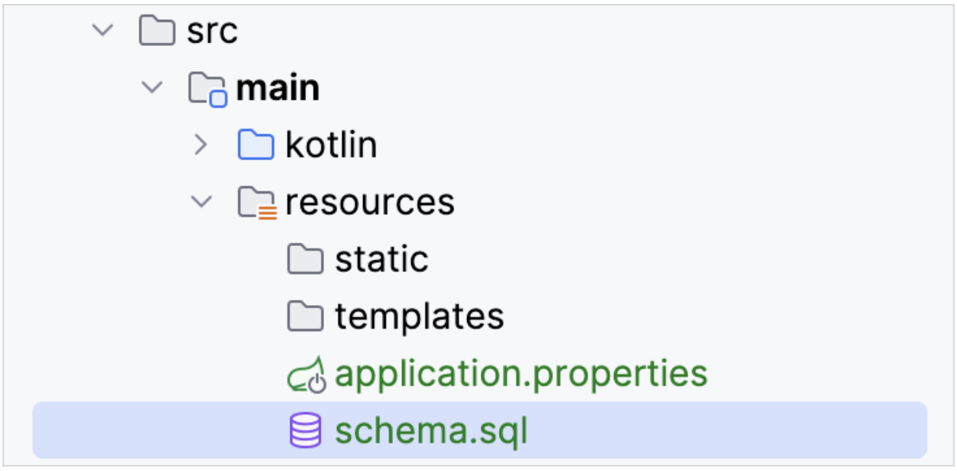
Elvis operator – ?:
The code message.id ?: UUID.randomUUID().toString() uses the Elvis operator (if-not-null-else shorthand) ?:. If the expression to the left of ?: is not null, the Elvis operator returns it; otherwise, it returns the expression to the right. Note that the expression on the right-hand side is evaluated only if the left-hand side is null.

The application code is ready to work with the database. It is now required to configure the data source.

Configure the database

Configure the database in the application:

1. Create schema.sql file in the src/main/resources directory. It will store the database object definitions:



Create database schema

2. Update the src/main/resources/schema.sql file with the following code:

```
-- schema.sql
CREATE TABLE IF NOT EXISTS messages (
id       VARCHAR(60)  PRIMARY KEY,
text     VARCHAR      NOT NULL
);
```

It creates the messages table with two columns: id and text. The table structure matches the structure of the Message class.

3. Open the application.properties file located in the src/main/resources folder and add the following application properties:

```
spring.application.name=demo
spring.datasource.driver-class-name=org.h2.Driver
spring.datasource.url=jdbc:h2:file:./data/testdb
spring.datasource.username=name
spring.datasource.password=password
spring.sql.init.schema-locations=classpath:schema.sql
spring.sql.init.mode=always
```

These settings enable the database for the Spring Boot application.
See the full list of common application properties in the Spring documentation.

Add messages to database via HTTP request

You should use an HTTP client to work with previously created endpoints. In IntelliJ IDEA, use the embedded HTTP client:

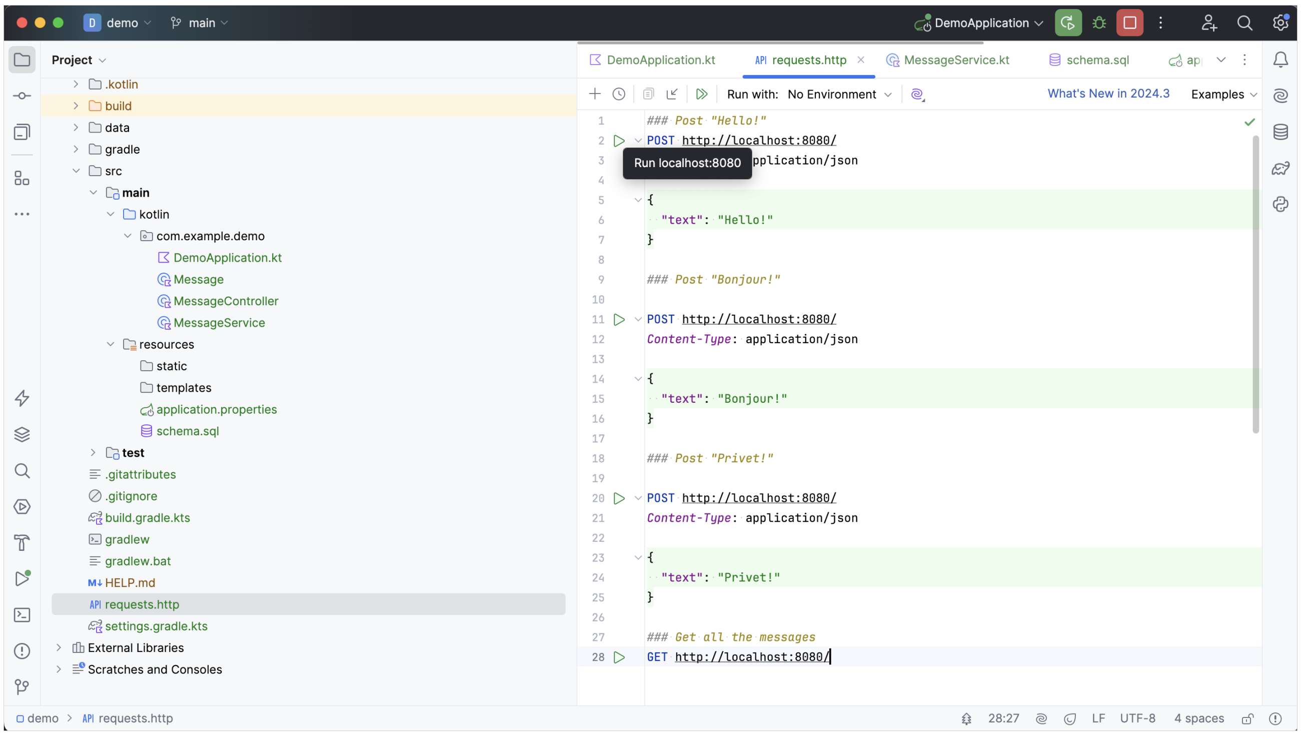
1. Run the application. Once the application is up and running, you can execute POST requests to store messages in the database.

2. Create the requests.http file in the project root folder and add the following HTTP requests:

```
### Post "Hello!"
POST http://localhost:8080/
Content-Type: application/json

{
  "text": "Hello!"
}

### Post "Bonjour!"

POST http://localhost:8080/
Content-Type: application/json

{
  "text": "Bonjour!"
}

### Post "Privet!"
```

```
POST http://localhost:8080/
Content-Type: application/json

{
  "text": "Privet!"
}

### Get all the messages
GET http://localhost:8080/
```

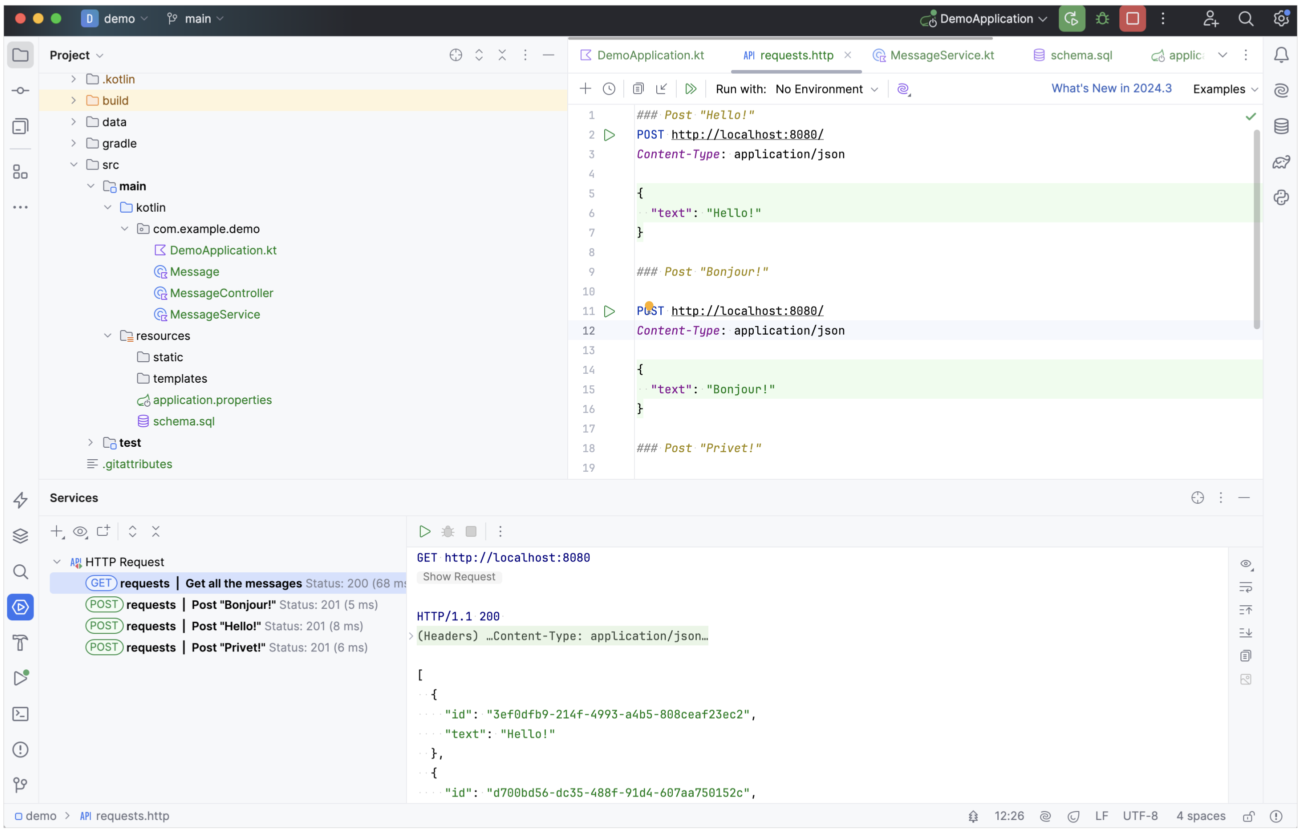
3. Execute all POST requests. Use the green Run icon in the gutter next to the request declaration. These requests write the text messages to the database:



```
### Post "Hello!"
POST http://localhost:8080/
                   pplication/json

{
  "text": "Hello!"
}

### Post "Bonjour!"

POST http://localhost:8080/
Content-Type: application/json

{
  "text": "Bonjour!"
}

### Post "Privet!"

POST http://localhost:8080/
Content-Type: application/json

{
  "text": "Privet!"
}

### Get all the messages
GET http://localhost:8080/
```

Execute POST request

4. Execute the GET request and see the result in the Run tool window:



```
### Post "Hello!"
POST http://localhost:8080/
Content-Type: application/json

{
  "text": "Hello!"
}

### Post "Bonjour!"

POST http://localhost:8080/
Content-Type: application/json

{
  "text": "Bonjour!"
}

### Post "Privet!"
```

```
GET requests | Get all the messages Status: 200 (68 ms
POST requests | Post "Bonjour!" Status: 201 (5 ms)
POST requests | Post "Hello!" Status: 201 (8 ms)
POST requests | Post "Privet!" Status: 201 (6 ms)
```

```
GET http://localhost:8080
Show Request

HTTP/1.1 200
(Headers) …Content-Type: application/json…

[
  {
    "id": "3ef0dfb9-214f-4993-a4b5-808ceaf23ec2",
    "text": "Hello!"
  },
  {
    "id": "d700bd56-dc35-488f-91d4-607aa750152c",
```

Execute GET requests

Alternative way to execute requests

You can also use any other HTTP client or the cURL command-line tool. For example, run the following commands in the terminal to get the same result:

```
curl -X POST --location "http://localhost:8080" -H "Content-Type: application/json" -d "{ \"text\": \"Hello!\" }"

curl -X POST --location "http://localhost:8080" -H "Content-Type: application/json" -d "{ \"text\": \"Bonjour!\" }"

curl -X POST --location "http://localhost:8080" -H "Content-Type: application/json" -d "{ \"text\": \"Privet!\" }"

curl -X GET --location "http://localhost:8080"
```

Retrieve messages by id

Extend the functionality of the application to retrieve the individual messages by id.

1. In the MessageService class, add the new function findMessageById(id: String) to retrieve the individual messages by id:

```kotlin
// MessageService.kt
package com.example.demo

import org.springframework.stereotype.Service
import org.springframework.jdbc.core.JdbcTemplate
import org.springframework.jdbc.core.query
import java.util.*

@Service
class MessageService(private val db: JdbcTemplate) {
    fun findMessages(): List<Message> = db.query("select * from messages") { response, _ ->
        Message(response.getString("id"), response.getString("text"))
    }

    fun findMessageById(id: String): Message? = db.query("select * from messages where id = ?", id) { response, _ ->
        Message(response.getString("id"), response.getString("text"))
    }.singleOrNull()
    fun save(message: Message): Message {
        val id = message.id ?: UUID.randomUUID().toString() // Generate new id if it is null
        db.update(
            "insert into messages values ( ?, ? )",
            id, message.text
        )
        return message.copy(id = id) // Return a copy of the message with the new id
    }
}
```

vararg argument position in the parameter list
The query() function takes three arguments:

- SQL query string that requires a parameter to run
- id, which is a parameter of type String
- RowMapper instance, which implemented by a lambda expression

The second parameter for the query() function is declared as a variable argument (vararg). In Kotlin, the position of the variable arguments parameter is not required to be the last in the parameters list.

singleOrNull() function
The singleOrNull() function returns a single element, or null if the array is empty or has more than one element with the same value.

> The .query() function that is used to fetch the message by its id is a Kotlin extension function provided by the Spring Framework. It requires an additional import import org.springframework.jdbc.core.query as demonstrated in the code above.

2. Add the new index(...) function with the id parameter to the MessageController class:

```
// MessageController.kt
package com.example.demo

import org.springframework.http.ResponseEntity
import org.springframework.web.bind.annotation.GetMapping
import org.springframework.web.bind.annotation.PathVariable
import org.springframework.web.bind.annotation.PostMapping
import org.springframework.web.bind.annotation.RequestBody
import org.springframework.web.bind.annotation.RequestMapping
import org.springframework.web.bind.annotation.RestController
import java.net.URI

@RestController
@RequestMapping("/")
class MessageController(private val service: MessageService) {
    @GetMapping
    fun listMessages() = ResponseEntity.ok(service.findMessages())

    @PostMapping
    fun post(@RequestBody message: Message): ResponseEntity<Message> {
        val savedMessage = service.save(message)
        return ResponseEntity.created(URI("/${savedMessage.id}")).body(savedMessage)
    }

    @GetMapping("/{id}")
    fun getMessage(@PathVariable id: String): ResponseEntity<Message> =
        service.findMessageById(id).toResponseEntity()

    private fun Message?.toResponseEntity(): ResponseEntity<Message> =
        // If the message is null (not found), set response code to 404
        this?.let { ResponseEntity.ok(it) } ?: ResponseEntity.notFound().build()
}
```

Retrieving a value from the context path
The message id is retrieved from the context path by the Spring Framework as you annotated the new function by @GetMapping("/{id}"). By annotating the function argument with @PathVariable, you tell the framework to use the retrieved value as a function argument. The new function makes a call to MessageService to retrieve the individual message by its id.

Extension function with nullable receiver
Extensions can be defined with a nullable receiver type. If the receiver is null, then this is also null. So when defining an extension with a nullable receiver type, it

is recommended performing a this == null check inside the function body.

You can also use the null-safe invocation operator (?.) to perform the null check as in the toResponseEntity() function above:

```
this?.let { ResponseEntity.ok(it) }
```

ResponseEntity
ResponseEntity represents the HTTP response, including the status code, headers, and body. It is a generic wrapper that allows you to send customized HTTP responses back to the client with more control over the content.

Here is a complete code of the application:

```
// DemoApplication.kt
package com.example.demo

import org.springframework.boot.autoconfigure.SpringBootApplication
import org.springframework.boot.runApplication

@SpringBootApplication
class DemoApplication

fun main(args: Array<String>) {
    runApplication<DemoApplication>(*args)
}
```

```
// Message.kt
package com.example.demo

data class Message(val id: String?, val text: String)
```

```
// MessageService.kt
package com.example.demo

import org.springframework.stereotype.Service
import org.springframework.jdbc.core.JdbcTemplate
import org.springframework.jdbc.core.query
import java.util.*

@Service
class MessageService(private val db: JdbcTemplate) {
    fun findMessages(): List<Message> = db.query("select * from messages") { response, _ ->
        Message(response.getString("id"), response.getString("text"))
    }

    fun findMessageById(id: String): Message? = db.query("select * from messages where id = ?", id) { response, _ ->
        Message(response.getString("id"), response.getString("text"))
    }.singleOrNull()

    fun save(message: Message): Message {
        val id = message.id ?: UUID.randomUUID().toString()
        db.update(
            "insert into messages values ( ?, ? )",
            id, message.text
        )
        return message.copy(id = id)
    }
}
```

```
// MessageController.kt
package com.example.demo

import org.springframework.http.ResponseEntity
import org.springframework.web.bind.annotation.GetMapping
import org.springframework.web.bind.annotation.PathVariable
import org.springframework.web.bind.annotation.PostMapping
import org.springframework.web.bind.annotation.RequestBody
import org.springframework.web.bind.annotation.RequestMapping
import org.springframework.web.bind.annotation.RestController
import java.net.URI

@RestController
@RequestMapping("/")
class MessageController(private val service: MessageService) {
    @GetMapping
    fun listMessages() = ResponseEntity.ok(service.findMessages())

    @PostMapping
    fun post(@RequestBody message: Message): ResponseEntity<Message> {
        val savedMessage = service.save(message)
        return ResponseEntity.created(URI("/${savedMessage.id}")).body(savedMessage)
    }

    @GetMapping("/{id}")
    fun getMessage(@PathVariable id: String): ResponseEntity<Message> =
        service.findMessageById(id).toResponseEntity()

    private fun Message?.toResponseEntity(): ResponseEntity<Message> =
        this?.let { ResponseEntity.ok(it) } ?: ResponseEntity.notFound().build()
}
```

Run the application

The Spring application is ready to run:

1. Run the application again.
2. Open the requests.http file and add the new GET request:

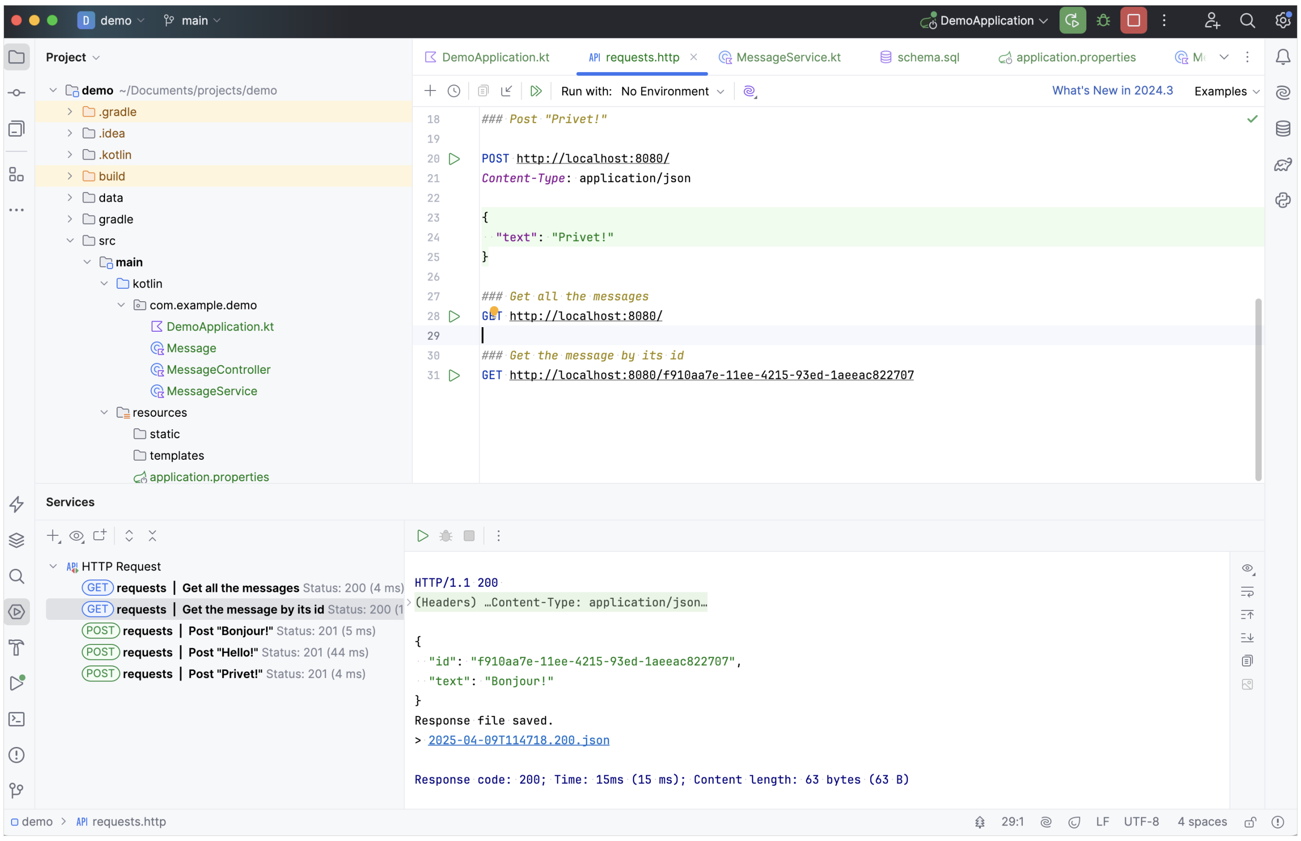
```
### Get the message by its id
GET http://localhost:8080/id
```

3. Execute the GET request to retrieve all the messages from the database.
4. In the Run tool window copy one of the ids and add it to the request, like this:

```
### Get the message by its id
GET http://localhost:8080/f910aa7e-11ee-4215-93ed-1aeeac822707
```

> Put your message id instead of the mentioned above.

5. Execute the GET request and see the result in the Run tool window:



```
### Post "Privet!"

POST http://localhost:8080/
Content-Type: application/json

{
  "text": "Privet!"
}

### Get all the messages
GET http://localhost:8080/

### Get the message by its id
GET http://localhost:8080/f910aa7e-11ee-4215-93ed-1aeeac822707
```

```
GET requests | Get all the messages Status: 200 (4 ms)
GET requests | Get the message by its id Status: 200 (1
POST requests | Post "Bonjour!" Status: 201 (5 ms)
POST requests | Post "Hello!" Status: 201 (44 ms)
POST requests | Post "Privet!" Status: 201 (4 ms)
```

```
HTTP/1.1 200
(Headers) …Content-Type: application/json…

{
  "id": "f910aa7e-11ee-4215-93ed-1aeeac822707",
  "text": "Bonjour!"
}
Response file saved.
> 2025-04-09T114718.200.json

Response code: 200; Time: 15ms (15 ms); Content length: 63 bytes (63 B)
```

Retrieve message by its id

Next step

The final step shows you how to use more popular connection to database using Spring Data.

Proceed to the next chapter

Use Spring Data CrudRepository for database access

In this part, you will migrate the service layer to use the Spring Data CrudRepository instead of JdbcTemplate for database access. CrudRepository is a Spring Data interface for generic CRUD operations on a repository of a specific type. It provides several methods out of the box for interacting with a database.

Update your application

First, you need to adjust the Message class for work with the CrudRepository API:

1. Add the @Table annotation to the Message class to declare mapping to a database table.
   Add the @Id annotation before the id field.

   These annotations also require additional imports.

```
// Message.kt
package com.example.demo

import org.springframework.data.annotation.Id
import org.springframework.data.relational.core.mapping.Table

@Table("MESSAGES")
```

```
data class Message(@Id val id: String?, val text: String)
```

In addition, to make the use of the Message class more idiomatic, you can set the default value for id property to null and flip the order of the data class properties:

```
@Table("MESSAGES")
data class Message(val text: String, @Id val id: String? = null)
```

Now if you need to create a new instance of the Message class, you can only specify the text property as a parameter:

```
val message = Message("Hello") // id is null
```

2. Declare an interface for the CrudRepository that will work with the Message data class. Create the MessageRepository.kt file and add the following code to it:

```
// MessageRepository.kt
package com.example.demo

import org.springframework.data.repository.CrudRepository

interface MessageRepository : CrudRepository<Message, String>
```

3. Update the MessageService class. It will now use the MessageRepository instead of executing SQL queries:

```
// MessageService.kt
package com.example.demo

import org.springframework.data.repository.findByIdOrNull
import org.springframework.stereotype.Service

@Service
class MessageService(private val db: MessageRepository) {
    fun findMessages(): List<Message> = db.findAll().toList()

    fun findMessageById(id: String): Message? = db.findByIdOrNull(id)

    fun save(message: Message): Message = db.save(message)
}
```

Extension functions
The findByIdOrNull() function is an extension function for CrudRepository interface in Spring Data JDBC.

CrudRepository save() function
This function works with an assumption that the new object doesn't have an id in the database. Hence, the id should be null for insertion.

If the id isn't null, CrudRepository assumes that the object already exists in the database and this is an update operation as opposed to an insert operation. After the insert operation, the id will be generated by the data store and assigned back to the Message instance. This is why the id property should be declared using the var keyword.

4. Update the messages table definition to generate the ids for the inserted objects. Since id is a string, you can use the RANDOM_UUID() function to generate the id value by default:

```
-- schema.sql
CREATE TABLE IF NOT EXISTS messages (
    id      VARCHAR(60)  DEFAULT RANDOM_UUID() PRIMARY KEY,
    text    VARCHAR      NOT NULL
);
```

5. Update the name of the database in the application.properties file located in the src/main/resources folder:

```
spring.application.name=demo
spring.datasource.driver-class-name=org.h2.Driver
spring.datasource.url=jdbc:h2:file:./data/testdb2
spring.datasource.username=name
spring.datasource.password=password
spring.sql.init.schema-locations=classpath:schema.sql
spring.sql.init.mode=always
```

Here is the complete code of the application:

```kotlin
// DemoApplication.kt
package com.example.demo

import org.springframework.boot.autoconfigure.SpringBootApplication
import org.springframework.boot.runApplication

@SpringBootApplication
class DemoApplication

fun main(args: Array<String>) {
    runApplication<DemoApplication>(*args)
}
```

```kotlin
// Message.kt
package com.example.demo

import org.springframework.data.annotation.Id
import org.springframework.data.relational.core.mapping.Table

@Table("MESSAGES")
data class Message(val text: String, @Id val id: String? = null)
```

```kotlin
// MessageRepository.kt
package com.example.demo

import org.springframework.data.repository.CrudRepository

interface MessageRepository : CrudRepository<Message, String>
```

```kotlin
// MessageService.kt
package com.example.demo

import org.springframework.data.repository.findByIdOrNull
import org.springframework.stereotype.Service

@Service
class MessageService(private val db: MessageRepository) {
    fun findMessages(): List<Message> = db.findAll().toList()

    fun findMessageById(id: String): Message? = db.findByIdOrNull(id)

    fun save(message: Message): Message = db.save(message)
}
```

```kotlin
// MessageController.kt
package com.example.demo

import org.springframework.http.ResponseEntity
import org.springframework.web.bind.annotation.GetMapping
import org.springframework.web.bind.annotation.PathVariable
import org.springframework.web.bind.annotation.PostMapping
import org.springframework.web.bind.annotation.RequestBody
import org.springframework.web.bind.annotation.RequestMapping
import org.springframework.web.bind.annotation.RestController
import java.net.URI

@RestController
@RequestMapping("/")
class MessageController(private val service: MessageService) {
    @GetMapping
    fun listMessages() = ResponseEntity.ok(service.findMessages())

    @PostMapping
    fun post(@RequestBody message: Message): ResponseEntity<Message> {
        val savedMessage = service.save(message)
        return ResponseEntity.created(URI("/${savedMessage.id}")).body(savedMessage)
    }

    @GetMapping("/{id}")
    fun getMessage(@PathVariable id: String): ResponseEntity<Message> =
        service.findMessageById(id).toResponseEntity()

    private fun Message?.toResponseEntity(): ResponseEntity<Message> =
        // If the message is null (not found), set response code to 404
        this?.let { ResponseEntity.ok(it) } ?: ResponseEntity.notFound().build()
}
```

Run the application

Congratulations! The application is ready to run again. After replacing JdbcTemplate with CrudRepository, the functionality remains the same, so the application works just as before.

You can now run the POST and GET HTTP requests from the requests.http file and get the same results.

What's next

Get your personal language map to help you navigate Kotlin features and track your progress in studying the language:

Get the Kotlin language map

- Learn more about Calling Java from Kotlin code and Calling Kotlin from Java code.
- Learn how to convert existing Java code to Kotlin with the Java-to-Kotlin converter.
- Check out our Java to Kotlin migration guides:
  - Strings in Java and Kotlin.
  - Collections in Java and Kotlin.
  - Nullability in Java and Kotlin.

Build a Kotlin app that uses Spring AI to answer questions based on documents stored in Qdrant — tutorial

In this tutorial, you'll learn how to build a Kotlin app that uses Spring AI to connect to an LLM, store documents in a vector database, and answer questions using context from those documents.

You will use the following tools during this tutorial:

- Spring Boot as the base to configure and run the web application.
- Spring AI to interact with the LLM and perform context-based retrieval.
- IntelliJ IDEA to generate the project and implement the application logic.
- Qdrant as the vector database for similarity search.
- Docker to run Qdrant locally.
- OpenAI as the LLM provider.

Before you start

1. Download and install the latest version of IntelliJ IDEA Ultimate Edition.

   > If you use IntelliJ IDEA Community Edition or another IDE, you can generate a Spring Boot project using a web-based project generator.

2. Create an OpenAI API key on the OpenAI platform to access the API.

3. Install Docker to run the Qdrant vector database locally.

4. After installing Docker, open your terminal and run the following command to start the container:

   ```
   docker run -p 6333:6333 -p 6334:6334 qdrant/qdrant
   ```

Create the project

> You can use Spring Boot web-based project generator as an alternative to generate your project.

Create a new Spring Boot project in IntelliJ IDEA Ultimate Edition:

1. In IntelliJ IDEA, select File | New | Project.

2. In the panel on the left, select New Project | Spring Boot.

3. Specify the following fields and options in the New Project window:

   - Name: springAIDemo

   - Language: Kotlin

   - Type: Gradle - Kotlin

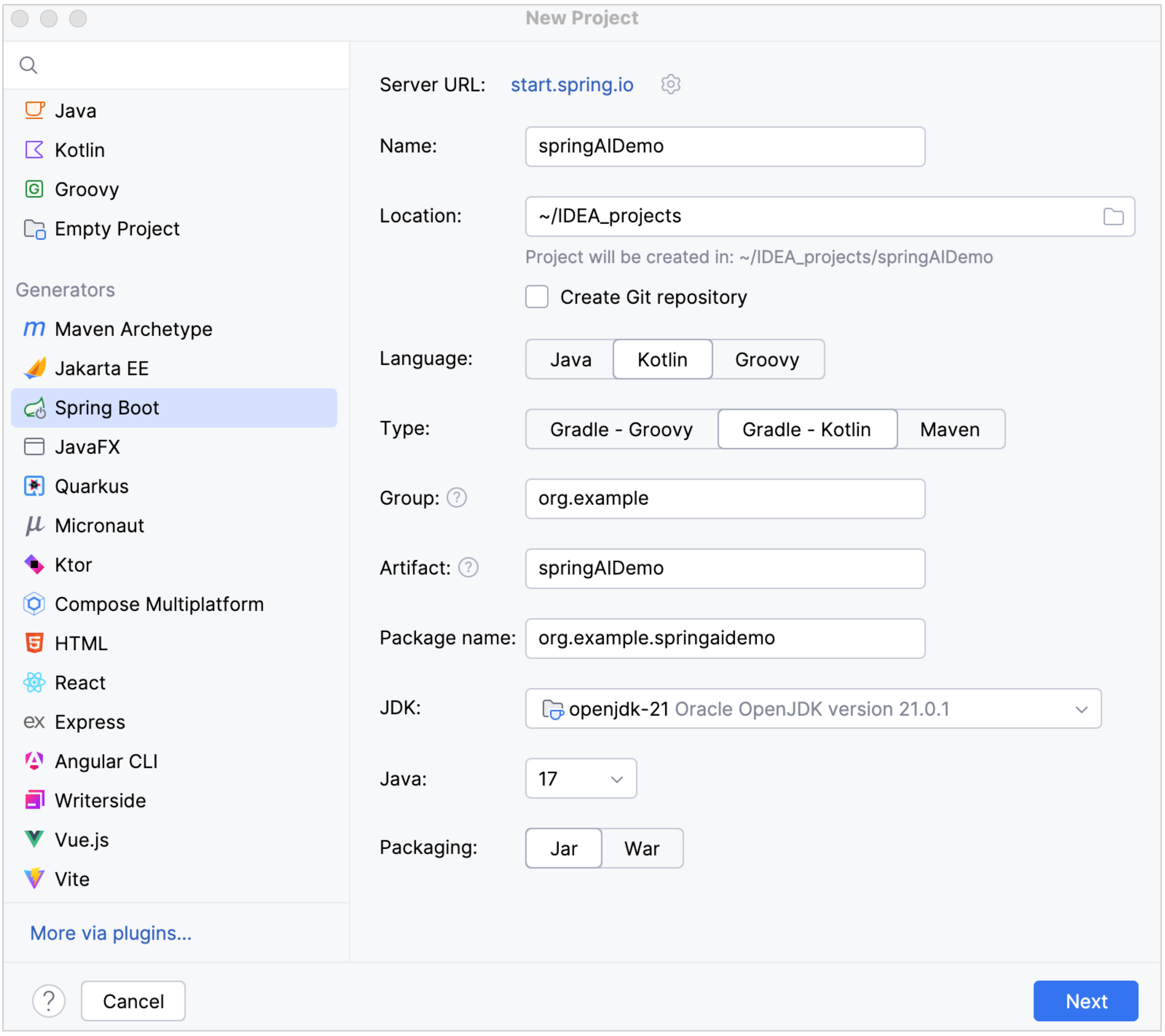
     > This option specifies the build system and the DSL.

   - Package name: com.example.springaidemo

   - JDK: Java JDK

     > This tutorial uses Oracle OpenJDK version 21.0.1. If you don't have a JDK installed, you can download it from the dropdown list.

   - Java: 17



Server URL: start.spring.io

Name: springAIDemo

Location: ~/IDEA_projects

Project will be created in: ~/IDEA_projects/springAIDemo

Create Git repository

Language: Java [✓ Kotlin] Groovy

Type: Gradle - Groovy [✓ Gradle - Kotlin] Maven

Group: org.example

Artifact: springAIDemo

Package name: org.example.springaidemo

JDK: openjdk-21 Oracle OpenJDK version 21.0.1

Java: 17

Packaging: [✓ Jar] War

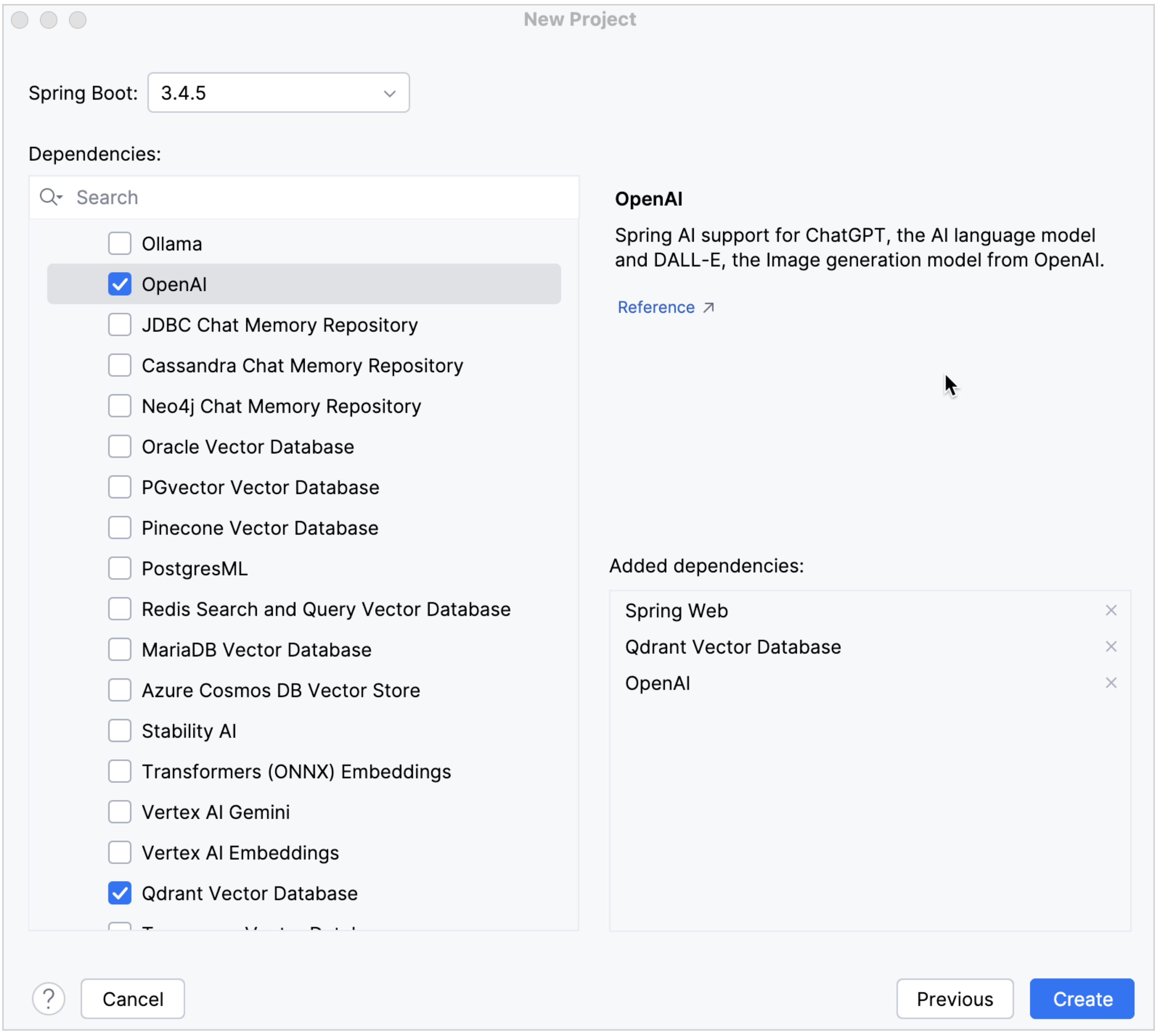
Create Spring Boot project

4. Make sure that you have specified all the fields and click Next.

5. Select the latest stable Spring Boot version in the Spring Boot field.

6. Select the following dependencies required for this tutorial:

- Web | Spring Web
- AI | OpenAI
- SQL | Qdrant Vector Database



Spring Boot: 3.4.5

Dependencies:

- [ ] Ollama
- [x] OpenAI
- [ ] JDBC Chat Memory Repository
- [ ] Cassandra Chat Memory Repository
- [ ] Neo4j Chat Memory Repository
- [ ] Oracle Vector Database
- [ ] PGvector Vector Database
- [ ] Pinecone Vector Database
- [ ] PostgresML
- [ ] Redis Search and Query Vector Database
- [ ] MariaDB Vector Database
- [ ] Azure Cosmos DB Vector Store
- [ ] Stability AI
- [ ] Transformers (ONNX) Embeddings
- [ ] Vertex AI Gemini
- [ ] Vertex AI Embeddings
- [x] Qdrant Vector Database

OpenAI

Spring AI support for ChatGPT, the AI language model and DALL-E, the Image generation model from OpenAI.

Reference ↗

Added dependencies:

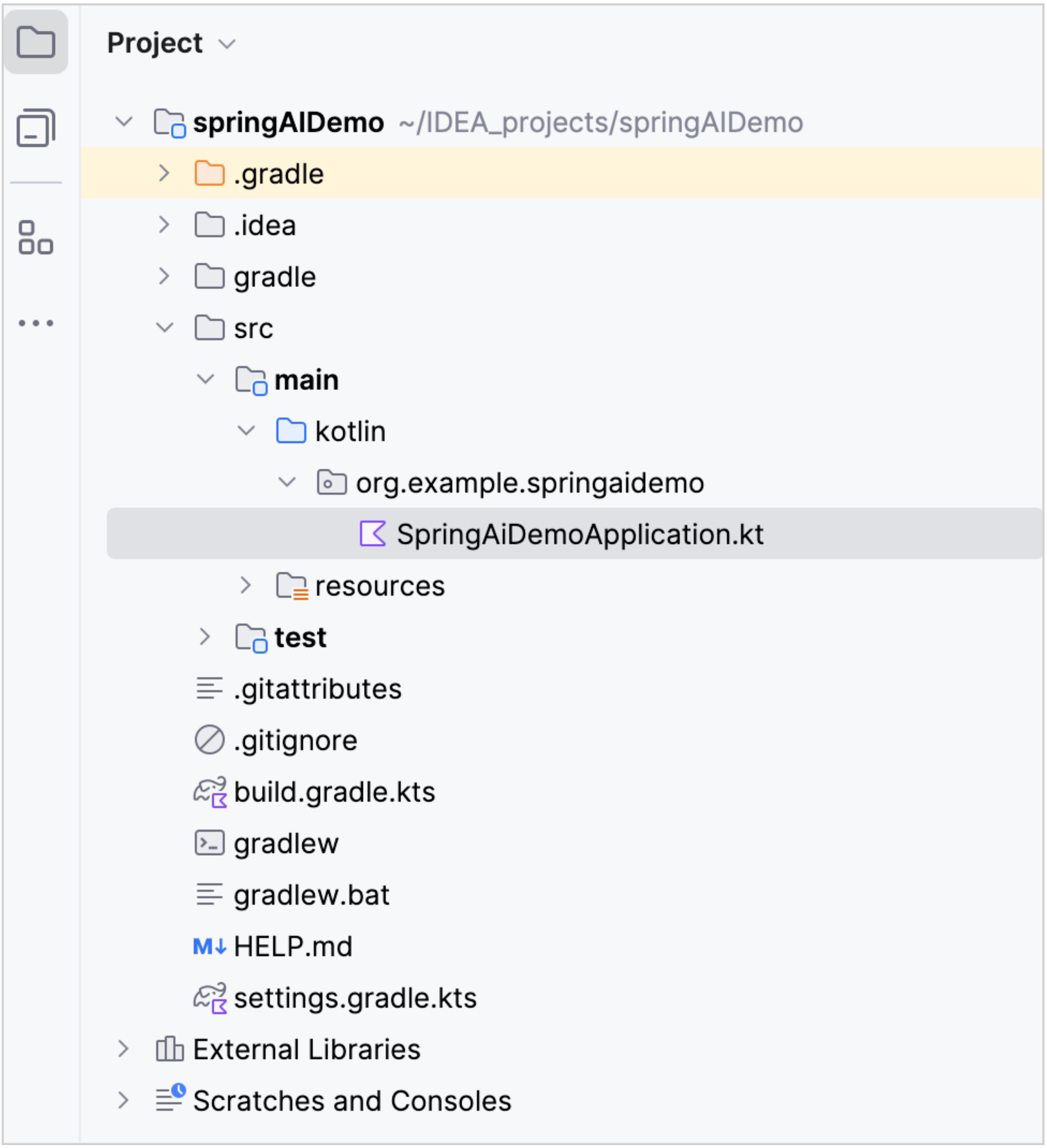
Spring Web
Qdrant Vector Database
OpenAI

Set up Spring Boot project

7. Click Create to generate and set up the project.

> The IDE will generate and open a new project. It may take some time to download and import the project dependencies.

After this, you can see the following structure in the Project view:


Project

```
springAIDemo ~/IDEA_projects/springAIDemo
    .gradle
    .idea
    gradle
    src
        main
            kotlin
                org.example.springaidemo
                    SpringAiDemoApplication.kt
            resources
        test
    .gitattributes
    .gitignore
    build.gradle.kts
    gradlew
    gradlew.bat
    HELP.md
    settings.gradle.kts
External Libraries
Scratches and Consoles
```

Spring Boot project view

The generated Gradle project corresponds to the Maven's standard directory layout:

- There are packages and classes under the main/kotlin folder that belong to the application.
- The entry point to the application is the main() method of the SpringAiDemoApplication.kt file.

Update the project configuration

1. Update your build.gradle.kts Gradle build file with the following:

```
plugins {
    kotlin("jvm") version "2.2.0"
    kotlin("plugin.spring") version "2.2.0"
    // Rest of the plugins
}
```

2. Update your springAiVersion to 1.0.0-M6:

```
extra["springAiVersion"] = "1.0.0-M6"
```

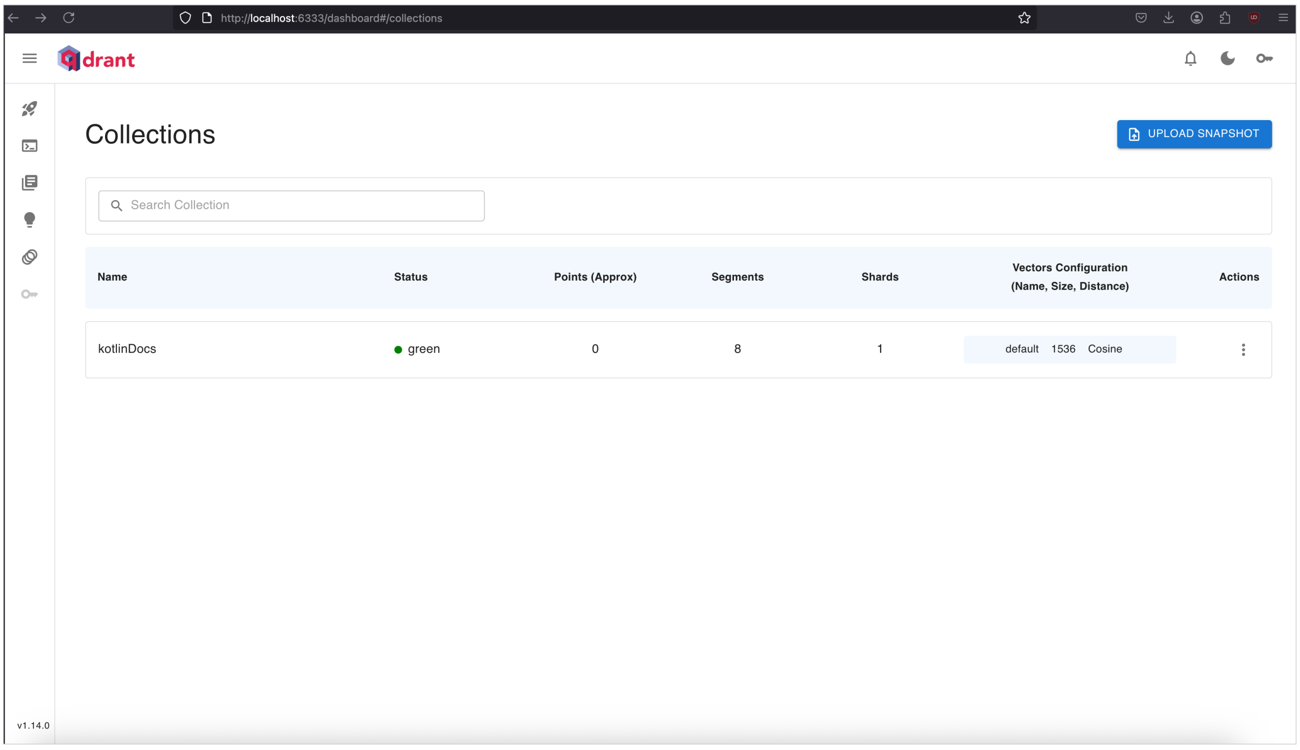
3. Click the Sync Gradle Changes button to synchronize the Gradle files.

4. Update your src/main/resources/application.properties file with the following:

```
# OpenAI
spring.ai.openai.api-key=YOUR_OPENAI_API_KEY
spring.ai.openai.chat.options.model=gpt-4o-mini
spring.ai.openai.embedding.options.model=text-embedding-ada-002
# Qdrant
spring.ai.vectorstore.qdrant.host=localhost
spring.ai.vectorstore.qdrant.port=6334
spring.ai.vectorstore.qdrant.collection-name=kotlinDocs
spring.ai.vectorstore.qdrant.initialize-schema=true
```

Set your OpenAI API key to the spring.ai.openai.api-key property.

5. Run the SpringAiDemoApplication.kt file to start the Spring Boot application. Once it's running, open the Qdrant collections page in your browser to see the result:



Name	Status	Points (Approx)	Segments	Shards	Vectors Configuration (Name, Size, Distance)	Actions
kotlinDocs	● green	0	8	1	default 1536 Cosine	⋮

Qdrant collections

Create a controller to load and search documents

Create a Spring @RestController to search documents and store them in the Qdrant collection:

1. In the src/main/kotlin/org/example/springaidemo directory, create a new file named KotlinSTDController.kt, and add the following code:

```
package org.example.springaidemo
```

```
// Imports the required Spring and utility classes
import org.slf4j.LoggerFactory
import org.springframework.ai.document.Document
import org.springframework.ai.vectorstore.SearchRequest
import org.springframework.ai.vectorstore.VectorStore
import org.springframework.web.bind.annotation.GetMapping
import org.springframework.web.bind.annotation.PostMapping
import org.springframework.web.bind.annotation.RequestMapping
import org.springframework.web.bind.annotation.RequestParam
import org.springframework.web.bind.annotation.RestController
import org.springframework.web.client.RestTemplate
import kotlin.uuid.ExperimentalUuidApi
import kotlin.uuid.Uuid

// Data class representing the chat request payload
data class ChatRequest(val query: String, val topK: Int = 3)

@RestController
@RequestMapping("/kotlin")
class KotlinSTDController(
private val restTemplate: RestTemplate,
private val vectorStore: VectorStore,
) {
private val logger = LoggerFactory.getLogger(this::class.java)

    @OptIn(ExperimentalUuidApi::class)
    @PostMapping("/load-docs")
    fun load() {
        // Loads a list of documents from the Kotlin documentation
        val kotlinStdTopics = listOf(
            "collections-overview", "constructing-collections", "iterators", "ranges", "sequences",
            "collection-operations", "collection-transformations", "collection-filtering", "collection-plus-minus",
            "collection-grouping", "collection-parts", "collection-elements", "collection-ordering",
            "collection-aggregate", "collection-write", "list-operations", "set-operations",
            "map-operations", "read-standard-input", "opt-in-requirements", "scope-functions", "time-measurement",
        )
        // Base URL for the documents
        val url = "https://raw.githubusercontent.com/JetBrains/kotlin-web-site/refs/heads/master/docs/topics/"
        // Retrieves each document from the URL and adds it to the vector store
        kotlinStdTopics.forEach { topic ->
            val data = restTemplate.getForObject("$url$topic.md", String::class.java)
            data?.let { it ->
                val doc = Document.builder()
                    // Builds a document with a random UUID
                    .id(Uuid.random().toString())
                    .text(it)
                    .metadata("topic", topic)
                    .build()
                vectorStore.add(listOf(doc))
                logger.info("Document $topic loaded.")
            } ?: logger.warn("Failed to load document for topic: $topic")
        }
    }

    @GetMapping("docs")
    fun query(
        @RequestParam query: String = "operations, filtering, and transformations",
        @RequestParam topK: Int = 2
    ): List<Document>? {
        val searchRequest = SearchRequest.builder()
            .query(query)
            .topK(topK)
            .build()
        val results = vectorStore.similaritySearch(searchRequest)
        logger.info("Found ${results?.size ?: 0} documents for query: '$query'")
        return results
    }
}
```

2. Update the SpringAiDemoApplication.kt file to declare a RestTemplate bean:

```
package org.example.springaidemo

import org.springframework.boot.autoconfigure.SpringBootApplication
import org.springframework.boot.runApplication
import org.springframework.context.annotation.Bean
import org.springframework.web.client.RestTemplate

@SpringBootApplication
```

```kotlin
class SpringAiDemoApplication {

    @Bean
    fun restTemplate(): RestTemplate = RestTemplate()
}

fun main(args: Array<String>) {
    runApplication<SpringAiDemoApplication>(*args)
}
```

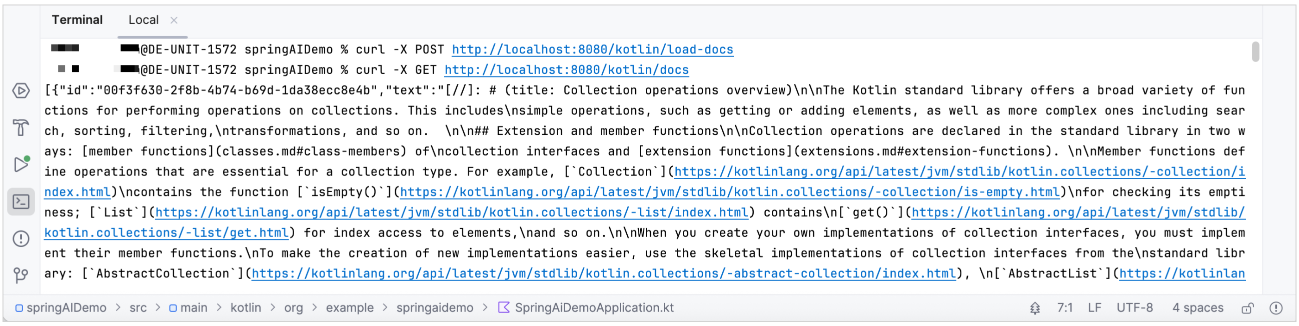
3. Run the application.

4. In the terminal, send a POST request to the /kotlin/load-docs endpoint to load the documents:

```
curl -X POST http://localhost:8080/kotlin/load-docs
```

5. Once the documents are loaded, you can search for them with a GET request:

```
curl -X GET http://localhost:8080/kotlin/docs
```



```
[redacted]@DE-UNIT-1572 springAIDemo % curl -X POST http://localhost:8080/kotlin/load-docs
[redacted]@DE-UNIT-1572 springAIDemo % curl -X GET http://localhost:8080/kotlin/docs
[{"id":"00f3f630-2f8b-4b74-b69d-1da38ecc8e4b","text":"[//]: # (title: Collection operations overview)\n\nThe Kotlin standard library offers a broad variety of fun
ctions for performing operations on collections. This includes\nsimple operations, such as getting or adding elements, as well as more complex ones including sear
ch, sorting, filtering,\ntransformations, and so on.  \n\n## Extension and member functions\n\nCollection operations are declared in the standard library in two w
ays: [member functions](classes.md#class-members) of\ncollection interfaces and [extension functions](extensions.md#extension-functions). \n\nMember functions def
ine operations that are essential for a collection type. For example, [`Collection`](https://kotlinlang.org/api/latest/jvm/stdlib/kotlin.collections/-collection/i
ndex.html)\ncontains the function [`isEmpty()`](https://kotlinlang.org/api/latest/jvm/stdlib/kotlin.collections/-collection/is-empty.html)\nfor checking its empti
ness; [`List`](https://kotlinlang.org/api/latest/jvm/stdlib/kotlin.collections/-list/index.html) contains\n[`get()`](https://kotlinlang.org/api/latest/jvm/stdlib/
kotlin.collections/-list/get.html) for index access to elements,\nand so on.\n\nWhen you create your own implementations of collection interfaces, you must implem
ent their member functions.\nTo make the creation of new implementations easier, use the skeletal implementations of collection interfaces from the\nstandard libr
ary: [`AbstractCollection`](https://kotlinlang.org/api/latest/jvm/stdlib/kotlin.collections/-abstract-collection/index.html), \n[`AbstractList`](https://kotlinlan
```

Terminal
Local
springAIDemo > src > main > kotlin > org > example > springaidemo > SpringAiDemoApplication.kt
7:1 LF UTF-8 4 spaces

GET request results

> You can also view the results on the Qdrant collections page.

Implement an AI chat endpoint

Once the documents are loaded, the final step is to add an endpoint that answers questions using the documents in Qdrant through Spring AI's Retrieval-Augmented Generation (RAG) support:

1. Open the KotlinSTDController.kt file, and import the following classes:

```kotlin
import org.springframework.ai.chat.client.ChatClient
import org.springframework.ai.chat.client.advisor.RetrievalAugmentationAdvisor
import org.springframework.ai.chat.client.advisor.SimpleLoggerAdvisor
import org.springframework.ai.chat.prompt.Prompt
import org.springframework.ai.chat.prompt.PromptTemplate
import org.springframework.ai.rag.preretrieval.query.transformation.RewriteQueryTransformer
import org.springframework.ai.rag.retrieval.search.VectorStoreDocumentRetriever
import org.springframework.web.bind.annotation.RequestBody
```

2. Add ChatClient.Builder to the controller's constructor parameters:

```kotlin
class KotlinSTDController(
    private val chatClientBuilder: ChatClient.Builder,
    private val restTemplate: RestTemplate,
    private val vectorStore: VectorStore,
)
```

3. Inside the controller class, create a ChatClient instance and a query transformer:

```kotlin
// Builds the chat client with a simple logging advisor
```

```kotlin
private val chatClient = chatClientBuilder.defaultAdvisors(SimpleLoggerAdvisor()).build()
// Builds the query transformer used to rewrite the input query
private val rqtBuilder = RewriteQueryTransformer.builder().chatClientBuilder(chatClientBuilder)
```

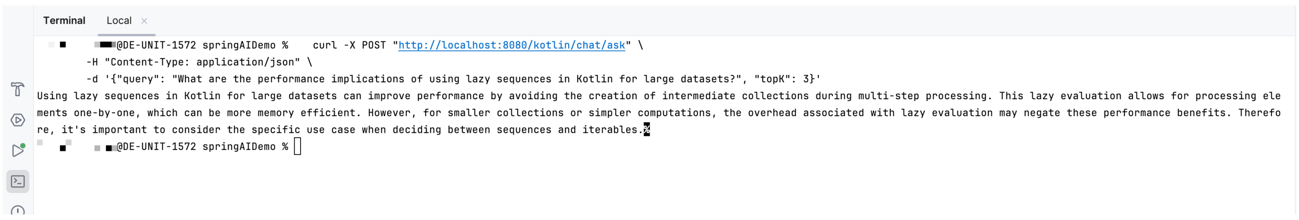
4. At the bottom of your KotlinSTDController.kt file, add a new chatAsk() endpoint, with the following logic:

```kotlin
@PostMapping("/chat/ask")
    fun chatAsk(@RequestBody request: ChatRequest): String? {
        // Defines the prompt template with placeholders
        val promptTemplate = PromptTemplate(
            """
            {query}.
            Please provide a concise answer based on the {target} documentation.
        """.trimIndent()
        )

        // Creates the prompt by substituting placeholders with actual values
        val prompt: Prompt =
            promptTemplate.create(mapOf("query" to request.query, "target" to "Kotlin standard library"))

        // Configures the retrieval advisor to augment the query with relevant documents
        val retrievalAdvisor = RetrievalAugmentationAdvisor.builder()
            .documentRetriever(
                VectorStoreDocumentRetriever.builder()
                    .similarityThreshold(0.7)
                    .topK(request.topK)
                    .vectorStore(vectorStore)
                    .build()
            )
            .queryTransformers(rqtBuilder.promptTemplate(promptTemplate).build())
            .build()

        // Sends the prompt to the LLM with the retrieval advisor and get the response
        val response = chatClient.prompt(prompt)
            .advisors(retrievalAdvisor)
            .call()
            .content()
        logger.info("Chat response generated for query: '${request.query}'")
        return response
    }
```

5. Run the application.

6. In the terminal, send a POST request to the new endpoint to see the results:

```bash
curl -X POST "http://localhost:8080/kotlin/chat/ask" \
     -H "Content-Type: application/json" \
     -d '{"query": "What are the performance implications of using lazy sequences in Kotlin for large datasets?", "topK": 3}'
```



```
[redacted]@DE-UNIT-1572 springAIDemo %    curl -X POST "http://localhost:8080/kotlin/chat/ask" \
       -H "Content-Type: application/json" \
       -d '{"query": "What are the performance implications of using lazy sequences in Kotlin for large datasets?", "topK": 3}'
Using lazy sequences in Kotlin for large datasets can improve performance by avoiding the creation of intermediate collections during multi-step processing. This lazy evaluation allows for processing ele
ments one-by-one, which can be more memory efficient. However, for smaller collections or simpler computations, the overhead associated with lazy evaluation may negate these performance benefits. Therefo
re, it's important to consider the specific use case when deciding between sequences and iterables.%
[redacted]@DE-UNIT-1572 springAIDemo %
```

OpenAI answer to chat request

Congratulations! You now have a Kotlin app that connects to OpenAI and answers questions using context retrieved from documentation stored in Qdrant. Try experimenting with different queries or importing other documents to explore more possibilities.

You can view the completed project in the Spring AI demo GitHub repository, or explore other Spring AI examples in Kotlin AI Examples.

Test code using JUnit in JVM – tutorial

This tutorial shows you how to write a simple unit test in a Kotlin/JVM project and run it with the Gradle build tool.

In this project, you'll use the kotlin.test library and run the test using JUnit. If you're working on a multiplatform app, see the Kotlin Multiplatform tutorial.

To get started, first download and install the latest version of IntelliJ IDEA.

Add dependencies

1. Open a Kotlin project in IntelliJ IDEA. If you don't have a project, create one.

2. Open the build.gradle(.kts) file and check that the testImplementation dependency is present. This dependency allows you to work with kotlin.test and JUnit:

   Kotlin

   ```
   dependencies {
       // Other dependencies.
       testImplementation(kotlin("test"))
   }
   ```

   Groovy

   ```
   dependencies {
       // Other dependencies.
       testImplementation 'org.jetbrains.kotlin:kotlin-test'
   }
   ```

3. Add the test task to the build.gradle(.kts) file:

   Kotlin

   ```
   tasks.test {
       useJUnitPlatform()
   }
   ```

   Groovy

   ```
   test {
       useJUnitPlatform()
   }
   ```

   If you use the useJUnitPlatform()function in your build script, the kotlin-test library automatically includes JUnit 5 as a dependency. This setup enables access to all JUnit 5 APIs, along with the kotlin-test API, in JVM-only projects and JVM tests of Kotlin Multiplatform (KMP) projects.

Here's a complete code for the build.gradle.kts:

```
plugins {
    kotlin("jvm") version "2.2.0"
}

group = "org.example"
version = "1.0-SNAPSHOT"

repositories {
    mavenCentral()
}

dependencies {
    testImplementation(kotlin("test"))
}

tasks.test {
    useJUnitPlatform()
}
```

Add the code to test it

1. Open the Main.kt file in src/main/kotlin.

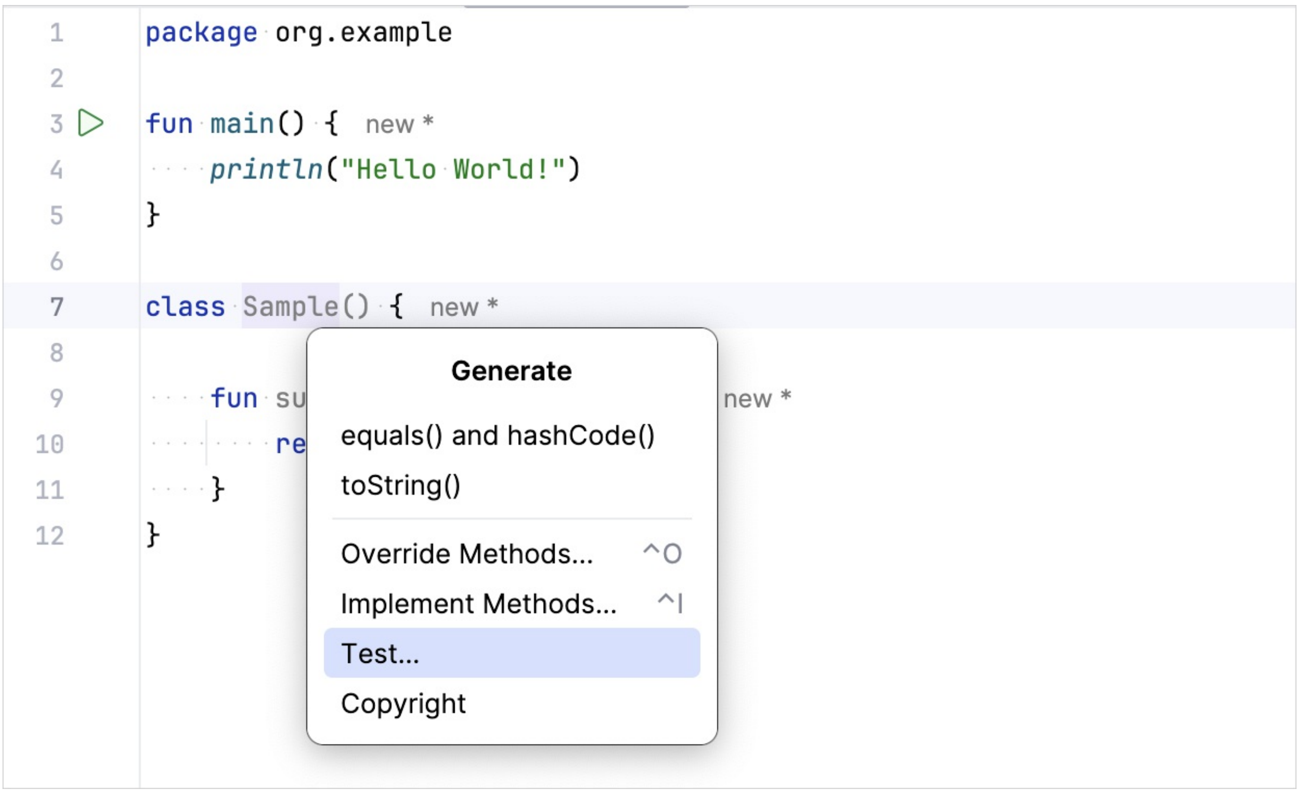
   The src directory contains Kotlin source files and resources. The Main.kt file contains sample code that prints Hello, World!.

2. Create the Sample class with the sum() function that adds two integers together:

```kotlin
class Sample() {
    fun sum(a: Int, b: Int): Int {
        return a + b
    }
}
```

Create a test

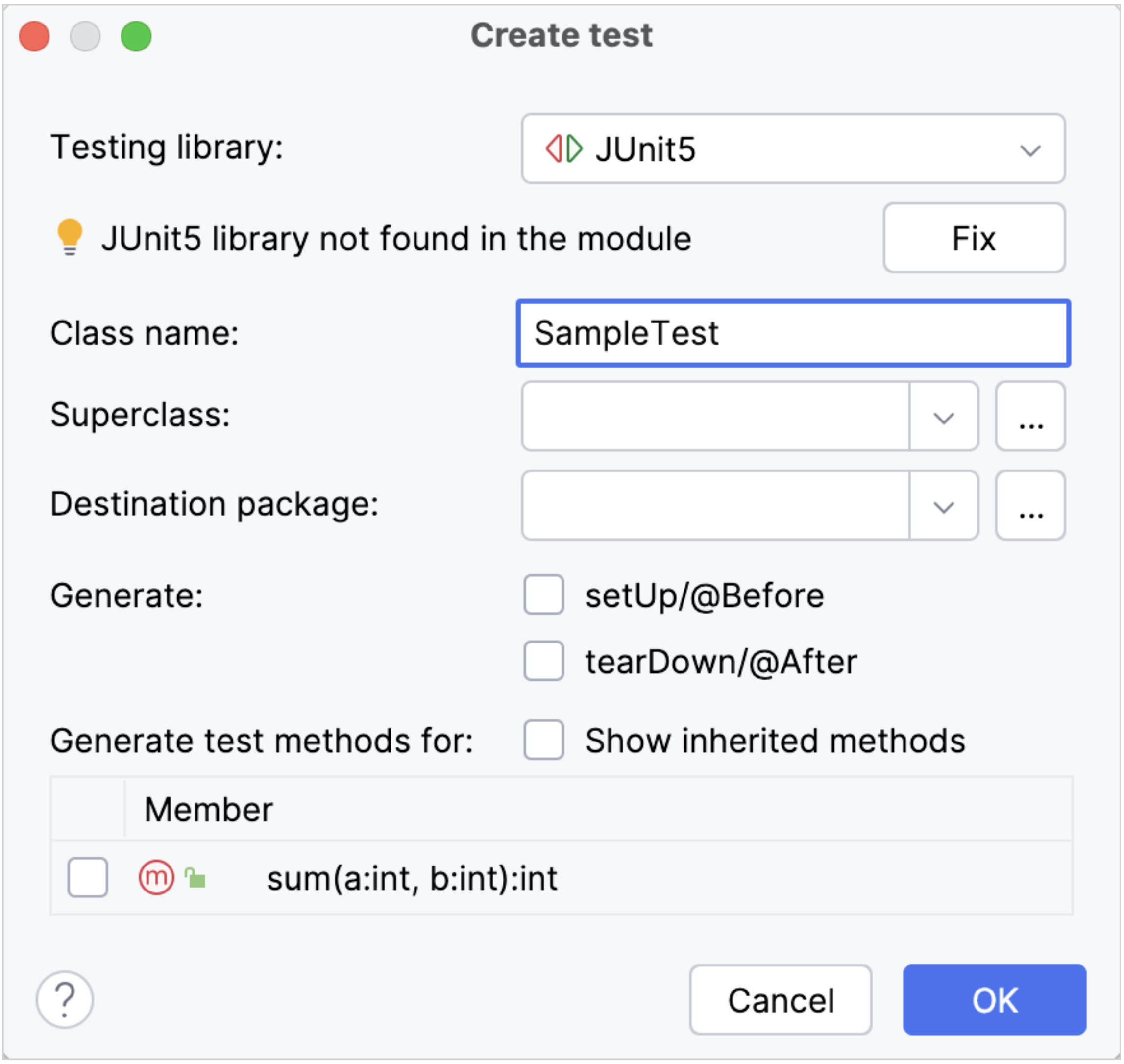
1. In IntelliJ IDEA, select Code | Generate | Test... for the Sample class:



```kotlin
package org.example

fun main() {  new *
    println("Hello World!")
}

class Sample() {  new *

    fun su                                 new *
        re
    }
}
```

Generate a test

2. Specify the name of the test class. For example, SampleTest:


Create test

Testing library: JUnit5

JUnit5 library not found in the module

Class name: SampleTest

Superclass:

Destination package:

Generate: setUp/@Before, tearDown/@After

Generate test methods for: Show inherited methods

	Member
☐	sum(a:int, b:int):int

Create a test

IntelliJ IDEA creates the SampleTest.kt file in the test directory. This directory contains Kotlin test source files and resources.

You can also manually create a *.kt file for tests in src/test/kotlin.

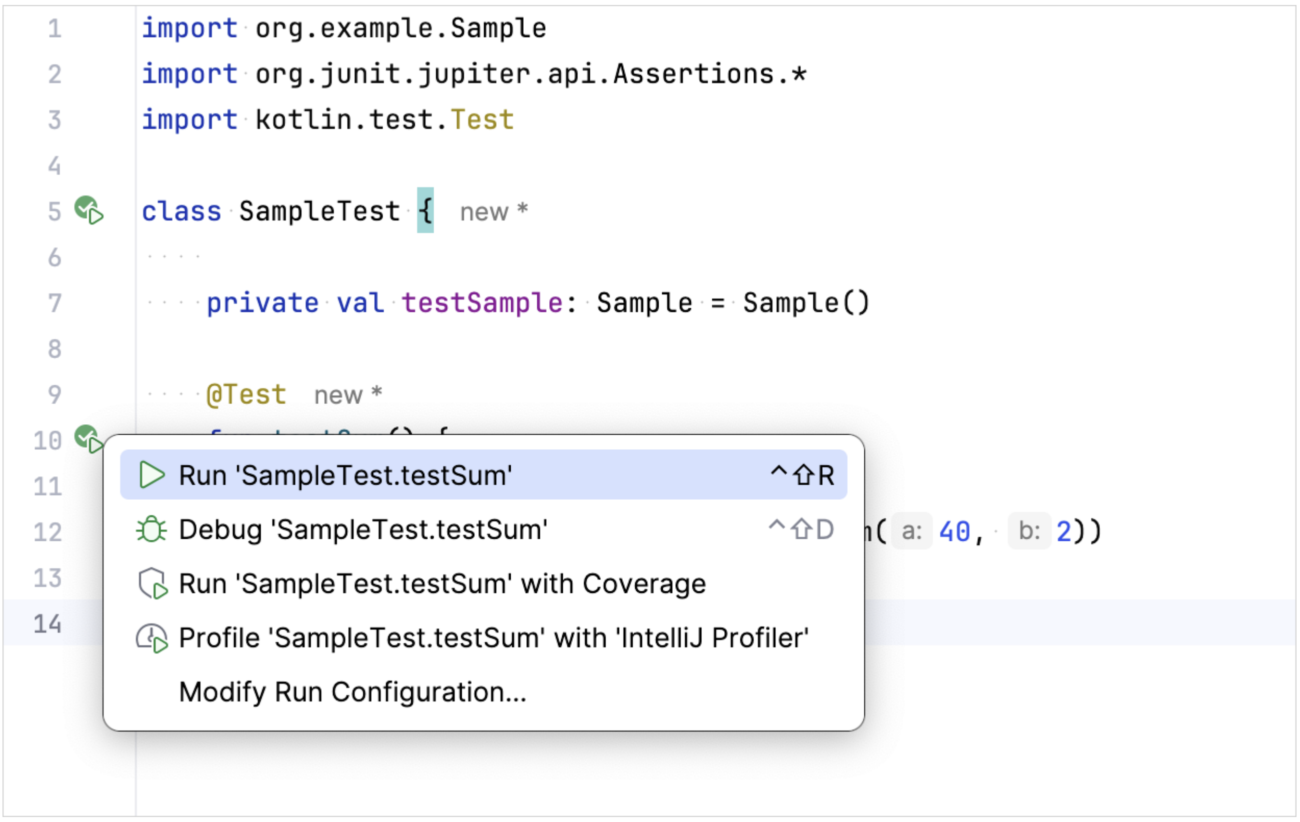
3. Add the test code for the sum() function in SampleTest.kt:

   - Define the test testSum() function using the @Test annotation.
   - Check that the sum() function returns the expected value by using the assertEquals() function.

```
import org.example.Sample
import org.junit.jupiter.api.Assertions.*
import kotlin.test.Test

class SampleTest {
    private val testSample: Sample = Sample()

    @Test
    fun testSum() {
        val expected = 42
        assertEquals(expected, testSample.sum(40, 2))
    }
}
```

Run a test

1. Run the test using the gutter icon:



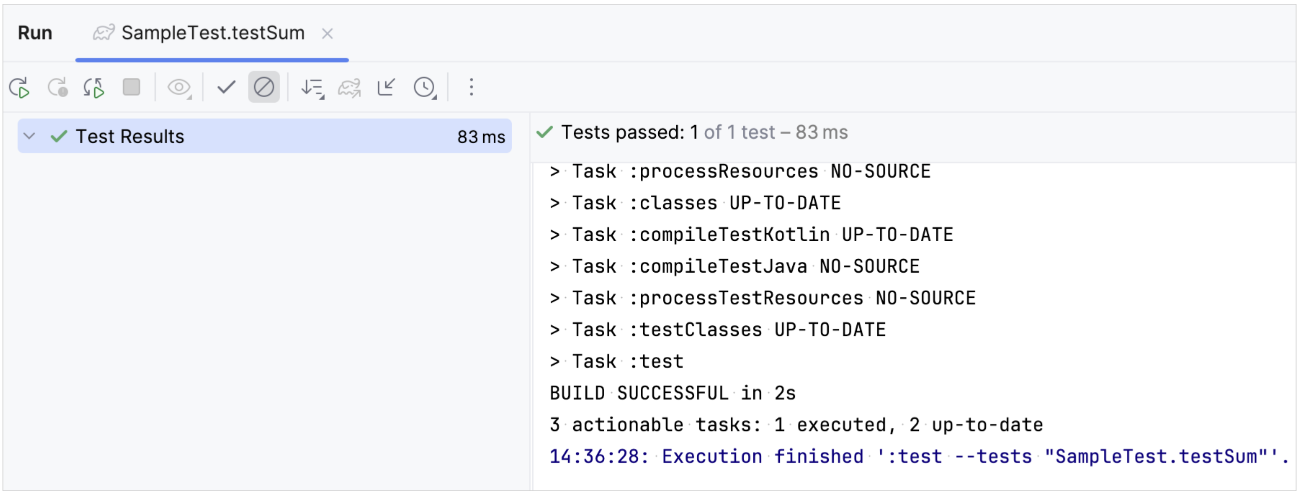
```
import org.example.Sample
import org.junit.jupiter.api.Assertions.*
import kotlin.test.Test

class SampleTest {  new *

    private val testSample: Sample = Sample()

    @Test  new *
```

Run 'SampleTest.testSum' ^⇧R
Debug 'SampleTest.testSum' ^⇧D
Run 'SampleTest.testSum' with Coverage
Profile 'SampleTest.testSum' with 'IntelliJ Profiler'
Modify Run Configuration...

Run the test

You can also run all project tests via the command-line interface using the ./gradlew check command.

2. Check the result in the Run tool window:



Tests passed: 1 of 1 test – 83 ms

```
> Task :processResources NO-SOURCE
> Task :classes UP-TO-DATE
> Task :compileTestKotlin UP-TO-DATE
> Task :compileTestJava NO-SOURCE
> Task :processTestResources NO-SOURCE
> Task :testClasses UP-TO-DATE
> Task :test
BUILD SUCCESSFUL in 2s
3 actionable tasks: 1 executed, 2 up-to-date
14:36:28: Execution finished ':test --tests "SampleTest.testSum"'.
```

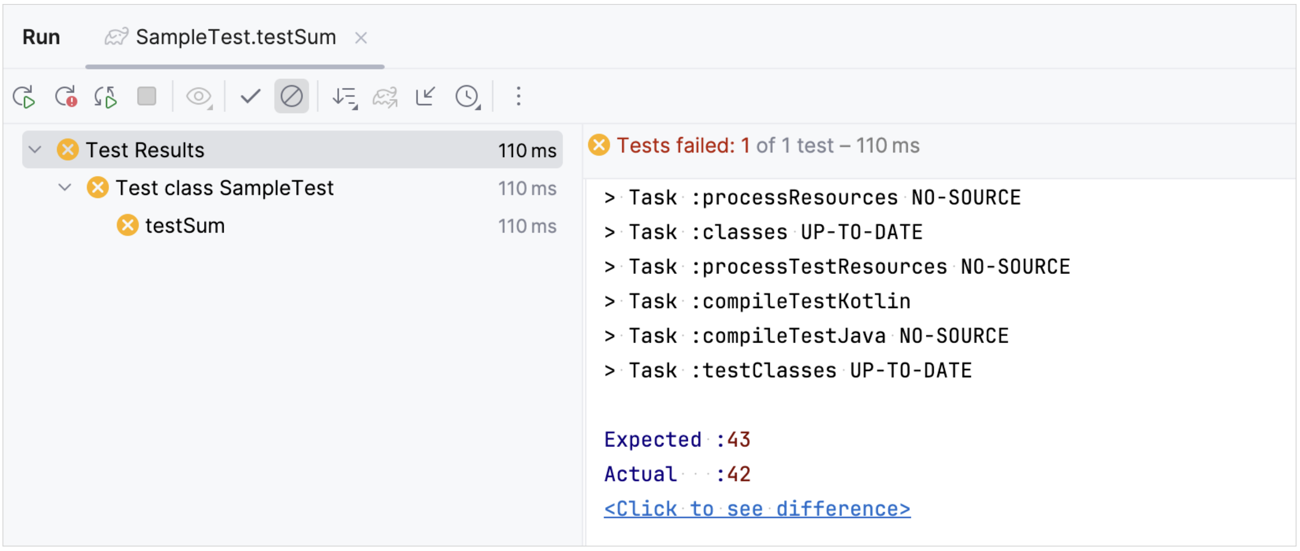
Check the test result. The test passed successfully

The test function was executed successfully.

3. Make sure that the test works correctly by changing the expected variable value to 43:

```kotlin
@Test
fun testSum() {
    val expected = 43
    assertEquals(expected, classForTesting.sum(40, 2))
}
```

4. Run the test again and check the result:


Run
SampleTest.testSum
Test Results 110 ms
Test class SampleTest 110 ms
testSum 110 ms
Tests failed: 1 of 1 test – 110 ms

```
> Task :processResources NO-SOURCE
> Task :classes UP-TO-DATE
> Task :processTestResources NO-SOURCE
> Task :compileTestKotlin
> Task :compileTestJava NO-SOURCE
> Task :testClasses UP-TO-DATE

Expected :43
Actual   :42
<Click to see difference>
```

Check the test result. The test has failed

The test execution failed.

What's next

Once you've finished your first test, you can:

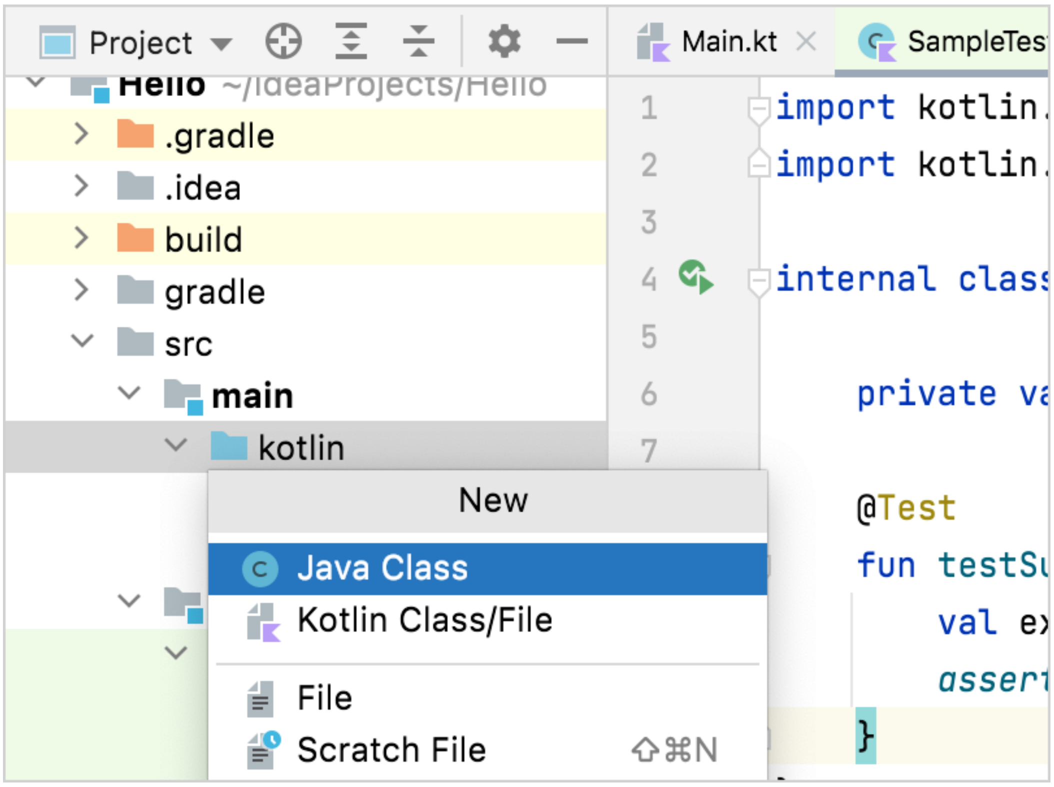
- Write more tests using other kotlin.test functions. For example, use the assertNotEquals() function.
- Improve your test output with the Kotlin Power-assert compiler plugin. The plugin enriches the test output with contextual information.
- Create your first server-side application with Kotlin and Spring Boot.

Mixing Java and Kotlin in one project – tutorial

Kotlin provides the first-class interoperability with Java, and modern IDEs make it even better. In this tutorial, you'll learn how to use both Kotlin and Java sources in the same project in IntelliJ IDEA. To learn how to start a new Kotlin project in IntelliJ IDEA, see Getting started with IntelliJ IDEA.

Adding Java source code to an existing Kotlin project

Adding Java classes to a Kotlin project is pretty straightforward. All you need to do is create a new Java file. Select a directory or a package inside your project and go to File | New | Java Class or use the Alt + Insert/Cmd + N shortcut.



```
import kotlin.
import kotlin.

internal class

    private va

    @Test
    fun testSu
        val ex
        assert
    }
```

Add new Java class

If you already have the Java classes, you can just copy them to the project directories.

You can now consume the Java class from Kotlin or vice versa without any further actions.

For example, adding the following Java class:

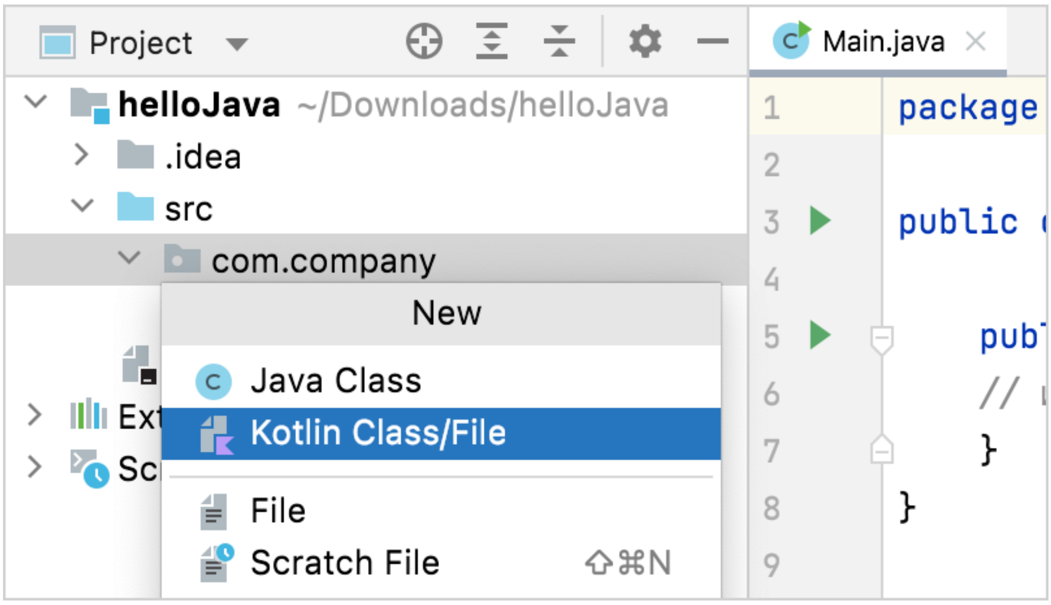
```
public class Customer {

    private String name;

    public Customer(String s){
        name = s;
    }

    public String getName() {
        return name;
    }

    public void setName(String name) {
        this.name = name;
    }

    public void placeOrder() {
        System.out.println("A new order is placed by " + name);
    }
}
```

lets you call it from Kotlin like any other type in Kotlin.

```
val customer = Customer("Phase")
println(customer.name)
println(customer.placeOrder())
```

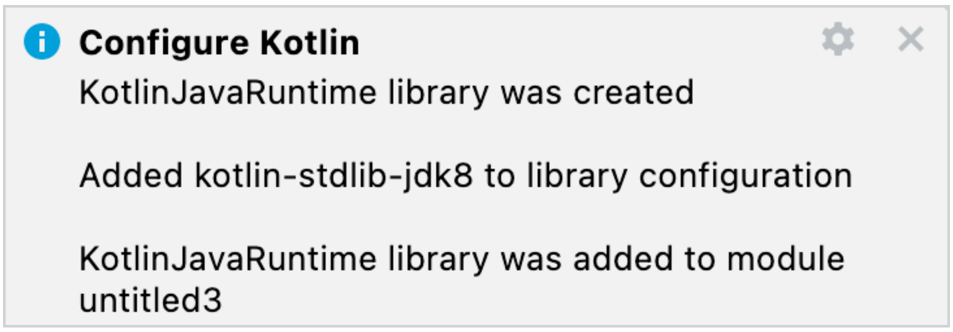
Adding Kotlin source code to an existing Java project

Adding a Kotlin file to an existing Java project is pretty much the same.



Add new Kotlin file class

If this is the first time you're adding a Kotlin file to this project, IntelliJ IDEA will automatically add the required Kotlin runtime.



Configure Kotlin

KotlinJavaRuntime library was created

Added kotlin-stdlib-jdk8 to library configuration

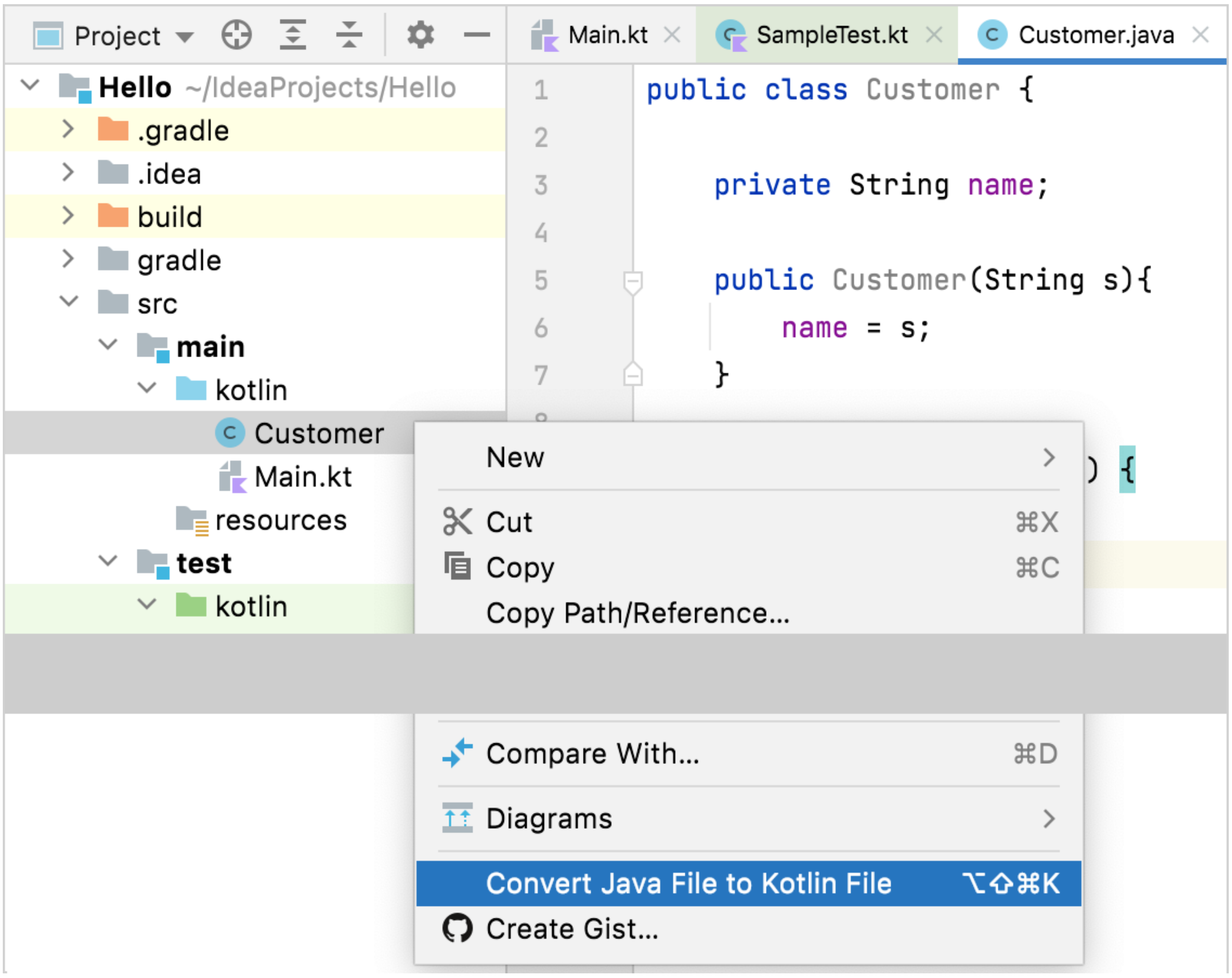
KotlinJavaRuntime library was added to module untitled3

Bundling Kotlin runtime

You can also open the Kotlin runtime configuration manually from Tools | Kotlin | Configure Kotlin in Project.

Converting an existing Java file to Kotlin with J2K

The Kotlin plugin also bundles a Java to Kotlin converter (J2K) that automatically converts Java files to Kotlin. To use J2K on a file, click Convert Java File to Kotlin File in its context menu or in the Code menu of IntelliJ IDEA.



```java
public class Customer {

    private String name;

    public Customer(String s){
        name = s;
    }
```

Convert Java to Kotlin

While the converter is not fool-proof, it does a pretty decent job of converting most boilerplate code from Java to Kotlin. Some manual tweaking however is sometimes required.

Using Java records in Kotlin

Records are classes in Java for storing immutable data. Records carry a fixed set of values – the records components. They have a concise syntax in Java and save you from having to write boilerplate code:

```java
// Java
public record Person (String name, int age) {}
```

The compiler automatically generates a final class inherited from java.lang.Record with the following members:

- a private final field for each record component
- a public constructor with parameters for all fields
- a set of methods to implement structural equality: equals(), hashCode(), toString()
- a public method for reading each record component

Records are very similar to Kotlin data classes.

Using Java records from Kotlin code

You can use record classes with components that are declared in Java the same way you would use classes with properties in Kotlin. To access the record component, just use its name like you do for Kotlin properties:

```
val newPerson = Person("Kotlin", 10)
val firstName = newPerson.name
```

Declare records in Kotlin

Kotlin supports record declaration only for data classes, and the data class must meet the requirements.

To declare a record class in Kotlin, use the @JvmRecord annotation:

> Applying @JvmRecord to an existing class is not a binary compatible change. It alters the naming convention of the class property accessors.

```
@JvmRecord
data class Person(val name: String, val age: Int)
```

This JVM-specific annotation enables generating:

- the record components corresponding to the class properties in the class file
- the property accessor methods named according to the Java record naming convention

The data class provides equals(), hashCode(), and toString() method implementations.

Requirements

To declare a data class with the @JvmRecord annotation, it must meet the following requirements:

- The class must be in a module that targets JVM 16 bytecode (or 15 if the -Xjvm-enable-preview compiler option is enabled).
- The class cannot explicitly inherit any other class (including Any) because all JVM records implicitly inherit java.lang.Record. However, the class can implement interfaces.
- The class cannot declare any properties with backing fields – except those initialized from the corresponding primary constructor parameters.
- The class cannot declare any mutable properties with backing fields.
- The class cannot be local.
- The primary constructor of the class must be as visible as the class itself.

Enable JVM records

JVM records require the 16 target version or higher of the generated JVM bytecode.

To specify it explicitly, use the jvmTarget compiler option in Gradle or Maven.

Annotate record components in Kotlin

In Java, annotations on a record component are automatically propagated to the backing field, getter, setter, and constructor parameter. You can replicate this behavior in Kotlin by using the all use-site target.

To use the all use-site target, you must opt in. Either use the -Xannotation-target-all compiler option or add the following to your build.gradle.kts file:

```
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xannotation-target-all")
    }
}
```

For example:

```
@JvmRecord
data class Person(val name: String, @all:Positive val age: Int)
```

When you use @JvmRecord with @all:, Kotlin:

- Propagates the annotation to the property, backing field, constructor parameter, getter and setter.
- Applies the annotation to the record component as well, if the annotation supports Java's RECORD_COMPONENT.

Make annotations work with record components

To make an annotation available for both Kotlin properties and Java record components, add the following meta-annotations to your annotation declaration:

- For Kotlin: @Target
- For Java record components: @java.lang.annotation.Target

For example:

```
@Target(AnnotationTarget.CLASS, AnnotationTarget.PROPERTY)
@java.lang.annotation.Target(ElementType.CLASS, ElementType.RECORD_COMPONENT)
annotation class exampleClass
```

You can now apply @ExampleClass to Kotlin classes and properties, as well as Java classes and record components.

Further discussion

See this language proposal for JVM records for further technical details and discussion.

Strings in Java and Kotlin

This guide contains examples of how to perform typical tasks with strings in Java and Kotlin. It will help you migrate from Java to Kotlin and write your code in the authentically Kotlin way.

Concatenate strings

In Java, you can do this in the following way:

```
// Java
String name = "Joe";
System.out.println("Hello, " + name);
System.out.println("Your name is " + name.length() + " characters long");
```

In Kotlin, use the dollar sign ($) before the variable name to interpolate the value of this variable into your string:

```
fun main() {
    // Kotlin
    val name = "Joe"
    println("Hello, $name")
    println("Your name is ${name.length} characters long")
}
```

You can interpolate the value of a complicated expression by surrounding it with curly braces, like in ${name.length}. See string templates for more information.

Build a string

In Java, you can use the StringBuilder:

```
// Java
StringBuilder countDown = new StringBuilder();
for (int i = 5; i > 0; i--) {
    countDown.append(i);
    countDown.append("\n");
}
System.out.println(countDown);
```

In Kotlin, use buildString() – an inline function that takes logic to construct a string as a lambda argument:

```
fun main() {
       // Kotlin
       val countDown = buildString {
           for (i in 5 downTo 1) {
               append(i)
               appendLine()
           }
       }
       println(countDown)
}
```

Under the hood, the buildString uses the same StringBuilder class as in Java, and you access it via an implicit this inside the lambda.

Learn more about lambda coding conventions.

Create a string from collection items

In Java, you use the Stream API to filter, map, and then collect the items:

```
// Java
List<Integer> numbers = List.of(1, 2, 3, 4, 5, 6);
String invertedOddNumbers = numbers
        .stream()
        .filter(it -> it % 2 != 0)
        .map(it -> -it)
        .map(Object::toString)
        .collect(Collectors.joining("; "));
System.out.println(invertedOddNumbers);
```

In Kotlin, use the joinToString() function, which Kotlin defines for every List:

```
fun main() {
    // Kotlin
    val numbers = listOf(1, 2, 3, 4, 5, 6)
    val invertedOddNumbers = numbers
        .filter { it % 2 != 0 }
        .joinToString(separator = ";") {"${-it}"}
    println(invertedOddNumbers)
}
```

In Java, if you want spaces between your delimiters and following items, you need to add a space to the delimiter explicitly.

Learn more about joinToString() usage.

Set default value if the string is blank

In Java, you can use the ternary operator:

```
// Java
public void defaultValueIfStringIsBlank() {
    String nameValue = getName();
    String name = nameValue.isBlank() ? "John Doe" : nameValue;
    System.out.println(name);
}

public String getName() {
    Random rand = new Random();
    return rand.nextBoolean() ? "" : "David";
}
```

Kotlin provides the inline function ifBlank() that accepts the default value as an argument:

```
// Kotlin
import kotlin.random.Random

fun main() {
    val name = getName().ifBlank { "John Doe" }
    println(name)
}

fun getName(): String =
    if (Random.nextBoolean()) "" else "David"
```

Replace characters at the beginning and end of a string

In Java, you can use the replaceAll() function. The replaceAll() function in this case accepts regular expressions ^## and ##$, which define strings starting and ending with ## respectively:

```
// Java
String input = "##place##holder##";
String result = input.replaceAll("^##|##$", "");
System.out.println(result);
```

In Kotlin, use the removeSurrounding() function with the string delimiter ##:

```
fun main() {
    // Kotlin
    val input = "##place##holder##"
    val result = input.removeSurrounding("##")
    println(result)
}
```

Replace occurrences

In Java, you can use the Pattern and the Matcher classes, for example, to obfuscate some data:

```
// Java
String input = "login: Pokemon5, password: 1q2w3e4r5t";
Pattern pattern = Pattern.compile("\\w*\\d+\\w*");
Matcher matcher = pattern.matcher(input);
String replacementResult = matcher.replaceAll(it -> "xxx");
System.out.println("Initial input: '" + input + "'");
System.out.println("Anonymized input: '" + replacementResult + "'");
```

In Kotlin, you use the Regex class that simplifies working with regular expressions. Additionally, use multiline strings to simplify a regex pattern by reducing the count of backslashes:

```
fun main() {
    // Kotlin
    val regex = Regex("""\w*\d+\w*""") // multiline string
    val input = "login: Pokemon5, password: 1q2w3e4r5t"
    val replacementResult = regex.replace(input, replacement = "xxx")
    println("Initial input: '$input'")
    println("Anonymized input: '$replacementResult'")
}
```

Split a string

In Java, to split a string with the period character (.), you need to use shielding (\\). This happens because the split() function of the String class accepts a regular expression as an argument:

```
// Java
System.out.println(Arrays.toString("Sometimes.text.should.be.split".split("\\.")));
```

In Kotlin, use the Kotlin function split(), which accepts varargs of delimiters as input parameters:

```
fun main() {
    // Kotlin
    println("Sometimes.text.should.be.split".split("."))
}
```

If you need to split with a regular expression, use the overloaded split() version that accepts the Regex as a parameter.

Take a substring

In Java, you can use the substring() function, which accepts an inclusive beginning index of a character to start taking the substring from. To take a substring after this character, you need to increment the index:

```
// Java
String input = "What is the answer to the Ultimate Question of Life, the Universe, and Everything? 42";
String answer = input.substring(input.indexOf("?") + 1);
System.out.println(answer);
```

In Kotlin, you use the substringAfter() function and don't need to calculate the index of the character you want to take a substring after:

```
fun main() {
    // Kotlin
    val input = "What is the answer to the Ultimate Question of Life, the Universe, and Everything? 42"
    val answer = input.substringAfter("?")
    println(answer)
}
```

Additionally, you can take a substring after the last occurrence of a character:

```
fun main() {
    // Kotlin
    val input = "To be, or not to be, that is the question."
    val question = input.substringAfterLast(",")
    println(question)
}
```

Use multiline strings

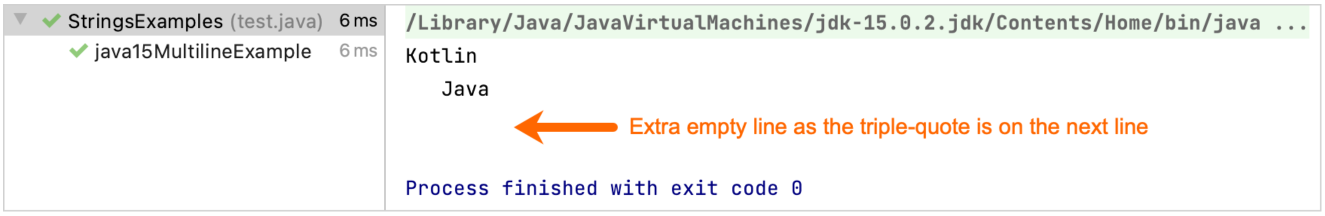
Before Java 15, there were several ways to create a multiline string. For example, using the join() function of the String class:

```
// Java
String lineSeparator = System.getProperty("line.separator");
String result = String.join(lineSeparator,
       "Kotlin",
       "Java");
System.out.println(result);
```

In Java 15, text blocks appeared. There is one thing to keep in mind: if you print a multiline string and the triple-quote is on the next line, there will be an extra empty line:

```
// Java
String result = """
    Kotlin
       Java
    """;
System.out.println(result);
```

The output:



```
StringsExamples (test.java)   6 ms
  java15MultilineExample      6 ms
```

```
/Library/Java/JavaVirtualMachines/jdk-15.0.2.jdk/Contents/Home/bin/java ...
Kotlin
   Java

Process finished with exit code 0
```

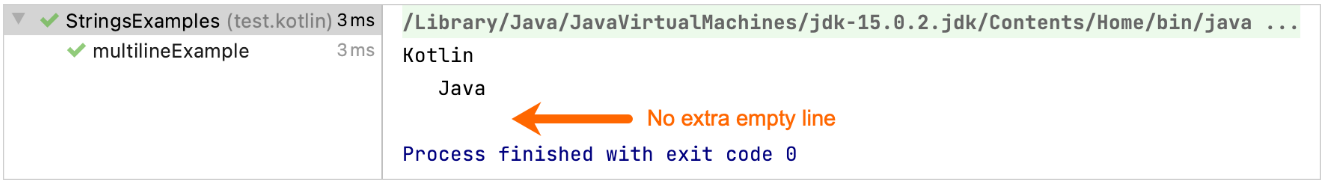
Java 15 multiline output

If you put the triple-quote on the same line as the last word, this difference in behavior disappears.

In Kotlin, you can format your line with the quotes on the new line, and there will be no extra empty line in the output. The left-most character of any line identifies the beginning of the line. The difference with Java is that Java automatically trims indents, and in Kotlin you should do it explicitly:

```
fun main() {
    // Kotlin
    val result = """
        Kotlin
           Java
    """.trimIndent()
    println(result)
}
```

The output:



```
StringsExamples (test.kotlin) 3 ms
  multilineExample            3 ms
```

```
/Library/Java/JavaVirtualMachines/jdk-15.0.2.jdk/Contents/Home/bin/java ...
Kotlin
   Java
Process finished with exit code 0
```

Kotlin multiline output

To have an extra empty line, you should add this empty line to your multiline string explicitly.

In Kotlin, you can also use the trimMargin() function to customize the indents:

```
// Kotlin
fun main() {
    val result = """
       #  Kotlin
       #  Java
   """.trimMargin("#")
    println(result)
}
```

Learn more about multiline strings.

What's next?

- Look through other Kotlin idioms.
- Learn how to convert existing Java code to Kotlin with the Java to Kotlin converter.

If you have a favorite idiom, we invite you to share it by sending a pull request.

Collections in Java and Kotlin

Collections are groups of a variable number of items (possibly zero) that are significant to the problem being solved and are commonly operated on. This guide explains and compares collection concepts and operations in Java and Kotlin. It will help you migrate from Java to Kotlin and write your code in the authentically Kotlin way.

The first part of this guide contains a quick glossary of operations on the same collections in Java and Kotlin. It is divided into operations that are the same and operations that exist only in Kotlin. The second part of the guide, starting from Mutability, explains some of the differences by looking at specific cases.

For an introduction to collections, see the Collections overview or watch this video by Sebastian Aigner, Kotlin Developer Advocate.

All of the examples below use Java and Kotlin standard library APIs only.

Operations that are the same in Java and Kotlin

In Kotlin, there are many operations on collections that look exactly the same as their counterparts in Java.

Operations on lists, sets, queues, and deques

Description	Common operations	More Kotlin alternatives
Add an element or elements	add(), addAll()	Use the plusAssign (+=) operator: collection += element, collection += anotherCollection.
Check whether a collection contains an element or elements	contains(), containsAll()	Use the in keyword to call contains() in the operator form: element in collection.
Check whether a collection is empty	isEmpty()	Use isNotEmpty() to check whether a collection is not empty.
Remove under a certain condition	removeIf()	
Leave only selected elements	retainAll()	
Remove all elements from a collection	clear()	
Get a stream from a collection	stream()	Kotlin has its own way to process streams: sequences and methods like map() and filter().
Get an iterator from a collection	iterator()	

Operations on maps

Description	Common operations	More Kotlin alternatives
Add an element or elements	put(), putAll(), putIfAbsent()	In Kotlin, the assignment map[key] = value behaves the same as put(key, value). Also, you may use the plusAssign (+=) operator: map += Pair(key, value) or map += anotherMap.
Replace an element or elements	put(), replace(), replaceAll()	Use the indexing operator map[key] = value instead of put() and replace().
Get an element	get()	Use the indexing operator to get an element: map[index].
Check whether a map contains an element or elements	containsKey(), containsValue()	Use the in keyword to call contains() in the operator form: element in map.
Check whether a map is empty	isEmpty()	Use isNotEmpty() to check whether a map is not empty.
Remove an element	remove(key), remove(key, value)	Use the minusAssign (-=) operator: map -= key.
Remove all elements from a map	clear()	
Get a stream from a map	stream() on entries, keys, or values	

Operations that exist only for lists

Description	Common operations	More Kotlin alternatives
Get an index of an element	indexOf()	
Get the last index of an element	lastIndexOf()	
Get an element	get()	Use the indexing operator to get an element: list[index].
Take a sublist	subList()	
Replace an element or elements	set(), replaceAll()	Use the indexing operator instead of set(): list[index] = value.

Operations that differ a bit

Operations on any collection type

Description	Java	Kotlin
Get a collection's size	size()	count(), size
Get flat access to nested collection elements	collectionOfCollections.forEach(flatCollection::addAll) or collectionOfCollections.stream().flatMap().collect()	flatten() or flatMap()
Apply the given function to every element	stream().map().collect()	map()
Apply the provided operation to collection elements sequentially and return the accumulated result	stream().reduce()	reduce(), fold()
Group elements by a classifier and count them	stream().collect(Collectors.groupingBy(classifier, counting()))	eachCount()
Filter by a condition	stream().filter().collect()	filter()
Check whether collection elements satisfy a condition	stream().noneMatch(), stream().anyMatch(), stream().allMatch()	none(), any(), all()
Sort elements	stream().sorted().collect()	sorted()
Take the first N elements	stream().limit(N).collect()	take(N)
Take elements with a predicate	stream().takeWhile().collect()	takeWhile()
Skip the first N elements	stream().skip(N).collect()	drop(N)
Skip elements with a predicate	stream().dropWhile().collect()	dropWhile()
Build maps from collection elements and certain values associated with them	stream().collect(toMap(keyMapper, valueMapper))	associate()

To perform all of the operations listed above on maps, you first need to get an entrySet of a map.

Operations on lists

Description	Java	Kotlin
Sort a list into natural order	sort(null)	sort()
Sort a list into descending order	sort(comparator)	sortDescending()

Description	Java	Kotlin
Remove an element from a list	remove(index), remove(element)	removeAt(index), remove(element) or collection -= element
Fill all elements of a list with a certain value	Collections.fill()	fill()
Get unique elements from a list	stream().distinct().toList()	distinct()

Operations that don't exist in Java's standard library

- zip(), unzip() – transform a collection.
- aggregate() – group by a condition.
- takeLast(), takeLastWhile(), dropLast(), dropLastWhile() – take or drop elements by a predicate.
- slice(), chunked(), windowed() – retrieve collection parts.
- Plus (+) and minus (-) operators – add or remove elements.

If you want to take a deep dive into zip(), chunked(), windowed(), and some other operations, watch this video by Sebastian Aigner about advanced collection operations in Kotlin:

Kotlin Standard Library Safari
Episode 4: Advanced Collection Operations
Gif

Watch video online.

Mutability

In Java, there are mutable collections:

```
// Java
// This list is mutable!
public List<Customer> getCustomers() { ... }
```

Partially mutable ones:

```
// Java
List<String> numbers = Arrays.asList("one", "two", "three", "four");
numbers.add("five"); // Fails in runtime with `UnsupportedOperationException`
```

And immutable ones:

```
// Java
List<String> numbers = new LinkedList<>();
// This list is immutable!
List<String> immutableCollection = Collections.unmodifiableList(numbers);
immutableCollection.add("five"); // Fails in runtime with `UnsupportedOperationException`
```

If you write the last two pieces of code in IntelliJ IDEA, the IDE will warn you that you're trying to modify an immutable object. This code will compile and fail in runtime with UnsupportedOperationException. You can't tell whether a collection is mutable by looking at its type.

Unlike in Java, in Kotlin you explicitly declare mutable or read-only collections depending on your needs. If you try to modify a read-only collection, the code won't compile:

```
// Kotlin
val numbers = mutableListOf("one", "two", "three", "four")
numbers.add("five")            // This is OK
val immutableNumbers = listOf("one", "two")
//immutableNumbers.add("five") // Compilation error - Unresolved reference: add
```

Read more about immutability on the Kotlin coding conventions page.

Covariance

In Java, you can't pass a collection with a descendant type to a function that takes a collection of the ancestor type. For example, if Rectangle extends Shape, you can't pass a collection of Rectangle elements to a function that takes a collection of Shape elements. To make the code compilable, use the ? extends Shape type so the function can take collections with any inheritors of Shape:

```
// Java
class Shape {}

class Rectangle extends Shape {}

public void doSthWithShapes(List<? extends Shape> shapes) {
/* If using just List<Shape>, the code won't compile when calling
this function with the List<Rectangle> as the argument as below */
}

public void main() {
    var rectangles = List.of(new Rectangle(), new Rectangle());
    doSthWithShapes(rectangles);
}
```

In Kotlin, read-only collection types are covariant. This means that if a Rectangle class inherits from the Shape class, you can use the type List<Rectangle> anywhere the List<Shape> type is required. In other words, the collection types have the same subtyping relationship as the element types. Maps are covariant on the value type, but not on the key type. Mutable collections aren't covariant – this would lead to runtime failures.

```
// Kotlin
open class Shape(val name: String)

class Rectangle(private val rectangleName: String) : Shape(rectangleName)

fun doSthWithShapes(shapes: List<Shape>) {
    println("The shapes are: ${shapes.joinToString { it.name }}")
}

fun main() {
    val rectangles = listOf(Rectangle("rhombus"), Rectangle("parallelepiped"))
    doSthWithShapes(rectangles)
}
```

Read more about collection types here.

Ranges and progressions

In Kotlin, you can create intervals using ranges. For example, Version(1, 11)..Version(1, 30) includes all of the versions from 1.11 to 1.30. You can check that your version is in the range by using the in operator: Version(0, 9) in versionRange.

In Java, you need to manually check whether a Version fits both bounds:

```
// Java
class Version implements Comparable<Version> {

    int major;
    int minor;

    Version(int major, int minor) {
        this.major = major;
        this.minor = minor;
    }

    @Override
    public int compareTo(Version o) {
        if (this.major != o.major) {
            return this.major - o.major;
        }
        return this.minor - o.minor;
    }
}

public void compareVersions() {
    var minVersion = new Version(1, 11);
    var maxVersion = new Version(1, 31);

   System.out.println(
           versionIsInRange(new Version(0, 9), minVersion, maxVersion));
   System.out.println(
           versionIsInRange(new Version(1, 20), minVersion, maxVersion));
}

public Boolean versionIsInRange(Version versionToCheck, Version minVersion,
                                Version maxVersion) {
    return versionToCheck.compareTo(minVersion) >= 0
            && versionToCheck.compareTo(maxVersion) <= 0;
}
```

In Kotlin, you operate with a range as a whole object. You don't need to create two variables and compare a Version with them:

```
// Kotlin
class Version(val major: Int, val minor: Int): Comparable<Version> {
    override fun compareTo(other: Version): Int {
        if (this.major != other.major) {
            return this.major - other.major
        }
        return this.minor - other.minor
    }
}

fun main() {
    val versionRange = Version(1, 11)..Version(1, 30)

    println(Version(0, 9) in versionRange)
    println(Version(1, 20) in versionRange)
}
```

As soon as you need to exclude one of the bounds, like to check whether a version is greater than or equal to (>=) the minimum version and less than (<) the maximum version, these inclusive ranges won't help.

Comparison by several criteria

In Java, to compare objects by several criteria, you may use the comparing() and thenComparingX() functions from the Comparator interface. For example, to compare people by their name and age:

```
class Person implements Comparable<Person> {
    String name;
    int age;

    public String getName() {
        return name;
    }

    public int getAge() {
        return age;
    }

    Person(String name, int age) {
        this.name = name;
        this.age = age;
    }

    @Override
    public String toString() {
        return this.name + " " + age;
    }
}

public void comparePersons() {
    var persons = List.of(new Person("Jack", 35), new Person("David", 30),
            new Person("Jack", 25));
    System.out.println(persons.stream().sorted(Comparator
            .comparing(Person::getName)
            .thenComparingInt(Person::getAge)).collect(toList()));
}
```

In Kotlin, you just enumerate which fields you want to compare:

```
data class Person(
    val name: String,
    val age: Int
)

fun main() {
    val persons = listOf(Person("Jack", 35), Person("David", 30),
        Person("Jack", 25))
    println(persons.sortedWith(compareBy(Person::name, Person::age)))
}
```

Sequences

In Java, you can generate a sequence of numbers this way:

```
// Java
int sum = IntStream.iterate(1, e -> e + 3)
    .limit(10).sum();
System.out.println(sum); // Prints 145
```

In Kotlin, use sequences. Multi-step processing of sequences is executed lazily when possible – actual computing happens only when the result of the whole processing chain is requested.

```
fun main() {
    // Kotlin
    val sum = generateSequence(1) {
        it + 3
    }.take(10).sum()
    println(sum) // Prints 145
}
```

Sequences may reduce the number of steps that are needed to perform some filtering operations. See the sequence processing example, which shows the difference between Iterable and Sequence.

Removal of elements from a list

In Java, the remove() function accepts an index of an element to remove.

When removing an integer element, use the Integer.valueOf() function as the argument for the remove() function:

```
// Java
public void remove() {
    var numbers = new ArrayList<>();
    numbers.add(1);
    numbers.add(2);
    numbers.add(3);
    numbers.add(1);
    numbers.remove(1); // This removes by index
    System.out.println(numbers); // [1, 3, 1]
    numbers.remove(Integer.valueOf(1));
    System.out.println(numbers); // [3, 1]
}
```

In Kotlin, there are two types of element removal: by index with removeAt() and by value with remove().

```
fun main() {
    // Kotlin
    val numbers = mutableListOf(1, 2, 3, 1)
    numbers.removeAt(0)
    println(numbers) // [2, 3, 1]
    numbers.remove(1)
    println(numbers) // [2, 3]
}
```

Traverse a map

In Java, you can traverse a map via forEach:

```
// Java
numbers.forEach((k,v) -> System.out.println("Key = " + k + ", Value = " + v));
```

In Kotlin, use a for loop or a forEach, similar to Java's forEach, to traverse a map:

```
// Kotlin
for ((k, v) in numbers) {
    println("Key = $k, Value = $v")
}
// Or
numbers.forEach { (k, v) -> println("Key = $k, Value = $v") }
```

Get the first and the last items of a possibly empty collection

In Java, you can safely get the first and the last items by checking the size of the collection and using indices:

```
// Java
var list = new ArrayList<>();
//...
if (list.size() > 0) {
    System.out.println(list.get(0));
    System.out.println(list.get(list.size() - 1));
}
```

You can also use the getFirst() and getLast() functions for Deque and its inheritors:

```
// Java
var deque = new ArrayDeque<>();
//...
```

```
if (deque.size() > 0) {
    System.out.println(deque.getFirst());
    System.out.println(deque.getLast());
}
```

In Kotlin, there are the special functions firstOrNull() and lastOrNull(). Using the Elvis operator, you can perform further actions right away depending on the result of a function. For example, firstOrNull():

```
// Kotlin
val emails = listOf<String>() // Might be empty
val theOldestEmail = emails.firstOrNull() ?: ""
val theFreshestEmail = emails.lastOrNull() ?: ""
```

Create a set from a list

In Java, to create a Set from a List, you can use the Set.copyOf function:

```
// Java
public void listToSet() {
    var sourceList = List.of(1, 2, 3, 1);
    var copySet = Set.copyOf(sourceList);
    System.out.println(copySet);
}
```

In Kotlin, use the function toSet():

```
fun main() {
    // Kotlin
    val sourceList = listOf(1, 2, 3, 1)
    val copySet = sourceList.toSet()
    println(copySet)
}
```

Group elements

In Java, you can group elements with the Collectors function groupingBy():

```
// Java
public void analyzeLogs() {
    var requests = List.of(
        new Request("https://kotlinlang.org/docs/home.html", 200),
        new Request("https://kotlinlang.org/docs/home.html", 400),
        new Request("https://kotlinlang.org/docs/comparison-to-java.html", 200)
    );
    var urlsAndRequests = requests.stream().collect(
            Collectors.groupingBy(Request::getUrl));
    System.out.println(urlsAndRequests);
}
```

In Kotlin, use the function groupBy():

```
data class Request(
    val url: String,
    val responseCode: Int
)

fun main() {
    // Kotlin
    val requests = listOf(
        Request("https://kotlinlang.org/docs/home.html", 200),
        Request("https://kotlinlang.org/docs/home.html", 400),
        Request("https://kotlinlang.org/docs/comparison-to-java.html", 200)
    )
    println(requests.groupBy(Request::url))
}
```

Filter elements

In Java, to filter elements from a collection, you need to use the Stream API. The Stream API has intermediate and terminal operations. filter() is an intermediate operation, which returns a stream. To receive a collection as the output, you need to use a terminal operation, like collect(). For example, to leave only those pairs whose keys end with 1 and whose values are greater than 10:

```
// Java
public void filterEndsWith() {
    var numbers = Map.of("key1", 1, "key2", 2, "key3", 3, "key11", 11);
    var filteredNumbers = numbers.entrySet().stream()
        .filter(entry -> entry.getKey().endsWith("1") && entry.getValue() > 10)
        .collect(Collectors.toMap(Map.Entry::getKey, Map.Entry::getValue));
    System.out.println(filteredNumbers);
}
```

In Kotlin, filtering is built into collections, and filter() returns the same collection type that was filtered. So, all you need to write is the filter() and its predicate:

```
fun main() {
    // Kotlin
    val numbers = mapOf("key1" to 1, "key2" to 2, "key3" to 3, "key11" to 11)
    val filteredNumbers = numbers.filter { (key, value) -> key.endsWith("1") && value > 10 }
    println(filteredNumbers)
}
```

Learn more about filtering maps here.

Filter elements by type

In Java, to filter elements by type and perform actions on them, you need to check their types with the instanceof operator and then do the type cast:

```
// Java
public void objectIsInstance() {
    var numbers = new ArrayList<>();
    numbers.add(null);
    numbers.add(1);
    numbers.add("two");
    numbers.add(3.0);
    numbers.add("four");
    System.out.println("All String elements in upper case:");
    numbers.stream().filter(it -> it instanceof String)
        .forEach( it -> System.out.println(((String) it).toUpperCase()));
}
```

In Kotlin, you just call filterIsInstance<NEEDED_TYPE>() on your collection, and the type cast is done by Smart casts:

```
// Kotlin
fun main() {
    // Kotlin
    val numbers = listOf(null, 1, "two", 3.0, "four")
    println("All String elements in upper case:")
    numbers.filterIsInstance<String>().forEach {
        println(it.uppercase())
    }
}
```

Test predicates

Some tasks require you to check whether all, none, or any elements satisfy a condition. In Java, you can do all of these checks via the Stream API functions allMatch(), noneMatch(), and anyMatch():

```
// Java
public void testPredicates() {
    var numbers = List.of("one", "two", "three", "four");
    System.out.println(numbers.stream().noneMatch(it -> it.endsWith("e"))); // false
    System.out.println(numbers.stream().anyMatch(it -> it.endsWith("e"))); // true
    System.out.println(numbers.stream().allMatch(it -> it.endsWith("e"))); // false
}
```

In Kotlin, the extension functions none(), any(), and all() are available for every Iterable object:

```
fun main() {
// Kotlin
    val numbers = listOf("one", "two", "three", "four")
    println(numbers.none { it.endsWith("e") })
    println(numbers.any { it.endsWith("e") })
    println(numbers.all { it.endsWith("e") })
}
```

Learn more about test predicates.

Collection transformation operations

Zip elements

In Java, you can make pairs from elements with the same positions in two collections by iterating simultaneously over them:

```
// Java
public void zip() {
    var colors = List.of("red", "brown");
    var animals = List.of("fox", "bear", "wolf");

    for (int i = 0; i < Math.min(colors.size(), animals.size()); i++) {
        String animal = animals.get(i);
        System.out.println("The " + animal.substring(0, 1).toUpperCase()
               + animal.substring(1) + " is " + colors.get(i));
   }
}
```

If you want to do something more complex than just printing pairs of elements into the output, you can use Records. In the example above, the record would be record AnimalDescription(String animal, String color) {}.

In Kotlin, use the zip() function to do the same thing:

```
fun main() {
    // Kotlin
    val colors = listOf("red", "brown")
    val animals = listOf("fox", "bear", "wolf")

    println(colors.zip(animals) { color, animal ->
        "The ${animal.replaceFirstChar { it.uppercase() }} is $color" })
}
```

zip() returns the List of Pair objects.

If collections have different sizes, the result of zip() is the smaller size. The last elements of the larger collection are not included in the result.

Associate elements

In Java, you can use the Stream API to associate elements with characteristics:

```
// Java
public void associate() {
    var numbers = List.of("one", "two", "three", "four");
    var wordAndLength = numbers.stream()
        .collect(toMap(number -> number, String::length));
    System.out.println(wordAndLength);
}
```

In Kotlin, use the associate() function:

```
fun main() {
    // Kotlin
    val numbers = listOf("one", "two", "three", "four")
    println(numbers.associateWith { it.length })
}
```

What's next?

- Visit Kotlin Koans – complete exercises to learn Kotlin syntax. Each exercise is created as a failing unit test and your job is to make it pass.
- Look through other Kotlin idioms.
- Learn how to convert existing Java code to Kotlin with the Java to Kotlin converter.
- Discover collections in Kotlin.

If you have a favorite idiom, we invite you to share it by sending a pull request.

Nullability in Java and Kotlin

Nullability is the ability of a variable to hold a null value. When a variable contains null, an attempt to dereference the variable leads to a NullPointerException. There are many ways to write code in order to minimize the probability of receiving null pointer exceptions.

This guide covers differences between Java's and Kotlin's approaches to handling possibly nullable variables. It will help you migrate from Java to Kotlin and write your code in authentic Kotlin style.

The first part of this guide covers the most important difference – support for nullable types in Kotlin and how Kotlin processes types from Java code. The second part, starting from Checking the result of a function call, examines several specific cases to explain certain differences.

Learn more about null safety in Kotlin.

Support for nullable types

The most important difference between Kotlin's and Java's type systems is Kotlin's explicit support for nullable types. It is a way to indicate which variables can possibly hold a null value. If a variable can be null, it's not safe to call a method on the variable because this can cause a NullPointerException. Kotlin prohibits such calls at compile time and thereby prevents lots of possible exceptions. At runtime, objects of nullable types and objects of non-nullable types are treated the same: A nullable type isn't a wrapper for a non-nullable type. All checks are performed at compile time. That means there's almost no runtime overhead for working with nullable types in Kotlin.

> We say "almost" because, even though intrinsic checks are generated, their overhead is minimal.

In Java, if you don't write null checks, methods may throw a NullPointerException:

```
// Java
int stringLength(String a) {
    return a.length();
}

void main() {
    stringLength(null); // Throws a `NullPointerException`
}
```

This call will have the following output:

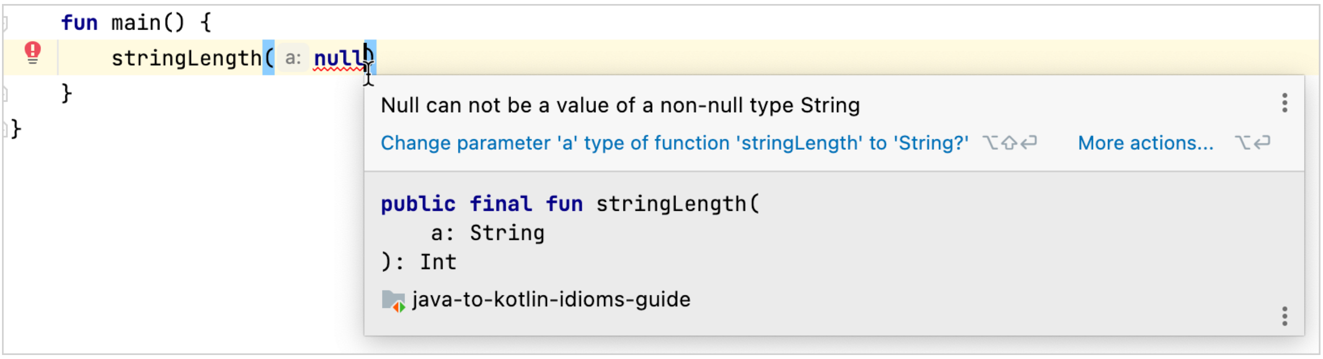
```
java.lang.NullPointerException: Cannot invoke "String.length()" because "a" is null
    at test.java.Nullability.stringLength(Nullability.java:8)
    at test.java.Nullability.main(Nullability.java:12)
    at java.base/java.util.ArrayList.forEach(ArrayList.java:1511)
    at java.base/java.util.ArrayList.forEach(ArrayList.java:1511)
```

In Kotlin, all regular types are non-nullable by default unless you explicitly mark them as nullable. If you don't expect a to be null, declare the stringLength() function as follows:

```
// Kotlin
fun stringLength(a: String) = a.length
```

The parameter a has the String type, which in Kotlin means it must always contain a String instance and it cannot contain null. Nullable types in Kotlin are marked with a question mark ?, for example, String?. The situation with a NullPointerException at runtime is impossible if a is String because the compiler enforces the rule that all arguments of stringLength() not be null.

An attempt to pass a null value to the stringLength(a: String) function will result in a compile-time error, "Null can not be a value of a non-null type String":



```
fun main() {
    stringLength( a: null)
}
}
```

Null can not be a value of a non-null type String

Change parameter 'a' type of function 'stringLength' to 'String?' ⌥⇧↩ More actions... ⌥↩

```
public final fun stringLength(
    a: String
): Int
```

java-to-kotlin-idioms-guide

Passing null to a non-nullable function error

If you want to use this function with any arguments, including null, use a question mark after the argument type String? and check inside the function body to ensure that the value of the argument is not null:

```
// Kotlin
fun stringLength(a: String?): Int = if (a != null) a.length else 0
```

After the check is passed successfully, the compiler treats the variable as if it were of the non-nullable type String in the scope where the compiler performs the check.

If you don't perform this check, the code will fail to compile with the following message: "Only safe (?.) or non-nullable asserted (!!.) calls are allowed on a nullable receiver of type String?".

You can write the same shorter – use the safe-call operator ?. (If-not-null shorthand), which allows you to combine a null check and a method call into a single operation:

```
// Kotlin
fun stringLength(a: String?): Int = a?.length ?: 0
```

Platform types

In Java, you can use annotations showing whether a variable can or cannot be null. Such annotations aren't part of the standard library, but you can add them separately. For example, you can use the JetBrains annotations @Nullable and @NotNull (from the org.jetbrains.annotations package) or annotations from Eclipse (org.eclipse.jdt.annotation). Kotlin can recognize such annotations when you're calling Java code from Kotlin code and will treat types according to their annotations.

If your Java code doesn't have these annotations, then Kotlin will treat Java types as platform types. But since Kotlin doesn't have nullability information for such types, its compiler will allow all operations on them. You will need to decide whether to perform null checks, because:

- Just as in Java, you'll get a NullPointerException if you try to perform an operation on null.
- The compiler won't highlight any redundant null checks, which it normally does when you perform a null-safe operation on a value of a non-nullable type.

Learn more about calling Java from Kotlin in regard to null-safety and platform types.

Support for definitely non-nullable types

In Kotlin, if you want to override a Java method that contains @NotNull as an argument, you need Kotlin's definitely non-nullable types.

For example, consider this load() method in Java:

```
import org.jetbrains.annotations.*;

public interface Game<T> {
  public T save(T x) {}
  @NotNull
  public T load(@NotNull T x) {}
}
```

To override the load() method in Kotlin successfully, you need T1 to be declared as definitely non-nullable (T1 & Any):

```
interface ArcadeGame<T1> : Game<T1> {
  override fun save(x: T1): T1
  // T1 is definitely non-nullable
  override fun load(x: T1 & Any): T1 & Any
}
```

Learn more about generic types that are definitely non-nullable.

Checking the result of a function call

One of the most common situations where you need to check for null is when you obtain a result from a function call.

In the following example, there are two classes, Order and Customer. Order has a reference to an instance of Customer. The findOrder() function returns an instance of the Order class, or null if it can't find the order. The objective is to process the customer instance of the retrieved order.

Here are the classes in Java:

```
//Java
record Order (Customer customer) {}

record Customer (String name) {}
```

In Java, call the function and do an if-not-null check on the result to proceed with the dereferencing of the required property:

```
// Java
Order order = findOrder();

if (order != null) {
    processCustomer(order.getCustomer());
}
```

Converting the Java code above to Kotlin code directly results in the following:

```
// Kotlin
data class Order(val customer: Customer)

data class Customer(val name: String)

val order = findOrder()

// Direct conversion
if (order != null){
    processCustomer(order.customer)
}
```

Use the safe-call operator ?. (If-not-null shorthand) in combination with any of the scope functions from the standard library. The let function is usually used for this:

```
// Kotlin
val order = findOrder()

order?.let {
    processCustomer(it.customer)
}
```

Here is a shorter version of the same:

```
// Kotlin
findOrder()?.customer?.let(::processCustomer)
```

Default values instead of null

Checking for null is often used in combination with setting the default value in case the null check is successful.

The Java code with a null check:

```
// Java
Order order = findOrder();
if (order == null) {
    order = new Order(new Customer("Antonio"))
}
```

To express the same in Kotlin, use the Elvis operator (If-not-null-else shorthand):

```
// Kotlin
val order = findOrder() ?: Order(Customer("Antonio"))
```

Functions returning a value or null

In Java, you need to be careful when working with list elements. You should always check whether an element exists at an index before you attempt to use the element:

```
// Java
var numbers = new ArrayList<Integer>();
numbers.add(1);
numbers.add(2);

System.out.println(numbers.get(0));
//numbers.get(5) // Exception!
```

The Kotlin standard library often provides functions whose names indicate whether they can possibly return a null value. This is especially common in the collections API:

```
fun main() {
    // Kotlin
    // The same code as in Java:
    val numbers = listOf(1, 2)

    println(numbers[0])  // Can throw IndexOutOfBoundsException if the collection is empty
    //numbers.get(5)     // Exception!

    // More abilities:
    println(numbers.firstOrNull())
    println(numbers.getOrNull(5)) // null
}
```

Aggregate operations

When you need to get the biggest element or null if there are no elements, in Java you would use the Stream API:

```
// Java
var numbers = new ArrayList<Integer>();
var max = numbers.stream().max(Comparator.naturalOrder()).orElse(null);
System.out.println("Max: " + max);
```

In Kotlin, use aggregate operations:

```
// Kotlin
val numbers = listOf<Int>()
```

```
println("Max: ${numbers.maxOrNull()}")
```

Learn more about collections in Java and Kotlin.

Casting types safely

When you need to safely cast a type, in Java you would use the instanceof operator and then check how well it worked:

```
// Java
int getStringLength(Object y) {
    return y instanceof String x ? x.length() : -1;
}

void main() {
    System.out.println(getStringLength(1)); // Prints `-1`
}
```

To avoid exceptions in Kotlin, use the safe cast operator as?, which returns null on failure:

```
// Kotlin
fun main() {
    println(getStringLength(1)) // Prints `-1`
}

fun getStringLength(y: Any): Int {
    val x: String? = y as? String // null
    return x?.length ?: -1 // Returns -1 because `x` is null
}
```

In the Java example above, the function getStringLength() returns a result of the primitive type int. To make it return null, you can use the boxed type Integer. However, it's more resource-efficient to make such functions return a negative value and then check the value – you would do the check anyway, but no additional boxing is performed this way.

What's next?

- Browse other Kotlin idioms.
- Learn how to convert existing Java code to Kotlin with the Java-to-Kotlin (J2K) converter.
- Check out other migration guides:
  - Strings in Java and Kotlin
  - Collections in Java and Kotlin

If you have a favorite idiom, feel free to share it with us by sending a pull request!

Standard input

Java Scanner is a slow tool. Use it only when you need the specific functionalities it offers. Otherwise, it's generally preferable to use Kotlin's readln() function to read standard input.

To read from the standard input, Java provides the Scanner class. Kotlin offers two main ways to read from the standard input: the Scanner class, similar to Java, and the readln() function.

Read from the standard input with Java Scanner

In Java, the standard input is typically accessed through the System.in object. You need to import the Scanner class, create an object, and use methods like

.nextLine() and .nextInt() to read different data types:

```
//Java implementation
import java.util.Scanner;

public class Main {
    public static void main(String[] args) {
        Scanner scanner = new Scanner(System.in);

        // Reads a single line of input. For example: Hi there!
        System.out.print("Enter a line: ");
        String line = scanner.nextLine();
        System.out.println("You entered: " + line);
        // You entered: Hi there!

        // Reads an integer. For example: 08081990
        System.out.print("Enter an integer: ");
        int number = scanner.nextInt();
        System.out.println("You entered: " + number);
        // You entered: 08081990

        scanner.close();
    }
}
```

Use Java Scanner in Kotlin

Due to Kotlin's interoperability with Java libraries, you can access Java Scanner from Kotlin code out of the box.

To use Java Scanner in Kotlin, you need to import the Scanner class and initialize it by passing a System.in object that represents the standard input stream and dictates how to read the data. You can use the available reading methods for reading values different from strings, such as .nextLine(), .next(), and .nextInt():

```
// Imports Java Scanner
import java.util.Scanner

fun main() {
    // Initializes the Scanner
    val scanner = Scanner(System.`in`)

    // Reads a whole string line. For example: "Hello, Kotlin"
    val line = scanner.nextLine()
    print(line)
    // Hello, Kotlin

    // Reads a string. For example: "Hello"
    val string = scanner.next()
    print(string)
    // Hello

    // Reads a number. For example: 123
    val num = scanner.nextInt()
    print(num)
    // 123
}
```

Other useful methods for reading input with Java Scanner are .hasNext(), .useDelimiter(), and .close():

- The .hasNext() method checks if there's more data available in the input. It returns the boolean value true if there are remaining elements to iterate and false if no more elements are left in the input.
- The .useDelimiter() method sets the delimiter for reading input elements. The delimiter is whitespaces by default, but you can specify other characters. For example, .useDelimiter(",") reads the input elements separated by commas.
- The .close() method closes the input stream associated with the Scanner, preventing further use of the Scanner for reading input.

Always use the .close() method when you're finished using Java Scanner. Closing the Java Scanner releases the resources it consumes and ensures proper program behavior.

Read from the standard input with readln()

In Kotlin, apart from the Java Scanner, you have the readln() function. It is the most straightforward way to read input. This function reads a line of text from the standard input and returns it as a string:

```
// Reads a string. For example: Charlotte
val name = readln()

// Reads a string and converts it into an integer. For example: 43
val age = readln().toInt()

println("Hello, $name! You are $age years old.")
// Hello, Charlotte! You are 43 years old.
```

For more information, see Read standard input.

Get started with Kotlin/Native

In this tutorial, you'll learn how to create a Kotlin/Native application. Choose the tool that works best for you and create your app using:

- The IDE. Here, you can clone the project template from a version control system and use it in IntelliJ IDEA.
- The Gradle build system. To better understand how things work under the hood, create build files for your project manually.
- The command line tool. You can use the Kotlin/Native compiler, which is shipped as a part of the standard Kotlin distribution, and create the app directly in the command line tool.

  Console compilation may seem easy and straightforward, but it doesn't scale well for larger projects with hundreds of files and libraries. For such projects, we recommend using an IDE or a build system.

With Kotlin/Native, you can compile for different targets, including Linux, macOS, and Windows. While cross-platform compilation is possible, which means using one platform to compile for a different one, in this tutorial, you'll be targeting the same platform you're compiling on.

If you use a Mac and want to create and run applications for macOS or other Apple targets, you also need to install Xcode Command Line Tools, launch it, and accept the license terms first.

In IDE

In this section, you'll learn how to use IntelliJ IDEA to create a Kotlin/Native application. You can use both the Community Edition and the Ultimate Edition.

Create the project

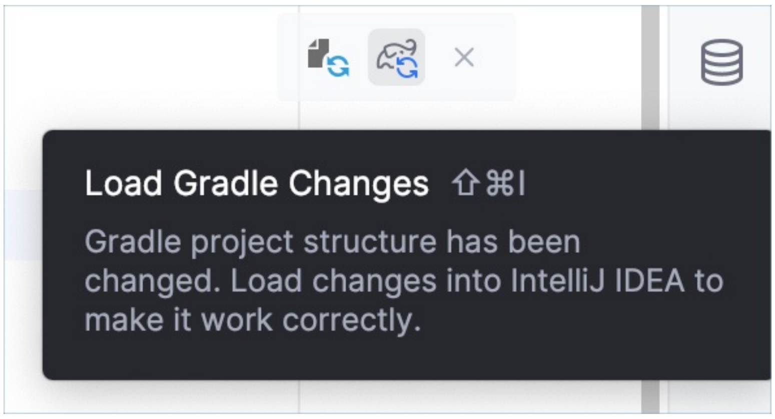
1. Download and install the latest version of IntelliJ IDEA.
2. Clone the project template by selecting File | New | Project from Version Control in IntelliJ IDEA and using this URL:

   ```
   https://github.com/Kotlin/kmp-native-wizard
   ```

3. Open the gradle/libs.versions.toml file, which is the version catalog for project dependencies. To create Kotlin/Native applications, you need the Kotlin Multiplatform Gradle plugin, which has the same version as Kotlin. Ensure that you use the latest Kotlin version:

   ```
   [versions]
   kotlin = "2.2.0"
   ```

4. Follow the suggestion to reload Gradle files:


Load Gradle Changes ⇧⌘I

Gradle project structure has been changed. Load changes into IntelliJ IDEA to make it work correctly.

Load Gradle changes button

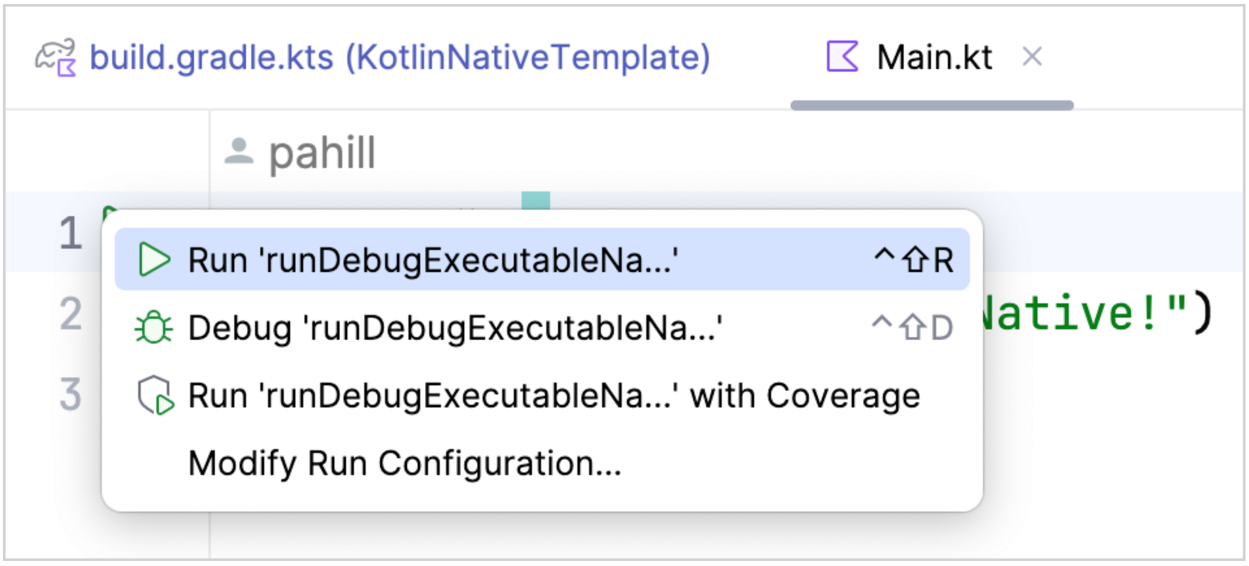
For more information about these settings, see the Multiplatform Gradle DSL reference.

Build and run the application

Open the Main.kt file in the src/nativeMain/kotlin/ directory:

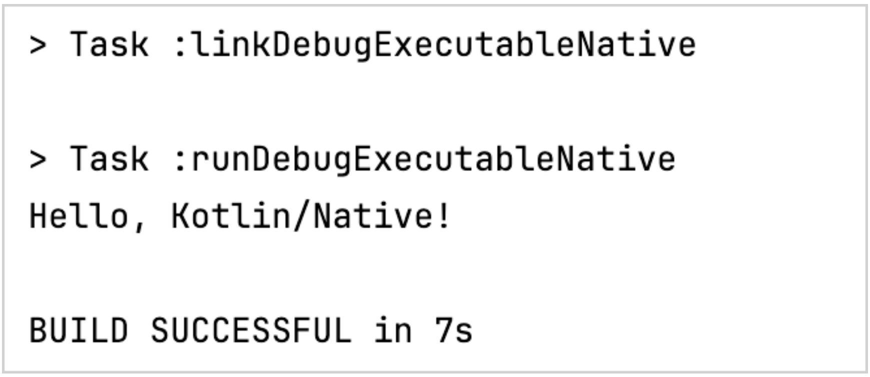
- The src directory contains Kotlin source files.
- The Main.kt file includes code that prints "Hello, Kotlin/Native!" using the println() function.

Press the green icon in the gutter to run the code:


build.gradle.kts (KotlinNativeTemplate)
Main.kt
pahill
Run 'runDebugExecutableNa...' ^⇧R
Debug 'runDebugExecutableNa...' ^⇧D
Run 'runDebugExecutableNa...' with Coverage
Modify Run Configuration...
lative!")

Run the application

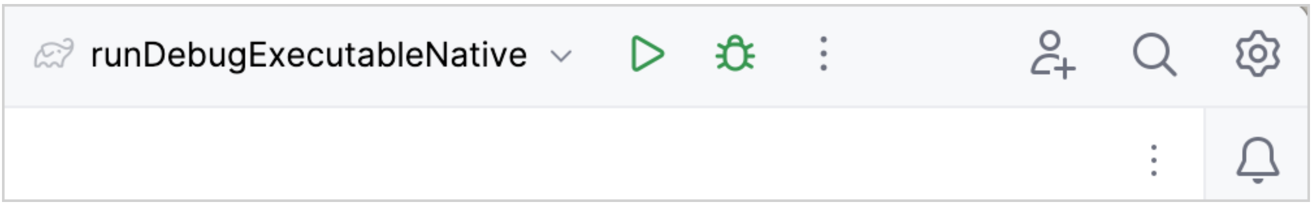
IntelliJ IDEA runs the code using the Gradle task and outputs the result in the Run tab:



```
> Task :linkDebugExecutableNative

> Task :runDebugExecutableNative
Hello, Kotlin/Native!

BUILD SUCCESSFUL in 7s
```

Application output

After the first run, the IDE creates the corresponding run configuration at the top:



Gradle run configuration

IntelliJ IDEA Ultimate users can install the Native Debugging Support plugin that allows debugging compiled native executables and also automatically creates run configurations for imported Kotlin/Native projects.

You can configure IntelliJ IDEA to build your project automatically:

1. Go to Settings | Build, Execution, Deployment | Compiler.
2. On the Compiler page, select Build project automatically.
3. Apply the changes.

Now, when you make changes in the class files or save the file (Ctrl + S/Cmd + S), IntelliJ IDEA automatically performs an incremental build of the project.

Update the application

Let's add a feature to your application so it can count the number of letters in your name:

1. In the Main.kt file, add code to read the input. Use the readln() function to read the input value and assign it to the name variable:

```kotlin
fun main() {
    // Read the input value.
    println("Hello, enter your name:")
    val name = readln()
}
```

2. To run this app using Gradle, specify System.in as the input to use in the build.gradle.kts file and load the Gradle changes:

```kotlin
kotlin {
    //...
    nativeTarget.apply {
        binaries {
            executable {
                entryPoint = "main"
                runTask?.standardInput = System.`in`
            }
        }
    }
    //...
}
```

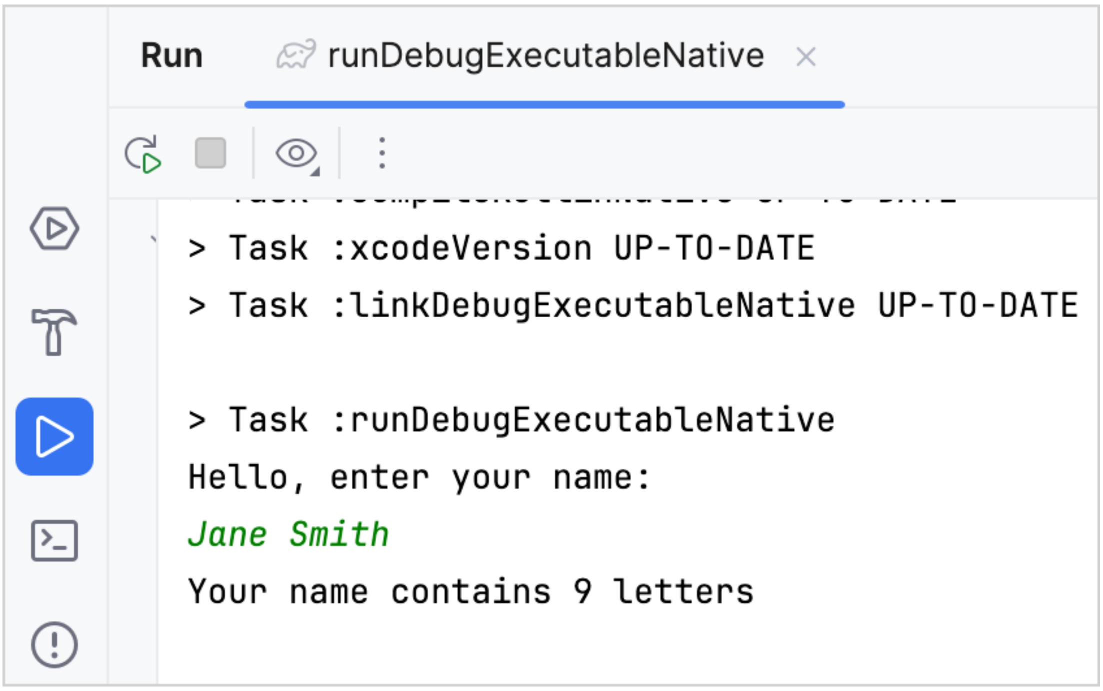
3. Eliminate the whitespaces and count the letters:

   - Use the replace() function to remove the empty spaces in the name.
   - Use the scope function let to run the function within the object context.
   - Use a string template to insert your name length into the string by adding a dollar sign $ and enclosing it in curly braces – ${it.length}. it is the default name of a lambda parameter.

```
fun main() {
    // Read the input value.
    println("Hello, enter your name:")
    val name = readln()
    // Count the letters in the name.
    name.replace(" ", "").let {
        println("Your name contains ${it.length} letters")
    }
}
```

4. Run the application.

5. Enter your name and enjoy the result:



```
> Task :xcodeVersion UP-TO-DATE
> Task :linkDebugExecutableNative UP-TO-DATE

> Task :runDebugExecutableNative
Hello, enter your name:
Jane Smith
Your name contains 9 letters
```

Application output

Now let's count only the unique letters in your name:

1. In the Main.kt file, declare the new extension function .countDistinctCharacters() for String:

   - Convert the name to lowercase using the .lowercase() function.
   - Convert the input string to a list of characters using the toList() function.
   - Select only the distinct characters in your name using the distinct() function.
   - Count the distinct characters using the count() function.

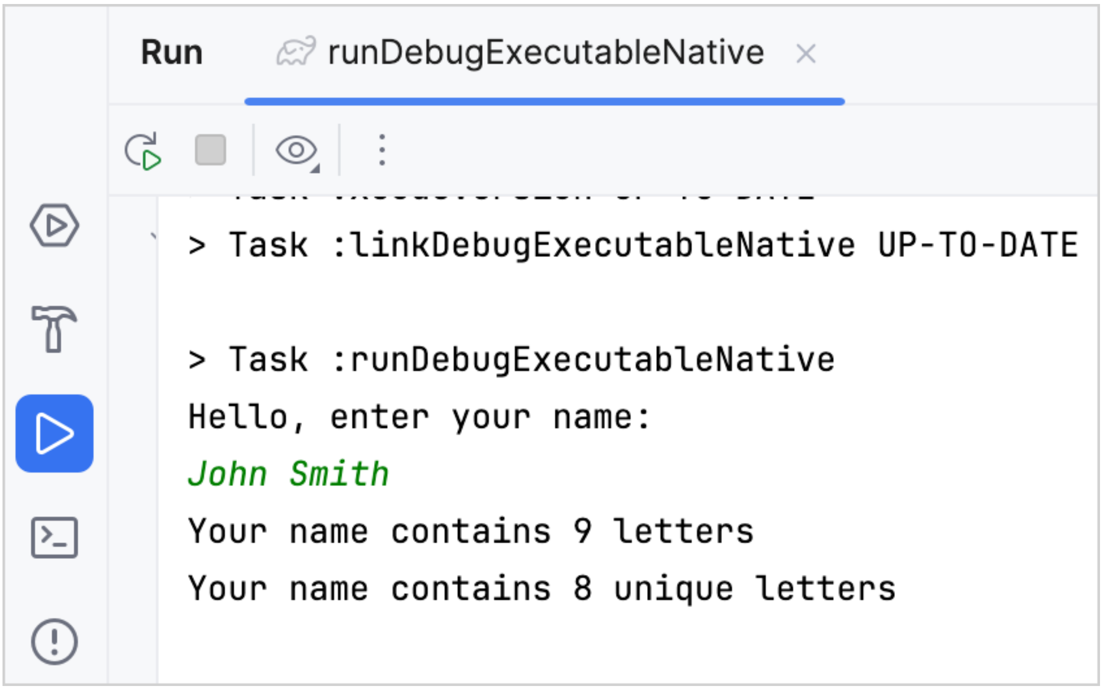
```
fun String.countDistinctCharacters() = lowercase().toList().distinct().count()
```

2. Use the .countDistinctCharacters() function to count the unique letters in your name:

```kotlin
fun String.countDistinctCharacters() = lowercase().toList().distinct().count()

fun main() {
    // Read the input value.
    println("Hello, enter your name:")
    val name = readln()
    // Count the letters in the name.
    name.replace(" ", "").let {
        println("Your name contains ${it.length} letters")
        // Print the number of unique letters.
        println("Your name contains ${it.countDistinctCharacters()} unique letters")
    }
}
```

3. Run the application.

4. Enter your name and see the result:



```
> Task :linkDebugExecutableNative UP-TO-DATE

> Task :runDebugExecutableNative
Hello, enter your name:
John Smith
Your name contains 9 letters
Your name contains 8 unique letters
```

Application output

Using Gradle

In this section, you'll learn how to manually create a Kotlin/Native application using Gradle. It's the default build system for Kotlin/Native and Kotlin Multiplatform projects, which is also commonly used in Java, Android, and other ecosystems.

Create project files

1. To get started, install a compatible version of Gradle. See the compatibility table to check the Kotlin Gradle plugin (KGP) compatibility with available Gradle versions.

2. Create an empty project directory. Inside it, create a build.gradle(.kts) file with the following content:

Kotlin

```kotlin
// build.gradle.kts
plugins {
    kotlin("multiplatform") version "2.2.0"
}
```

```
repositories {
    mavenCentral()
}

kotlin {
    macosArm64("native") {  // on macOS
    // linuxArm64("native") // on Linux
    // mingwX64("native")   // on Windows
        binaries {
            executable()
        }
    }
}

tasks.withType<Wrapper> {
    gradleVersion = "8.14"
    distributionType = Wrapper.DistributionType.BIN
}
```

Groovy

```
// build.gradle
plugins {
    id 'org.jetbrains.kotlin.multiplatform' version '2.2.0'
}

repositories {
    mavenCentral()
}

kotlin {
    macosArm64('native') {  // on macOS
    // linuxArm64('native') // on Linux
    // mingwX64('native')   // on Windows
        binaries {
            executable()
        }
    }
}

wrapper {
    gradleVersion = '8.14'
    distributionType = 'BIN'
}
```

You can use different target names, such as macosArm64, iosArm64 linuxArm64, and mingwX64 to define the targets for which you are compiling your code. These target names can optionally take the platform name as a parameter, which in this case is native. The platform name is used to generate the source paths and task names in the project.

3. Create an empty settings.gradle(.kts) file in the project directory.

4. Create a src/nativeMain/kotlin directory and place a hello.kt file inside with the following content:

```
fun main() {
    println("Hello, Kotlin/Native!")
}
```

By convention, all sources are located in the src/<target name>[Main|Test]/kotlin directories, where Main is for the source code and Test is for tests. <target name> corresponds to the target platform (in this case, native), as specified in the build file.

Build and run the project

1. From the root project directory, run the build command:

```
./gradlew nativeBinaries
```

This command creates the build/bin/native directory with two directories inside: debugExecutable and releaseExecutable. They contain the corresponding binary files.

By default, the name of the binary file is the same as the project directory.

2. To run the project, execute the following command:

   ```
   build/bin/native/debugExecutable/<project_name>.kexe
   ```

The terminal prints "Hello, Kotlin/Native!".

Open the project in IDE

Now, you can open your project in any IDE that supports Gradle. If you use IntelliJ IDEA:

1. Select File | Open.
2. Select the project directory and click Open. IntelliJ IDEA automatically detects if it's a Kotlin/Native project.

If you encounter a problem with the project, IntelliJ IDEA displays the error message in the Build tab.

Using the command-line compiler

In this section, you'll learn how to create a Kotlin/Native application using the Kotlin compiler in the command line tool.

Download and install the compiler

To install the compiler:

1. Go to the Kotlin's GitHub releases page.
2. Look for a file with kotlin-native in the name and download one that is suitable for your operating system, for example kotlin-native-prebuilt-linux-x86_64-2.0.21.tar.gz.
3. Unpack the archive to a directory of your choice.
4. Open your shell profile and add the path to the compiler's /bin directory to the PATH environment variable:

   ```
   export PATH="/<path to the compiler>/kotlin-native/bin:$PATH"
   ```

> Although the compiler output has no dependencies or virtual machine requirements, the compiler itself requires Java 1.8 or higher runtime. It's supported by JDK 8 (JAVA SE 8) or later versions.

Create the program

Choose a working directory and create a file named hello.kt. Update it with the following code:

```
fun main() {
    println("Hello, Kotlin/Native!")
}
```

Compile the code from the console

To compile the application, execute the following command with the downloaded compiler:

```
kotlinc-native hello.kt -o hello
```

The value of the -o option specifies the name of the output file, so this call generates the hello.kexe binary file on macOS and Linux (and hello.exe on Windows).

For the full list of available options, see Kotlin compiler options.

Run the program

To run the program, in your command line tool, navigate to the directory containing the binary file and run the following command:

macOS and Linux

```
./hello.kexe
```

Windows

```
./hello.exe
```

The application prints "Hello, Kotlin/Native" to the standard output.

What's next?

- Complete the Create an app using C interop and libcurl tutorial that explains how to create a native HTTP client and interoperate with C libraries.
- Learn how to write Gradle build scripts for real-life Kotlin/Native projects.
- Read more about the Gradle build system in the documentation.

Definition file

Kotlin/Native enables you to consume C and Objective-C libraries, allowing you to use their functionality in Kotlin. A special tool called cinterop takes a C or an Objective-C library and generates the corresponding Kotlin bindings, so that the library's methods can be used in your Kotlin code as usual.

To generate these bindings, each library needs a definition file, usually with the same name as the library. This is a property file that describes exactly how the library should be consumed. See the full list of available properties.

Here's a general workflow when working with a project:

1. Create a .def file describing what to include in the bindings.
2. Use the generated bindings in your Kotlin code.
3. Run the Kotlin/Native compiler to produce the final executable.

Create and configure a definition file

Let's create a definition file and generate bindings for a C library:

1. In your IDE, select the src folder and create a new directory with File | New | Directory.
2. Name the new directory nativeInterop/cinterop.

   This is the default convention for .def file locations, but it can be overridden in the build.gradle.kts file if you use a different location.
3. Select the new subfolder and create a png.def file with File | New | File.
4. Add the necessary properties:

   ```
   headers = png.h
   headerFilter = png.h
   package = png

   compilerOpts.linux = -I/usr/include -I/usr/include/x86_64-linux-gnu
   linkerOpts.osx = -L/opt/local/lib -L/usr/local/opt/png/lib -lpng
   linkerOpts.linux = -L/usr/lib/x86_64-linux-gnu -lpng
   ```

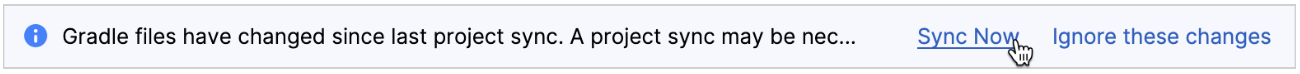
   - headers is the list of header files to generate Kotlin stubs for. You can add multiple files to this entry, separating each with a space. In this case, it's only png.h. The referenced files need to be available on the specified path (in this case, it's /usr/include/png).

- headerFilter shows what exactly is included. In C, all the headers are also included when one file references another one with the #include directive. Sometimes it's not necessary, and you can add this parameter using glob patterns to make adjustments.

  You can use headerFilter if you don't want to fetch external dependencies (such as system stdint.h header) into the interop library. Also, it may be useful for library size optimization and fixing potential conflicts between the system and the provided Kotlin/Native compilation environment.

- If the behavior for a certain platform needs to be modified, you can use a format like compilerOpts.osx or compilerOpts.linux to provide platform-specific values to the options. In this case, they are macOS (the .osx suffix) and Linux (the .linux suffix). Parameters without a suffix are also possible (for example, linkerOpts=) and applied to all platforms.

5. To generate bindings, synchronize the Gradle files by clicking Sync Now in the notification.


Gradle files have changed since last project sync. A project sync may be nec...

Synchronize the Gradle files

After the bindings generation, the IDE can use them as a proxy view of the native library.

> You can also configure bindings generation by using the cinterop tool in the command line.

Properties

Here's the full list of properties you can use in your definition file to adjust the content of the generated binaries. For more information, see the corresponding sections below.

Property	Description
headers	The list of headers from a library to be included in the bindings.
modules	The list of Clang modules from an Objective-C library to be included in the bindings.
language	Specifies the language. C is used by default; change to Objective-C if necessary.
compilerOpts	Compiler options that the cinterop tool passes to the C compiler.
linkerOpts	Linker options that the cinterop tool passes to the linker.
excludedFunctions	A space-separated list of function names that should be ignored.
staticLibraries	Experimental. Includes a static library into .klib.
libraryPaths	Experimental. A space-separated list of directories where the cinterop tool searches for the library to be included in .klib.
packageName	Package prefix for the generated Kotlin API.
headerFilter	Filters headers by globs and includes only them when importing a library.

Property	Description
excludeFilter	Excludes specific headers when importing a library and takes priority over headerFilter.
strictEnums	A space-separated list of enums that should be generated as Kotlin enums.
nonStrictEnums	A space-separated list of enums that should be generated as integral values.
noStringConversion	A space-separated list of functions whose const char* parameters should not be auto-converted to Kotlin Strings.
allowedOverloadsForCFunctions	By default, it's assumed that C functions have unique names. If several functions have the same name, only one is picked. However, you can change this by specifying these functions in allowedOverloadsForCFunctions.
disableDesignatedInitializerChecks	Disables the compiler check that doesn't allow calling a non-designated Objective-C initializer as a super() constructor.
foreignExceptionMode	Wraps exceptions from Objective-C code into Kotlin exceptions with the ForeignException type.
userSetupHint	Adds a custom message, for example, to help users resolve linker errors.

In addition to the list of properties, you can include custom declarations in your definition file.

Import headers

If a C library does not have a Clang module and instead consists of a set of headers, use the headers property to specify headers that should be imported:

```
headers = curl/curl.h
```

Filter headers by globs

You can filter headers by globs using filter properties from the .def file. To include declarations from headers, use the headerFilter property. If a header matches any of the globs, its declarations are included in the bindings.

The globs are applied to the header paths relative to the appropriate include path elements, for example, time.h or curl/curl.h. So if the library is usually included with #include <SomeLibrary/Header.h>, you can probably filter headers with the following filter:

```
headerFilter = SomeLibrary/**
```

If headerFilter is not provided, all the headers are included. However, we encourage you to use headerFilter and specify the glob as precisely as possible. In this case, the generated library contains only the necessary declarations. It can help avoid various issues when upgrading Kotlin or tools in your development environment.

Exclude headers

To exclude specific headers, use the excludeFilter property. It can be helpful to remove redundant or problematic headers and optimize compilation, as declarations from the specified headers are not included in the bindings:

```
excludeFilter = SomeLibrary/time.h
```

If the same header is both included with headerFilter, and excluded with excludeFilter, the specified header will not be included in the bindings.

Import modules

If an Objective-C library has a Clang module, use the modules property to specify the module to be imported:

```
modules = UIKit
```

Pass compiler and linker options

Use the compilerOpts property to pass options to the C compiler, which is used to analyze headers under the hood. To pass options to the linker, which is used to link final executables, use linkerOpts. For example:

```
compilerOpts = -DFOO=bar
linkerOpts = -lpng
```

You can also specify target-specific options that apply only to a certain target:

```
compilerOpts = -DBAR=bar
compilerOpts.linux_x64 = -DFOO=foo1
compilerOpts.macos_x64 = -DFOO=foo2
```

With this configuration, headers are analyzed using -DBAR=bar -DFOO=foo1 on Linux and -DBAR=bar -DFOO=foo2 on macOS. Note that any definition file option can have both common and platform-specific parts.

Ignore specific functions

Use the excludedFunctions property to specify a list of the function names that should be ignored. This can be useful if a function declared in the header isn't guaranteed to be callable, and it's difficult or impossible to determine this automatically. You can also use this property to work around a bug in the interop itself.

Include a static library

This feature is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes.

Sometimes it's more convenient to ship a static library with your product, rather than assume it is available within the user's environment. To include a static library into .klib, use staticLibrary and libraryPaths properties:

```
headers = foo.h
staticLibraries = libfoo.a
libraryPaths = /opt/local/lib /usr/local/opt/curl/lib
```

When given the above snippet, the cinterop tool searches libfoo.a in /opt/local/lib and /usr/local/opt/curl/lib, and if found, includes the library binary in the klib.

When using a klib like this in your program, the library is linked automatically.

Configure enums generation

Use the strictEnums property to generate enums as Kotlin enums or nonStrictEnums to generate them as integral values. If an enum is not included in either of these lists, it is generated based on heuristics.

Set up string conversion

Use the noStringConversion property to disable automatic conversion of the const char* function parameters as Kotlin Strings.

Allow calling a non-designated initializer

By default, the Kotlin/Native compiler doesn't allow calling a non-designated Objective-C initializer as a super() constructor. This behavior can be inconvenient if the designated Objective-C initializers aren't marked properly in the library. To disable these compiler checks, use the disableDesignatedInitializerChecks property.

Handle Objective-C exceptions

By default, the program crashes if Objective-C exceptions reach the Objective-C to Kotlin interop boundary and get to the Kotlin code.

To propagate Objective-C exceptions to Kotlin, enable wrapping with the foreignExceptionMode = objc-wrap property. In this case, Objective-C exceptions are translated into Kotlin exceptions that get the ForeignException type.

Help resolve linker errors

Linker errors might occur when a Kotlin library depends on C or Objective-C libraries, for example, using the CocoaPods integration. If dependent libraries aren't installed locally on the machine or configured explicitly in the project build script, the "Framework not found" error occurs.

If you're a library author, you can help your users resolve linker errors with custom messages. To do that, add a userSetupHint=message property to your .def file or pass the -Xuser-setup-hint compiler option to cinterop.

Add custom declarations

Sometimes it is required to add custom C declarations to the library before generating bindings (for example, for macros). Instead of creating an additional header file with these declarations, you can include them directly to the end of the .def file, after a separating line, containing only the separator sequence ---:

```
headers = errno.h
---

static inline int getErrno() {
    return errno;
}
```

Note that this part of the .def file is treated as part of the header file, so functions with the body should be declared as static. The declarations are parsed after including the files from the headers list.

Generate bindings using command line

In addition to the definition file, you can specify what to include in bindings by passing the corresponding properties as options in the cinterop call.

Here's an example of the command that produces a png.klib compiled library:

```
cinterop -def png.def -compiler-option -I/usr/local/include -o png
```

Note that the generated bindings are generally platform-specific, so if you are developing for multiple targets, the bindings need to be regenerated.

- For host libraries that are not included in the sysroot search paths, headers may be needed.
- For a typical UNIX library with a configuration script, the compilerOpts will likely contain the output of a configuration script with the --cflags option (maybe without exact paths).
- The output of a configuration script with --libs can be passed to the linkerOpts property.

What's next

- Bindings for C-interoperability
- Interoperability with Swift/Objective-C

Interoperability with C

The C libraries import is Experimental. All Kotlin declarations generated by the cinterop tool from C libraries should have the @ExperimentalForeignApi annotation.

Native platform libraries shipped with Kotlin/Native (like Foundation, UIKit, and POSIX) require opt-in only for some APIs.

This document covers general aspects of Kotlin's interoperability with C. Kotlin/Native comes with a cinterop tool, which you can use to quickly generate everything you need to interact with an external C library.

The tool analyzes C headers and produces a straightforward mapping of C types, functions, and strings into Kotlin. The generated stubs then can be imported into an IDE to enable code completion and navigation.

Kotlin also provides interoperability with Objective-C. Objective-C libraries are imported through the cinterop tool as well. For more details, see Swift/Objective-C interop.

Setting up your project

Here's a general workflow when working with a project that needs to consume a C library:

1. Create and configure a definition file. It describes what the cinterop tool should include into Kotlin bindings.
2. Configure your Gradle build file to include cinterop in the build process.
3. Compile and run the project to produce the final executable.

For a hands-on experience, complete the Create an app using C interop tutorial.

In many cases, there's no need to configure custom interoperability with a C library. Instead, you can use APIs available on the platform standardized bindings called platform libraries. For example, POSIX on Linux/macOS platforms, Win32 on the Windows platform, or Apple frameworks on macOS/iOS are available this way.

Bindings

Basic interop types

All the supported C types have corresponding representations in Kotlin:

- Signed, unsigned integral, and floating point types are mapped to their Kotlin counterpart with the same width.
- Pointers and arrays are mapped to CPointer<T>?.
- Enums can be mapped to either Kotlin enum or integral values, depending on heuristics and the definition file settings.
- Structs and unions are mapped to types having fields available via the dot notation, i.e. someStructInstance.field1.
- typedef are represented as typealias.

Also, any C type has the Kotlin type representing the lvalue of this type, i.e., the value located in memory rather than a simple immutable self-contained value. Think C++ references as a similar concept. For structs (and typedefs to structs), this representation is the main one and has the same name as the struct itself. For Kotlin enums, it's named ${type}.Var; for CPointer<T>, it's CPointerVar<T>; and for most other types, it's ${type}Var.

For types that have both representations, the one with the lvalue has a mutable .value property for accessing the value.

Pointer types

The type argument T of CPointer<T> must be one of the lvalue types described above. For example, the C type struct S* is mapped to CPointer<S>, int8_t* is mapped to CPointer<int_8tVar>, and char** is mapped to CPointer<CPointerVar<ByteVar>>.

C null pointer is represented as Kotlin's null, and the pointer type CPointer<T> is not nullable, but the CPointer<T>? is. The values of this type support all the Kotlin operations related to handling null, for example, ?:, ?., !!, and so on:

```
val path = getenv("PATH")?.toKString() ?: ""
```

Since the arrays are also mapped to CPointer<T>, it supports the [] operator for accessing values by index:

```
import kotlinx.cinterop.*

@OptIn(ExperimentalForeignApi::class)
fun shift(ptr: CPointer<ByteVar>, length: Int) {
    for (index in 0 .. length - 2) {
        ptr[index] = ptr[index + 1]
    }
}
```

The .pointed property for CPointer<T> returns the lvalue of type T, pointed by this pointer. The reverse operation is .ptr, it takes the lvalue and returns the pointer to it.

void* is mapped to COpaquePointer – the special pointer type which is the supertype for any other pointer type. So if the C function takes void*, the Kotlin binding accepts any CPointer.

Casting a pointer (including COpaquePointer) can be done with .reinterpret<T>, for example:

```
import kotlinx.cinterop.*

@OptIn(ExperimentalForeignApi::class)
val intPtr = bytePtr.reinterpret<IntVar>()
```

Or:

```
import kotlinx.cinterop.*

@OptIn(ExperimentalForeignApi::class)
val intPtr: CPointer<IntVar> = bytePtr.reinterpret()
```

As is with C, these .reinterpret casts are unsafe and can potentially lead to subtle memory problems in the application.

Also, there are unsafe casts between CPointer<T>? and Long available, provided by the .toLong() and .toCPointer<T>() extension methods:

```
val longValue = ptr.toLong()
val originalPtr = longValue.toCPointer<T>()
```

If the type of the result is known from the context, you can omit the type argument thanks to the type inference.

Memory allocation

The native memory can be allocated using the NativePlacement interface, for example:

```
import kotlinx.cinterop.*

@OptIn(ExperimentalForeignApi::class)
val byteVar = placement.alloc<ByteVar>()
```

Or:

```
import kotlinx.cinterop.*

@OptIn(ExperimentalForeignApi::class)
val bytePtr = placement.allocArray<ByteVar>(5)
```

The most logical placement is in the object nativeHeap. It corresponds to allocating native memory with malloc and provides an additional .free() operation to free allocated memory:

```
import kotlinx.cinterop.*

@OptIn(kotlinx.cinterop.ExperimentalForeignApi::class)
fun main() {
    val size: Long = 0
    val buffer = nativeHeap.allocArray<ByteVar>(size)
    nativeHeap.free(buffer)
}
```

nativeHeap requires memory to be freed manually. However, it's often useful to allocate memory with a lifetime bound to the lexical scope. It's helpful if such memory is freed automatically.

To address this, you can use memScoped { }. Inside the braces, the temporary placement is available as an implicit receiver, so it's possible to allocate native memory with alloc and allocArray, and the allocated memory will be automatically freed after leaving the scope.

For example, a C function returning values through pointer parameters can be used like:

```
import kotlinx.cinterop.*
import platform.posix.*

@OptIn(ExperimentalForeignApi::class)
val fileSize = memScoped {
    val statBuf = alloc<stat>()
    val error = stat("/", statBuf.ptr)
    statBuf.st_size
}
```

Pass pointers to bindings

Although C pointers are mapped to the CPointer<T> type, C function pointer-typed parameters are mapped to CValuesRef<T>. When passing a CPointer<T> as a value of such a parameter, it's passed to the C function as is. However, a sequence of values can be passed instead of a pointer. In this case, the sequence is passed "by value", i.e., the C function receives the pointer to the temporary copy of that sequence, which is valid only until the function returns.

The CValuesRef<T> representation of pointer parameters is designed to support C array literals without explicit native memory allocation. To construct the immutable self-contained sequence of C values, the following methods are provided:

- ${type}Array.toCValues(), where type is the Kotlin primitive type
- Array<CPointer<T>?>.toCValues(), List<CPointer<T>?>.toCValues()
- cValuesOf(vararg elements: ${type}), where type is a primitive or pointer

For example:

```
// C:
void foo(int* elements, int count);
...
int elements[] = {1, 2, 3};
foo(elements, 3);
```

```
// Kotlin:

foo(cValuesOf(1, 2, 3), 3)
```

Strings

Unlike other pointers, the parameters of type const char* are represented as a Kotlin String. So it's possible to pass any Kotlin string to a binding expecting a C string.

There are also some tools available to convert between Kotlin and C strings manually:

- fun CPointer<ByteVar>.toKString(): String
- val String.cstr: CValuesRef<ByteVar>.

To get the pointer, .cstr should be allocated in native memory, for example:

```
val cString = kotlinString.cstr.getPointer(nativeHeap)
```

In all cases, the C string is supposed to be encoded as UTF-8.

To skip automatic conversion and ensure raw pointers are used in the bindings, add the noStringConversion property to the .def file:

```
noStringConversion = LoadCursorA LoadCursorW
```

This way, any value of type CPointer<ByteVar> can be passed as an argument of const char* type. If a Kotlin string should be passed, code like this could be used:

```
import kotlinx.cinterop.*

@OptIn(kotlinx.cinterop.ExperimentalForeignApi::class)
memScoped {
    LoadCursorA(null, "cursor.bmp".cstr.ptr)  // for ASCII or UTF-8 version
    LoadCursorW(null, "cursor.bmp".wcstr.ptr) // for UTF-16 version
}
```

Scope-local pointers

It's possible to create a scope-stable pointer of C representation for the CValues<T> instance using the CValues<T>.ptr extension property, available under memScoped {}. It allows using APIs that require C pointers with a lifetime bound to a certain MemScope. For example:

```
import kotlinx.cinterop.*

@OptIn(kotlinx.cinterop.ExperimentalForeignApi::class)
memScoped {
    items = arrayOfNulls<CPointer<ITEM>?>(6)
    arrayOf("one", "two").forEachIndexed { index, value -> items[index] = value.cstr.ptr }
    menu = new_menu("Menu".cstr.ptr, items.toCValues().ptr)
    // ...
}
```

In this example, all values passed to the C API new_menu() have a lifetime of the innermost memScope it belongs to. Once the control flow leaves the memScoped scope, C pointers become invalid.

Pass and receive structs by value

When a C function takes or returns a struct/union T by value, the corresponding argument type or return type is represented as CValue<T>.

CValue<T> is an opaque type, so the structure fields cannot be accessed with the appropriate Kotlin properties. This can be fine if an API uses structures as opaque handles. However, if field access is required, the following conversion methods are available:

- fun T.readValue(): CValue<T> converts (the lvalue) T to a CValue<T>. So to construct the CValue<T>, T can be allocated, filled, and then converted to CValue<T>.
- CValue<T>.useContents(block: T.() -> R): R temporarily stores the CValue<T> in memory, and then runs the passed lambda with this placed value T as receiver. So to read a single field, you can use the following code:

  ```
  val fieldValue = structValue.useContents { field }
  ```

- fun cValue(initialize: T.() -> Unit): CValue<T> applies the provided initialize function to allocate T in memory and converts the result into a CValue<T>.
- fun CValue<T>.copy(modify: T.() -> Unit): CValue<T> creates a modified copy of an existing CValue<T>. The original value is placed in memory, altered using the modify() function, and then converted back into a new CValue<T>.
- fun CValues<T>.placeTo(scope: AutofreeScope): CPointer<T> places the CValues<T> into an AutofreeScope, returning a pointer to the allocated memory. The allocated memory is automatically freed when the AutofreeScope is disposed.

Callbacks

To convert a Kotlin function to a pointer to a C function, you can use staticCFunction(::kotlinFunction). It's also possible to provide a lambda instead of a function reference. The function or lambda must not capture any values.

Pass user data to callbacks

Often C APIs allow passing some user data to callbacks. Such data is usually provided by the user when configuring the callback. It's passed to some C function (or written to the struct) as void*, for example. However, references to Kotlin objects can't be directly passed to C. So they require wrapping before configuring the callback and then unwrapping in the callback itself, to safely swim from Kotlin to Kotlin through the C world. Such wrapping is possible with the StableRef class.

To wrap the reference:

```
import kotlinx.cinterop.*

@OptIn(ExperimentalForeignApi::class)
val stableRef = StableRef.create(kotlinReference)
val voidPtr = stableRef.asCPointer()
```

Here, the voidPtr is a COpaquePointer and can be passed to the C function.

To unwrap the reference:

```
@OptIn(ExperimentalForeignApi::class)
val stableRef = voidPtr.asStableRef<KotlinClass>()
val kotlinReference = stableRef.get()
```

Here, kotlinReference is the original wrapped reference.

The created StableRef eventually be manually disposed using the .dispose() method to prevent memory leaks:

```
stableRef.dispose()
```

After that it becomes invalid, so voidPtr can't be unwrapped anymore.

Macros

Every C macro that expands to a constant is represented as a Kotlin property.

Macros without parameters are supported in cases when the compiler can infer the type:

```
int foo(int);
#define FOO foo(42)
```

In this case, FOO is available in Kotlin.

To support other macros, you can expose them manually by wrapping them with supported declarations. For example, function-like macro FOO can be exposed as a function foo() by adding custom declaration to the library:

```
headers = library/base.h

---

static inline int foo(int arg) {
    return FOO(arg);
}
```

Portability

Sometimes the C libraries have function parameters or struct fields of a platform-dependent type, for example, long or size_t. Kotlin itself doesn't provide either implicit integer casts or C-style integer casts (for example, (size_t) intValue), so to make writing portable code in such cases easier, the convert method is provided:

```
fun ${type1}.convert<${type2}>(): ${type2}
```

Here, each of type1 and type2 must be an integral type, either signed or unsigned.

.convert<${type}> has the same semantics as one of the .toByte, .toShort, .toInt, .toLong, .toUByte, .toUShort, .toUInt or .toULong methods, depending on type.

An example of using convert:

```kotlin
import kotlinx.cinterop.*
import platform.posix.*

@OptIn(ExperimentalForeignApi::class)
fun zeroMemory(buffer: COpaquePointer, size: Int) {
    memset(buffer, 0, size.convert<size_t>())
}
```

Also, the type parameter can be inferred automatically and so may be omitted in some cases.

Object pinning

Kotlin objects could be pinned, i.e. their position in memory is guaranteed to be stable until they are unpinned, and pointers to such objects' inner data could be passed to C functions.

There's a couple of approaches you can take:

- Use the .usePinned() extension function that pins an object, executes a block, and unpins it on normal and exception paths:

  ```kotlin
  import kotlinx.cinterop.*
  import platform.posix.*

  @OptIn(ExperimentalForeignApi::class)
  fun readData(fd: Int) {
      val buffer = ByteArray(1024)
      buffer.usePinned { pinned ->
          while (true) {
              val length = recv(fd, pinned.addressOf(0), buffer.size.convert(), 0).toInt()
              if (length <= 0) {
                  break
              }
              // Now `buffer` has raw data obtained from the `recv()` call.
          }
      }
  }
  ```

  Here, pinned is an object of a special type Pinned<T>. It provides useful extensions like .addressOf(), which allows getting the address of a pinned array body.

- Use the .refTo() extension function that has similar functionality under the hood but, in certain cases, may help you reduce boilerplate code:

  ```kotlin
  import kotlinx.cinterop.*
  import platform.posix.*

  @OptIn(ExperimentalForeignApi::class)
  fun readData(fd: Int) {
      val buffer = ByteArray(1024)
      while (true) {
          val length = recv(fd, buffer.refTo(0), buffer.size.convert(), 0).toInt()

          if (length <= 0) {
              break
          }
          // Now `buffer` has raw data obtained from the `recv()` call.
      }
  }
  ```

  Here, buffer.refTo(0) has the CValuesRef type that pins the array before entering the recv() function, passes the address of its zeroth element to the function, and unpins the array after exiting.

Forward declarations

To import forward declarations, use the cnames package. For example, to import a cstructName forward declaration declared in a C library with a library.package, use a special forward declaration package: import cnames.structs.cstructName.

Consider two cinterop libraries: one that has a forward declaration of a struct and another with an actual implementation in another package:

```c
// First C library
#include <stdio.h>

struct ForwardDeclaredStruct;
```

```
void consumeStruct(struct ForwardDeclaredStruct* s) {
    printf("Struct consumed\n");
}
```

```
// Second C library
// Header:
#include <stdlib.h>

struct ForwardDeclaredStruct {
    int data;
};

// Implementation:
struct ForwardDeclaredStruct* produceStruct() {
    struct ForwardDeclaredStruct* s = malloc(sizeof(struct ForwardDeclaredStruct));
    s->data = 42;
    return s;
}
```

To transfer objects between the two libraries, use an explicit as cast in your Kotlin code:

```
// Kotlin code:
fun test() {
    consumeStruct(produceStruct() as CPointer<cnames.structs.ForwardDeclaredStruct>)
}
```

What's next

Learn how types, functions, and strings are mapped between Kotlin and C by completing the following tutorials:

- Mapping primitive data types from C
- Mapping struct and union types from C
- Mapping function pointers from C
- Mapping strings from C

Mapping primitive data types from C – tutorial

The C libraries import is Experimental. All Kotlin declarations generated by the cinterop tool from C libraries should have the @ExperimentalForeignApi annotation.

Native platform libraries shipped with Kotlin/Native (like Foundation, UIKit, and POSIX) require opt-in only for some APIs.

Let's explore which C data types are visible in Kotlin/Native and vice versa and examine advanced C interop-related use cases of Kotlin/Native and multiplatform Gradle builds.

In this tutorial, you'll:

- Learn about data types in the C language
- Create a C Library that uses those types in exports
- Inspect generated Kotlin APIs from a C library

You can use the command line to generate a Kotlin library, either directly or with a script file (such as .sh or .bat file). However, this approach doesn't scale well for larger projects that have hundreds of files and libraries. Using a build system simplifies the process by downloading and caching the Kotlin/Native compiler binaries and libraries with transitive dependencies, as well as by running the compiler and tests. Kotlin/Native can use the Gradle build system through the Kotlin Multiplatform plugin.

Types in C language

The C programming language has the following data types:

- Basic types: char, int, float, double with modifiers signed, unsigned, short, long
- Structures, unions, arrays
- Pointers
- Function pointers

There are also more specific types:

- Boolean type (from C99)
- size_t and ptrdiff_t (also ssize_t)
- Fixed width integer types, such as int32_t or uint64_t (from C99)

There are also the following type qualifiers in the C language: const, volatile, restrict, atomic.

Let's see which C data types are visible in Kotlin.

Create a C library

In this tutorial, you won't create a lib.c source file, which is only necessary if you want to compile and run your C library. For this setup, you'll only need a .h header file that is required for running the cinterop tool.

The cinterop tool generates a Kotlin/Native library (a .klib file) for each set of .h files. The generated library helps bridge calls from Kotlin/Native to C. It includes Kotlin declarations that correspond to the definitions from the .h files.

To create a C library:

1. Create an empty folder for your future project.
2. Inside, create a lib.h file with the following content to see how C functions are mapped into Kotlin:

   ```
   #ifndef LIB2_H_INCLUDED
   #define LIB2_H_INCLUDED

   void ints(char c, short d, int e, long f);
   void uints(unsigned char c, unsigned short d, unsigned int e, unsigned long f);
   void doubles(float a, double b);

   #endif
   ```

   The file doesn't have the extern "C" block, which is not needed for this example but may be necessary if you use C++ and overloaded functions. See this Stackoverflow thread for more details.
3. Create the lib.def definition file with the following content:

   ```
   headers = lib.h
   ```

4. It can be helpful to include macros or other C definitions in the code generated by the cinterop tool. This way, method bodies are also compiled and fully included in the binary. With this feature, you can create a runnable example without needing a C compiler.

   To do that, add implementations to the C functions from the lib.h file to a new interop.def file after the --- separator:

   ```
   ---

   void ints(char c, short d, int e, long f) { }
   void uints(unsigned char c, unsigned short d, unsigned int e, unsigned long f) { }
   void doubles(float a, double b) { }
   ```

The interop.def file provides everything necessary to compile, run, or open the application in an IDE.

Create a Kotlin/Native project

> See the Get started with Kotlin/Native tutorial for detailed first steps and instructions on how to create a new Kotlin/Native project and open it in IntelliJ IDEA.

To create project files:

1. In your project folder, create a build.gradle(.kts) Gradle build file with the following content:

   Kotlin

```kotlin
plugins {
    kotlin("multiplatform") version "2.2.0"
}

repositories {
    mavenCentral()
}

kotlin {
    macosArm64("native") {    // macOS on Apple Silicon
    // macosX64("native") {   // macOS on x86_64 platforms
    // linuxArm64("native") { // Linux on ARM64 platforms
    // linuxX64("native") {   // Linux on x86_64 platforms
    // mingwX64("native") {   // on Windows
        val main by compilations.getting
        val interop by main.cinterops.creating

        binaries {
            executable()
        }
    }
}

tasks.wrapper {
    gradleVersion = "8.14"
    distributionType = Wrapper.DistributionType.BIN
}
```

   Groovy

```groovy
plugins {
    id 'org.jetbrains.kotlin.multiplatform' version '2.2.0'
}

repositories {
    mavenCentral()
}

kotlin {
    macosArm64("native") {    // Apple Silicon macOS
    // macosX64("native") {   // macOS on x86_64 platforms
    // linuxArm64("native") { // Linux on ARM64 platforms
    // linuxX64("native") {   // Linux on x86_64 platforms
    // mingwX64("native") {   // Windows
        compilations.main.cinterops {
            interop
        }

        binaries {
            executable()
        }
    }
}

wrapper {
    gradleVersion = '8.14'
    distributionType = 'BIN'
}
```

   The project file configures the C interop as an additional build step. Check out the Multiplatform Gradle DSL reference to learn about different ways you can configure it.

2. Move your interop.def, lib.h, and lib.def files to the src/nativeInterop/cinterop directory.

3. Create a src/nativeMain/kotlin directory. This is where you should place all the source files, following Gradle's recommendations on using conventions instead of configurations.

   By default, all the symbols from C are imported to the interop package.

4. In src/nativeMain/kotlin, create a hello.kt stub file with the following content:

```kotlin
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi

@OptIn(ExperimentalForeignApi::class)
fun main() {
    println("Hello Kotlin/Native!")

    ints(/* fix me*/)
    uints(/* fix me*/)
    doubles(/* fix me*/)
}
```

You'll complete the code later as you learn how C primitive type declarations look from the Kotlin side.

Inspect generated Kotlin APIs for a C library

Let's see how C primitive types are mapped into Kotlin/Native and update the example project accordingly.

Use IntelliJ IDEA's Go to declaration command (Cmd + B/Ctrl + B) to navigate to the following generated API for C functions:

```kotlin
fun ints(c: kotlin.Byte, d: kotlin.Short, e: kotlin.Int, f: kotlin.Long)
fun uints(c: kotlin.UByte, d: kotlin.UShort, e: kotlin.UInt, f: kotlin.ULong)
fun doubles(a: kotlin.Float, b: kotlin.Double)
```

C types are mapped directly, except for the char type, which is mapped to kotlin.Byte as it's usually an 8-bit signed value:

C	Kotlin
char	kotlin.Byte
unsigned char	kotlin.UByte
short	kotlin.Short
unsigned short	kotlin.UShort
int	kotlin.Int
unsigned int	kotlin.UInt
long long	kotlin.Long
unsigned long long	kotlin.ULong
float	kotlin.Float

C	Kotlin
double	kotlin.Double

Update Kotlin code

Now that you've seen the C definitions, you can update your Kotlin code. The final code in the hello.kt file may look like this:

```
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi

@OptIn(ExperimentalForeignApi::class)
fun main() {
    println("Hello Kotlin/Native!")

    ints(1, 2, 3, 4)
    uints(5u, 6u, 7u, 8u)
    doubles(9.0f, 10.0)
}
```

To verify that everything works as expected, run the runDebugExecutableNative Gradle task in your IDE or use the following command to run the code:

```
./gradlew runDebugExecutableNative
```

Next step

In the next part of the series, you'll learn how struct and union types are mapped between Kotlin and C:

Proceed to the next part

See also

Learn more in the Interoperability with C documentation that covers more advanced scenarios.

Mapping struct and union types from C – tutorial

The C libraries import is Experimental. All Kotlin declarations generated by the cinterop tool from C libraries should have the @ExperimentalForeignApi annotation.

Native platform libraries shipped with Kotlin/Native (like Foundation, UIKit, and POSIX) require opt-in only for some APIs.

Let's explore which C struct and union declarations are visible from Kotlin and examine advanced C interop-related use cases of Kotlin/Native and multiplatform Gradle builds.

In the tutorial, you'll learn:

- How struct and union types are mapped
- How to use struct and union types from Kotlin

Mapping struct and union C types

To understand how Kotlin maps struct and union types, let's declare them in C and examine how they are represented in Kotlin.

In the previous tutorial, you've already created a C library with the necessary files. For this step, update the declarations in the interop.def file after the --- separator:

```
---

typedef struct {
  int a;
  double b;
} MyStruct;

void struct_by_value(MyStruct s) {}
void struct_by_pointer(MyStruct* s) {}

typedef union {
  int a;
  MyStruct b;
  float c;
} MyUnion;

void union_by_value(MyUnion u) {}
void union_by_pointer(MyUnion* u) {}
```

The interop.def file provides everything necessary to compile, run, or open the application in an IDE.

Inspect generated Kotlin APIs for a C library

Let's see how C struct and union types are mapped into Kotlin/Native and update your project:

1. In src/nativeMain/kotlin, update your hello.kt file from the previous tutorial with the following content:

```kotlin
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi

@OptIn(ExperimentalForeignApi::class)
fun main() {
    println("Hello Kotlin/Native!")

    struct_by_value(/* fix me*/)
    struct_by_pointer(/* fix me*/)
    union_by_value(/* fix me*/)
    union_by_pointer(/* fix me*/)
}
```

2. To avoid compiler errors, add interoperability to the build process. For that, update your build.gradle(.kts) build file with the following content:

Kotlin

```kotlin
kotlin {
    macosArm64("native") {    // macOS on Apple Silicon
    // macosX64("native") {   // macOS on x86_64 platforms
    // linuxArm64("native") { // Linux on ARM64 platforms
    // linuxX64("native") {   // Linux on x86_64 platforms
    // mingwX64("native") {   // on Windows
        val main by compilations.getting
        val interop by main.cinterops.creating {
            definitionFile.set(project.file("src/nativeInterop/cinterop/interop.def"))
        }

        binaries {
            executable()
        }
    }
}
```

Groovy

```groovy
kotlin {
    macosArm64("native") {    // Apple Silicon macOS
    // macosX64("native") {   // macOS on x86_64 platforms
    // linuxArm64("native") { // Linux on ARM64 platforms
    // linuxX64("native") {   // Linux on x86_64 platforms
    // mingwX64("native") {   // Windows
        compilations.main.cinterops {
            interop {
                definitionFile = project.file('src/nativeInterop/cinterop/interop.def')
            }
        }

        binaries {
            executable()
        }
    }
}
```

3. Use IntelliJ IDEA's Go to declaration command (Cmd + B/Ctrl + B) to navigate to the following generated API for C functions, struct, and union:

```
fun struct_by_value(s: kotlinx.cinterop.CValue<interop.MyStruct>)
fun struct_by_pointer(s: kotlinx.cinterop.CValuesRef<interop.MyStruct>?)

fun union_by_value(u: kotlinx.cinterop.CValue<interop.MyUnion>)
fun union_by_pointer(u: kotlinx.cinterop.CValuesRef<interop.MyUnion>?)
```

Technically, there is no difference between struct and union types on the Kotlin side. The cinterop tool generates Kotlin types for both struct and union C declarations.

The generated API includes fully qualified package names for CValue<T> and CValuesRef<T>, reflecting their location in kotlinx.cinterop. CValue<T> represents a by-value structure parameter, while CValuesRef<T>? is used to pass a pointer to a structure or a union.

Use struct and union types from Kotlin

Using C struct and union types from Kotlin is straightforward thanks to the generated API. The only question is how to create new instances of these types.

Let's take a look at the generated functions that take MyStruct and MyUnion as parameters. By-value parameters are represented as kotlinx.cinterop.CValue<T>, while pointer-typed parameters use kotlinx.cinterop.CValuesRef<T>?.

Kotlin provides a convenient API for creating and working with these types. Let's explore how to use it in practice.

Create a CValue<T>

CValue<T> type is used to pass by-value parameters to a C function call. Use the cValue function to create a CValue<T> instance. The function requires a lambda function with a receiver to initialize the underlying C type in-place. The function is declared as follows:

```
fun <reified T : CStructVar> cValue(initialize: T.() -> Unit): CValue<T>
```

Here's how to use cValue and pass by-value parameters:

```
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi
import kotlinx.cinterop.cValue

@OptIn(ExperimentalForeignApi::class)
fun callValue() {

    val cStruct = cValue<MyStruct> {
        a = 42
        b = 3.14
    }
    struct_by_value(cStruct)

    val cUnion = cValue<MyUnion> {
        b.a = 5
        b.b = 2.7182
    }

    union_by_value(cUnion)
}
```

Create struct and union as CValuesRef<T>

The CValuesRef<T> type is used in Kotlin to pass a pointer-typed parameter of a C function. To allocate MyStruct and MyUnion in the native memory, use the following extension function on kotlinx.cinterop.NativePlacement type:

```
fun <reified T : kotlinx.cinterop.CVariable> alloc(): T
```

NativePlacement represents native memory with functions similar to malloc and free. There are several implementations of NativePlacement:

- The global implementation is kotlinx.cinterop.nativeHeap, but you must call nativeHeap.free() to release the memory after use.
- A safer alternative is memScoped(), which creates a short-lived memory scope where all allocations are automatically freed at the end of the block:

  ```
  fun <R> memScoped(block: kotlinx.cinterop.MemScope.() -> R): R
  ```

With memScoped(), your code for calling functions with pointers can look like this:

```
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi
import kotlinx.cinterop.memScoped
import kotlinx.cinterop.alloc
import kotlinx.cinterop.ptr

@OptIn(ExperimentalForeignApi::class)
fun callRef() {
    memScoped {
        val cStruct = alloc<MyStruct>()
        cStruct.a = 42
        cStruct.b = 3.14

        struct_by_pointer(cStruct.ptr)

        val cUnion = alloc<MyUnion>()
        cUnion.b.a = 5
        cUnion.b.b = 2.7182

        union_by_pointer(cUnion.ptr)
    }
}
```

Here, the ptr extension property, which is available within the memScoped {} block, converts MyStruct and MyUnion instances into native pointers.

Since memory is managed inside the memScoped {} block, it's automatically freed at the end of the block. Avoid using pointers outside of this scope to prevent accessing deallocated memory. If you need longer-lived allocations (for example, for caching in a C library), consider using Arena() or nativeHeap.

Conversion between CValue<T> and CValuesRef<T>

Sometimes you need to pass a struct as a value in one function call and then pass the same struct as a reference in another.

To do this, you'll need a NativePlacement, but first, let's see how CValue<T> is turned into a pointer:

```
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi
import kotlinx.cinterop.cValue
import kotlinx.cinterop.memScoped

@OptIn(ExperimentalForeignApi::class)
fun callMix_ref() {
    val cStruct = cValue<MyStruct> {
        a = 42
        b = 3.14
    }

    memScoped {
        struct_by_pointer(cStruct.ptr)
    }
}
```

Here again, the ptr extension property from memScoped {} turns MyStruct instances into native pointers. These pointers are only valid inside the memScoped {} block.

To turn a pointer back into a by-value variable, call the .readValue() extension function:

```kotlin
import interop.*
import kotlinx.cinterop.alloc
import kotlinx.cinterop.ExperimentalForeignApi
import kotlinx.cinterop.memScoped
import kotlinx.cinterop.readValue

@OptIn(ExperimentalForeignApi::class)
fun callMix_value() {
    memScoped {
        val cStruct = alloc<MyStruct>()
        cStruct.a = 42
        cStruct.b = 3.14

        struct_by_value(cStruct.readValue())
    }
}
```

Update Kotlin code

Now that you've learned how to use C declarations in Kotlin code, try to use them in your project. The final code in the hello.kt file may look like this:

```kotlin
import interop.*
import kotlinx.cinterop.alloc
import kotlinx.cinterop.cValue
import kotlinx.cinterop.memScoped
import kotlinx.cinterop.ptr
import kotlinx.cinterop.readValue
import kotlinx.cinterop.ExperimentalForeignApi

@OptIn(ExperimentalForeignApi::class)
fun main() {
    println("Hello Kotlin/Native!")

    val cUnion = cValue<MyUnion> {
        b.a = 5
        b.b = 2.7182
    }

    memScoped {
        union_by_value(cUnion)
        union_by_pointer(cUnion.ptr)
    }

    memScoped {
        val cStruct = alloc<MyStruct> {
            a = 42
            b = 3.14
        }

        struct_by_value(cStruct.readValue())
        struct_by_pointer(cStruct.ptr)
    }
}
```

To verify that everything works as expected, run the runDebugExecutableNative Gradle task in your IDE or use the following command to run the code:

```
./gradlew runDebugExecutableNative
```

Next step

In the next part of the series, you'll learn how function pointers are mapped between Kotlin and C:

Proceed to the next part

See also

Learn more in the Interoperability with C documentation that covers more advanced scenarios.

Mapping function pointers from C – tutorial

The C libraries import is Experimental. All Kotlin declarations generated by the cinterop tool from C libraries should have the @ExperimentalForeignApi annotation.

Native platform libraries shipped with Kotlin/Native (like Foundation, UIKit, and POSIX) require opt-in only for some APIs.

Let's explore which C function pointers are visible from Kotlin and examine advanced C interop-related use cases of Kotlin/Native and multiplatform Gradle builds.

In this tutorial, you'll:

- Learn how to pass Kotlin function as a C function pointer
- Use C function pointers from Kotlin

Mapping function pointer types from C

To understand the mapping between Kotlin and C, let's declare two functions: one that accepts a function pointer as a parameter and another that returns a function pointer.

In the first part of the series of the series, you've already created a C library with the necessary files. For this step, update the declarations in the interop.def file after the --- separator:

```
---

int myFun(int i) {
  return i+1;
}

typedef int  (*MyFun)(int);

void accept_fun(MyFun f) {
  f(42);
}

MyFun supply_fun() {
  return myFun;
}
```

The interop.def file provides everything necessary to compile, run, or open the application in an IDE.

Inspect generated Kotlin APIs for a C library

Let's see how C function pointers are mapped into Kotlin/Native and update your project:

1. In src/nativeMain/kotlin, update your hello.kt file from the previous tutorial with the following content:

```
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi

@OptIn(ExperimentalForeignApi::class)
fun main() {
    println("Hello Kotlin/Native!")

    accept_fun(/* fix me*/)
    val useMe = supply_fun()
}
```

2. Use IntelliJ IDEA's Go to declaration command (Cmd + B/Ctrl + B) to navigate to the following generated API for C functions:

```
fun myFun(i: kotlin.Int): kotlin.Int
fun accept_fun(f: kotlinx.cinterop.CPointer<kotlinx.cinterop.CFunction<(kotlin.Int) -> kotlin.Int>>? /* from: interop.MyFun? */)
fun supply_fun(): kotlinx.cinterop.CPointer<kotlinx.cinterop.CFunction<(kotlin.Int) -> kotlin.Int>>? /* from: interop.MyFun? */
```

As you can see, C function pointers are represented in Kotlin using CPointer<CFunction<...>>. The accept_fun() function takes an optional function pointer as a parameter, while supply_fun() returns a function pointer.

CFunction<(Int) -> Int> represents the function signature, and CPointer<CFunction<...>>? represents a nullable function pointer. There is an .invoke() operator extension function available for all CPointer<CFunction<...>> types, allowing you to call function pointers as if they were regular Kotlin functions.

Pass Kotlin function as a C function pointer

It's time to try using C functions from Kotlin code. Call the accept_fun() function and pass the C function pointer to a Kotlin lambda:

```
import interop.*
import kotlinx.cinterop.staticCFunction
import kotlinx.cinterop.ExperimentalForeignApi

@OptIn(ExperimentalForeignApi::class)
fun myFun() {
    accept_fun(staticCFunction<Int, Int> { it + 1 })
}
```

This call uses the staticCFunction {} helper function from Kotlin/Native to wrap a Kotlin lambda function into a C function pointer. It allows only unbound and non-capturing lambda functions. For example, it cannot capture a local variable from the function, only globally visible declarations.

Ensure that the function doesn't throw any exceptions. Throwing exceptions from a staticCFunction {} causes non-deterministic side effects.

Use the C function pointer from Kotlin

The next step is to invoke a C function pointer returned from the supply_fun() call:

```
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi
import kotlinx.cinterop.invoke

@OptIn(ExperimentalForeignApi::class)
fun myFun2() {
    val functionFromC = supply_fun() ?: error("No function is returned")

    functionFromC(42)
}
```

Kotlin turns the function pointer return type into a nullable CPointer<CFunction<> object. You need to first explicitly check for null, which is why the Elvis operator is used in the code above. The cinterop tool allows you to call a C function pointer as a regular Kotlin function call: functionFromC(42).

Update Kotlin code

Now that you've seen all the definitions, try to use them in your project. The code in the hello.kt file may look like this:

```
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi
import kotlinx.cinterop.invoke
import kotlinx.cinterop.staticCFunction

@OptIn(ExperimentalForeignApi::class)
fun main() {
    println("Hello Kotlin/Native!")

    val cFunctionPointer = staticCFunction<Int, Int> { it + 1 }
    accept_fun(cFunctionPointer)

    val funFromC = supply_fun() ?: error("No function is returned")
    funFromC(42)
}
```

To verify that everything works as expected, run the runDebugExecutableNative Gradle task in your IDE or use the following command to run the code:

```
./gradlew runDebugExecutableNative
```

Next step

In the next part of the series, you'll learn how strings are mapped between Kotlin and C:

Proceed to the next part

See also

Learn more in the Interoperability with C documentation that covers more advanced scenarios.

Mapping strings from C – tutorial

The C libraries import is Experimental. All Kotlin declarations generated by the cinterop tool from C libraries should have the @ExperimentalForeignApi annotation.

Native platform libraries shipped with Kotlin/Native (like Foundation, UIKit, and POSIX) require opt-in only for some APIs.

In the final part of the series, let's see how to deal with C strings in Kotlin/Native.

In this tutorial, you'll learn how to:

- Pass a Kotlin string to C
- Read a C string in Kotlin
- Receive C string bytes into a Kotlin string

Working with C strings

C doesn't have a dedicated string type. Method signatures or documentation can help you identify whether a given char * represents a C string in a particular context.

Strings in the C language are null-terminated, so a trailing zero character \0 is added to the end of a byte sequence to mark the end of a string. Usually, UTF-8 encoded strings are used. The UTF-8 encoding uses variable-width characters and is backward-compatible with ASCII. Kotlin/Native uses UTF-8 character encoding by default.

To understand how strings are mapped between Kotlin and C, first create the library headers. In the first part of the series, you've already created a C library with the necessary files. For this step:

1. Update your lib.h file with the following function declarations that work with C strings:

   ```
   #ifndef LIB2_H_INCLUDED
   #define LIB2_H_INCLUDED

   void pass_string(char* str);
   char* return_string();
   int copy_string(char* str, int size);

   #endif
   ```

   This example shows common ways to pass or receive a string in the C language. Handle the return value of the return_string() function carefully. Ensure you use the correct free() function to release the returned char*.

2. Update the declarations in the interop.def file after the --- separator:

   ```
   ---

   void pass_string(char* str) {
   }

   char* return_string() {
     return "C string";
   }
   ```

```
int copy_string(char* str, int size) {
    *str++ = 'C';
    *str++ = ' ';
    *str++ = 'K';
    *str++ = '/';
    *str++ = 'N';
    *str++ = 0;
    return 0;
}
```

The interop.def file provides everything necessary to compile, run, or open the application in an IDE.

Inspect generated Kotlin APIs for a C library

Let's see how C string declarations are mapped into Kotlin/Native:

1. In src/nativeMain/kotlin, update your hello.kt file from the previous tutorial with the following content:

```
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi

@OptIn(ExperimentalForeignApi::class)
fun main() {
    println("Hello Kotlin/Native!")

    pass_string(/*fix me*/)
    val useMe = return_string()
    val useMe2 = copy_string(/*fix me*/)
}
```

2. Use IntelliJ IDEA's Go to declaration command (Cmd + B/Ctrl + B) to navigate to the following generated API for C functions:

```
fun pass_string(str: kotlinx.cinterop.CValuesRef<kotlinx.cinterop.ByteVarOf<kotlin.Byte> /* from: kotlinx.cinterop.ByteVar */>?)
fun return_string(): kotlinx.cinterop.CPointer<kotlinx.cinterop.ByteVarOf<kotlin.Byte> /* from: kotlinx.cinterop.ByteVar */>?
fun copy_string(str: kotlinx.cinterop.CValuesRef<kotlinx.cinterop.ByteVarOf<kotlin.Byte> /* from: kotlinx.cinterop.ByteVar */>?,
size: kotlin.Int): kotlin.Int
```

These declarations are straightforward. In Kotlin, C char * pointers are mapped into str: CValuesRef<ByteVarOf>? for parameters and into CPointer<ByteVarOf>? for return types. Kotlin represents the char type as kotlin.Byte, as it's usually an 8-bit signed value.

In the generated Kotlin declarations, str is defined as CValuesRef<ByteVarOf<Byte>>?. Since this type is nullable, you can pass null as the argument value.

Pass Kotlin strings to C

Let's try to use the API from Kotlin. Call the pass_string() function first:

```
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi
import kotlinx.cinterop.cstr

@OptIn(ExperimentalForeignApi::class)
fun passStringToC() {
    val str = "This is a Kotlin string"
    pass_string(str.cstr)
}
```

Passing a Kotlin string to C is straightforward, thanks to the String.cstr extension property. There is also the String.wcstr property for cases that involve UTF-16 characters.

Read C strings in Kotlin

Now take a returned char * from the return_string() function and turn it into a Kotlin string:

```
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi
import kotlinx.cinterop.toKString

@OptIn(ExperimentalForeignApi::class)
fun passStringToC() {
    val stringFromC = return_string()?.toKString()

    println("Returned from C: $stringFromC")
}
```

Here, the .toKString() extension function converts a C string returned from the return_string() function into a Kotlin string.

Kotlin provides several extension functions for converting C char * strings into Kotlin strings, depending on the encoding:

```
fun CPointer<ByteVarOf<Byte>>.toKString(): String // Standard function for UTF-8 strings
fun CPointer<ByteVarOf<Byte>>.toKStringFromUtf8(): String // Explicitly converts UTF-8 strings
fun CPointer<ShortVarOf<Short>>.toKStringFromUtf16(): String // Converts UTF-16 encoded strings
fun CPointer<IntVarOf<Int>>.toKStringFromUtf32(): String // Converts UTF-32 encoded strings
```

Receive C string bytes from Kotlin

This time, use the copy_string() C function to write a C string to a given buffer. It takes two arguments: a pointer to the memory location where the string should be written and the allowed buffer size.

The function should also return something to indicate if it has succeeded or failed. Let's assume 0 means it succeeded, and the supplied buffer was big enough:

```
import interop.*
import kotlinx.cinterop.ExperimentalForeignApi
import kotlinx.cinterop.addressOf
import kotlinx.cinterop.usePinned

@OptIn(ExperimentalForeignApi::class)
fun sendString() {
    val buf = ByteArray(255)
    buf.usePinned { pinned ->
        if (copy_string(pinned.addressOf(0), buf.size - 1) != 0) {
            throw Error("Failed to read string from C")
        }
    }

    val copiedStringFromC = buf.decodeToString()
    println("Message from C: $copiedStringFromC")
}
```

Here, a native pointer is passed to the C function first. The .usePinned() extension function temporarily pins the native memory address of the byte array. The C function fills in the byte array with data. Another extension function, ByteArray.decodeToString(), turns the byte array into a Kotlin string, assuming UTF-8 encoding.

Update Kotlin code

Now that you've learned how to use C declarations in Kotlin code, try to use them in your project. The code in the final hello.kt file may look like this:

```
import interop.*
import kotlinx.cinterop.*

@OptIn(ExperimentalForeignApi::class)
fun main() {
    println("Hello Kotlin/Native!")

    val str = "This is a Kotlin string"
    pass_string(str.cstr)

    val useMe = return_string()?.toKString() ?: error("null pointer returned")
    println(useMe)

    val copyFromC = ByteArray(255).usePinned { pinned ->
        val useMe2 = copy_string(pinned.addressOf(0), pinned.get().size - 1)
        if (useMe2 != 0) throw Error("Failed to read a string from C")
        pinned.get().decodeToString()
    }

    println(copyFromC)
}
```

To verify that everything works as expected, run the runDebugExecutableNative Gradle task in your IDE or use the following command to run the code:

```
./gradlew runDebugExecutableNative
```

What's next

Learn more in the Interoperability with C documentation that covers more advanced scenarios.

Kotlin/Native as a dynamic library – tutorial

You can create dynamic libraries to use Kotlin code from existing programs. This enables code sharing across many platforms or languages, including JVM, Python, Android, and others.

> For iOS and other Apple targets, we recommend generating a framework. See the Kotlin/Native as an Apple framework tutorial.

You can use the Kotlin/Native code from existing native applications or libraries. For this, you need to compile the Kotlin code into a dynamic library in the .so, .dylib, or .dll format.

In this tutorial, you will:

- Compile Kotlin code to a dynamic library
- Examine generated C headers
- Use the Kotlin dynamic library from C
- Compile and run the project

You can use the command line to generate a Kotlin library, either directly or with a script file (such as .sh or .bat file). However, this approach doesn't scale well for larger projects that have hundreds of files and libraries. Using a build system simplifies the process by downloading and caching the Kotlin/Native compiler binaries and libraries with transitive dependencies, as well as by running the compiler and tests. Kotlin/Native can use the Gradle build system through the Kotlin Multiplatform plugin.

Let's examine the advanced C interop-related usages of Kotlin/Native and Kotlin Multiplatform builds with Gradle.

> If you use a Mac and want to create and run applications for macOS or other Apple targets, you also need to install the Xcode Command Line Tools, launch it, and accept the license terms first.

Create a Kotlin library

The Kotlin/Native compiler can produce a dynamic library from the Kotlin code. A dynamic library often comes with a .h header file, which you use to call the compiled code from C.

Let's create a Kotlin library and use it from a C program.

> See the Get started with Kotlin/Native tutorial for detailed first steps and instructions on how to create a new Kotlin/Native project and open it in IntelliJ IDEA.

1. Navigate to the src/nativeMain/kotlin directory and create the lib.kt file with the following library contents:

   ```
   package example

   object Object {
       val field = "A"
   ```

```
}

class Clazz {
    fun memberFunction(p: Int): ULong = 42UL
}

fun forIntegers(b: Byte, s: Short, i: UInt, l: Long) { }
fun forFloats(f: Float, d: Double) { }

fun strings(str: String) : String? {
    return "That is '$str' from C"
}

val globalString = "A global String"
```

2. Update your build.gradle(.kts) Gradle build file with the following:

Kotlin

```kotlin
plugins {
    kotlin("multiplatform") version "2.2.0"
}

repositories {
    mavenCentral()
}

kotlin {
    macosArm64("native") {    // macOS on Apple Silicon
    // macosX64("native") {   // macOS on x86_64 platforms
    // linuxArm64("native") { // Linux on ARM64 platforms
    // linuxX64("native") {   // Linux on x86_64 platforms
    // mingwX64("native") {   // Windows
        binaries {
            sharedLib {
                baseName = "native"       // macOS and Linux
                // baseName = "libnative" // Windows
            }
        }
    }
}

tasks.wrapper {
    gradleVersion = "8.14"
    distributionType = Wrapper.DistributionType.ALL
}
```

Groovy

```groovy
plugins {
    id 'org.jetbrains.kotlin.multiplatform' version '2.2.0'
}

repositories {
    mavenCentral()
}

kotlin {
    macosArm64("native") {    // Apple Silicon macOS
    // macosX64("native") {   // macOS on x86_64 platforms
    // linuxArm64("native") { // Linux on ARM64 platforms
    // linuxX64("native") {   // Linux on x86_64 platforms
    // mingwX64("native") {   // Windows
        binaries {
            sharedLib {
                baseName = "native"       // macOS and Linux
                // baseName = "libnative" // Windows
            }
        }
    }
}

wrapper {
    gradleVersion = "8.14"
    distributionType = "ALL"
}
```

- The binaries {} block configures the project to generate a dynamic or shared library.
- libnative is used as the library name, the prefix for the generated header file name. It also prefixes all declarations in the header file.

3. Run the linkDebugSharedNative Gradle task in the IDE or use the following console command in your terminal to build the library:

```
./gradlew linkDebugSharedNative
```

The build generates the library into the build/bin/native/debugShared directory with the following files:

- macOS: libnative_api.h and libnative.dylib
- Linux: libnative_api.h and libnative.so
- Windows: libnative_api.h, libnative.def, and libnative.dll

> You can also use the linkNative Gradle task to generate both debug and release variants of the library.

The Kotlin/Native compiler uses the same rules to generate the .h file for all platforms. Let's check out the C API of the Kotlin library.

Generated header file

Let's examine how Kotlin/Native declarations are mapped to C functions.

In the build/bin/native/debugShared directory, open the libnative_api.h header file. The very first part contains the standard C/C++ header and footer:

```
#ifndef KONAN_LIBNATIVE_H
#define KONAN_LIBNATIVE_H
#ifdef __cplusplus
extern "C" {
#endif

/// The rest of the generated code

#ifdef __cplusplus
}  /* extern "C" */
#endif
#endif  /* KONAN_LIBNATIVE_H */
```

Following this, the libnative_api.h includes a block with the common type definitions:

```
#ifdef __cplusplus
typedef bool            libnative_KBoolean;
#else
typedef _Bool           libnative_KBoolean;
#endif
typedef unsigned short     libnative_KChar;
typedef signed char        libnative_KByte;
typedef short              libnative_KShort;
typedef int                libnative_KInt;
typedef long long          libnative_KLong;
typedef unsigned char      libnative_KUByte;
typedef unsigned short     libnative_KUShort;
typedef unsigned int       libnative_KUInt;
typedef unsigned long long libnative_KULong;
typedef float              libnative_KFloat;
typedef double             libnative_KDouble;
typedef float __attribute__ ((__vector_size__ (16))) libnative_KVector128;
typedef void*              libnative_KNativePtr;
```

Kotlin uses the libnative_ prefix for all declarations in the created libnative_api.h file. Here's the complete list of type mappings:

Kotlin definition	C type

Kotlin definition	C type
libnative_KBoolean	bool or _Bool
libnative_KChar	unsigned short
libnative_KByte	signed char
libnative_KShort	short
libnative_KInt	int
libnative_KLong	long long
libnative_KUByte	unsigned char
libnative_KUShort	unsigned short
libnative_KUInt	unsigned int
libnative_KULong	unsigned long long
libnative_KFloat	float
libnative_KDouble	double
libnative_KVector128	float __attribute__ ((__vector_size__ (16))
libnative_KNativePtr	void*

The definition section of the libnative_api.h file shows how Kotlin primitive types are mapped to C primitive types. The Kotlin/Native compiler generates these entries automatically for every library. The reverse mapping is described in the Mapping primitive data types from C tutorial.

After the automatically generated type definitions, you'll find the separate type definitions used in your library:

```
struct libnative_KType;
typedef struct libnative_KType libnative_KType;

/// Automatically generated type definitions

typedef struct {
  libnative_KNativePtr pinned;
} libnative_kref_example_Object;
typedef struct {
  libnative_KNativePtr pinned;
} libnative_kref_example_Clazz;
```

In C, the typedef struct { ... } TYPE_NAME syntax declares the structure.

See this StackOverflow thread for more explanations of this pattern.

As you can see from these definitions, Kotlin types are mapped using the same pattern: Object is mapped to libnative_kref_example_Object, and Clazz is mapped to libnative_kref_example_Clazz. All structs contain nothing but the pinned field with a pointer. The field type libnative_KNativePtr is defined as void* earlier in the file.

Since C doesn't support namespaces, the Kotlin/Native compiler generates long names to avoid any possible clashes with other symbols in the existing native project.

Service runtime functions

The libnative_ExportedSymbols structure defines all the functions provided by Kotlin/Native and your library. It uses nested anonymous structures heavily to mimic packages. The libnative_ prefix comes from the library name.

libnative_ExportedSymbols includes several helper functions in the header file:

```
typedef struct {
  /* Service functions. */
  void (*DisposeStablePointer)(libnative_KNativePtr ptr);
  void (*DisposeString)(const char* string);
```

These functions deal with Kotlin/Native objects. DisposeStablePointer is called to release a reference to a Kotlin object, and DisposeString is called to release a Kotlin string, which has the char* type in C.

The next part of the libnative_api.h file consists of structure declarations of runtime functions:

```
libnative_KBoolean (*IsInstance)(libnative_KNativePtr ref, const libnative_KType* type);
libnative_KBoolean (*IsInstance)(libnative_KNativePtr ref, const libnative_KType* type);
libnative_kref_kotlin_Byte (*createNullableByte)(libnative_KByte);
libnative_KByte (*getNonNullValueOfByte)(libnative_kref_kotlin_Byte);
libnative_kref_kotlin_Short (*createNullableShort)(libnative_KShort);
libnative_KShort (*getNonNullValueOfShort)(libnative_kref_kotlin_Short);
libnative_kref_kotlin_Int (*createNullableInt)(libnative_KInt);
libnative_KInt (*getNonNullValueOfInt)(libnative_kref_kotlin_Int);
libnative_kref_kotlin_Long (*createNullableLong)(libnative_KLong);
libnative_KLong (*getNonNullValueOfLong)(libnative_kref_kotlin_Long);
libnative_kref_kotlin_Float (*createNullableFloat)(libnative_KFloat);
libnative_KFloat (*getNonNullValueOfFloat)(libnative_kref_kotlin_Float);
libnative_kref_kotlin_Double (*createNullableDouble)(libnative_KDouble);
libnative_KDouble (*getNonNullValueOfDouble)(libnative_kref_kotlin_Double);
libnative_kref_kotlin_Char (*createNullableChar)(libnative_KChar);
libnative_KChar (*getNonNullValueOfChar)(libnative_kref_kotlin_Char);
libnative_kref_kotlin_Boolean (*createNullableBoolean)(libnative_KBoolean);
libnative_KBoolean (*getNonNullValueOfBoolean)(libnative_kref_kotlin_Boolean);
libnative_kref_kotlin_Unit (*createNullableUnit)(void);
libnative_kref_kotlin_UByte (*createNullableUByte)(libnative_KUByte);
libnative_KUByte (*getNonNullValueOfUByte)(libnative_kref_kotlin_UByte);
libnative_kref_kotlin_UShort (*createNullableUShort)(libnative_KUShort);
libnative_KUShort (*getNonNullValueOfUShort)(libnative_kref_kotlin_UShort);
libnative_kref_kotlin_UInt (*createNullableUInt)(libnative_KUInt);
libnative_KUInt (*getNonNullValueOfUInt)(libnative_kref_kotlin_UInt);
libnative_kref_kotlin_ULong (*createNullableULong)(libnative_KULong);
libnative_KULong (*getNonNullValueOfULong)(libnative_kref_kotlin_ULong);
```

You can use the IsInstance function to check if a Kotlin object (referenced with its .pinned pointer) is an instance of a type. The actual set of operations generated depends on actual usages.

Kotlin/Native has its own garbage collector, but it doesn't manage Kotlin objects accessed from C. However, Kotlin/Native provides interoperability with Swift/Objective-C, and the garbage collector is integrated with Swift/Objective-C ARC.

Your library functions

Let's take a look at the separate structure declarations used in your library. The libnative_kref_example field mimics the package structure of your Kotlin code with a libnative_kref. prefix:

```
typedef struct {
  /* User functions. */
  struct {
    struct {
      struct {
        struct {
          libnative_KType* (*_type)(void);
          libnative_kref_example_Object (*_instance)();
          const char* (*get_field)(libnative_kref_example_Object thiz);
        } Object;
        struct {
          libnative_KType* (*_type)(void);
          libnative_kref_example_Clazz (*Clazz)();
          libnative_KULong (*memberFunction)(libnative_kref_example_Clazz thiz, libnative_KInt p);
        } Clazz;
        const char* (*get_globalString)();
        void (*forFloats)(libnative_KFloat f, libnative_KDouble d);
        void (*forIntegers)(libnative_KByte b, libnative_KShort s, libnative_KUInt i, libnative_KLong l);
        const char* (*strings)(const char* str);
      } example;
    } root;
  } kotlin;
} libnative_ExportedSymbols;
```

The code uses anonymous structure declarations. Here, struct { ... } foo declares a field in the outer struct of the anonymous structure type, which has no name.

Since C doesn't support objects either, function pointers are used to mimic object semantics. A function pointer is declared as RETURN_TYPE (* FIELD_NAME)(PARAMETERS).

The libnative_kref_example_Clazz field represents the Clazz from Kotlin. The libnative_KULong is accessible with the memberFunction field. The only difference is that the memberFunction accepts a thiz reference as the first parameter. Since C doesn't support objects, the thiz pointer is passed explicitly.

There is a constructor in the Clazz field (aka libnative_kref_example_Clazz_Clazz), which acts as the constructor function to create an instance of the Clazz.

The Kotlin object Object is accessible as libnative_kref_example_Object. The _instance function retrieves the only instance of the object.

Properties are translated into functions. The get_ and set_ prefixes name the getter and the setter functions, respectively. For example, the read-only property globalString from Kotlin is turned into a get_globalString function in C.

Global functions forFloats, forIntegers, and strings are turned into functions pointers in the libnative_kref_example anonymous struct.

Entry point

Now you know how the API is created, the initialization of the libnative_ExportedSymbols structure is the starting point. Let's then take a look at the final part of the libnative_api.h:

```
extern libnative_ExportedSymbols* libnative_symbols(void);
```

The libnative_symbols function allows you to open the gateway from the native code to the Kotlin/Native library. This is the entry point for accessing the library. The library name is used as a prefix for the function name.

> It might be necessary to host the returned libnative_ExportedSymbols* pointer per thread.

Use generated headers from C

Using the generated headers from C is straightforward. In the library directory, create the main.c file with the following code:

```
#include "libnative_api.h"
#include "stdio.h"

int main(int argc, char** argv) {
  // Obtain reference for calling Kotlin/Native functions
  libnative_ExportedSymbols* lib = libnative_symbols();

  lib->kotlin.root.example.forIntegers(1, 2, 3, 4);
  lib->kotlin.root.example.forFloats(1.0f, 2.0);

  // Use C and Kotlin/Native strings
```

```
    const char* str = "Hello from Native!";
    const char* response = lib->kotlin.root.example.strings(str);
    printf("in: %s\nout:%s\n", str, response);
    lib->DisposeString(response);

    // Create Kotlin object instance
    libnative_kref_example_Clazz newInstance = lib->kotlin.root.example.Clazz.Clazz();
    long x = lib->kotlin.root.example.Clazz.memberFunction(newInstance, 42);
    lib->DisposeStablePointer(newInstance.pinned);

    printf("DemoClazz returned %ld\n", x);

    return 0;
  }
```

Compile and run the project

On macOS

To compile the C code and link it with the dynamic library, navigate to the library directory and run the following command:

```
clang main.c libnative.dylib
```

The compiler generates an executable called a.out. Run it to execute the Kotlin code from the C library.

On Linux

To compile the C code and link it with the dynamic library, navigate to the library directory and run the following command:

```
gcc main.c libnative.so
```

The compiler generates an executable called a.out. Run it to execute the Kotlin code from the C library. On Linux, you need to include . into the LD_LIBRARY_PATH to let the application know to load the libnative.so library from the current folder.

On Windows

First, you'll need to install a Microsoft Visual C++ compiler that supports the x64_64 target.

The easiest way to do this is to install Microsoft Visual Studio on a Windows machine. During installation, select the necessary components to work with C++, for example, Desktop development with C++.

On Windows, you can include dynamic libraries either by generating a static library wrapper or manually with the LoadLibrary or similar Win32API functions.

Let's use the first option and generate the static wrapper library for the libnative.dll:

1. Call lib.exe from the toolchain to generate the static library wrapper libnative.lib that automates the DLL usage from the code:

   ```
   lib /def:libnative.def /out:libnative.lib
   ```

2. Compile your main.c into an executable. Include the generated libnative.lib into the build command and start:

   ```
   cl.exe main.c libnative.lib
   ```

   The command produces the main.exe file, which you can run.

What's next

- Learn more about interoperability with Swift/Objective-C
- Check out the Kotlin/Native as an Apple framework tutorial

Create an app using C interop and libcurl – tutorial

This tutorial demonstrates how to use IntelliJ IDEA to create a command-line application. You'll learn how to create a simple HTTP client that can run natively on specified platforms using Kotlin/Native and the libcurl library.

The output will be an executable command-line app that you can run on macOS and Linux and make simple HTTP GET requests.

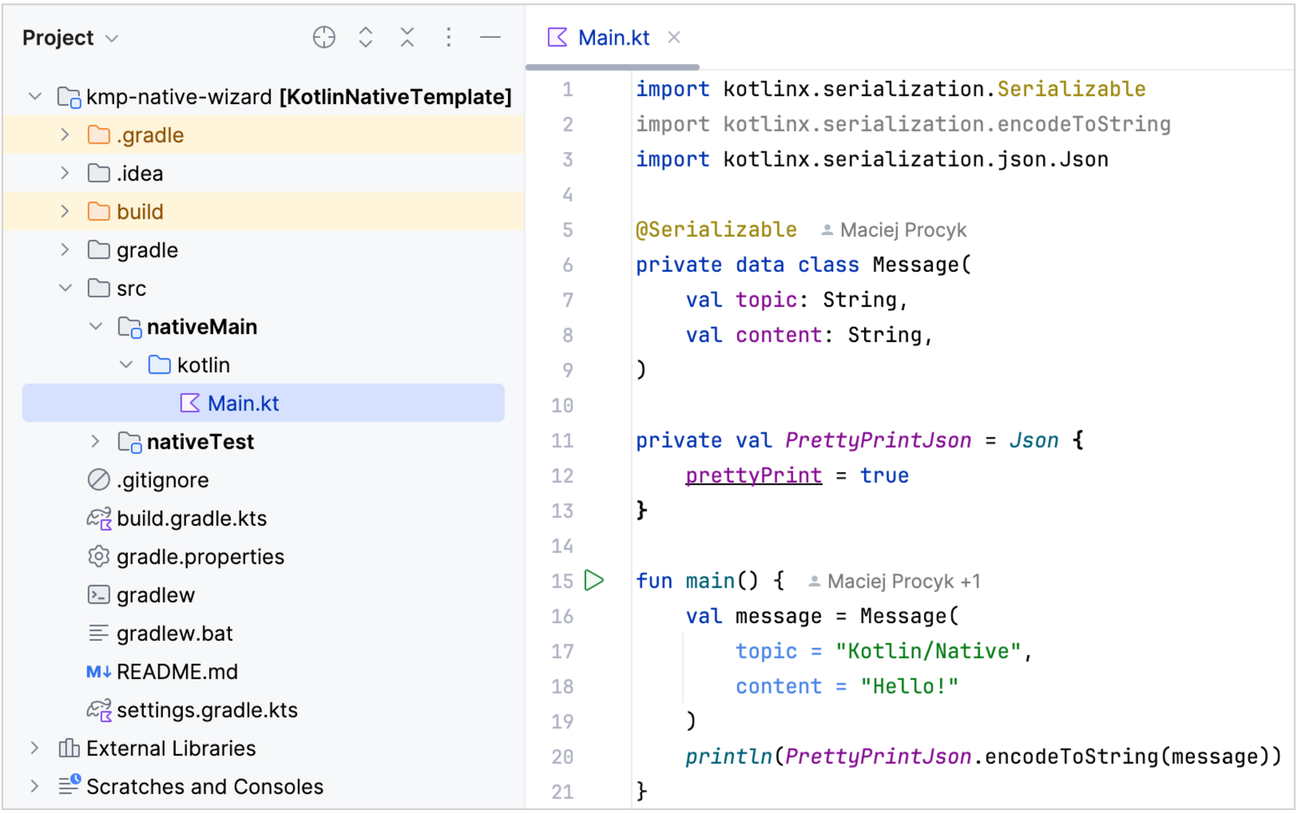
You can use the command line to generate a Kotlin library, either directly or with a script file (such as .sh or .bat file). However, this approach doesn't scale well for larger projects that have hundreds of files and libraries. Using a build system simplifies the process by downloading and caching the Kotlin/Native compiler binaries and libraries with transitive dependencies, as well as by running the compiler and tests. Kotlin/Native can use the Gradle build system through the Kotlin Multiplatform plugin.

Before you start

1. Download and install the latest version of IntelliJ IDEA.
2. Clone the project template by selecting File | New | Project from Version Control in IntelliJ IDEA and using this URL:

```
https://github.com/Kotlin/kmp-native-wizard
```

3. Explore the project structure:



```kotlin
import kotlinx.serialization.Serializable
import kotlinx.serialization.encodeToString
import kotlinx.serialization.json.Json

@Serializable
private data class Message(
    val topic: String,
    val content: String,
)

private val PrettyPrintJson = Json {
    prettyPrint = true
}

fun main() {
    val message = Message(
        topic = "Kotlin/Native",
        content = "Hello!"
    )
    println(PrettyPrintJson.encodeToString(message))
}
```

Native application project structure

The template includes a project with the files and folders you need to get started. It's important to understand that an application written in Kotlin/Native can target different platforms if the code does not have platform-specific requirements. Your code is placed in the nativeMain directory with a corresponding nativeTest. For this tutorial, keep the folder structure as is.

4. Open the build.gradle.kts file, the build script that contains the project settings. Pay special attention to the following in the build file:

```kotlin
kotlin {
    val hostOs = System.getProperty("os.name")
    val isArm64 = System.getProperty("os.arch") == "aarch64"
    val isMingwX64 = hostOs.startsWith("Windows")
    val nativeTarget = when {
        hostOs == "Mac OS X" && isArm64 -> macosArm64("native")
        hostOs == "Mac OS X" && !isArm64 -> macosX64("native")
        hostOs == "Linux" && isArm64 -> linuxArm64("native")
        hostOs == "Linux" && !isArm64 -> linuxX64("native")
        isMingwX64 -> mingwX64("native")
        else -> throw GradleException("Host OS is not supported in Kotlin/Native.")
    }

    nativeTarget.apply {
        binaries {
            executable {
                entryPoint = "main"
            }
        }
    }
}
```

- Targets are defined using macosArm64, macosX64, linuxArm64, linuxX64, and mingwX64 for macOS, Linux, and Windows. See the complete list of supported platforms.
- The binaries {} block defines how the binary is generated and the entry point of the application. These can be left as default values.
- C interoperability is configured as an additional step in the build. By default, all the symbols from C are imported to the interop package. You may want to import the whole package in .kt files. Learn more about how to configure it.

Create a definition file

When writing native applications, you often need access to certain functionalities that are not included in the Kotlin standard library, such as making HTTP requests, reading and writing from disk, and so on.

Kotlin/Native helps consume standard C libraries, opening up an entire ecosystem of functionality that exists for pretty much anything you may need. Kotlin/Native is already shipped with a set of prebuilt platform libraries, which provide some additional common functionality to the standard library.

An ideal scenario for interop is to call C functions as if you are calling Kotlin functions, following the same signature and conventions. This is when the cinterop tool comes in handy. It takes a C library and generates the corresponding Kotlin bindings, so that the library can be used as if it were Kotlin code.

To generate these bindings, each library needs a definition file, usually with the same name as the library. This is a property file that describes exactly how the library should be consumed.

In this app, you'll need the libcurl library to make some HTTP calls. To create its definition file:

1. Select the src folder and create a new directory with File | New | Directory.
2. Name the new directory nativeInterop/cinterop. This is the default convention for header file locations, though it can be overridden in the build.gradle.kts file if you use a different location.
3. Select this new subfolder and create a new libcurl.def file with File | New | File.
4. Update your file with the following code:

```
headers = curl/curl.h
headerFilter = curl/*

compilerOpts.linux = -I/usr/include -I/usr/include/x86_64-linux-gnu
linkerOpts.osx = -L/opt/local/lib -L/usr/local/opt/curl/lib -lcurl
linkerOpts.linux = -L/usr/lib/x86_64-linux-gnu -lcurl
```

- headers is the list of header files to generate Kotlin stubs for. You can add multiple files here, separating each with a space. In this case, it's only curl.h. The referenced files need to be available on the specified path (in this case, it's /usr/include/curl).
- headerFilter shows what exactly is included. In C, all the headers are also included when one file references another one with the #include directive. Sometimes it's not necessary, and you can add this parameter using glob patterns to make adjustments.

  You can use headerFilter if you don't want to fetch external dependencies (such as system stdint.h header) into the interop library. Also, it may be useful for library size optimization and fixing potential conflicts between the system and the provided Kotlin/Native compilation environment.
- If the behavior for a certain platform needs to be modified, you can use a format like compilerOpts.osx or compilerOpts.linux to provide platform-specific values to the options. In this case, they are macOS (the .osx suffix) and Linux (the .linux suffix). Parameters without a suffix are also possible (for example, linkerOpts=) and applied to all platforms.

For the full list of available options, see Definition file.

You need to have the curl library binaries on your system to make the sample work. On macOS and Linux, they are usually included. On Windows, you can build it from sources (you'll need Microsoft Visual Studio or Windows SDK command-line tools). For more details, see the related blog post. Alternatively, you may want to consider a MinGW/MSYS2 curl binary.

Add interoperability to the build process

To use header files, make sure they are generated as a part of the build process. For this, add the following compilations {} block to the build.gradle.kts file:

```
nativeTarget.apply {
    compilations.getByName("main") {
        cinterops {
            val libcurl by creating
        }
    }
    binaries {
        executable {
            entryPoint = "main"
        }
    }
}
```

First, cinterops is added, and then an entry for a definition file. By default, the name of the file is used. You can override this with additional parameters:

```
cinterops {
    val libcurl by creating {
        definitionFile.set(project.file("src/nativeInterop/cinterop/libcurl.def"))
        packageName("com.jetbrains.handson.http")
        compilerOpts("-I/path")
        includeDirs.allHeaders("path")
    }
}
```

Write the application code

Now that you have the library and the corresponding Kotlin stubs, you can use them from your application. For this tutorial, convert the simple.c example to Kotlin.

In the src/nativeMain/kotlin/ folder, update your Main.kt file with the following code:

```
import kotlinx.cinterop.*
import libcurl.*

@OptIn(ExperimentalForeignApi::class)
fun main(args: Array<String>) {
    val curl = curl_easy_init()
    if (curl != null) {
        curl_easy_setopt(curl, CURLOPT_URL, "https://example.com")
        curl_easy_setopt(curl, CURLOPT_FOLLOWLOCATION, 1L)
        val res = curl_easy_perform(curl)
        if (res != CURLE_OK) {
            println("curl_easy_perform() failed ${curl_easy_strerror(res)?.toKString()}")
        }
        curl_easy_cleanup(curl)
    }
}
```

As you can see, explicit variable declarations are eliminated in the Kotlin version, but everything else is pretty much the same as the C version. All the calls you'd expect in the libcurl library are available in the Kotlin equivalent.

This is a line-by-line literal translation. You could also write this in a more Kotlin idiomatic way.

Compile and run the application

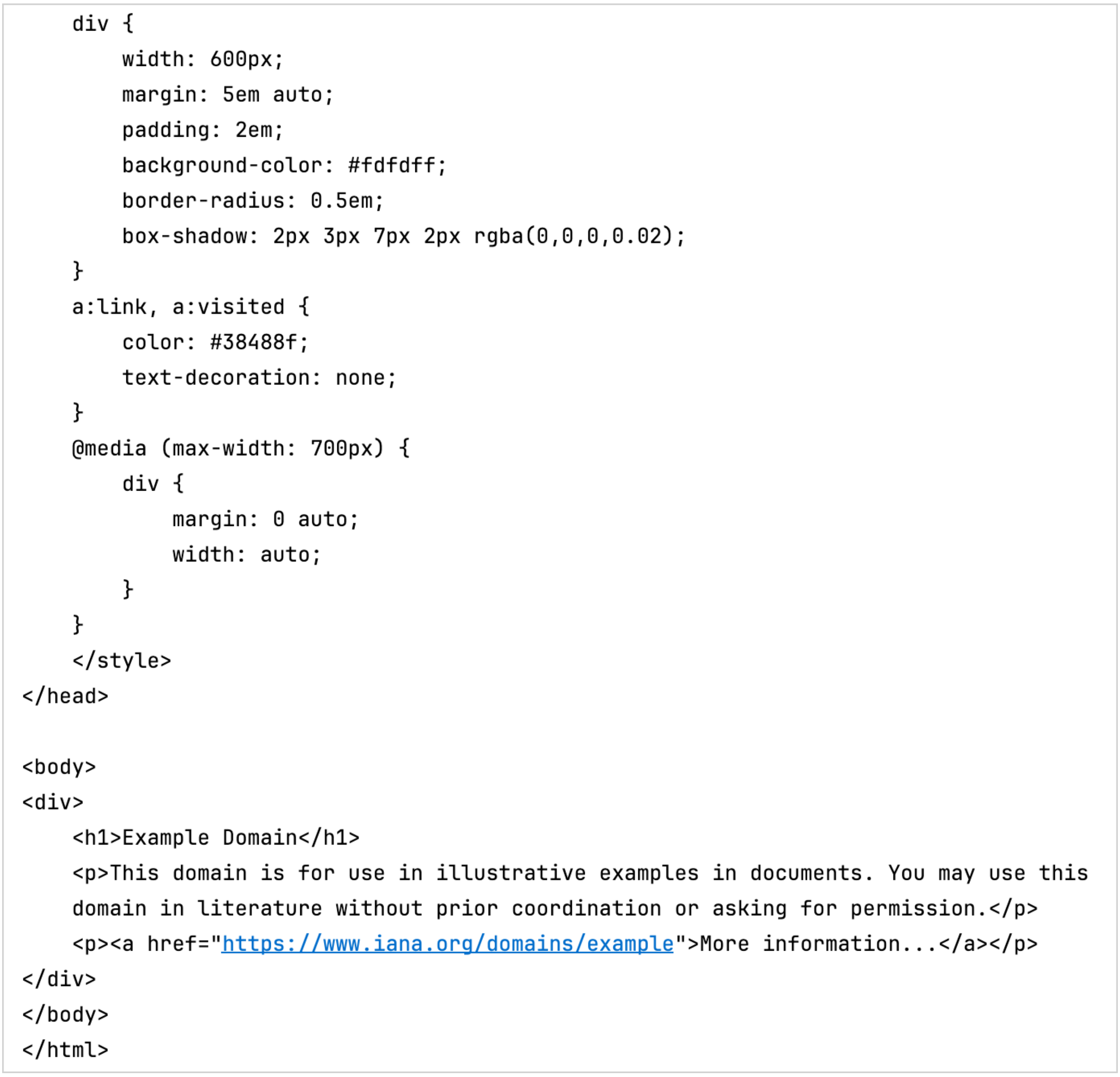
1. Compile the application. To do that, run the runDebugExecutableNative Gradle task from the task list or use the following command in the terminal:

   ```
   ./gradlew runDebugExecutableNative
   ```

   In this case, the part generated by the cinterop tool is implicitly included in the build.

2. If there are no errors during compilation, click the green Run icon in the gutter next to the main() function or use the Shift + Cmd + R/Shift + F10 shortcut.

   IntelliJ IDEA opens the Run tab and shows the output — the contents of example.com:



```
    div {
        width: 600px;
        margin: 5em auto;
        padding: 2em;
        background-color: #fdfdff;
        border-radius: 0.5em;
        box-shadow: 2px 3px 7px 2px rgba(0,0,0,0.02);
    }
    a:link, a:visited {
        color: #38488f;
        text-decoration: none;
    }
    @media (max-width: 700px) {
        div {
            margin: 0 auto;
            width: auto;
        }
    }
    </style>
</head>

<body>
<div>
    <h1>Example Domain</h1>
    <p>This domain is for use in illustrative examples in documents. You may use this
    domain in literature without prior coordination or asking for permission.</p>
    <p><a href="https://www.iana.org/domains/example">More information...</a></p>
</div>
</body>
</html>
```

Application output with HTML-code

You can see the actual output because the call curl_easy_perform prints the result to the standard output. You could hide this using curl_easy_setopt.

> You can get the full project code in our GitHub repository.

What's next

Learn more about Kotlin's interoperability with C.

Interoperability with Swift/Objective-C

> The Objective-C libraries import is Experimental. All Kotlin declarations generated by the cinterop tool from Objective-C libraries should have the @ExperimentalForeignApi annotation.
>
> Native platform libraries shipped with Kotlin/Native (like Foundation, UIKit, and POSIX) require opt-in only for some APIs.

Kotlin/Native provides indirect interoperability with Swift through Objective-C. This document covers how you can use Kotlin declarations in Swift/Objective-C code and Objective-C declarations in Kotlin code.

Some other resources you might find useful:

- The Kotlin-Swift interopedia, a collection of examples on how to use Kotlin declarations in Swift code.
- The Integration with Swift/Objective-C ARC section, covering the details of integration between Kotlin's tracing GC and Objective-C's ARC.

Importing Swift/Objective-C libraries to Kotlin

Objective-C frameworks and libraries can be used in Kotlin code if properly imported to the build (system frameworks are imported by default). For more details, see:

- Create and configure a library definition file
- Configure compilation for native libraries

A Swift library can be used in Kotlin code if its API is exported to Objective-C with @objc. Pure Swift modules are not yet supported.

Using Kotlin in Swift/Objective-C

Kotlin modules can be used in Swift/Objective-C code if compiled into a framework:

- See Build final native binaries to see how to declare binaries.
- Check out the Kotlin Multiplatform sample project for an example.

Hide Kotlin declarations from Objective-C and Swift

> The @HiddenFromObjC annotation is Experimental and requires opt-in.

To make your Kotlin code more Swift/Objective-C-friendly, use the @HiddenFromObjC annotation to hide a Kotlin declaration from Objective-C and Swift. It disables the function or property export to Objective-C.

Alternatively, you can mark Kotlin declarations with the internal modifier to restrict their visibility in the compilation module. Use @HiddenFromObjC if you want to hide the Kotlin declaration from Objective-C and Swift while keeping it visible to other Kotlin modules.

See an example in the Kotlin-Swift interopedia.

Use refining in Swift

> The @ShouldRefineInSwift annotation is Experimental and requires opt-in.

@ShouldRefineInSwift helps to replace a Kotlin declaration with a wrapper written in Swift. The annotation marks a function or property as swift_private in the generated Objective-C API. Such declarations get the __ prefix, which makes them invisible from Swift.

You can still use these declarations in your Swift code to create a Swift-friendly API, but they won't be suggested in the Xcode autocomplete.

- For more information on refining Objective-C declarations in Swift, see the official Apple documentation.
- For an example on how to use the @ShouldRefineInSwift annotation, see the Kotlin-Swift interopedia.

Change declaration names

The @ObjCName annotation is Experimental and requires opt-in.

To avoid renaming Kotlin declarations, use the @ObjCName annotation. It instructs the Kotlin compiler to use the custom Objective-C and Swift name for the annotated class, interface, or another Kotlin entity:

```
@ObjCName(swiftName = "MySwiftArray")
class MyKotlinArray {
    @ObjCName("index")
    fun indexOf(@ObjCName("of") element: String): Int = TODO()
}

// Usage with the ObjCName annotations
let array = MySwiftArray()
let index = array.index(of: "element")
```

See another example in the Kotlin-Swift interopedia.

Provide documentation with KDoc comments

Documentation is essential for understanding any API. Providing documentation for the shared Kotlin API allows you to communicate with its users on matters of usage, dos and don'ts, and so on.

By default, KDocs comments are not translated into corresponding comments when generating an Objective-C header. For example, the following Kotlin code with KDoc:

```
/**
 * Prints the sum of the arguments.
 * Properly handles the case when the sum doesn't fit in 32-bit integer.
 */
fun printSum(a: Int, b: Int) = println(a.toLong() + b)
```

Will produce an Objective-C declaration without any comments:

```
+ (void)printSumA:(int32_t)a b:(int32_t)b __attribute__((swift_name("printSum(a:b:)")));
```

To enable export of KDoc comments, add the following compiler option to your build.gradle(.kts):

Kotlin

```
kotlin {
    targets.withType<org.jetbrains.kotlin.gradle.plugin.mpp.KotlinNativeTarget> {
        compilations.get("main").compilerOptions.options.freeCompilerArgs.add("-Xexport-kdoc")
    }
}
```

Groovy

```
kotlin {
    targets.withType(org.jetbrains.kotlin.gradle.plugin.mpp.KotlinNativeTarget) {
        compilations.get("main").compilerOptions.options.freeCompilerArgs.add("-Xexport-kdoc")
    }
}
```

After that, the Objective-C header will contain a corresponding comment:

```
/**
 * Prints the sum of the arguments.
 * Properly handles the case when the sum doesn't fit in 32-bit integer.
 */
+ (void)printSumA:(int32_t)a b:(int32_t)b __attribute__((swift_name("printSum(a:b:)")));
```

You'll be able to see comments on classes and methods in autocompletion, for example, in Xcode. If you go to the definition of functions (in the .h file), you'll see comments on @param, @return, and so on.

Known limitations:

> The ability to export KDoc comments to generated Objective-C headers is Experimental. It may be dropped or changed at any time. Opt-in is required (see the details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

- Dependency documentation is not exported unless it is compiled with -Xexport-kdoc itself. The feature is Experimental, so libraries compiled with this option might be incompatible with other compiler versions.
- KDoc comments are mostly exported as is. Many KDoc features, for example @property, are not supported.

Mappings

The table below shows how Kotlin concepts are mapped to Swift/Objective-C and vice versa.

"->" and "<-" indicate that mapping only goes one way.

Kotlin	Swift	Objective-C	Notes
class	class	@interface	note
interface	protocol	@protocol	
constructor/create	Initializer	Initializer	note
Property	Property	Property	note 1, note 2
Method	Method	Method	note 1, note 2
enum class	class	@interface	note
suspend->	completionHandler:/async	completionHandler:	note 1, note 2
@Throws fun	throws	error:(NSError**)error	note
Extension	Extension	Category member	note
companion member <-	Class method or property	Class method or property	

Kotlin	Swift	Objective-C	Notes
null	nil	nil	
Singleton	shared or companion property	shared or companion property	note
Primitive type	Primitive type / NSNumber		note
Unit return type	Void	void	
String	String	NSString	note
String	NSMutableString	NSMutableString	note
List	Array	NSArray	
MutableList	NSMutableArray	NSMutableArray	
Set	Set	NSSet	
MutableSet	NSMutableSet	NSMutableSet	note
Map	Dictionary	NSDictionary	
MutableMap	NSMutableDictionary	NSMutableDictionary	note
Function type	Function type	Block pointer type	note
Inline classes	Unsupported	Unsupported	note

Classes

Name translation

Objective-C classes are imported into Kotlin with their original names. Protocols are imported as interfaces with a Protocol name suffix, for example, @protocol Foo-> interface FooProtocol. These classes and interfaces are placed into a package specified in build configuration (platform.* packages for preconfigured system frameworks).

The names of Kotlin classes and interfaces are prefixed when imported to Objective-C. The prefix is derived from the framework name.

Objective-C does not support packages in a framework. If the Kotlin compiler finds Kotlin classes in the same framework which have the same name but different packages, it renames them. This algorithm is not stable yet and can change between Kotlin releases. To work around this, you can rename the conflicting Kotlin classes in the framework.

Strong linking

Whenever you use an Objective-C class in the Kotlin source, it's marked as a strongly linked symbol. The resulting build artifact mentions related symbols as strong external references.

This means that the app tries to link symbols during the launch dynamically, and if they are unavailable, the app crashes. The crash happens even if symbols were never used. Symbols might be unavailable on a particular device or OS version.

To work around this issue and avoid "Symbol not found" errors, use a Swift or Objective-C wrapper that checks if the class is actually available. See how this workaround was implemented in the Compose Multiplatform framework.

Initializers

A Swift/Objective-C initializer is imported to Kotlin as constructors or as factory methods named create. The latter happens with initializers declared in the Objective-C category or as a Swift extension, because Kotlin has no concept of extension constructors.

> Before importing Swift initializers to Kotlin, don't forget to annotate them with @objc.

Kotlin constructors are imported as initializers to Swift/Objective-C.

Setters

Writeable Objective-C properties overriding read-only properties of the superclass are represented as the setFoo() method for the property foo. The same goes for a protocol's read-only properties that are implemented as mutable.

Top-level functions and properties

Top-level Kotlin functions and properties are accessible as members of special classes. Each Kotlin file is translated into such a class, for example:

```
// MyLibraryUtils.kt
package my.library

fun foo() {}
```

You can then call the foo() function from Swift like this:

```
MyLibraryUtilsKt.foo()
```

See a collection of examples on accessing top-level Kotlin declarations in the Kotlin-Swift interopedia:

- Top-level functions
- Top-level read-only properties
- Top-level mutable properties

Method names translation

Generally, Swift argument labels and Objective-C selector pieces are mapped to Kotlin parameter names. These two concepts have different semantics, so sometimes Swift/Objective-C methods can be imported with a clashing Kotlin signature. In this case, the clashing methods can be called from Kotlin using named arguments, for example:

```
[player moveTo:LEFT byMeters:17]
[player moveTo:UP byInches:42]
```

In Kotlin, it's:

```
player.moveTo(LEFT, byMeters = 17)
player.moveTo(UP, byInches = 42)
```

Here's how the kotlin.Any functions are mapped to Swift/Objective-C:

Kotlin	Swift	Objective-C
equals()	isEquals(_:)	isEquals:
hashCode()	hash	hash
toString()	description	description

See an example with data classes in the Kotlin-Swift interopedia.

You can specify a more idiomatic name in Swift or Objective-C, instead of renaming the Kotlin declaration with the @ObjCName annotation.

Errors and exceptions

All Kotlin exceptions are unchecked, meaning that errors are caught at runtime. However, Swift has only checked errors that are handled at compile time. So, if Swift or Objective-C code calls a Kotlin method that throws an exception, the Kotlin method should be marked with the @Throws annotation, specifying a list of "expected" exception classes.

When compiling to the Swift/Objective-C framework, non-suspend functions that have or inherit the @Throws annotation are represented as NSError*-producing methods in Objective-C and as throws methods in Swift. Representations for suspend functions always have an NSError*/Error parameter in the completion handler.

When a Kotlin function called from Swift/Objective-C code throws an exception which is an instance of one of the classes specified with @Throws or their subclasses, the exception is propagated as an NSError. Other Kotlin exceptions reaching Swift/Objective-C are considered unhandled and cause program termination.

suspend functions without @Throws propagate only CancellationException (as NSError). Non-suspend functions without @Throws don't propagate Kotlin exceptions at all.

Note that the opposite reversed translation is not implemented yet: Swift/Objective-C error-throwing methods aren't imported to Kotlin as exception-throwing.

See an example in the Kotlin-Swift interopedia.

Enums

Kotlin enums are imported into Objective-C as @interface and into Swift as class. These data structures have properties corresponding to each enum value. Consider this Kotlin code:

```
// Kotlin
enum class Colors {
    RED, GREEN, BLUE
}
```

You can access the properties of this enum class from Swift as follows:

```
// Swift
Colors.red
Colors.green
Colors.blue
```

To use variables of a Kotlin enum in a Swift switch statement, provide a default statement to prevent a compilation error:

```
switch color {
    case .red: print("It's red")
    case .green: print("It's green")
    case .blue: print("It's blue")
    default: fatalError("No such color")
}
```

See another example in the Kotlin-Swift interopedia.

Suspending functions

> Support for calling suspend functions from Swift code as async is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Kotlin's suspending functions (suspend) are presented in the generated Objective-C headers as functions with callbacks, or completion handlers in Swift/Objective-C terminology.

Starting from Swift 5.5, Kotlin's suspend functions are also available for calling from Swift as async functions without using the completion handlers. Currently, this functionality is highly experimental and has certain limitations. See this YouTrack issue for details.

- Learn more about the async/await mechanism in the Swift documentation.
- See an example and recommendations on third-party libraries that implement the same functionality in the Kotlin-Swift interopedia.

Extensions and category members

Members of Objective-C categories and Swift extensions are generally imported to Kotlin as extensions. That's why these declarations can't be overridden in Kotlin, and the extension initializers aren't available as Kotlin constructors.

> Currently, there are two exceptions. Starting with Kotlin 1.8.20, category members that are declared in the same headers as the NSView class (from the AppKit framework) or UIView classes (from the UIKit framework) are imported as members of these classes. This means that you can override methods that subclass from NSView or UIView.

Kotlin extensions to "regular" Kotlin classes are imported to Swift and Objective-C as extensions and category members, respectively. Kotlin extensions to other types are treated as top-level declarations with an additional receiver parameter. These types include:

- Kotlin String type
- Kotlin collection types and subtypes
- Kotlin interface types
- Kotlin primitive types
- Kotlin inline classes
- Kotlin Any type
- Kotlin function types and subtypes
- Objective-C classes and protocols

See a collection of examples in the Kotlin-Swift interopedia.

Kotlin singletons

Kotlin singleton (made with an object declaration, including companion object) is imported to Swift/Objective-C as a class with a single instance.

The instance is available through the shared and companion properties.

For the following Kotlin code:

```kotlin
object MyObject {
    val x = "Some value"
}

class MyClass {
    companion object {
        val x = "Some value"
    }
}
```

Access these objects as follows:

```
MyObject.shared
MyObject.shared.x
MyClass.companion
MyClass.Companion.shared
```

Access objects through [MySingleton mySingleton] in Objective-C and MySingleton() in Swift has been deprecated.

See more examples in the Kotlin-Swift interopedia:

- How to access Kotlin objects using shared
- How to access members of Kotlin companion objects from Swift.

Primitive types

Kotlin primitive type boxes are mapped to special Swift/Objective-C classes. For example, the kotlin.Int box is represented as the KotlinInt class instance in Swift (or the ${prefix}Int instance in Objective-C, where prefix is the framework's name prefix). These classes are derived from NSNumber, so the instances are proper NSNumbers supporting all corresponding operations.

The NSNumber type is not automatically translated to Kotlin primitive types when used as a Swift/Objective-C parameter type or return value. The reason is that the NSNumber type doesn't provide enough information about a wrapped primitive value type, for example, NSNumber is statically not known to be Byte, Boolean, or Double. So Kotlin primitive values should be cast to and from NSNumber manually.

Strings

When a Kotlin String is passed to Swift, it's first exported as an Objective-C object, and then the Swift compiler copies it one more time for a Swift conversion. This results in additional runtime overhead.

To avoid that, access Kotlin strings in Swift directly as an Objective-C NSString instead. See the conversion example.

NSMutableString

NSMutableString Objective-C class is not available from Kotlin. All instances of NSMutableString are copied when passed to Kotlin.

Collections

Kotlin -> Objective-C -> Swift

When a Kotlin collection is passed to Swift, it's first converted to an Objective-C equivalent, and then the Swift compiler copies the entire collection and converts it into a Swift-native collection as described in the mappings table.

This last conversion leads to performance costs. To prevent this, when using Kotlin collections in Swift, explicitly cast them to their Objective-C counterparts: NSDictionary, NSArray, or NSSet.

See the conversion example
For example, the following Kotlin declaration:

```
val map: Map<String, String>
```

In Swift, might look like this:

```
map[key]?.count ?? 0
```

Here, the map is implicitly converted to Swift's Dictionary, and its string values are mapped to Swift's String. This results in a performance cost.

To avoid the conversion, explicitly cast map to Objective-C's NSDictionary and access values as NSString instead:

```
let nsMap: NSDictionary = map as NSDictionary
(nsMap[key] as? NSString)?.length ?? 0
```

This ensures that the Swift compiler doesn't perform an additional conversion step.

Swift -> Objective-C -> Kotlin

Swift/Objective-C collections are mapped to Kotlin as described in the mappings table, except for NSMutableSet and NSMutableDictionary.

NSMutableSet isn't converted to a Kotlin's MutableSet. To pass an object to Kotlin MutableSet, explicitly create this kind of Kotlin collection. To do this, use, for example, the mutableSetOf() function in Kotlin or the KotlinMutableSet class in Swift and ${prefix}MutableSet in Objective-C (prefix is the framework names prefix). The same is true for MutableMap.

See an example in the Kotlin-Swift interopedia.

Function types

Kotlin function-typed objects (for example, lambdas) are converted to functions in Swift and blocks in Objective-C. See an example of a Kotlin function with a lambda in the Kotlin-Swift interopedia.

However, there is a difference in how types of parameters and return values are mapped when translating a function and a function type. In the latter case, primitive types are mapped to their boxed representation. Kotlin Unit return value is represented as a corresponding Unit singleton in Swift/Objective-C. The value of this singleton can be retrieved the same way as for any other Kotlin object. See singletons in the table above.

Consider the following Kotlin function:

```
fun foo(block: (Int) -> Unit) { ... }
```

It's represented in Swift as follows:

```
func foo(block: (KotlinInt) -> KotlinUnit)
```

And you can call it like this:

```
foo {
    bar($0 as! Int32)
    return KotlinUnit()
}
```

Generics

Objective-C supports "lightweight generics" defined in classes, with a relatively limited feature set. Swift can import generics defined on classes to help provide additional type information to the compiler.

Generic feature support for Objective-C and Swift differ from Kotlin, so the translation will inevitably lose some information, but the features supported retain meaningful information.

For specific examples on how to use Kotlin generics in Swift, see the Kotlin-Swift interopedia.

Limitations

Objective-C generics do not support all features of either Kotlin or Swift, so there will be some information lost in the translation.

Generics can only be defined on classes, not on interfaces (protocols in Objective-C and Swift) or functions.

Nullability

Kotlin and Swift both define nullability as part of the type specification, while Objective-C defines nullability on methods and properties of a type. So, the following Kotlin code:

```
class Sample<T>() {
    fun myVal(): T
}
```

Looks in Swift like this:

```
class Sample<T>() {
    fun myVal(): T?
}
```

To support a potentially nullable type, the Objective-C header needs to define myVal with a nullable return value.

To mitigate this, when defining your generic classes, provide a non-nullable type constraint if the generic type should never be null:

```
class Sample<T : Any>() {
    fun myVal(): T
}
```

That will force the Objective-C header to mark myVal as non-nullable.

Variance

Objective-C allows generics to be declared covariant or contravariant. Swift has no support for variance. Generic classes coming from Objective-C can be force-cast as needed.

```
data class SomeData(val num: Int = 42) : BaseData()
class GenVarOut<out T : Any>(val arg: T)
```

```
let variOut = GenVarOut<SomeData>(arg: sd)
let variOutAny : GenVarOut<BaseData> = variOut as! GenVarOut<BaseData>
```

Constraints

In Kotlin, you can provide upper bounds for a generic type. Objective-C also supports this, but that support is unavailable in more complex cases and is currently not supported in the Kotlin - Objective-C interop. The exception here being a non-nullable upper bound will make Objective-C methods/properties non-nullable.

To disable

To have the framework header written without generics, add the following compiler option in your build file:

```
binaries.framework {
    freeCompilerArgs += "-Xno-objc-generics"
}
```

Forward declarations

To import forward declarations, use the objcnames.classes and objcnames.protocols packages. For example, to import a objcprotocolName forward declaration declared in an Objective-C library with a library.package, use a special forward declaration package: import objcnames.protocols.objcprotocolName.

Consider two objcinterop libraries: one that uses objcnames.protocols.ForwardDeclaredProtocolProtocol and another with an actual implementation in another package:

```
// First objcinterop library
#import <Foundation/Foundation.h>

@protocol ForwardDeclaredProtocol;

NSString* consumeProtocol(id<ForwardDeclaredProtocol> s) {
    return [NSString stringWithUTF8String:"Protocol"];
}
```

```
// Second objcinterop library
// Header:
#import <Foundation/Foundation.h>
@protocol ForwardDeclaredProtocol
@end
// Implementation:
@interface ForwardDeclaredProtocolImpl : NSObject <ForwardDeclaredProtocol>
@end

id<ForwardDeclaredProtocol> produceProtocol() {
    return [ForwardDeclaredProtocolImpl new];
}
```

To transfer objects between the two libraries, use an explicit as cast in your Kotlin code:

```
// Kotlin code:
fun test() {
    consumeProtocol(produceProtocol() as objcnames.protocols.ForwardDeclaredProtocolProtocol)
}
```

You can only cast to objcnames.protocols.ForwardDeclaredProtocolProtocol from the corresponding real class. Otherwise, you'll get an error.

Casting between mapped types

When writing Kotlin code, an object may need to be converted from a Kotlin type to the equivalent Swift/Objective-C type (or vice versa). In this case, a plain old Kotlin cast can be used, for example:

```
val nsArray = listOf(1, 2, 3) as NSArray
val string = nsString as String
val nsNumber = 42 as NSNumber
```

Subclassing

Subclassing Kotlin classes and interfaces from Swift/Objective-C

Kotlin classes and interfaces can be subclassed by Swift/Objective-C classes and protocols.

Subclassing Swift/Objective-C classes and protocols from Kotlin

Swift/Objective-C classes and protocols can be subclassed with a Kotlin final class. Non-final Kotlin classes inheriting Swift/Objective-C types aren't supported yet, so it is not possible to declare a complex class hierarchy inheriting Swift/Objective-C types.

Normal methods can be overridden using the override Kotlin keyword. In this case, the overriding method must have the same parameter names as the overridden one.

Sometimes it is required to override initializers, for example when subclassing UIViewController. Initializers imported as Kotlin constructors can be overridden by Kotlin constructors marked with the @OverrideInit annotation:

```
class ViewController : UIViewController {
    @OverrideInit constructor(coder: NSCoder) : super(coder)

    ...
}
```

The overriding constructor must have the same parameter names and types as the overridden one.

To override different methods with clashing Kotlin signatures, you can add the @ObjCSignatureOverride annotation to the class. The annotation instructs the Kotlin compiler to ignore conflicting overloads, in case several functions with the same argument types, but different argument names, are inherited from the Objective-C class.

By default, the Kotlin/Native compiler doesn't allow calling a non-designated Objective-C initializer as a super() constructor. This behavior can be inconvenient if the designated initializers aren't marked properly in the Objective-C library. To disable these compiler checks, add the disableDesignatedInitializerChecks = true to the library's .def file.

C features

See Interoperability with C for an example case where the library uses some plain C features, such as unsafe pointers, structs, and so on.

Unsupported

Some features of the Kotlin programming language are not yet mapped into the respective features of Objective-C or Swift. Currently, the following features are not properly exposed in generated framework headers:

- Inline classes (arguments are mapped as either underlying primitive type or id)
- Custom classes implementing standard Kotlin collection interfaces (List, Map, Set) and other special classes
- Kotlin subclasses of Objective-C classes

Kotlin/Native as an Apple framework – tutorial

> The Objective-C libraries import is Experimental. All Kotlin declarations generated by the cinterop tool from Objective-C libraries should have the @ExperimentalForeignApi annotation.
>
> Native platform libraries shipped with Kotlin/Native (like Foundation, UIKit, and POSIX) require opt-in only for some APIs.

Kotlin/Native provides bidirectional interoperability with Swift/Objective-C. You can both use Objective-C frameworks and libraries in Kotlin code, and Kotlin modules in Swift/Objective-C code.

Kotlin/Native comes with a set of pre-imported system frameworks; it's also possible to import an existing framework and use it from Kotlin. In this tutorial, you'll learn how to create your own framework and use Kotlin/Native code from Swift/Objective-C applications on macOS and iOS.

In this tutorial, you will:

- Create a Kotlin library and compile it to a framework
- Examine the generated Swift/Objective-C API code
- Use the framework from Objective-C
- Use the framework from Swift

You can use the command line to generate a Kotlin framework, either directly or with a script file (such as .sh or .bat file). However, this approach doesn't scale well for larger projects that have hundreds of files and libraries. Using a build system simplifies the process by downloading and caching the Kotlin/Native compiler binaries and libraries with transitive dependencies, as well as by running the compiler and tests. Kotlin/Native can use the Gradle build system through the Kotlin Multiplatform plugin.

> If you use a Mac and want to create and run applications for iOS or other Apple targets, you also need to install the Xcode Command Line Tools, launch it, and accept the license terms first.

Create a Kotlin library

> See the Get started with Kotlin/Native tutorial for detailed first steps and instructions on how to create a new Kotlin/Native project and open it in IntelliJ IDEA.

The Kotlin/Native compiler can produce a framework for macOS and iOS from the Kotlin code. The created framework contains all declarations and binaries needed to use it with Swift/Objective-C.

Let's first create a Kotlin library:

1. In the src/nativeMain/kotlin directory, create the lib.kt file with the library contents:

```kotlin
package example

object Object {
    val field = "A"
}

interface Interface {
    fun iMember() {}
}

class Clazz : Interface {
    fun member(p: Int): ULong? = 42UL
}

fun forIntegers(b: Byte, s: UShort, i: Int, l: ULong?) { }
fun forFloats(f: Float, d: Double?) { }

fun strings(str: String?) : String {
    return "That is '$str' from C"
}

fun acceptFun(f: (String) -> String?) = f("Kotlin/Native rocks!")
fun supplyFun() : (String) -> String? = { "$it is cool!" }
```

2. Update your build.gradle(.kts) Gradle build file with the following:

Kotlin

```kotlin
plugins {
    kotlin("multiplatform") version "2.2.0"
}

repositories {
    mavenCentral()
}

kotlin {
    iosArm64("native") {
        binaries {
            framework {
                baseName = "Demo"
            }
        }
    }
}

tasks.wrapper {
    gradleVersion = "8.14"
    distributionType = Wrapper.DistributionType.ALL
}
```

Groovy

```groovy
plugins {
    id 'org.jetbrains.kotlin.multiplatform' version '2.2.0'
}

repositories {
    mavenCentral()
}

kotlin {
    iosArm64("native") {
        binaries {
            framework {
                baseName = "Demo"
            }
        }
    }
}
```

```
wrapper {
    gradleVersion = "8.14"
    distributionType = "ALL"
}
```

The binaries {} block configures the project to generate a dynamic or shared library.

Kotlin/Native supports the iosArm64, iosX64, and iosSimulatorArm64 targets for iOS, as well as macosX64 and macosArm64 targets for macOS. So, you can replace the iosArm64() with the respective Gradle function for your target platform:

Target platform/device	Gradle function
macOS x86_64	macosX64()
macOS ARM64	macosArm64()
iOS ARM64	iosArm64()
iOS Simulator (x86_64)	iosX64()
iOS Simulator (ARM64)	iosSimulatorArm64()

For information on other supported Apple targets, see Kotlin/Native target support.

3. Run the linkDebugFrameworkNative Gradle task in the IDE or use the following console command in your terminal to build the framework:

```
./gradlew linkDebugFrameworkNative
```

The build generates the framework into the build/bin/native/debugFramework directory.

You can also use the linkNative Gradle task to generate both debug and release variants of the framework.

Generated framework headers

Each framework variant contains a header file. The headers don't depend on the target platform. Header files contain definitions for your Kotlin code and a few Kotlin-wide declarations. Let's see what's inside.

Kotlin/Native runtime declarations

In the build/bin/native/debugFramework/Demo.framework/Headers directory, open the Demo.h header file. Take a look at Kotlin runtime declarations:

```
NS_ASSUME_NONNULL_BEGIN
#pragma clang diagnostic push
#pragma clang diagnostic ignored "-Wunknown-warning-option"
#pragma clang diagnostic ignored "-Wincompatible-property-type"
#pragma clang diagnostic ignored "-Wnullability"

#pragma push_macro("_Nullable_result")
#if !__has_feature(nullability_nullable_result)
#undef _Nullable_result
#define _Nullable_result _Nullable
#endif

__attribute__((swift_name("KotlinBase")))
@interface DemoBase : NSObject
```

```
- (instancetype)init __attribute__((unavailable));
+ (instancetype)new __attribute__((unavailable));
+ (void)initialize __attribute__((objc_requires_super));
@end

@interface DemoBase (DemoBaseCopying) <NSCopying>
@end

__attribute__((swift_name("KotlinMutableSet")))
@interface DemoMutableSet<ObjectType> : NSMutableSet<ObjectType>
@end

__attribute__((swift_name("KotlinMutableDictionary")))
@interface DemoMutableDictionary<KeyType, ObjectType> : NSMutableDictionary<KeyType, ObjectType>
@end

@interface NSError (NSErrorDemoKotlinException)
@property (readonly) id _Nullable kotlinException;
@end
```

Kotlin classes have a KotlinBase base class in Swift/Objective-C that extends the NSObject class there. There are also wrappers for collections and exceptions. Most of the collection types are mapped to similar collection types in Swift/Objective-C:

Kotlin	Swift	Objective-C
List	Array	NSArray
MutableList	NSMutableArray	NSMutableArray
Set	Set	NSSet
MutableSet	NSMutableSet	NSMutableSet
Map	Dictionary	NSDictionary
MutableMap	NSMutableDictionary	NSMutableDictionary

Kotlin numbers and NSNumber

The next part of the Demo.h file contains type mappings between Kotlin/Native number types and NSNumber. The base class is called DemoNumber in Objective-C and KotlinNumber in Swift. It extends NSNumber.

For each Kotlin number type, there is a corresponding predefined child class:

Kotlin	Swift	Objective-C	Simple type
-	KotlinNumber	<Package>Number	-
Byte	KotlinByte	<Package>Byte	char
UByte	KotlinUByte	<Package>UByte	unsigned char

Kotlin	Swift	Objective-C	Simple type
Short	KotlinShort	<Package>Short	short
UShort	KotlinUShort	<Package>UShort	unsigned short
Int	KotlinInt	<Package>Int	int
UInt	KotlinUInt	<Package>UInt	unsigned int
Long	KotlinLong	<Package>Long	long long
ULong	KotlinULong	<Package>ULong	unsigned long long
Float	KotlinFloat	<Package>Float	float
Double	KotlinDouble	<Package>Double	double
Boolean	KotlinBoolean	<Package>Boolean	BOOL/Bool

Every number type has a class method to create a new instance from the corresponding simple type. Also, there is an instance method to extract a simple value back. Schematically, all such declarations look like that:

```
__attribute__((swift_name("Kotlin__TYPE__")))
@interface Demo__TYPE__ : DemoNumber
- (instancetype)initWith__TYPE__:(__CTYPE__)value;
+ (instancetype)numberWith__TYPE__:(__CTYPE__)value;
@end;
```

Here, __TYPE__ is one of the simple type names, and __CTYPE__ is the corresponding Objective-C type, for example, initWithChar(char).

These types are used to map boxed Kotlin number types to Swift/Objective-C. In Swift, you can call the constructor to create an instance, for example, KotlinLong(value: 42).

Classes and objects from Kotlin

Let's see how class and object are mapped to Swift/Objective-C. The generated Demo.h file contains the exact definitions for Class, Interface, and Object:

```
__attribute__((swift_name("Interface")))
@protocol DemoInterface
@required
- (void)iMember __attribute__((swift_name("iMember()")));
@end

__attribute__((objc_subclassing_restricted))
__attribute__((swift_name("Clazz")))
@interface DemoClazz : DemoBase <DemoInterface>
- (instancetype)init __attribute__((swift_name("init()"))) __attribute__((objc_designated_initializer));
+ (instancetype)new __attribute__((availability(swift, unavailable, message="use object initializers instead")));
- (DemoULong * _Nullable)memberP:(int32_t)p __attribute__((swift_name("member(p:)")));
@end

__attribute__((objc_subclassing_restricted))
__attribute__((swift_name("Object")))
@interface DemoObject : DemoBase
```

```
+ (instancetype)alloc __attribute__((unavailable));
+ (instancetype)allocWithZone:(struct _NSZone *)zone __attribute__((unavailable));
+ (instancetype)object __attribute__((swift_name("init()")));
@property (class, readonly, getter=shared) DemoObject *shared __attribute__((swift_name("shared")));
@property (readonly) NSString *field __attribute__((swift_name("field")));
@end
```

Objective-C attributes in this code help use the framework from both Swift and Objective-C languages. DemoInterface, DemoClazz, and DemoObject are created for Interface, Clazz, and Object, respectively.

The Interface is turned into @protocol, while both a class and an object are represented as @interface. The Demo prefix comes from the framework name. The nullable return type ULong? is turned into DemoULong in Objective-C.

Global declarations from Kotlin

All global functions from Kotlin are turned into DemoLibKt in Objective-C and into LibKt in Swift, where Demo is the framework name set by the -output parameter of kotlinc-native:

```
__attribute__((objc_subclassing_restricted))
__attribute__((swift_name("LibKt")))
@interface DemoLibKt : DemoBase
+ (NSString * _Nullable)acceptFunF:(NSString * _Nullable (^)(NSString *))f __attribute__((swift_name("acceptFun(f:)")));
+ (void)forFloatsF:(float)f d:(DemoDouble * _Nullable)d __attribute__((swift_name("forFloats(f:d:)")));
+ (void)forIntegersB:(int8_t)b s:(uint16_t)s i:(int32_t)i l:(DemoULong * _Nullable)l
__attribute__((swift_name("forIntegers(b:s:i:l:)")));
+ (NSString *)stringsStr:(NSString * _Nullable)str __attribute__((swift_name("strings(str:)")));
+ (NSString * _Nullable (^)(NSString *))supplyFun __attribute__((swift_name("supplyFun()")));
@end
```

Kotlin String and Objective-C NSString* are mapped transparently. Similarly, Unit type from Kotlin is mapped to void. The primitive types are mapped directly. Non-nullable primitive types are mapped transparently. Nullable primitive types are mapped to Kotlin<TYPE>* types, as shown in the table. Both higher-order functions acceptFunF and supplyFun are included and accept Objective-C blocks.

You can find more information about type mapping in Interoperability with Swift/Objective-C.

Garbage collection and reference counting

Swift and Objective-C use automatic reference counting (ARC). Kotlin/Native has its own garbage collector, which is also integrated with Swift/Objective-C ARC.

Unused Kotlin objects are automatically removed. You don't need to take additional steps to control the lifetime of Kotlin/Native instances from Swift or Objective-C.

Use code from Objective-C

Let's call the framework from Objective-C. In the framework directory, create the main.m file with the following code:

```
#import <Foundation/Foundation.h>
#import <Demo/Demo.h>

int main(int argc, const char * argv[]) {
    @autoreleasepool {
        [DemoObject.shared field];

        DemoClazz* clazz = [[ DemoClazz alloc] init];
        [clazz memberP:42];

        [DemoLibKt forIntegersB:1 s:1 i:3 l:[DemoULong numberWithUnsignedLongLong:4]];
        [DemoLibKt forIntegersB:1 s:1 i:3 l:nil];

        [DemoLibKt forFloatsF:2.71 d:[DemoDouble numberWithDouble:2.71]];
        [DemoLibKt forFloatsF:2.71 d:nil];

        NSString* ret = [DemoLibKt acceptFunF:^NSString * _Nullable(NSString * it) {
            return [it stringByAppendingString:@" Kotlin is fun"];
        }];

        NSLog(@"%@", ret);
        return 0;
    }
}
```

Here, you call Kotlin classes directly from Objective-C code. A Kotlin object uses the <object name>.shared class property, which allows you to get the object's only instance and call object methods on it.

The widespread pattern is used to create an instance of the Clazz class. You call the [[DemoClazz alloc] init] on Objective-C. You can also use [DemoClazz new] for constructors without parameters.

Global declarations from the Kotlin sources are scoped under the DemoLibKt class in Objective-C. All Kotlin functions are turned into class methods of that class.

The strings function is turned into DemoLibKt.stringsStr function in Objective-C, so you can pass NSString directly to it. The return value is visible as NSString too.

Use code from Swift

The framework you generated has helper attributes to make it easier to use with Swift. Let's convert the previous Objective-C example into Swift.

In the framework directory, create the main.swift file with the following code:

```swift
import Foundation
import Demo

let kotlinObject = Object.shared

let field = Object.shared.field

let clazz = Clazz()
clazz.member(p: 42)

LibKt.forIntegers(b: 1, s: 2, i: 3, l: 4)
LibKt.forFloats(f: 2.71, d: nil)

let ret = LibKt.acceptFun { "\($0) Kotlin is fun" }
if (ret != nil) {
    print(ret!)
}
```

There are some small differences between the original Kotlin code and its Swift version. In Kotlin, any object declaration has only one instance. The Object.shared syntax is used to access this single instance.

Kotlin function and property names are translated as is. Kotlin's String is turned into Swift's String. Swift hides NSNumber* boxing too. You can also pass a Swift closure to Kotlin and call a Kotlin lambda function from Swift.

You can find more information about type mapping in Interoperability with Swift/Objective-C.

Connect the framework to your iOS project

Now you can connect the generated framework to your iOS project as a dependency. There are multiple ways to set it up and automate the process, choose the method that suits you best:

Choose iOS integration method →

Choose iOS integration method

What's next

- Learn more about interoperability with Objective-C
- See how interoperability with C is implemented in Kotlin
- Check out the Kotlin/Native as a dynamic library tutorial

Kotlin/Native libraries

Kotlin compiler specifics

To produce a library with the Kotlin/Native compiler use the -produce library or -p library flag. For example:

```
$ kotlinc-native foo.kt -p library -o bar
```

This command will produce a bar.klib with the compiled contents of foo.kt.

To link to a library use the -library <name> or -l <name> flag. For example:

```
$ kotlinc-native qux.kt -l bar
```

This command will produce a program.kexe out of qux.kt and bar.klib

cinterop tool specifics

The cinterop tool produces .klib wrappers for native libraries as its main output. For example, using the simple libgit2.def native library definition file provided in your Kotlin/Native distribution

```
$ cinterop -def samples/gitchurn/src/nativeInterop/cinterop/libgit2.def -compiler-option -I/usr/local/include -o libgit2
```

we will obtain libgit2.klib.

See more details in C Interop.

klib utility

The klib library management utility allows you to inspect and install the libraries.

The following commands are available:

- content – list library contents:

  ```
  $ klib contents <name>
  ```

- info – inspect the bookkeeping details of the library

  ```
  $ klib info <name>
  ```

- install – install the library to the default location use

  ```
  $ klib install <name>
  ```

- remove – remove the library from the default repository use

  ```
  $ klib remove <name>
  ```

All of the above commands accept an additional -repository <directory> argument for specifying a repository different to the default one.

```
$ klib <command> <name> -repository <directory>
```

Several examples

First let's create a library. Place the tiny library source code into kotlinizer.kt:

```
package kotlinizer
val String.kotlinized
```

```
    get() = "Kotlin $this"
```

```
$ kotlinc-native kotlinizer.kt -p library -o kotlinizer
```

The library has been created in the current directory:

```
$ ls kotlinizer.klib
kotlinizer.klib
```

Now let's check out the contents of the library:

```
$ klib contents kotlinizer
```

You can install kotlinizer to the default repository:

```
$ klib install kotlinizer
```

Remove any traces of it from the current directory:

```
$ rm kotlinizer.klib
```

Create a very short program and place it into a use.kt:

```
import kotlinizer.*

fun main(args: Array<String>) {
    println("Hello, ${"world".kotlinized}!")
}
```

Now compile the program linking with the library you have just created:

```
$ kotlinc-native use.kt -l kotlinizer -o kohello
```

And run the program:

```
$ ./kohello.kexe
Hello, Kotlin world!
```

Have fun!

Advanced topics

Library search sequence

When given a -library foo flag, the compiler searches the foo library in the following order:

- Current compilation directory or an absolute path.
- All repositories specified with -repo flag.
- Libraries installed in the default repository.

> The default repository is ~/.konan. You can change it by setting the kotlin.data.dir Gradle property.
>
> Alternatively, you can use the -Xkonan-data-dir compiler option to configure your custom path to the directory via the cinterop and konanc tools.

- Libraries installed in $installation/klib directory.

Library format

Kotlin/Native libraries are zip files containing a predefined directory structure, with the following layout:

foo.klib when unpacked as foo/ gives us:

```
- foo/
    - $component_name/
      - ir/
        - Serialized Kotlin IR.
      - targets/
        - $platform/
          - kotlin/
            - Kotlin compiled to LLVM bitcode.
          - native/
            - Bitcode files of additional native objects.
        - $another_platform/
          - There can be several platform specific kotlin and native pairs.
      - linkdata/
        - A set of ProtoBuf files with serialized linkage metadata.
      - resources/
        - General resources such as images. (Not used yet).
      - manifest - A file in the java property format describing the library.
```

An example layout can be found in klib/stdlib directory of your installation.

Using relative paths in klibs

Using relative paths in klibs is available since Kotlin 1.6.20.

A serialized IR representation of source files is a part of a klib library. It includes paths of files for generating proper debug information. By default, stored paths are absolute. With the -Xklib-relative-path-base compiler option, you can change the format and use only relative path in the artifact. To make it work, pass one or multiple base paths of source files as an argument:

Kotlin

```kotlin
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask
// ...

tasks.named<KotlinCompilationTask<*>>("compileKotlin").configure {
    // $base is a base path of source files
    compilerOptions.freeCompilerArgs.add("-Xklib-relative-path-base=$base")
}
```

Groovy

```groovy
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask
// ...

tasks.named('compileKotlin', KotlinCompilationTask) {
    compilerOptions {
        // $base is a base path of source files
        freeCompilerArgs.add("-Xklib-relative-path-base=$base")
    }
}
```

Platform libraries

To provide access to native services of operating systems, the Kotlin/Native distribution includes a set of prebuilt libraries specific to each target. These are called platform libraries.

The packages from platform libraries are available by default. You don't need to specify additional link options to use them. The Kotlin/Native compiler automatically detects which platform libraries are accessed and links the necessary ones.

However, platform libraries in the compiler distribution are merely wrappers and bindings to the native libraries. That means you need to install native libraries themselves (.so, .a, .dylib, .dll, and so on) on your local machine.

POSIX bindings

Kotlin provides the POSIX platform library for all UNIX- and Windows-based targets, including Android and iOS. These platform libraries contain bindings to the platform's implementation, which follows the POSIX standard.

To use the library, import it into your project:

```kotlin
import platform.posix.*
```

> The platform.posix contents differ across platforms because of variations in POSIX implementations.

You can explore the contents of the posix.def file for each supported platform here:

- iOS
- macOS
- tvOS
- watchOS
- Linux
- Windows (MinGW)
- Android

The POSIX platform library is not available for the WebAssembly target.

Popular native libraries

Kotlin/Native provides bindings for various popular native libraries that are commonly used on different platforms, such as OpenGL, zlib, and Foundation.

On Apple platforms, the objc library is included to enable interoperability with Objective-C APIs.

You can explore the native libraries available for Kotlin/Native targets in your compiler distribution, depending on your setup:

- If you installed a standalone Kotlin/Native compiler:
  1. Go to the unpacked archive with the compiler distribution, for example, kotlin-native-prebuilt-macos-aarch64-2.1.0.
  2. Navigate to the klib/platform directory.
  3. Choose the folder with the corresponding target.
- If you use the Kotlin plugin in your IDE (bundled with IntelliJ IDEA and Android Studio):
  1. In your command line tool, run the following to navigate to the .konan folder:

     macOS and Linux

     ```
     ~/.konan/
     ```

     Windows

     ```
     %USERPROFILE%\.konan
     ```

  2. Open the Kotlin/Native compiler distribution, for example, kotlin-native-prebuilt-macos-aarch64-2.1.0.

3. Navigate to the klib/platform directory.
4. Choose the folder with the corresponding target.

> If you'd like to explore the definition file for each supported platform library: in the compiler distribution folder, navigate to the konan/platformDef directory and choose the necessary target.

What's next

Learn more about interoperability with Swift/Objective-C

Kotlin/Native memory management

Kotlin/Native uses a modern memory manager that is similar to the JVM, Go, and other mainstream technologies, including the following features:

- Objects are stored in a shared heap and can be accessed from any thread.
- Tracing garbage collection is performed periodically to collect objects that are not reachable from the "roots", like local and global variables.

Garbage collector

Kotlin/Native's garbage collector (GC) algorithm is constantly evolving. Currently, it functions as a stop-the-world mark and concurrent sweep collector that does not separate the heap into generations.

The GC is executed on a separate thread and started based on the memory pressure heuristics or by a timer. Alternatively, it can be called manually.

The GC processes the mark queue on several threads in parallel, including application threads, the GC thread, and optional marker threads. Application threads and at least one GC thread participate in the marking process. By default, application threads must be paused when the GC is marking objects in the heap.

> You can disable the parallelization of the mark phase with the kotlin.native.binary.gcMarkSingleThreaded=true compiler option. However, this may increase the garbage collector's pause time on large heaps.

When the marking phase is completed, the GC processes weak references and nullifies reference points to an unmarked object. By default, weak references are processed concurrently to decrease the GC pause time.

See how to monitor and optimize garbage collection.

Enable garbage collection manually

To force-start the garbage collector, call kotlin.native.internal.GC.collect(). This method triggers a new collection and waits for its completion.

Monitor GC performance

To monitor the GC performance, you can look through its logs and diagnose issues. To enable logging, set the following compiler option in your Gradle build script:

```
-Xruntime-logs=gc=info
```

Currently, the logs are only printed to stderr.

On Apple platforms, you can take advantage of the Xcode Instruments toolkit to debug iOS app performance. The garbage collector reports pauses with signposts available in Instruments. Signposts enable custom logging within your app, allowing you to check if a GC pause corresponds to an application freeze.

To track GC-related pauses in your app:

1. To enable the feature, set the following compiler option in your gradle.properties file:

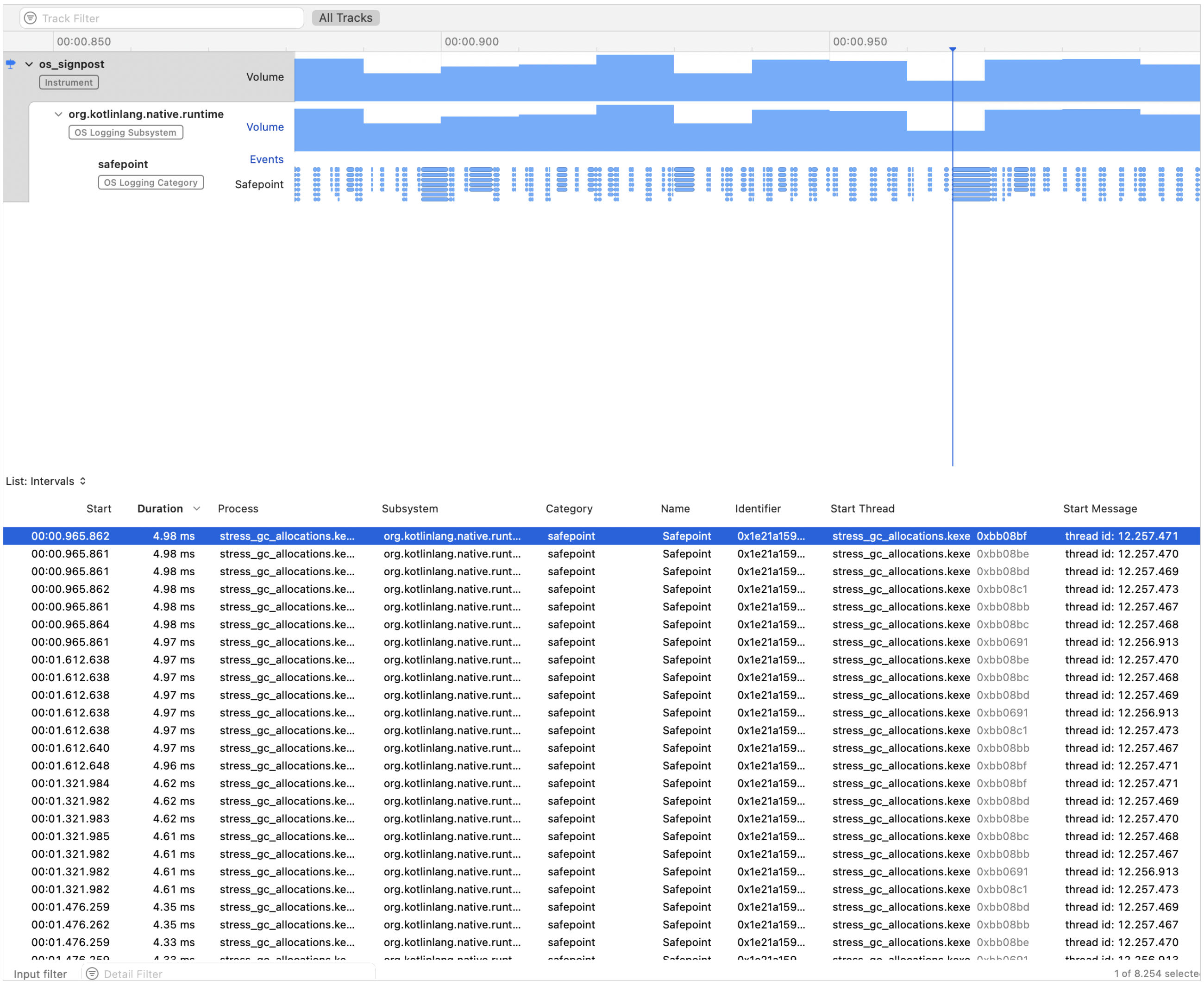
   ```
   kotlin.native.binary.enableSafepointSignposts=true
   ```

2. Open Xcode, go to Product | Profile or press Cmd + I. This action compiles your app and launches Instruments.

3. In the template selection, select os_signpost.

4. Configure it by specifying org.kotlinlang.native.runtime as subsystem and safepoint as category.

5. Click the red record button to run your app and start recording signpost events:



Start	Duration	Process	Subsystem	Category	Name	Identifier	Start Thread	Start Message
00:00.965.862	4.98 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bf	thread id: 12.257.471
00:00.965.861	4.98 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08be	thread id: 12.257.470
00:00.965.861	4.98 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bd	thread id: 12.257.469
00:00.965.862	4.98 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08c1	thread id: 12.257.473
00:00.965.861	4.98 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bb	thread id: 12.257.467
00:00.965.864	4.98 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bc	thread id: 12.257.468
00:00.965.861	4.97 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb0691	thread id: 12.256.913
00:01.612.638	4.97 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08be	thread id: 12.257.470
00:01.612.638	4.97 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bc	thread id: 12.257.468
00:01.612.638	4.97 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bd	thread id: 12.257.469
00:01.612.638	4.97 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb0691	thread id: 12.256.913
00:01.612.638	4.97 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08c1	thread id: 12.257.473
00:01.612.640	4.97 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bb	thread id: 12.257.467
00:01.612.648	4.96 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bf	thread id: 12.257.471
00:01.321.984	4.62 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bf	thread id: 12.257.471
00:01.321.982	4.62 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bd	thread id: 12.257.469
00:01.321.983	4.62 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08be	thread id: 12.257.470
00:01.321.985	4.61 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bc	thread id: 12.257.468
00:01.321.982	4.61 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bb	thread id: 12.257.467
00:01.321.982	4.61 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb0691	thread id: 12.256.913
00:01.321.982	4.61 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08c1	thread id: 12.257.473
00:01.476.259	4.35 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bd	thread id: 12.257.469
00:01.476.262	4.35 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08bb	thread id: 12.257.467
00:01.476.259	4.33 ms	stress_gc_allocations.ke...	org.kotlinlang.native.runt...	safepoint	Safepoint	0x1e21a159...	stress_gc_allocations.kexe 0xbb08be	thread id: 12.257.470

Tracking GC pauses as signposts

Here, each blue blob on the lowest graph represents a separate signpost event, which is a GC pause.

Optimize GC performance

To improve GC performance, you can enable concurrent marking to decrease the GC pause time. This allows the marking phase of garbage collection to run simultaneously with application threads.

The feature is currently Experimental. To enable it, set the following compiler option in your gradle.properties file:

```
kotlin.native.binary.gc=cms
```

Disable garbage collection

It's recommended to keep the GC enabled. However, you can disable it in certain cases, such as for testing purposes or if you encounter issues and have a short-lived program. To do so, set the following binary option in your gradle.properties file:

```
kotlin.native.binary.gc=noop
```

With this option enabled, the GC doesn't collect Kotlin objects, so memory consumption will keep rising as long as the program runs. Be careful not to exhaust the system memory.

Memory consumption

Kotlin/Native uses its own memory allocator. It divides system memory into pages, allowing independent sweeping in consecutive order. Each allocation becomes a memory block within a page, and the page keeps track of block sizes. Different page types are optimized for various allocation sizes. The consecutive arrangement of memory blocks ensures efficient iteration through all allocated blocks.

When a thread allocates memory, it searches for a suitable page based on the allocation size. Threads maintain a set of pages for different size categories. Typically, the current page for a given size can accommodate the allocation. If not, the thread requests a different page from the shared allocation space. This page may already be available, require sweeping, or have to be created first.

The Kotlin/Native memory allocator comes with protection against sudden spikes in memory allocations. It prevents situations where the mutator starts to allocate a lot of garbage quickly and the GC thread cannot keep up with it, making the memory usage grow endlessly. In this case, the GC forces a stop-the-world phase until the iteration is completed.

You can monitor memory consumption yourself, check for memory leaks, and adjust memory consumption.

Monitor memory consumption

To debug memory issues, you can check memory manager metrics. In addition, it's possible to track Kotlin's memory consumption on Apple platforms.

Check for memory leaks

To access the memory manager metrics, call kotlin.native.internal.GC.lastGCInfo(). This method returns statistics for the last run of the garbage collector. The statistics can be useful for:

- Debugging memory leaks when using global variables
- Checking for leaks when running tests

```kotlin
import kotlin.native.internal.*
import kotlin.test.*

class Resource

val global = mutableListOf<Resource>()

@OptIn(ExperimentalStdlibApi::class)
fun getUsage(): Long {
    GC.collect()
    return GC.lastGCInfo!!.memoryUsageAfter["heap"]!!.totalObjectsSizeBytes
}

fun run() {
    global.add(Resource())
    // The test will fail if you remove the next line
    global.clear()
}

@Test
fun test() {
    val before = getUsage()
    // A separate function is used to ensure that all temporary objects are cleared
    run()
    val after = getUsage()
    assertEquals(before, after)
}
```

Track memory consumption on Apple platforms

When debugging memory issues on Apple platforms, you can see how much memory is reserved by Kotlin code. Kotlin's share is tagged with an identifier and can be tracked through tools like VM Tracker in Xcode Instruments.

The feature is available only for the default Kotlin/Native memory allocator when all the following conditions are met:

- Tagging enabled. The memory should be tagged with a valid identifier. Apple recommends numbers between 240 and 255; the default value is 246.

  If you set up the kotlin.native.binary.mmapTag=0 Gradle property, tagging is disabled.

- Allocation with mmap. The allocator should use the mmap system call to map files into memory.

  If you set up the kotlin.native.binary.disableMmap=true Gradle property, the default allocator uses malloc instead of mmap.

- Paging enabled. Paging of allocations (buffering) should be enabled.

  If you set up the kotlin.native.binary.pagedAllocator=false Gradle property, the memory is reserved on a per-object basis instead.

Adjust memory consumption

If you experience unexpectedly high memory consumption, try the following solutions:

Update Kotlin

Update Kotlin to the latest version. We're constantly improving the memory manager, so even a simple compiler update might improve memory consumption.

Disable allocator paging

You can disable paging of allocations (buffering) so that the memory allocator reserves memory on a per-object basis. In some cases, it may help you satisfy strict memory limitations or reduce memory consumption on the application's startup.

To do that, set the following option in your gradle.properties file:

```
kotlin.native.binary.pagedAllocator=false
```

> With allocator paging disabled, tracking memory consumption on Apple platforms is not possible.

Enable support for Latin-1 strings

By default, strings in Kotlin are stored using UTF-16 encoding, where each character is represented by two bytes. In some cases, it leads to strings taking up twice as much space in the binary compared to the source code and reading data taking up twice as much memory.

To reduce the application's binary size and adjust memory consumption, you can enable support for Latin-1-encoded strings. The Latin-1 (ISO 8859-1) encoding represents each of the first 256 Unicode characters by just one byte.

To enable it, set the following option in your gradle.properties file:

```
kotlin.native.binary.latin1Strings=true
```

With the Latin-1 support, strings are stored in Latin-1 encoding as long as all the characters fall within its range. Otherwise, the default UTF-16 encoding is used.

> While the feature is Experimental, the cinterop extension functions String.pin, String.usePinned, and String.refTo become less efficient. Each call to them may trigger an automatic string conversion to UTF-16.

If none of these options helped, create an issue in YouTrack.

Unit tests in the background

In unit tests, nothing processes the main thread queue, so don't use Dispatchers.Main unless it was mocked. Mocking it can be done by calling Dispatchers.setMain from kotlinx-coroutines-test.

If you don't rely on kotlinx.coroutines or if Dispatchers.setMain doesn't work for you for some reason, try the following workaround for implementing the test launcher:

```
package testlauncher

import platform.CoreFoundation.*
import kotlin.native.concurrent.*
import kotlin.native.internal.test.*
import kotlin.system.*

fun mainBackground(args: Array<String>) {
    val worker = Worker.start(name = "main-background")
    worker.execute(TransferMode.SAFE, { args.freeze() }) {
        val result = testLauncherEntryPoint(it)
        exitProcess(result)
    }
    CFRunLoopRun()
    error("CFRunLoopRun should never return")
}
```

Then, compile the test binary with the -e testlauncher.mainBackground compiler option.

What's next

- Migrate from the legacy memory manager
- Check the specifics of integration with Swift/Objective-C ARC

Integration with Swift/Objective-C ARC

Kotlin and Objective-C use different memory management strategies. Kotlin has a tracing garbage collector, while Objective-C relies on automatic reference counting (ARC).

The integration between these strategies is usually seamless and generally requires no additional work. However, there are some specifics you should keep in mind:

Threads

Deinitializers

Deinitialization on the Swift/Objective-C objects and the objects they refer to is called on the main thread if these objects are passed to Kotlin on the main thread, for example:

```
// Kotlin
class KotlinExample {
    fun action(arg: Any) {
        println(arg)
    }
}
```

```
// Swift
class SwiftExample {
    init() {
        print("init on \(Thread.current)")
    }

    deinit {
        print("deinit on \(Thread.current)")
    }
}

func test() {
    KotlinExample().action(arg: SwiftExample())
}
```

The resulting output:

```
init on <_NSMainThread: 0x600003bc0000>{number = 1, name = main}
shared.SwiftExample
deinit on <_NSMainThread: 0x600003bc0000>{number = 1, name = main}
```

Deinitialization on the Swift/Objective-C objects is called on a special GC thread instead of the main one if:

- Swift/Objective-C objects are passed to Kotlin on a thread other than main.
- The main dispatch queue isn't processed.

If you want to call deinitialization on a special GC thread explicitly, set kotlin.native.binary.objcDisposeOnMain=false in your gradle.properties. This option enables deinitialization on a special GC thread, even if Swift/Objective-C objects were passed to Kotlin on the main thread.

A special GC thread complies with the Objective-C runtime, meaning that it has a run loop and drain autorelease pools.

Completion handlers

When calling Kotlin suspending functions from Swift, completion handlers might be called on threads other than the main one, for example:

```
// Kotlin
// coroutineScope, launch, and delay are from kotlinx.coroutines
suspend fun asyncFunctionExample() = coroutineScope {
    launch {
        delay(1000L)
        println("World!")
    }
    println("Hello")
}
```

```
// Swift
func test() {
    print("Running test on \(Thread.current)")
    PlatformKt.asyncFunctionExample(completionHandler: { _ in
        print("Running completion handler on \(Thread.current)")
    })
}
```

The resulting output:

```
Running test on <_NSMainThread: 0x600001b100c0>{number = 1, name = main}
Hello
World!
Running completion handler on <NSThread: 0x600001b45bc0>{number = 7, name = (null)}
```

Garbage collection and lifecycle

Object reclamation

An object is reclaimed only during the garbage collection. This applies to Swift/Objective-C objects that cross interop boundaries into Kotlin/Native, for example:

```
// Kotlin
class KotlinExample {
    fun action(arg: Any) {
        println(arg)
    }
}
```

```
// Swift
class SwiftExample {
    deinit {
        print("SwiftExample deinit")
    }
}

func test() {
    swiftTest()
    kotlinTest()
}

func swiftTest() {
    print(SwiftExample())
    print("swiftTestFinished")
}

func kotlinTest() {
    KotlinExample().action(arg: SwiftExample())
    print("kotlinTest finished")
}
```

The resulting output:

```
shared.SwiftExample
SwiftExample deinit
swiftTestFinished
shared.SwiftExample
kotlinTest finished
SwiftExample deinit
```

Objective-C objects lifecycle

The Objective-C objects might live longer than they should, which sometimes might cause performance issues. For example, when a long-running loop creates several temporary objects that cross the Swift/Objective-C interop boundary on each iteration.

In the GC logs, there's a number of stable refs in the root set. If this number keeps growing, it may indicate that the Swift/Objective-C objects are not freed up when they should. In this case, try the autoreleasepool block around loop bodies that do interop calls:

```
// Kotlin
fun growingMemoryUsage() {
    repeat(Int.MAX_VALUE) {
        NSLog("$it\n")
    }
}

fun steadyMemoryUsage() {
    repeat(Int.MAX_VALUE) {
        autoreleasepool {
            NSLog("$it\n")
        }
    }
}
```

Garbage collection of Swift and Kotlin objects' chains

Consider the following example:

```
// Kotlin
interface Storage {
    fun store(arg: Any)
}

class KotlinStorage(var field: Any? = null) : Storage {
    override fun store(arg: Any) {
        field = arg
    }
}

class KotlinExample {
    fun action(firstSwiftStorage: Storage, secondSwiftStorage: Storage) {
        // Here, we create the following chain:
        // firstKotlinStorage -> firstSwiftStorage -> secondKotlinStorage -> secondSwiftStorage.
        val firstKotlinStorage = KotlinStorage()
        firstKotlinStorage.store(firstSwiftStorage)
        val secondKotlinStorage = KotlinStorage()
        firstSwiftStorage.store(secondKotlinStorage)
        secondKotlinStorage.store(secondSwiftStorage)
    }
}
```

```
// Swift
class SwiftStorage : Storage {

    let name: String

    var field: Any? = nil

    init(_ name: String) {
        self.name = name
    }

    func store(arg: Any) {
        field = arg
    }

    deinit {
        print("deinit SwiftStorage \(name)")
    }
}

func test() {
    KotlinExample().action(
        firstSwiftStorage: SwiftStorage("first"),
        secondSwiftStorage: SwiftStorage("second")
    )
}
```

It takes some time between "deinit SwiftStorage first" and "deinit SwiftStorage second" messages to appear in the log. The reason is that firstKotlinStorage and secondKotlinStorage are collected in different GC cycles. Here's the sequence of events:

1. KotlinExample.action finishes. firstKotlinStorage is considered "dead" because nothing references it, while secondKotlinStorage is not because it is referenced by firstSwiftStorage.
2. First GC cycle starts, and firstKotlinStorage is collected.
3. There are no references to firstSwiftStorage, so it is "dead" as well, and deinit is called.
4. Second GC cycle starts. secondKotlinStorage is collected because firstSwiftStorage is no longer referencing it.
5. secondSwiftStorage is finally reclaimed.

It requires two GC cycles to collect these four objects because deinitialization of Swift and Objective-C objects happens after the GC cycle. The limitation stems from deinit, which can call arbitrary code, including the Kotlin code that cannot be run during the GC pause.

Retain cycles

In a retain cycle, a number of objects refer each other using strong references cyclically:

Kotlin's tracing GC and Objective-C's ARC handle retain cycles differently. When objects become unreachable, Kotlin's GC can properly reclaim such cycles, while Objective-C's ARC cannot. Therefore, retain cycles of Kotlin objects can be reclaimed, while retain cycles of Swift/Objective-C objects cannot.

Consider the case when a retain cycle contains both Objective-C and Kotlin objects:

This involves combining Kotlin's and Objective-C's memory management models that cannot handle (reclaim) retain cycles together. That means if at least one Objective-C object is present, the retain cycle of a whole graph of objects cannot be reclaimed, and it's impossible to break the cycle from the Kotlin side.

Unfortunately, no special instruments are currently available to automatically detect retain cycles in Kotlin/Native code. To avoid retain cycles, use weak or unowned references.

Support for background state and App Extensions

The current memory manager does not track application state by default and does not integrate with App Extensions out of the box.

It means that the memory manager doesn't adjust GC behavior accordingly, which might be harmful in some cases. To change this behavior, add the following

Experimental binary option to your gradle.properties:

```
kotlin.native.binary.appStateTracking=enabled
```

It turns off a timer-based invocation of the garbage collector when the application is in the background, so GC is called only when memory consumption becomes too high.

What's next

Learn more about Swift/Objective-C interoperability.

Migrate to the new memory manager

> Support for the legacy memory manager has been completely removed in Kotlin 1.9.20. Migrate your projects to the current memory model, enabled by default since Kotlin 1.7.20.

This guide compares the new Kotlin/Native memory manager with the legacy one and describes how to migrate your projects.

The most noticeable change in the new memory manager is lifting restrictions on object sharing. You don't need to freeze objects to share them between threads, specifically:

- Top-level properties can be accessed and modified by any thread without using @SharedImmutable.
- Objects passing through interop can be accessed and modified by any thread without freezing them.
- Worker.executeAfter no longer requires operations to be frozen.
- Worker.execute no longer requires producers to return an isolated object subgraph.
- Reference cycles containing AtomicReference and FreezableAtomicReference do not cause memory leaks.

Apart from easy object sharing, the new memory manager also brings other major changes:

- Global properties are initialized lazily when the file they are defined in is accessed first. Previously global properties were initialized at the program startup. As a workaround, you can mark properties that must be initialized at the program start with the @EagerInitialization annotation. Before using, check its documentation.
- by lazy {} properties support thread-safety modes and do not handle unbounded recursion.
- Exceptions that escape operation in Worker.executeAfter are processed like in other runtime parts, by trying to execute a user-defined unhandled exception hook or terminating the program if the hook was not found or failed with an exception itself.
- Freezing is deprecated and always disabled.

Follow these guidelines to migrate your projects from the legacy memory manager:

Update Kotlin

The new Kotlin/Native memory manager has been enabled by default since Kotlin 1.7.20. Check the Kotlin version and update to the latest one if necessary.

Update dependencies

kotlinx.coroutines
Update to version 1.6.0 or later. Do not use versions with the native-mt suffix.

There are also some specifics with the new memory manager you should keep in mind:

- Every common primitive (channels, flows, coroutines) works through the Worker boundaries, since freezing is not required.
- Dispatchers.Default is backed by a pool of Workers on Linux and Windows and by a global queue on Apple targets.
- Use newSingleThreadContext to create a coroutine dispatcher that is backed by a Worker.

- Use newFixedThreadPoolContext to create a coroutine dispatcher backed by a pool of N Workers.
- Dispatchers.Main is backed by the main queue on Darwin and by a standalone Worker on other platforms.

Ktor
Update to version 2.0 or later.

Other dependencies
The majority of libraries should work without any changes, however, there might be exceptions.

Make sure that you update dependencies to the latest versions, and there is no difference between library versions for the legacy and the new memory manager.

Update your code

To support the new memory manager, remove usages of the affected API:

Old API	What to do
@SharedImmutable	You can remove all usages, though there are no warnings for using this API in the new memory manager.
The FreezableAtomicReference class	Use AtomicReference instead.
The FreezingException class	Remove all usages.
The InvalidMutabilityException class	Remove all usages.
The IncorrectDereferenceException class	Remove all usages.
The freeze() function	Remove all usages.
The isFrozen property	You can remove all usages. Since freezing is deprecated, the property always returns false.
The ensureNeverFrozen() function	Remove all usages.
The atomicLazy() function	Use lazy() instead.
The MutableData class	Use any regular collection instead.
The WorkerBoundReference<out T : Any> class	Use T directly.
The DetachedObjectGraph<T> class	Use T directly. To pass the value through the C interop, use the StableRef class.

What's next

- Learn more about the new memory manager
- Check the specifics of integration with Swift/Objective-C ARC

* Learn how to reference objects safely from different coroutines

Debugging Kotlin/Native

Currently, the Kotlin/Native compiler produces debug info compatible with the DWARF 2 specification, so modern debugger tools can perform the following operations:

* breakpoints
* stepping
* inspection of type information
* variable inspection

> Supporting the DWARF 2 specification means that the debugger tool recognizes Kotlin as C89, because before the DWARF 5 specification, there is no identifier for the Kotlin language type in specification.

Produce binaries with debug info with Kotlin/Native compiler

To produce binaries with the Kotlin/Native compiler, use the -g option on the command line.

```
0:b-debugger-fixes:minamoto@unit-703(0)# cat - > hello.kt
fun main(args: Array<String>) {
  println("Hello world")
  println("I need your clothes, your boots and your motocycle")
}
0:b-debugger-fixes:minamoto@unit-703(0)# dist/bin/konanc -g hello.kt -o terminator
KtFile: hello.kt
0:b-debugger-fixes:minamoto@unit-703(0)# lldb terminator.kexe
(lldb) target create "terminator.kexe"
Current executable set to 'terminator.kexe' (x86_64).
(lldb) b kfun:main(kotlin.Array<kotlin.String>)
Breakpoint 1: where = terminator.kexe`kfun:main(kotlin.Array<kotlin.String>) + 4 at hello.kt:2, address = 0x00000001000012e4
(lldb) r
Process 28473 launched: '/Users/minamoto/ws/.git-trees/debugger-fixes/terminator.kexe' (x86_64)
Process 28473 stopped
* thread #1, queue = 'com.apple.main-thread', stop reason = breakpoint 1.1
    frame #0: 0x00000001000012e4 terminator.kexe`kfun:main(kotlin.Array<kotlin.String>) at hello.kt:2
   1    fun main(args: Array<String>) {
-> 2      println("Hello world")
   3      println("I need your clothes, your boots and your motocycle")
   4    }
(lldb) n
Hello world
Process 28473 stopped
* thread #1, queue = 'com.apple.main-thread', stop reason = step over
    frame #0: 0x00000001000012f0 terminator.kexe`kfun:main(kotlin.Array<kotlin.String>) at hello.kt:3
   1    fun main(args: Array<String>) {
   2      println("Hello world")
-> 3      println("I need your clothes, your boots and your motocycle")
   4    }
(lldb)
```

Breakpoints

Modern debuggers provide several ways to set a breakpoint, see below for a tool-by-tool breakdown:

lldb

* by name

```
(lldb) b -n kfun:main(kotlin.Array<kotlin.String>)
Breakpoint 4: where = terminator.kexe`kfun:main(kotlin.Array<kotlin.String>) + 4 at hello.kt:2, address = 0x00000001000012e4
```

-n is optional, this flag is applied by default

- by location (filename, line number)

```
(lldb) b -f hello.kt -l 1
Breakpoint 1: where = terminator.kexe`kfun:main(kotlin.Array<kotlin.String>) + 4 at hello.kt:2, address = 0x00000001000012e4
```

- by address

```
(lldb) b -a 0x00000001000012e4
Breakpoint 2: address = 0x00000001000012e4
```

- by regex, you might find it useful for debugging generated artifacts, like lambda etc. (where used # symbol in name).

```
3: regex = 'main\(', locations = 1
  3.1: where = terminator.kexe`kfun:main(kotlin.Array<kotlin.String>) + 4 at hello.kt:2, address =
terminator.kexe[0x00000001000012e4], unresolved, hit count = 0
```

gdb

- by regex

```
(gdb) rbreak main(
Breakpoint 1 at 0x1000109b4
struct ktype:kotlin.Unit &kfun:main(kotlin.Array<kotlin.String>);
```

- by name unusable, because : is a separator for the breakpoint by location

```
(gdb) b kfun:main(kotlin.Array<kotlin.String>)
No source file named kfun.
Make breakpoint pending on future shared library load? (y or [n]) y
Breakpoint 1 (kfun:main(kotlin.Array<kotlin.String>)) pending
```

- by location

```
(gdb) b hello.kt:1
Breakpoint 2 at 0x100001704: file /Users/minamoto/ws/.git-trees/hello.kt, line 1.
```

- by address

```
(gdb) b *0x100001704
Note: breakpoint 2 also set at pc 0x100001704.
Breakpoint 3 at 0x100001704: file /Users/minamoto/ws/.git-trees/hello.kt, line 2.
```

Stepping

Stepping functions works mostly the same way as for C/C++ programs.

Variable inspection

Variable inspections for var variables works out of the box for primitive types. For non-primitive types there are custom pretty printers for lldb in konan_lldb.py:

```
λ cat main.kt | nl
     1  fun main(args: Array<String>) {
     2      var x = 1
     3      var y = 2
     4      var p = Point(x, y)
     5      println("p = $p")
     6  }

     7  data class Point(val x: Int, val y: Int)
```

```
λ lldb ./program.kexe -o 'b main.kt:5' -o
(lldb) target create "./program.kexe"
Current executable set to './program.kexe' (x86_64).
(lldb) b main.kt:5
Breakpoint 1: where = program.kexe`kfun:main(kotlin.Array<kotlin.String>) + 289 at main.kt:5, address = 0x000000000040af11
(lldb) r
Process 4985 stopped
* thread #1, name = 'program.kexe', stop reason = breakpoint 1.1
    frame #0: program.kexe`kfun:main(kotlin.Array<kotlin.String>) at main.kt:5
   2        var x = 1
   3        var y = 2
   4        var p = Point(x, y)
-> 5        println("p = $p")
   6    }
   7
   8    data class Point(val x: Int, val y: Int)

Process 4985 launched: './program.kexe' (x86_64)
(lldb) fr var
(int) x = 1
(int) y = 2
(ObjHeader *) p = 0x00000000007643d8
(lldb) command script import dist/tools/konan_lldb.py
(lldb) fr var
(int) x = 1
(int) y = 2
(ObjHeader *) p = [x: ..., y: ...]
(lldb) p p
(ObjHeader *) $2 = [x: ..., y: ...]
(lldb) script lldb.frame.FindVariable("p").GetChildMemberWithName("x").Dereference().GetValue()
'1'
(lldb)
```

Getting representation of the object variable (var) could also be done using the built-in runtime function Konan_DebugPrint (this approach also works for gdb, using a module of command syntax):

```
0:b-debugger-fixes:minamoto@unit-703(0)# cat ../debugger-plugin/1.kt | nl -p
     1  fun foo(a:String, b:Int) = a + b
     2  fun one() = 1
     3  fun main(arg:Array<String>) {
     4    var a_variable = foo("(a_variable) one is ", 1)
     5    var b_variable = foo("(b_variable) two is ", 2)
     6    var c_variable = foo("(c_variable) two is ", 3)
     7    var d_variable = foo("(d_variable) two is ", 4)
     8    println(a_variable)
     9    println(b_variable)
    10    println(c_variable)
    11    println(d_variable)
    12  }
0:b-debugger-fixes:minamoto@unit-703(0)# lldb ./program.kexe -o 'b -f 1.kt -l 9' -o r
(lldb) target create "./program.kexe"
Current executable set to './program.kexe' (x86_64).
(lldb) b -f 1.kt -l 9
Breakpoint 1: where = program.kexe`kfun:main(kotlin.Array<kotlin.String>) + 463 at 1.kt:9, address = 0x0000000100000dbf
(lldb) r
(a_variable) one is 1
Process 80496 stopped
* thread #1, queue = 'com.apple.main-thread', stop reason = breakpoint 1.1
    frame #0: 0x0000000100000dbf program.kexe`kfun:main(kotlin.Array<kotlin.String>) at 1.kt:9
   6      var c_variable = foo("(c_variable) two is ", 3)
   7      var d_variable = foo("(d_variable) two is ", 4)
   8      println(a_variable)
-> 9      println(b_variable)
   10     println(c_variable)
   11     println(d_variable)
   12   }

Process 80496 launched: './program.kexe' (x86_64)
(lldb) expression -- (int32_t)Konan_DebugPrint(a_variable)
(a_variable) one is 1(int32_t) $0 = 0
(lldb)
```

Known issues

- performance of Python bindings.

Symbolicating iOS crash reports

Debugging an iOS application crash sometimes involves analyzing crash reports. More info about crash reports can be found in the Apple documentation.

Crash reports generally require symbolication to become properly readable: symbolication turns machine code addresses into human-readable source locations. The document below describes some specific details of symbolicating crash reports from iOS applications using Kotlin.

Producing .dSYM for release Kotlin binaries

To symbolicate addresses in Kotlin code (e.g. for stack trace elements corresponding to Kotlin code) .dSYM bundle for Kotlin code is required.

By default, Kotlin/Native compiler produces .dSYM for release (i.e. optimized) binaries on Darwin platforms. This can be disabled with -Xadd-light-debug=disable compiler flag. At the same time, this option is disabled by default for other platforms. To enable it, use the -Xadd-light-debug=enable compiler option.

Kotlin

```
kotlin {
    targets.withType<org.jetbrains.kotlin.gradle.plugin.mpp.KotlinNativeTarget> {
        binaries.all {
            freeCompilerArgs += "-Xadd-light-debug={enable|disable}"
        }
    }
}
```

Groovy

```
kotlin {
    targets.withType(org.jetbrains.kotlin.gradle.plugin.mpp.KotlinNativeTarget) {
        binaries.all {
            freeCompilerArgs += "-Xadd-light-debug={enable|disable}"
        }
    }
}
```

In projects created from IntelliJ IDEA or AppCode templates these .dSYM bundles are then discovered by Xcode automatically.

Make frameworks static when using rebuild from bitcode

Rebuilding Kotlin-produced framework from bitcode invalidates the original .dSYM. If it is performed locally, make sure the updated .dSYM is used when symbolicating crash reports.

If rebuilding is performed on App Store side, then .dSYM of rebuilt dynamic framework seems discarded and not downloadable from App Store Connect. In this case, it may be required to make the framework static.

Kotlin

```
kotlin {
    targets.withType<org.jetbrains.kotlin.gradle.plugin.mpp.KotlinNativeTarget> {
        binaries.withType<org.jetbrains.kotlin.gradle.plugin.mpp.Framework> {
            isStatic = true
        }
    }
}
```

Groovy

```
kotlin {
    targets.withType(org.jetbrains.kotlin.gradle.plugin.mpp.KotlinNativeTarget) {
        binaries.withType(org.jetbrains.kotlin.gradle.plugin.mpp.Framework) {
            isStatic = true
        }
    }
}
```

Kotlin/Native target support

The Kotlin/Native compiler supports a great number of different targets, though it is hard to provide the same level of support for all of them. This document describes which targets Kotlin/Native supports and breaks them into several tiers depending on how well the compiler supports them.

> We can adjust the number of tiers, the list of supported targets, and their features as we go.

Mind the following terms used in tier tables:

- Gradle target name is a target name that is used in the Kotlin Multiplatform Gradle plugin to enable the target.
- Target triple is a target name according to the <architecture>-<vendor>-<system>-<abi> structure that is commonly used by compilers.
- Running tests indicates out of the box support for running tests in Gradle and IDE.

  This is only available on a native host for the specific target. For example, you can run macosX64 and iosX64 tests only on macOS x86-64 host.

Tier 1

- The target is regularly tested on CI to be able to compile and run.
- We provide a source and binary compatibility between compiler releases.

Gradle target name	Target triple	Running tests	Description
Apple macOS hosts only:			
macosX64	x86_64-apple-macos		Apple macOS on x86_64 platforms
macosArm64	aarch64-apple-macos		Apple macOS on Apple Silicon platforms
iosSimulatorArm64	aarch64-apple-ios-simulator		Apple iOS simulator on Apple Silicon platforms
iosX64	x86_64-apple-ios-simulator		Apple iOS simulator on x86-64 platforms
iosArm64	aarch64-apple-ios		Apple iOS and iPadOS on ARM64 platforms

Tier 2

- The target is regularly tested on CI to be able to compile, but may not be automatically tested to be able to run.
- We're doing our best to provide a source and binary compatibility between compiler releases.

Gradle target name	Target triple	Running tests	Description
linuxX64	x86_64-unknown-linux-gnu		Linux on x86_64 platforms

Gradle target name	Target triple	Running tests	Description
linuxArm64	aarch64-unknown-linux-gnu		Linux on ARM64 platforms
Apple macOS hosts only:			
watchosSimulatorArm64	aarch64-apple-watchos-simulator		Apple watchOS simulator on Apple Silicon platforms
watchosX64	x86_64-apple-watchos-simulator		Apple watchOS 64-bit simulator on x86_64 platforms
watchosArm32	armv7k-apple-watchos		Apple watchOS on ARM32 platforms
watchosArm64	arm64_32-apple-watchos		Apple watchOS on ARM64 platforms with ILP32
tvosSimulatorArm64	aarch64-apple-tvos-simulator		Apple tvOS simulator on Apple Silicon platforms
tvosX64	x86_64-apple-tvos-simulator		Apple tvOS simulator on x86_64 platforms
tvosArm64	aarch64-apple-tvos		Apple tvOS on ARM64 platforms

Tier 3

- The target is not guaranteed to be tested on CI.
- We can't promise a source and binary compatibility between different compiler releases, though such changes for these targets are quite rare.

Gradle target name	Target triple	Running tests	Description
androidNativeArm32	arm-unknown-linux-androideabi		Android NDK on ARM32 platforms
androidNativeArm64	aarch64-unknown-linux-android		Android NDK on ARM64 platforms
androidNativeX86	i686-unknown-linux-android		Android NDK on x86 platforms
androidNativeX64	x86_64-unknown-linux-android		Android NDK on x86_64 platforms
mingwX64	x86_64-pc-windows-gnu		64-bit Windows 10 and later using MinGW compatibility layer
Apple macOS hosts only:			
watchosDeviceArm64	aarch64-apple-watchos		Apple watchOS on ARM64 platforms

The linuxArm32Hfp target is deprecated and will be removed in future releases.

For library authors

We don't recommend library authors to test more targets or provide stricter guarantees than the Kotlin/Native compiler does. You can use the following approach when considering support for native targets:

- Support all the targets from tier 1, 2, and 3.
- Regularly test targets from tier 1 and 2 that support running tests out of the box.

The Kotlin team uses this approach in the official Kotlin libraries, for example, kotlinx.coroutines and kotlinx.serialization.

Tips for improving compilation time

The Kotlin/Native compiler is constantly receiving updates that improve its performance. With the latest Kotlin/Native compiler and a properly configured build environment, you can significantly improve the compilation times of your projects with Kotlin/Native targets.

Read on for our tips on how to speed up the Kotlin/Native compilation process.

General recommendations

Use the latest version of Kotlin

This way, you always get the latest performance improvements. The most recent Kotlin version is 2.2.0.

Avoid creating huge classes

Try to avoid huge classes that take a long time to compile and load during execution.

Preserve downloaded and cached components between builds

When compiling projects, Kotlin/Native downloads the required components and caches some results of its work to the $USER_HOME/.konan directory. The compiler uses this directory for subsequent compilations, making them take less time to complete.

When building in containers (such as Docker) or with continuous integration systems, the compiler may have to create the ~/.konan directory from scratch for each build. To avoid this step, configure your environment to preserve ~/.konan between builds. For example, redefine its location using the kotlin.data.dir Gradle property.

Alternatively, you can use the -Xkonan-data-dir compiler option to configure your custom path to the directory via the cinterop and konanc tools.

Gradle configuration

The first compilation with Gradle usually takes more time than subsequent ones due to the need to download the dependencies, build caches, and perform additional steps. You should build your project at least twice to get an accurate reading of the actual compilation times.

Below are some recommendations for configuring Gradle for better compilation performance.

Increase Gradle heap size

To increase the Gradle heap size, add org.gradle.jvmargs=-Xmx3g to your gradle.properties file.

If you use parallel builds, you might need to choose the right number of workers with the org.gradle.workers.max property or the --max-workers command-line option. The default value is the number of CPU processors.

Build only necessary binaries

Don't run Gradle tasks that build the whole project, such as build or assemble, unless you really need to. These tasks build the same code more than once, increasing the compilation times. In typical cases, such as running tests from IntelliJ IDEA or starting the app from Xcode, the Kotlin tooling avoids executing unnecessary tasks.

If you have a non-typical case or build configuration, you might need to choose the task yourself:

- linkDebug*. To run your code during development, you usually need only one binary, so running the corresponding linkDebug* task should be enough.
- embedAndSignAppleFrameworkForXcode. Since iOS simulators and devices have different processor architectures, it's a common approach to distribute a Kotlin/Native binary as a universal (fat) framework.

  However, during local development, it's faster to build the .framework file only for the platform you're using. To build a platform-specific framework, use the embedAndSignAppleFrameworkForXcode task.

Build only for necessary targets

Similarly to the recommendation above, don't build a binary for all native platforms at once. For example, compiling an XCFramework (using an *XCFramework task) builds the same code for all targets, which takes proportionally more time than building for a single target.

If you do need XCFrameworks for your setup, you can reduce the number of targets. For example, you don't need iosX64 if you don't run this project on iOS simulators on Intel-based Macs.

> Binaries for different targets are built with linkDebug*$Target and linkRelease*$Target Gradle tasks. You can look for the executed tasks in the build log or in the Gradle build scan by running a Gradle build with the --scan option.

Don't build unnecessary release binaries

Kotlin/Native supports two build modes, debug and release. Release is highly optimized, and this takes a lot of time: compilation of release binaries takes an order of magnitude more time than debug binaries.

Apart from an actual release, all these optimizations might be unnecessary in a typical development cycle. If you use a task with Release in its name during the development process, consider replacing it with Debug. Similarly, instead of running assembleXCFramework, you can run assembleSharedDebugXCFramework, for example.

> Release binaries are built with linkRelease* Gradle tasks. You can check for them in the build log or in the Gradle build scan by running a Gradle build with the --scan option.

Don't disable Gradle daemon

Don't disable the Gradle daemon without having a good reason. By default, Kotlin/Native runs from the Gradle daemon. When it's enabled, the same JVM process is used, and there is no need to warm it up for each compilation.

Don't use transitive export

Using transitiveExport = true disables dead code elimination in many cases, so the compiler has to process a lot of unused code. It increases the compilation time. Instead, use the export method explicitly for exporting the required projects and dependencies.

Don't export modules too much

Try to avoid unnecessary module export. Each exported module negatively affects compilation time and binary size.

Use Gradle build caching

Enable the Gradle build cache feature:

- Local build cache. For local caching, add org.gradle.caching=true to your gradle.properties file or run the build with the --build-cache option in the command line.

- Remote build cache. Learn how to configure the remote build cache for continuous integration environments.

Use Gradle configuration cache

To use the Gradle configuration cache, add org.gradle.configuration-cache=true to your gradle.properties file.

> Configuration cache also enables running link* tasks in parallel which could heavily load the machine, specifically with a lot of CPU cores. This issue will be fixed in KT-70915.

Enable previously disabled features

There are Kotlin/Native properties that disable the Gradle daemon and compiler caches:

- kotlin.native.disableCompilerDaemon=true
- kotlin.native.cacheKind=none
- kotlin.native.cacheKind.$target=none, where $target is a Kotlin/Native compilation target, for example iosSimulatorArm64.

If you had issues with these features before and added these lines to your gradle.properties file or Gradle arguments, remove them and check whether the build completes successfully. It is possible that these properties were added previously to work around issues that have already been fixed.

Try incremental compilation of klib artifacts

With incremental compilation, if only a part of the klib artifact produced by the project module changes, just a part of klib is further recompiled into a binary.

This feature is Experimental. To enable it, add the kotlin.incremental.native=true option to your gradle.properties file. If you face any problems, create an issue in YouTrack.

Windows configuration

Windows Security may slow down the Kotlin/Native compiler. You can avoid this by adding the .konan directory, which is located in %USERPROFILE% by default, to Windows Security exclusions. Learn how to add exclusions to Windows Security.

License files for the Kotlin/Native binaries

Like many other open-source projects, Kotlin relies on third-party code, meaning that the Kotlin project includes some code not developed by JetBrains or the Kotlin programming language contributors. Sometimes it is derived work, such as code rewritten from C++ to Kotlin.

> You can find licenses for the third-party work used in Kotlin in our GitHub repository:
>
> - Kotlin compiler
> - Kotlin/Native

In particular, the Kotlin/Native compiler produces binaries that can include third-party code, data, or derived work. This means that the Kotlin/Native-compiled binaries are subject to the terms and conditions of the third-party licenses.

In practice, if you distribute a Kotlin/Native-compiled final binary, you should always include necessary license files in your binary distribution. The files should be accessible to users of your distribution in a readable form.

Always include the following license files for the corresponding projects:

Project	Files to be included

Project	Files to be included
Kotlin	• Apache license 2.0 • Apache Harmony copyright notice
Apache Harmony	
GWT	
Guava	
libbacktrace	3-clause BSD license with copyright notice
mimalloc	MIT license Include in case you use the mimalloc memory allocator instead of the default one (the -Xallocator=mimalloc compiler option is set).
Unicode character database	Unicode license
Multi-producer/multi-consumer bounded queue	Copyright notice

The mingwX64 target requires additional license files:

Project	Files to be included
MinGW-w64 headers and runtime libraries	• MinGW-w64 runtime license • Winpthreads license

None of these libraries require the distributed Kotlin/Native binaries to be open-sourced.

Kotlin/Native FAQ

How do I run my program?

Define a top-level function fun main(args: Array<String>) or just fun main() if you are not interested in passed arguments, please ensure it's not in a package. Also, compiler switch -entry could be used to make any function taking Array<String> or no arguments and return Unit as an entry point.

What is Kotlin/Native memory management model?

Kotlin/Native uses an automated memory management scheme that is similar to what Java or Swift provide.

Learn about the Kotlin/Native memory manager

How do I create a shared library?

Use the -produce dynamic compiler option or binaries.sharedLib() in your Gradle build file:

```
kotlin {
    iosArm64("mylib") {
        binaries.sharedLib()
    }
}
```

It produces a platform-specific shared object (.so on Linux, .dylib on macOS, and .dll on Windows targets) and a C language header, allowing the use of all public APIs available in your Kotlin/Native program from C/C++ code.

Complete the Kotlin/Native as a dynamic library tutorial

How do I create a static library or an object file?

Use the -produce static compiler option or binaries.staticLib() in your Gradle build file:

```
kotlin {
    iosArm64("mylib") {
        binaries.staticLib()
    }
}
```

It produces a platform-specific static object (.a library format) and a C language header, allowing you to use all the public APIs available in your Kotlin/Native program from C/C++ code.

How do I run Kotlin/Native behind a corporate proxy?

As Kotlin/Native needs to download a platform specific toolchain, you need to specify -Dhttp.proxyHost=xxx -Dhttp.proxyPort=xxx as the compiler's or gradlew arguments, or set it via the JAVA_OPTS environment variable.

How do I specify a custom Objective-C prefix/name for my Kotlin framework?

Use the -module-name compiler option or matching Gradle DSL statement.

Kotlin

```
kotlin {
    iosArm64("myapp") {
        binaries.framework {
            freeCompilerArgs += listOf("-module-name", "TheName")
        }
    }
}
```

Groovy

```
kotlin {
    iosArm64("myapp") {
        binaries.framework {
            freeCompilerArgs += ["-module-name", "TheName"]
        }
    }
}
```

How do I rename the iOS framework?

The default name is for an iOS framework is <project name>.framework. To set a custom name, use the baseName option. This will also set the module name.

```
kotlin {
    iosArm64("myapp") {
        binaries {
            framework {
                baseName = "TheName"
            }
        }
    }
}
```

How do I enable bitcode for my Kotlin framework?

Bitcode embedding was deprecated in Xcode 14 and removed in Xcode 15 for all Apple targets. The Kotlin/Native compiler does not support bitcode embedding since Kotlin 2.0.20.

If you're using earlier versions of Xcode but want to upgrade to Kotlin 2.0.20 or later versions, disable bitcode embedding in your Xcode projects.

How do I reference objects safely from different coroutines?

To safely access or update an object across multiple coroutines in Kotlin/Native, consider using concurrency-safe constructs, such as @Volatile and AtomicReference.

Use @Volatile to annotate a var property. This makes all reads and writes to the property's backing field atomic. In addition, writes become immediately visible to other threads. When another thread accesses this property, it observes not only the updated value but also the changes that happened before the update.

Alternatively, use AtomicReference, which supports atomic reads and updates. On Kotlin/Native, it wraps a volatile variable and performs atomic operations. Kotlin also provides a set of types for atomic operations tailored to specific data types. You can use AtomicInt, AtomicLong, AtomicBoolean, AtomicArray, as well as AtomicIntArray and AtomicLongArray.

For more information about access to shared mutable state, see the Coroutines documentation.

How can I compile my project with unreleased versions of Kotlin/Native?

First, please consider trying preview versions.

In case you need an even more recent development version, you can build Kotlin/Native from source code: clone Kotlin repository and follow these steps.

Get started with Kotlin/Wasm and Compose Multiplatform

Kotlin/Wasm is in Alpha. It may be changed at any time.

Join the Kotlin/Wasm community.

This tutorial demonstrates how to run a Compose Multiplatform app with Kotlin/Wasm in IntelliJ IDEA, and generate artifacts to publish as a site on GitHub pages.

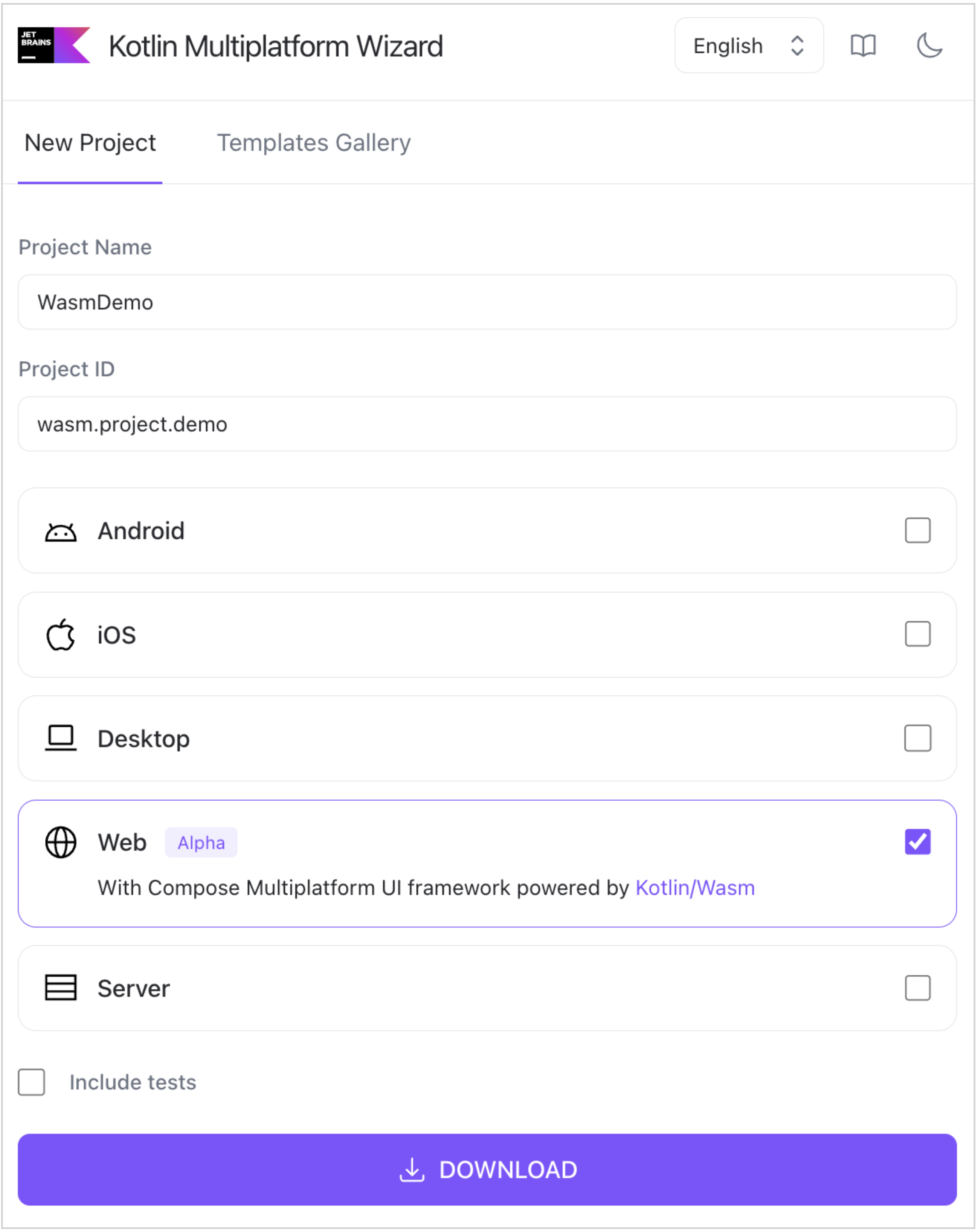
Before you start

Create a project using the Kotlin Multiplatform wizard:

1. Open the Kotlin Multiplatform wizard.
2. On the New Project tab, change the project name and ID to your preference. In this tutorial, we set the name to "WasmDemo" and the ID to "wasm.project.demo".

   These are the name and ID of the project directory. You can also leave them as they are.

3. Select the Web option. Make sure that no other options are selected.
4. Click the Download button and unpack the resulting archive.



Project Name

WasmDemo

Project ID

wasm.project.demo

Android [ ]

iOS [ ]

Desktop [ ]

Web Alpha [✓]

With Compose Multiplatform UI framework powered by Kotlin/Wasm

Server [ ]

[ ] Include tests

Kotlin Multiplatform wizard

Open the project in IntelliJ IDEA

1. Download and install the latest version of IntelliJ IDEA.
2. On the Welcome screen of IntelliJ IDEA, click Open or select File | Open in the menu bar.
3. Navigate to the unpacked "WasmDemo" folder and click Open.

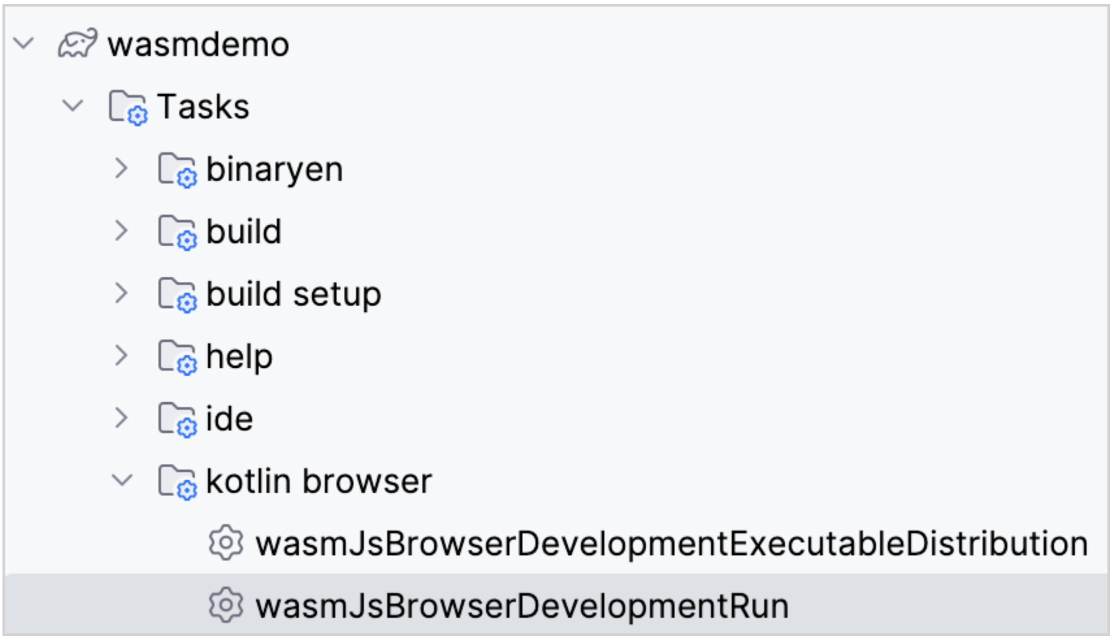
Run the application

1. In IntelliJ IDEA, open the Gradle tool window by selecting View | Tool Windows | Gradle.

   You can find the Gradle tasks in the Gradle tool window once the project loads.

   > You need at least Java 11 as your Gradle JVM for the tasks to load successfully.

2. In wasmdemo | Tasks | kotlin browser, select and run the wasmJsBrowserDevelopmentRun task.

   
   wasmdemo
   Tasks
   binaryen
   build
   build setup
   help
   ide
   kotlin browser
   wasmJsBrowserDevelopmentExecutableDistribution
   wasmJsBrowserDevelopmentRun

   Run the Gradle task

   Alternatively, you can run the following command in the terminal from the WasmDemo root directory:

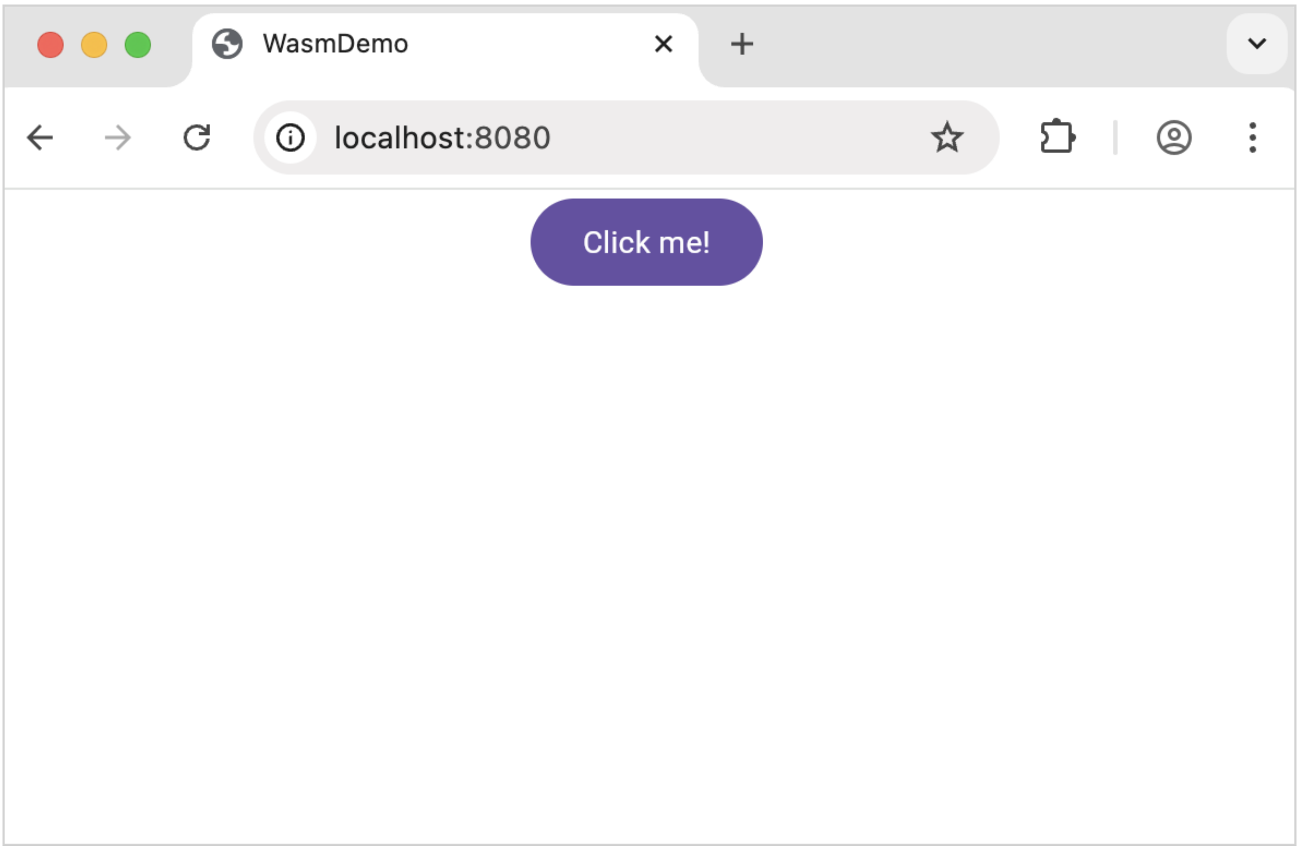
   ```
   ./gradlew wasmJsBrowserDevelopmentRun -t
   ```

3. Once the application starts, open the following URL in your browser:

   ```
   http://localhost:8080/
   ```

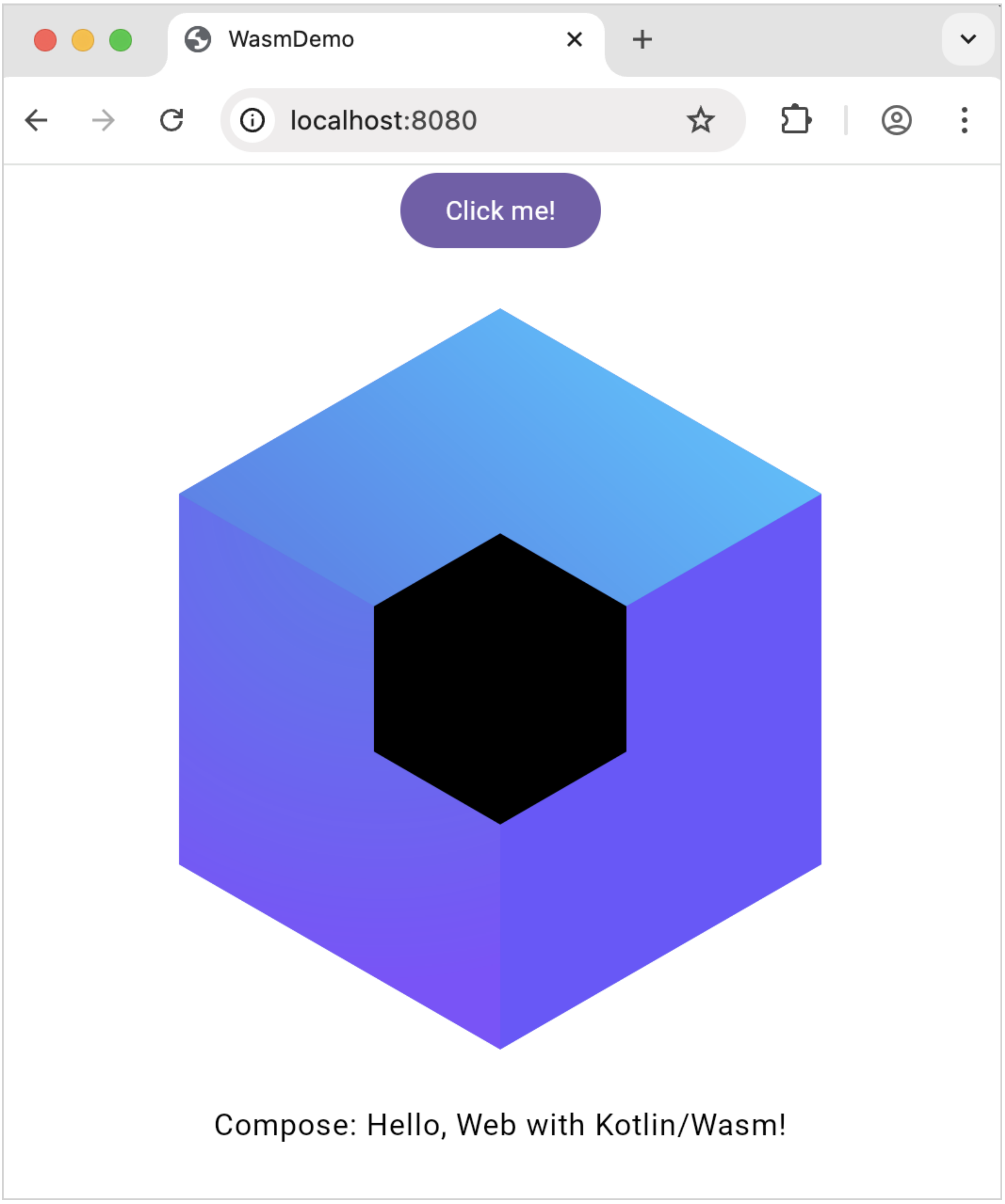
   > The port number can vary because the 8080 port may be unavailable. You can find the actual port number printed in the Gradle build console.

   You see a "Click me!" button. Click it:



Click me

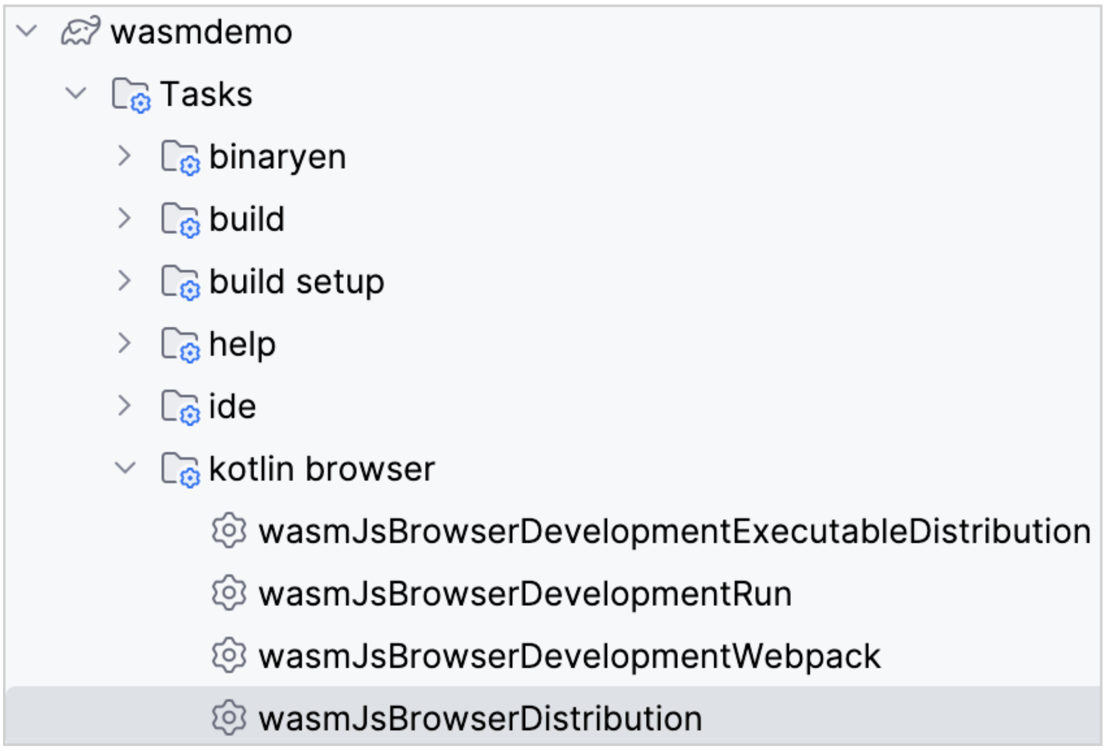
Now you see the Compose Multiplatform logo:



Compose app in browser

Generate artifacts

In wasmdemo | Tasks | kotlin browser, select and run the wasmJsBrowserDistribution task.

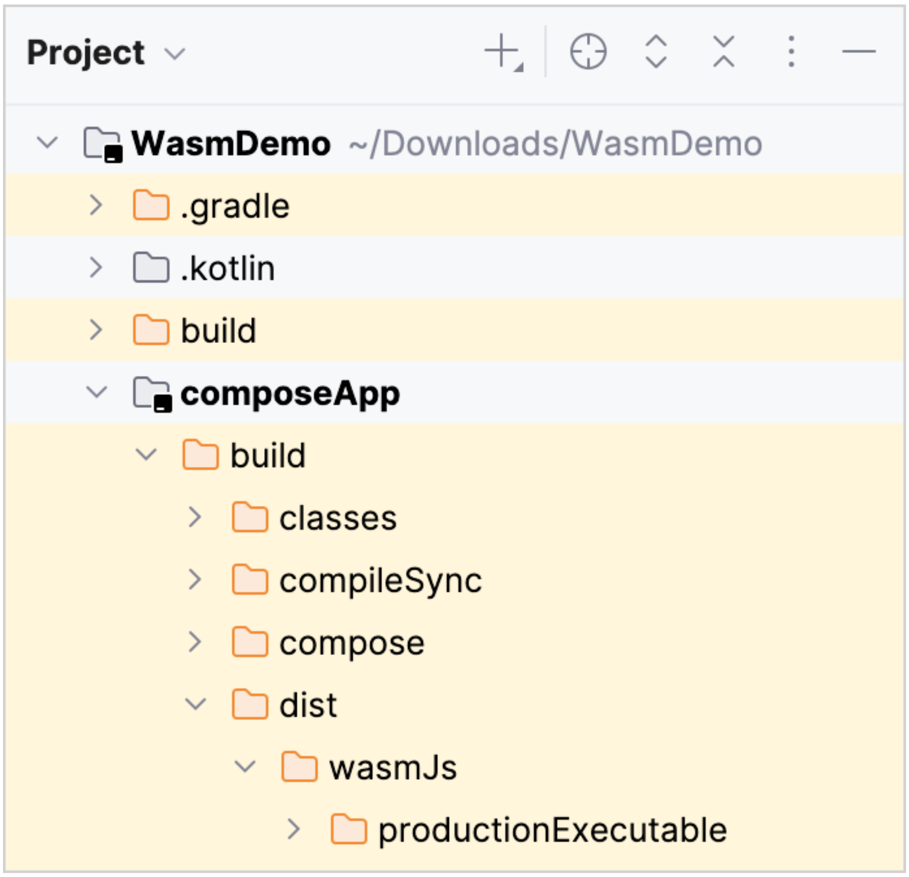

wasmdemo
Tasks
binaryen
build
build setup
help
ide
kotlin browser
wasmJsBrowserDevelopmentExecutableDistribution
wasmJsBrowserDevelopmentRun
wasmJsBrowserDevelopmentWebpack
wasmJsBrowserDistribution

Run the Gradle task

Alternatively, you can run the following command in the terminal from the WasmDemo root directory:

```
./gradlew wasmJsBrowserDistribution
```

Once the application task completes, you can find the generated artifacts in the composeApp/build/dist/wasmJs/productionExecutable directory:



Artifacts directory

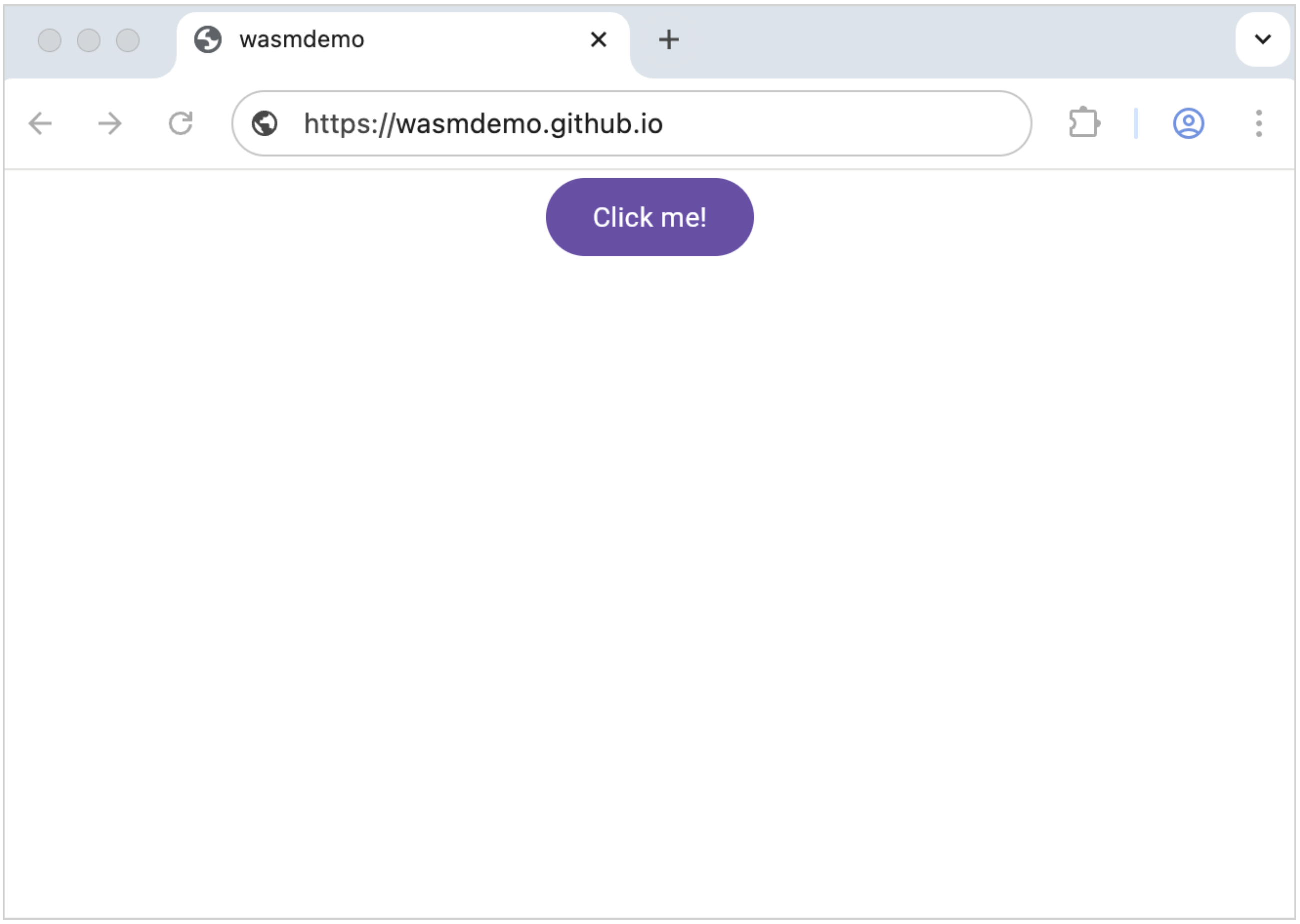
Publish on GitHub pages

1. Copy all the contents in your productionExecutable directory into the repository where you want to create a site.

2. Follow GitHub's instructions for creating your site.

> It can take up to 10 minutes for changes to your site to publish after you push the changes to GitHub.

3. In a browser, navigate to your GitHub pages domain.



Navigate to GitHub pages

Congratulations! You have published your artifacts on GitHub pages.

What's next?

Join the Kotlin/Wasm community in Kotlin Slack:

Join the Kotlin Slack channel →

Join the Kotlin/Wasm community

Try more Kotlin/Wasm examples:

- Compose image viewer
- Jetsnack application
- Node.js example
- WASI example
- Compose example

Get started with Kotlin/Wasm and WASI

Kotlin/Wasm is in Alpha. It may be changed at any time.

Join the Kotlin/Wasm community.

This tutorial demonstrates how to run a simple Kotlin/Wasm application using the WebAssembly System Interface (WASI) in various WebAssembly virtual machines.

You can find examples of an application running on Node.js, Deno, and WasmEdge virtual machines. The output is a simple application that uses the standard WASI API.

Currently, Kotlin/Wasm supports WASI 0.1, also known as Preview 1. Support for WASI 0.2 is planned for future releases.

The Kotlin/Wasm toolchain provides Node.js tasks (wasmWasiNode*) out of the box. Other task variants in the project, such as those utilizing Deno or WasmEdge, are included as custom tasks.

Before you start

1. Download and install the latest version of IntelliJ IDEA.

2. Clone the Kotlin/Wasm WASI template repository by selecting File | New | Project from Version Control in IntelliJ IDEA.

   You can also clone it from the command line:

   ```
   git clone git@github.com:Kotlin/kotlin-wasm-wasi-template.git
   ```

Run the application

1. Open the Gradle tool window by selecting View | Tool Windows | Gradle.

   In the Gradle tool window, you can find the Gradle tasks under kotlin-wasm-wasi-example once the project loads.

   You need at least Java 11 as your Gradle JVM for the tasks to load successfully.

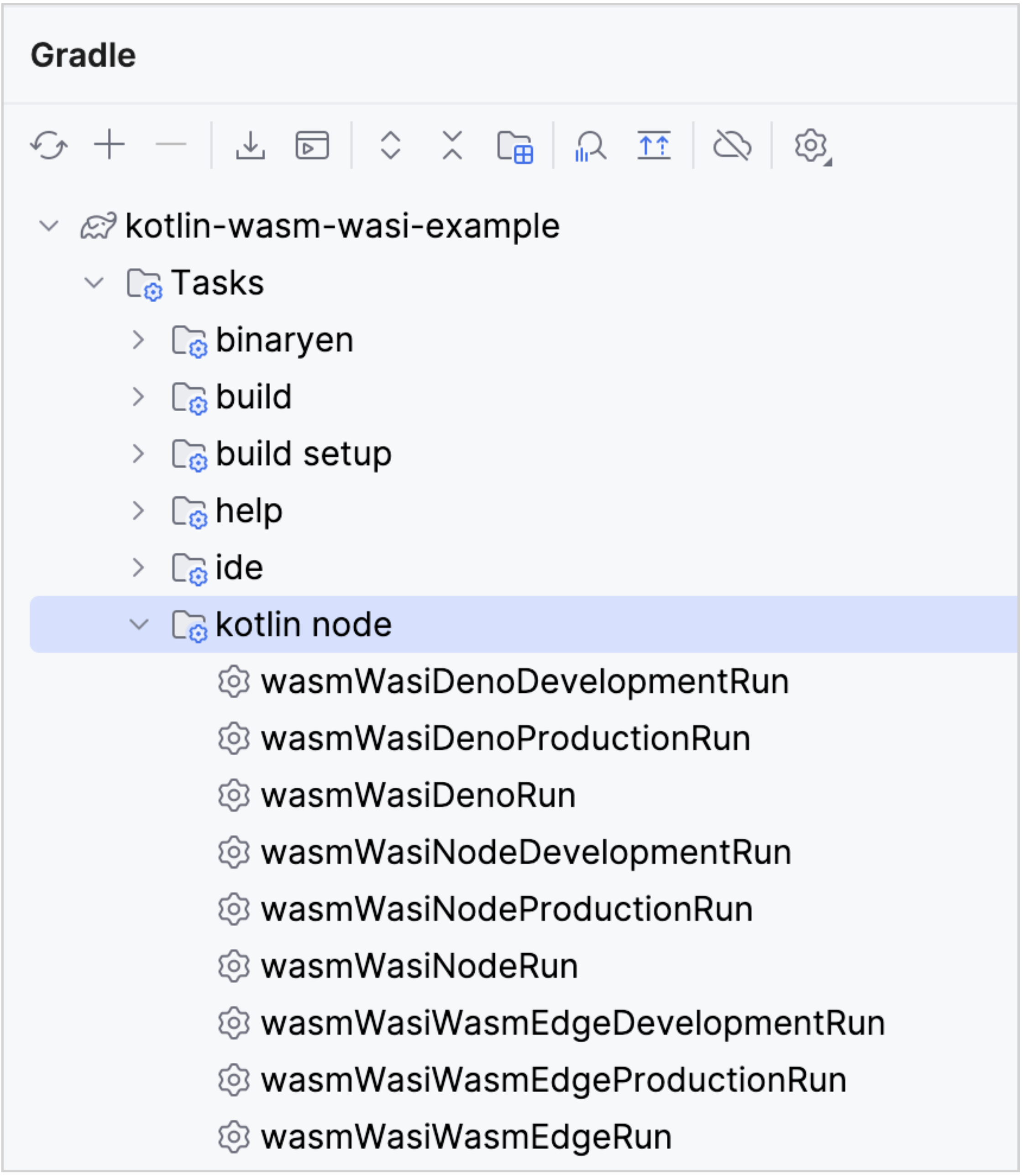
2. From kotlin-wasm-wasi-example | Tasks | kotlin node, select and run one of the following Gradle tasks:

   - wasmWasiNodeRun to run the application in Node.js.

   - wasmWasiDenoRun to run the application in Deno.

   - wasmWasiWasmEdgeRun to run the application in WasmEdge.

     When using Deno on a Windows platform, ensure deno.exe is installed. For more information, see Deno's installation documentation.


Gradle
kotlin-wasm-wasi-example
Tasks
binaryen
build
build setup
help
ide
kotlin node
wasmWasiDenoDevelopmentRun
wasmWasiDenoProductionRun
wasmWasiDenoRun
wasmWasiNodeDevelopmentRun
wasmWasiNodeProductionRun
wasmWasiNodeRun
wasmWasiWasmEdgeDevelopmentRun
wasmWasiWasmEdgeProductionRun
wasmWasiWasmEdgeRun

Kotlin/Wasm and WASI tasks

Alternatively, run one of the following commands in the terminal from the kotlin-wasm-wasi-template root directory:

* To run the application in Node.js:

```
./gradlew wasmWasiNodeRun
```

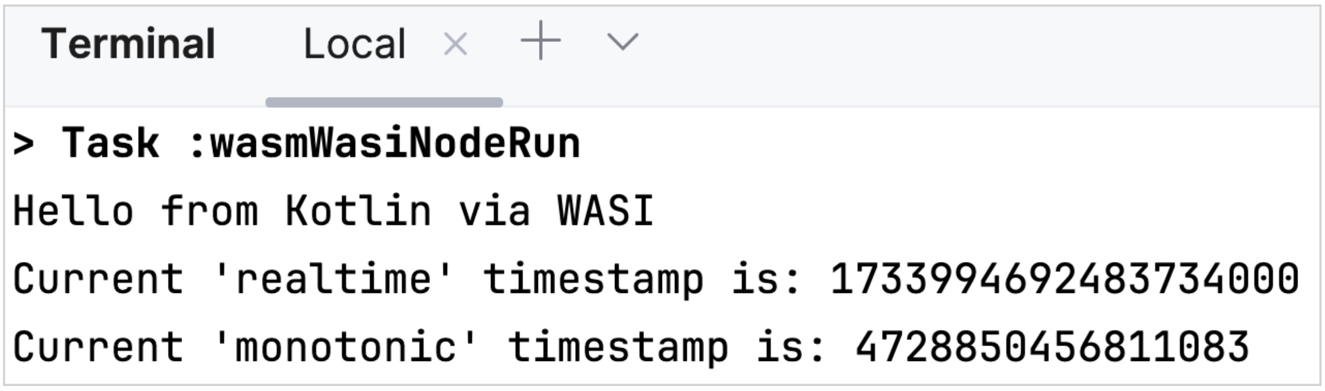
* To run the application in Deno:

```
./gradlew wasmWasiDenoRun
```

* To run the application in WasmEdge:

```
./gradlew wasmWasiWasmEdgeRun
```

The terminal displays a message when your application is built successfully:



```
> Task :wasmWasiNodeRun
Hello from Kotlin via WASI
Current 'realtime' timestamp is: 1733994692483734000
Current 'monotonic' timestamp is: 4728850456811083
```

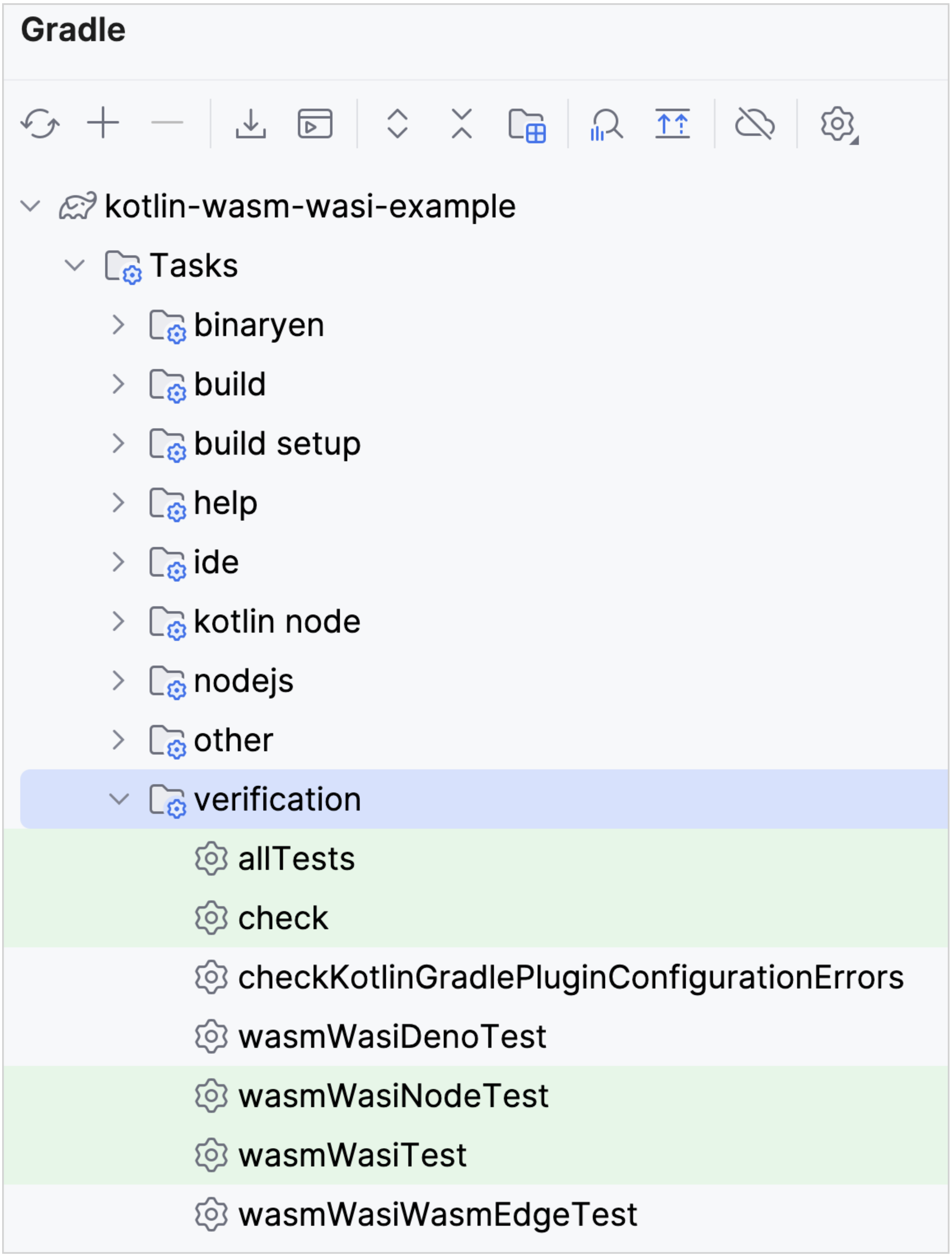
Kotlin/Wasm and WASI app

Test the application

You can also test that the Kotlin/Wasm application works correctly across various virtual machines.

In the Gradle tool window, run one of the following Gradle tasks from kotlin-wasm-wasi-example | Tasks | verification:

- wasmWasiNodeTest to test the application in Node.js.
- wasmWasiDenoTest to test the application in Deno.
- wasmWasiWasmEdgeTest to test the application in WasmEdge.



```
kotlin-wasm-wasi-example
  Tasks
    binaryen
    build
    build setup
    help
    ide
    kotlin node
    nodejs
    other
    verification
      allTests
      check
      checkKotlinGradlePluginConfigurationErrors
      wasmWasiDenoTest
      wasmWasiNodeTest
      wasmWasiTest
      wasmWasiWasmEdgeTest
```

Kotlin/Wasm and WASI test tasks

Alternatively, run one of the following commands in the terminal from the kotlin-wasm-wasi-template root directory:

* To test the application in Node.js:

```
./gradlew wasmWasiNodeTest
```

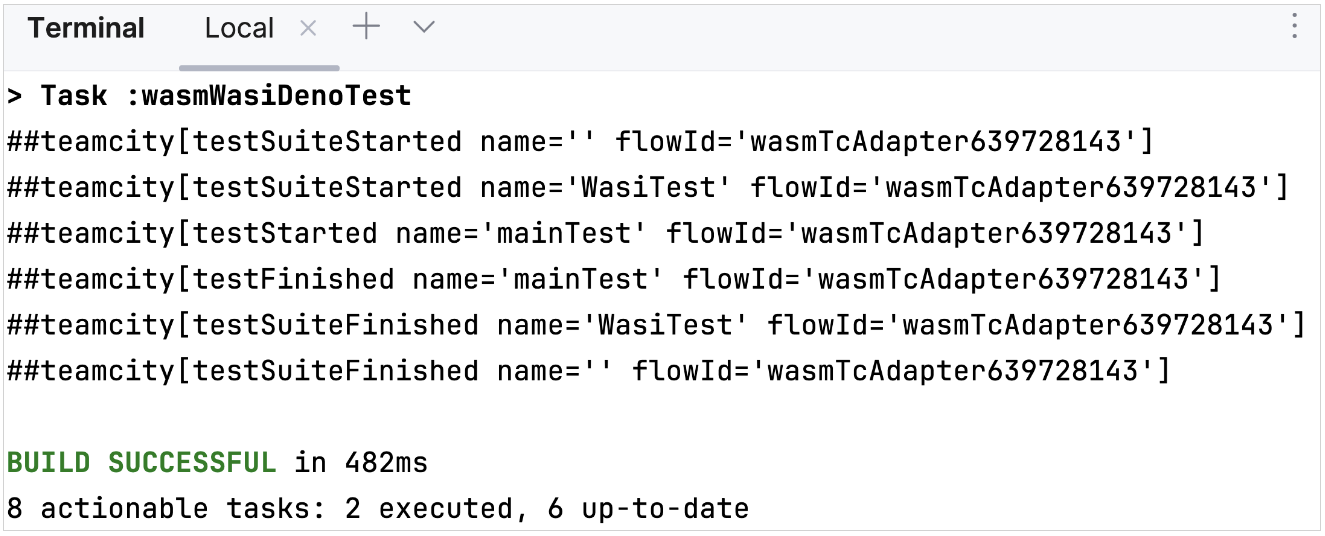
* To test the application in Deno:

```
./gradlew wasmWasiDenoTest
```

* To test the application in WasmEdge:

```
./gradlew wasmWasiWasmEdgeTest
```

The terminal displays the test results:



```
> Task :wasmWasiDenoTest
##teamcity[testSuiteStarted name='' flowId='wasmTcAdapter639728143']
##teamcity[testSuiteStarted name='WasiTest' flowId='wasmTcAdapter639728143']
##teamcity[testStarted name='mainTest' flowId='wasmTcAdapter639728143']
##teamcity[testFinished name='mainTest' flowId='wasmTcAdapter639728143']
##teamcity[testSuiteFinished name='WasiTest' flowId='wasmTcAdapter639728143']
##teamcity[testSuiteFinished name='' flowId='wasmTcAdapter639728143']

BUILD SUCCESSFUL in 482ms
8 actionable tasks: 2 executed, 6 up-to-date
```

Kotlin/Wasm and WASI test

What's next?

Join the Kotlin/Wasm community in Kotlin Slack:

Join the Kotlin Slack channel →

Join the Kotlin/Wasm community

Try more Kotlin/Wasm examples:

* Compose image viewer
* Jetsnack application
* Node.js example
* Compose example

Debug Kotlin/Wasm code

Kotlin/Wasm is Alpha. It may be changed at any time.

This tutorial demonstrates how to use your browser to debug your Compose Multiplatform application built with Kotlin/Wasm.

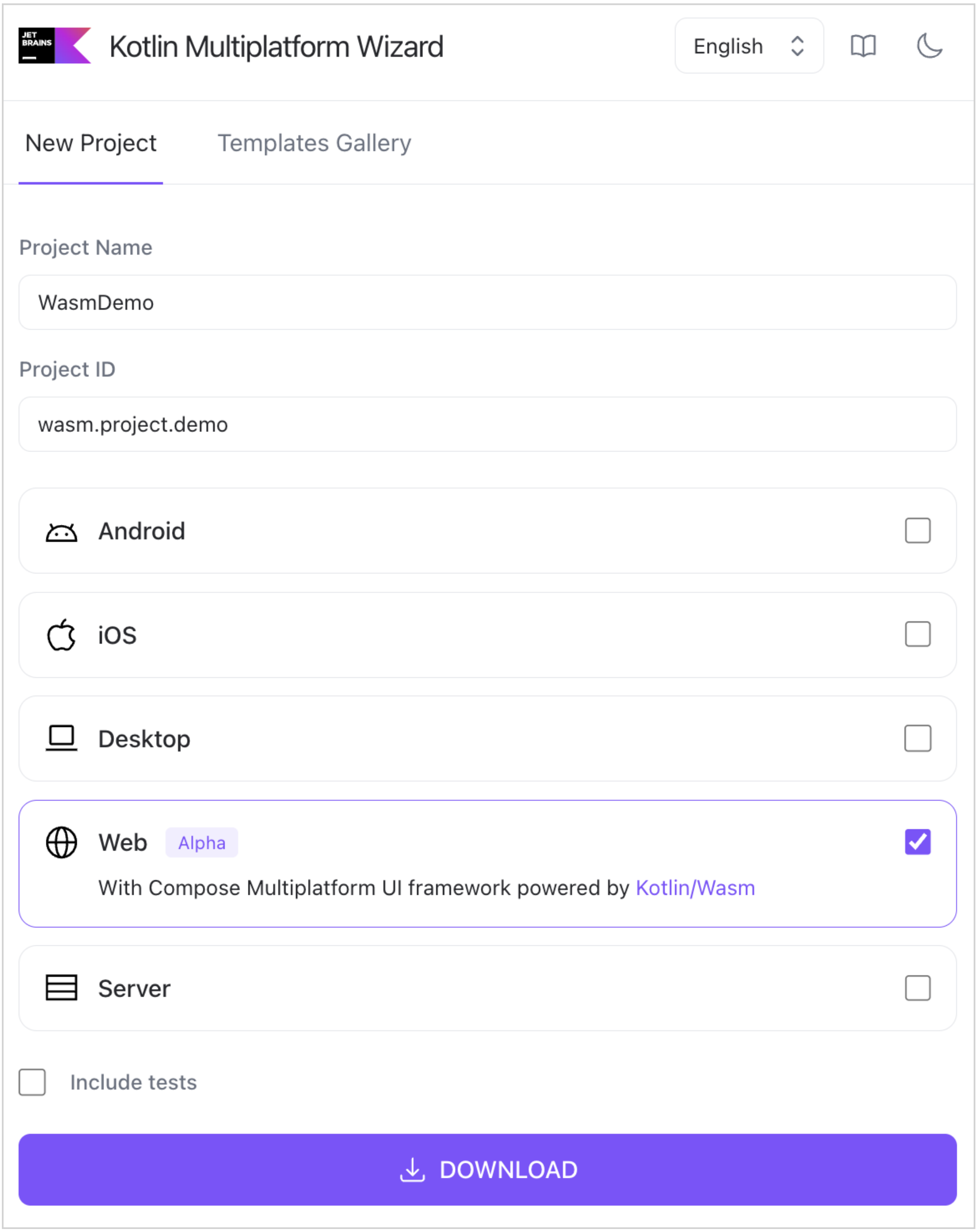
Before you start

Create a project using the Kotlin Multiplatform wizard:

1. Open the Kotlin Multiplatform wizard.
2. On the New Project tab, change the project name and ID to your preference. In this tutorial, we set the name to "WasmDemo" and the ID to "wasm.project.demo".

   > These are the name and ID of the project directory. You can also leave them as they are.

3. Select the Web option. Make sure that no other options are selected.
4. Click the Download button and unpack the resulting archive.



Project Name

WasmDemo

Project ID

wasm.project.demo

Android [ ]

iOS [ ]

Desktop [ ]

Web Alpha [✓]
With Compose Multiplatform UI framework powered by Kotlin/Wasm

Server [ ]

[ ] Include tests

Kotlin Multiplatform wizard

Open the project in IntelliJ IDEA

1. Download and install the latest version of IntelliJ IDEA.

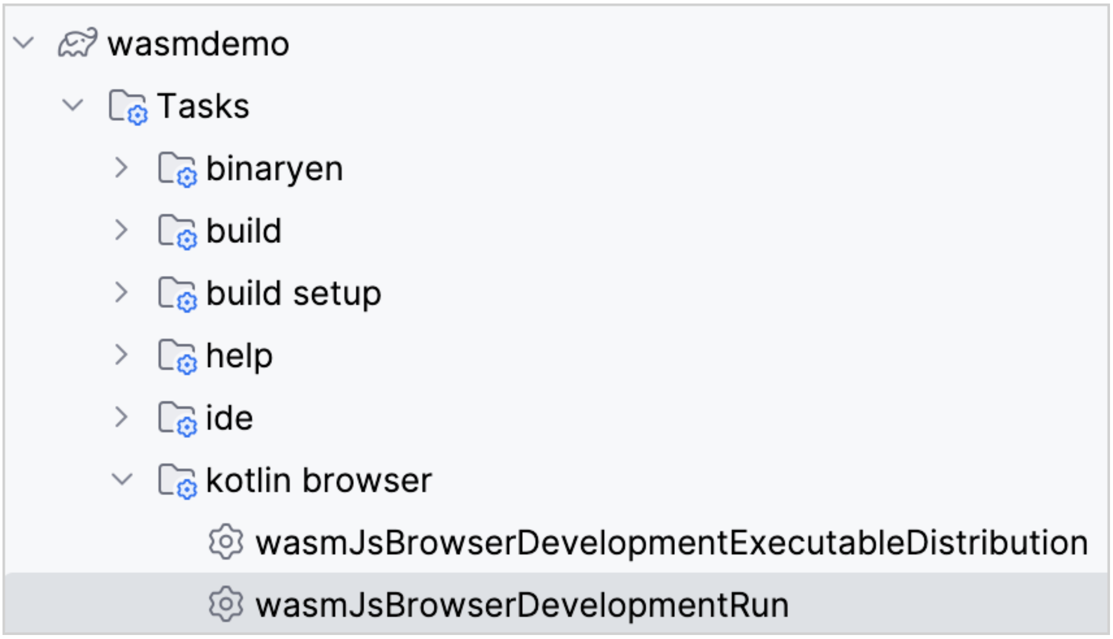
2. On the Welcome screen of IntelliJ IDEA, click Open or select File | Open in the menu bar.
3. Navigate to the unpacked "WasmDemo" folder and click Open.

Run the application

1. In IntelliJ IDEA, open the Gradle tool window by selecting View | Tool Windows | Gradle.

   > You need at least Java 11 as your Gradle JVM for the tasks to load successfully.

2. In composeApp | Tasks | kotlin browser, select and run the wasmJsBrowserDevelopmentRun task.

   
   wasmdemo
   Tasks
   binaryen
   build
   build setup
   help
   ide
   kotlin browser
   wasmJsBrowserDevelopmentExecutableDistribution
   wasmJsBrowserDevelopmentRun

   Run the Gradle task

   Alternatively, you can run the following command in the terminal from the WasmDemo root directory:

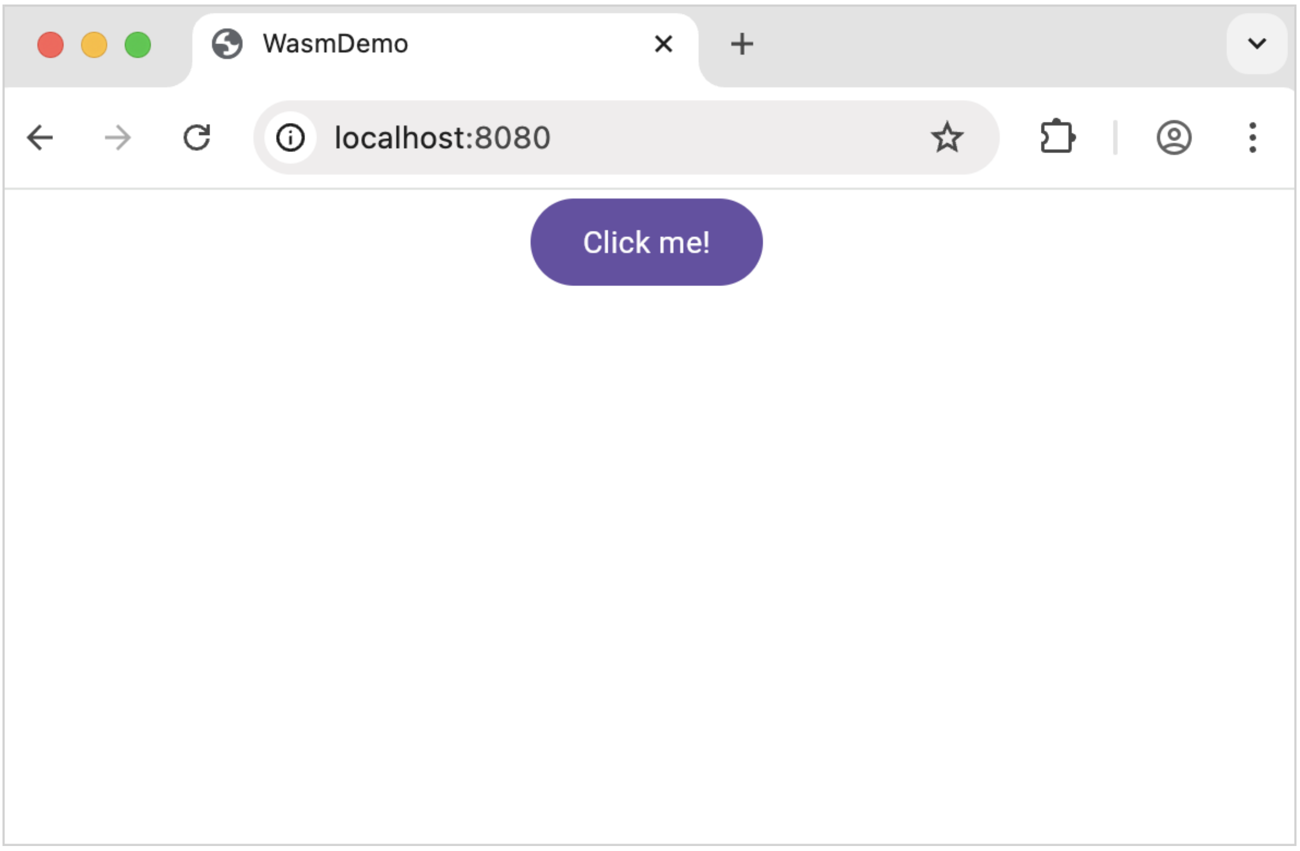
   ```
   ./gradlew wasmJsBrowserDevelopmentRun
   ```

3. Once the application starts, open the following URL in your browser:

   ```
   http://localhost:8080/
   ```

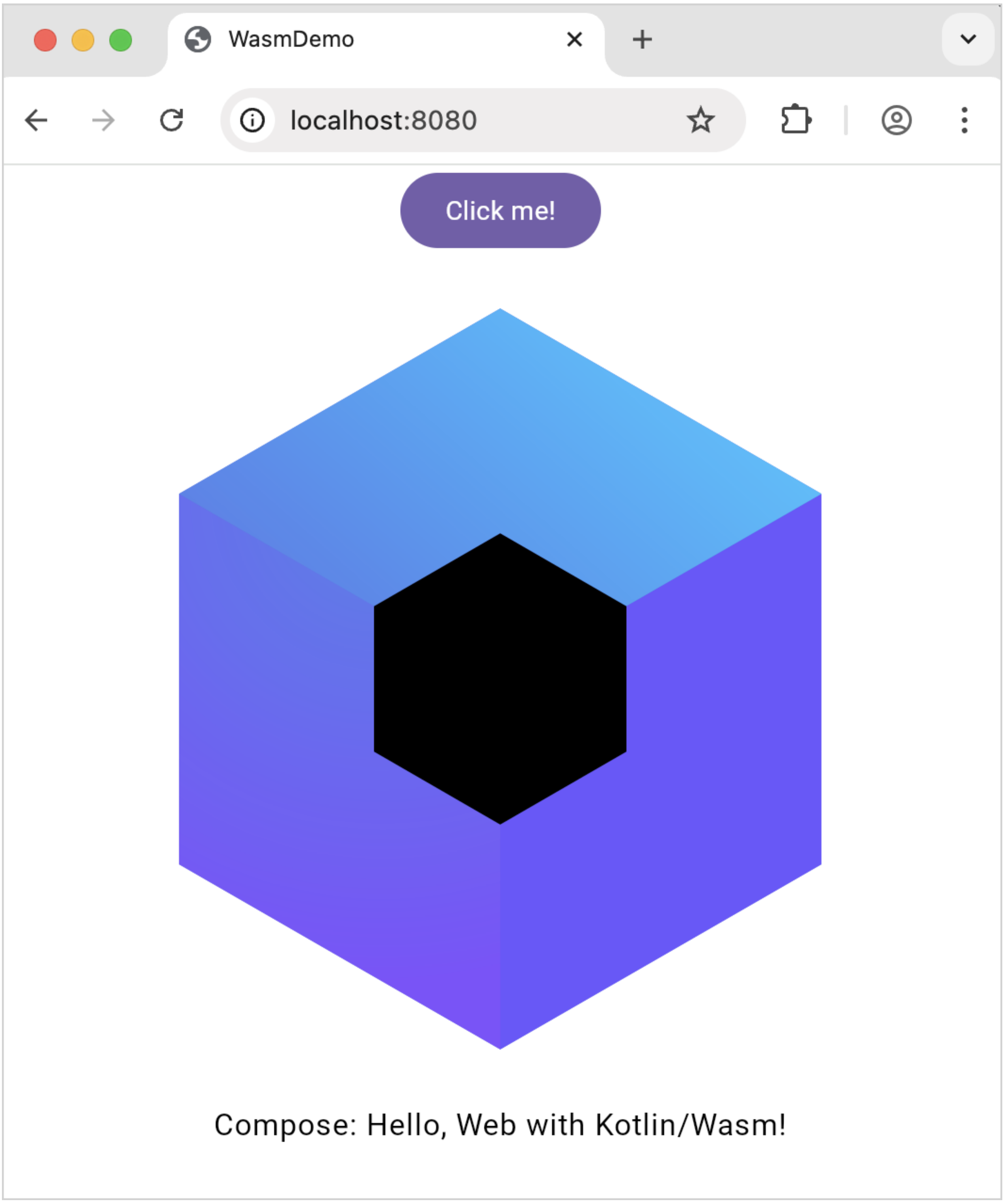
   > The port number can vary because the 8080 port may be unavailable. You can find the actual port number printed in the Gradle build console.

   You see a "Click me!" button. Click it:



Click me

Now you see the Compose Multiplatform logo:



Compose app in browser

Debug in your browser

Currently, debugging is only available in your browser. In the future, you will be able to debug your code in IntelliJ IDEA.

You can debug this Compose Multiplatform application in your browser out of the box, without additional configurations.

However, for other projects, you may need to configure additional settings in your Gradle build file. For more information about how to configure your browser for debugging, expand the next section.

Configure your browser for debugging

Enable access to project's sources

By default, browsers can't access some of the project's sources necessary for debugging. To provide access, you can configure the Webpack DevServer to serve these sources. In the ComposeApp directory, add the following code snippets to your build.gradle.kts file.

Add this import as a top-level declaration:

```
import org.jetbrains.kotlin.gradle.targets.js.webpack.KotlinWebpackConfig
```

Add this code snippet inside the commonWebpackConfig{} block, located in the wasmJs{} target DSL and browser{} platform DSL within kotlin{}:

```
devServer = (devServer ?: KotlinWebpackConfig.DevServer()).apply {
    static = (static ?: mutableListOf()).apply {
        // Serve sources to debug inside browser
        add(project.rootDir.path)
        add(project.projectDir.path)
    }
}
```

The resulting code block looks like this:

```
kotlin {
    @OptIn(ExperimentalWasmDsl::class)
    wasmJs {
        moduleName = "composeApp"
        browser {
            commonWebpackConfig {
                outputFileName = "composeApp.js"
                devServer = (devServer ?: KotlinWebpackConfig.DevServer()).apply {
                    static = (static ?: mutableListOf()).apply {
                        // Serve sources to debug inside browser
                        add(project.rootDir.path)
                        add(project.projectDir.path)
                    }
                }
            }
        }
    }
}
```

Currently, you can't debug library sources. We will support this in the future.

Use custom formatters

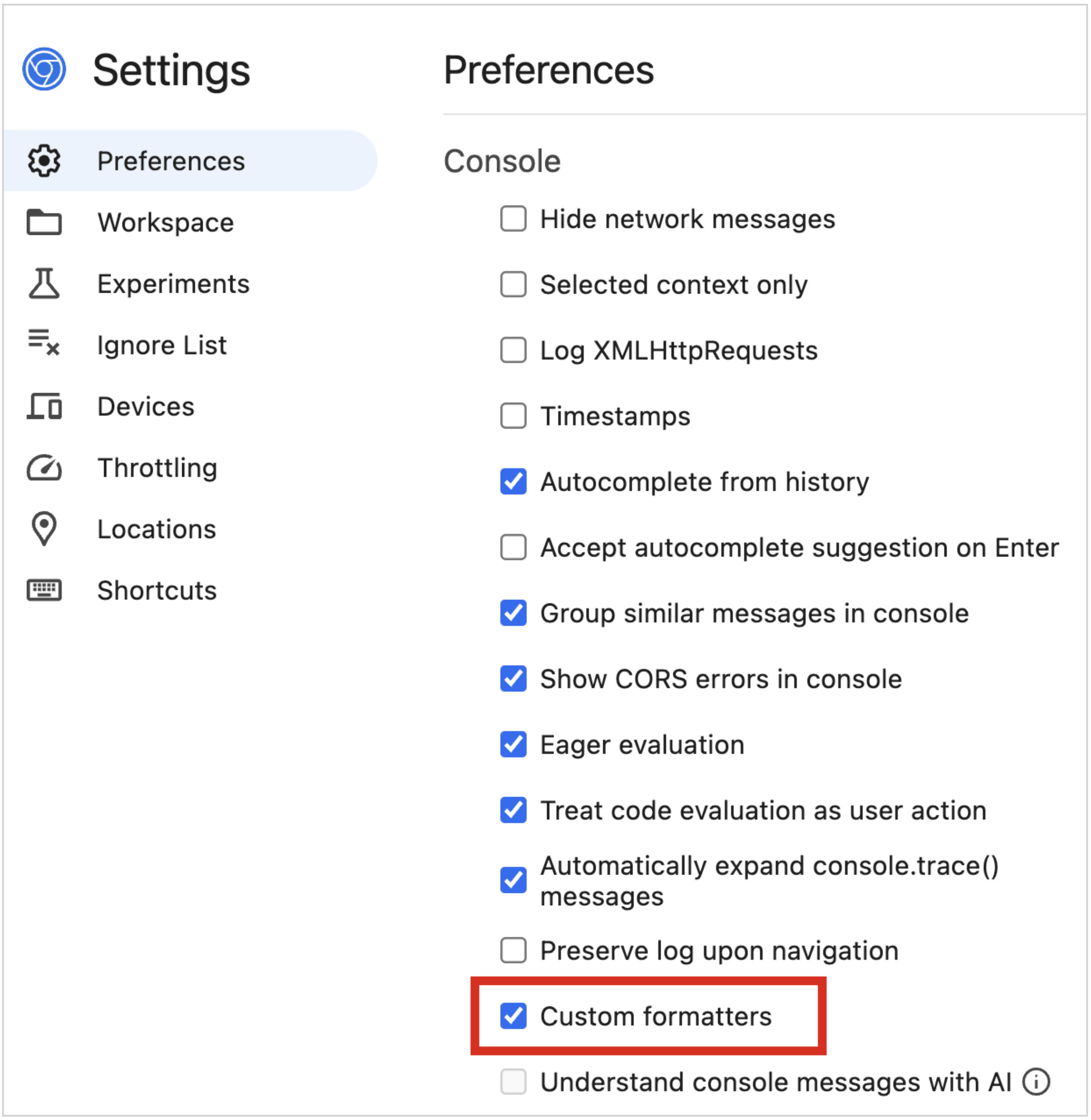
Custom formatters help display and locate variable values in a more user-friendly and comprehensible manner when debugging Kotlin/Wasm code.

Custom formatters are enabled by default in development builds, so you don't need additional Gradle configurations.

This feature is supported in Firefox and Chromium-based browsers as it uses the custom formatters API.

To use this feature, ensure that custom formatters are enabled in your browser's developer tools:

- In Chrome DevTools, find the custom formatters checkbox in Settings | Preferences | Console:


Settings

Preferences

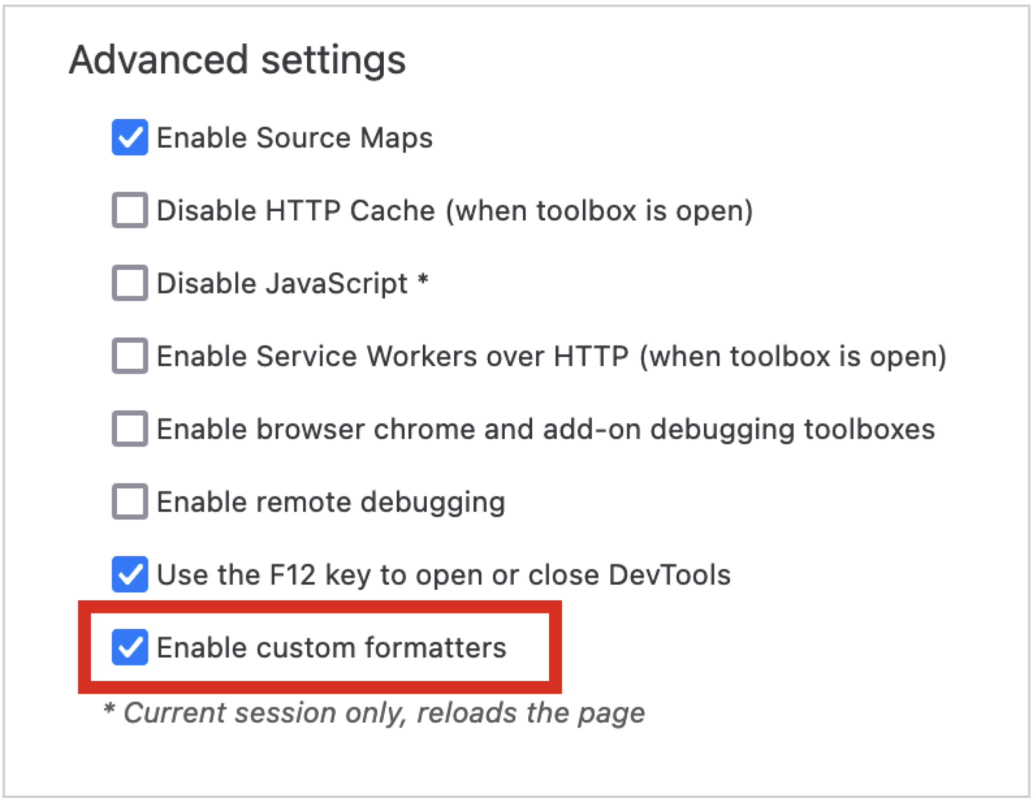
- Preferences
- Workspace
- Experiments
- Ignore List
- Devices
- Throttling
- Locations
- Shortcuts

Console

- [ ] Hide network messages
- [ ] Selected context only
- [ ] Log XMLHttpRequests
- [ ] Timestamps
- [✓] Autocomplete from history
- [ ] Accept autocomplete suggestion on Enter
- [✓] Group similar messages in console
- [✓] Show CORS errors in console
- [✓] Eager evaluation
- [✓] Treat code evaluation as user action
- [✓] Automatically expand console.trace() messages
- [ ] Preserve log upon navigation
- [✓] Custom formatters
- [ ] Understand console messages with AI

Enable custom formatters in Chrome

- In Firefox DevTools, find the custom formatters checkbox in Settings | Advanced settings:



Advanced settings

- [✓] Enable Source Maps
- [ ] Disable HTTP Cache (when toolbox is open)
- [ ] Disable JavaScript *
- [ ] Enable Service Workers over HTTP (when toolbox is open)
- [ ] Enable browser chrome and add-on debugging toolboxes
- [ ] Enable remote debugging
- [✓] Use the F12 key to open or close DevTools
- [✓] Enable custom formatters

Current session only, reloads the page

Enable custom formatters in Firefox

Custom formatters work for Kotlin/Wasm development builds. If you have specific requirements for production builds, you need to adjust your Gradle configuration accordingly. Add the following compiler option to the wasmJs {} block:

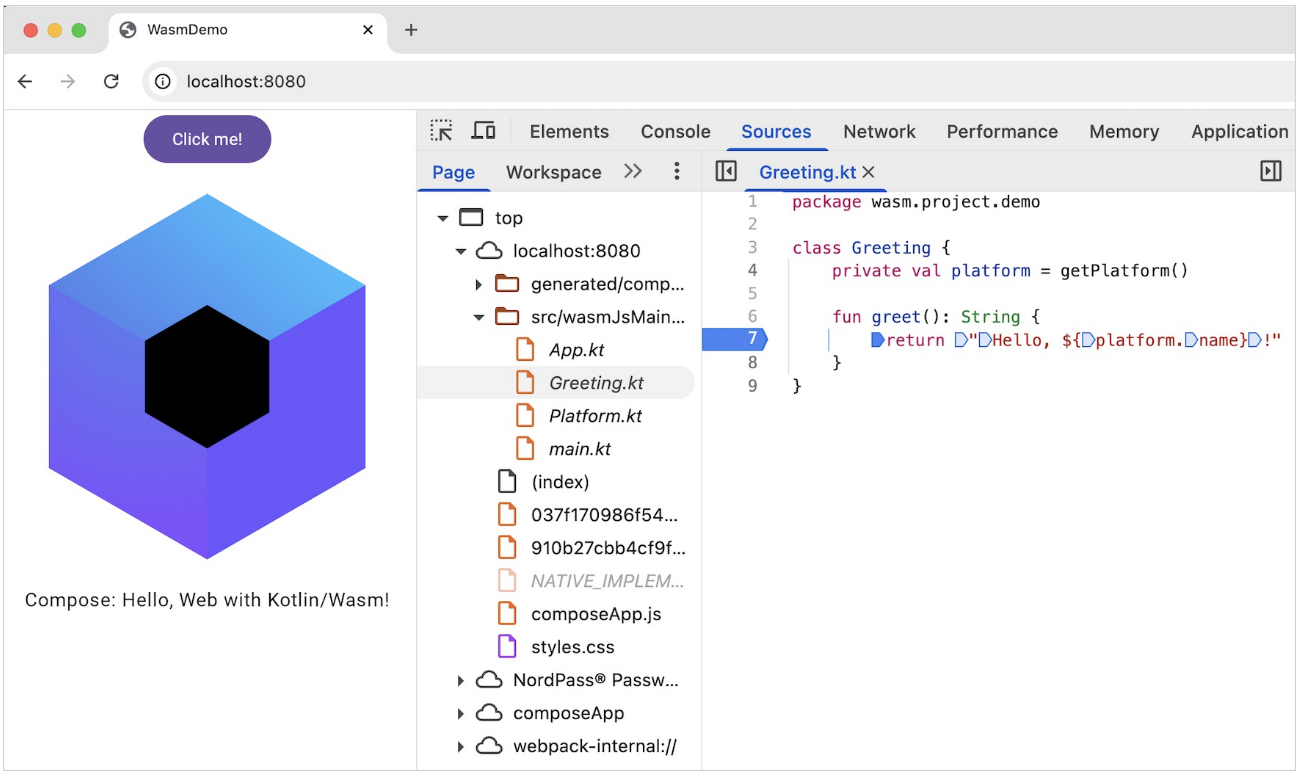
```
// build.gradle.kts
kotlin {
    wasmJs {
        // ...

        compilerOptions {
            freeCompilerArgs.add("-Xwasm-debugger-custom-formatters")
        }
    }
}
```

After enabling custom formatters, you can continue with the debugging tutorial.

Debug your Kotlin/Wasm application

This tutorial uses the Chrome browser, but you should be able to follow these steps with other browsers. For more information, see Browser versions.

1. In the browser window of the application, right-click and select the Inspect action to access developer tools. Alternatively, you can use the F12 shortcut or select View | Developer | Developer Tools.
2. Switch to the Sources tab and select the Kotlin file to debug. In this tutorial, we'll work with the Greeting.kt file.
3. Click on the line numbers to set breakpoints on the code that you want to inspect. Only the lines with darker numbers can have breakpoints.



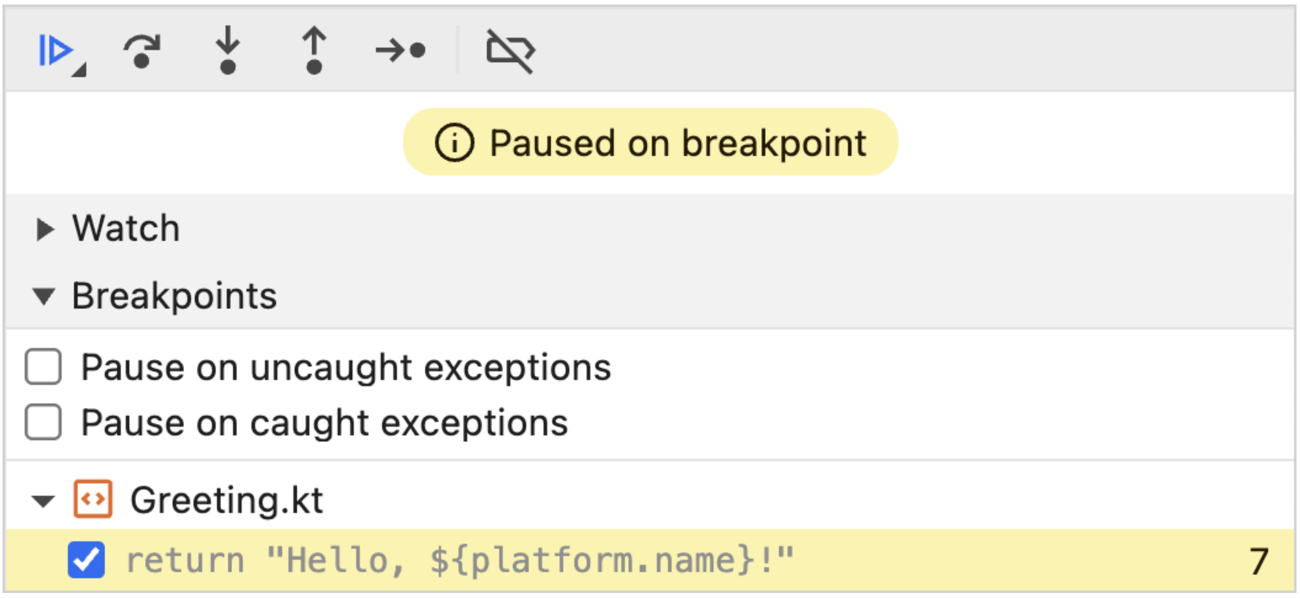
```
package wasm.project.demo

class Greeting {
    private val platform = getPlatform()

    fun greet(): String {
        return "Hello, ${platform.name}!"
    }
}
```

Set breakpoints

4. Click on the Click me! button to interact with the application. This action triggers the execution of the code, and the debugger pauses when the execution reaches a breakpoint.

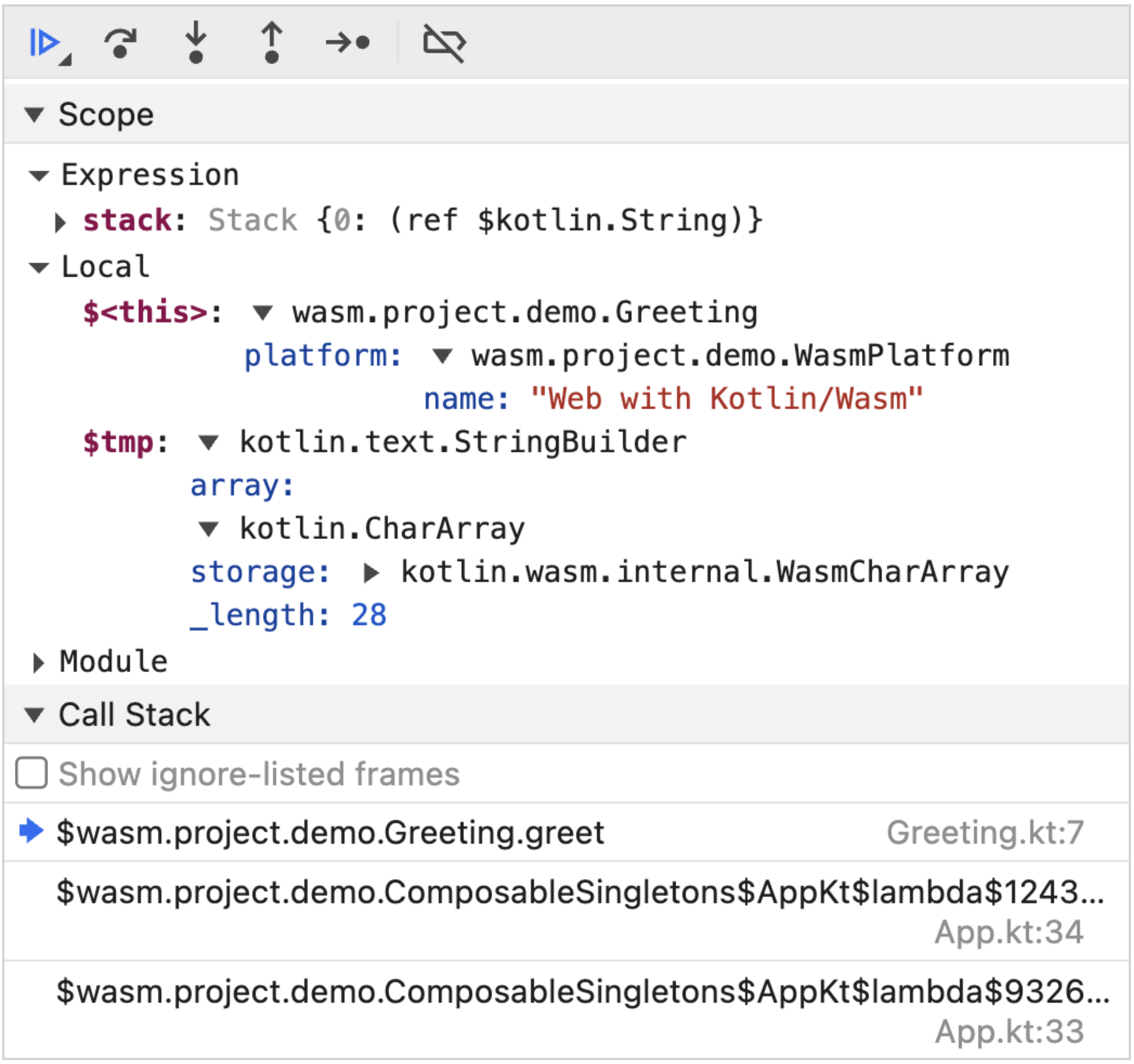
5. In the debugging pane, use the debugging control buttons to inspect variables and code execution at the breakpoints:

- Step into to investigate a function more deeply.
- Step over to execute the current line and pause on the next line.
- Step out to execute the code until it exits the current function.


Paused on breakpoint
Watch
Breakpoints
Pause on uncaught exceptions
Pause on caught exceptions
Greeting.kt
return "Hello, ${platform.name}!"
7

Debug controls

6. Check the Call stack and Scope panes to trace the sequence of function calls and pinpoint the location of any errors.



```
▼ Scope
  ▼ Expression
    ▶ stack: Stack {0: (ref $kotlin.String)}
  ▼ Local
      $<this>: ▼ wasm.project.demo.Greeting
                  platform: ▼ wasm.project.demo.WasmPlatform
                              name: "Web with Kotlin/Wasm"
      $tmp: ▼ kotlin.text.StringBuilder
            array:
            ▼ kotlin.CharArray
            storage: ▶ kotlin.wasm.internal.WasmCharArray
            _length: 28
  ▶ Module
▼ Call Stack
  ☐ Show ignore-listed frames
  ➡ $wasm.project.demo.Greeting.greet                         Greeting.kt:7
    $wasm.project.demo.ComposableSingletons$AppKt$lambda$1243...
                                                                  App.kt:34
    $wasm.project.demo.ComposableSingletons$AppKt$lambda$9326...
                                                                  App.kt:33
```

Check call stack

For an improved visualization of the variable values, see Use custom formatters within the Configure your browser for debugging section.

7. Make changes to your code and run the application again to verify that everything works as expected.

8. Click on the line numbers with breakpoints to remove the breakpoints.

Leave feedback

We would appreciate any feedback you may have on your debugging experience!

- Slack: get a Slack invite and provide your feedback directly to the developers in our #webassembly channel.
- Provide your feedback in YouTrack.

What's next?

- See Kotlin/Wasm debugging in action in this YouTube video.
- Try the Kotlin/Wasm examples from our kotlin-wasm-examples repository:
  - Compose image viewer
  - Jetsnack application
  - Node.js example
  - WASI example
  - Compose example

Interoperability with JavaScript

Kotlin/Wasm allows you to use both JavaScript code in Kotlin and Kotlin code in JavaScript.

As with Kotlin/JS, the Kotlin/Wasm compiler also has interoperability with JavaScript. If you are familiar with Kotlin/JS interoperability, you can notice that Kotlin/Wasm interoperability is similar. However, there are key differences to consider.

> Kotlin/Wasm is Alpha. It may be changed at any time. Use it in scenarios before production. We would appreciate your feedback in YouTrack.

Use JavaScript code in Kotlin

Learn how to use JavaScript code in Kotlin by using external declarations, functions with JavaScript code snippets, and the @JsModule annotation.

External declarations

External JavaScript code is not visible in Kotlin by default. To use JavaScript code in Kotlin, you can describe its API with external declarations.

JavaScript functions

Consider this JavaScript function:

```
function greet (name) {
    console.log("Hello, " + name + "!");
}
```

You can declare it in Kotlin as an external function:

```
external fun greet(name: String)
```

External functions don't have bodies, and you can call it as a regular Kotlin function:

```
fun main() {
    greet("Alice")
}
```

JavaScript properties

Consider this global JavaScript variable:

```
let globalCounter = 0;
```

You can declare it in Kotlin using external var or val properties:

```
external var globalCounter: Int
```

These properties are initialized externally. The properties can't have = value initializers in Kotlin code.

JavaScript classes

Consider this JavaScript class:

```
class Rectangle {
    constructor (height, width) {
        this.height = height;
        this.width = width;
    }

    area () {
        return this.height * this.width;
    }
}
```

You can use it in Kotlin as an external class:

```
external class Rectangle(height: Double, width: Double) : JsAny {
    val height: Double
    val width: Double
    fun area(): Double
}
```

All declarations inside the external class are implicitly considered external.

External interfaces

You can describe the shape of a JavaScript object in Kotlin. Consider this JavaScript function and what it returns:

```
function createUser (name, age) {
    return { name: name, age: age };
}
```

See how its shape can be described in Kotlin with an external interface User type:

```
external interface User : JsAny {
    val name: String
    val age: Int
}

external fun createUser(name: String, age: Int): User
```

External interfaces don't have runtime type information and are a compile-time-only concept. Therefore, external interfaces have some restrictions compared to regular interfaces:

- You can't use them on the right-hand side of is checks.
- You can't use them in class literal expressions (such as User::class).
- You can't pass them as reified type arguments.
- Casting with as to external interfaces always succeed.

External objects

Consider these JavaScript variables holding an object:

```
let Counter = {
    value: 0,
    step: 1,
    increment () {
        this.value += this.step;
    }
};
```

You can use them in Kotlin as an external object:

```
external object Counter : JsAny {
    fun increment()
    val value: Int
    var step: Int
}
```

External type hierarchy

Similar to regular classes and interfaces, you can declare external declarations to extend other external classes and implement external interfaces. However, you can't mix external and non-external declarations in the same type hierarchy.

Kotlin functions with JavaScript code

You can add a JavaScript snippet to Kotlin/Wasm code by defining a function with = js("code") body:

```
fun getCurrentURL(): String =
    js("window.location.href")
```

If you want to run a block of JavaScript statements, surround your code inside the string with curly brackets {}:

```
fun setLocalSettings(value: String): Unit = js(
    """{
        localStorage.setItem('settings', value);
}"""
)
```

If you want to return an object, surround the curly brackets {} with parentheses ():

```
fun createJsUser(name: String, age: Int): JsAny =
    js("({ name: name, age: age })")
```

Kotlin/Wasm treats calls to the js() function in a special way, and the implementation has some restrictions:

- A js() function call must be provided with a string literal argument.
- A js() function call must be the only expression in the function body.
- The js() function is only allowed to be called from package-level functions.
- The function return type must be provided explicitly.
- Types are restricted, similar to external fun.

The Kotlin compiler puts the code string into a function in the generated JavaScript file and imports it into WebAssembly format. The Kotlin compiler doesn't verify these JavaScript snippets. If there are JavaScript syntax errors, they are reported when you run your JavaScript code.

> The @JsFun annotation has similar functionality and will likely be deprecated.

JavaScript modules

By default, external declarations correspond to the JavaScript global scope. If you annotate a Kotlin file with the @JsModule annotation, then all external declarations within it are imported from the specified module.

Consider this JavaScript code sample:

```
// users.mjs
export let maxUsers = 10;

export class User {
    constructor (username) {
        this.username = username;
    }
}
```

Use this JavaScript code in Kotlin with the @JsModule annotation:

```
// Kotlin
@file:JsModule("./users.mjs")

external val maxUsers: Int

external class User : JsAny {
    constructor(username: String)

    val username: String
}
```

Array interoperability

You can copy JavaScript's JsArray<T> into Kotlin's native Array or List types; likewise, you can copy these Kotlin types to JsArray<T>.

To convert JsArray<T> to Array<T> or the other way around, use one of the available adapter functions.

Here's an example of conversion between generic types:

```
val list: List<JsString> =
    listOf("Kotlin", "Wasm").map { it.toJsString() }

// Uses .toJsArray() to convert List or Array to JsArray
val jsArray: JsArray<JsString> = list.toJsArray()

// Uses .toArray() and .toList() to convert it back to Kotlin types
val kotlinArray: Array<JsString> = jsArray.toArray()
val kotlinList: List<JsString> = jsArray.toList()
```

Similar adapter functions are available for converting typed arrays to their Kotlin equivalents (for example, IntArray and Int32Array). For detailed information and implementation, see the kotlinx-browser repository.

Here's an example of conversion between typed arrays:

```
import org.khronos.webgl.*

    // ...

    val intArray: IntArray = intArrayOf(1, 2, 3)

    // Uses .toInt32Array() to convert Kotlin IntArray to JavaScript Int32Array
    val jsInt32Array: Int32Array = intArray.toInt32Array()

    // Uses toIntArray() to convert JavaScript Int32Array back to Kotlin IntArray
    val kotlnIntArray: IntArray = jsInt32Array.toIntArray()
```

Use Kotlin code in JavaScript

Learn how to use your Kotlin code in JavaScript by using the @JsExport annotation.

Functions with the @JsExport annotation

To make a Kotlin/Wasm function available to JavaScript code, use the @JsExport annotation:

```
// Kotlin/Wasm

@JsExport
fun addOne(x: Int): Int = x + 1
```

Kotlin/Wasm functions marked with the @JsExport annotation are visible as properties on a default export of the generated .mjs module. You can then use this function in JavaScript:

```
// JavaScript

import exports from "./module.mjs"

exports.addOne(10)
```

The Kotlin/Wasm compiler is capable of generating TypeScript definitions from any @JsExport declarations in your Kotlin code. These definitions can be used by IDEs and JavaScript tools to provide code autocompletion, help with type-checks, and make it easier to consume Kotlin code from JavaScript and TypeScript.

The Kotlin/Wasm compiler collects any top-level functions marked with the @JsExport annotation and automatically generates TypeScript definitions in a .d.ts file.

To generate TypeScript definitions, in your build.gradle.kts file in the wasmJs{} block, add the generateTypeScriptDefinitions() function:

```
kotlin {
    wasmJs {
        binaries.executable()
        browser {
        }
        generateTypeScriptDefinitions()
    }
}
```

Generating TypeScript declaration files in Kotlin/Wasm is Experimental. It may be dropped or changed at any time.

Type correspondence

Kotlin/Wasm allows only certain types in signatures of JavaScript interop declarations. These limitations apply uniformly to declarations with external, = js("code") or @JsExport.

See how Kotlin types correspond to Javascript types:

Kotlin	JavaScript
Byte, Short, Int, Char, UByte, UShort, UInt,	Number
Float, Double,	Number
Long, ULong,	BigInt
Boolean,	Boolean
String,	String
Unit in return position	undefined
Function type, for example (String) -> Int	Function
JsAny and subtypes	Any JavaScript value
JsReference	Opaque reference to Kotlin object

Kotlin	JavaScript
Other types	Not supported

You can use nullable versions of these types as well.

JsAny type

JavaScript values are represented in Kotlin using the JsAny type and its subtypes.

The Kotlin/Wasm standard library provides representation for some of these types:

- Package kotlin.js:
  - JsAny
  - JsBoolean, JsNumber, JsString
  - JsArray
  - Promise

You can also create custom JsAny subtypes by declaring an external interface or class.

JsReference type

Kotlin values can be passed to JavaScript as opaque references using the JsReference type.

For example, if you want to expose this Kotlin class User to JavaScript:

```kotlin
class User(var name: String)
```

You can use the toJsReference() function to create JsReference<User> and return it to JavaScript:

```kotlin
@JsExport
fun createUser(name: String): JsReference<User> {
    return User(name).toJsReference()
}
```

These references aren't directly available in JavaScript and behave like empty frozen JavaScript objects. To operate on these objects, you need to export more functions to JavaScript using the get() method where you unwrap the reference value:

```kotlin
@JsExport
fun setUserName(user: JsReference<User>, name: String) {
    user.get().name = name
}
```

You can create a class and change its name from JavaScript:

```javascript
import UserLib from "./userlib.mjs"

let user = UserLib.createUser("Bob");
UserLib.setUserName(user, "Alice");
```

Type parameters

JavaScript interop declarations can have type parameters if they have an upper bound of JsAny or its subtypes. For example:

```kotlin
external fun <T : JsAny> processData(data: JsArray<T>): T
```

Exception handling

You can use Kotlin try-catch expression to catch JavaScript exceptions. However, accessing specific details about the thrown value in Kotlin/Wasm isn't possible by default.

You can configure the JsException type to include the original error message and stack trace from JavaScript. To do so, add the following compiler option to your build.gradle.kts file:

```
kotlin {
    wasmJs {
        compilerOptions {
            freeCompilerArgs.add("-Xwasm-attach-js-exception")
        }
    }
}
```

This behavior depends on the WebAssembly.JSTag API, which is only available in certain browsers:

- Chrome: Supported from version 115
- Firefox: Supported from version 129
- Safari: Not yet supported

Here's an example demonstrating this behavior:

```
external object JSON {
    fun <T: JsAny> parse(json: String): T
}

fun main() {
    try {
        JSON.parse("an invalid JSON")
    } catch (e: JsException) {
        println("Thrown value is: ${e.thrownValue}")
        // SyntaxError: Unexpected token 'a', "an invalid JSON" is not valid JSON

        println("Message: ${e.message}")
        // Message: Unexpected token 'a', "an invalid JSON" is not valid JSON

        println("Stacktrace:")
        // Stacktrace:

        // Prints the full JavaScript stack trace
        e.printStackTrace()
    }
}
```

With the -Xwasm-attach-js-exception compiler option enabled, the JsException type provides specific details from the JavaScript error. Without enabling this compiler option, JsException includes only a generic message stating that an exception was thrown while running JavaScript code.

If you try to use a JavaScript try-catch expression to catch Kotlin/Wasm exceptions, it looks like a generic WebAssembly.Exception without directly accessible messages and data.

Kotlin/Wasm and Kotlin/JS interoperability differences

Although Kotlin/Wasm interoperability shares similarities with Kotlin/JS interoperability, there are key differences to consider:

	Kotlin/Wasm	Kotlin/JS
External enums	Doesn't support external enum classes.	Supports external enum classes.
Type extensions	Doesn't support non-external types to extend external types.	Supports non-external types.

	Kotlin/Wasm	Kotlin/JS
JsName annotation	Only has an effect when annotating external declarations.	Can be used to change names of regular non-external declarations.
js() function	js("code") function calls are allowed as a single expression body of package-level functions.	The js("code") function can be called in any context and returns a dynamic value.
Module systems	Supports ES modules only. There is no analog of the @JsNonModule annotation. Provides its exports as properties on the default object. Allows exporting package-level functions only.	Supports ES modules and legacy module systems. Provides named ESM exports. Allows exporting classes and objects.
Types	Applies stricter type restrictions uniformly to all interop declarations external, = js("code"), and @JsExport. Allows a select number of built-in Kotlin types and JsAny subtypes.	Allows all types in external declarations. Restricts types that can be used in @JsExport.
Long	Type corresponds to JavaScript BigInt.	Visible as a custom class in JavaScript.
Arrays	Not supported in interop directly yet. You can use the new JsArray type instead.	Implemented as JavaScript arrays.
Other types	Requires JsReference<> to pass Kotlin objects to JavaScript.	Allows the use of non-external Kotlin class types in external declarations.
Exception handling	You can catch any JavaScript exception with the JsException and Throwable types.	Can catch JavaScript Error using the Throwable type. It can catch any JavaScript exception using the dynamic type.
Dynamic types	Does not support the dynamic type. Use JsAny instead (see sample code below).	Supports the dynamic type.

Kotlin/JS dynamic type for interoperability with untyped or loosely typed objects is not supported in Kotlin/Wasm. Instead of dynamic type, you can use JsAny type:

```kotlin
// Kotlin/JS
fun processUser(user: dynamic, age: Int) {
    // ...
    user.profile.updateAge(age)
    // ...
}

// Kotlin/Wasm
private fun updateUserAge(user: JsAny, age: Int): Unit =
    js("{ user.profile.updateAge(age); }")

fun processUser(user: JsAny, age: Int) {
    // ...
    updateUserAge(user, age)
    // ...
}
```

Web-related browser APIs

The kotlinx-browser library is a standalone library that provides JavaScript browser APIs, including:

- Package org.khronos.webgl:
  - Typed arrays, like Int8Array.
  - WebGL types.
- Packages org.w3c.dom.*:
  - DOM API types.
- Package kotlinx.browser:
  - DOM API global objects, like window and document.

To use the declarations from the kotlinx-browser library, add it as a dependency in your project's build configuration file:

```
val wasmJsMain by getting {
    dependencies {
        implementation("org.jetbrains.kotlinx:kotlinx-browser:0.3")
    }
}
```

Troubleshooting

Kotlin/Wasm is Alpha. It may be changed at any time. Use it in scenarios before production. We would appreciate your feedback in YouTrack.

Kotlin/Wasm relies on new WebAssembly proposals like garbage collection and exception handling to introduce improvements and new features within WebAssembly.

However, to ensure these features work properly, you need an environment that supports the new proposals. In some cases, you may need to set up the environment to make it compatible with the proposals.

Browser versions

To run applications built with Kotlin/Wasm in a browser, you need a browser version supporting the new WebAssembly garbage collection (WasmGC) feature. Check if the browser version supports the new WasmGC by default or if you need to make changes to the environment.

Chrome

- For version 119 or later:

  Works by default.

- For older versions:

  To run applications in an older browser, you need a Kotlin version older than 1.9.20.

  1. In your browser, go to chrome://flags/#enable-webassembly-garbage-collection.
  2. Enable WebAssembly Garbage Collection.
  3. Relaunch your browser.

Chromium-based

Including Chromium-based browsers such as Edge, Brave, Opera, or Samsung Internet.

- For version 119 or later:

  Works by default.

- For older versions:

  > To run applications in an older browser, you need a Kotlin version older than 1.9.20.

  Run the application with the --js-flags=--experimental-wasm-gc command line argument.

Firefox

- For version 120 or later:

  Works by default.

- For version 119:

  1. In your browser, go to about:config.
  2. Enable javascript.options.wasm_gc option.
  3. Refresh the page.

Safari/WebKit

- For version 18.2 or later:

  Works by default.

- For older versions:

  Not supported.

> Safari 18.2 is available for iOS 18.2, iPadOS 18.2, visionOS 2.2, macOS 15.2, macOS Sonoma, and macOS Ventura. On iOS and iPadOS, Safari 18.2 is bundled with the operating system. To get it, update your device to version 18.2 or later.
>
> For more information, see the Safari release notes.

Wasm proposals support

Kotlin/Wasm improvements are based on WebAssembly proposals. Here you can find details about the support for WebAssembly's garbage collection and (legacy) exception handling proposals.

Garbage collection proposal

Since Kotlin 1.9.20, the Kotlin toolchain uses the latest version of the Wasm garbage collection (WasmGC) proposal.

For this reason, we strongly recommend that you update your Wasm projects to the latest version of Kotlin. We also recommend you use the latest versions of browsers with the Wasm environment.

Exception handling proposal

The Kotlin toolchain uses the legacy exception handling proposal by default which allows running produced Wasm binaries in wider range of environments.

Since Kotlin 2.0.0, we have introduced support for the new version of Wasm exception handling proposal within Kotlin/Wasm.

This update ensures the new exception handling proposal aligns with Kotlin requirements, enabling the use of Kotlin/Wasm on virtual machines that only support the latest version of the proposal.

The new exception handling proposal is activated using the -Xwasm-use-new-exception-proposal compiler option. It is turned off by default.

> Learn more about setting up projects, using dependencies, and other tasks with our Kotlin/Wasm examples.

Use default import

Importing Kotlin/Wasm code into Javascript has shifted to named exports, moving away from default exports.

If you still want to use a default import, generate a new JavaScript wrapper module. Create a .mjs file with the following snippet:

```
// Specifies the path to the main .mjs file
import * as moduleExports from "./wasm-test.mjs";

export { moduleExports as default };
```

You can place your new .mjs file in the resources folder, and it will automatically be placed next to the main .mjs file during the build process.

You can also place your .mjs file in a custom location. In this case, you need to either manually move it next to the main .mjs file or adjust the path in the import statement to match its location.

Slow Kotlin/Wasm compilation

When working on Kotlin/Wasm projects, you may experience slow compilation times. This happens because the Kotlin/Wasm toolchain recompiles the entire codebase every time you make a change.

To mitigate this issue, Kotlin/Wasm targets support incremental compilation, which enables the compiler to recompile only those files relevant to changes from the last compilation.

Using incremental compilation reduces the compilation time. It doubles the development speed for now, with plans to improve it further in future releases.

In the current setup, incremental compilation for the Wasm targets is disabled by default. To enable it, add the following line to your project's local.properties or gradle.properties file:

```
kotlin.incremental.wasm=true
```

> Try out the Kotlin/Wasm incremental compilation and share your feedback. Your insights help make the feature stable and enabled by default sooner.

Set up a Kotlin/JS project

Kotlin/JS projects use Gradle as a build system. To let developers easily manage their Kotlin/JS projects, we offer the kotlin.multiplatform Gradle plugin that provides project configuration tools together with helper tasks for automating routines typical for JavaScript development.

The plugin downloads npm dependencies in the background using the npm or Yarn package managers and builds a JavaScript bundle from a Kotlin project using webpack. Dependency management and configuration adjustments can be done to a large part directly from the Gradle build file, with the option to override automatically generated configurations for full control.

You can apply the org.jetbrains.kotlin.multiplatform plugin to a Gradle project manually in the build.gradle(.kts) file:

Kotlin

```
plugins {
    kotlin("multiplatform") version "2.2.0"
}
```

Groovy

```
plugins {
    id 'org.jetbrains.kotlin.multiplatform' version '2.2.0'
}
```

The Kotlin Multiplatform Gradle plugin lets you manage aspects of your project in the kotlin {} block of the build script:

```
kotlin {
    // ...
}
```

Inside the kotlin {} block, you can manage the following aspects:

- Target execution environment: browser or Node.js
- Support for ES2015 features: classes, modules, and generators
- Project dependencies: Maven and npm
- Run configuration
- Test configuration
- Bundling and CSS support for browser projects
- Target directory and module name
- Project's package.json file

Execution environments

Kotlin/JS projects can target two different execution environments:

- Browser for client-side scripting in browsers
- Node.js for running JavaScript code outside of a browser, for example, for server-side scripting.

To define the target execution environment for a Kotlin/JS project, add the js {} block with browser {} or nodejs {} inside:

```
kotlin {
    js {
        browser {
        }
        binaries.executable()
    }
}
```

The instruction binaries.executable() explicitly instructs the Kotlin compiler to emit executable .js files. Omitting binaries.executable() will cause the compiler to only generate Kotlin-internal library files, which can be used from other projects, but not run on their own.

> This is typically faster than creating executable files, and can be a possible optimization when dealing with non-leaf modules of your project.

The Kotlin Multiplatform plugin automatically configures its tasks for working with the selected environment. This includes downloading and installing the required environment and dependencies for running and testing the application. This allows developers to build, run, and test simple projects without additional configuration. For projects targeting Node.js, there is also an option to use an existing Node.js installation. Learn how to use pre-installed Node.js.

Support for ES2015 features

Kotlin provides an Experimental support for the following ES2015 features:

- Modules that simplify your codebase and improve maintainability.
- Classes that allow incorporating OOP principles, resulting in cleaner and more intuitive code.

- Generators for compiling suspend functions that improve the final bundle size and help with debugging.

You can enable all the supported ES2015 features at once by adding the es2015 compilation target to your build.gradle(.kts) file:

```
tasks.withType<KotlinJsCompile>().configureEach {
    kotlinOptions {
        target = "es2015"
    }
}
```

Learn more about ES2015 (ECMAScript 2015, ES6) in the official documentation.

Dependencies

Like any other Gradle projects, Kotlin/JS projects support traditional Gradle dependency declarations in the dependencies {} block of the build script:

Kotlin

```
dependencies {
    implementation("org.example.myproject", "1.1.0")
}
```

Groovy

```
dependencies {
    implementation 'org.example.myproject:1.1.0'
}
```

The Kotlin Multiplatform Gradle plugin also supports dependency declarations for particular source sets in the kotlin {} block of the build script:

Kotlin

```
kotlin {
    sourceSets {
        val jsMain by getting {
            dependencies {
                implementation("org.example.myproject:1.1.0")
            }
        }
    }
}
```

Groovy

```
kotlin {
    sourceSets {
        jsMain {
            dependencies {
                implementation 'org.example.myproject:1.1.0'
            }
        }
    }
}
```

Not all libraries available for the Kotlin programming language are available when targeting JavaScript: only libraries that include artifacts for Kotlin/JS can be used.

If the library you are adding has dependencies on packages from npm, Gradle will automatically resolve these transitive dependencies as well.

Kotlin standard libraries

The dependencies on the standard library are added automatically. The version of the standard library is the same as the version of the Kotlin Multiplatform plugin.

For multiplatform tests, the kotlin.test API is available. When you create a multiplatform project, you can add test dependencies to all the source sets by using a single dependency in commonTest:

Kotlin

```
kotlin {
    sourceSets {
        commonTest.dependencies {
            implementation(kotlin("test")) // Brings all the platform dependencies automatically
        }
    }
}
```

Groovy

```
kotlin {
    sourceSets {
        commonTest {
            dependencies {
                implementation kotlin("test") // Brings all the platform dependencies automatically
            }
        }
    }
}
```

npm dependencies

In the JavaScript world, the most common way to manage dependencies is npm. It offers the biggest public repository of JavaScript modules.

The Kotlin Multiplatform Gradle plugin lets you declare npm dependencies in the Gradle build script, just how you declare any other dependencies.

To declare an npm dependency, pass its name and version to the npm() function inside a dependency declaration. You can also specify one or multiple version ranges based on npm's semver syntax.

Kotlin

```
dependencies {
    implementation(npm("react", "> 14.0.0 <=16.9.0"))
}
```

Groovy

```
dependencies {
    implementation npm('react', '> 14.0.0 <=16.9.0')
}
```

By default, the plugin uses a separate instance of the Yarn package manager to download and install npm dependencies. It works out of the box without additional configuration, but you can tune it to specific needs.

You can also work with npm dependencies directly using the npm package manager instead. To use npm as your package manager, in your gradle.properties file, set the following property:

```
kotlin.js.yarn=false
```

Besides regular dependencies, there are three more types of dependencies that can be used from the Gradle DSL. To learn more about when each type of dependency can best be used, have a look at the official documentation linked from npm:

- devDependencies, via devNpm(...),
- optionalDependencies via optionalNpm(...), and
- peerDependencies via peerNpm(...).

Once an npm dependency is installed, you can use its API in your code as described in Calling JS from Kotlin.

run task

The Kotlin Multiplatform Gradle plugin provides a jsBrowserDevelopmentRun task that lets you run pure Kotlin/JS projects without additional configuration.

For running Kotlin/JS projects in the browser, this task is an alias for the browserDevelopmentRun task (which is also available in Kotlin multiplatform projects). It uses the webpack-dev-server to serve your JavaScript artifacts. If you want to customize the configuration used by webpack-dev-server, for example, adjust the port the server runs on, use the webpack configuration file.

For running Kotlin/JS projects targeting Node.js, use the jsNodeDevelopmentRun task that is an alias for the nodeRun task.

To run a project, execute the standard lifecycle jsBrowserDevelopmentRun task, or the alias to which it corresponds:

```
./gradlew jsBrowserDevelopmentRun
```

To automatically trigger a re-build of your application after making changes to the source files, use the Gradle continuous build feature:

```
./gradlew jsBrowserDevelopmentRun --continuous
```

or

```
./gradlew jsBrowserDevelopmentRun -t
```

Once the build of your project has succeeded, the webpack-dev-server will automatically refresh the browser page.

test task

The Kotlin Multiplatform Gradle plugin automatically sets up a test infrastructure for projects. For browser projects, it downloads and installs the Karma test runner with other required dependencies; for Node.js projects, the Mocha test framework is used.

The plugin also provides useful testing features, for example:

- Source maps generation
- Test reports generation
- Test run results in the console

For running browser tests, the plugin uses Headless Chrome by default. You can also choose another browser to run tests in, by adding the corresponding entries inside the useKarma {} block of the build script:

```
kotlin {
    js {
        browser {
            testTask {
                useKarma {
                    useIe()
                    useSafari()
                    useFirefox()
                    useChrome()
                    useChromeCanary()
                    useChromeHeadless()
                    usePhantomJS()
                    useOpera()
                }
            }
        }
        binaries.executable()
        // ...
    }
}
```

Alternatively, you can add test targets for browsers in the gradle.properties file:

```
kotlin.js.browser.karma.browsers=firefox,safari
```

This approach allows you to define a list of browsers for all modules, and then add specific browsers in the build scripts of particular modules.

Please note that the Kotlin Multiplatform Gradle plugin does not automatically install these browsers for you, but only uses those that are available in its execution environment. If you are executing Kotlin/JS tests on a continuous integration server, for example, make sure that the browsers you want to test against are installed.

If you want to skip tests, add the line enabled = false to the testTask {}:

```
kotlin {
    js {
        browser {
            testTask {
                enabled = false
            }
        }
        binaries.executable()
        // ...
    }
}
```

To run tests, execute the standard lifecycle check task:

```
./gradlew check
```

To specify environment variables used by your Node.js test runners (for example, to pass external information to your tests, or to fine-tune package resolution), use the environment() function with a key-value pair inside the testTask {} block in your build script:

```
kotlin {
    js {
        nodejs {
            testTask {
                environment("key", "value")
            }
        }
    }
}
```

Karma configuration

The Kotlin Multiplatform Gradle plugin automatically generates a Karma configuration file at build time which includes your settings from the kotlin.js.browser.testTask.useKarma {} block in your build.gradle(.kts). You can find the file at build/js/packages/projectName-test/karma.conf.js. To make adjustments to the configuration used by Karma, place your additional configuration files inside a directory called karma.config.d in the root of your project. All .js configuration files in this directory will be picked up and are automatically merged into the generated karma.conf.js at build time.

All Karma configuration abilities are well described in Karma's documentation.

webpack bundling

For browser targets, the Kotlin Multiplatform Gradle plugin uses the widely known webpack module bundler.

webpack version

The Kotlin Multiplatform plugin uses webpack 5.

If you have projects created with plugin versions earlier than 1.5.0, you can temporarily switch back to webpack 4 used in these versions by adding the following line to the project's gradle.properties:

```
kotlin.js.webpack.major.version=4
```

webpack task

The most common webpack adjustments can be made directly via the kotlin.js.browser.webpackTask {} configuration block in the Gradle build file:

- outputFileName - the name of the webpacked output file. It will be generated in <projectDir>/build/dist/<targetName> after an execution of a webpack task. The default value is the project name.
- output.libraryTarget - the module system for the webpacked output. Learn more about available module systems for Kotlin/JS projects. The default value is umd.

```
webpackTask {
    outputFileName = "mycustomfilename.js"
    output.libraryTarget = "commonjs2"
}
```

You can also configure common webpack settings to use in bundling, running, and testing tasks in the commonWebpackConfig {} block.

webpack configuration file

The Kotlin Multiplatform Gradle plugin automatically generates a standard webpack configuration file at the build time. It is located in build/js/packages/projectName/webpack.config.js.

If you want to make further adjustments to the webpack configuration, place your additional configuration files inside a directory called webpack.config.d in the root of your project. When building your project, all .js configuration files will automatically be merged into the build/js/packages/projectName/webpack.config.js file. For example, To add a new webpack loader, add the following to a .js file inside the webpack.config.d directory:

> In this case, the configuration object is the config global object. You need to modify it in your script.

```
config.module.rules.push({
    test: /\.extension$/,
    loader: 'loader-name'
});
```

All webpack configuration capabilities are well described in its documentation.

Building executables

For building executable JavaScript artifacts through webpack, the Kotlin Multiplatform Gradle plugin contains the browserDevelopmentWebpack and browserProductionWebpack Gradle tasks.

- browserDevelopmentWebpack creates development artifacts, which are larger in size, but take little time to create. As such, use the browserDevelopmentWebpack tasks during active development.
- browserProductionWebpack applies dead code elimination to the generated artifacts and minifies the resulting JavaScript file, which takes more time, but generates executables that are smaller in size. As such, use the browserProductionWebpack task when preparing your project for production use.

Execute either of these tasks to obtain the respective artifacts for development or production. The generated files will be available in build/dist unless specified otherwise.

```
./gradlew browserProductionWebpack
```

Note that these tasks will only be available if your target is configured to generate executable files (via binaries.executable()).

CSS

The Kotlin Multiplatform Gradle plugin also provides support for webpack's CSS and style loaders. While all options can be changed by directly modifying the webpack configuration files that are used to build your project, the most commonly used settings are available directly from the build.gradle(.kts) file.

To turn on CSS support in your project, set the cssSupport.enabled option in the Gradle build file in the commonWebpackConfig {} block. This configuration is also enabled by default when creating a new project using the wizard.

Kotlin

```
browser {
    commonWebpackConfig {
        cssSupport {
            enabled.set(true)
        }
    }
}
```

Groovy

```
browser {
    commonWebpackConfig {
        cssSupport {
            it.enabled = true
        }
    }
}
```

Alternatively, you can add CSS support independently for webpackTask {}, runTask {}, and testTask {}:

Kotlin

```
browser {
    webpackTask {
        cssSupport {
            enabled.set(true)
        }
    }
    runTask {
        cssSupport {
            enabled.set(true)
        }
    }
    testTask {
        useKarma {
            // ...
            webpackConfig.cssSupport {
                enabled.set(true)
            }
        }
    }
}
```

Groovy

```
browser {
    webpackTask {
        cssSupport {
            it.enabled = true
        }
    }
    runTask {
        cssSupport {
            it.enabled = true
        }
    }
    testTask {
        useKarma {
            // ...
            webpackConfig.cssSupport {
                it.enabled = true
            }
        }
    }
}
```

Activating CSS support in your project helps prevent common errors that occur when trying to use style sheets from an unconfigured project, such as Module parse failed: Unexpected character '@' (14:0).

You can use cssSupport.mode to specify how encountered CSS should be handled. The following values are available:

- "inline" (default): styles are added to the global <style> tag.
- "extract": styles are extracted into a separate file. They can then be included from an HTML page.
- "import": styles are processed as strings. This can be useful if you need access to the CSS from your code (such as val styles = require("main.css")).

To use different modes for the same project, use cssSupport.rules. Here, you can specify a list of KotlinWebpackCssRules, each of which defines a mode, as well as include and exclude patterns.

Node.js

For Kotlin/JS projects targeting Node.js, the plugin automatically downloads and installs the Node.js environment on the host. You can also use an existing Node.js instance if you have it.

Configuring Node.js settings

You can configure Node.js settings for each subproject, or set them for the project as a whole.

For example, to set the Node.js version for a specific subproject, add the following lines to its Gradle block in your build.gradle(.kts) file:

Kotlin

```
project.plugins.withType<org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsPlugin> {
    project.the<org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsEnvSpec>().version = "your Node.js version"
}
```

Groovy

```
project.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsPlugin) {
    project.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsEnvSpec).version = "your Node.js version"
}
```

To set a version for the entire project, including all subprojects, apply the same code to the allProjects {} block:

Kotlin

```
allprojects {
    project.plugins.withType<org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsPlugin> {
        project.the<org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsEnvSpec>().version = "your Node.js version"
    }
}
```

Groovy

```
allprojects {
    project.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsPlugin) {
        project.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsEnvSpec).version = "your Node.js version"
}
```

Using the NodeJsRootPlugin class to configure Node.js setting for the entire project is deprecated and will eventually stop being supported.

Use pre-installed Node.js

If Node.js is already installed on the host where you build Kotlin/JS projects, you can configure the Kotlin Multiplatform Gradle plugin to use it instead of installing its own Node.js instance.

To use a pre-installed Node.js instance, add the following lines to your build.gradle(.kts) file:

Kotlin

```
project.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsPlugin) {
    // Set to `true` for default behavior
    project.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsEnvSpec).download = false
}
```

Groovy

```
project.plugins.withType<org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsPlugin> {
    // Set to `true` for default behavior
    project.the<org.jetbrains.kotlin.gradle.targets.js.nodejs.NodeJsEnvSpec>().download = false
}
```

Yarn

By default, to download and install your declared dependencies at build time, the plugin manages its own instance of the Yarn package manager. It works out of the box without additional configuration, but you can tune it or use Yarn already installed on your host.

Additional Yarn features: .yarnrc

To configure additional Yarn features, place a .yarnrc file in the root of your project. At build time, it gets picked up automatically.

For example, to use a custom registry for npm packages, add the following line to a file called .yarnrc in the project root:

```
registry "http://my.registry/api/npm/"
```

To learn more about .yarnrc, visit the official Yarn documentation.

Use pre-installed Yarn

If Yarn is already installed on the host where you build Kotlin/JS projects, you can configure the Kotlin Multiplatform Gradle plugin to use it instead of installing its own Yarn instance.

To use the pre-installed Yarn instance, add the following lines to build.gradle(.kts):

Kotlin

```
rootProject.plugins.withType<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin> {
    rootProject.the<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension>().download = false
    // "true" for default behavior
}
```

Groovy

```
rootProject.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin) {
    rootProject.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension).download = false
}
```

Version locking via kotlin-js-store

Version locking via kotlin-js-store is available since Kotlin 1.6.10.

The kotlin-js-store directory in the project root is automatically generated by the Kotlin Multiplatform Gradle plugin to hold the yarn.lock file, which is necessary for version locking. The lockfile is entirely managed by the Yarn plugin and gets updated during the execution of the kotlinNpmInstall Gradle task.

To follow a recommended practice, commit kotlin-js-store and its contents to your version control system. It ensures that your application is being built with the exact same dependency tree on all machines.

If needed, you can change both directory and lockfile names in build.gradle(.kts):

Kotlin

```
rootProject.plugins.withType<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin> {
    rootProject.the<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension>().lockFileDirectory =
        project.rootDir.resolve("my-kotlin-js-store")
    rootProject.the<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension>().lockFileName = "my-yarn.lock"
}
```

Groovy

```
rootProject.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin) {
    rootProject.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension).lockFileDirectory =
        file("my-kotlin-js-store")
    rootProject.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension).lockFileName = 'my-yarn.lock'
}
```

Changing the name of the lockfile may cause dependency inspection tools to no longer pick up the file.

To learn more about yarn.lock, visit the official Yarn documentation.

Reporting that yarn.lock has been updated

Kotlin/JS provides Gradle settings that could notify you if the yarn.lock file has been updated. You can use these settings when you want to be notified if yarn.lock has been changed silently during the CI build process:

- YarnLockMismatchReport, which specifies how changes to the yarn.lock file are reported. You can use one of the following values:
  - FAIL fails the corresponding Gradle task. This is the default.
  - WARNING writes the information about changes in the warning log.
  - NONE disables reporting.
- reportNewYarnLock, which reports about the recently created yarn.lock file explicitly. By default, this option is disabled: it's a common practice to generate a new yarn.lock file at the first start. You can use this option to ensure that the file has been committed to your repository.
- yarnLockAutoReplace, which replaces yarn.lock automatically every time the Gradle task is run.

To use these options, update build.gradle(.kts) as follows:

Kotlin

```
import org.jetbrains.kotlin.gradle.targets.js.yarn.YarnLockMismatchReport
import org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension

rootProject.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin::class.java) {
    rootProject.the<YarnRootExtension>().yarnLockMismatchReport =
        YarnLockMismatchReport.WARNING // NONE | FAIL
    rootProject.the<YarnRootExtension>().reportNewYarnLock = false // true
    rootProject.the<YarnRootExtension>().yarnLockAutoReplace = false // true
}
```

Groovy

```
import org.jetbrains.kotlin.gradle.targets.js.yarn.YarnLockMismatchReport
import org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension

rootProject.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin) {
    rootProject.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension).yarnLockMismatchReport =
        YarnLockMismatchReport.WARNING // NONE | FAIL
    rootProject.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension).reportNewYarnLock = false //
true
    rootProject.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension).yarnLockAutoReplace = false //
true
}
```

Installing npm dependencies with --ignore-scripts by default

Installing npm dependencies with --ignore-scripts by default is available since Kotlin 1.6.10.

To reduce the likelihood of executing malicious code from compromised npm packages, the Kotlin Multiplatform Gradle plugin prevents the execution of lifecycle scripts during the installation of npm dependencies by default.

You can explicitly enable lifecycle scripts execution by adding the following lines to build.gradle(.kts):

Kotlin

```
rootProject.plugins.withType<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin> {
    rootProject.the<org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension>().ignoreScripts = false
}
```

Groovy

```
rootProject.plugins.withType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnPlugin) {
    rootProject.extensions.getByType(org.jetbrains.kotlin.gradle.targets.js.yarn.YarnRootExtension).ignoreScripts = false
}
```

Distribution target directory

By default, the results of a Kotlin/JS project build reside in the /build/dist/<targetName>/<binaryName> directory within the project root.

Prior to Kotlin 1.9.0, the default distribution target directory was /build/distributions.

To set another location for project distribution files, in your build script inside the browser {} block, add a distribution {} block and assign a value to the outputDirectory property by using the set() method. Once you run a project build task, Gradle will save the output bundle in this location together with project resources.

Kotlin

```
kotlin {
    js {
        browser {
            distribution {
                outputDirectory.set(projectDir.resolve("output"))
            }
        }
        binaries.executable()
        // ...
    }
}
```

Groovy

```
kotlin {
    js {
        browser {
            distribution {
                outputDirectory = file("$projectDir/output")
            }
        }
        binaries.executable()
        // ...
    }
}
```

Module name

To adjust the name for the JavaScript module (which is generated in build/js/packages/myModuleName), including the corresponding .js and .d.ts files, use the moduleName option:

```
js {
    moduleName = "myModuleName"
}
```

Note that this does not affect the webpacked output in build/dist.

package.json customization

The package.json file holds the metadata of a JavaScript package. Popular package registries such as npm require all published packages to have such a file. They use it to track and manage package publications.

The Kotlin Multiplatform Gradle plugin automatically generates package.json for Kotlin/JS projects during build time. By default, the file contains essential data: name, version, license, dependencies, and some other package attributes.

Aside from basic package attributes, package.json can define how a JavaScript project should behave, for example, identifying scripts that are available to run.

You can add custom entries to the project's package.json via the Gradle DSL. To add custom fields to your package.json, use the customField() function in the compilations packageJson block:

```
kotlin {
    js {
        compilations["main"].packageJson {
            customField("hello", mapOf("one" to 1, "two" to 2))
        }
    }
}
```

When you build the project, this code adds the following block to the package.json file:

```
"hello": {
    "one": 1,
    "two": 2
}
```

Learn more about writing package.json files for npm registry in the npm docs.

Run Kotlin/JS

Since Kotlin/JS projects are managed with the Kotlin Multiplatform Gradle plugin, you can run your project using the appropriate tasks. If you're starting with a blank project, ensure that you have some sample code to execute. Create the file src/jsMain/kotlin/App.kt and fill it with a small "Hello, World"-type code snippet:

```
fun main() {
    console.log("Hello, Kotlin/JS!")
}
```

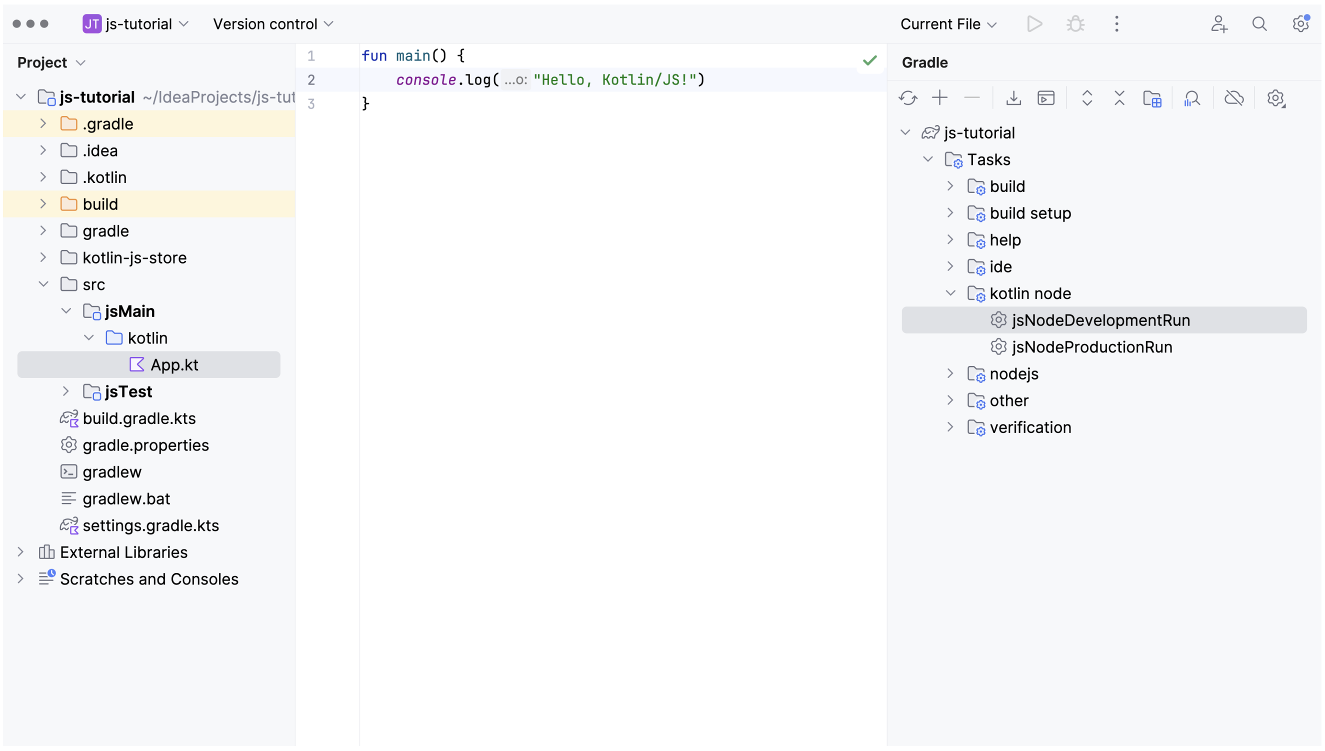
Depending on the target platform, some platform-specific extra setup might be required to run your code for the first time.

Run the Node.js target

When targeting Node.js with Kotlin/JS, you can simply execute the jsNodeDevelopmentRun Gradle task. This can be done for example via the command line, using the Gradle wrapper:

```
./gradlew jsNodeDevelopmentRun
```

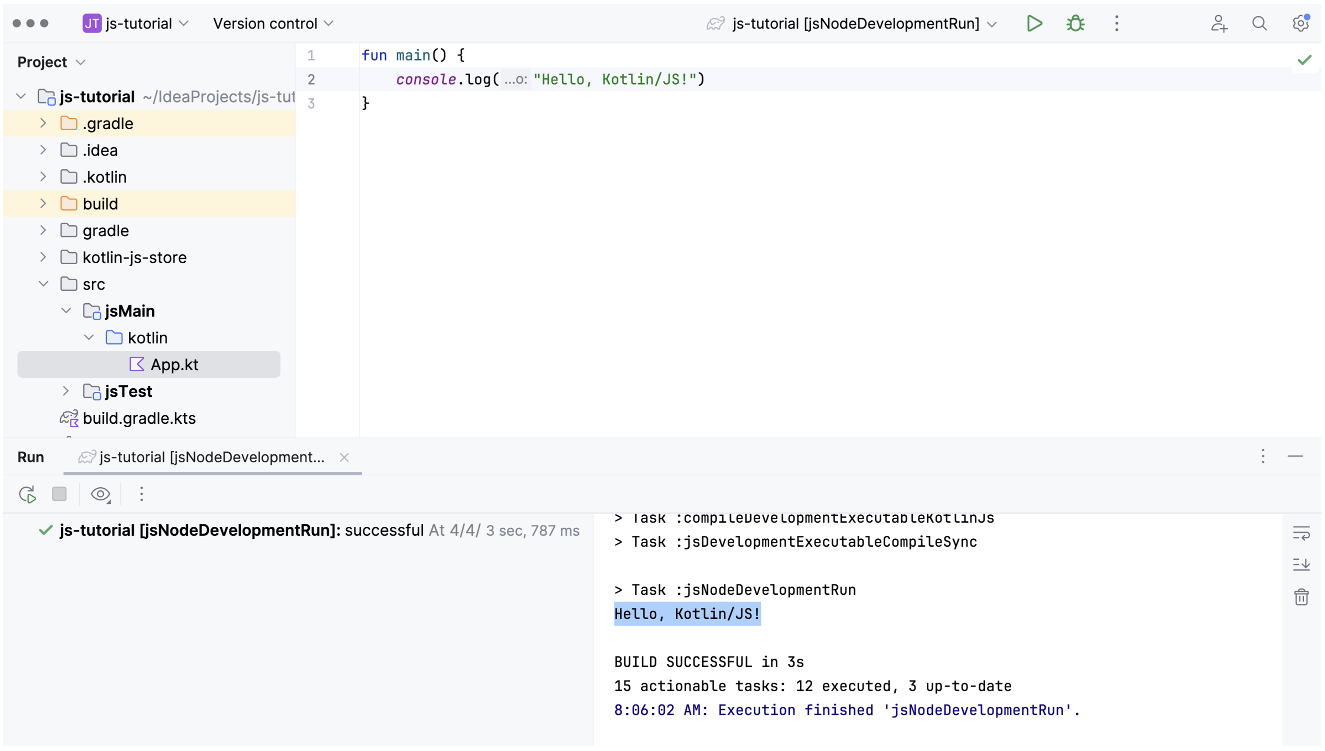
If you're using IntelliJ IDEA, you can find the jsNodeDevelopmentRun action in the Gradle tool window:



```kotlin
fun main() {
    console.log("Hello, Kotlin/JS!")
}
```

Gradle Run task in IntelliJ IDEA

On first start, the kotlin.multiplatform Gradle plugin will download all required dependencies to get you up and running. After the build is completed, the program is executed, and you can see the logging output in the terminal:



```kotlin
fun main() {
    console.log("Hello, Kotlin/JS!")
}
```

js-tutorial [jsNodeDevelopmentRun]: successful At 4/4/ 3 sec, 787 ms

```
> Task :compileDevelopmentExecutableKotlinJs
> Task :jsDevelopmentExecutableCompileSync

> Task :jsNodeDevelopmentRun
Hello, Kotlin/JS!

BUILD SUCCESSFUL in 3s
15 actionable tasks: 12 executed, 3 up-to-date
8:06:02 AM: Execution finished 'jsNodeDevelopmentRun'.
```

Executing the JS target in a Kotlin Multiplatform project in IntelliJ IDEA

Run the browser target

When targeting the browser, your project is required to have an HTML page. This page will be served by the development server while you are working on your application, and should embed your compiled Kotlin/JS file. Create and fill an HTML file /src/jsMain/resources/index.html:

```
<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="UTF-8">
    <title>JS Client</title>
</head>
<body>
<script src="js-tutorial.js"></script>
</body>
</html>
```

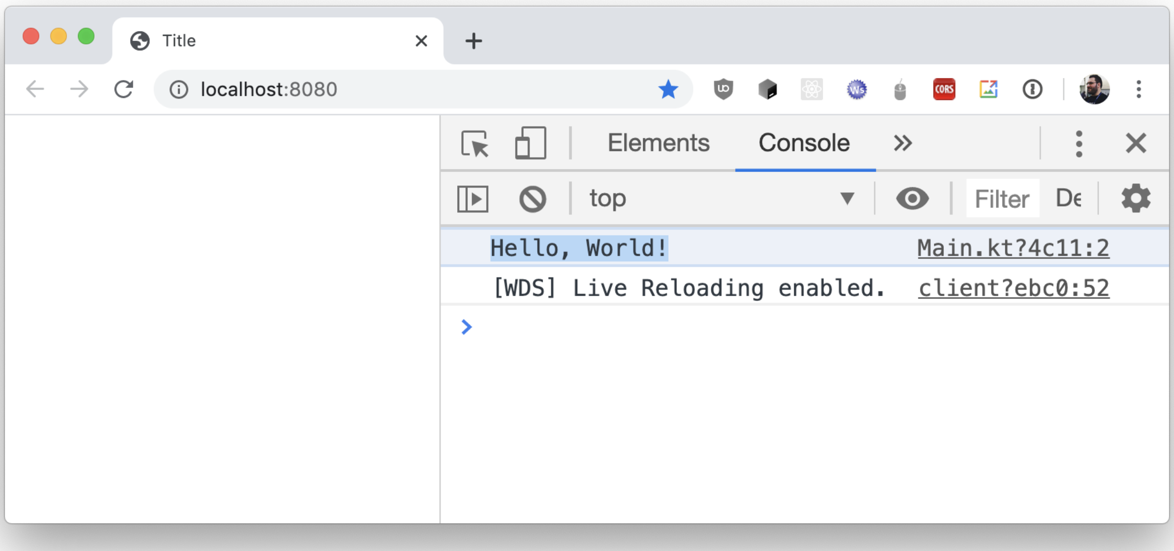
By default, the name of your project's generated artifact (which is created through webpack) that needs to be referenced is your project name (in this case, js-tutorial). If you've named your project followAlong, make sure to embed followAlong.js instead of js-tutorial.js

After making these adjustments, start the integrated development server. You can do this from the command line via the Gradle wrapper:

```
./gradlew jsBrowserDevelopmentRun
```

When working from IntelliJ IDEA, you can find the jsBrowserDevelopmentRun action in the Gradle tool window.

After the project has been built, the embedded webpack-dev-server will start running, and will open a (seemingly empty) browser window pointing to the HTML file you specified previously. To validate that your program is running correctly, open the developer tools of your browser (for example by right-clicking and choosing the Inspect action). Inside the developer tools, navigate to the console, where you can see the results of the executed JavaScript code:



```
Hello, World!                    Main.kt?4c11:2
[WDS] Live Reloading enabled.    client?ebc0:52
```

Console output in browser developer tools

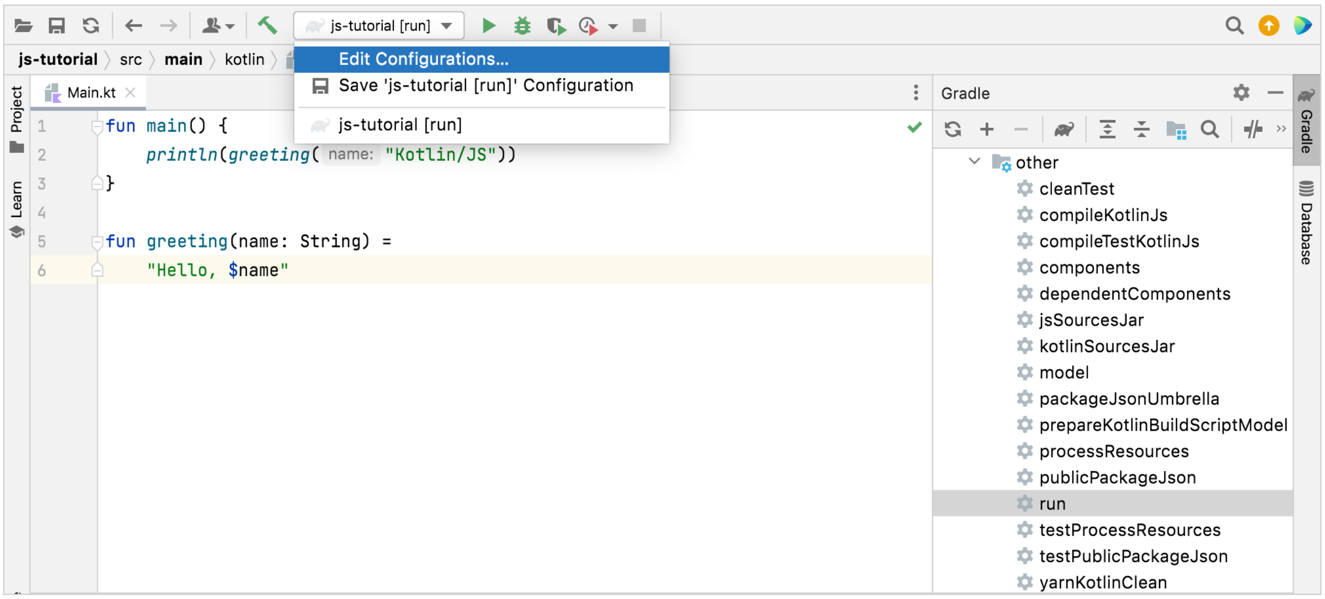
With this setup, you can recompile your project after each code change to see your changes. Kotlin/JS also supports a more convenient way of automatically rebuilding the application while you are developing it. To find out how to set up this continuous mode, check out the corresponding tutorial.

Development server and continuous compilation

Instead of manually compiling and executing a Kotlin/JS project every time you want to see the changes you made, you can use the continuous compilation mode. Instead of using the regular run command, invoke the Gradle wrapper in continuous mode:

```
./gradlew run --continuous
```

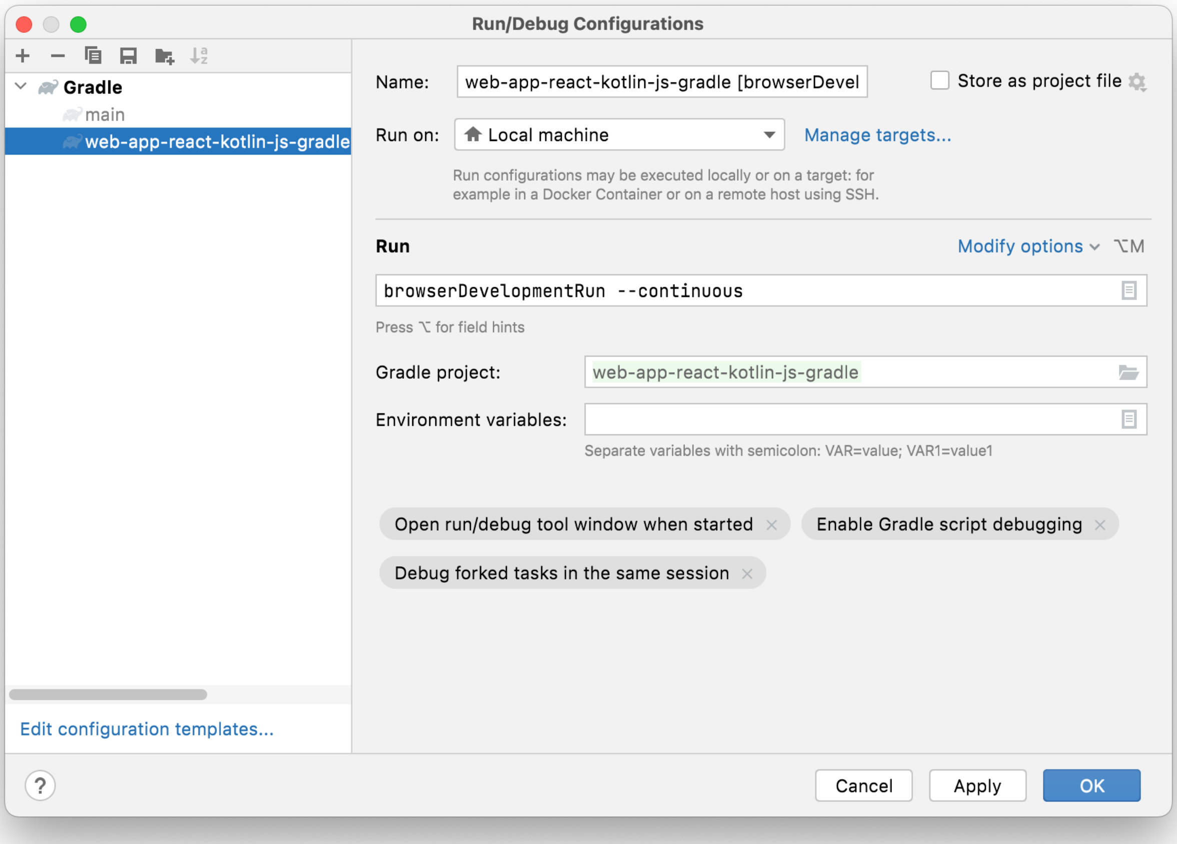
If you are working in IntelliJ IDEA, you can pass the same flag via the run configuration. After running the Gradle run task for the first time from the IDE, IntelliJ IDEA automatically generates a run configuration for it, which you can edit:



```kotlin
fun main() {
    println(greeting( name: "Kotlin/JS"))
}

fun greeting(name: String) =
    "Hello, $name"
```

Editing run configurations in IntelliJ IDEA

Enabling continuous mode via the Run/Debug Configurations dialog is as easy as adding the --continuous flag to the arguments for the run configuration:


Run/Debug Configurations
Gradle
main
web-app-react-kotlin-js-gradle
Edit configuration templates...
Cancel
Apply
OK

Name: web-app-react-kotlin-js-gradle [browserDevel
Store as project file
Run on: Local machine
Manage targets...
Run configurations may be executed locally or on a target: for example in a Docker Container or on a remote host using SSH.

Run
Modify options ⌥M

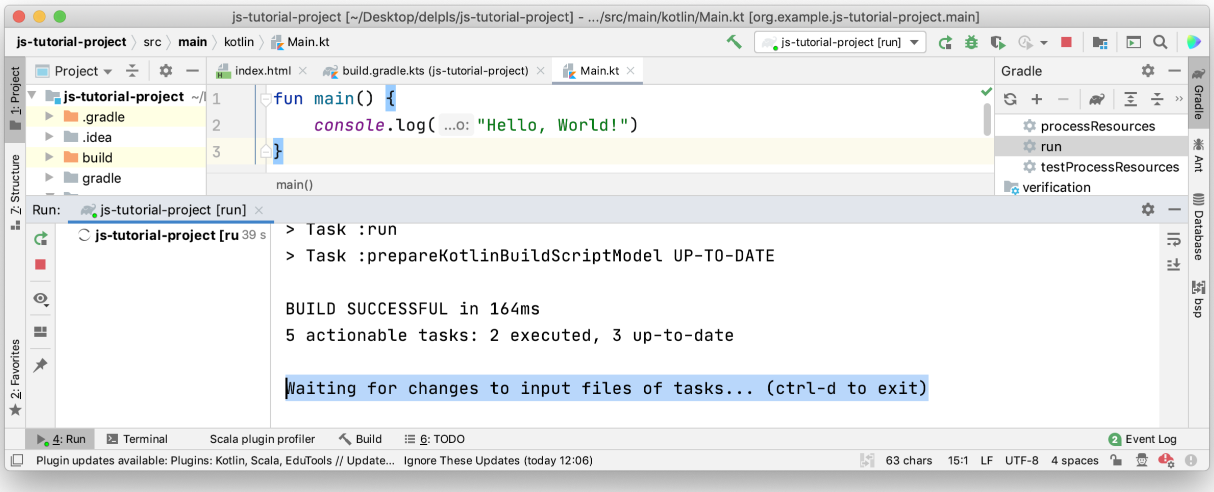
```
browserDevelopmentRun --continuous
```

Press ⌥ for field hints
Gradle project: web-app-react-kotlin-js-gradle
Environment variables:
Separate variables with semicolon: VAR=value; VAR1=value1

Open run/debug tool window when started
Enable Gradle script debugging
Debug forked tasks in the same session

Adding the continuous flag to a run configuration in IntelliJ IDEA

When executing this run configuration, you can note that the Gradle process continues watching for changes to the program:



```
fun main() {
    console.log( ...o: "Hello, World!")
}
```

```
> Task :run
> Task :prepareKotlinBuildScriptModel UP-TO-DATE

BUILD SUCCESSFUL in 164ms
5 actionable tasks: 2 executed, 3 up-to-date

Waiting for changes to input files of tasks... (ctrl-d to exit)
```

Plugin updates available: Plugins: Kotlin, Scala, EduTools // Update... Ignore These Updates (today 12:06)   63 chars 15:1 LF UTF-8 4 spaces

Gradle waiting for changes

Once a change has been detected, the program will be recompiled automatically. If you still have the page open in the browser, the development server will trigger an automatic reload of the page, and the changes will become visible. This is thanks to the integrated webpack-dev-server that is managed by the Kotlin

Multiplatform Gradle plugin.

Debug Kotlin/JS code

JavaScript source maps provide mappings between the minified code produced by bundlers or minifiers and the actual source code a developer works with. This way, the source maps enable support for debugging the code during its execution.

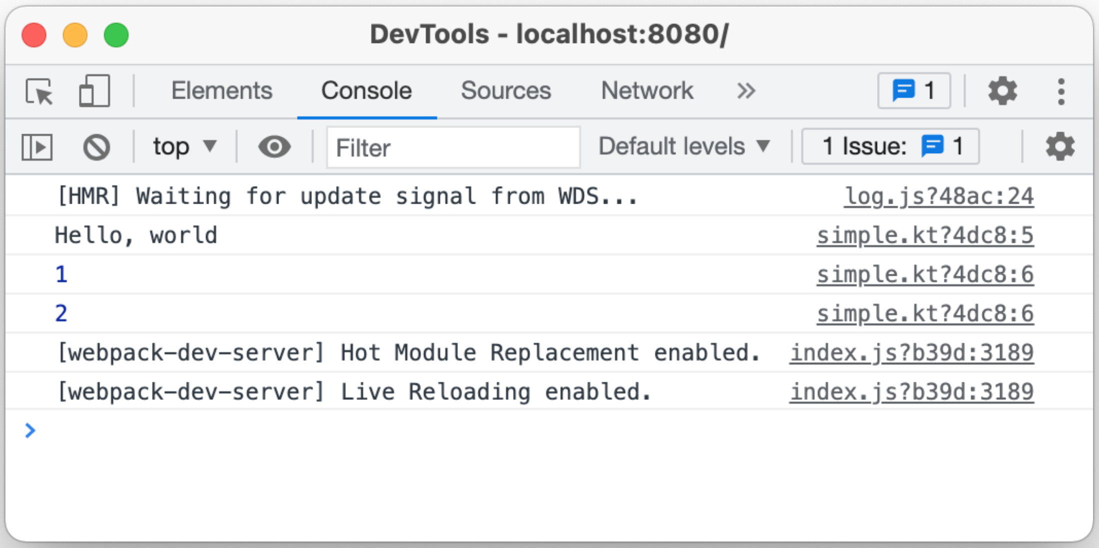
The Kotlin Multiplatform Gradle plugin automatically generates source maps for the project builds, making them available without any additional configuration.

Debug in browser

Most modern browsers provide tools that allow inspecting the page content and debugging the code that executes on it. Refer to your browser's documentation for more details.

To debug Kotlin/JS in the browser:

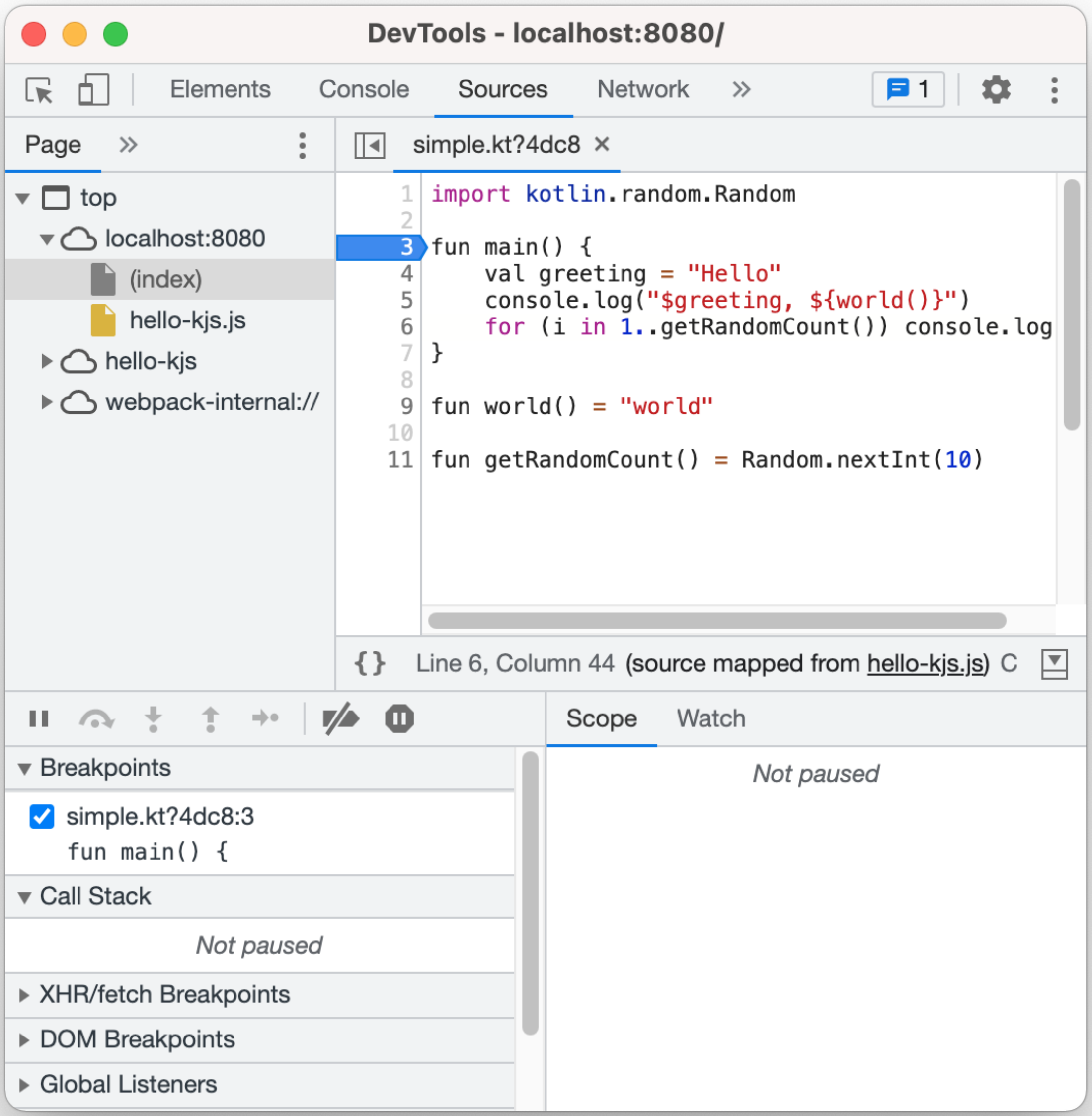
1. Run the project by calling one of the available run Gradle tasks, for example, browserDevelopmentRun or jsBrowserDevelopmentRun in a multiplatform project. Learn more about running Kotlin/JS.
2. Navigate to the page in the browser and launch its developer tools (for example, by right-clicking and selecting the Inspect action). Learn how to find the developer tools in popular browsers.
3. If your program is logging information to the console, navigate to the Console tab to see this output. Depending on your browser, these logs can reference the Kotlin source files and lines they come from:



```
[HMR] Waiting for update signal from WDS...                    log.js?48ac:24
Hello, world                                                simple.kt?4dc8:5
1                                                           simple.kt?4dc8:6
2                                                           simple.kt?4dc8:6
[webpack-dev-server] Hot Module Replacement enabled.    index.js?b39d:3189
[webpack-dev-server] Live Reloading enabled.            index.js?b39d:3189
```

Chrome DevTools console

4. Click the file reference on the right to navigate to the corresponding line of code. Alternatively, you can manually switch to the Sources tab and find the file you need in the file tree. Navigating to the Kotlin file shows you the regular Kotlin code (as opposed to minified JavaScript):



```
import kotlin.random.Random

fun main() {
    val greeting = "Hello"
    console.log("$greeting, ${world()}")
    for (i in 1..getRandomCount()) console.log
}

fun world() = "world"

fun getRandomCount() = Random.nextInt(10)
```

Line 6, Column 44 (source mapped from hello-kjs.js)

```
fun main() {
```

Debugging in Chrome DevTools

You can now start debugging the program. Set a breakpoint by clicking on one of the line numbers. The developer tools even support setting breakpoints within a statement. As with regular JavaScript code, any set breakpoints will persist across page reloads. This also makes it possible to debug Kotlin's main() method which is executed when the script is loaded for the first time.

Debug in the IDE

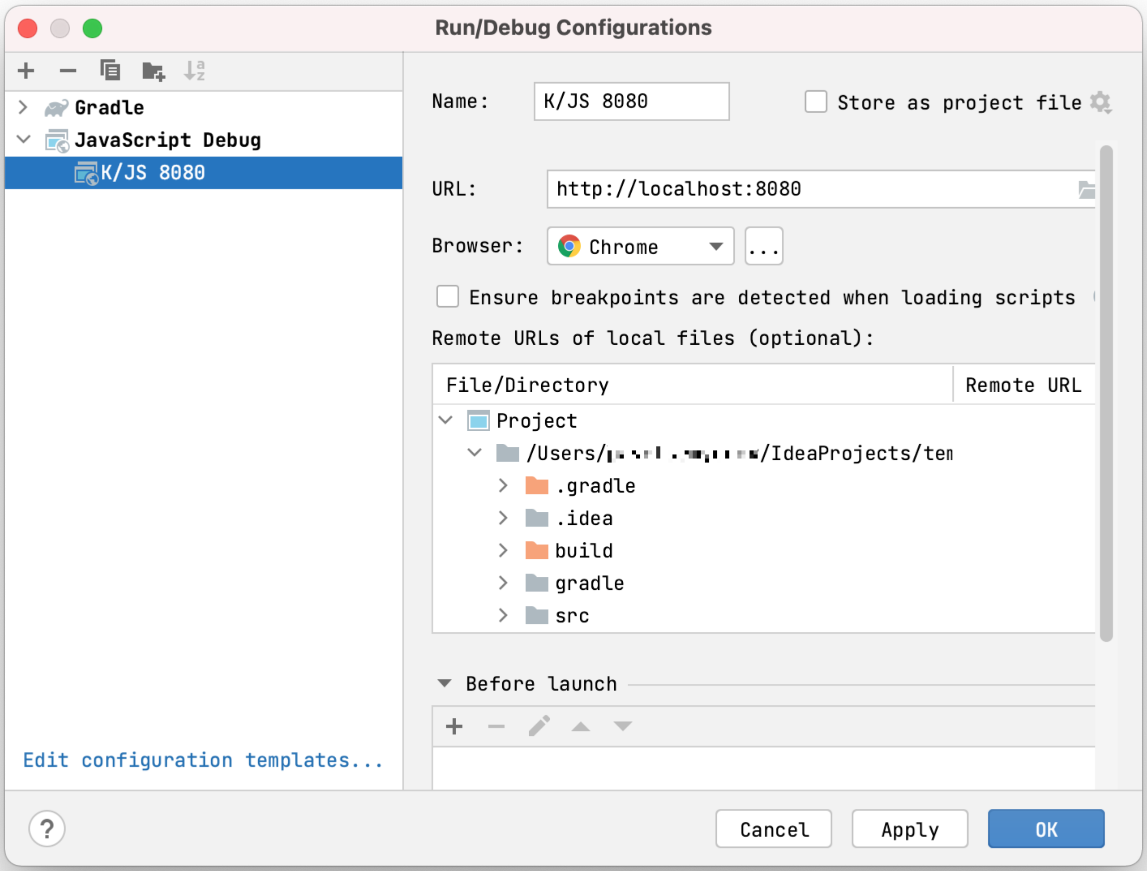
IntelliJ IDEA Ultimate provides a powerful set of tools for debugging code during development.

For debugging Kotlin/JS in IntelliJ IDEA, you'll need a JavaScript Debug configuration. To add such a debug configuration:

1. Go to Run | Edit Configurations.

2. Click + and select JavaScript Debug.

3. Specify the configuration Name and provide the URL on which the project runs (http://localhost:8080 by default).



Name: K/JS 8080

Store as project file

URL: http://localhost:8080

Browser: Chrome

Ensure breakpoints are detected when loading scripts

Remote URLs of local files (optional):

File/Directory	Remote URL
Project	
/Users/[redacted]/IdeaProjects/tem	
.gradle	
.idea	
build	
gradle	
src	

Before launch

JavaScript debug configuration

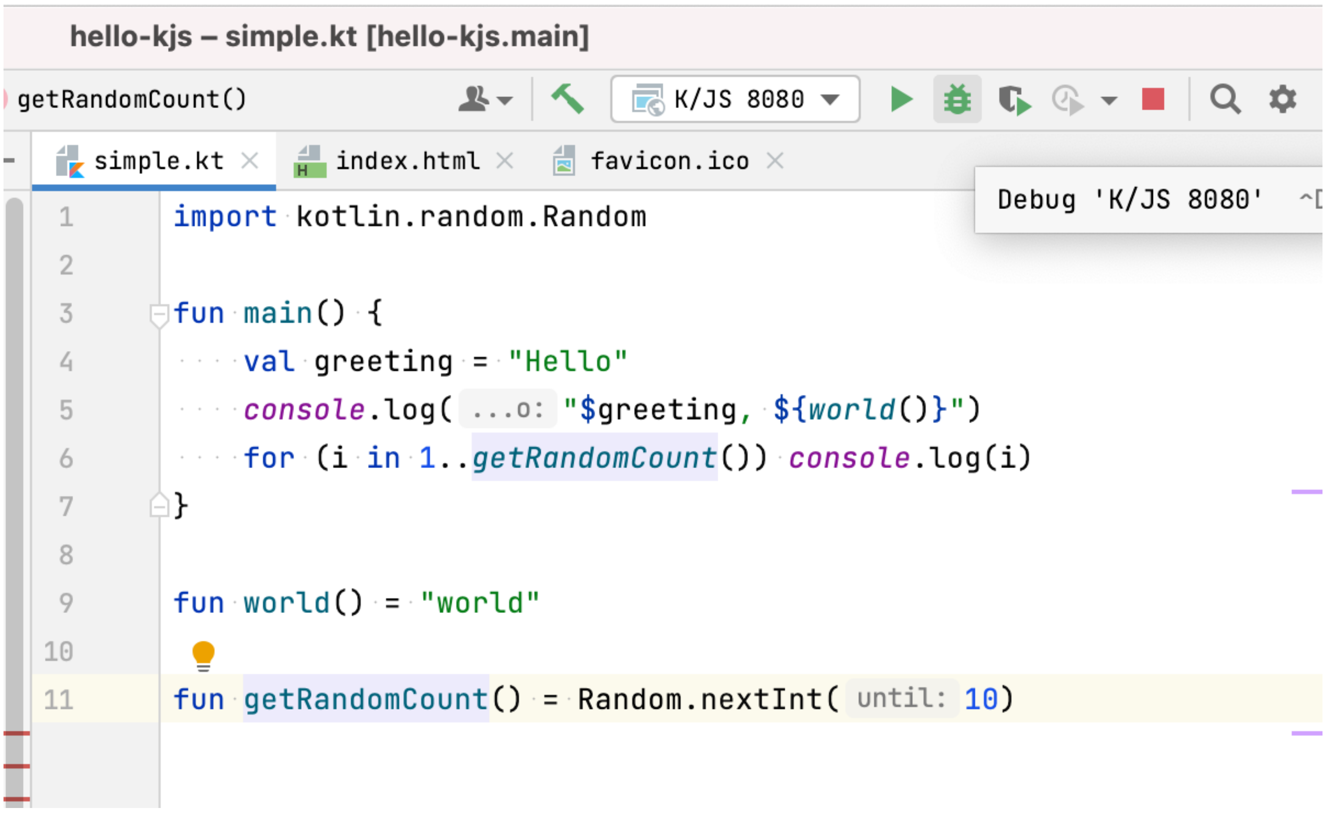
4. Save the configuration.

Learn more about setting up JavaScript debug configurations.

Now you're ready to debug your project!

1. Run the project by calling one of the available run Gradle tasks, for example, browserDevelopmentRun or jsBrowserDevelopmentRun in a multiplatform project. Learn more about running Kotlin/JS.

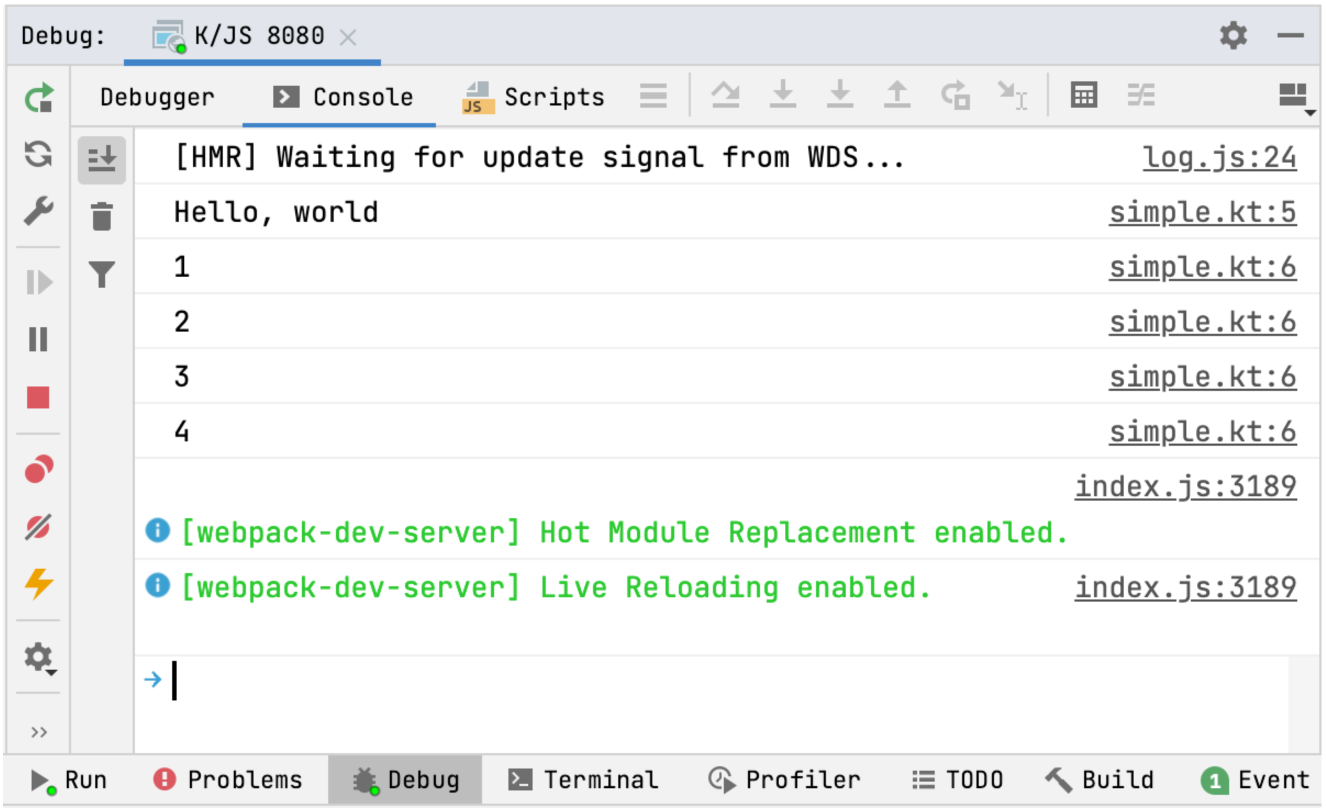
2. Start the debugging session by running the JavaScript debug configuration you've created previously:



```kotlin
import kotlin.random.Random

fun main() {
    val greeting = "Hello"
    console.log( ...o: "$greeting, ${world()}")
    for (i in 1..getRandomCount()) console.log(i)
}

fun world() = "world"

fun getRandomCount() = Random.nextInt( until: 10)
```

JavaScript debug configuration

3. You can see the console output of your program in the Debug window in IntelliJ IDEA. The output items reference the Kotlin source files and lines they come from:



```
[HMR] Waiting for update signal from WDS...                    log.js:24
Hello, world                                                simple.kt:5
1                                                           simple.kt:6
2                                                           simple.kt:6
3                                                           simple.kt:6
4                                                           simple.kt:6
                                                          index.js:3189
[webpack-dev-server] Hot Module Replacement enabled.
[webpack-dev-server] Live Reloading enabled.              index.js:3189
```

JavaScript debug output in the IDE

4. Click the file reference on the right to navigate to the corresponding line of code.

You can now start debugging the program using the whole set of tools that the IDE offers: breakpoints, stepping, expression evaluation, and more. Learn more about debugging in IntelliJ IDEA.

> Because of the limitations of the current JavaScript debugger in IntelliJ IDEA, you may need to rerun the JavaScript debug to make the execution stop on breakpoints.

Debug in Node.js

If your project targets Node.js, you can debug it in this runtime.

To debug a Kotlin/JS application targeting Node.js:

1. Build the project by running the build Gradle task.
2. Find the resulting .js file for Node.js in the build/js/packages/your-module/kotlin/ directory inside your project's directory.
3. Debug it in Node.js as described in the Node.js Debugging Guide.

What's next?

Now that you know how to start debug sessions with your Kotlin/JS project, learn to make efficient use of the debugging tools:

- Learn how to debug JavaScript in Google Chrome
- Get familiar with IntelliJ IDEA JavaScript debugger
- Learn how to debug in Node.js.

If you run into any problems

If you face any issues with debugging Kotlin/JS, please report them to our issue tracker, YouTrack

Run tests in Kotlin/JS

The Kotlin Multiplatform Gradle plugin lets you run tests through a variety of test runners that can be specified via the Gradle configuration.

When you create a multiplatform project, you can add test dependencies to all the source sets, including the JavaScript target, by using a single dependency in commonTest:

Kotlin

```kotlin
// build.gradle.kts

kotlin {
    sourceSets {
         commonTest.dependencies {
            implementation(kotlin("test")) // This makes test annotations and functionality available in JS
        }
    }
}
```

Groovy

```groovy
// build.gradle

kotlin {
    sourceSets {
        commonTest {
            dependencies {
                implementation kotlin("test") // This makes test annotations and functionality available in JS
            }
        }
    }
}
```

You can tune how tests are executed in Kotlin/JS by adjusting the settings available in the testTask block in the Gradle build script. For example, using the Karma test runner together with a headless instance of Chrome and an instance of Firefox looks like this:

```
kotlin {
    js {
        browser {
            testTask {
                useKarma {
                    useChromeHeadless()
                    useFirefox()
                }
            }
        }
    }
}
```

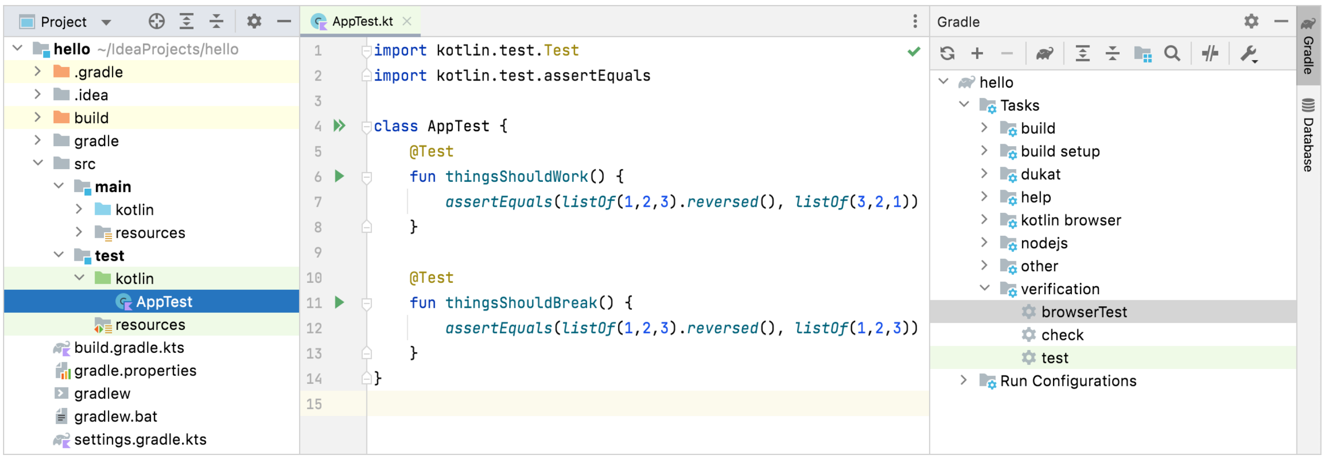
For a detailed description of the available functionality, check out the Kotlin/JS reference on configuring the test task.

Please note that by default, no browsers are bundled with the plugin. This means that you'll have to ensure they're available on the target system.

To check that tests are executed properly, add a file src/jsTest/kotlin/AppTest.kt and fill it with this content:

```
import kotlin.test.Test
import kotlin.test.assertEquals

class AppTest {
    @Test
    fun thingsShouldWork() {
        assertEquals(listOf(1,2,3).reversed(), listOf(3,2,1))
    }

    @Test
    fun thingsShouldBreak() {
        assertEquals(listOf(1,2,3).reversed(), listOf(1,2,3))
    }
}
```

To run the tests in the browser, execute the jsBrowserTest task via IntelliJ IDEA, or use the gutter icons to execute all or individual tests:



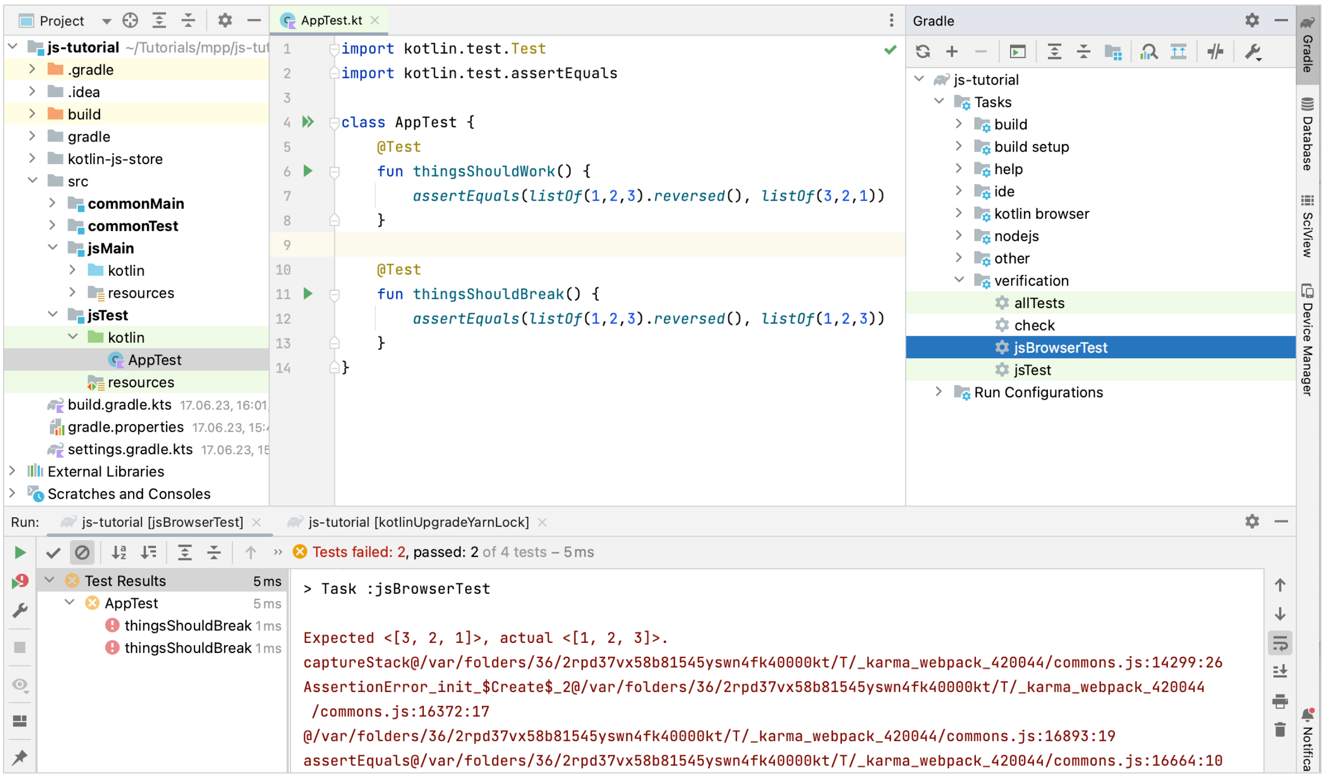
```
import kotlin.test.Test
import kotlin.test.assertEquals

class AppTest {
    @Test
    fun thingsShouldWork() {
        assertEquals(listOf(1,2,3).reversed(), listOf(3,2,1))
    }

    @Test
    fun thingsShouldBreak() {
        assertEquals(listOf(1,2,3).reversed(), listOf(1,2,3))
    }
}
```

Gradle browserTest task

Alternatively, if you want to run the tests via the command line, use the Gradle wrapper:

```
./gradlew jsBrowserTest
```

After running the tests from IntelliJ IDEA, the Run tool window will show the test results. You can click failed tests to see their stack trace, and navigate to the corresponding test implementation via a double click.



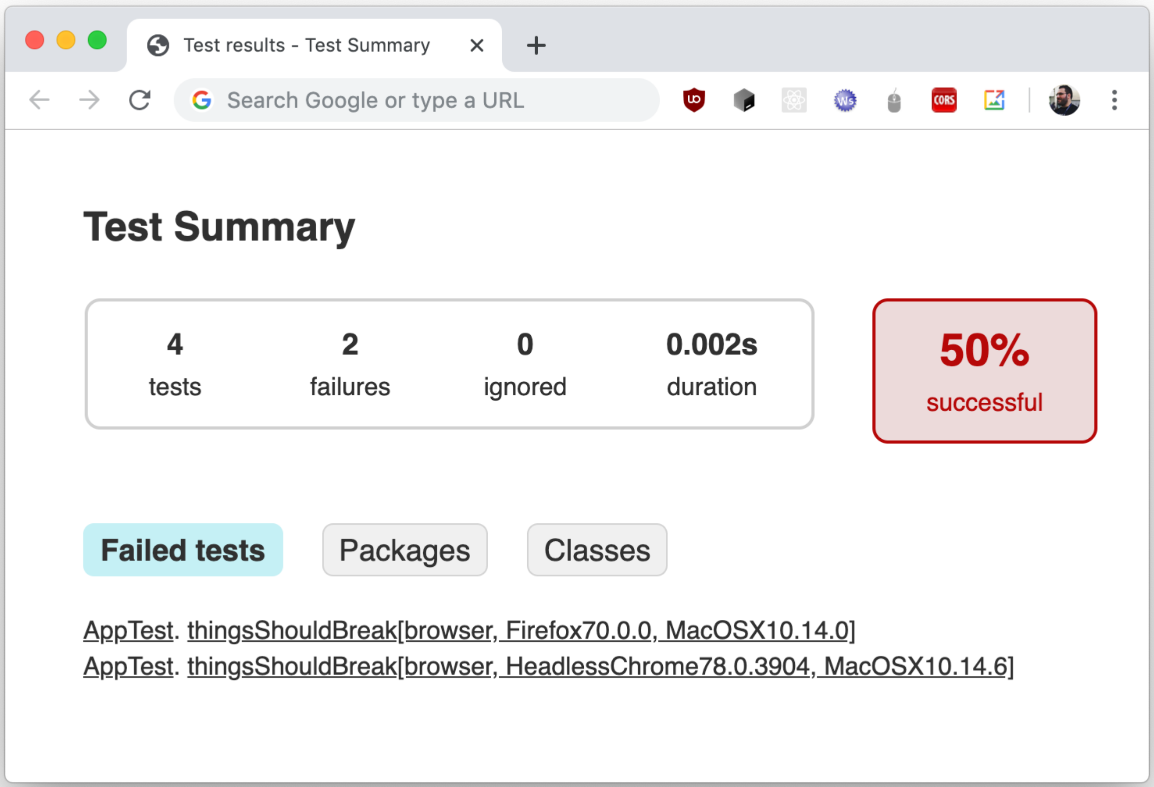
```kotlin
import kotlin.test.Test
import kotlin.test.assertEquals

class AppTest {
    @Test
    fun thingsShouldWork() {
        assertEquals(listOf(1,2,3).reversed(), listOf(3,2,1))
    }

    @Test
    fun thingsShouldBreak() {
        assertEquals(listOf(1,2,3).reversed(), listOf(1,2,3))
    }
}
```

Tests failed: 2, passed: 2 of 4 tests – 5 ms

```
> Task :jsBrowserTest

Expected <[3, 2, 1]>, actual <[1, 2, 3]>.
captureStack@/var/folders/36/2rpd37vx58b81545yswn4fk40000kt/T/_karma_webpack_420044/commons.js:14299:26
AssertionError_init_$Create$_2@/var/folders/36/2rpd37vx58b81545yswn4fk40000kt/T/_karma_webpack_420044
 /commons.js:16372:17
@/var/folders/36/2rpd37vx58b81545yswn4fk40000kt/T/_karma_webpack_420044/commons.js:16893:19
assertEquals@/var/folders/36/2rpd37vx58b81545yswn4fk40000kt/T/_karma_webpack_420044/commons.js:16664:10
```

Test results in IntelliJ IDEA

After each test run, regardless of how you executed the test, you can find a properly formatted test report from Gradle in build/reports/tests/jsBrowserTest/index.html. Open this file in a browser to see another overview of the test results:


Test results - Test Summary

Search Google or type a URL

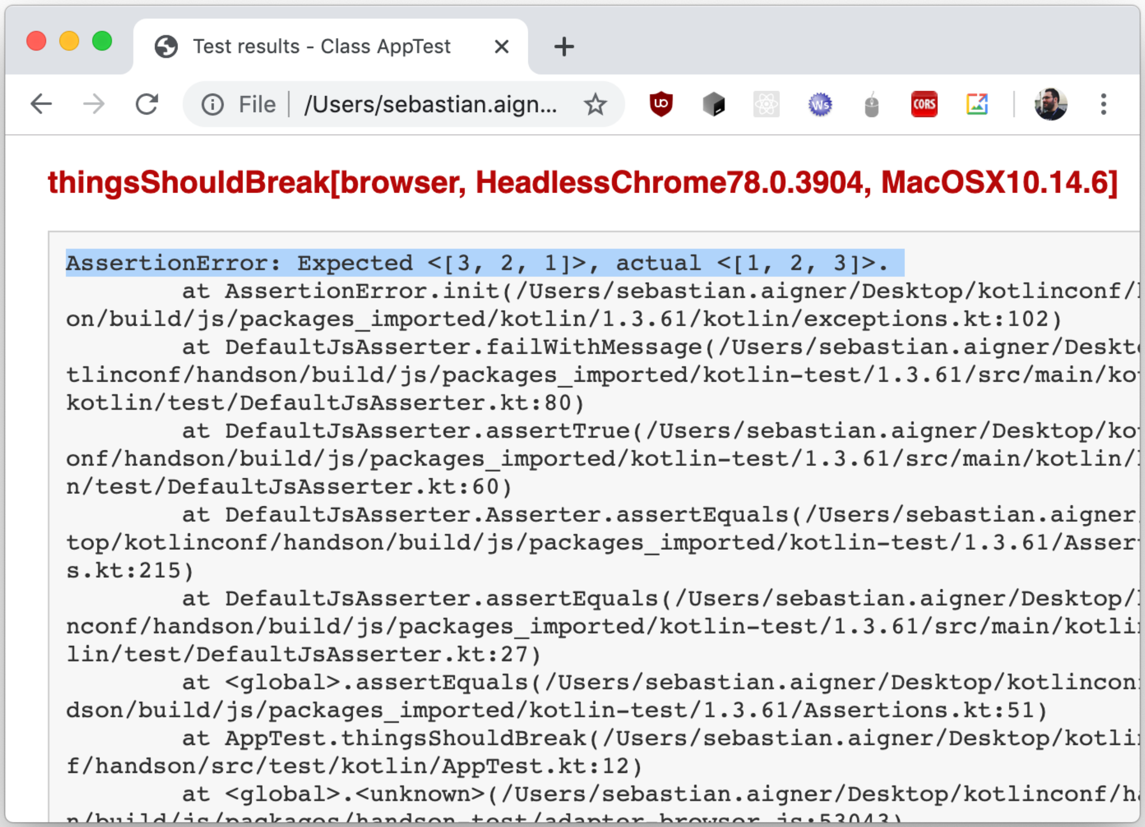
Test Summary

4	2	0	0.002s	50%
tests	failures	ignored	duration	successful

AppTest. thingsShouldBreak[browser, Firefox70.0.0, MacOSX10.14.0]
AppTest. thingsShouldBreak[browser, HeadlessChrome78.0.3904, MacOSX10.14.6]

Gradle test summary

If you are using the set of example tests shown in the snippet above, one test passes, and one test breaks, which gives the resulting total of 50% successful tests. To get more information about individual test cases, you can navigate via the provided hyperlinks:



thingsShouldBreak[browser, HeadlessChrome78.0.3904, MacOSX10.14.6]

```
AssertionError: Expected <[3, 2, 1]>, actual <[1, 2, 3]>.
        at AssertionError.init(/Users/sebastian.aigner/Desktop/kotlinconf/
on/build/js/packages_imported/kotlin/1.3.61/kotlin/exceptions.kt:102)
        at DefaultJsAsserter.failWithMessage(/Users/sebastian.aigner/Deskt
tlinconf/handson/build/js/packages_imported/kotlin-test/1.3.61/src/main/ko
kotlin/test/DefaultJsAsserter.kt:80)
        at DefaultJsAsserter.assertTrue(/Users/sebastian.aigner/Desktop/ko
onf/handson/build/js/packages_imported/kotlin-test/1.3.61/src/main/kotlin/
n/test/DefaultJsAsserter.kt:60)
        at DefaultJsAsserter.Asserter.assertEquals(/Users/sebastian.aigner
top/kotlinconf/handson/build/js/packages_imported/kotlin-test/1.3.61/Asser
s.kt:215)
        at DefaultJsAsserter.assertEquals(/Users/sebastian.aigner/Desktop/
nconf/handson/build/js/packages_imported/kotlin-test/1.3.61/src/main/kotli
lin/test/DefaultJsAsserter.kt:27)
        at <global>.assertEquals(/Users/sebastian.aigner/Desktop/kotlincon
dson/build/js/packages_imported/kotlin-test/1.3.61/Assertions.kt:51)
        at AppTest.thingsShouldBreak(/Users/sebastian.aigner/Desktop/kotli
f/handson/src/test/kotlin/AppTest.kt:12)
        at <global>.<unknown>(/Users/sebastian.aigner/Desktop/kotlinconf/h
```

Stacktrace of failed test in the Gradle summary

Kotlin/JS IR compiler

The Kotlin/JS IR compiler backend is the main focus of innovation around Kotlin/JS, and paves the way forward for the technology.

Rather than directly generating JavaScript code from Kotlin source code, the Kotlin/JS IR compiler backend leverages a new approach. Kotlin source code is first transformed into a Kotlin intermediate representation (IR), which is subsequently compiled into JavaScript. For Kotlin/JS, this enables aggressive optimizations, and allows improvements on pain points that were present in the previous compiler, such as generated code size (through dead code elimination), and JavaScript and TypeScript ecosystem interoperability, to name some examples.

The IR compiler backend is available starting with Kotlin 1.4.0 through the Kotlin Multiplatform Gradle plugin. To enable it in your project, pass a compiler type to the js function in your Gradle build script:

```
kotlin {
    js(IR) { // or: LEGACY, BOTH
        // ...
        binaries.executable() // not applicable to BOTH, see details below
    }
}
```

- IR uses the new IR compiler backend for Kotlin/JS.
- LEGACY uses the old compiler backend.
- BOTH compiles your project with the new IR compiler as well as the default compiler backend. Use this mode for authoring libraries compatible with both backends.

The old compiler backend has been deprecated since Kotlin 1.8.0. Starting with Kotlin 1.9.0, using compiler types LEGACY or BOTH leads to an error.

The compiler type can also be set in the gradle.properties file, with the key kotlin.js.compiler=ir. This behaviour is overwritten by any settings in the build.gradle(.kts), however.

Lazy initialization of top-level properties

For better application startup performance, the Kotlin/JS IR compiler initializes top-level properties lazily. This way, the application loads without initializing all the top-level properties used in its code. It initializes only the ones needed at startup; other properties receive their values later when the code that uses them actually runs.

```
val a = run {
    val result = // intensive computations
    println(result)
    result
} // value is computed upon the first usage
```

If for some reason you need to initialize a property eagerly (upon the application start), mark it with the @EagerInitialization annotation.

Incremental compilation for development binaries

The JS IR compiler provides the incremental compilation mode for development binaries that speeds up the development process. In this mode, the compiler caches the results of compileDevelopmentExecutableKotlinJs Gradle task on the module level. It uses the cached compilation results for unchanged source files during subsequent compilations, making them complete faster, especially with small changes.

Incremental compilation is enabled by default. To disable incremental compilation for development binaries, add the following line to the project's gradle.properties or local.properties:

```
kotlin.incremental.js.ir=false // true by default
```

The clean build in the incremental compilation mode is usually slower because of the need to create and populate the caches.

Output mode

You can choose how the JS IR compiler outputs .js files in your project:

- One per module. By default, the JS compiler outputs separate .js files for each module of a project as a compilation result.
- One per project. You can compile the whole project into a single .js file by adding the following line to gradle.properties:

  ```
  kotlin.js.ir.output.granularity=whole-program // 'per-module' is the default
  ```

- One per file. You can set up a more granular output that generates one (or two, if the file contains exported declarations) JavaScript file per each Kotlin file. To enable the per-file compilation mode:

  1. Add the useEsModules() function to your build file to support ECMAScript modules:

     ```
     // build.gradle.kts
     kotlin {
         js(IR) {
             useEsModules() // Enables ES2015 modules
             browser()
         }
     }
     ```

     Alternatively, you can use the es2015 compilation target to support ES2015 features in your project.

  2. Apply the -Xir-per-file compiler option or update your gradle.properties file with:

```
# gradle.properties
kotlin.js.ir.output.granularity=per-file // 'per-module' is the default
```

Minification of member names in production

The Kotlin/JS IR compiler uses its internal information about the relationships of your Kotlin classes and functions to apply more efficient minification, shortening the names of functions, properties, and classes. This reduces the size of resulting bundled applications.

This type of minification is automatically applied when you build your Kotlin/JS application in production mode, and enabled by default. To disable member name minification, use the -Xir-minimized-member-names compiler option:

```
kotlin {
    js(IR) {
        compilations.all {
            compileTaskProvider.configure {
                compilerOptions.freeCompilerArgs.add("-Xir-minimized-member-names=false")
            }
        }
    }
}
```

Dead code elimination

Dead code elimination (DCE) reduces the size of the resulting JavaScript code by removing unused properties, functions, and classes.

Unused declarations can appear in cases like:

- A function is inlined and never gets called directly (which always happens except for a few cases).
- A module uses a shared library. Without DCE, parts of the library that you don't use are still included in the resulting bundle. For example, the Kotlin standard library contains functions for manipulating lists, arrays, char sequences, adapters for DOM, and so on. All of this functionality would require about 1.3 MB as a JavaScript file. A simple "Hello, world" application only requires console routines, which are only a few kilobytes for the entire file.

In the Kotlin/JS compiler, DCE is handled automatically:

- DCE is disabled in development bundling tasks, which corresponds to the following Gradle tasks:
  - jsBrowserDevelopmentRun
  - jsBrowserDevelopmentWebpack
  - jsNodeDevelopmentRun
  - compileDevelopmentExecutableKotlinJs
  - compileDevelopmentLibraryKotlinJs
  - Other Gradle tasks including "development" in their name
- DCE is enabled if you build a production bundle, which corresponds to the following Gradle tasks:
  - jsBrowserProductionRun
  - jsBrowserProductionWebpack
  - compileProductionExecutableKotlinJs
  - compileProductionLibraryKotlinJs
  - Other Gradle tasks including "production" in their name

With the @JsExport annotation, you can specify the declarations you want DCE to treat as roots.

Preview: generation of TypeScript declaration files (d.ts)

The generation of TypeScript declaration files (d.ts) is Experimental. It may be dropped or changed at any time. Opt-in is required (see the details below), and you should use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

The Kotlin/JS IR compiler is capable of generating TypeScript definitions from your Kotlin code. These definitions can be used by JavaScript tools and IDEs when working on hybrid apps to provide autocompletion, support static analyzers, and make it easier to include Kotlin code in JavaScript and TypeScript projects.

If your project produces executable files (binaries.executable()), the Kotlin/JS IR compiler collects any top-level declarations marked with @JsExport and automatically generates TypeScript definitions in a .d.ts file.

If you want to generate TypeScript definitions, you have to explicitly configure this in your Gradle build file. Add generateTypeScriptDefinitions() to your build.gradle.kts file in the js section. For example:

```
kotlin {
    js {
        binaries.executable()
        browser {
        }
        generateTypeScriptDefinitions()
    }
}
```

The definitions can be found in build/js/packages/<package_name>/kotlin alongside the corresponding un-webpacked JavaScript code.

Current limitations of the IR compiler

A major change with the new IR compiler backend is the absence of binary compatibility with the default backend. A library created with the new IR compiler uses a klib format and can't be used from the default backend. In the meantime, a library created with the old compiler is a jar with js files, which can't be used from the IR backend.

If you want to use the IR compiler backend for your project, you need to update all Kotlin dependencies to versions that support this new backend. Libraries published by JetBrains for Kotlin 1.4+ targeting Kotlin/JS already contain all artifacts required for usage with the new IR compiler backend.

If you are a library author looking to provide compatibility with the current compiler backend as well as the new IR compiler backend, additionally check out the section about authoring libraries for the IR compiler section.

The IR compiler backend also has some discrepancies in comparison to the default backend. When trying out the new backend, it's good to be mindful of these possible pitfalls.

- Some libraries that rely on specific characteristics of the default backend, such as kotlin-wrappers, can display some problems. You can follow the investigation and progress on YouTrack.
- The IR backend does not make Kotlin declarations available to JavaScript by default at all. To make Kotlin declarations visible to JavaScript, they must be annotated with @JsExport.

Migrating existing projects to the IR compiler

Due to significant differences between the two Kotlin/JS compilers, making your Kotlin/JS code work with the IR compiler may require some adjustments. Learn how to migrate existing Kotlin/JS projects to the IR compiler in the Kotlin/JS IR compiler migration guide.

Authoring libraries for the IR compiler with backwards compatibility

If you're a library maintainer who is looking to provide compatibility with the default backend as well as the new IR compiler backend, a setting for the compiler selection is available that allows you to create artifacts for both backends, allowing you to keep compatibility for your existing users while providing support for the next generation of Kotlin compiler. This so-called both-mode can be turned on using the kotlin.js.compiler=both setting in your gradle.properties file, or can be set as one of the project-specific options inside your js block inside the build.gradle(.kts) file:

```
kotlin {
    js(BOTH) {
        // ...
    }
}
```

When in both mode, the IR compiler backend and default compiler backend are both used when building a library from your sources (hence the name). This means that both klib files with Kotlin IR as well as jar files for the default compiler will be generated. When published under the same Maven coordinate, Gradle will automatically choose the right artifact depending on the use case – js for the old compiler, klib for the new one. This enables you to compile and publish your library for projects that are using either of the two compiler backends.

Migrating Kotlin/JS projects to the IR compiler

We replaced the old Kotlin/JS compiler with the IR-based compiler in order to unify Kotlin's behavior on all platforms and to make it possible to implement new JS-specific optimizations, among other reasons. You can learn more about the internal differences between the two compilers in the blog post Migrating our Kotlin/JS app to the new IR compiler by Sebastian Aigner.

Due to the significant differences between the compilers, switching your Kotlin/JS project from the old backend to the new one may require adjusting your code. On this page, we've compiled a list of known migration issues along with suggested solutions.

> Install the Kotlin/JS Inspection pack plugin to get valuable tips on how to fix some of the issues that occur during migration.

Note that this guide may change over time as we fix issues and find new ones. Please help us keep it complete – report any issues you encounter when switching to the IR compiler by submitting them to our issue tracker YouTrack or filling out this form.

Convert JS- and React-related classes and interfaces to external interfaces

Issue: Using Kotlin interfaces and classes (including data classes) that derive from pure JS classes, such as React's State and Props, can cause a ClassCastException. Such exceptions appear because the compiler attempts to work with instances of these classes as if they were Kotlin objects, when they actually come from JS.

Solution: convert all classes and interfaces that derive from pure JS classes to external interfaces:

```
// Replace this
interface AppState : State { }
interface AppProps : Props { }
data class CustomComponentState(var name: String) : State
```

```
// With this
external interface AppState : State { }
external interface AppProps : Props { }
external interface CustomComponentState : State {
   var name: String
}
```

In IntelliJ IDEA, you can use these structural search and replace templates to automatically mark interfaces as external:

- Template for State
- Template for Props

Convert properties of external interfaces to var

Issue: properties of external interfaces in Kotlin/JS code can't be read-only (val) properties because their values can be assigned only after the object is created with js() or jso() (a helper function from kotlin-wrappers):

```
import kotlinx.js.jso

val myState = jso<CustomComponentState>()
myState.name = "name"
```

Solution: convert all properties of external interfaces to var:

```
// Replace this
external interface CustomComponentState : State {
    val name: String
}
```

```
// With this
external interface CustomComponentState : State {
    var name: String
}
```

Convert functions with receivers in external interfaces to regular functions

Issue: external declarations can't contain functions with receivers, such as extension functions or properties with corresponding functional types.

Solution: convert such functions and properties to regular functions by adding the receiver object as an argument:

```
// Replace this
external interface ButtonProps : Props {
    var inside: StyledDOMBuilder<BUTTON>.() -> Unit
}
```

```
external interface ButtonProps : Props {
    var inside: (StyledDOMBuilder<BUTTON>) -> Unit
}
```

Create plain JS objects for interoperability

Issue: properties of a Kotlin object that implements an external interface are not enumerable. This means that they are not visible for operations that iterate over the object's properties, for example:

- for (var name in obj)
- console.log(obj)
- JSON.stringify(obj)

Although they are still accessible by the name: obj.myProperty

```
external interface AppProps { var name: String }
data class AppPropsImpl(override var name: String) : AppProps
fun main() {
    val jsApp = js("{name: 'App1'}") as AppProps // plain JS object
    println("Kotlin sees: ${jsApp.name}") // "App1"
    println("JSON.stringify sees:" + JSON.stringify(jsApp)) // {"name":"App1"} - OK

    val ktApp = AppPropsImpl("App2") // Kotlin object
    println("Kotlin sees: ${ktApp.name}") // "App2"
    // JSON sees only the backing field, not the property
    println("JSON.stringify sees:" + JSON.stringify(ktApp)) // {"_name_3":"App2"}
}
```

Solution 1: create plain JavaScript objects with js() or jso() (a helper function from kotlin-wrappers):

```
external interface AppProps { var name: String }
data class AppPropsImpl(override var name: String) : AppProps
```

```
// Replace this
val ktApp = AppPropsImpl("App1") // Kotlin object
```

```
// With this
val jsApp = js("{name: 'App1'}") as AppProps // or jso {}
```

Solution 2: create objects with kotlin.js.json():

```kotlin
// or with this
val jsonApp = kotlin.js.json(Pair("name", "App1")) as AppProps
```

Replace toString() calls on function references with .name

Issue: in the IR backend, calling toString() on function references doesn't produce unique values.

Solution: use the name property instead of toString().

Explicitly specify binaries.executable() in the build script

Issue: the compiler doesn't produce executable .js files.

This may happen because the default compiler produces JavaScript executables by default while the IR compiler needs an explicit instruction to do this. Learn more in the Kotlin/JS project setup instruction.

Solution: add the line binaries.executable() to the project's build.gradle(.kts).

```kotlin
kotlin {
    js(IR) {
        browser {
        }
        binaries.executable()
    }
}
```

Additional troubleshooting tips when working with the Kotlin/JS IR compiler

These hints may help you when troubleshooting problems in your projects using the Kotlin/JS IR compiler.

Make boolean properties nullable in external interfaces

Issue: when you call toString on a Boolean from an external interface, you're getting an error like Uncaught TypeError: Cannot read properties of undefined (reading 'toString'). JavaScript treats the null or undefined values of a boolean variable as false. If you rely on calling toString on a Boolean that may be null or undefined (for example when your code is called from JavaScript code you have no control over), be aware of this:

```kotlin
external interface SomeExternal {
    var visible: Boolean
}

fun main() {
    val empty: SomeExternal = js("{}")
    println(empty.visible.toString()) // Uncaught TypeError: Cannot read properties of undefined (reading 'toString')
}
```

Solution: you can make your Boolean properties of external interfaces nullable (Boolean?):

```kotlin
// Replace this
external interface SomeExternal {
    var visible: Boolean
}
```

```kotlin
// With this
external interface SomeExternal {
    var visible: Boolean?
}
```

Browser and DOM API

The Kotlin/JS standard library lets you access browser-specific functionality using the kotlinx.browser package, which includes typical top-level objects such as document and window. The standard library provides typesafe wrappers for the functionality exposed by these objects wherever possible. As a fallback, the dynamic type is used to provide interaction with functions that do not map well into the Kotlin type system.

Interaction with the DOM

For interaction with the Document Object Model (DOM), you can use the variable document. For example, you can set the background color of our website through this object:

```
document.bgColor = "FFAA12"
```

The document object also provides you a way to retrieve a specific element by ID, name, class name, tag name and so on. All returned elements are of type Element?. To access their properties, you need to cast them to their appropriate type. For example, assume that you have an HTML page with an email <input> field:

```
<body>
    <input type="text" name="email" id="email"/>

    <script type="text/javascript" src="tutorial.js"></script>
</body>
```

Note that your script is included at the bottom of the body tag. This ensures that the DOM is fully available before the script is loaded.

With this setup, you can access elements of the DOM. To access the properties of the input field, invoke getElementById and cast it to HTMLInputElement. You can then safely access its properties, such as value:

```
val email = document.getElementById("email") as HTMLInputElement
email.value = "hadi@jetbrains.com"
```

Much like you reference this input element, you can access other elements on the page, casting them to the appropriate types.

To see how to create and structure elements in the DOM in a concise way, check out the Typesafe HTML DSL.

Use JavaScript code from Kotlin

Kotlin was first designed for easy interoperation with the Java platform: it sees Java classes as Kotlin classes, and Java sees Kotlin classes as Java classes.

However, JavaScript is a dynamically typed language, which means it does not check types at compile time. You can freely talk to JavaScript from Kotlin via dynamic types. If you want to use the full power of the Kotlin type system, you can create external declarations for JavaScript libraries which will be understood by the Kotlin compiler and the surrounding tooling.

Inline JavaScript

You can inline JavaScript code into your Kotlin code using the js() function. For example:

```
fun jsTypeOf(o: Any): String {
    return js("typeof o")
}
```

Because the parameter of js is parsed at compile time and translated to JavaScript code "as-is", it is required to be a string constant. So, the following code is incorrect:

```
fun jsTypeOf(o: Any): String {
    return js(getTypeof() + " o") // error reported here
}

fun getTypeof() = "typeof"
```

As the JavaScript code is parsed by the Kotlin compiler, not all ECMAScript features might be supported. In this case, you can encounter compilation errors.

Note that invoking js() returns a result of type dynamic, which provides no type safety at compile time.

external modifier

To tell Kotlin that a certain declaration is written in pure JavaScript, you should mark it with the external modifier. When the compiler sees such a declaration, it assumes that the implementation for the corresponding class, function or property is provided externally (by the developer or via an npm dependency), and therefore does not try to generate any JavaScript code from the declaration. This is also why external declarations can't have a body. For example:

```kotlin
external fun alert(message: Any?): Unit

external class Node {
    val firstChild: Node

    fun append(child: Node): Node

    fun removeChild(child: Node): Node

    // etc
}

external val window: Window
```

Note that the external modifier is inherited by nested declarations. This is why in the example Node class, there is no external modifier before member functions and properties.

The external modifier is only allowed on package-level declarations. You can't declare an external member of a non-external class.

Declare (static) members of a class

In JavaScript you can define members either on a prototype or a class itself:

```javascript
function MyClass() { ... }
MyClass.sharedMember = function() { /* implementation */ };
MyClass.prototype.ownMember = function() { /* implementation */ };
```

There is no such syntax in Kotlin. However, in Kotlin we have companion objects. Kotlin treats companion objects of external classes in a special way: instead of expecting an object, it assumes members of companion objects to be members of the class itself. MyClass from the example above can be described as follows:

```kotlin
external class MyClass {
    companion object {
        fun sharedMember()
    }

    fun ownMember()
}
```

Declare optional parameters

If you are writing an external declaration for a JavaScript function which has an optional parameter, use definedExternally. This delegates the generation of the default values to the JavaScript function itself:

```kotlin
external fun myFunWithOptionalArgs(
    x: Int,
    y: String = definedExternally,
    z: String = definedExternally
)
```

With this external declaration, you can call myFunWithOptionalArgs with one required argument and two optional arguments, where the default values are calculated by the JavaScript implementation of myFunWithOptionalArgs.

Extend JavaScript classes

You can easily extend JavaScript classes as if they were Kotlin classes. Just define an external open class and extend it by a non-external class. For example:

```
open external class Foo {
    open fun run()
    fun stop()
}

class Bar : Foo() {
    override fun run() {
        window.alert("Running!")
    }

    fun restart() {
        window.alert("Restarting")
    }
}
```

There are some limitations:

- When a function of an external base class is overloaded by signature, you can't override it in a derived class.
- You can't override a function with default arguments.
- Non-external classes can't be extended by external classes.

external interfaces

JavaScript does not have the concept of interfaces. When a function expects its parameter to support two methods foo and bar, you would just pass in an object that actually has these methods.

You can use interfaces to express this concept in statically typed Kotlin:

```
external interface HasFooAndBar {
    fun foo()

    fun bar()
}

external fun myFunction(p: HasFooAndBar)
```

A typical use case for external interfaces is to describe settings objects. For example:

```
external interface JQueryAjaxSettings {
    var async: Boolean

    var cache: Boolean

    var complete: (JQueryXHR, String) -> Unit

    // etc
}

fun JQueryAjaxSettings(): JQueryAjaxSettings = js("{}")

external class JQuery {
    companion object {
        fun get(settings: JQueryAjaxSettings): JQueryXHR
    }
}

fun sendQuery() {
    JQuery.get(JQueryAjaxSettings().apply {
        complete = { (xhr, data) ->
            window.alert("Request complete")
        }
    })
}
```

External interfaces have some restrictions:

- They can't be used on the right-hand side of is checks.

- They can't be passed as reified type arguments.
- They can't be used in class literal expressions (such as I::class).
- as casts to external interfaces always succeed. Casting to external interfaces produces the "Unchecked cast to external interface" compile time warning. The warning can be suppressed with the @Suppress("UNCHECKED_CAST_TO_EXTERNAL_INTERFACE") annotation.

  IntelliJ IDEA can also automatically generate the @Suppress annotation. Open the intentions menu via the light bulb icon or Alt-Enter, and click the small arrow next to the "Unchecked cast to external interface" inspection. Here, you can select the suppression scope, and your IDE will add the annotation to your file accordingly.

Casts

In addition to the "unsafe" cast operator as, which throws a ClassCastException in case a cast is not possible, Kotlin/JS also provides unsafeCast<T>(). When using unsafeCast, no type checking is done at all during runtime. For example, consider the following two methods:

```
fun usingUnsafeCast(s: Any) = s.unsafeCast<String>()
fun usingAsOperator(s: Any) = s as String
```

They will be compiled accordingly:

```
function usingUnsafeCast(s) {
    return s;
}

function usingAsOperator(s) {
    var tmp$;
    return typeof (tmp$ = s) === 'string' ? tmp$ : throwCCE();
}
```

Equality

Kotlin/JS has particular semantics for equality checks compared to other platforms.

In Kotlin/JS, the Kotlin referential equality operator (===) always translates to the JavaScript strict equality operator (===).

The JavaScript === operator checks not only that two values are equal but also that the types of these two values are equal:

```
fun main() {
   val name = "kotlin"
   val value1 = name.substring(0, 1)
   val value2 = name.substring(0, 1)

   println(if (value1 === value2) "yes" else "no")
   // Prints 'yes' on Kotlin/JS
   // Prints 'no' on other platforms
}
```

Also, in Kotlin/JS, the Byte, Short, Int, Float, and Double numeric types are all represented with the Number JavaScript type in runtime. Therefore, the values of these five types are indistinguishable:

```
fun main() {
   println(1.0 as Any === 1 as Any)
   // Prints 'true' on Kotlin/JS
   // Prints 'false' on other platforms
}
```

> For more information about equality in Kotlin, see the Equality documentation.

Dynamic type

The dynamic type is not supported in code targeting the JVM.

Being a statically typed language, Kotlin still has to interoperate with untyped or loosely typed environments, such as the JavaScript ecosystem. To facilitate these use cases, the dynamic type is available in the language:

```
val dyn: dynamic = ...
```

The dynamic type basically turns off Kotlin's type checker:

- A value of the dynamic type can be assigned to any variable or passed anywhere as a parameter.
- Any value can be assigned to a variable of the dynamic type or passed to a function that takes dynamic as a parameter.
- null-checks are disabled for the dynamic type values.

The most peculiar feature of dynamic is that we are allowed to call any property or function with any parameters on a dynamic variable:

```
dyn.whatever(1, "foo", dyn) // 'whatever' is not defined anywhere
dyn.whatever(*arrayOf(1, 2, 3))
```

On the JavaScript platform this code will be compiled "as is": dyn.whatever(1) in Kotlin becomes dyn.whatever(1) in the generated JavaScript code.

When calling functions written in Kotlin on values of dynamic type, keep in mind the name mangling performed by the Kotlin to JavaScript compiler. You may need to use the @JsName annotation to assign well-defined names to the functions that you need to call.

A dynamic call always returns dynamic as a result, so you can chain such calls freely:

```
dyn.foo().bar.baz()
```

When you pass a lambda to a dynamic call, all of its parameters by default have the type dynamic:

```
dyn.foo {
    x -> x.bar() // x is dynamic
}
```

Expressions using values of dynamic type are translated to JavaScript "as is", and do not use the Kotlin operator conventions. The following operators are supported:

- binary: +, -, *, /, %, >, < >=, <=, ==, !=, ===, !==, &&, ||
- unary
  - prefix: -, +, !
  - prefix and postfix: ++, --
- assignments: +=, -=, *=, /=, %=
- indexed access:
  - read: d[a], more than one argument is an error
  - write: d[a1] = a2, more than one argument in [] is an error

in, !in and .. operations with values of type dynamic are forbidden.

For a more technical description, see the spec document.

Use dependencies from npm

In Kotlin/JS projects, all dependencies can be managed through the Gradle plugin. This includes Kotlin/Multiplatform libraries such as kotlinx.coroutines, kotlinx.serialization, or ktor-client.

For depending on JavaScript packages from npm, the Gradle DSL exposes an npm function that lets you specify packages you want to import from npm. Let's consider the import of an NPM package called is-sorted.

The corresponding part in the Gradle build file looks as follows:

```
dependencies {
    // ...
    implementation(npm("is-sorted", "1.0.5"))
}
```

Because JavaScript modules are usually dynamically typed and Kotlin is a statically typed language, you need to provide a kind of adapter. In Kotlin, such adapters are called external declarations. For the is-sorted package which offers only one function, this declaration is small to write. Inside the source folder, create a new file called is-sorted.kt, and fill it with these contents:

```
@JsModule("is-sorted")
@JsNonModule
external fun <T> sorted(a: Array<T>): Boolean
```

Please note that if you're using CommonJS as a target, the @JsModule and @JsNonModule annotations need to be adjusted accordingly.

This JavaScript function can now be used just like a regular Kotlin function. Because we provided type information in the header file (as opposed to simply defining parameter and return type to be dynamic), proper compiler support and type-checking is also available.

```
console.log("Hello, Kotlin/JS!")
console.log(sorted(arrayOf(1,2,3)))
console.log(sorted(arrayOf(3,1,2)))
```

Running these three lines either in the browser or Node.js, the output shows that the call to sorted was properly mapped to the function exported by the is-sorted package:

```
Hello, Kotlin/JS!
true
false
```

Because the JavaScript ecosystem has multiple ways of exposing functions in a package (for example through named or default exports), other npm packages might need a slightly altered structure for their external declarations.

To learn more about how to write declarations, please refer to Calling JavaScript from Kotlin.

Use Kotlin code from JavaScript

Depending on the selected JavaScript Module system, the Kotlin/JS compiler generates different output. But in general, the Kotlin compiler generates normal JavaScript classes, functions and properties, which you can freely use from JavaScript code. There are some subtle things you should remember, though.

Isolating declarations in a separate JavaScript object in plain mode

If you have explicitly set your module kind to be plain, Kotlin creates an object that contains all Kotlin declarations from the current module. This is done to prevent spoiling the global object. This means that for a module myModule, all declarations are available to JavaScript via the myModule object. For example:

```
fun foo() = "Hello"
```

Can be called from JavaScript like this:

```
alert(myModule.foo());
```

This is not applicable when you compile your Kotlin module to JavaScript modules like UMD (which is the default setting for both browser and nodejs targets), CommonJS or AMD. In this case, your declarations will be exposed in the format specified by your chosen JavaScript module system. When using UMD or CommonJS, for example, your call site could look like this:

```
alert(require('myModule').foo());
```

Check the article on JavaScript Modules for more information on the topic of JavaScript module systems.

Package structure

Kotlin exposes its package structure to JavaScript, so unless you define your declarations in the root package, you have to use fully qualified names in JavaScript. For example:

```
package my.qualified.packagename

fun foo() = "Hello"
```

When using UMD or CommonJS, for example, your callsite could look like this:

```
alert(require('myModule').my.qualified.packagename.foo())
```

Or, in the case of using plain as a module system setting:

```
alert(myModule.my.qualified.packagename.foo());
```

@JsName annotation

In some cases (for example, to support overloads), the Kotlin compiler mangles the names of generated functions and attributes in JavaScript code. To control the generated names, you can use the @JsName annotation:

```
// Module 'kjs'
class Person(val name: String) {
    fun hello() {
        println("Hello $name!")
    }

    @JsName("helloWithGreeting")
    fun hello(greeting: String) {
        println("$greeting $name!")
    }
}
```

Now you can use this class from JavaScript in the following way:

```
// If necessary, import 'kjs' according to chosen module system
var person = new kjs.Person("Dmitry");   // refers to module 'kjs'
person.hello();                          // prints "Hello Dmitry!"
person.helloWithGreeting("Servus");      // prints "Servus Dmitry!"
```

If we didn't specify the @JsName annotation, the name of the corresponding function would contain a suffix calculated from the function signature, for example hello_61zpoe$.

Note that there are some cases in which the Kotlin compiler does not apply mangling:

- external declarations are not mangled.
- Any overridden functions in non-external classes inheriting from external classes are not mangled.

The parameter of @JsName is required to be a constant string literal which is a valid identifier. The compiler will report an error on any attempt to pass non-identifier string to @JsName. The following example produces a compile-time error:

```
@JsName("new C()")   // error here
external fun newC()
```

@JsExport annotation

This feature is Experimental. Its design may change in future versions.

By applying the @JsExport annotation to a top-level declaration (like a class or function), you make the Kotlin declaration available from JavaScript. The annotation exports all nested declarations with the name given in Kotlin. It can also be applied on file-level using @file:JsExport.

To resolve ambiguities in exports (like overloads for functions with the same name), you can use the @JsExport annotation together with @JsName to specify the names for the generated and exported functions.

In the current IR compiler backend, the @JsExport annotation is the only way to make your functions visible from Kotlin.

For multiplatform projects, @JsExport is available in common code as well. It only has an effect when compiling for the JavaScript target, and allows you to also export Kotlin declarations that are not platform specific.

@JsStatic

This feature is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

The @JsStatic annotation instructs the compiler to generate additional static methods for the target declaration. This helps you use static members from your Kotlin code directly in JavaScript.

You can apply the @JsStatic annotation to functions defined in named objects, as well as in companion objects declared inside classes and interfaces. If you use this annotation, the compiler will generate both a static method of the object and an instance method in the object itself. For example:

```
// Kotlin
class C {
    companion object {
        @JsStatic
        fun callStatic() {}
        fun callNonStatic() {}
    }
}
```

Now, the callStatic() function is static in JavaScript while the callNonStatic() function is not:

```
// JavaScript
C.callStatic();              // Works, accessing the static function
C.callNonStatic();           // Error, not a static function in the generated JavaScript
C.Companion.callStatic();    // Instance method remains
C.Companion.callNonStatic(); // The only way it works
```

It's also possible to apply the @JsStatic annotation to a property of an object or a companion object, making its getter and setter methods static members in that object or the class containing the companion object.

Kotlin types in JavaScript

See how Kotlin types are mapped to JavaScript ones:

Kotlin	JavaScript	Comments
Byte, Short, Int, Float, Double	Number	
Char	Number	The number represents the character's code.
Long	Not supported	There is no 64-bit integer number type in JavaScript, so it is emulated by a Kotlin class.
Boolean	Boolean	

Kotlin	JavaScript	Comments
String	String	
Array	Array	
ByteArray	Int8Array	
ShortArray	Int16Array	
IntArray	Int32Array	
CharArray	UInt16Array	Carries the property $type$ == "CharArray".
FloatArray	Float32Array	
DoubleArray	Float64Array	
LongArray	Array<kotlin.Long>	Carries the property $type$ == "LongArray". Also see Kotlin's Long type comment.
BooleanArray	Int8Array	Carries the property $type$ == "BooleanArray".
List, MutableList	KtList, KtMutableList	Exposes an Array via KtList.asJsReadonlyArrayView or KtMutableList.asJsArrayView.
Map, MutableMap	KtMap, KtMutableMap	Exposes an ES2015 Map via KtMap.asJsReadonlyMapView or KtMutableMap.asJsMapView.
Set, MutableSet	KtSet, KtMutableSet	Exposes an ES2015 Set via KtSet.asJsReadonlySetView or KtMutableSet.asJsSetView.
Unit	Undefined	Exportable when used as return type, but not when used as parameter type.
Any	Object	
Throwable	Error	
Nullable Type?	Type | null | undefined	

Kotlin	JavaScript	Comments
All other Kotlin types (except for those marked with JsExport annotation)	Not supported	Includes Kotlin's unsigned integer types.

Additionally, it is important to know that:

- Kotlin preserves overflow semantics for kotlin.Int, kotlin.Byte, kotlin.Short, kotlin.Char and kotlin.Long.
- Kotlin cannot distinguish between numeric types at runtime (except for kotlin.Long), so the following code works:

```
fun f() {
    val x: Int = 23
    val y: Any = x
    println(y as Float)
}
```

- Kotlin preserves lazy object initialization in JavaScript.
- Kotlin does not implement lazy initialization of top-level properties in JavaScript.

JavaScript modules

You can compile your Kotlin projects to JavaScript modules for various popular module systems. We currently support the following configurations for JavaScript modules:

- Unified Module Definitions (UMD), which is compatible with both AMD and CommonJS. UMD modules are also able to be executed without being imported or when no module system is present. This is the default option for the browser and nodejs targets.
- Asynchronous Module Definitions (AMD), which is in particular used by the RequireJS library.
- CommonJS, widely used by Node.js/npm (require function and module.exports object).
- Plain. Don't compile for any module system. You can access a module by its name in the global scope.

Browser targets

If you intend to run your code in a web browser environment and want to use a module system other than UMD, you can specify the desired module type in the webpackTask configuration block. For example, to switch to CommonJS, use:

```
kotlin {
    js {
        browser {
            webpackTask {
                output.libraryTarget = "commonjs2"
            }
        }
        binaries.executable()
    }
}
```

Webpack provides two different flavors of CommonJS, commonjs and commonjs2, which affect the way your declarations are made available. In most cases, you probably want commonjs2, which adds the module.exports syntax to the generated library. Alternatively, you can also opt for the commonjs option, which adheres strictly to the CommonJS specification. To learn more about the difference between commonjs and commonjs2, see the Webpack repository.

JavaScript libraries and Node.js files

If you are creating a library for use in JavaScript or Node.js environments, and want to use a different module system, the instructions are slightly different.

Choose the target module system

To select the target module system, set the moduleKind compiler option in the Gradle build script:

Kotlin

```
tasks.withType<org.jetbrains.kotlin.gradle.targets.js.ir.KotlinJsIrLink> {
    compilerOptions.moduleKind.set(org.jetbrains.kotlin.gradle.dsl.JsModuleKind.MODULE_COMMONJS)
}
```

Groovy

```
compileKotlinJs.compilerOptions.moduleKind = org.jetbrains.kotlin.gradle.dsl.JsModuleKind.MODULE_COMMONJS
```

The available values are: umd (default), commonjs, amd, plain.

> This is different from adjusting webpackTask.output.libraryTarget. The library target changes the output generated by webpack (after your code has already been compiled). compilerOptions.moduleKind changes the output generated by the Kotlin compiler.

In the Kotlin Gradle DSL, there is also a shortcut for setting the CommonJS module kind:

```
kotlin {
    js {
        useCommonJs()
        // ...
    }
}
```

@JsModule annotation

To tell Kotlin that an external class, package, function or property is a JavaScript module, you can use @JsModule annotation. Consider you have the following CommonJS module called "hello":

```
module.exports.sayHello = function (name) { alert("Hello, " + name); }
```

You should declare it like this in Kotlin:

```
@JsModule("hello")
external fun sayHello(name: String)
```

Apply @JsModule to packages

Some JavaScript libraries export packages (namespaces) instead of functions and classes. In terms of JavaScript, it's an object that has members that are classes, functions and properties. Importing these packages as Kotlin objects often looks unnatural. The compiler can map imported JavaScript packages to Kotlin packages, using the following notation:

```
@file:JsModule("extModule")

package ext.jspackage.name

external fun foo()

external class C
```

Where the corresponding JavaScript module is declared like this:

```
module.exports = {
  foo: { /* some code here */ },
  C: { /* some code here */ }
}
```

Files marked with @file:JsModule annotation can't declare non-external members. The example below produces a compile-time error:

```
@file:JsModule("extModule")

package ext.jspackage.name

external fun foo()

fun bar() = "!" + foo() + "!" // error here
```

Import deeper package hierarchies

In the previous example the JavaScript module exports a single package. However, some JavaScript libraries export multiple packages from within a module. This case is also supported by Kotlin, though you have to declare a new .kt file for each package you import.

For example, let's make the example a bit more complicated:

```
module.exports = {
  mylib: {
    pkg1: {
      foo: function () { /* some code here */ },
      bar: function () { /* some code here */ }
    },
    pkg2: {
      baz: function () { /* some code here */ }
    }
  }
}
```

To import this module in Kotlin, you have to write two Kotlin source files:

```
@file:JsModule("extModule")
@file:JsQualifier("mylib.pkg1")

package extlib.pkg1

external fun foo()

external fun bar()
```

and

```
@file:JsModule("extModule")
@file:JsQualifier("mylib.pkg2")

package extlib.pkg2

external fun baz()
```

@JsNonModule annotation

When a declaration is marked as @JsModule, you can't use it from Kotlin code when you don't compile it to a JavaScript module. Usually, developers distribute their libraries both as JavaScript modules and downloadable .js files that you can copy to your project's static resources and include via a <script> tag. To tell Kotlin that it's okay to use a @JsModule declaration from a non-module environment, add the @JsNonModule annotation. For example, consider the following JavaScript code:

```
function topLevelSayHello (name) { alert("Hello, " + name); }

if (module && module.exports) {
  module.exports = topLevelSayHello;
}
```

You could describe it from Kotlin as follows:

```
@JsModule("hello")
@JsNonModule
@JsName("topLevelSayHello")
external fun sayHello(name: String)
```

Module system used by the Kotlin Standard Library

Kotlin is distributed with the Kotlin/JS standard library as a single file, which is itself compiled as an UMD module, so you can use it with any module system described above. For most use cases of Kotlin/JS, it is recommended to use a Gradle dependency on kotlin-stdlib-js, which is also available on NPM as the kotlin package.

Kotlin/JS reflection

Kotlin/JS provides a limited support for the Kotlin reflection API. The only supported parts of the API are:

- Class references (::class)
- KType and typeof()
- KClass and createInstance()

Class references

The ::class syntax returns a reference to the class of an instance, or the class corresponding to the given type. In Kotlin/JS, the value of a ::class expression is a stripped-down KClass implementation that supports only:

- simpleName and isInstance() members.
- cast() and safeCast() extension functions.

In addition to that, you can use KClass.js to access the JsClass instance corresponding to the class. The JsClass instance itself is a reference to the constructor function. This can be used to interoperate with JS functions that expect a reference to a constructor.

KType and typeOf()

The typeof() function constructs an instance of KType for a given type. The KType API is fully supported in Kotlin/JS except for Java-specific parts.

KClass and createInstance()

The createInstance() function from the KClass interface creates a new instance of the specified class, which is useful for getting the runtime reference to a Kotlin class.

Example

Here is an example of the reflection usage in Kotlin/JS.

```
open class Shape
class Rectangle : Shape()

inline fun <reified T> accessReifiedTypeArg() =
    println(typeOf<T>().toString())

fun main() {
    val s = Shape()
    val r = Rectangle()

    println(r::class.simpleName) // Prints "Rectangle"
    println(Shape::class.simpleName) // Prints "Shape"
    println(Shape::class.js.name) // Prints "Shape"
    println(Shape::class.isInstance(r)) // Prints "true"
    println(Rectangle::class.isInstance(s)) // Prints "false"
    val rShape = Shape::class.cast(r) // Casts a Rectangle "r" to Shape

    accessReifiedTypeArg<Rectangle>() // Accesses the type via typeOf(). Prints "Rectangle"
}
```

Typesafe HTML DSL

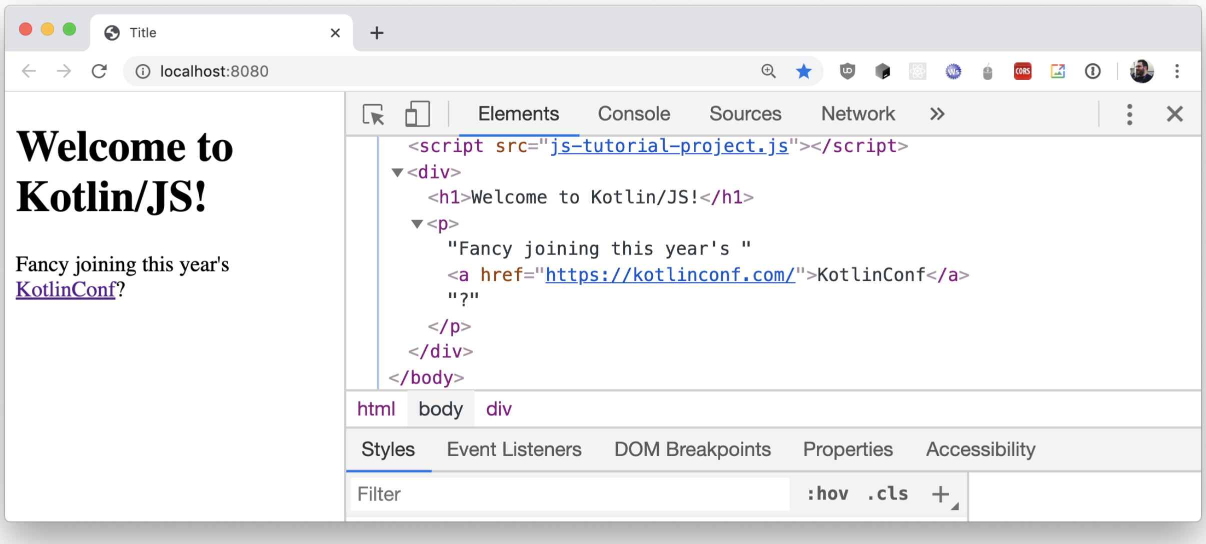
The kotlinx.html library provides the ability to generate DOM elements using statically typed HTML builders (and besides JavaScript, it is even available on the JVM target!) To use the library, include the corresponding repository and dependency to our build.gradle.kts file:

```
repositories {
    // ...
    mavenCentral()
}

dependencies {
    implementation(kotlin("stdlib-js"))
    implementation("org.jetbrains.kotlinx:kotlinx-html-js:0.8.0")
    // ...
}
```

Once the dependency is included, you can access the different interfaces provided to generate the DOM. To render a headline, some text, and a link, the following snippet would be sufficient, for example:

```
import kotlinx.browser.*
import kotlinx.html.*
import kotlinx.html.dom.*

fun main() {
    document.body!!.append.div {
        h1 {
            +"Welcome to Kotlin/JS!"
        }
        p {
            +"Fancy joining this year's "
            a("https://kotlinconf.com/") {
                +"KotlinConf"
            }
            +"?"
        }
    }
}
```

When running this example in the browser, the DOM will be assembled in a straightforward way. This is easily confirmed by checking the Elements of the website using the developer tools of our browser:



Welcome to Kotlin/JS!

Fancy joining this year's KotlinConf?

```
<script src="js-tutorial-project.js"></script>
▼<div>
   <h1>Welcome to Kotlin/JS!</h1>
  ▼<p>
     "Fancy joining this year's "
     <a href="https://kotlinconf.com/">KotlinConf</a>
     "?"
   </p>
 </div>
</body>
```

Rendering a website from kotlinx.html

To learn more about the kotlinx.html library, check out the GitHub Wiki, where you can find more information about how to create elements without adding them to the DOM, binding to events like onClick, and examples on how to apply CSS classes to your HTML elements, to name just a few.

Get started with Kotlin custom scripting – tutorial

Kotlin custom scripting is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We appreciate your feedback on it in YouTrack.

Kotlin scripting is the technology that enables executing Kotlin code as scripts without prior compilation or packaging into executables.

For an overview of Kotlin scripting with examples, check out the talk Implementing the Gradle Kotlin DSL by Rodrigo Oliveira from KotlinConf'19.

In this tutorial, you'll create a Kotlin scripting project that executes arbitrary Kotlin code with Maven dependencies. You'll be able to execute scripts like this:

```
@file:Repository("https://maven.pkg.jetbrains.space/public/p/kotlinx-html/maven")
@file:DependsOn("org.jetbrains.kotlinx:kotlinx-html-jvm:0.7.3")

import kotlinx.html.*
import kotlinx.html.stream.*
import kotlinx.html.attributes.*

val addressee = "World"

print(
    createHTML().html {
        body {
            h1 { +"Hello, $addressee!" }
        }
    }
)
```

The specified Maven dependency (kotlinx-html-jvm for this example) will be resolved from the specified Maven repository or local cache during execution and used for the rest of the script.

Project structure

A minimal Kotlin custom scripting project contains two parts:

* Script definition – a set of parameters and configurations that define how this script type should be recognized, handled, compiled, and executed.
* Scripting host – an application or component that handles script compilation and execution – actually running scripts of this type.

With all of this in mind, it's best to split the project into two modules.

Before you start

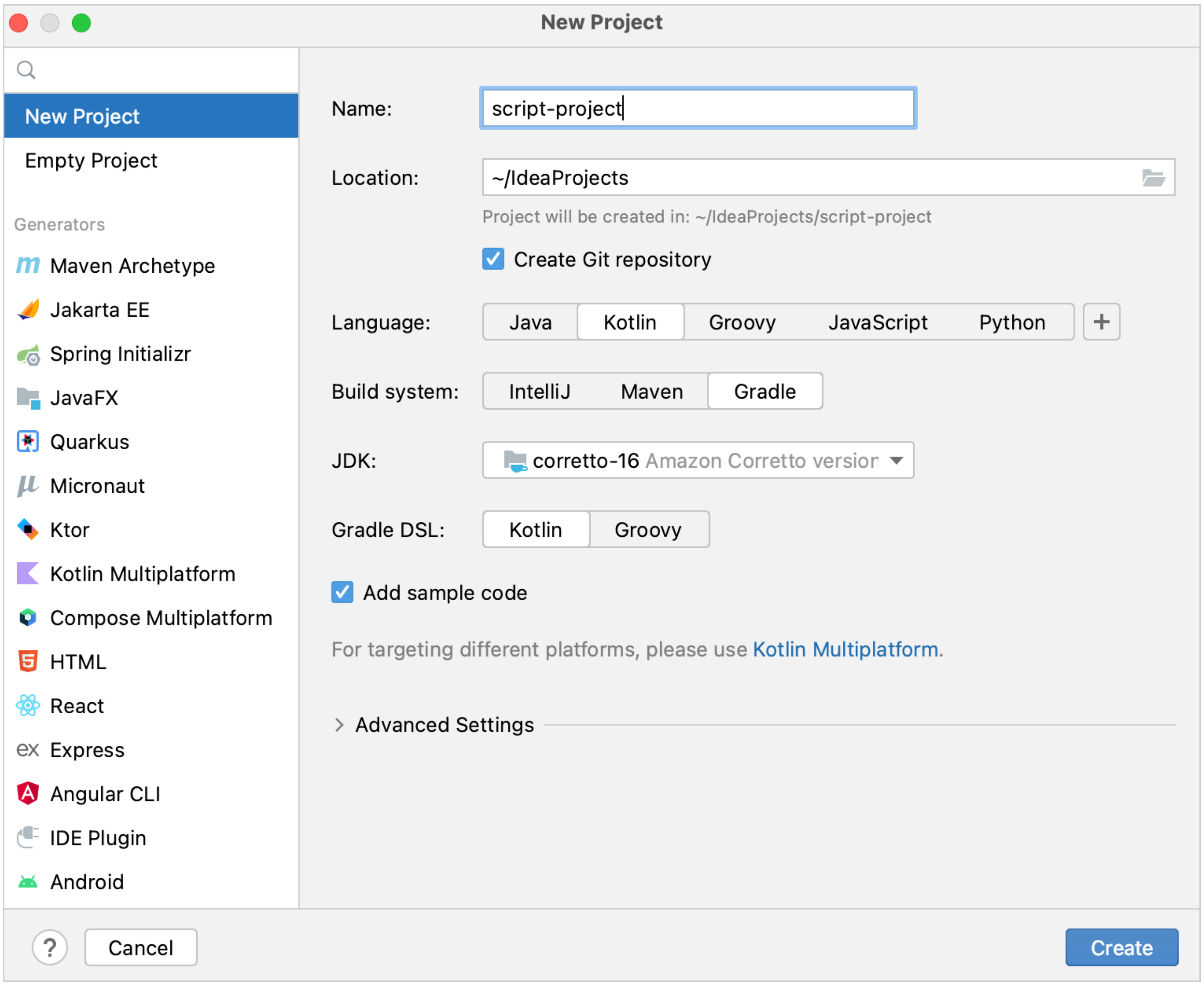
Download and install the latest version of IntelliJ IDEA.

Create a project

1. In IntelliJ IDEA, select File | New | Project.
2. In the panel on the left, select New Project.
3. Name the new project and change its location if necessary.

   > Select the Create Git repository checkbox to place the new project under version control. You will be able to do it later at any time.

4. From the Language list, select Kotlin.
5. Select the Gradle build system.
6. From the JDK list, select the JDK that you want to use in your project.
   * If the JDK is installed on your computer, but not defined in the IDE, select Add JDK and specify the path to the JDK home directory.
   * If you don't have the necessary JDK on your computer, select Download JDK.
7. Select the Kotlin or Gradle language for the Gradle DSL.
8. Click Create.


New Project

Name: script-project

Location: ~/IdeaProjects

Project will be created in: ~/IdeaProjects/script-project

☑ Create Git repository

Language: Java [✓ Kotlin] Groovy JavaScript Python

Build system: IntelliJ Maven [✓ Gradle]

JDK: corretto-16 Amazon Corretto version

Gradle DSL: [✓ Kotlin] Groovy

☑ Add sample code

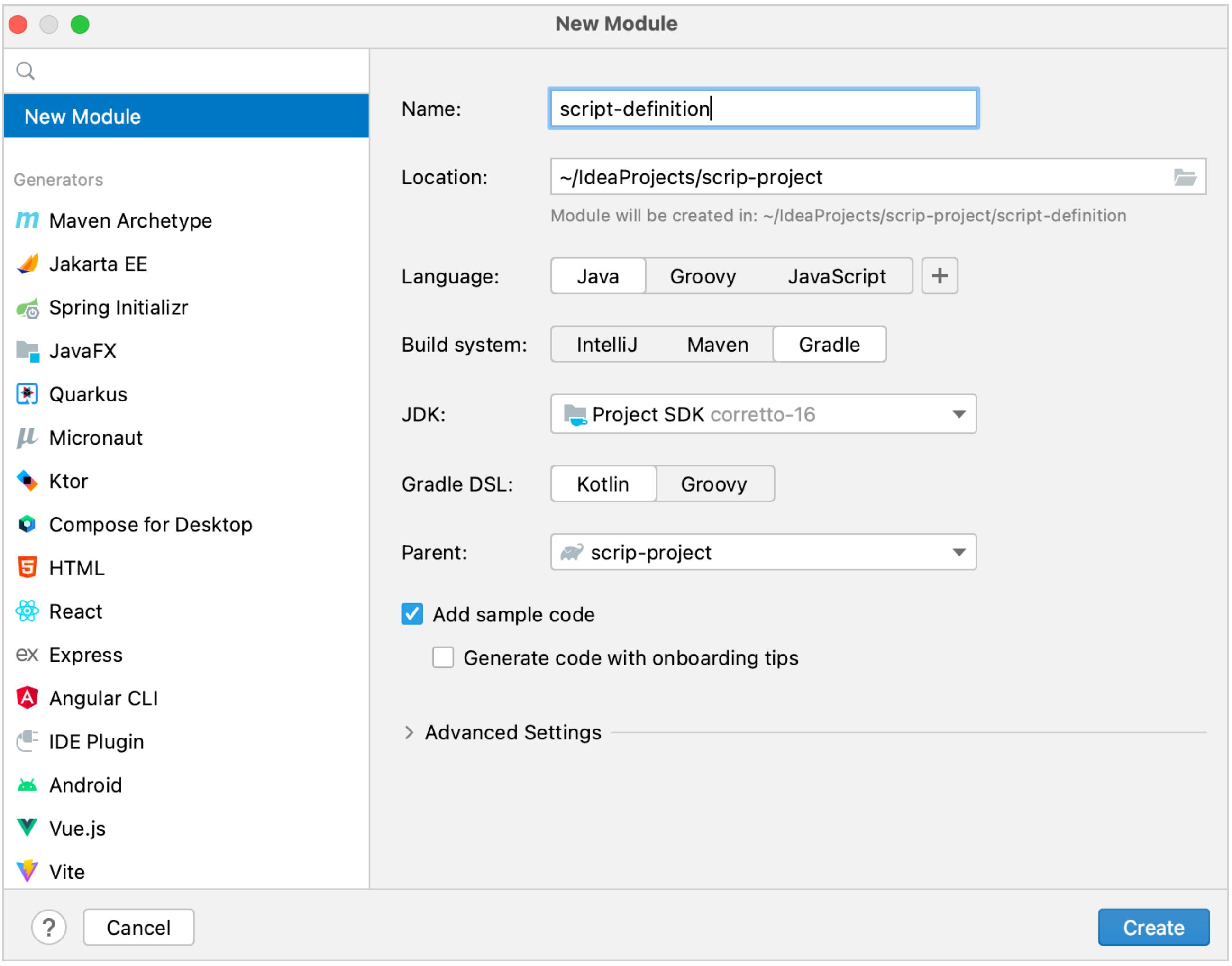
For targeting different platforms, please use Kotlin Multiplatform.

Create a root project for custom Kotlin scripting

Add scripting modules

Now you have an empty Kotlin/JVM Gradle project. Add the required modules, script definition and scripting host:

1. In IntelliJ IDEA, select File | New | Module.
2. In the panel on the left, select New Module. This module will be the script definition.
3. Name the new module and change its location if necessary.
4. From the Language list, select Java.
5. Select the Gradle build system and Kotlin for the Gradle DSL if you want to write the build script in Kotlin.
6. As a module's parent, select the root module.
7. Click Create.



Name: script-definition

Location: ~/IdeaProjects/scrip-project

Module will be created in: ~/IdeaProjects/scrip-project/script-definition

Language: Java Groovy JavaScript

Build system: IntelliJ Maven Gradle

JDK: Project SDK corretto-16

Gradle DSL: Kotlin Groovy

Parent: scrip-project

☑ Add sample code

☐ Generate code with onboarding tips

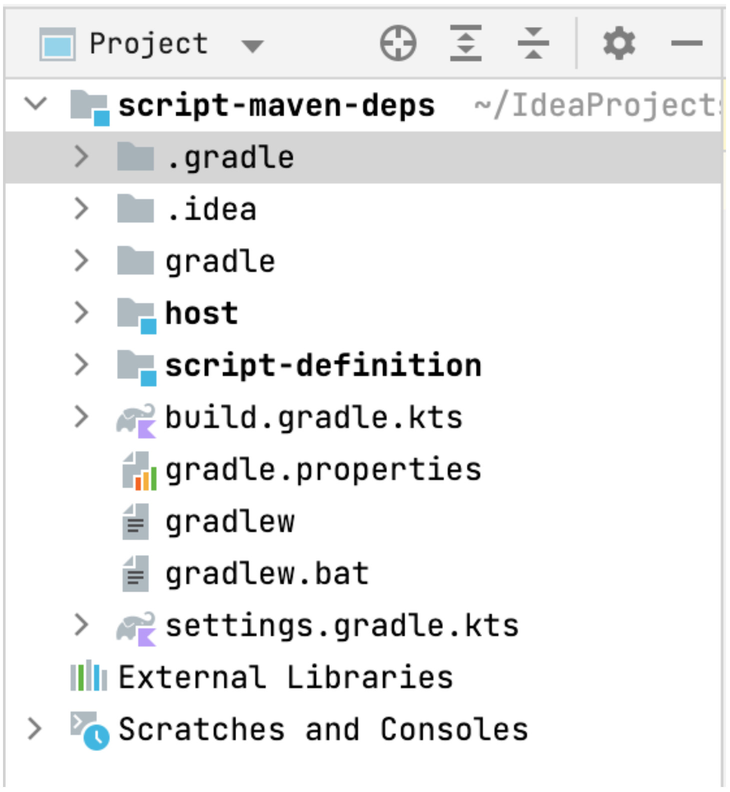
Advanced Settings

Create script definition module

8. In the module's build.gradle(.kts) file, remove the version of the Kotlin Gradle plugin. It is already in the root project's build script.

9. Repeat previous steps one more time to create a module for the scripting host.

The project should have the following structure:


```
Project
script-maven-deps  ~/IdeaProject
  .gradle
  .idea
  gradle
  host
  script-definition
  build.gradle.kts
  gradle.properties
  gradlew
  gradlew.bat
  settings.gradle.kts
External Libraries
Scratches and Consoles
```

Custom scripting project structure

You can find an example of such a project and more Kotlin scripting examples in the kotlin-script-examples GitHub repository.

Create a script definition

First, define the script type: what developers can write in scripts of this type and how it will be handled. In this tutorial, this includes support for the @Repository and @DependsOn annotations in the scripts.

1. In the script definition module, add the dependencies on the Kotlin scripting components in the dependencies block of build.gradle(.kts). These dependencies provide the APIs you will need for the script definition:

   Kotlin

```kotlin
dependencies {
    implementation("org.jetbrains.kotlin:kotlin-scripting-common")
    implementation("org.jetbrains.kotlin:kotlin-scripting-jvm")
    implementation("org.jetbrains.kotlin:kotlin-scripting-dependencies")
    implementation("org.jetbrains.kotlin:kotlin-scripting-dependencies-maven")
    // coroutines dependency is required for this particular definition
    implementation("org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2")
}
```

   Groovy

```groovy
dependencies {
    implementation 'org.jetbrains.kotlin:kotlin-scripting-common'
    implementation 'org.jetbrains.kotlin:kotlin-scripting-jvm'
    implementation 'org.jetbrains.kotlin:kotlin-scripting-dependencies'
    implementation 'org.jetbrains.kotlin:kotlin-scripting-dependencies-maven'
    // coroutines dependency is required for this particular definition
    implementation 'org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2'

}
```

2. Create the src/main/kotlin/ directory in the module and add a Kotlin source file, for example, scriptDef.kt.
3. In scriptDef.kt, create a class. It will be a superclass for scripts of this type, so declare it abstract or open.

```
// abstract (or open) superclass for scripts of this type
abstract class ScriptWithMavenDeps
```

   This class will also serve as a reference to the script definition later.

4. To make the class a script definition, mark it with the @KotlinScript annotation. Pass two parameters to the annotation:

   - fileExtension – a string ending with .kts that defines a file extension for scripts of this type.
   - compilationConfiguration – a Kotlin class that extends ScriptCompilationConfiguration and defines the compilation specifics for this script definition. You'll create it in the next step.

```
// @KotlinScript annotation marks a script definition class
 @KotlinScript(
     // File extension for the script type
     fileExtension = "scriptwithdeps.kts",
     // Compilation configuration for the script type
     compilationConfiguration = ScriptWithMavenDepsConfiguration::class
 )
 abstract class ScriptWithMavenDeps

 object ScriptWithMavenDepsConfiguration: ScriptCompilationConfiguration()
```

   In this tutorial, we provide only the working code without explaining Kotlin scripting API. You can find the same code with a detailed explanation on GitHub.

5. Define the script compilation configuration as shown below.

```
object ScriptWithMavenDepsConfiguration : ScriptCompilationConfiguration(
     {
         // Implicit imports for all scripts of this type
         defaultImports(DependsOn::class, Repository::class)
         jvm {
             // Extract the whole classpath from context classloader and use it as dependencies
             dependenciesFromCurrentContext(wholeClasspath = true)
         }
         // Callbacks
         refineConfiguration {
             // Process specified annotations with the provided handler
             onAnnotations(DependsOn::class, Repository::class, handler = ::configureMavenDepsOnAnnotations)
         }
     }
 )
```

   The configureMavenDepsOnAnnotations function is as follows:

```
// Handler that reconfigures the compilation on the fly
 fun configureMavenDepsOnAnnotations(context: ScriptConfigurationRefinementContext):
ResultWithDiagnostics<ScriptCompilationConfiguration> {
     val annotations = context.collectedData?.get(ScriptCollectedData.collectedAnnotations)?.takeIf { it.isNotEmpty() }
         ?: return context.compilationConfiguration.asSuccess()
     return runBlocking {
         resolver.resolveFromScriptSourceAnnotations(annotations)
     }.onSuccess {
         context.compilationConfiguration.with {
             dependencies.append(JvmDependency(it))
         }.asSuccess()
     }
 }

 private val resolver = CompoundDependenciesResolver(FileSystemDependenciesResolver(), MavenDependenciesResolver())
```

   You can find the full code here.

Create a scripting host

The next step is creating the scripting host – the component that handles the script execution.

1. In the scripting host module, add the dependencies in the dependencies block of build.gradle(.kts):

   - Kotlin scripting components that provide the APIs you need for the scripting host

   - The script definition module you created previously

   Kotlin

   ```
   dependencies {
       implementation("org.jetbrains.kotlin:kotlin-scripting-common")
       implementation("org.jetbrains.kotlin:kotlin-scripting-jvm")
       implementation("org.jetbrains.kotlin:kotlin-scripting-jvm-host")
       implementation(project(":script-definition")) // the script definition module
   }
   ```

   Groovy

   ```
   dependencies {
       implementation 'org.jetbrains.kotlin:kotlin-scripting-common'
       implementation 'org.jetbrains.kotlin:kotlin-scripting-jvm'
       implementation 'org.jetbrains.kotlin:kotlin-scripting-jvm-host'
       implementation project(':script-definition') // the script definition module
   }
   ```

2. Create the src/main/kotlin/ directory in the module and add a Kotlin source file, for example, host.kt.

3. Define the main function for the application. In its body, check that it has one argument – the path to the script file – and execute the script. You'll define the script execution in a separate function evalFile in the next step. Declare it empty for now.

   main can look like this:

   ```
   fun main(vararg args: String) {
        if (args.size != 1) {
            println("usage: <app> <script file>")
        } else {
            val scriptFile = File(args[0])
            println("Executing script $scriptFile")
            evalFile(scriptFile)
        }
    }
   ```

4. Define the script evaluation function. This is where you'll use the script definition. Obtain it by calling createJvmCompilationConfigurationFromTemplate with the script definition class as a type parameter. Then call BasicJvmScriptingHost().eval, passing it the script code and its compilation configuration. eval returns an instance of ResultWithDiagnostics, so set it as your function's return type.

   ```
   fun evalFile(scriptFile: File): ResultWithDiagnostics<EvaluationResult> {
        val compilationConfiguration = createJvmCompilationConfigurationFromTemplate<ScriptWithMavenDeps>()
        return BasicJvmScriptingHost().eval(scriptFile.toScriptSource(), compilationConfiguration, null)
    }
   ```

5. Adjust the main function to print information about the script execution:

   ```
   fun main(vararg args: String) {
        if (args.size != 1) {
            println("usage: <app> <script file>")
        } else {
            val scriptFile = File(args[0])
            println("Executing script $scriptFile")
            val res = evalFile(scriptFile)
            res.reports.forEach {
                if (it.severity > ScriptDiagnostic.Severity.DEBUG) {
                    println(" : ${it.message}" + if (it.exception == null) "" else ": ${it.exception}")
                }
            }
   ```

```
    }
}
```

You can find the full code here

Run scripts

To check how your scripting host works, prepare a script to execute and a run configuration.

1. Create the file html.scriptwithdeps.kts with the following content in the project root directory:

```
@file:Repository("https://maven.pkg.jetbrains.space/public/p/kotlinx-html/maven")
@file:DependsOn("org.jetbrains.kotlinx:kotlinx-html-jvm:0.7.3")

import kotlinx.html.*; import kotlinx.html.stream.*; import kotlinx.html.attributes.*

val addressee = "World"

print(
    createHTML().html {
        body {
            h1 { +"Hello, $addressee!" }
        }
    }
)
```

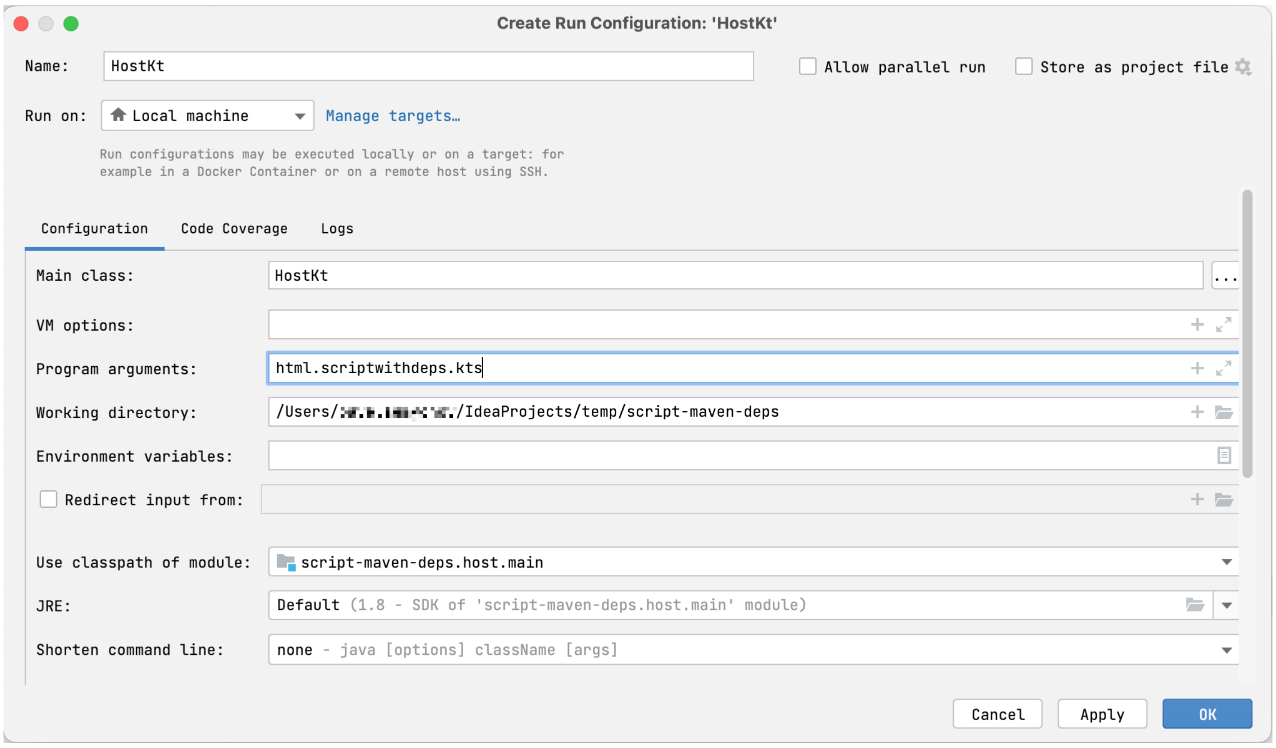
   It uses functions from the kotlinx-html-jvm library which is referenced in the @DependsOn annotation argument.

2. Create a run configuration that starts the scripting host and executes this file:

   1. Open host.kt and navigate to the main function. It has a Run gutter icon on the left.

   2. Right-click the gutter icon and select Modify Run Configuration.

   3. In the Create Run Configuration dialog, add the script file name to Program arguments and click OK.



Create Run Configuration: 'HostKt'

Name: HostKt   ☐ Allow parallel run   ☐ Store as project file

Run on: Local machine   Manage targets…

Run configurations may be executed locally or on a target: for example in a Docker Container or on a remote host using SSH.

Configuration   Code Coverage   Logs

Main class: HostKt

VM options:

Program arguments: html.scriptwithdeps.kts

Working directory: /Users/[redacted]/IdeaProjects/temp/script-maven-deps

Environment variables:

☐ Redirect input from:

Use classpath of module: script-maven-deps.host.main

JRE: Default (1.8 - SDK of 'script-maven-deps.host.main' module)

Shorten command line: none - java [options] className [args]

Scripting host run configuration

3. Run the created configuration.

You'll see how the script is executed, resolving the dependency on kotlinx-html-jvm in the specified repository and printing the results of calling its functions:

```
<html>
  <body>
    <h1>Hello, World!</h1>
  </body>
</html>
```

Resolving dependencies may take some time on the first run. Subsequent runs will complete much faster because they use downloaded dependencies from the local Maven repository.

What's next?

Once you've created a simple Kotlin scripting project, find more information on this topic:

- Read the Kotlin scripting KEEP
- Browse more Kotlin scripting examples
- Watch the talk Implementing the Gradle Kotlin DSL by Rodrigo Oliveira

Collections overview

The Kotlin Standard Library provides a comprehensive set of tools for managing collections – groups of a variable number of items (possibly zero) that are significant to the problem being solved and are commonly operated on.

Collections are a common concept for most programming languages, so if you're familiar with, for example, Java or Python collections, you can skip this introduction and proceed to the detailed sections.

A collection usually contains a number of objects of the same type (and its subtypes). Objects in a collection are called elements or items. For example, all the students in a department form a collection that can be used to calculate their average age.

The following collection types are relevant for Kotlin:

- List is an ordered collection with access to elements by indices – integer numbers that reflect their position. Elements can occur more than once in a list. An example of a list is a telephone number: it's a group of digits, their order is important, and they can repeat.
- Set is a collection of unique elements. It reflects the mathematical abstraction of set: a group of objects without repetitions. Generally, the order of set elements has no significance. For example, the numbers on lottery tickets form a set: they are unique, and their order is not important.
- Map (or dictionary) is a set of key-value pairs. Keys are unique, and each of them maps to exactly one value. The values can be duplicates. Maps are useful for storing logical connections between objects, for example, an employee's ID and their position.

Kotlin lets you manipulate collections independently of the exact type of objects stored in them. In other words, you add a String to a list of Strings the same way as you would do with Ints or a user-defined class. So, the Kotlin Standard Library offers generic interfaces, classes, and functions for creating, populating, and managing collections of any type.

The collection interfaces and related functions are located in the kotlin.collections package. Let's get an overview of its contents.

> Arrays are not a type of collection. For more information, see Arrays.

Collection types

The Kotlin Standard Library provides implementations for basic collection types: sets, lists, and maps. A pair of interfaces represent each collection type:

- A read-only interface that provides operations for accessing collection elements.
- A mutable interface that extends the corresponding read-only interface with write operations: adding, removing, and updating its elements.

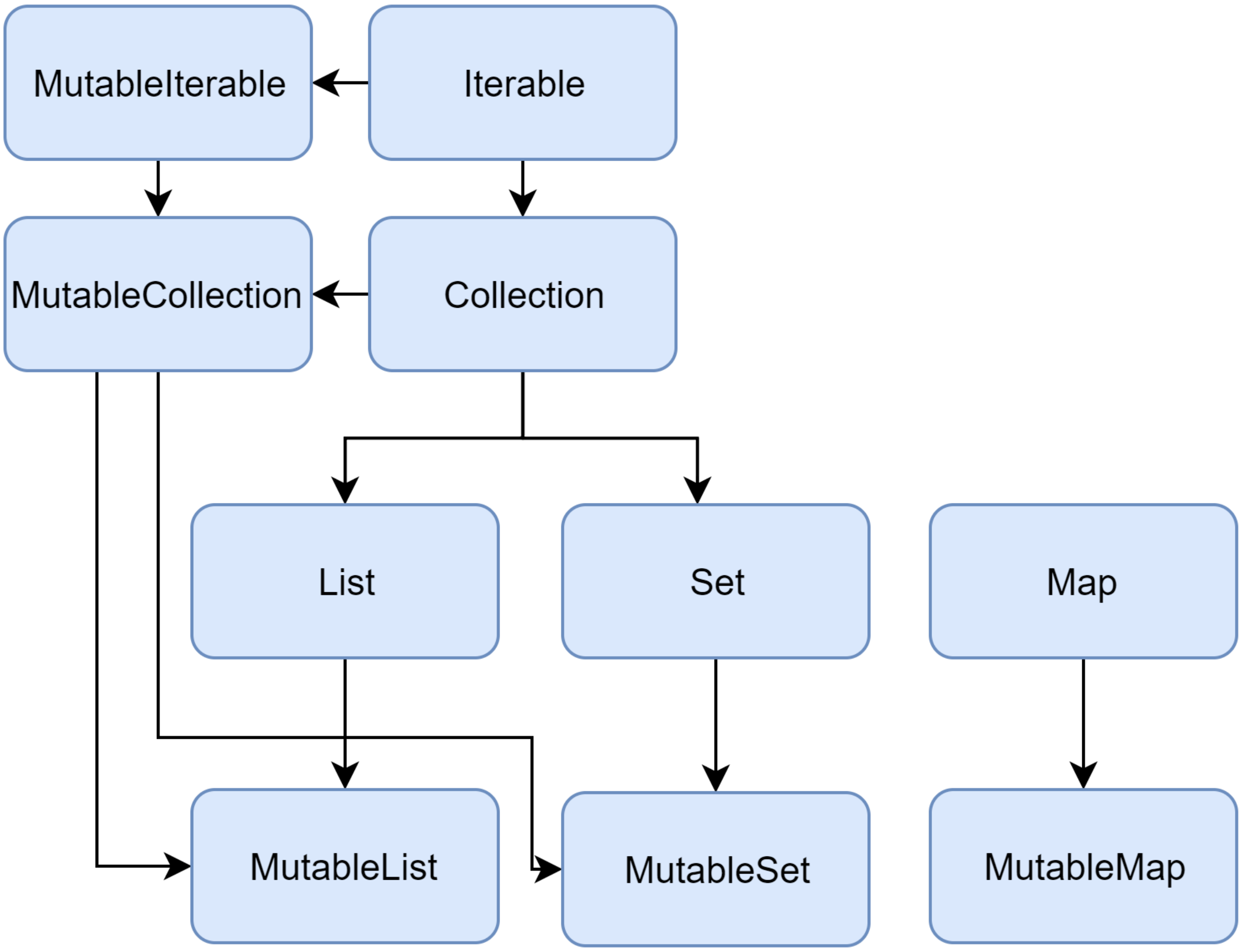
Note that a mutable collection doesn't have to be assigned to a var. Write operations with a mutable collection are still possible even if it is assigned to a val. The benefit of assigning mutable collections to val is that you protect the reference to the mutable collection from modification. Over time, as your code grows and becomes more complex, it becomes even more important to prevent unintentional modification to references. Use val as much as possible for safer and more robust code. If you try to reassign a val collection, you get a compilation error:

```kotlin
fun main() {
    val numbers = mutableListOf("one", "two", "three", "four")
    numbers.add("five")   // this is OK
    println(numbers)
    //numbers = mutableListOf("six", "seven")      // compilation error

}
```

The read-only collection types are covariant. This means that, if a Rectangle class inherits from Shape, you can use a List<Rectangle> anywhere the List<Shape> is required. In other words, the collection types have the same subtyping relationship as the element types. Maps are covariant on the value type, but not on the key type.

In turn, mutable collections aren't covariant; otherwise, this would lead to runtime failures. If MutableList<Rectangle> was a subtype of MutableList<Shape>, you could insert other Shape inheritors (for example, Circle) into it, thus violating its Rectangle type argument.

Below is a diagram of the Kotlin collection interfaces:



Collection interfaces hierarchy

Let's walk through the interfaces and their implementations. To learn about Collection, read the section below. To learn about List, Set, and Map, you can either read the corresponding sections or watch a video by Sebastian Aigner, Kotlin Developer Advocate:

Watch video online.

Collection

Collection<T> is the root of the collection hierarchy. This interface represents the common behavior of a read-only collection: retrieving size, checking item membership, and so on. Collection inherits from the Iterable<T> interface that defines the operations for iterating elements. You can use Collection as a parameter of a function that applies to different collection types. For more specific cases, use the Collection's inheritors: List and Set.

```kotlin
fun printAll(strings: Collection<String>) {
    for(s in strings) print("$s ")
    println()
}

fun main() {
    val stringList = listOf("one", "two", "one")
    printAll(stringList)

    val stringSet = setOf("one", "two", "three")
    printAll(stringSet)
}
```

MutableCollection<T> is a Collection with write operations, such as add and remove.

```kotlin
fun List<String>.getShortWordsTo(shortWords: MutableList<String>, maxLength: Int) {
    this.filterTo(shortWords) { it.length <= maxLength }
    // throwing away the articles
    val articles = setOf("a", "A", "an", "An", "the", "The")
    shortWords -= articles
}

fun main() {
    val words = "A long time ago in a galaxy far far away".split(" ")
    val shortWords = mutableListOf<String>()
    words.getShortWordsTo(shortWords, 3)
    println(shortWords)
}
```

List

List<T> stores elements in a specified order and provides indexed access to them. Indices start from zero – the index of the first element – and go to lastIndex which is the (list.size - 1).

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    println("Number of elements: ${numbers.size}")
    println("Third element: ${numbers.get(2)}")
    println("Fourth element: ${numbers[3]}")
    println("Index of element \"two\" ${numbers.indexOf("two")}")
}
```

List elements (including nulls) can duplicate: a list can contain any number of equal objects or occurrences of a single object. Two lists are considered equal if they have the same sizes and structurally equal elements at the same positions.

```
data class Person(var name: String, var age: Int)

fun main() {
    val bob = Person("Bob", 31)
    val people = listOf(Person("Adam", 20), bob, bob)
    val people2 = listOf(Person("Adam", 20), Person("Bob", 31), bob)
    println(people == people2)
    bob.age = 32
    println(people == people2)
}
```

MutableList<T> is a List with list-specific write operations, for example, to add or remove an element at a specific position.

```
fun main() {
    val numbers = mutableListOf(1, 2, 3, 4)
    numbers.add(5)
    numbers.removeAt(1)
    numbers[0] = 0
    numbers.shuffle()
    println(numbers)
}
```

As you see, in some aspects lists are very similar to arrays. However, there is one important difference: an array's size is defined upon initialization and is never changed; in turn, a list doesn't have a predefined size; a list's size can be changed as a result of write operations: adding, updating, or removing elements.

In Kotlin, the default implementation of MutableList is ArrayList which you can think of as a resizable array.

Set

Set<T> stores unique elements; their order is generally undefined. null elements are unique as well: a Set can contain only one null. Two sets are equal if they have the same size, and for each element of a set there is an equal element in the other set.

```
fun main() {
    val numbers = setOf(1, 2, 3, 4)
    println("Number of elements: ${numbers.size}")
    if (numbers.contains(1)) println("1 is in the set")

    val numbersBackwards = setOf(4, 3, 2, 1)
    println("The sets are equal: ${numbers == numbersBackwards}")
}
```

MutableSet is a Set with write operations from MutableCollection.

The default implementation of MutableSet – LinkedHashSet – preserves the order of elements insertion. Hence, the functions that rely on the order, such as first() or last(), return predictable results on such sets.

```
fun main() {
    val numbers = setOf(1, 2, 3, 4)  // LinkedHashSet is the default implementation
    val numbersBackwards = setOf(4, 3, 2, 1)

    println(numbers.first() == numbersBackwards.first())
    println(numbers.first() == numbersBackwards.last())
}
```

An alternative implementation – HashSet – says nothing about the elements order, so calling such functions on it returns unpredictable results. However, HashSet requires less memory to store the same number of elements.

Map

Map<K, V> is not an inheritor of the Collection interface; however, it's a Kotlin collection type as well. A Map stores key-value pairs (or entries); keys are unique, but different keys can be paired with equal values. The Map interface provides specific functions, such as access to value by key, searching keys and values, and so on.

```
fun main() {
    val numbersMap = mapOf("key1" to 1, "key2" to 2, "key3" to 3, "key4" to 1)

    println("All keys: ${numbersMap.keys}")
    println("All values: ${numbersMap.values}")
    if ("key2" in numbersMap) println("Value by key \"key2\": ${numbersMap["key2"]}")
    if (1 in numbersMap.values) println("The value 1 is in the map")
    if (numbersMap.containsValue(1)) println("The value 1 is in the map") // same as previous
}
```

Two maps containing the equal pairs are equal regardless of the pair order.

```
fun main() {
    val numbersMap = mapOf("key1" to 1, "key2" to 2, "key3" to 3, "key4" to 1)
    val anotherMap = mapOf("key2" to 2, "key1" to 1, "key4" to 1, "key3" to 3)

    println("The maps are equal: ${numbersMap == anotherMap}")
}
```

MutableMap is a Map with map write operations, for example, you can add a new key-value pair or update the value associated with the given key.

```
fun main() {
    val numbersMap = mutableMapOf("one" to 1, "two" to 2)
    numbersMap.put("three", 3)
    numbersMap["one"] = 11

    println(numbersMap)
}
```

The default implementation of MutableMap – LinkedHashMap – preserves the order of elements insertion when iterating the map. In turn, an alternative implementation – HashMap – says nothing about the elements order.

ArrayDeque

ArrayDeque<T> is an implementation of a double-ended queue, which allows you to add or remove elements both at the beginning or end of the queue. As such, ArrayDeque also fills the role of both a Stack and Queue data structure in Kotlin. Behind the scenes, ArrayDeque is realized using a resizable array that automatically adjusts in size when required:

```
fun main() {
    val deque = ArrayDeque(listOf(1, 2, 3))

    deque.addFirst(0)
    deque.addLast(4)
    println(deque) // [0, 1, 2, 3, 4]

    println(deque.first()) // 0
    println(deque.last()) // 4

    deque.removeFirst()
    deque.removeLast()
    println(deque) // [1, 2, 3]
}
```

Constructing collections

Construct from elements

The most common way to create a collection is with the standard library functions listOf<T>(), setOf<T>(), mutableListOf<T>(), mutableSetOf<T>(). If you provide a comma-separated list of collection elements as arguments, the compiler detects the element type automatically. When creating empty collections, specify the type explicitly.

```
val numbersSet = setOf("one", "two", "three", "four")
val emptySet = mutableSetOf<String>()
```

The same is available for maps with the functions mapOf() and mutableMapOf(). The map's keys and values are passed as Pair objects (usually created with to infix function).

```
val numbersMap = mapOf("key1" to 1, "key2" to 2, "key3" to 3, "key4" to 1)
```

Note that the to notation creates a short-living Pair object, so it's recommended that you use it only if performance isn't critical. To avoid excessive memory usage, use alternative ways. For example, you can create a mutable map and populate it using the write operations. The apply() function can help to keep the initialization fluent here.

```
val numbersMap = mutableMapOf<String, String>().apply { this["one"] = "1"; this["two"] = "2" }
```

Create with collection builder functions

Another way of creating a collection is to call a builder function – buildList(), buildSet(), or buildMap(). They create a new, mutable collection of the corresponding type, populate it using write operations, and return a read-only collection with the same elements:

```
val map = buildMap { // this is MutableMap<String, Int>, types of key and value are inferred from the `put()` calls below
    put("a", 1)
    put("b", 0)
    put("c", 4)
}

println(map) // {a=1, b=0, c=4}
```

Empty collections

There are also functions for creating collections without any elements: emptyList(), emptySet(), and emptyMap(). When creating empty collections, you should specify the type of elements that the collection will hold.

```
val empty = emptyList<String>()
```

Initializer functions for lists

For lists, there is a constructor-like function that takes the list size and the initializer function that defines the element value based on its index.

```
fun main() {
    val doubled = List(3, { it * 2 })  // or MutableList if you want to change its content later
    println(doubled)
}
```

Concrete type constructors

To create a concrete type collection, such as an ArrayList or LinkedList, you can use the available constructors for these types. Similar constructors are available for implementations of Set and Map.

```
val linkedList = LinkedList<String>(listOf("one", "two", "three"))
val presizedSet = HashSet<Int>(32)
```

Copy

To create a collection with the same elements as an existing collection, you can use copying functions. Collection copying functions from the standard library create shallow copy collections with references to the same elements. Thus, a change made to a collection element reflects in all its copies.

Collection copying functions, such as toList(), toMutableList(), toSet() and others, create a snapshot of a collection at a specific moment. Their result is a new collection of the same elements. If you add or remove elements from the original collection, this won't affect the copies. Copies may be changed independently of the source as well.

```
class Person(var name: String)
fun main() {
    val alice = Person("Alice")
    val sourceList = mutableListOf(alice, Person("Bob"))
    val copyList = sourceList.toList()
    sourceList.add(Person("Charles"))
    alice.name = "Alicia"
    println("First item's name is: ${sourceList[0].name} in source and ${copyList[0].name} in copy")
    println("List size is: ${sourceList.size} in source and ${copyList.size} in copy")
}
```

These functions can also be used for converting collections to other types, for example, build a set from a list or vice versa.

```
fun main() {
    val sourceList = mutableListOf(1, 2, 3)
    val copySet = sourceList.toMutableSet()
    copySet.add(3)
    copySet.add(4)
    println(copySet)
}
```

Alternatively, you can create new references to the same collection instance. New references are created when you initialize a collection variable with an existing collection. So, when the collection instance is altered through a reference, the changes are reflected in all its references.

```
fun main() {
    val sourceList = mutableListOf(1, 2, 3)
    val referenceList = sourceList
    referenceList.add(4)
    println("Source size: ${sourceList.size}")
}
```

Collection initialization can be used for restricting mutability. For example, if you create a List reference to a MutableList, the compiler will produce errors if you try to modify the collection through this reference.

```
fun main() {
//sampleStart
    val sourceList = mutableListOf(1, 2, 3)
    val referenceList: List<Int> = sourceList
    //referenceList.add(4)            //compilation error
    sourceList.add(4)
    println(referenceList) // shows the current state of sourceList
}
```

Invoke functions on other collections

Collections can be created as a result of various operations on other collections. For example, filtering a list creates a new list of elements that match the filter:

```
fun main() {
//sampleStart
    val numbers = listOf("one", "two", "three", "four")
    val longerThan3 = numbers.filter { it.length > 3 }
    println(longerThan3)
}
```

Mapping produces a list from a transformation's results:

```
fun main() {
//sampleStart
```

```
    val numbers = setOf(1, 2, 3)
    println(numbers.map { it * 3 })
    println(numbers.mapIndexed { idx, value -> value * idx })
}
```

Association produces maps:

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    println(numbers.associateWith { it.length })
}
```

For more information about operations on collections in Kotlin, see Collection operations overview.

Iterators

For traversing collection elements, the Kotlin standard library supports the commonly used mechanism of iterators – objects that provide access to the elements sequentially without exposing the underlying structure of the collection. Iterators are useful when you need to process all the elements of a collection one-by-one, for example, print values or make similar updates to them.

Iterators can be obtained for inheritors of the Iterable<T> interface, including Set and List, by calling the iterator() function.

Once you obtain an iterator, it points to the first element of a collection; calling the next() function returns this element and moves the iterator position to the following element if it exists.

Once the iterator passes through the last element, it can no longer be used for retrieving elements; neither can it be reset to any previous position. To iterate through the collection again, create a new iterator.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    val numbersIterator = numbers.iterator()
    while (numbersIterator.hasNext()) {
        println(numbersIterator.next())
        // one
        // two
        // three
        // four
    }
}
```

Another way to go through an Iterable collection is the well-known for loop. When using for on a collection, you obtain the iterator implicitly. So, the following code is equivalent to the example above:

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    for (item in numbers) {
        println(item)
        // one
        // two
        // three
        // four
    }
}
```

Finally, there is a useful forEach() function that lets you automatically iterate a collection and execute the given code for each element. So, the same example would look like this:

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    numbers.forEach {
        println(it)
        // one
        // two
        // three
        // four
    }
}
```

List iterators

For lists, there is a special iterator implementation: ListIterator. It supports iterating lists in both directions: forwards and backwards.

Backward iteration is implemented by the functions hasPrevious() and previous(). Additionally, the ListIterator provides information about the element indices with the functions nextIndex() and previousIndex().

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    val listIterator = numbers.listIterator()
    while (listIterator.hasNext()) listIterator.next()
    println("Iterating backwards:")
    // Iterating backwards:
    while (listIterator.hasPrevious()) {
        print("Index: ${listIterator.previousIndex()}")
        println(", value: ${listIterator.previous()}")
        // Index: 3, value: four
        // Index: 2, value: three
        // Index: 1, value: two
        // Index: 0, value: one
    }
}
```

Having the ability to iterate in both directions, means the ListIterator can still be used after it reaches the last element.

Mutable iterators

For iterating mutable collections, there is MutableIterator that extends Iterator with the element removal function remove(). So, you can remove elements from a collection while iterating it.

```
fun main() {
    val numbers = mutableListOf("one", "two", "three", "four")
    val mutableIterator = numbers.iterator()

    mutableIterator.next()
    mutableIterator.remove()
    println("After removal: $numbers")
    // After removal: [two, three, four]
}
```

In addition to removing elements, the MutableListIterator can also insert and replace elements while iterating the list by using the add() and set() functions.

```
fun main() {
    val numbers = mutableListOf("one", "four", "four")
    val mutableListIterator = numbers.listIterator()

    mutableListIterator.next()
    mutableListIterator.add("two")
    println(numbers)
    // [one, two, four, four]
    mutableListIterator.next()
    mutableListIterator.set("three")
    println(numbers)
    // [one, two, three, four]
}
```

Ranges and progressions

Ranges and progressions define sequences of values in Kotlin, supporting range operators, iteration, custom step values, and arithmetic progressions.

Ranges

Kotlin lets you easily create ranges of values using the .rangeTo() and .rangeUntil() functions from the kotlin.ranges package.

A range represents an ordered set of values with a defined start and end. By default, it increments by 1 at each step. For example, 1..4 represents the numbers 1, 2, 3, and 4.

To create:

- a closed-ended range, call the .rangeTo() function with the .. operator. This includes both the start and end values.
- an open-ended range, call the .rangeUntil() function with the ..< operator. This includes the start value but excludes the end value.

For example:

```
fun main() {
    // Closed-ended range: includes both 1 and 4
    println(4 in 1..4)
    // true

    // Open-ended range: includes 1, excludes 4
    println(4 in 1..<4)
    // false
}
```

Ranges are particularly useful for iterating over for loops:

```
fun main() {
    for (i in 1..4) print(i)
    // 1234
}
```

To iterate numbers in reverse order, use the downTo function instead of ...

```
fun main() {
    for (i in 4 downTo 1) print(i)
    // 4321
}
```

You can also iterate over numbers with a custom step using the step() function, instead of the default increment of 1:

```
fun main() {
    for (i in 0..8 step 2) print(i)
    println()
    // 02468
    for (i in 0..<8 step 2) print(i)
    println()
    // 0246
    for (i in 8 downTo 0 step 2) print(i)
    // 86420
}
```

Progression

The ranges of integral types, such as Int, Long, and Char, can be treated as arithmetic progressions. In Kotlin, these progressions are defined by special types: IntProgression, LongProgression, and CharProgression.

Progressions have three essential properties: the first element, the last element, and a non-zero step. The first element is first, subsequent elements are the previous element plus a step. Iteration over a progression with a positive step is equivalent to an indexed for loop in Java/JavaScript.

```
for (int i = first; i <= last; i += step) {
  // ...
}
```

When you create a progression implicitly by iterating a range, this progression's first and last elements are the range's endpoints, and the step is 1.

```
fun main() {
    for (i in 1..10) print(i)
    // 12345678910
}
```

To define a custom progression step, use the step function on a range.

```
fun main() {
    for (i in 1..8 step 2) print(i)
    // 1357
}
```

The last element of the progression is calculated this way:

- For a positive step: the maximum value not greater than the end value such that (last - first) % step == 0.
- For a negative step: the minimum value not less than the end value such that (last - first) % step == 0.

Thus, the last element is not always the same as the specified end value.

```
fun main() {
    for (i in 1..9 step 3) print(i) // the last element is 7
    // 147
}
```

Progressions implement Iterable<N>, where N is Int, Long, or Char respectively, so you can use them in various collection functions like map, filter, and other.

```
fun main() {
    println((1..10).filter { it % 2 == 0 })
    // [2, 4, 6, 8, 10]
}
```

Sequences

Along with collections, the Kotlin standard library contains another type – sequences (Sequence<T>). Unlike collections, sequences don't contain elements, they produce them while iterating. Sequences offer the same functions as Iterable but implement another approach to multi-step collection processing.

When the processing of an Iterable includes multiple steps, they are executed eagerly: each processing step completes and returns its result – an intermediate collection. The following step executes on this collection. In turn, multi-step processing of sequences is executed lazily when possible: actual computing happens only when the result of the whole processing chain is requested.

The order of operations execution is different as well: Sequence performs all the processing steps one-by-one for every single element. In turn, Iterable completes each step for the whole collection and then proceeds to the next step.

So, the sequences let you avoid building results of intermediate steps, therefore improving the performance of the whole collection processing chain. However, the lazy nature of sequences adds some overhead which may be significant when processing smaller collections or doing simpler computations. Hence, you should consider both Sequence and Iterable and decide which one is better for your case.

Construct

From elements

To create a sequence, call the sequenceOf() function listing the elements as its arguments.

```
val numbersSequence = sequenceOf("four", "three", "two", "one")
```

From an Iterable

If you already have an Iterable object (such as a List or a Set), you can create a sequence from it by calling asSequence().

```
val numbers = listOf("one", "two", "three", "four")
val numbersSequence = numbers.asSequence()
```

From a function

One more way to create a sequence is by building it with a function that calculates its elements. To build a sequence based on a function, call generateSequence()

with this function as an argument. Optionally, you can specify the first element as an explicit value or a result of a function call. The sequence generation stops when the provided function returns null. So, the sequence in the example below is infinite.

```
fun main() {
    val oddNumbers = generateSequence(1) { it + 2 } // `it` is the previous element
    println(oddNumbers.take(5).toList())
    //println(oddNumbers.count())     // error: the sequence is infinite
}
```

To create a finite sequence with generateSequence(), provide a function that returns null after the last element you need.

```
fun main() {
    val oddNumbersLessThan10 = generateSequence(1) { if (it < 8) it + 2 else null }
    println(oddNumbersLessThan10.count())
}
```

From chunks

Finally, there is a function that lets you produce sequence elements one by one or by chunks of arbitrary sizes – the sequence() function. This function takes a lambda expression containing calls of yield() and yieldAll() functions. They return an element to the sequence consumer and suspend the execution of sequence() until the next element is requested by the consumer. yield() takes a single element as an argument; yieldAll() can take an Iterable object, an Iterator, or another Sequence. A Sequence argument of yieldAll() can be infinite. However, such a call must be the last: all subsequent calls will never be executed.

```
fun main() {
    val oddNumbers = sequence {
        yield(1)
        yieldAll(listOf(3, 5))
        yieldAll(generateSequence(7) { it + 2 })
    }
    println(oddNumbers.take(5).toList())
}
```

Sequence operations

The sequence operations can be classified into the following groups regarding their state requirements:

- Stateless operations require no state and process each element independently, for example, map() or filter(). Stateless operations can also require a small constant amount of state to process an element, for example, take() or drop().
- Stateful operations require a significant amount of state, usually proportional to the number of elements in a sequence.

If a sequence operation returns another sequence, which is produced lazily, it's called intermediate. Otherwise, the operation is terminal. Examples of terminal operations are toList() or sum(). Sequence elements can be retrieved only with terminal operations.

Sequences can be iterated multiple times; however some sequence implementations might constrain themselves to be iterated only once. That is mentioned specifically in their documentation.

Sequence processing example

Let's take a look at the difference between Iterable and Sequence with an example.

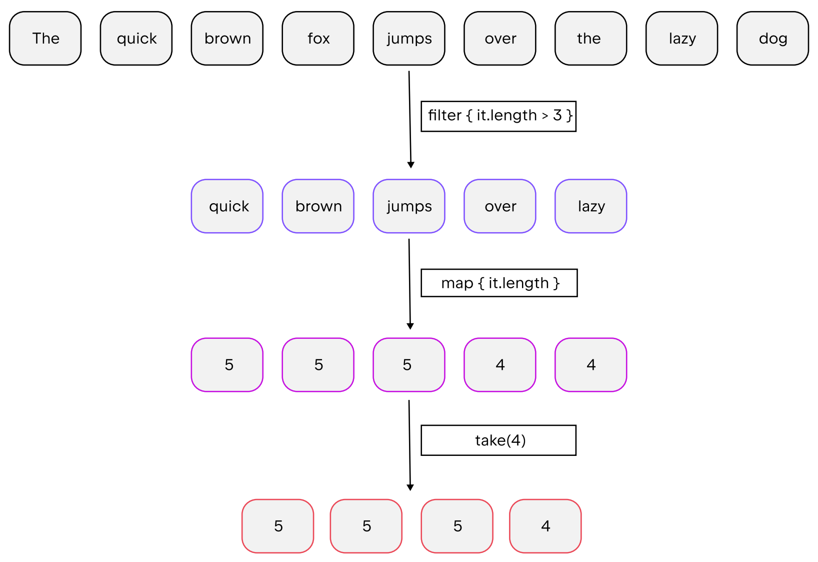
Iterable

Assume that you have a list of words. The code below filters the words longer than three characters and prints the lengths of first four such words.

```
fun main() {
    val words = "The quick brown fox jumps over the lazy dog".split(" ")
    val lengthsList = words.filter { println("filter: $it"); it.length > 3 }
        .map { println("length: ${it.length}"); it.length }
        .take(4)

    println("Lengths of first 4 words longer than 3 chars:")
    println(lengthsList)
}
```

When you run this code, you'll see that the filter() and map() functions are executed in the same order as they appear in the code. First, you see filter: for all elements, then length: for the elements left after filtering, and then the output of the two last lines.

This is how the list processing goes:



List processing

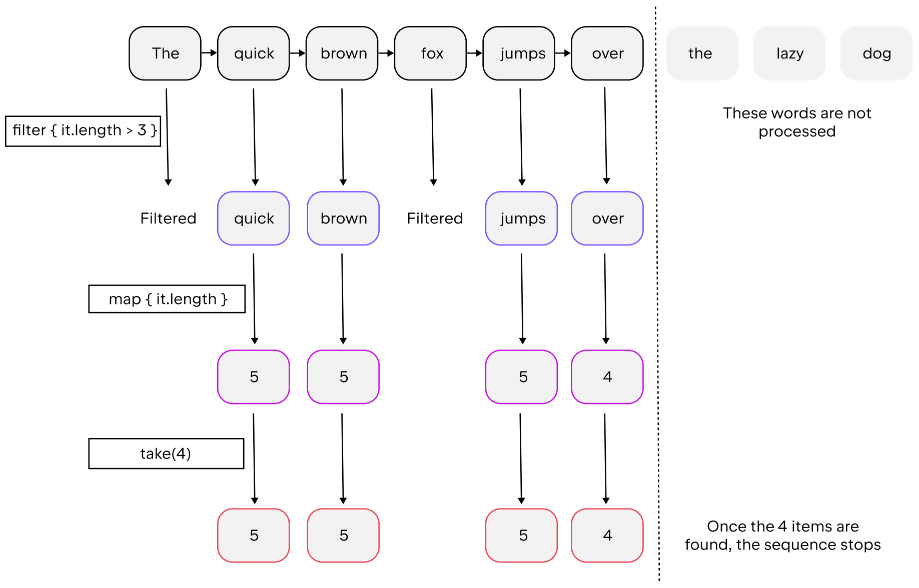
Sequence

Now let's write the same with sequences:

```
fun main() {
    val words = "The quick brown fox jumps over the lazy dog".split(" ")
    //convert the List to a Sequence
    val wordsSequence = words.asSequence()

    val lengthsSequence = wordsSequence.filter { println("filter: $it"); it.length > 3 }
        .map { println("length: ${it.length}"); it.length }
        .take(4)

    println("Lengths of first 4 words longer than 3 chars")
    // terminal operation: obtaining the result as a List
    println(lengthsSequence.toList())
}
```

The output of this code shows that the filter() and map() functions are called only when building the result list. So, you first see the line of text "Lengths of.." and then the sequence processing starts. Note that for elements left after filtering, the map executes before filtering the next element. When the result size reaches 4, the processing stops because it's the largest possible size that take(4) can return.

The sequence processing goes like this:



Sequences processing

In this example, the lazy processing of elements and stopping after finding four items reduces the number of operations compared to using a list approach.

Collection operations overview

The Kotlin standard library offers a broad variety of functions for performing operations on collections. This includes simple operations, such as getting or adding elements, as well as more complex ones including search, sorting, filtering, transformations, and so on.

Extension and member functions

Collection operations are declared in the standard library in two ways: member functions of collection interfaces and extension functions.

Member functions define operations that are essential for a collection type. For example, Collection contains the function isEmpty() for checking its emptiness; List contains get() for index access to elements, and so on.

When you create your own implementations of collection interfaces, you must implement their member functions. To make the creation of new implementations easier, use the skeletal implementations of collection interfaces from the standard library: AbstractCollection, AbstractList, AbstractSet, AbstractMap, and their mutable counterparts.

Other collection operations are declared as extension functions. These are filtering, transformation, ordering, and other collection processing functions.

Common operations

Common operations are available for both read-only and mutable collections. Common operations fall into these groups:

- Transformations
- Filtering
- plus and minus operators
- Grouping
- Retrieving collection parts
- Retrieving single elements
- Ordering
- Aggregate operations

Operations described on these pages return their results without affecting the original collection. For example, a filtering operation produces a new collection that contains all the elements matching the filtering predicate. Results of such operations should be either stored in variables, or used in some other way, for example, passed in other functions.

```kotlin
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    numbers.filter { it.length > 3 }  // nothing happens with `numbers`, result is lost
    println("numbers are still $numbers")
    val longerThan3 = numbers.filter { it.length > 3 } // result is stored in `longerThan3`
    println("numbers longer than 3 chars are $longerThan3")
}
```

For certain collection operations, there is an option to specify the destination object. Destination is a mutable collection to which the function appends its resulting items instead of returning them in a new object. For performing operations with destinations, there are separate functions with the To postfix in their names, for example, filterTo() instead of filter() or associateTo() instead of associate(). These functions take the destination collection as an additional parameter.

```kotlin
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    val filterResults = mutableListOf<String>()  //destination object
    numbers.filterTo(filterResults) { it.length > 3 }
    numbers.filterIndexedTo(filterResults) { index, _ -> index == 0 }
    println(filterResults) // contains results of both operations
}
```

For convenience, these functions return the destination collection back, so you can create it right in the corresponding argument of the function call:

```kotlin
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    // filter numbers right into a new hash set,
    // thus eliminating duplicates in the result
    val result = numbers.mapTo(HashSet()) { it.length }
    println("distinct item lengths are $result")
}
```

Functions with destination are available for filtering, association, grouping, flattening, and other operations. For the complete list of destination operations see the Kotlin collections reference.

Write operations

For mutable collections, there are also write operations that change the collection state. Such operations include adding, removing, and updating elements. Write operations are listed in the Write operations and corresponding sections of List-specific operations and Map specific operations.

For certain operations, there are pairs of functions for performing the same operation: one applies the operation in-place and the other returns the result as a separate collection. For example, sort() sorts a mutable collection in-place, so its state changes; sorted() creates a new collection that contains the same elements in the sorted order.

```kotlin
fun main() {
    val numbers = mutableListOf("one", "two", "three", "four")
    val sortedNumbers = numbers.sorted()
    println(numbers == sortedNumbers)  // false
    numbers.sort()
    println(numbers == sortedNumbers)  // true
}
```

Collection transformation operations

The Kotlin standard library provides a set of extension functions for collection transformations. These functions build new collections from existing ones based on the transformation rules provided. In this page, we'll give an overview of the available collection transformation functions.

Map

The mapping transformation creates a collection from the results of a function on the elements of another collection. The basic mapping function is map(). It applies the given lambda function to each subsequent element and returns the list of the lambda results. The order of results is the same as the original order of elements. To apply a transformation that additionally uses the element index as an argument, use mapIndexed().

```
fun main() {
    val numbers = setOf(1, 2, 3)
    println(numbers.map { it * 3 })
    println(numbers.mapIndexed { idx, value -> value * idx })
}
```

If the transformation produces null on certain elements, you can filter out the nulls from the result collection by calling the mapNotNull() function instead of map(), or mapIndexedNotNull() instead of mapIndexed().

```
fun main() {
    val numbers = setOf(1, 2, 3)
    println(numbers.mapNotNull { if ( it == 2) null else it * 3 })
    println(numbers.mapIndexedNotNull { idx, value -> if (idx == 0) null else value * idx })
}
```

When transforming maps, you have two options: transform keys leaving values unchanged and vice versa. To apply a given transformation to keys, use mapKeys(); in turn, mapValues() transforms values. Both functions use the transformations that take a map entry as an argument, so you can operate both its key and value.

```
fun main() {
    val numbersMap = mapOf("key1" to 1, "key2" to 2, "key3" to 3, "key11" to 11)
    println(numbersMap.mapKeys { it.key.uppercase() })
    println(numbersMap.mapValues { it.value + it.key.length })
}
```

Zip

Zipping transformation is building pairs from elements with the same positions in both collections. In the Kotlin standard library, this is done by the zip() extension function.

When called on a collection or an array with another collection (or array) as an argument, zip() returns the List of Pair objects. The elements of the receiver collection are the first elements in these pairs.

If the collections have different sizes, the result of the zip() is the smaller size; the last elements of the larger collection are not included in the result.

zip() can also be called in the infix form a zip b.

```
fun main() {
    val colors = listOf("red", "brown", "grey")
    val animals = listOf("fox", "bear", "wolf")
    println(colors zip animals)

    val twoAnimals = listOf("fox", "bear")
    println(colors.zip(twoAnimals))
}
```

You can also call zip() with a transformation function that takes two parameters: the receiver element and the argument element. In this case, the result List contains the return values of the transformation function called on pairs of the receiver and the argument elements with the same positions.

```
fun main() {
    val colors = listOf("red", "brown", "grey")
    val animals = listOf("fox", "bear", "wolf")

    println(colors.zip(animals) { color, animal -> "The ${animal.replaceFirstChar { it.uppercase() }} is $color"})
}
```

When you have a List of Pairs, you can do the reverse transformation – unzipping – that builds two lists from these pairs:

- The first list contains the first elements of each Pair in the original list.
- The second list contains the second elements.

To unzip a list of pairs, call unzip().

```
fun main() {
    val numberPairs = listOf("one" to 1, "two" to 2, "three" to 3, "four" to 4)
    println(numberPairs.unzip())
}
```

Associate

Association transformations allow building maps from the collection elements and certain values associated with them. In different association types, the elements can be either keys or values in the association map.

The basic association function associateWith() creates a Map in which the elements of the original collection are keys, and values are produced from them by the given transformation function. If two elements are equal, only the last one remains in the map.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    println(numbers.associateWith { it.length })
}
```

For building maps with collection elements as values, there is the function associateBy(). It takes a function that returns a key based on an element's value. If two elements' keys are equal, only the last one remains in the map.

associateBy() can also be called with a value transformation function.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")

    println(numbers.associateBy { it.first().uppercaseChar() })
    println(numbers.associateBy(keySelector = { it.first().uppercaseChar() }, valueTransform = { it.length }))
}
```

Another way to build maps in which both keys and values are somehow produced from collection elements is the function associate(). It takes a lambda function that returns a Pair: the key and the value of the corresponding map entry.

Note that associate() produces short-living Pair objects which may affect the performance. Thus, associate() should be used when the performance isn't critical or it's more preferable than other options.

An example of the latter is when a key and the corresponding value are produced from an element together.

```
fun main() {
data class FullName (val firstName: String, val lastName: String)

fun parseFullName(fullName: String): FullName {
    val nameParts = fullName.split(" ")
    if (nameParts.size == 2) {
        return FullName(nameParts[0], nameParts[1])
    } else throw Exception("Wrong name format")
}

    val names = listOf("Alice Adams", "Brian Brown", "Clara Campbell")
    println(names.associate { name -> parseFullName(name).let { it.lastName to it.firstName } })
}
```

Here we call a transform function on an element first, and then build a pair from the properties of that function's result.

Flatten

If you operate nested collections, you may find the standard library functions that provide flat access to nested collection elements useful.

The first function is flatten(). You can call it on a collection of collections, for example, a List of Sets. The function returns a single List of all the elements of the nested collections.

```
fun main() {
    val numberSets = listOf(setOf(1, 2, 3), setOf(4, 5, 6), setOf(1, 2))
    println(numberSets.flatten())
}
```

Another function – flatMap() provides a flexible way to process nested collections. It takes a function that maps a collection element to another collection. As a result, flatMap() returns a single list of its return values on all the elements. So, flatMap() behaves as a subsequent call of map() (with a collection as a mapping result) and flatten().

```
data class StringContainer(val values: List<String>)

fun main() {
    val containers = listOf(
        StringContainer(listOf("one", "two", "three")),
        StringContainer(listOf("four", "five", "six")),
        StringContainer(listOf("seven", "eight"))
    )
    println(containers.flatMap { it.values })
}
```

String representation

If you need to retrieve the collection content in a readable format, use functions that transform the collections to strings: joinToString() and joinTo().

joinToString() builds a single String from the collection elements based on the provided arguments. joinTo() does the same but appends the result to the given Appendable object.

When called with the default arguments, the functions return the result similar to calling toString() on the collection: a String of elements' string representations separated by commas with spaces.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")

    println(numbers)
    println(numbers.joinToString())

    val listString = StringBuffer("The list of numbers: ")
    numbers.joinTo(listString)
    println(listString)
}
```

To build a custom string representation, you can specify its parameters in function arguments separator, prefix, and postfix. The resulting string will start with the prefix and end with the postfix. The separator will come after each element except the last.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    println(numbers.joinToString(separator = " | ", prefix = "start: ", postfix = ": end"))
}
```

For bigger collections, you may want to specify the limit – a number of elements that will be included into result. If the collection size exceeds the limit, all the other elements will be replaced with a single value of the truncated argument.

```
fun main() {
    val numbers = (1..100).toList()
    println(numbers.joinToString(limit = 10, truncated = "<...>"))
}
```

Finally, to customize the representation of elements themselves, provide the transform function.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    println(numbers.joinToString { "Element: ${it.uppercase()}"})
}
```

Filtering collections

Filtering is one of the most popular tasks in collection processing. In Kotlin, filtering conditions are defined by predicates – lambda functions that take a collection element and return a boolean value: true means that the given element matches the predicate, false means the opposite.

The standard library contains a group of extension functions that let you filter collections in a single call. These functions leave the original collection unchanged, so they are available for both mutable and read-only collections. To operate the filtering result, you should assign it to a variable or chain the functions after filtering.

Filter by predicate

The basic filtering function is filter(). When called with a predicate, filter() returns the collection elements that match it. For both List and Set, the resulting collection is a List, for Map it's a Map as well.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    val longerThan3 = numbers.filter { it.length > 3 }
    println(longerThan3)

    val numbersMap = mapOf("key1" to 1, "key2" to 2, "key3" to 3, "key11" to 11)
    val filteredMap = numbersMap.filter { (key, value) -> key.endsWith("1") && value > 10}
    println(filteredMap)
}
```

The predicates in filter() can only check the values of the elements. If you want to use element positions in the filter, use filterIndexed(). It takes a predicate with two arguments: the index and the value of an element.

To filter collections by negative conditions, use filterNot(). It returns a list of elements for which the predicate yields false.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")

    val filteredIdx = numbers.filterIndexed { index, s -> (index != 0) && (s.length < 5)  }
    val filteredNot = numbers.filterNot { it.length <= 3 }

    println(filteredIdx)
    println(filteredNot)
}
```

There are also functions that narrow the element type by filtering elements of a given type:

- filterIsInstance() returns collection elements of a given type. Being called on a List<Any>, filterIsInstance<T>() returns a List<T>, thus allowing you to call functions of the T type on its items.

  ```
  fun main() {
      val numbers = listOf(null, 1, "two", 3.0, "four")
      println("All String elements in upper case:")
      numbers.filterIsInstance<String>().forEach {
          println(it.uppercase())
      }
  }
  ```

- filterNotNull() returns all non-nullable elements. Being called on a List<T?>, filterNotNull() returns a List<T: Any>, thus allowing you to treat the elements as non-nullable objects.

  ```
  fun main() {
      val numbers = listOf(null, "one", "two", null)
      numbers.filterNotNull().forEach {
          println(it.length)   // length is unavailable for nullable Strings
      }
  }
  ```

Partition

Another filtering function – partition() – filters a collection by a predicate and keeps the elements that don't match it in a separate list. So, you have a Pair of Lists as a return value: the first list containing elements that match the predicate and the second one containing everything else from the original collection.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    val (match, rest) = numbers.partition { it.length > 3 }

    println(match)
```

```
    println(rest)
}
```

Test predicates

Finally, there are functions that simply test a predicate against collection elements:

- any() returns true if at least one element matches the given predicate.
- none() returns true if none of the elements match the given predicate.
- all() returns true if all elements match the given predicate. Note that all() returns true when called with any valid predicate on an empty collection. Such behavior is known in logic as vacuous truth.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")

    println(numbers.any { it.endsWith("e") })
    println(numbers.none { it.endsWith("a") })
    println(numbers.all { it.endsWith("e") })

    println(emptyList<Int>().all { it > 5 })   // vacuous truth
}
```

any() and none() can also be used without a predicate: in this case they just check the collection emptiness. any() returns true if there are elements and false if there aren't; none() does the opposite.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    val empty = emptyList<String>()

    println(numbers.any())
    println(empty.any())

    println(numbers.none())
    println(empty.none())
}
```

Plus and minus operators

In Kotlin, plus (+) and minus (-) operators are defined for collections. They take a collection as the first operand; the second operand can be either an element or another collection. The return value is a new read-only collection:

- The result of plus contains the elements from the original collection and from the second operand.
- The result of minus contains the elements of the original collection except the elements from the second operand. If it's an element, minus removes its first occurrence; if it's a collection, all occurrences of its elements are removed.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")

    val plusList = numbers + "five"
    val minusList = numbers - listOf("three", "four")
    println(plusList)
    println(minusList)
}
```

For the details on plus and minus operators for maps, see Map specific operations. The augmented assignment operators plusAssign (+=) and minusAssign (-=) are also defined for collections. However, for read-only collections, they actually use the plus or minus operators and try to assign the result to the same variable. Thus, they are available only on var read-only collections. For mutable collections, they modify the collection if it's a val. For more details see Collection write operations.

Grouping

The Kotlin standard library provides extension functions for grouping collection elements. The basic function groupBy() takes a lambda function and returns a Map. In this map, each key is the lambda result, and the corresponding value is the List of elements on which this result is returned. This function can be used, for example, to group a list of Strings by their first letter.

You can also call groupBy() with a second lambda argument – a value transformation function. In the result map of groupBy() with two lambdas, the keys produced by keySelector function are mapped to the results of the value transformation function instead of the original elements.

This example illustrates using the groupBy() function to group the strings by their first letter, iterating through the groups on the resulting Map with the for operator, and then transforming the values to uppercase using the valueTransform function:

```kotlin
fun main() {
    val numbers = listOf("one", "two", "three", "four", "five")

    // Groups the strings by their first letter using groupBy()
    val groupedByFirstLetter = numbers.groupBy { it.first().uppercase() }
    println(groupedByFirstLetter)
    // {O=[one], T=[two, three], F=[four, five]}

    // Iterates through each group and prints the key and its associated values
    for ((key, value) in groupedByFirstLetter) {
        println("Key: $key, Values: $value")
    }
    // Key: O, Values: [one]
    // Key: T, Values: [two, three]
    // Key: F, Values: [four, five]

    // Groups the strings by their first letter and transforms the values to uppercase
    val groupedAndTransformed = numbers.groupBy(keySelector = { it.first() }, valueTransform = { it.uppercase() })
    println(groupedAndTransformed)
    // {o=[ONE], t=[TWO, THREE], f=[FOUR, FIVE]}
}
```

If you want to group elements and then apply an operation to all groups at one time, use the function groupingBy(). It returns an instance of the Grouping type. The Grouping instance lets you apply operations to all groups in a lazy manner: the groups are actually built right before the operation execution.

Namely, Grouping supports the following operations:

- eachCount() counts the elements in each group.
- fold() and reduce() perform fold and reduce operations on each group as a separate collection and return the results.
- aggregate() applies a given operation subsequently to all the elements in each group and returns the result. This is the generic way to perform any operations on a Grouping. Use it to implement custom operations when fold or reduce are not enough.

You can use the for operator on the resulting Map to iterate through the groups created by the groupingBy() function. This allows you to access each key and the count of elements associated with that key.

The following example demonstrates how to group strings by their first letter using the groupingBy() function, count the elements in each group, and then iterate through each group to print the key and count of elements:

```kotlin
fun main() {
    val numbers = listOf("one", "two", "three", "four", "five")

    // Groups the strings by their first letter using groupingBy() and counts the elements in each group
    val grouped = numbers.groupingBy { it.first() }.eachCount()

    // Iterates through each group and prints the key and its associated values
    for ((key, count) in grouped) {
        println("Key: $key, Count: $count")
        // Key: o, Count: 1
        // Key: t, Count: 2
        // Key: f, Count: 2
    }
}
```

Retrieve collection parts

The Kotlin standard library contains extension functions for retrieving parts of a collection. These functions provide a variety of ways to select elements for the result collection: listing their positions explicitly, specifying the result size, and others.

Slice

slice() returns a list of the collection elements with given indices. The indices may be passed either as a range or as a collection of integer values.

```
fun main() {
//sampleStart
    val numbers = listOf("one", "two", "three", "four", "five", "six")
    println(numbers.slice(1..3))
    println(numbers.slice(0..4 step 2))
    println(numbers.slice(setOf(3, 5, 0)))
}
```

Take and drop

To get the specified number of elements starting from the first, use the take() function. For getting the last elements, use takeLast(). When called with a number larger than the collection size, both functions return the whole collection.

To take all the elements except a given number of first or last elements, call the drop() and dropLast() functions respectively.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four", "five", "six")
    println(numbers.take(3))
    println(numbers.takeLast(3))
    println(numbers.drop(1))
    println(numbers.dropLast(5))
}
```

You can also use predicates to define the number of elements for taking or dropping. There are four functions similar to the ones described above:

- takeWhile() is take() with a predicate: it takes the elements up to but excluding the first one not matching the predicate. If the first collection element doesn't match the predicate, the result is empty.
- takeLastWhile() is similar to takeLast(): it takes the range of elements matching the predicate from the end of the collection. The first element of the range is the element next to the last element not matching the predicate. If the last collection element doesn't match the predicate, the result is empty;
- dropWhile() is the opposite to takeWhile() with the same predicate: it returns the elements from the first one not matching the predicate to the end.
- dropLastWhile() is the opposite to takeLastWhile() with the same predicate: it returns the elements from the beginning to the last one not matching the predicate.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four", "five", "six")
    println(numbers.takeWhile { !it.startsWith('f') })
    println(numbers.takeLastWhile { it != "three" })
    println(numbers.dropWhile { it.length == 3 })
    println(numbers.dropLastWhile { it.contains('i') })
}
```

Chunked

To break a collection into parts of a given size, use the chunked() function. chunked() takes a single argument – the size of the chunk – and returns a List of Lists of the given size. The first chunk starts from the first element and contains the size elements, the second chunk holds the next size elements, and so on. The last chunk may have a smaller size.

```
fun main() {
    val numbers = (0..13).toList()
    println(numbers.chunked(3))
}
```

You can also apply a transformation for the returned chunks right away. To do this, provide the transformation as a lambda function when calling chunked(). The lambda argument is a chunk of the collection. When chunked() is called with a transformation, the chunks are short-living Lists that should be consumed right in that lambda.

```
fun main() {
    val numbers = (0..13).toList()
    println(numbers.chunked(3) { it.sum() })  // `it` is a chunk of the original collection
}
```

Windowed

You can retrieve all possible ranges of the collection elements of a given size. The function for getting them is called windowed(): it returns a list of element ranges that you would see if you were looking at the collection through a sliding window of the given size. Unlike chunked(), windowed() returns element ranges (windows) starting from each collection element. All the windows are returned as elements of a single List.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four", "five")
    println(numbers.windowed(3))
}
```

windowed() provides more flexibility with optional parameters:

- step defines a distance between first elements of two adjacent windows. By default the value is 1, so the result contains windows starting from all elements. If you increase the step to 2, you will receive only windows starting from odd elements: first, third, and so on.
- partialWindows includes windows of smaller sizes that start from the elements at the end of the collection. For example, if you request windows of three elements, you can't build them for the last two elements. Enabling partialWindows in this case includes two more lists of sizes 2 and 1.

Finally, you can apply a transformation to the returned ranges right away. To do this, provide the transformation as a lambda function when calling windowed().

```
fun main() {
    val numbers = (1..10).toList()
    println(numbers.windowed(3, step = 2, partialWindows = true))
    println(numbers.windowed(3) { it.sum() })
}
```

To build two-element windows, there is a separate function - zipWithNext(). It creates pairs of adjacent elements of the receiver collection. Note that zipWithNext() doesn't break the collection into pairs; it creates a Pair for each element except the last one, so its result on [1, 2, 3, 4] is [[1, 2], [2, 3], [3, 4]], not [[1, 2], [3, 4]]. zipWithNext() can be called with a transformation function as well; it should take two elements of the receiver collection as arguments.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four", "five")
    println(numbers.zipWithNext())
    println(numbers.zipWithNext() { s1, s2 -> s1.length > s2.length})
}
```

Retrieve single elements

Kotlin collections provide a set of functions for retrieving single elements from collections. Functions described on this page apply to both lists and sets.

As the definition of list says, a list is an ordered collection. Hence, every element of a list has its position that you can use for referring. In addition to functions described on this page, lists offer a wider set of ways to retrieve and search for elements by indices. For more details, see List-specific operations.

In turn, set is not an ordered collection by definition. However, the Kotlin Set stores elements in certain orders. These can be the order of insertion (in LinkedHashSet), natural sorting order (in SortedSet), or another order. The order of a set of elements can also be unknown. In such cases, the elements are still ordered somehow, so the functions that rely on the element positions still return their results. However, such results are unpredictable to the caller unless they know the specific implementation of Set used.

Retrieve by position

For retrieving an element at a specific position, there is the function elementAt(). Call it with the integer number as an argument, and you'll receive the collection element at the given position. The first element has the position 0, and the last one is (size - 1).

elementAt() is useful for collections that do not provide indexed access, or are not statically known to provide one. In case of List, it's more idiomatic to use indexed access operator (get() or []).

```
fun main() {
    val numbers = linkedSetOf("one", "two", "three", "four", "five")
    println(numbers.elementAt(3))

    val numbersSortedSet = sortedSetOf("one", "two", "three", "four")
    println(numbersSortedSet.elementAt(0)) // elements are stored in the ascending order
}
```

There are also useful aliases for retrieving the first and the last element of the collection: first() and last().

```
fun main() {
    val numbers = listOf("one", "two", "three", "four", "five")
    println(numbers.first())
    println(numbers.last())
}
```

To avoid exceptions when retrieving element with non-existing positions, use safe variations of elementAt():

- elementAtOrNull() returns null when the specified position is out of the collection bounds.
- elementAtOrElse() additionally takes a lambda function that maps an Int argument to an instance of the collection element type. When called with an out-of-bounds position, the elementAtOrElse() returns the result of the lambda on the given value.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four", "five")
    println(numbers.elementAtOrNull(5))
    println(numbers.elementAtOrElse(5) { index -> "The value for index $index is undefined"})
}
```

Retrieve by condition

Functions first() and last() also let you search a collection for elements matching a given predicate. When you call first() with a predicate that tests a collection element, you'll receive the first element on which the predicate yields true. In turn, last() with a predicate returns the last element matching it.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four", "five", "six")
    println(numbers.first { it.length > 3 })
    println(numbers.last { it.startsWith("f") })
}
```

If no elements match the predicate, both functions throw exceptions. To avoid them, use firstOrNull() and lastOrNull() instead: they return null if no matching elements are found.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four", "five", "six")
    println(numbers.firstOrNull { it.length > 6 })
}
```

Use the aliases if their names suit your situation better:

- find() instead of firstOrNull()
- findLast() instead of lastOrNull()

```
fun main() {
    val numbers = listOf(1, 2, 3, 4)
    println(numbers.find { it % 2 == 0 })
    println(numbers.findLast { it % 2 == 0 })
}
```

Retrieve with selector

If you need to map the collection before retrieving the element, there is a function firstNotNullOf(). It combines 2 actions:

- Maps the collection with the selector function
- Returns the first non-null value in the result

firstNotNullOf() throws the NoSuchElementException if the resulting collection doesn't have a non-nullable element. Use the counterpart firstNotNullOfOrNull() to return null in this case.

```kotlin
fun main() {
    val list = listOf<Any>(0, "true", false)
    // Converts each element to string and returns the first one that has required length
    val longEnough = list.firstNotNullOf { item -> item.toString().takeIf { it.length >= 4 } }
    println(longEnough)
}
```

Random element

If you need to retrieve an arbitrary element of a collection, call the random() function. You can call it without arguments or with a Random object as a source of the randomness.

```kotlin
fun main() {
    val numbers = listOf(1, 2, 3, 4)
    println(numbers.random())
}
```

On empty collections, random() throws an exception. To receive null instead, use randomOrNull()

Check element existence

To check the presence of an element in a collection, use the contains() function. It returns true if there is a collection element that equals() the function argument. You can call contains() in the operator form with the in keyword.

To check the presence of multiple instances together at once, call containsAll() with a collection of these instances as an argument.

```kotlin
fun main() {
    val numbers = listOf("one", "two", "three", "four", "five", "six")
    println(numbers.contains("four"))
    println("zero" in numbers)

    println(numbers.containsAll(listOf("four", "two")))
    println(numbers.containsAll(listOf("one", "zero")))
}
```

Additionally, you can check if the collection contains any elements by calling isEmpty() or isNotEmpty().

```kotlin
fun main() {
    val numbers = listOf("one", "two", "three", "four", "five", "six")
    println(numbers.isEmpty())
    println(numbers.isNotEmpty())

    val empty = emptyList<String>()
    println(empty.isEmpty())
    println(empty.isNotEmpty())
}
```

Ordering

The order of elements is an important aspect of certain collection types. For example, two lists of the same elements are not equal if their elements are ordered differently.

In Kotlin, the orders of objects can be defined in several ways.

First, there is natural order. It is defined for implementations of the Comparable interface. Natural order is used for sorting them when no other order is specified.

Most built-in types are comparable:

- Numeric types use the traditional numerical order: 1 is greater than 0; -3.4f is greater than -5f, and so on.
- Char and String use the lexicographical order: b is greater than a; world is greater than hello.

To define a natural order for a user-defined type, make the type an implementer of Comparable. This requires implementing the compareTo() function. compareTo()

must take another object of the same type as an argument and return an integer value showing which object is greater:

- Positive values show that the receiver object is greater.
- Negative values show that it's less than the argument.
- Zero shows that the objects are equal.

Below is a class for ordering versions that consist of the major and the minor part.

```kotlin
class Version(val major: Int, val minor: Int): Comparable<Version> {
    override fun compareTo(other: Version): Int = when {
        this.major != other.major -> this.major compareTo other.major // compareTo() in the infix form
        this.minor != other.minor -> this.minor compareTo other.minor
        else -> 0
    }
}

fun main() {
    println(Version(1, 2) > Version(1, 3))
    println(Version(2, 0) > Version(1, 5))
}
```

Custom orders let you sort instances of any type in a way you like. Particularly, you can define an order for non-comparable objects or define an order other than natural for a comparable type. To define a custom order for a type, create a Comparator for it. Comparator contains the compare() function: it takes two instances of a class and returns the integer result of the comparison between them. The result is interpreted in the same way as the result of a compareTo() as is described above.

```kotlin
fun main() {
    val lengthComparator = Comparator { str1: String, str2: String -> str1.length - str2.length }
    println(listOf("aaa", "bb", "c").sortedWith(lengthComparator))
}
```

Having the lengthComparator, you are able to arrange strings by their length instead of the default lexicographical order.

A shorter way to define a Comparator is the compareBy() function from the standard library. compareBy() takes a lambda function that produces a Comparable value from an instance and defines the custom order as the natural order of the produced values.

With compareBy(), the length comparator from the example above looks like this:

```kotlin
fun main() {
//sampleStart
    println(listOf("aaa", "bb", "c").sortedWith(compareBy { it.length }))
}
```

You can also define an order based on multiple criteria. For example, to sort strings by their length and alphabetically when the lengths are equal, you can write:

```kotlin
fun main() {
    val sortedStrings = listOf("aaa", "bb", "c", "b", "a", "aa", "ccc")
        .sortedWith { a, b ->
           when (val compareLengths = a.length.compareTo(b.length)) {
             0 -> a.compareTo(b)
             else -> compareLengths
           }
         }

    println(sortedStrings)
    // [a, b, c, aa, bb, aaa, ccc]
}
```

Since sorting by multiple criteria is a common scenario, the Kotlin standard library provides the thenBy() function that you can use to add a secondary sorting rule.

For example, you can combine compareBy() with thenBy() to sort strings by their length first and alphabetically second, just like in the previous example:

```kotlin
fun main() {
    val sortedStrings = listOf("aaa", "bb", "c", "b", "a", "aa", "ccc")
        .sortedWith(compareBy<String> { it.length }.thenBy { it })

    println(sortedStrings)
    // [a, b, c, aa, bb, aaa, ccc]
}
```

The Kotlin collections package provides functions for sorting collections in natural, custom, and even random orders. On this page, we'll describe sorting functions that apply to read-only collections. These functions return their result as a new collection containing the elements of the original collection in the requested order. To learn about functions for sorting mutable collections in place, see the List-specific operations.

Natural order

The basic functions sorted() and sortedDescending() return elements of a collection sorted into ascending and descending sequence according to their natural order. These functions apply to collections of Comparable elements.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")

    println("Sorted ascending: ${numbers.sorted()}")
    println("Sorted descending: ${numbers.sortedDescending()}")
}
```

Custom orders

For sorting in custom orders or sorting non-comparable objects, there are the functions sortedBy() and sortedByDescending(). They take a selector function that maps collection elements to Comparable values and sort the collection in natural order of that values.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")

    val sortedNumbers = numbers.sortedBy { it.length }
    println("Sorted by length ascending: $sortedNumbers")
    val sortedByLast = numbers.sortedByDescending { it.last() }
    println("Sorted by the last letter descending: $sortedByLast")
}
```

To define a custom order for the collection sorting, you can provide your own Comparator. To do this, call the sortedWith() function passing in your Comparator. With this function, sorting strings by their length looks like this:

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    println("Sorted by length ascending: ${numbers.sortedWith(compareBy { it.length })}")
}
```

Reverse order

You can retrieve the collection in the reversed order using the reversed() function.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    println(numbers.reversed())
}
```

reversed() returns a new collection with the copies of the elements. So, if you change the original collection later, this won't affect the previously obtained results of reversed().

Another reversing function - asReversed()

- returns a reversed view of the same collection instance, so it may be more lightweight and preferable than reversed() if the original list is not going to change.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    val reversedNumbers = numbers.asReversed()
    println(reversedNumbers)
}
```

If the original list is mutable, all its changes reflect in its reversed views and vice versa.

```kotlin
fun main() {
    val numbers = mutableListOf("one", "two", "three", "four")
    val reversedNumbers = numbers.asReversed()
    println(reversedNumbers)
    numbers.add("five")
    println(reversedNumbers)
}
```

However, if the mutability of the list is unknown or the source is not a list at all, reversed() is more preferable since its result is a copy that won't change in the future.

Random order

Finally, there is a function that returns a new List containing the collection elements in a random order - shuffled(). You can call it without arguments or with a Random object.

```kotlin
fun main() {
     val numbers = listOf("one", "two", "three", "four")
     println(numbers.shuffled())
}
```

Aggregate operations

Kotlin collections contain functions for commonly used aggregate operations – operations that return a single value based on the collection content. Most of them are well known and work the same way as they do in other languages:

- minOrNull() and maxOrNull() return the smallest and the largest element respectively. On empty collections, they return null.
- average() returns the average value of elements in the collection of numbers.
- sum() returns the sum of elements in the collection of numbers.
- count() returns the number of elements in a collection.

```kotlin
fun main() {
    val numbers = listOf(6, 42, 10, 4)

    println("Count: ${numbers.count()}")
    println("Max: ${numbers.maxOrNull()}")
    println("Min: ${numbers.minOrNull()}")
    println("Average: ${numbers.average()}")
    println("Sum: ${numbers.sum()}")
}
```

There are also functions for retrieving the smallest and the largest elements by certain selector function or custom Comparator:

- maxByOrNull() and minByOrNull() take a selector function and return the element for which it returns the largest or the smallest value.
- maxWithOrNull() and minWithOrNull() take a Comparator object and return the largest or smallest element according to that Comparator.
- maxOfOrNull() and minOfOrNull() take a selector function and return the largest or the smallest return value of the selector itself.
- maxOfWithOrNull() and minOfWithOrNull() take a Comparator object and return the largest or smallest selector return value according to that Comparator.

These functions return null on empty collections. There are also alternatives – maxOf, minOf, maxOfWith, and minOfWith – which do the same as their counterparts but throw a NoSuchElementException on empty collections.

```kotlin
fun main() {
    val numbers = listOf(5, 42, 10, 4)
    val min3Remainder = numbers.minByOrNull { it % 3 }
    println(min3Remainder)

    val strings = listOf("one", "two", "three", "four")
    val longestString = strings.maxWithOrNull(compareBy { it.length })
    println(longestString)
}
```

Besides regular sum(), there is an advanced summation function sumOf() that takes a selector function and returns the sum of its application to all collection elements. Selector can return different numeric types: Int, Long, Double, UInt, and ULong (also BigInteger and BigDecimal on the JVM).

```
fun main() {
    val numbers = listOf(5, 42, 10, 4)
    println(numbers.sumOf { it * 2 })
    println(numbers.sumOf { it.toDouble() / 2 })
}
```

Fold and reduce

For more specific cases, there are the functions reduce() and fold() that apply the provided operation to the collection elements sequentially and return the accumulated result. The operation takes two arguments: the previously accumulated value and the collection element.

The difference between the two functions is that fold() takes an initial value and uses it as the accumulated value on the first step, whereas the first step of reduce() uses the first and the second elements as operation arguments on the first step.

```
fun main() {
    val numbers = listOf(5, 2, 10, 4)

    val simpleSum = numbers.reduce { sum, element -> sum + element }
    println(simpleSum)
    val sumDoubled = numbers.fold(0) { sum, element -> sum + element * 2 }
    println(sumDoubled)

    //incorrect: the first element isn't doubled in the result
    //val sumDoubledReduce = numbers.reduce { sum, element -> sum + element * 2 }
    //println(sumDoubledReduce)
}
```

The example above shows the difference: fold() is used for calculating the sum of doubled elements. If you pass the same function to reduce(), it will return another result because it uses the list's first and second elements as arguments on the first step, so the first element won't be doubled.

To apply a function to elements in the reverse order, use functions reduceRight() and foldRight(). They work in a way similar to fold() and reduce() but start from the last element and then continue to previous. Note that when folding or reducing right, the operation arguments change their order: first goes the element, and then the accumulated value.

```
fun main() {
    val numbers = listOf(5, 2, 10, 4)
    val sumDoubledRight = numbers.foldRight(0) { element, sum -> sum + element * 2 }
    println(sumDoubledRight)
}
```

You can also apply operations that take element indices as parameters. For this purpose, use functions reduceIndexed() and foldIndexed() passing element index as the first argument of the operation.

Finally, there are functions that apply such operations to collection elements from right to left - reduceRightIndexed() and foldRightIndexed().

```
fun main() {
    val numbers = listOf(5, 2, 10, 4)
    val sumEven = numbers.foldIndexed(0) { idx, sum, element -> if (idx % 2 == 0) sum + element else sum }
    println(sumEven)

    val sumEvenRight = numbers.foldRightIndexed(0) { idx, element, sum -> if (idx % 2 == 0) sum + element else sum }
    println(sumEvenRight)
}
```

All reduce operations throw an exception on empty collections. To receive null instead, use their *OrNull() counterparts:

- reduceOrNull()
- reduceRightOrNull()
- reduceIndexedOrNull()
- reduceRightIndexedOrNull()

For cases where you want to save intermediate accumulator values, there are functions runningFold() (or its synonym scan()) and runningReduce().

```
fun main() {
    val numbers = listOf(0, 1, 2, 3, 4, 5)
    val runningReduceSum = numbers.runningReduce { sum, item -> sum + item }
    val runningFoldSum = numbers.runningFold(10) { sum, item -> sum + item }
    val transform = { index: Int, element: Int -> "N = ${index + 1}: $element" }
    println(runningReduceSum.mapIndexed(transform).joinToString("\n", "Sum of first N elements with runningReduce:\n"))
    println(runningFoldSum.mapIndexed(transform).joinToString("\n", "Sum of first N elements with runningFold:\n"))
}
```

If you need an index in the operation parameter, use runningFoldIndexed() or runningReduceIndexed().

Collection write operations

Mutable collections support operations for changing the collection contents, for example, adding or removing elements. On this page, we'll describe write operations available for all implementations of MutableCollection. For more specific operations available for List and Map, see List-specific Operations and Map Specific Operations respectively.

Adding elements

To add a single element to a list or a set, use the add() function. The specified object is appended to the end of the collection.

```
fun main() {
    val numbers = mutableListOf(1, 2, 3, 4)
    numbers.add(5)
    println(numbers)
}
```

addAll() adds every element of the argument object to a list or a set. The argument can be an Iterable, a Sequence, or an Array. The types of the receiver and the argument may be different, for example, you can add all items from a Set to a List.

When called on lists, addAll() adds new elements in the same order as they go in the argument. You can also call addAll() specifying an element position as the first argument. The first element of the argument collection will be inserted at this position. Other elements of the argument collection will follow it, shifting the receiver elements to the end.

```
fun main() {
    val numbers = mutableListOf(1, 2, 5, 6)
    numbers.addAll(arrayOf(7, 8))
    println(numbers)
    numbers.addAll(2, setOf(3, 4))
    println(numbers)
}
```

You can also add elements using the in-place version of the plus operator - plusAssign (+=) When applied to a mutable collection, += appends the second operand (an element or another collection) to the end of the collection.

```
fun main() {
    val numbers = mutableListOf("one", "two")
    numbers += "three"
    println(numbers)
    numbers += listOf("four", "five")
    println(numbers)
}
```

Removing elements

To remove an element from a mutable collection, use the remove() function. remove() accepts the element value and removes one occurrence of this value.

```
fun main() {
    val numbers = mutableListOf(1, 2, 3, 4, 3)
    numbers.remove(3)                    // removes the first `3`
    println(numbers)
    numbers.remove(5)                    // removes nothing
    println(numbers)
}
```

For removing multiple elements at once, there are the following functions :

- removeAll() removes all elements that are present in the argument collection. Alternatively, you can call it with a predicate as an argument; in this case the function removes all elements for which the predicate yields true.
- retainAll() is the opposite of removeAll(): it removes all elements except the ones from the argument collection. When used with a predicate, it leaves only elements that match it.
- clear() removes all elements from a list and leaves it empty.

```
fun main() {
    val numbers = mutableListOf(1, 2, 3, 4)
    println(numbers)
    numbers.retainAll { it >= 3 }
    println(numbers)
    numbers.clear()
    println(numbers)

    val numbersSet = mutableSetOf("one", "two", "three", "four")
    numbersSet.removeAll(setOf("one", "two"))
    println(numbersSet)
}
```

Another way to remove elements from a collection is with the minusAssign (-=) operator – the in-place version of minus. The second argument can be a single instance of the element type or another collection. With a single element on the right-hand side, -= removes the first occurrence of it. In turn, if it's a collection, all occurrences of its elements are removed. For example, if a list contains duplicate elements, they are removed at once. The second operand can contain elements that are not present in the collection. Such elements don't affect the operation execution.

```
fun main() {
    val numbers = mutableListOf("one", "two", "three", "three", "four")
    numbers -= "three"
    println(numbers)
    numbers -= listOf("four", "five")
    //numbers -= listOf("four")    // does the same as above
    println(numbers)
}
```

Updating elements

Lists and maps also provide operations for updating elements. They are described in List-specific Operations and Map Specific Operations. For sets, updating doesn't make sense since it's actually removing an element and adding another one.

List-specific operations

List is the most popular type of built-in collection in Kotlin. Index access to the elements of lists provides a powerful set of operations for lists.

Retrieve elements by index

Lists support all common operations for element retrieval: elementAt(), first(), last(), and others listed in Retrieve single elements. What is specific for lists is index access to the elements, so the simplest way to read an element is retrieving it by index. That is done with the get() function with the index passed in the argument or the shorthand [index] syntax.

If the list size is less than the specified index, an exception is thrown. There are two other functions that help you avoid such exceptions:

- getOrElse() lets you provide the function for calculating the default value to return if the index isn't present in the collection.
- getOrNull() returns null as the default value.

```
fun main() {
    val numbers = listOf(1, 2, 3, 4)
    println(numbers.get(0))
    println(numbers[0])
    //numbers.get(5)                         // exception!
    println(numbers.getOrNull(5))             // null
    println(numbers.getOrElse(5, {it}))        // 5
}
```

Retrieve list parts

In addition to common operations for Retrieving Collection Parts, lists provide the subList() function that returns a view of the specified elements range as a list. Thus, if an element of the original collection changes, it also changes in the previously created sublists and vice versa.

```
fun main() {
    val numbers = (0..13).toList()
    println(numbers.subList(3, 6))
}
```

Find element positions

Linear search

In any lists, you can find the position of an element using the functions indexOf() and lastIndexOf(). They return the first and the last position of an element equal to the given argument in the list. If there are no such elements, both functions return -1.

```
fun main() {
    val numbers = listOf(1, 2, 3, 4, 2, 5)
    println(numbers.indexOf(2))
    println(numbers.lastIndexOf(2))
}
```

There is also a pair of functions that take a predicate and search for elements matching it:

- indexOfFirst() returns the index of the first element matching the predicate or -1 if there are no such elements.
- indexOfLast() returns the index of the last element matching the predicate or -1 if there are no such elements.

```
fun main() {
    val numbers = mutableListOf(1, 2, 3, 4)
    println(numbers.indexOfFirst { it > 2})
    println(numbers.indexOfLast { it % 2 == 1})
}
```

Binary search in sorted lists

There is one more way to search elements in lists – binary search. It works significantly faster than other built-in search functions but requires the list to be sorted in ascending order according to a certain ordering: natural or another one provided in the function parameter. Otherwise, the result is undefined.

To search an element in a sorted list, call the binarySearch() function passing the value as an argument. If such an element exists, the function returns its index; otherwise, it returns (-insertionPoint - 1) where insertionPoint is the index where this element should be inserted so that the list remains sorted. If there is more than one element with the given value, the search can return any of their indices.

You can also specify an index range to search in: in this case, the function searches only between two provided indices.

```
fun main() {
    val numbers = mutableListOf("one", "two", "three", "four")
    numbers.sort()
    println(numbers)
    println(numbers.binarySearch("two"))  // 3
    println(numbers.binarySearch("z")) // -5
    println(numbers.binarySearch("two", 0, 2))  // -3
}
```

Comparator binary search

When list elements aren't Comparable, you should provide a Comparator to use in the binary search. The list must be sorted in ascending order according to this Comparator. Let's have a look at an example:

```kotlin
data class Product(val name: String, val price: Double)

fun main() {
    val productList = listOf(
        Product("WebStorm", 49.0),
        Product("AppCode", 99.0),
        Product("DotTrace", 129.0),
        Product("ReSharper", 149.0))

    println(productList.binarySearch(Product("AppCode", 99.0), compareBy<Product> { it.price }.thenBy { it.name }))
}
```

Here's a list of Product instances that aren't Comparable and a Comparator that defines the order: product p1 precedes product p2 if p1's price is less than p2's price. So, having a list sorted ascending according to this order, we use binarySearch() to find the index of the specified Product.

Custom comparators are also handy when a list uses an order different from natural one, for example, a case-insensitive order for String elements.

```kotlin
fun main() {
    val colors = listOf("Blue", "green", "ORANGE", "Red", "yellow")
    println(colors.binarySearch("RED", String.CASE_INSENSITIVE_ORDER)) // 3
}
```

Comparison binary search

Binary search with comparison function lets you find elements without providing explicit search values. Instead, it takes a comparison function mapping elements to Int values and searches for the element where the function returns zero. The list must be sorted in the ascending order according to the provided function; in other words, the return values of comparison must grow from one list element to the next one.

```kotlin
import kotlin.math.sign
data class Product(val name: String, val price: Double)

fun priceComparison(product: Product, price: Double) = sign(product.price - price).toInt()

fun main() {
    val productList = listOf(
        Product("WebStorm", 49.0),
        Product("AppCode", 99.0),
        Product("DotTrace", 129.0),
        Product("ReSharper", 149.0))

    println(productList.binarySearch { priceComparison(it, 99.0) })
}
```

Both comparator and comparison binary search can be performed for list ranges as well.

List write operations

In addition to the collection modification operations described in Collection write operations, mutable lists support specific write operations. Such operations use the index to access elements to broaden the list modification capabilities.

Add

To add elements to a specific position in a list, use add() and addAll() providing the position for element insertion as an additional argument. All elements that come after the position shift to the right.

```kotlin
fun main() {
    val numbers = mutableListOf("one", "five", "six")
    numbers.add(1, "two")
    numbers.addAll(2, listOf("three", "four"))
    println(numbers)
}
```

Update

Lists also offer a function to replace an element at a given position - set() and its operator form []. set() doesn't change the indexes of other elements.

```kotlin
fun main() {
    val numbers = mutableListOf("one", "five", "three")
    numbers[1] =  "two"
    println(numbers)
}
```

fill() simply replaces all the collection elements with the specified value.

```kotlin
fun main() {
    val numbers = mutableListOf(1, 2, 3, 4)
    numbers.fill(3)
    println(numbers)
}
```

Remove

To remove an element at a specific position from a list, use the removeAt() function providing the position as an argument. All indices of elements that come after the element being removed will decrease by one.

```kotlin
fun main() {
    val numbers = mutableListOf(1, 2, 3, 4, 3)
    numbers.removeAt(1)
    println(numbers)
}
```

Sort

In Collection Ordering, we describe operations that retrieve collection elements in specific orders. For mutable lists, the standard library offers similar extension functions that perform the same ordering operations in place. When you apply such an operation to a list instance, it changes the order of elements in that exact instance.

The in-place sorting functions have similar names to the functions that apply to read-only lists, but without the ed/d suffix:

- sort* instead of sorted* in the names of all sorting functions: sort(), sortDescending(), sortBy(), and so on.
- shuffle() instead of shuffled().
- reverse() instead of reversed().

asReversed() called on a mutable list returns another mutable list which is a reversed view of the original list. Changes in that view are reflected in the original list. The following example shows sorting functions for mutable lists:

```kotlin
fun main() {
    val numbers = mutableListOf("one", "two", "three", "four")

    numbers.sort()
    println("Sort into ascending: $numbers")
    numbers.sortDescending()
    println("Sort into descending: $numbers")

    numbers.sortBy { it.length }
    println("Sort into ascending by length: $numbers")
    numbers.sortByDescending { it.last() }
    println("Sort into descending by the last letter: $numbers")

    numbers.sortWith(compareBy<String> { it.length }.thenBy { it })
    println("Sort by Comparator: $numbers")

    numbers.shuffle()
    println("Shuffle: $numbers")

    numbers.reverse()
    println("Reverse: $numbers")
}
```

Set-specific operations

The Kotlin collections package contains extension functions for popular operations on sets: finding intersections, merging, or subtracting collections from each other.

To merge two collections into one, use the union() function. It can be used in the infix form a union b. Note that for ordered collections the order of the operands is important. In the resulting collection, the elements of the first operand go before the elements of the second:

```kotlin
fun main() {
    val numbers = setOf("one", "two", "three")

    // output according to the order
    println(numbers union setOf("four", "five"))
    // [one, two, three, four, five]
    println(setOf("four", "five") union numbers)
    // [four, five, one, two, three]
}
```

To find an intersection between two collections (elements present in both of them), use the intersect() function. To find collection elements not present in another collection, use the subtract() function. Both these functions can be called in the infix form as well, for example, a intersect b:

```kotlin
fun main() {
    val numbers = setOf("one", "two", "three")

    // same output
    println(numbers intersect setOf("two", "one"))
    // [one, two]
    println(numbers subtract setOf("three", "four"))
    // [one, two]
    println(numbers subtract setOf("four", "three"))
    // [one, two]
}
```

To find the elements present in either one of the two collections but not in their intersection, you can also use the union() function. For this operation (known as symmetric difference), calculate the differences between the two collections and merge the results:

```kotlin
fun main() {
    val numbers = setOf("one", "two", "three")
    val numbers2 = setOf("three", "four")

    // merge differences
    println((numbers - numbers2) union (numbers2 - numbers))
    // [one, two, four]
}
```

You can also apply union(), intersect(), and subtract() functions to lists. However, their result is always a Set. In this result, all the duplicate elements are merged into one and the index access is not available:

```kotlin
fun main() {
    val list1 = listOf(1, 1, 2, 3, 5, 8, -1)
    val list2 = listOf(1, 1, 2, 2, 3, 5)

    // result of intersecting two lists is a Set
    println(list1 intersect list2)
    // [1, 2, 3, 5]

    // equal elements are merged into one
    println(list1 union list2)
    // [1, 2, 3, 5, 8, -1]
}
```

Map-specific operations

In maps, types of both keys and values are user-defined. Key-based access to map entries enables various map-specific processing capabilities from getting a value by key to separate filtering of keys and values. On this page, we provide descriptions of the map processing functions from the standard library.

Retrieve keys and values

For retrieving a value from a map, you must provide its key as an argument of the get() function. The shorthand [key] syntax is also supported. If the given key is not found, it returns null. There is also the function getValue() which has slightly different behavior: it throws an exception if the key is not found in the map. Additionally, you have two more options to handle the key absence:

- getOrElse() works the same way as for lists: the values for non-existent keys are returned from the given lambda function.
- getOrDefault() returns the specified default value if the key is not found.

```
fun main() {
    val numbersMap = mapOf("one" to 1, "two" to 2, "three" to 3)
    println(numbersMap.get("one"))
    println(numbersMap["one"])
    println(numbersMap.getOrDefault("four", 10))
    println(numbersMap["five"])               // null
    //numbersMap.getValue("six")      // exception!
}
```

To perform operations on all keys or all values of a map, you can retrieve them from the properties keys and values accordingly. keys is a set of all map keys and values is a collection of all map values.

```
fun main() {
    val numbersMap = mapOf("one" to 1, "two" to 2, "three" to 3)
    println(numbersMap.keys)
    println(numbersMap.values)
}
```

Filter

You can filter maps with the filter() function as well as other collections. When calling filter() on a map, pass to it a predicate with a Pair as an argument. This enables you to use both the key and the value in the filtering predicate.

```
fun main() {
    val numbersMap = mapOf("key1" to 1, "key2" to 2, "key3" to 3, "key11" to 11)
    val filteredMap = numbersMap.filter { (key, value) -> key.endsWith("1") && value > 10}
    println(filteredMap)
}
```

There are also two specific ways for filtering maps: by keys and by values. For each way, there is a function: filterKeys() and filterValues(). Both return a new map of entries which match the given predicate. The predicate for filterKeys() checks only the element keys, the one for filterValues() checks only values.

```
fun main() {
    val numbersMap = mapOf("key1" to 1, "key2" to 2, "key3" to 3, "key11" to 11)
    val filteredKeysMap = numbersMap.filterKeys { it.endsWith("1") }
    val filteredValuesMap = numbersMap.filterValues { it < 10 }

    println(filteredKeysMap)
    println(filteredValuesMap)
}
```

Plus and minus operators

Due to the key access to elements, plus (+) and minus (-) operators work for maps differently than for other collections. plus returns a Map that contains elements of its both operands: a Map on the left and a Pair or another Map on the right. When the right-hand side operand contains entries with keys present in the left-hand side Map, the result map contains the entries from the right side.

```
fun main() {
    val numbersMap = mapOf("one" to 1, "two" to 2, "three" to 3)
    println(numbersMap + Pair("four", 4))
    println(numbersMap + Pair("one", 10))
    println(numbersMap + mapOf("five" to 5, "one" to 11))
}
```

minus creates a Map from entries of a Map on the left except those with keys from the right-hand side operand. So, the right-hand side operand can be either a single key or a collection of keys: list, set, and so on.

```
fun main() {
    val numbersMap = mapOf("one" to 1, "two" to 2, "three" to 3)
    println(numbersMap - "one")
    println(numbersMap - listOf("two", "four"))
}
```

For details on using plusAssign (+=) and minusAssign (-=) operators on mutable maps, see Map write operations below.

Map write operations

Mutable maps offer map-specific write operations. These operations let you change the map content using the key-based access to the values.

There are certain rules that define write operations on maps:

- Values can be updated. In turn, keys never change: once you add an entry, its key is constant.
- For each key, there is always a single value associated with it. You can add and remove whole entries.

Below are descriptions of the standard library functions for write operations available on mutable maps.

Add and update entries

To add a new key-value pair to a mutable map, use put(). When a new entry is put into a LinkedHashMap (the default map implementation), it is added so that it comes last when iterating the map. In sorted maps, the positions of new elements are defined by the order of their keys.

```
fun main() {
    val numbersMap = mutableMapOf("one" to 1, "two" to 2)
    numbersMap.put("three", 3)
    println(numbersMap)
}
```

To add multiple entries at a time, use putAll(). Its argument can be a Map or a group of Pairs: Iterable, Sequence, or Array.

```
fun main() {
    val numbersMap = mutableMapOf("one" to 1, "two" to 2, "three" to 3)
    numbersMap.putAll(setOf("four" to 4, "five" to 5))
    println(numbersMap)
}
```

Both put() and putAll() overwrite the values if the given keys already exist in the map. Thus, you can use them to update values of map entries.

```
fun main() {
    val numbersMap = mutableMapOf("one" to 1, "two" to 2)
    val previousValue = numbersMap.put("one", 11)
    println("value associated with 'one', before: $previousValue, after: ${numbersMap["one"]}")
    println(numbersMap)
}
```

You can also add new entries to maps using the shorthand operator form. There are two ways:

- plusAssign (+=) operator.
- the [] operator alias for set().

```
fun main() {
    val numbersMap = mutableMapOf("one" to 1, "two" to 2)
    numbersMap["three"] = 3     // calls numbersMap.put("three", 3)
    numbersMap += mapOf("four" to 4, "five" to 5)
    println(numbersMap)
}
```

When called with the key present in the map, operators overwrite the values of the corresponding entries.

Remove entries

To remove an entry from a mutable map, use the remove() function. When calling remove(), you can pass either a key or a whole key-value-pair. If you specify both the key and value, the element with this key will be removed only if its value matches the second argument.

```
fun main() {
    val numbersMap = mutableMapOf("one" to 1, "two" to 2, "three" to 3)
    numbersMap.remove("one")
    println(numbersMap)
    numbersMap.remove("three", 4)            //doesn't remove anything
    println(numbersMap)
}
```

You can also remove entries from a mutable map by their keys or values. To do this, call remove() on the map's keys or values providing the key or the value of an entry. When called on values, remove() removes only the first entry with the given value.

```
fun main() {
    val numbersMap = mutableMapOf("one" to 1, "two" to 2, "three" to 3, "threeAgain" to 3)
    numbersMap.keys.remove("one")
    println(numbersMap)
    numbersMap.values.remove(3)
    println(numbersMap)
}
```

The minusAssign (-=) operator is also available for mutable maps.

```
fun main() {
    val numbersMap = mutableMapOf("one" to 1, "two" to 2, "three" to 3)
    numbersMap -= "two"
    println(numbersMap)
    numbersMap -= "five"             //doesn't remove anything
    println(numbersMap)
}
```

Read standard input

Use the readln() function to read data from the standard input. It reads the whole line as a string:

```
// Reads and stores the user input in a variable. For example: Hi there!
val myInput = readln()

println(myInput)
// Hi there!

// Reads and prints the user input without storing it in a variable. For example: Hi, Kotlin!
println(readln())
// Hi, Kotlin!
```

To work with data types other than strings, you can convert the input using conversion functions like .toInt(), .toLong(), .toDouble(), .toFloat(), or .toBoolean(). It is possible to read multiple inputs of different data types and store each input in a variable:

```
// Converts the input from a string to an integer value. For example: 12
val myNumber = readln().toInt()
println(myNumber)
// 12

// Converts the input from a string to a double value. For example: 345
val myDouble = readln().toDouble()
println(myDouble)
// 345.0

// Converts the input from a string to a boolean value. For example: true
val myBoolean = readln().toBoolean()
println(myBoolean)
// true
```

These conversion functions assume the user enters a valid representation of the target data type. For example, converting "hello" to an integer using .toInt() would result in an exception as the function expects a number in the string input.

To read several input elements separated by a delimiter, use the .split() function specifying the delimiter. The following code sample reads from the standard input, splits the input into a list of elements based on the delimiter, and converts each element of the list into a specific type:

```kotlin
// Reads the input, assuming the elements are separated by spaces, and converts them into integers. For example: 1 2 3
val numbers = readln().split(' ').map { it.toInt() }
println(numbers)
//[1, 2, 3]

// Reads the input, assuming the elements are separated by commas, and converts them into doubles. For example: 4,5,6
val doubles = readln().split(',').map { it.toDouble() }
println(doubles)
//[4.0, 5.0, 6.0]
```

For an alternative way to read user input in Kotlin/JVM, see Standard input with Java Scanner.

Handle standard input safely

You can use the .toIntOrNull() function to safely convert user input from a string to an integer. This function returns an integer if the conversion is successful. However, if the input is not a valid representation of an integer, it returns null:

```kotlin
// Returns null if the input is invalid. For example: Hello!
val wrongInt = readln().toIntOrNull()
println(wrongInt)
// null

// Converts a valid input from a string to an integer. For example: 13
val correctInt = readln().toIntOrNull()
println(correctInt)
// 13
```

The readlnOrNull() function is also helpful in safely handling the user input. The readlnOrNull() function reads from the standard input and returns null if the end of the input is reached, whereas readln() throws an exception in such a case.

Opt-in requirements

The Kotlin standard library provides a mechanism for requiring and giving explicit consent to use certain API elements. This mechanism allows library authors to inform users about specific conditions that require opt-in, such as when an API is in an experimental state and is likely to change in the future.

To protect users, the compiler warns about these conditions and requires them to opt in before the API can be used.

Opt in to API

If a library author marks a declaration from their library's API as requiring opt-in, you must give explicit consent before you can use it in your code. There are several ways to opt in. We recommend choosing the approach that best suits your situation.

Opt in locally

To opt in to a specific API element when you use it in your code, use the @OptIn annotation with a reference to the experimental API marker. For example, suppose you want to use the DateProvider class, which requires an opt-in:

```kotlin
// Library code
@RequiresOptIn(message = "This API is experimental. It could change in the future without notice.")
@Retention(AnnotationRetention.BINARY)
@Target(AnnotationTarget.CLASS, AnnotationTarget.FUNCTION)
annotation class MyDateTime

@MyDateTime
// A class requiring opt-in
class DateProvider
```

In your code, before declaring a function that uses the DateProvider class, add the @OptIn annotation with a reference to the MyDateTime annotation class:

```
// Client code
@OptIn(MyDateTime::class)

// Uses DateProvider
fun getDate(): Date {
    val dateProvider: DateProvider
    // ...
}
```

It's important to note that with this approach, if the getDate() function is called elsewhere in your code or used by another developer, no opt-in is required:

```
// Client code
@OptIn(MyDateTime::class)

// Uses DateProvider
fun getDate(): Date {
    val dateProvider: DateProvider
    // ...
}

fun displayDate() {
    // OK: No opt-in is required
    println(getDate())
}
```

The opt-in requirement is not propagated, which means others might unknowingly use experimental APIs. To avoid this, it is safer to propagate the opt-in requirements.

Propagate opt-in requirements

When you use API in your code that's intended for third-party use, such as in a library, you can propagate its opt-in requirement to your API as well. To do this, mark your declaration with the same opt-in requirement annotation used by the library.

For example, before declaring a function that uses the DateProvider class, add the @MyDateTime annotation:

```
// Client code
@MyDateTime
fun getDate(): Date {
    // OK: the function requires opt-in as well
    val dateProvider: DateProvider
    // ...
}

fun displayDate() {
    println(getDate())
    // Error: getDate() requires opt-in
}
```

As you can see in this example, the annotated function appears to be a part of the @MyDateTime API. The opt-in propagates the opt-in requirement to users of the getDate() function.

If the signature of an API element includes a type that requires opt-in, the signature itself must also require opt-in. Otherwise, if an API element doesn't require opt-in, but its signature includes a type that does, using it triggers an error.

```
// Client code
@MyDateTime
fun getDate(dateProvider: DateProvider = DateProvider()): Date

@MyDateTime
fun displayDate() {
    // OK: the function requires opt-in as well
    println(getDate())
}
```

Similarly, if you apply @OptIn to a declaration whose signature includes a type that requires opt-in, the opt-in requirement still propagates:

```
// Client code
@OptIn(MyDateTime::class)
// Propagates opt-in due to DateProvider in the signature
fun getDate(dateProvider: DateProvider = DateProvider()): Date
```

```kotlin
fun displayDate() {
    println(getDate())
    // Error: getDate() requires opt-in
}
```

When propagating opt-in requirements, it's important to understand that if an API element becomes stable and no longer has an opt-in requirement, any other API elements that still have the opt-in requirement remain experimental. For example, suppose a library author removes the opt-in requirement for the getDate() function because it's now stable:

```kotlin
// Library code
// No opt-in requirement
fun getDate(): Date {
    val dateProvider: DateProvider
    // ...
}
```

If you use the displayDate() function without removing the opt-in annotation, it remains experimental even though the opt-in is no longer needed:

```kotlin
// Client code

// Still experimental!
@MyDateTime
fun displayDate() {
    // Uses a stable library function
    println(getDate())
}
```

Opt in to multiple APIs

To opt in to multiple APIs, mark the declaration with all their opt-in requirement annotations. For example:

```kotlin
@ExperimentalCoroutinesApi
@FlowPreview
```

Or alternatively with @OptIn:

```kotlin
@OptIn(ExperimentalCoroutinesApi::class, FlowPreview::class)
```

Opt in a file

To use an API that requires opt-in for all functions and classes in a file, add the file-level annotation @file:OptIn to the top of the file before the package specification and imports.

```kotlin
// Client code
@file:OptIn(MyDateTime::class)
```

Opt in a module

The -opt-in compiler option is available since Kotlin 1.6.0. For earlier Kotlin versions, use -Xopt-in.

If you don't want to annotate every usage of APIs that require opt-in, you can opt in to them for your whole module. To opt in to using an API in a module, compile it with the argument -opt-in, specifying the fully qualified name of the opt-in requirement annotation of the API you use: -opt-in=org.mylibrary.OptInAnnotation. Compiling with this argument has the same effect as if every declaration in the module has the annotation@OptIn(OptInAnnotation::class).

If you build your module with Gradle, you can add arguments like this:

Kotlin

```
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask
// ...

tasks.named<KotlinCompilationTask<*>>("compileKotlin").configure {
    compilerOptions.optIn.add("org.mylibrary.OptInAnnotation")
}
```

Groovy

```
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask
// ...

tasks.named('compileKotlin', KotlinCompilationTask) {
    compilerOptions {
        optIn.add('org.mylibrary.OptInAnnotation')
    }
}
```

If your Gradle module is a multiplatform module, use the optIn method:

Kotlin

```
sourceSets {
    all {
        languageSettings.optIn("org.mylibrary.OptInAnnotation")
    }
}
```

Groovy

```
sourceSets {
    all {
        languageSettings {
            optIn('org.mylibrary.OptInAnnotation')
        }
    }
}
```

For Maven, use the following:

```
<build>
    <plugins>
        <plugin>
            <groupId>org.jetbrains.kotlin</groupId>
            <artifactId>kotlin-maven-plugin</artifactId>
            <version>${kotlin.version}</version>
            <executions>...</executions>
            <configuration>
                <args>
                    <arg>-opt-in=org.mylibrary.OptInAnnotation</arg>
                </args>
            </configuration>
        </plugin>
    </plugins>
</build>
```

To opt in to multiple APIs on the module level, add one of the described arguments for each opt-in requirement marker used in your module.

Opt in to inherit from a class or interface

Sometimes, a library author provides an API but wants to require users to explicitly opt in before they can extend it. For example, the library API may be stable for use but not for inheritance, as it might be extended in the future with new abstract functions. Library authors can enforce this by marking open or abstract classes and non-functional interfaces with the @SubclassOptInRequired annotation.

To opt in to use such an API element and extend it in your code, use the @SubclassOptInRequired annotation with a reference to the annotation class. For example, suppose you want to use the CoreLibraryApi interface, which requires an opt-in:

```
// Library code
@RequiresOptIn(
 level = RequiresOptIn.Level.WARNING,
 message = "Interfaces in this library are experimental"
)
annotation class UnstableApi()

@SubclassOptInRequired(UnstableApi::class)
// An interface requiring opt-in to extend
interface CoreLibraryApi
```

In your code, before creating a new interface that inherits from the CoreLibraryApi interface, add the @SubclassOptInRequired annotation with a reference to the UnstableApi annotation class:

```
// Client code
@SubclassOptInRequired(UnstableApi::class)
interface SomeImplementation : CoreLibraryApi
```

Note that when you use the @SubclassOptInRequired annotation on a class, the opt-in requirement is not propagated to any inner or nested classes:

```
// Library code
@RequiresOptIn
annotation class ExperimentalFeature

@SubclassOptInRequired(ExperimentalFeature::class)
open class FileSystem {
    open class File
}

// Client code

// Opt-in is required
class NetworkFileSystem : FileSystem()

// Nested class
// No opt-in required
class TextFile : FileSystem.File()
```

Alternatively, you can opt in by using the @OptIn annotation. You can also use an experimental marker annotation to propagate the requirement further to any uses of the class in your code:

```
// Client code
// With @OptIn annotation
@OptInRequired(UnstableApi::class)
interface SomeImplementation : CoreLibraryApi

// With annotation referencing annotation class
// Propagates the opt-in requirement further
@UnstableApi
interface SomeImplementation : CoreLibraryApi
```

Require opt-in to use API

You can require users of your library to opt in before they are able to use your API. Additionally, you can inform users about any special conditions for using your API until you decide to remove the opt-in requirement.

Create opt-in requirement annotations

To require opt-in to use your module's API, create an annotation class to use as an opt-in requirement annotation. This class must be annotated with @RequiresOptIn:

```
@RequiresOptIn
@Retention(AnnotationRetention.BINARY)
@Target(AnnotationTarget.CLASS, AnnotationTarget.FUNCTION)
annotation class MyDateTime
```

Opt-in requirement annotations must meet several requirements. They must have:

- BINARY or RUNTIME retention.
- EXPRESSION, FILE, TYPE, or TYPE_PARAMETER as a target.
- No parameters.

An opt-in requirement can have one of two severity levels:

- RequiresOptIn.Level.ERROR. Opt-in is mandatory. Otherwise, the code that uses marked API won't compile. This is the default level.
- RequiresOptIn.Level.WARNING. Opt-in is not mandatory, but advisable. Without it, the compiler raises a warning.

To set the desired level, specify the level parameter of the @RequiresOptIn annotation.

Additionally, you can provide a message to API users. The compiler shows this message to users that try to use the API without opt-in:

```
@RequiresOptIn(level = RequiresOptIn.Level.WARNING, message = "This API is experimental. It can be incompatibly changed in the
future.")
@Retention(AnnotationRetention.BINARY)
@Target(AnnotationTarget.CLASS, AnnotationTarget.FUNCTION)
annotation class ExperimentalDateTime
```

If you publish multiple independent features that require opt-in, declare an annotation for each. This makes using your API safer for your clients because they can use only the features that they explicitly accept. This also means that you can remove the opt-in requirements from features independently, which makes your API easier to maintain.

Mark API elements

To require an opt-in to use an API element, annotate its declaration with an opt-in requirement annotation:

```
@MyDateTime
class DateProvider

@MyDateTime
fun getTime(): Time {}
```

Note that for some language elements, an opt-in requirement annotation is not applicable:

- You can't annotate a backing field or a getter of a property, just the property itself.
- You can't annotate a local variable or a value parameter.

Require opt-in to extend API

There may be times when you want more granular control over which specific parts of your API can be used and extended. For example, when you have some API that is stable to use but:

- Unstable to implement due to ongoing evolution, such as when you have a family of interfaces where you expect to add new abstract functions without default implementations.
- Delicate or fragile to implement, such as individual functions that need to behave in a coordinated manner.
- Has a contract that may be weakened in the future in a backward-incompatible way for external implementations, such as changing an input parameter T to a nullable version T? where the code didn't previously consider null values.

In such cases, you can require users to opt in to your API before they can extend it further. Users can extend your API by inheriting from the API or implementing abstract functions. By using the @SubclassOptInRequired annotation, you can enforce this requirement to opt-in for open or abstract classes and non-functional interfaces.

To add the opt-in requirement to an API element, use the @SubclassOptInRequired annotation with a reference to the annotation class:

```
@RequiresOptIn(
 level = RequiresOptIn.Level.WARNING,
 message = "Interfaces in this library are experimental"
)
annotation class UnstableApi()
```

```
@SubclassOptInRequired(UnstableApi::class)
// An interface requiring opt-in to extend
interface CoreLibraryApi
```

Note that when you use the @SubclassOptInRequired annotation to require opt-in, the requirement is not propagated to any inner or nested classes.

For a real-world example of how to use the @SubclassOptInRequired annotation in your API, check out the SharedFlow interface in the kotlinx.coroutines library.

Opt-in requirements for pre-stable APIs

If you use opt-in requirements for features that are not stable yet, carefully handle the API graduation to avoid breaking client code.

Once your pre-stable API graduates and is released in a stable state, remove opt-in requirement annotations from your declarations. The clients can then use them without restriction. However, you should leave the annotation classes in modules so that the existing client code remains compatible.

To encourage API users to update their modules by removing any annotations from their code and recompiling, mark the annotations as @Deprecated and provide an explanation in the deprecation message.

```
@Deprecated("This opt-in requirement is not used anymore. Remove its usages from your code.")
@RequiresOptIn
annotation class ExperimentalDateTime
```

Scope functions

The Kotlin standard library contains several functions whose sole purpose is to execute a block of code within the context of an object. When you call such a function on an object with a lambda expression provided, it forms a temporary scope. In this scope, you can access the object without its name. Such functions are called scope functions. There are five of them: let, run, with, apply, and also.

Basically, these functions all perform the same action: execute a block of code on an object. What's different is how this object becomes available inside the block and what the result of the whole expression is.

Here's a typical example of how to use a scope function:

```
data class Person(var name: String, var age: Int, var city: String) {
    fun moveTo(newCity: String) { city = newCity }
    fun incrementAge() { age++ }
}

fun main() {
    Person("Alice", 20, "Amsterdam").let {
        println(it)
        it.moveTo("London")
        it.incrementAge()
        println(it)
    }
}
```

If you write the same without let, you'll have to introduce a new variable and repeat its name whenever you use it.

```
data class Person(var name: String, var age: Int, var city: String) {
    fun moveTo(newCity: String) { city = newCity }
    fun incrementAge() { age++ }
}

fun main() {
    val alice = Person("Alice", 20, "Amsterdam")
    println(alice)
    alice.moveTo("London")
    alice.incrementAge()
    println(alice)
}
```

Scope functions don't introduce any new technical capabilities, but they can make your code more concise and readable.

Due to the many similarities between scope functions, choosing the right one for your use case can be tricky. The choice mainly depends on your intent and the consistency of use in your project. Below, we provide detailed descriptions of the differences between scope functions and their conventions.

Function selection

To help you choose the right scope function for your purpose, we provide this table that summarizes the key differences between them.

Function	Object reference	Return value	Is extension function
let	it	Lambda result	Yes
run	this	Lambda result	Yes
run	-	Lambda result	No: called without the context object
with	this	Lambda result	No: takes the context object as an argument.
apply	this	Context object	Yes
also	it	Context object	Yes

Detailed information about these functions is provided in the dedicated sections below.

Here is a short guide for choosing scope functions depending on the intended purpose:

- Executing a lambda on non-nullable objects: let
- Introducing an expression as a variable in local scope: let
- Object configuration: apply
- Object configuration and computing the result: run
- Running statements where an expression is required: non-extension run
- Additional effects: also
- Grouping function calls on an object: with

The use cases of different scope functions overlap, so you can choose which functions to use based on the specific conventions used in your project or team.

Although scope functions can make your code more concise, avoid overusing them: it can make your code hard to read and lead to errors. We also recommend that you avoid nesting scope functions and be careful when chaining them because it's easy to get confused about the current context object and value of this or it.

Distinctions

Because scope functions are similar in nature, it's important to understand the differences between them. There are two main differences between each scope function:

- The way they refer to the context object.
- Their return value.

Context object: this or it

Inside the lambda passed to a scope function, the context object is available by a short reference instead of its actual name. Each scope function uses one of two ways to reference the context object: as a lambda receiver (this) or as a lambda argument (it). Both provide the same capabilities, so we describe the pros and cons of each for different use cases and provide recommendations for their use.

```
fun main() {
    val str = "Hello"
    // this
    str.run {
        println("The string's length: $length")
        //println("The string's length: ${this.length}") // does the same
    }

    // it
    str.let {
        println("The string's length is ${it.length}")
    }
}
```

this

run, with, and apply reference the context object as a lambda receiver - by keyword this. Hence, in their lambdas, the object is available as it would be in ordinary class functions.

In most cases, you can omit this when accessing the members of the receiver object, making the code shorter. On the other hand, if this is omitted, it can be hard to distinguish between the receiver members and external objects or functions. So having the context object as a receiver (this) is recommended for lambdas that mainly operate on the object's members by calling its functions or assigning values to properties.

```
data class Person(var name: String, var age: Int = 0, var city: String = "")

fun main() {
    val adam = Person("Adam").apply {
        age = 20                       // same as this.age = 20
        city = "London"
    }
    println(adam)
}
```

it

In turn, let and also reference the context object as a lambda argument. If the argument name is not specified, the object is accessed by the implicit default name it. it is shorter than this and expressions with it are usually easier to read.

However, when calling the object's functions or properties, you don't have the object available implicitly like this. Hence, accessing the context object via it is better when the object is mostly used as an argument in function calls. it is also better if you use multiple variables in the code block.

```
import kotlin.random.Random

fun writeToLog(message: String) {
    println("INFO: $message")
}

fun main() {
    fun getRandomInt(): Int {
        return Random.nextInt(100).also {
            writeToLog("getRandomInt() generated value $it")
        }
    }

    val i = getRandomInt()
    println(i)
}
```

The example below demonstrates referencing the context object as a lambda argument with argument name: value.

```
import kotlin.random.Random

fun writeToLog(message: String) {
    println("INFO: $message")
}

fun main() {
    fun getRandomInt(): Int {
        return Random.nextInt(100).also { value ->
            writeToLog("getRandomInt() generated value $value")
        }
    }
    val i = getRandomInt()
    println(i)
}
```

Return value

Scope functions differ by the result they return:

- apply and also return the context object.
- let, run, and with return the lambda result.

You should consider carefully what return value you want based on what you want to do next in your code. This helps you to choose the best scope function to use.

Context object

The return value of apply and also is the context object itself. Hence, they can be included into call chains as side steps: you can continue chaining function calls on the same object, one after another.

```
fun main() {
    val numberList = mutableListOf<Double>()
    numberList.also { println("Populating the list") }
        .apply {
            add(2.71)
            add(3.14)
            add(1.0)
        }
        .also { println("Sorting the list") }
        .sort()
    println(numberList)
}
```

They also can be used in return statements of functions returning the context object.

```
import kotlin.random.Random

fun writeToLog(message: String) {
    println("INFO: $message")
}

fun main() {
    fun getRandomInt(): Int {
        return Random.nextInt(100).also {
            writeToLog("getRandomInt() generated value $it")
        }
    }

    val i = getRandomInt()
}
```

Lambda result

let, run, and with return the lambda result. So you can use them when assigning the result to a variable, chaining operations on the result, and so on.

```
fun main() {
    val numbers = mutableListOf("one", "two", "three")
    val countEndsWithE = numbers.run {
        add("four")
        add("five")
        count { it.endsWith("e") }
    }
    println("There are $countEndsWithE elements that end with e.")
}
```

Additionally, you can ignore the return value and use a scope function to create a temporary scope for local variables.

```
fun main() {
    val numbers = mutableListOf("one", "two", "three")
    with(numbers) {
        val firstItem = first()
        val lastItem = last()
        println("First item: $firstItem, last item: $lastItem")
    }
}
```

Functions

To help you choose the right scope function for your use case, we describe them in detail and provide recommendations for use. Technically, scope functions are interchangeable in many cases, so the examples show conventions for using them.

let

- The context object is available as an argument (it).
- The return value is the lambda result.

let can be used to invoke one or more functions on results of call chains. For example, the following code prints the results of two operations on a collection:

```
fun main() {
    val numbers = mutableListOf("one", "two", "three", "four", "five")
    val resultList = numbers.map { it.length }.filter { it > 3 }
    println(resultList)
}
```

With let, you can rewrite the above example so that you're not assigning the result of the list operations to a variable:

```
fun main() {
    val numbers = mutableListOf("one", "two", "three", "four", "five")
    numbers.map { it.length }.filter { it > 3 }.let {
        println(it)
        // and more function calls if needed
    }
}
```

If the code block passed to let contains a single function with it as an argument, you can use the method reference (::) instead of the lambda argument:

```
fun main() {
    val numbers = mutableListOf("one", "two", "three", "four", "five")
    numbers.map { it.length }.filter { it > 3 }.let(::println)
}
```

let is often used to execute a code block containing non-null values. To perform actions on a non-null object, use the safe call operator ?. on it and call let with the actions in its lambda.

```
fun processNonNullString(str: String) {}

fun main() {
    val str: String? = "Hello"
    //processNonNullString(str)       // compilation error: str can be null
    val length = str?.let {
        println("let() called on $it")
        processNonNullString(it)      // OK: 'it' is not null inside '?.let { }'
        it.length
    }
}
```

You can also use let to introduce local variables with a limited scope to make your code easier to read. To define a new variable for the context object, provide its name as the lambda argument so that it can be used instead of the default it.

```
fun main() {
    val numbers = listOf("one", "two", "three", "four")
    val modifiedFirstItem = numbers.first().let { firstItem ->
        println("The first item of the list is '$firstItem'")
        if (firstItem.length >= 5) firstItem else "!" + firstItem + "!"
    }.uppercase()
    println("First item after modifications: '$modifiedFirstItem'")
}
```

with

- The context object is available as a receiver (this).
- The return value is the lambda result.

As with is not an extension function: the context object is passed as an argument, but inside the lambda, it's available as a receiver (this).

We recommend using with for calling functions on the context object when you don't need to use the returned result. In code, with can be read as " with this object, do the following. "

```
fun main() {
    val numbers = mutableListOf("one", "two", "three")
    with(numbers) {
        println("'with' is called with argument $this")
        println("It contains $size elements")
    }
}
```

You can also use with to introduce a helper object whose properties or functions are used for calculating a value.

```
fun main() {
    val numbers = mutableListOf("one", "two", "three")
    val firstAndLast = with(numbers) {
        "The first element is ${first()}," +
        " the last element is ${last()}"
    }
    println(firstAndLast)
}
```

run

- The context object is available as a receiver (this).
- The return value is the lambda result.

run does the same as with but it is implemented as an extension function. So like let, you can call it on the context object using dot notation.

run is useful when your lambda both initializes objects and computes the return value.

```
class MultiportService(var url: String, var port: Int) {
    fun prepareRequest(): String = "Default request"
    fun query(request: String): String = "Result for query '$request'"
}

fun main() {
    val service = MultiportService("https://example.kotlinlang.org", 80)

    val result = service.run {
        port = 8080
        query(prepareRequest() + " to port $port")
    }

    // the same code written with let() function:
    val letResult = service.let {
        it.port = 8080
        it.query(it.prepareRequest() + " to port ${it.port}")
    }
    println(result)
    println(letResult)
}
```

You can also invoke run as a non-extension function. The non-extension variant of run has no context object, but it still returns the lambda result. Non-extension run lets you execute a block of several statements where an expression is required. In code, non-extension run can be read as " run the code block and compute the result. "

```
fun main() {
    val hexNumberRegex = run {
        val digits = "0-9"
        val hexDigits = "A-Fa-f"
        val sign = "+-"

        Regex("[$sign]?[$digits$hexDigits]+")
    }

    for (match in hexNumberRegex.findAll("+123 -FFFF !%*& 88 XYZ")) {
        println(match.value)
    }
}
```

apply

- The context object is available as a receiver (this).
- The return value is the object itself.

As apply returns the context object itself, we recommend that you use it for code blocks that don't return a value and that mainly operate on the members of the receiver object. The most common use case for apply is for object configuration. Such calls can be read as " apply the following assignments to the object. "

```
data class Person(var name: String, var age: Int = 0, var city: String = "")

fun main() {
    val adam = Person("Adam").apply {
        age = 32
        city = "London"
    }
    println(adam)
}
```

Another use case for apply is to include apply in multiple call chains for more complex processing.

also

- The context object is available as an argument (it).
- The return value is the object itself.

also is useful for performing some actions that take the context object as an argument. Use also for actions that need a reference to the object rather than its properties and functions, or when you don't want to shadow the this reference from an outer scope.

When you see also in code, you can read it as " and also do the following with the object. "

```
fun main() {
    val numbers = mutableListOf("one", "two", "three")
    numbers
        .also { println("The list elements before adding new one: $it") }
        .add("four")
}
```

takeIf and takeUnless

In addition to scope functions, the standard library contains the functions takeIf and takeUnless. These functions let you embed checks of an object's state in call chains.

When called on an object along with a predicate, takeIf returns this object if it satisfies the given predicate. Otherwise, it returns null. So, takeIf is a filtering function for a single object.

takeUnless has the opposite logic of takeIf. When called on an object along with a predicate, takeUnless returns null if it satisfies the given predicate. Otherwise, it returns the object.

When using takeIf or takeUnless, the object is available as a lambda argument (it).

```
import kotlin.random.*

fun main() {
    val number = Random.nextInt(100)

    val evenOrNull = number.takeIf { it % 2 == 0 }
    val oddOrNull = number.takeUnless { it % 2 == 0 }
    println("even: $evenOrNull, odd: $oddOrNull")
}
```

When chaining other functions after takeIf and takeUnless, don't forget to perform a null check or use a safe call (?.) because their return value is nullable.

```
fun main() {
    val str = "Hello"
    val caps = str.takeIf { it.isNotEmpty() }?.uppercase()
   //val caps = str.takeIf { it.isNotEmpty() }.uppercase() //compilation error
    println(caps)
}
```

takeIf and takeUnless are especially useful in combination with scope functions. For example, you can chain takeIf and takeUnless with let to run a code block on objects that match the given predicate. To do this, call takeIf on the object and then call let with a safe call (?). For objects that don't match the predicate, takeIf returns null and let isn't invoked.

```
fun main() {
    fun displaySubstringPosition(input: String, sub: String) {
        input.indexOf(sub).takeIf { it >= 0 }?.let {
            println("The substring $sub is found in $input.")
            println("Its start position is $it.")
        }
    }

    displaySubstringPosition("010000011", "11")
    displaySubstringPosition("010000011", "12")
}
```

For comparison, below is an example of how the same function can be written without using takeIf or scope functions:

```
fun main() {
    fun displaySubstringPosition(input: String, sub: String) {
        val index = input.indexOf(sub)
        if (index >= 0) {
            println("The substring $sub is found in $input.")
            println("Its start position is $index.")
        }
    }

    displaySubstringPosition("010000011", "11")
    displaySubstringPosition("010000011", "12")
}
```

Time measurement

The Kotlin standard library gives you the tools to calculate and measure time in different units. Accurate time measurement is important for activities like:

- Managing threads or processes
- Collecting statistics
- Detecting timeouts
- Debugging

By default, time is measured using a monotonic time source, but other time sources can be configured. For more information, see Create time source.

Calculate duration

To represent an amount of time, the standard library has the Duration class. A Duration can be expressed in the following units from the DurationUnit enum class:

- NANOSECONDS
- MICROSECONDS
- MILLISECONDS
- SECONDS
- MINUTES
- HOURS
- DAYS

A Duration can be positive, negative, zero, positive infinity, or negative infinity.

Create duration

To create a Duration, use the extension properties available for Int, Long, and Double types: nanoseconds, microseconds, milliseconds, seconds, minutes, hours, and days.

> Days refer to periods of 24 hours. They are not calendar days.

For example:

```kotlin
import kotlin.time.*
import kotlin.time.Duration.Companion.nanoseconds
import kotlin.time.Duration.Companion.milliseconds
import kotlin.time.Duration.Companion.seconds
import kotlin.time.Duration.Companion.minutes
import kotlin.time.Duration.Companion.days

fun main() {
    val fiveHundredMilliseconds: Duration = 500.milliseconds
    val zeroSeconds: Duration = 0.seconds
    val tenMinutes: Duration = 10.minutes
    val negativeNanosecond: Duration = (-1).nanoseconds
    val infiniteDays: Duration = Double.POSITIVE_INFINITY.days
    val negativeInfiniteDays: Duration = Double.NEGATIVE_INFINITY.days

    println(fiveHundredMilliseconds) // 500ms
    println(zeroSeconds)             // 0s
    println(tenMinutes)              // 10m
    println(negativeNanosecond)      // -1ns
    println(infiniteDays)            // Infinity
    println(negativeInfiniteDays)    // -Infinity
}
```

You can also perform basic arithmetic with Duration objects:

```kotlin
import kotlin.time.*
import kotlin.time.Duration.Companion.seconds

fun main() {
    val fiveSeconds: Duration = 5.seconds
    val thirtySeconds: Duration = 30.seconds

    println(fiveSeconds + thirtySeconds)
    // 35s
    println(thirtySeconds - fiveSeconds)
    // 25s
    println(fiveSeconds * 2)
    // 10s
    println(thirtySeconds / 2)
    // 15s
    println(thirtySeconds / fiveSeconds)
    // 6.0
    println(-thirtySeconds)
    // -30s
    println((-thirtySeconds).absoluteValue)
    // 30s
}
```

Get string representation

It can be useful to have a string representation of a Duration so that you can print, serialize, transfer, or store it.

To get a string representation, use the .toString() function. By default, the time is reported using each unit that is present. For example: 1h 0m 45.677s or -(6d 5h 5m 28.284s)

To configure the output, use the .toString() function with your desired DurationUnit and number of decimal places as function parameters:

```
import kotlin.time.Duration
import kotlin.time.Duration.Companion.milliseconds
import kotlin.time.DurationUnit

fun main() {
    // Print in seconds with 2 decimal places
    println(5887.milliseconds.toString(DurationUnit.SECONDS, 2))
    // 5.89s
}
```

To get an ISO-8601-compatible string, use the toIsoString() function:

```
import kotlin.time.Duration.Companion.seconds

fun main() {
    println(86420.seconds.toIsoString()) // PT24H0M20S
}
```

Convert duration

To convert your Duration into a different DurationUnit, use the following properties:

- inWholeNanoseconds
- inWholeMicroseconds
- inWholeSeconds
- inWholeMinutes
- inWholeHours
- inWholeDays

For example:

```
import kotlin.time.Duration
import kotlin.time.Duration.Companion.minutes

fun main() {
    val thirtyMinutes: Duration = 30.minutes
    println(thirtyMinutes.inWholeSeconds)
    // 1800
}
```

Alternatively, you can use your desired DurationUnit as a function parameter in the following extension functions:

- .toInt()
- .toDouble()
- .toLong()

For example:

```kotlin
import kotlin.time.Duration.Companion.seconds
import kotlin.time.DurationUnit

fun main() {
    println(270.seconds.toDouble(DurationUnit.MINUTES))
    // 4.5
}
```

Compare duration

To check if Duration objects are equal, use the equality operator (==):

```kotlin
import kotlin.time.Duration
import kotlin.time.Duration.Companion.hours
import kotlin.time.Duration.Companion.minutes

fun main() {
    val thirtyMinutes: Duration = 30.minutes
    val halfHour: Duration = 0.5.hours
    println(thirtyMinutes == halfHour)
    // true
}
```

To compare Duration objects, use the comparison operators (<, >):

```kotlin
import kotlin.time.Duration.Companion.microseconds
import kotlin.time.Duration.Companion.nanoseconds

fun main() {
    println(3000.microseconds < 25000.nanoseconds)
    // false
}
```

Break duration into components

To break down a Duration into its time components and perform a further action, use the overload of the toComponents() function. Add your desired action as a function or lambda expression as a function parameter.

For example:

```kotlin
import kotlin.time.Duration
import kotlin.time.Duration.Companion.minutes

fun main() {
    val thirtyMinutes: Duration = 30.minutes
    println(thirtyMinutes.toComponents { hours, minutes, _, _ -> "${hours}h:${minutes}m" })
    // 0h:30m
}
```

In this example, the lambda expression has hours and minutes as function parameters with underscores (_) for the unused seconds and nanoseconds parameters. The expression returns a concatenated string using string templates to get the desired output format of hours and minutes.

Measure time

To track the passage of time, the standard library provides tools so that you can easily:

- Measure the time taken to execute some code with your desired time unit.
- Mark a moment in time.
- Compare and subtract two moments in time.
- Check how much time has passed since a specific moment in time.
- Check whether the current time has passed a specific moment in time.

Measure code execution time

To measure the time taken to execute a block of code, use the measureTime inline function:

```
import kotlin.time.measureTime

fun main() {
    val timeTaken = measureTime {
        Thread.sleep(100)
    }
    println(timeTaken) // e.g. 103 ms
}
```

To measure the time taken to execute a block of code and return the value of the block of code, use inline function measureTimedValue.

For example:

```
import kotlin.time.measureTimedValue

fun main() {
    val (value, timeTaken) = measureTimedValue {
        Thread.sleep(100)
        42
    }
    println(value)     // 42
    println(timeTaken) // e.g. 103 ms
}
```

By default, both functions use a monotonic time source.

Mark moments in time

To mark a specific moment in time, use the TimeSource interface and the markNow() function to create a TimeMark:

```
import kotlin.time.*

fun main() {
   val timeSource = TimeSource.Monotonic
   val mark = timeSource.markNow()
}
```

Measure differences in time

To measure differences between TimeMark objects from the same time source, use the subtraction operator (-).

To compare TimeMark objects from the same time source, use the comparison operators (<, >).

For example:

```
import kotlin.time.*

fun main() {
   val timeSource = TimeSource.Monotonic
   val mark1 = timeSource.markNow()
   Thread.sleep(500) // Sleep 0.5 seconds.
   val mark2 = timeSource.markNow()

   repeat(4) { n ->
       val mark3 = timeSource.markNow()
       val elapsed1 = mark3 - mark1
       val elapsed2 = mark3 - mark2

       println("Measurement 1.${n + 1}: elapsed1=$elapsed1, elapsed2=$elapsed2, diff=${elapsed1 - elapsed2}")
   }

   println(mark2 > mark1) // This is true, as mark2 was captured later than mark1.
   // true
}
```

To check if a deadline has passed or a timeout has been reached, use the hasPassedNow() and hasNotPassedNow() extension functions:

```kotlin
import kotlin.time.*
import kotlin.time.Duration.Companion.seconds

fun main() {
   val timeSource = TimeSource.Monotonic
   val mark1 = timeSource.markNow()
   val fiveSeconds: Duration = 5.seconds
   val mark2 = mark1 + fiveSeconds

   // It hasn't been 5 seconds yet
   println(mark2.hasPassedNow())
   // false

   // Wait six seconds
   Thread.sleep(6000)
   println(mark2.hasPassedNow())
   // true

}
```

Time sources

By default, time is measured using a monotonic time source. Monotonic time sources only move forward and are not affected by variations like timezones. An alternative to monotonic time is elapsed real time which is also known as wall-clock time. Elapsed real time is measured relative to another point in time.

Default time sources per platform

This table explains the default source of monotonic time for each platform:

Platform	Source
Kotlin/JVM	System.nanoTime()
Kotlin/JS (Node.js)	process.hrtime()
Kotlin/JS (browser)	window.performance.now() or Date.now()
Kotlin/Native	std::chrono::high_resolution_clock or std::chrono::steady_clock

Create time source

There are some cases where you might want to use a different time source. For example in Android, System.nanoTime() only counts time while the device is active. It loses track of time when the device enters deep sleep. To keep track of time while the device is in deep sleep, you can create a time source that uses SystemClock.elapsedRealtimeNanos():

```kotlin
object RealtimeMonotonicTimeSource : AbstractLongTimeSource(DurationUnit.NANOSECONDS) {
    override fun read(): Long = SystemClock.elapsedRealtimeNanos()
}
```

Then you can use your time source to make time measurements:

```kotlin
fun main() {
    val elapsed: Duration = RealtimeMonotonicTimeSource.measureTime {
        Thread.sleep(100)
    }
    println(elapsed) // e.g. 103 ms
}
```

For more information about the kotlin.time package, see our standard library API reference.

Coroutines guide

Kotlin provides only minimal low-level APIs in its standard library to enable other libraries to utilize coroutines. Unlike many other languages with similar capabilities, async and await are not keywords in Kotlin and are not even part of its standard library. Moreover, Kotlin's concept of suspending function provides a safer and less error-prone abstraction for asynchronous operations than futures and promises.

kotlinx.coroutines is a rich library for coroutines developed by JetBrains. It contains a number of high-level coroutine-enabled primitives that this guide covers, including launch, async, and others.

This is a guide about the core features of kotlinx.coroutines with a series of examples, divided up into different topics.

In order to use coroutines as well as follow the examples in this guide, you need to add a dependency on the `kotlinx-coroutines-core` module as explained in the project README.

Table of contents

Additional references

- Guide to UI programming with coroutines
- Coroutines design document (KEEP)
- Full kotlinx.coroutines API reference
- Best practices for coroutines in Android
- Additional Android resources for Kotlin coroutines and flow

Coroutines basics

This section covers basic coroutine concepts.

Your first coroutine

A coroutine is an instance of a suspendable computation. It is conceptually similar to a thread, in the sense that it takes a block of code to run that works concurrently with the rest of the code. However, a coroutine is not bound to any particular thread. It may suspend its execution in one thread and resume in another one.

Coroutines can be thought of as light-weight threads, but there is a number of important differences that make their real-life usage very different from threads.

Run the following code to get to your first working coroutine:

```
import kotlinx.coroutines.*

fun main() = runBlocking { // this: CoroutineScope
    launch { // launch a new coroutine and continue
        delay(1000L) // non-blocking delay for 1 second (default time unit is ms)
        println("World!") // print after delay
    }
    println("Hello") // main coroutine continues while a previous one is delayed
}
```

You can get the full code here.

You will see the following result:

```
Hello
World!
```

Let's dissect what this code does.

launch is a coroutine builder. It launches a new coroutine concurrently with the rest of the code, which continues to work independently. That's why Hello has been printed first.

delay is a special suspending function. It suspends the coroutine for a specific time. Suspending a coroutine does not block the underlying thread, but allows other coroutines to run and use the underlying thread for their code.

runBlocking is also a coroutine builder that bridges the non-coroutine world of a regular fun main() and the code with coroutines inside of runBlocking { ... } curly braces. This is highlighted in an IDE by this: CoroutineScope hint right after the runBlocking opening curly brace.

If you remove or forget runBlocking in this code, you'll get an error on the launch call, since launch is declared only on the CoroutineScope:

```
Unresolved reference: launch
```

The name of runBlocking means that the thread that runs it (in this case — the main thread) gets blocked for the duration of the call, until all the coroutines inside runBlocking { ... } complete their execution. You will often see runBlocking used like that at the very top-level of the application and quite rarely inside the real code, as threads are expensive resources and blocking them is inefficient and is often not desired.

Structured concurrency

Coroutines follow a principle of structured concurrency which means that new coroutines can only be launched in a specific CoroutineScope which delimits the lifetime of the coroutine. The above example shows that runBlocking establishes the corresponding scope and that is why the previous example waits until World! is printed after a second's delay and only then exits.

In a real application, you will be launching a lot of coroutines. Structured concurrency ensures that they are not lost and do not leak. An outer scope cannot complete until all its children coroutines complete. Structured concurrency also ensures that any errors in the code are properly reported and are never lost.

Extract function refactoring

Let's extract the block of code inside launch { ... } into a separate function. When you perform "Extract function" refactoring on this code, you get a new function with the suspend modifier. This is your first suspending function. Suspending functions can be used inside coroutines just like regular functions, but their additional feature is that they can, in turn, use other suspending functions (like delay in this example) to suspend execution of a coroutine.

```
import kotlinx.coroutines.*

fun main() = runBlocking { // this: CoroutineScope
    launch { doWorld() }
    println("Hello")
}

// this is your first suspending function
```

```
suspend fun doWorld() {
    delay(1000L)
    println("World!")
}
```

You can get the full code here.

Scope builder

In addition to the coroutine scope provided by different builders, it is possible to declare your own scope using the coroutineScope builder. It creates a coroutine scope and does not complete until all launched children complete.

runBlocking and coroutineScope builders may look similar because they both wait for their body and all its children to complete. The main difference is that the runBlocking method blocks the current thread for waiting, while coroutineScope just suspends, releasing the underlying thread for other usages. Because of that difference, runBlocking is a regular function and coroutineScope is a suspending function.

You can use coroutineScope from any suspending function. For example, you can move the concurrent printing of Hello and World into a suspend fun doWorld() function:

```
import kotlinx.coroutines.*

fun main() = runBlocking {
    doWorld()
}

suspend fun doWorld() = coroutineScope {  // this: CoroutineScope
    launch {
        delay(1000L)
        println("World!")
    }
    println("Hello")
}
```

You can get the full code here.

This code also prints:

```
Hello
World!
```

Scope builder and concurrency

A coroutineScope builder can be used inside any suspending function to perform multiple concurrent operations. Let's launch two concurrent coroutines inside a doWorld suspending function:

```
import kotlinx.coroutines.*

// Sequentially executes doWorld followed by "Done"
fun main() = runBlocking {
    doWorld()
    println("Done")
}

// Concurrently executes both sections
suspend fun doWorld() = coroutineScope { // this: CoroutineScope
    launch {
        delay(2000L)
        println("World 2")
    }
    launch {
        delay(1000L)
        println("World 1")
    }
    println("Hello")
}
```

You can get the full code here.

Both pieces of code inside launch { ... } blocks execute concurrently, with World 1 printed first, after a second from start, and World 2 printed next, after two seconds from start. A coroutineScope in doWorld completes only after both are complete, so doWorld returns and allows Done string to be printed only after that:

```
Hello
World 1
World 2
Done
```

An explicit job

A launch coroutine builder returns a Job object that is a handle to the launched coroutine and can be used to wait for its completion explicitly. For example, you can wait for the completion of the child coroutine and then print the "Done" string:

```kotlin
import kotlinx.coroutines.*

fun main() = runBlocking {
    val job = launch { // launch a new coroutine and keep a reference to its Job
        delay(1000L)
        println("World!")
    }
    println("Hello")
    job.join() // wait until child coroutine completes
    println("Done")
}
```

You can get the full code here.

This code produces:

```
Hello
World!
Done
```

Coroutines are light-weight

Coroutines are less resource-intensive than JVM threads. Code that exhausts the JVM's available memory when using threads can be expressed using coroutines without hitting resource limits. For example, the following code launches 50,000 distinct coroutines that each waits 5 seconds and then prints a period ('.') while consuming very little memory:

```kotlin
import kotlinx.coroutines.*

fun main() = runBlocking {
    repeat(50_000) { // launch a lot of coroutines
        launch {
            delay(5000L)
            print(".")
        }
    }
}
```

You can get the full code here.

If you write the same program using threads (remove runBlocking, replace launch with thread, and replace delay with Thread.sleep), it will consume a lot of memory.

Depending on your operating system, JDK version, and its settings, it will either throw an out-of-memory error or start threads slowly so that there are never too many concurrently running threads.

Coroutines and channels – tutorial

In this tutorial, you'll learn how to use coroutines in IntelliJ IDEA to perform network requests without blocking the underlying thread or callbacks.

> No prior knowledge of coroutines is required, but you're expected to be familiar with basic Kotlin syntax.

You'll learn:

- Why and how to use suspending functions to perform network requests.
- How to send requests concurrently using coroutines.
- How to share information between different coroutines using channels.

For network requests, you'll need the Retrofit library, but the approach shown in this tutorial works similarly for any other libraries that support coroutines.

> You can find solutions for all of the tasks on the solutions branch of the project's repository.

Before you start

1. Download and install the latest version of IntelliJ IDEA.
2. Clone the project template by choosing Get from VCS on the Welcome screen or selecting File | New | Project from Version Control.

   You can also clone it from the command line:

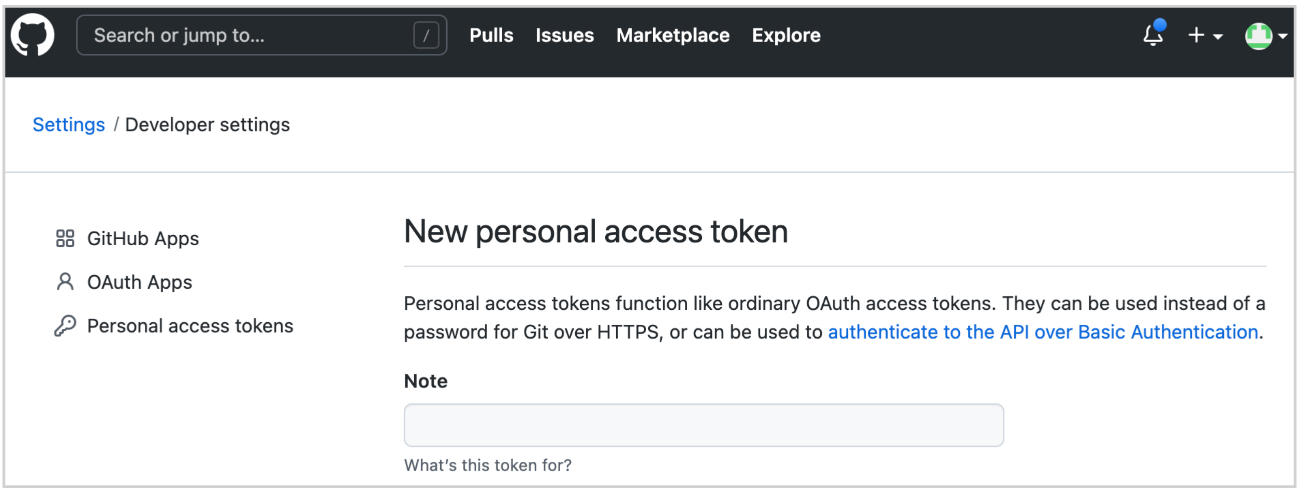
```
git clone https://github.com/kotlin-hands-on/intro-coroutines
```

Generate a GitHub developer token

You'll be using the GitHub API in your project. To get access, provide your GitHub account name and either a password or a token. If you have two-factor authentication enabled, a token will be enough.

Generate a new GitHub token to use the GitHub API with your account:

1. Specify the name of your token, for example, coroutines-tutorial:



New personal access token

Personal access tokens function like ordinary OAuth access tokens. They can be used instead of a password for Git over HTTPS, or can be used to authenticate to the API over Basic Authentication.

Note

What's this token for?

Generate a new GitHub token

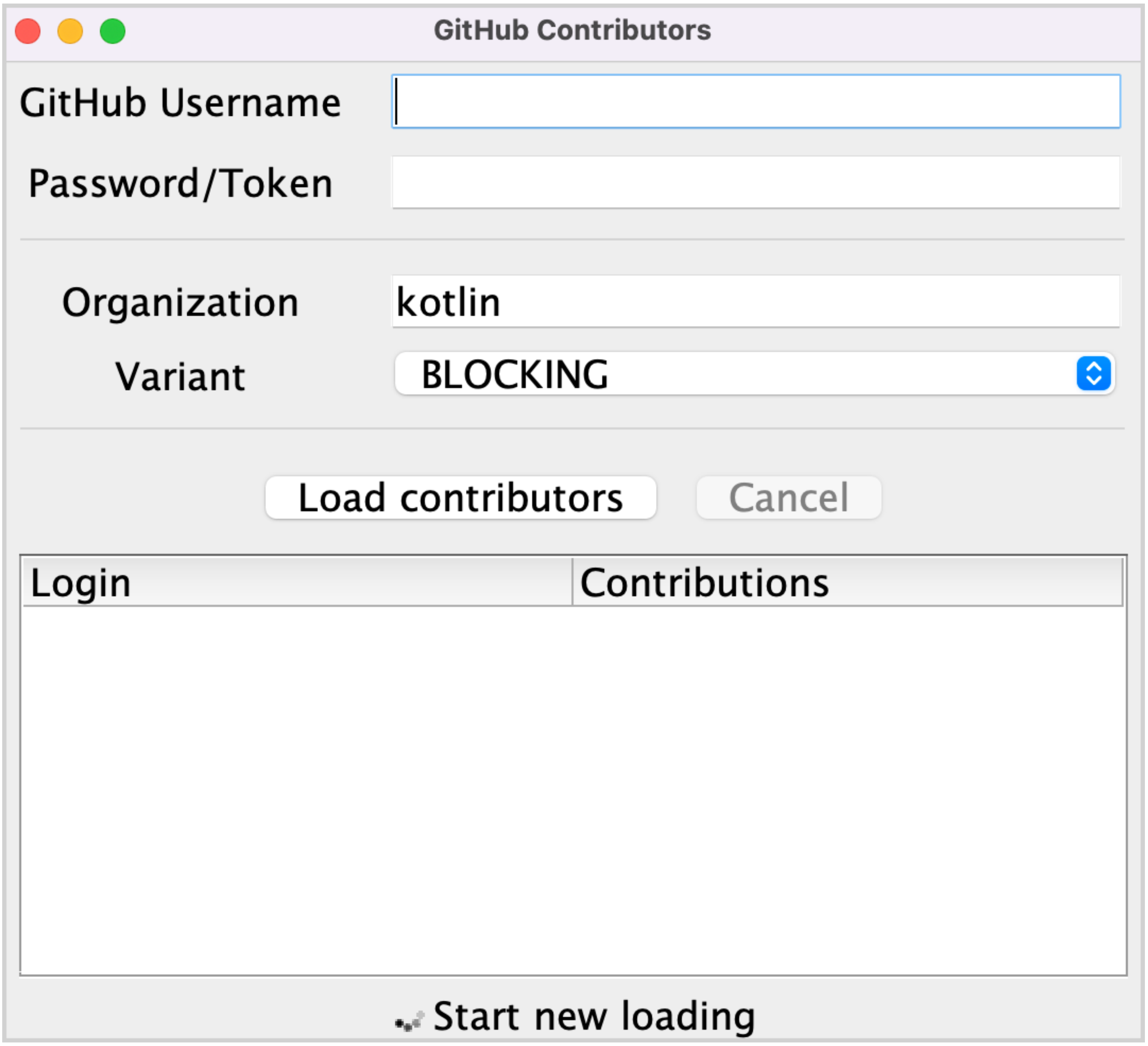
2. Do not select any scopes. Click Generate token at the bottom of the page.

3. Copy the generated token.

Run the code

The program loads the contributors for all of the repositories under the given organization (named “kotlin” by default). Later you'll add logic to sort the users by the number of their contributions.

1. Open the src/contributors/main.kt file and run the main() function. You'll see the following window:



First window

If the font is too small, adjust it by changing the value of setDefaultFontSize(18f) in the main() function.

2. Provide your GitHub username and token (or password) in the corresponding fields.

3. Make sure that the BLOCKING option is selected in the Variant dropdown menu.

4. Click Load contributors. The UI should freeze for some time and then show the list of contributors.

5. Open the program output to ensure the data has been loaded. The list of contributors is logged after each successful request.

There are different ways of implementing this logic: by using blocking requests or callbacks. You'll compare these solutions with one that uses coroutines and see how channels can be used to share information between different coroutines.

Blocking requests

You will use the Retrofit library to perform HTTP requests to GitHub. It allows requesting the list of repositories under the given organization and the list of contributors for each repository:

```kotlin
interface GitHubService {
    @GET("orgs/{org}/repos?per_page=100")
    fun getOrgReposCall(
        @Path("org") org: String
    ): Call<List<Repo>>

    @GET("repos/{owner}/{repo}/contributors?per_page=100")
    fun getRepoContributorsCall(
        @Path("owner") owner: String,
        @Path("repo") repo: String
    ): Call<List<User>>
}
```

This API is used by the loadContributorsBlocking() function to fetch the list of contributors for the given organization.

1. Open src/tasks/Request1Blocking.kt to see its implementation:

```kotlin
fun loadContributorsBlocking(
    service: GitHubService,
    req: RequestData
): List<User> {
    val repos = service
        .getOrgReposCall(req.org)   // #1
        .execute()                  // #2
        .also { logRepos(req, it) } // #3
        .body() ?: emptyList()      // #4

    return repos.flatMap { repo ->
        service
            .getRepoContributorsCall(req.org, repo.name) // #1
            .execute()                                   // #2
            .also { logUsers(repo, it) }                 // #3
            .bodyList()                                  // #4
    }.aggregate()
}
```

- At first, you get a list of the repositories under the given organization and store it in the repos list. Then for each repository, the list of contributors is requested, and all of the lists are merged into one final list of contributors.
- getOrgReposCall() and getRepoContributorsCall() both return an instance of the *Call class (#1). At this point, no request is sent.
- *Call.execute() is then invoked to perform the request (#2). execute() is a synchronous call that blocks the underlying thread.
- When you get the response, the result is logged by calling the specific logRepos() and logUsers() functions (#3). If the HTTP response contains an error, this error will be logged here.
- Finally, get the response's body, which contains the data you need. For this tutorial, you'll use an empty list as a result in case there is an error, and you'll log the corresponding error (#4).

2. To avoid repeating .body() ?: emptyList(), an extension function bodyList() is declared:

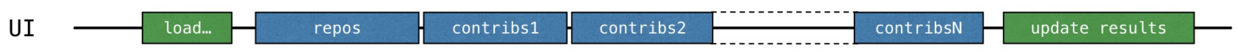
```kotlin
fun <T> Response<List<T>>.bodyList(): List<T> {
    return body() ?: emptyList()
}
```

3. Run the program again and take a look at the system output in IntelliJ IDEA. It should have something like this:

```
1770 [AWT-EventQueue-0] INFO  Contributors - kotlin: loaded 40 repos
2025 [AWT-EventQueue-0] INFO  Contributors - kotlin-examples: loaded 23 contributors
2229 [AWT-EventQueue-0] INFO  Contributors - kotlin-koans: loaded 45 contributors
...
```

* The first item on each line is the number of milliseconds that have passed since the program started, then the thread name in square brackets. You can see from which thread the loading request is called.
* The final item on each line is the actual message: how many repositories or contributors were loaded.

This log output demonstrates that all of the results were logged from the main thread. When you run the code with a BLOCKING option, the window freezes and doesn't react to input until the loading is finished. All of the requests are executed from the same thread as the one called loadContributorsBlocking() is from, which is the main UI thread (in Swing, it's an AWT event dispatching thread). This main thread becomes blocked, and that's why the UI is frozen:



The blocked main thread

After the list of contributors has loaded, the result is updated.

4. In src/contributors/Contributors.kt, find the loadContributors() function responsible for choosing how the contributors are loaded and look at how loadContributorsBlocking() is called:

```
when (getSelectedVariant()) {
    BLOCKING -> { // Blocking UI thread
        val users = loadContributorsBlocking(service, req)
        updateResults(users, startTime)
    }
}
```

* The updateResults() call goes right after the loadContributorsBlocking() call.
* updateResults() updates the UI, so it must always be called from the UI thread.
* Since loadContributorsBlocking() is also called from the UI thread, the UI thread becomes blocked and the UI is frozen.

Task 1

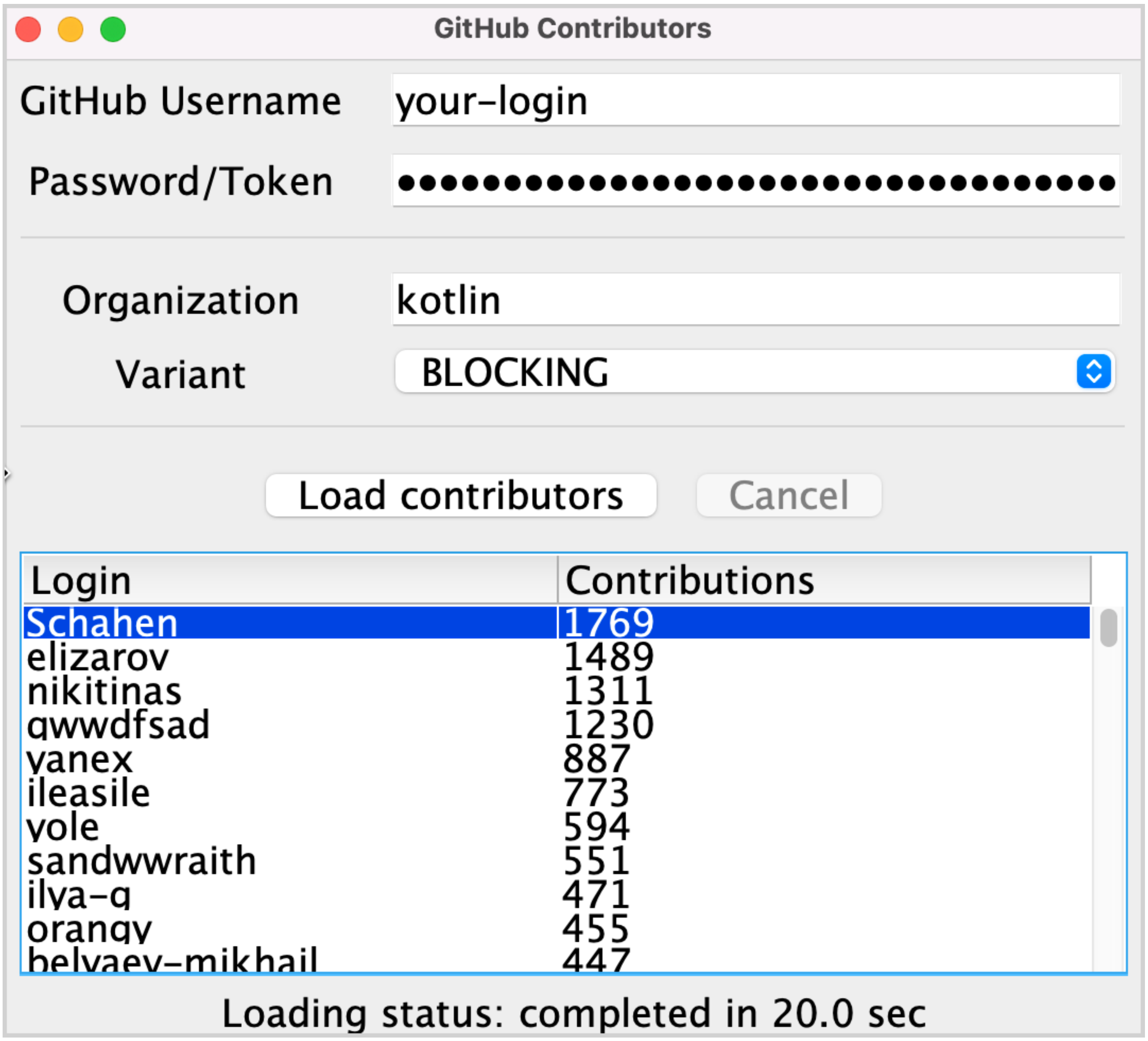
The first task helps you familiarize yourself with the task domain. Currently, each contributor's name is repeated several times, once for every project they have taken part in. Implement the aggregate() function combining the users so that each contributor is added only once. The User.contributions property should contain the total number of contributions of the given user to all the projects. The resulting list should be sorted in descending order according to the number of contributions.

Open src/tasks/Aggregation.kt and implement the List<User>.aggregate() function. Users should be sorted by the total number of their contributions.

The corresponding test file test/tasks/AggregationKtTest.kt shows an example of the expected result.

> You can jump between the source code and the test class automatically by using the IntelliJ IDEA shortcut Ctrl+Shift+T/⇧ ⌘ T.

After implementing this task, the resulting list for the "kotlin" organization should be similar to the following:



GitHub Contributors

GitHub Username: your-login

Password/Token: ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

Organization: kotlin

Variant: BLOCKING

Login	Contributions
Schahen	1769
elizarov	1489
nikitinas	1311
qwwdfsad	1230
vanex	887
ileasile	773
vole	594
sandwwraith	551
ilya-g	471
orangy	455
belyaev-mikhail	447

Loading status: completed in 20.0 sec

The list for the "kotlin" organization

Solution for task 1

1. To group users by login, use groupBy(), which returns a map from a login to all occurrences of the user with this login in different repositories.
2. For each map entry, count the total number of contributions for each user and create a new instance of the User class by the given name and total of contributions.
3. Sort the resulting list in descending order:

```kotlin
fun List<User>.aggregate(): List<User> =
    groupBy { it.login }
        .map { (login, group) -> User(login, group.sumOf { it.contributions }) }
        .sortedByDescending { it.contributions }
```

An alternative solution is to use the groupingBy() function instead of groupBy().

Callbacks

The previous solution works, but it blocks the thread and therefore freezes the UI. A traditional approach that avoids this is to use callbacks.

Instead of calling the code that should be invoked right after the operation is completed, you can extract it into a separate callback, often a lambda, and pass that lambda to the caller in order for it to be called later.

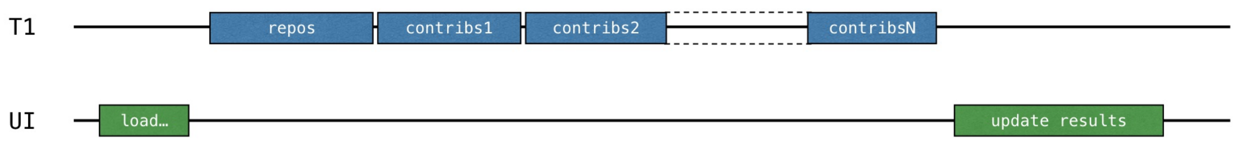
To make the UI responsive, you can either move the whole computation to a separate thread or switch to the Retrofit API which uses callbacks instead of blocking calls.

Use a background thread

1. Open src/tasks/Request2Background.kt and see its implementation. First, the whole computation is moved to a different thread. The thread() function starts a new thread:

   ```
   thread {
       loadContributorsBlocking(service, req)
   }
   ```

   Now that all of the loading has been moved to a separate thread, the main thread is free and can be occupied by other tasks:

   The freed main thread

2. The signature of the loadContributorsBackground() function changes. It takes an updateResults() callback as the last argument to call it after all the loading completes:

   ```
   fun loadContributorsBackground(
       service: GitHubService, req: RequestData,
       updateResults: (List<User>) -> Unit
   )
   ```

3. Now when the loadContributorsBackground() is called, the updateResults() call goes in the callback, not immediately afterward as it did before:

   ```
   loadContributorsBackground(service, req) { users ->
       SwingUtilities.invokeLater {
           updateResults(users, startTime)
       }
   }
   ```

   By calling SwingUtilities.invokeLater, you ensure that the updateResults() call, which updates the results, happens on the main UI thread (AWT event dispatching thread).

However, if you try to load the contributors via the BACKGROUND option, you can see that the list is updated but nothing changes.

Task 2

Fix the loadContributorsBackground() function in src/tasks/Request2Background.kt so that the resulting list is shown in the UI.

Solution for task 2

If you try to load the contributors, you can see in the log that the contributors are loaded but the result isn't displayed. To fix this, call updateResults() on the resulting list of users:

```
thread {
    updateResults(loadContributorsBlocking(service, req))
}
```

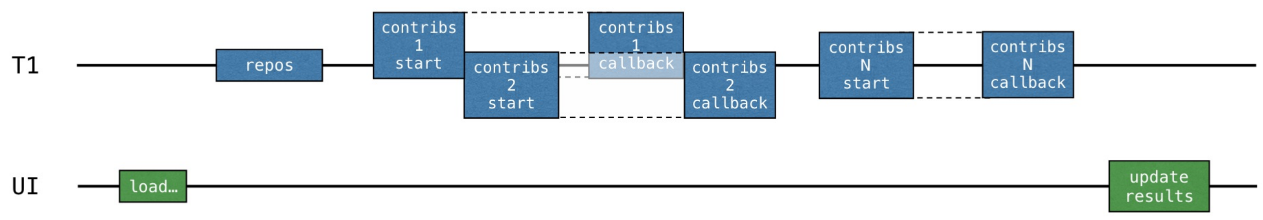
Make sure to call the logic passed in the callback explicitly. Otherwise, nothing will happen.

Use the Retrofit callback API

In the previous solution, the whole loading logic is moved to the background thread, but that still isn't the best use of resources. All of the loading requests go sequentially and the thread is blocked while waiting for the loading result, while it could have been occupied by other tasks. Specifically, the thread could start loading another request to receive the entire result earlier.

Handling the data for each repository should then be divided into two parts: loading and processing the resulting response. The second processing part should be extracted into a callback.

The loading for each repository can then be started before the result for the previous repository is received (and the corresponding callback is called):



Using callback API

The Retrofit callback API can help achieve this. The Call.enqueue() function starts an HTTP request and takes a callback as an argument. In this callback, you need to specify what needs to be done after each request.

Open src/tasks/Request3Callbacks.kt and see the implementation of loadContributorsCallbacks() that uses this API:

```
fun loadContributorsCallbacks(
    service: GitHubService, req: RequestData,
    updateResults: (List<User>) -> Unit
) {
    service.getOrgReposCall(req.org).onResponse { responseRepos ->  // #1
        logRepos(req, responseRepos)
        val repos = responseRepos.bodyList()

        val allUsers = mutableListOf<User>()
        for (repo in repos) {
            service.getRepoContributorsCall(req.org, repo.name)
                .onResponse { responseUsers ->  // #2
                    logUsers(repo, responseUsers)
                    val users = responseUsers.bodyList()
                    allUsers += users
                }
            }
        }
        // TODO: Why doesn't this code work? How to fix that?
        updateResults(allUsers.aggregate())
    }
```

- For convenience, this code fragment uses the onResponse() extension function declared in the same file. It takes a lambda as an argument rather than an object expression.
- The logic for handling the responses is extracted into callbacks: the corresponding lambdas start at lines #1 and #2.

However, the provided solution doesn't work. If you run the program and load contributors by choosing the CALLBACKS option, you'll see that nothing is shown. However, the test from Request3CallbacksKtTest immediately returns the result that it successfully passed.

Think about why the given code doesn't work as expected and try to fix it, or see the solutions below.

Task 3 (optional)

Rewrite the code in the src/tasks/Request3Callbacks.kt file so that the loaded list of contributors is shown.

The first attempted solution for task 3

In the current solution, many requests are started concurrently, which decreases the total loading time. However, the result isn't loaded. This is because the updateResults() callback is called right after all of the loading requests are started, before the allUsers list has been filled with the data.

You could try to fix this with a change like the following:

```
val allUsers = mutableListOf<User>()
for ((index, repo) in repos.withIndex()) {   // #1
    service.getRepoContributorsCall(req.org, repo.name)
        .onResponse { responseUsers ->
            logUsers(repo, responseUsers)
            val users = responseUsers.bodyList()
            allUsers += users
            if (index == repos.lastIndex) {    // #2
                updateResults(allUsers.aggregate())
            }
        }
}
```

- First, you iterate over the list of repos with an index (#1).
- Then, from each callback, you check whether it's the last iteration (#2).
- And if that's the case, the result is updated.

However, this code also fails to achieve our objective. Try to find the answer yourself, or see the solution below.

The second attempted solution for task 3

Since the loading requests are started concurrently, there's no guarantee that the result for the last one comes last. The results can come in any order.

Thus, if you compare the current index with the lastIndex as a condition for completion, you risk losing the results for some repos.

If the request that processes the last repo returns faster than some prior requests (which is likely to happen), all of the results for requests that take more time will be lost.

One way to fix this is to introduce an index and check whether all of the repositories have already been processed:

```
val allUsers = Collections.synchronizedList(mutableListOf<User>())
val numberOfProcessed = AtomicInteger()
for (repo in repos) {
    service.getRepoContributorsCall(req.org, repo.name)
        .onResponse { responseUsers ->
            logUsers(repo, responseUsers)
            val users = responseUsers.bodyList()
            allUsers += users
            if (numberOfProcessed.incrementAndGet() == repos.size) {
                updateResults(allUsers.aggregate())
            }
        }
}
```

This code uses a synchronized version of the list and AtomicInteger() because, in general, there's no guarantee that different callbacks that process getRepoContributors() requests will always be called from the same thread.

The third attempted solution for task 3

An even better solution is to use the CountDownLatch class. It stores a counter initialized with the number of repositories. This counter is decremented after processing each repository. It then waits until the latch is counted down to zero before updating the results:

```
val countDownLatch = CountDownLatch(repos.size)
for (repo in repos) {
    service.getRepoContributorsCall(req.org, repo.name)
        .onResponse { responseUsers ->
            // processing repository
            countDownLatch.countDown()
        }
}
countDownLatch.await()
updateResults(allUsers.aggregate())
```

The result is then updated from the main thread. This is more direct than delegating the logic to the child threads.

After reviewing these three attempts at a solution, you can see that writing correct code with callbacks is non-trivial and error-prone, especially when several underlying threads and synchronization occur.

As an additional exercise, you can implement the same logic using a reactive approach with the RxJava library. All of the necessary dependencies and solutions for using RxJava can be found in a separate rx branch. It is also possible to complete this tutorial and implement or check the proposed Rx versions for a proper comparison.

Suspending functions

You can implement the same logic using suspending functions. Instead of returning Call<List<Repo>>, define the API call as a suspending function as follows:

```
interface GitHubService {
    @GET("orgs/{org}/repos?per_page=100")
    suspend fun getOrgRepos(
        @Path("org") org: String
    ): List<Repo>
}
```

- getOrgRepos() is defined as a suspend function. When you use a suspending function to perform a request, the underlying thread isn't blocked. More details about how this works will come in later sections.
- getOrgRepos() returns the result directly instead of returning a Call. If the result is unsuccessful, an exception is thrown.

Alternatively, Retrofit allows returning the result wrapped in Response. In this case, the result body is provided, and it is possible to check for errors manually. This tutorial uses the versions that return Response.

In src/contributors/GitHubService.kt, add the following declarations to the GitHubService interface:

```
interface GitHubService {
    // getOrgReposCall & getRepoContributorsCall declarations

    @GET("orgs/{org}/repos?per_page=100")
    suspend fun getOrgRepos(
        @Path("org") org: String
    ): Response<List<Repo>>

    @GET("repos/{owner}/{repo}/contributors?per_page=100")
    suspend fun getRepoContributors(
        @Path("owner") owner: String,
        @Path("repo") repo: String
    ): Response<List<User>>
}
```

Task 4

Your task is to change the code of the function that loads contributors to make use of two new suspending functions, getOrgRepos() and getRepoContributors(). The new loadContributorsSuspend() function is marked as suspend to use the new API.

Suspending functions can't be called everywhere. Calling a suspending function from loadContributorsBlocking() will result in an error with the message "Suspend function 'getOrgRepos' should be called only from a coroutine or another suspend function".

1. Copy the implementation of loadContributorsBlocking() that is defined in src/tasks/Request1Blocking.kt into the loadContributorsSuspend() that is defined in src/tasks/Request4Suspend.kt.
2. Modify the code so that the new suspending functions are used instead of the ones that return Calls.
3. Run the program by choosing the SUSPEND option and ensure that the UI is still responsive while the GitHub requests are performed.

Solution for task 4

Replace .getOrgReposCall(req.org).execute() with .getOrgRepos(req.org) and repeat the same replacement for the second "contributors" request:

```
suspend fun loadContributorsSuspend(service: GitHubService, req: RequestData): List<User> {
    val repos = service
        .getOrgRepos(req.org)
        .also { logRepos(req, it) }
        .bodyList()

    return repos.flatMap { repo ->
        service.getRepoContributors(req.org, repo.name)
            .also { logUsers(repo, it) }
            .bodyList()
    }.aggregate()
}
```

- loadContributorsSuspend() should be defined as a suspend function.
- You no longer need to call execute, which returned the Response before, because now the API functions return the Response directly. Note that this detail is specific to the Retrofit library. With other libraries, the API will be different, but the concept is the same.

Coroutines

The code with suspending functions looks similar to the "blocking" version. The major difference from the blocking version is that instead of blocking the thread, the coroutine is suspended:

```
block -> suspend
thread -> coroutine
```

Coroutines are often called lightweight threads because you can run code on coroutines, similar to how you run code on threads. The operations that were blocking before (and had to be avoided) can now suspend the coroutine instead.

Starting a new coroutine

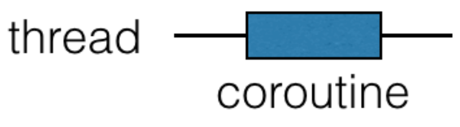
If you look at how loadContributorsSuspend() is used in src/contributors/Contributors.kt, you can see that it's called inside launch. launch is a library function that takes a lambda as an argument:

```
launch {
    val users = loadContributorsSuspend(req)
    updateResults(users, startTime)
}
```

Here launch starts a new computation that is responsible for loading the data and showing the results. The computation is suspendable – when performing network requests, it is suspended and releases the underlying thread. When the network request returns the result, the computation is resumed.

Such a suspendable computation is called a coroutine. So, in this case, launch starts a new coroutine responsible for loading data and showing the results.

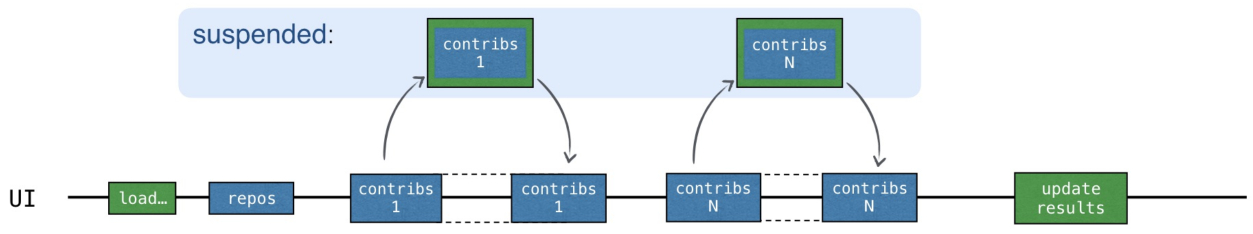
Coroutines run on top of threads and can be suspended. When a coroutine is suspended, the corresponding computation is paused, removed from the thread, and stored in memory. Meanwhile, the thread is free to be occupied by other tasks:



When the computation is ready to be continued, it is returned to a thread (not necessarily the same one).

In the loadContributorsSuspend() example, each "contributors" request now waits for the result using the suspension mechanism. First, the new request is sent. Then, while waiting for the response, the whole "load contributors" coroutine that was started by the launch function is suspended.

The coroutine resumes only after the corresponding response is received:



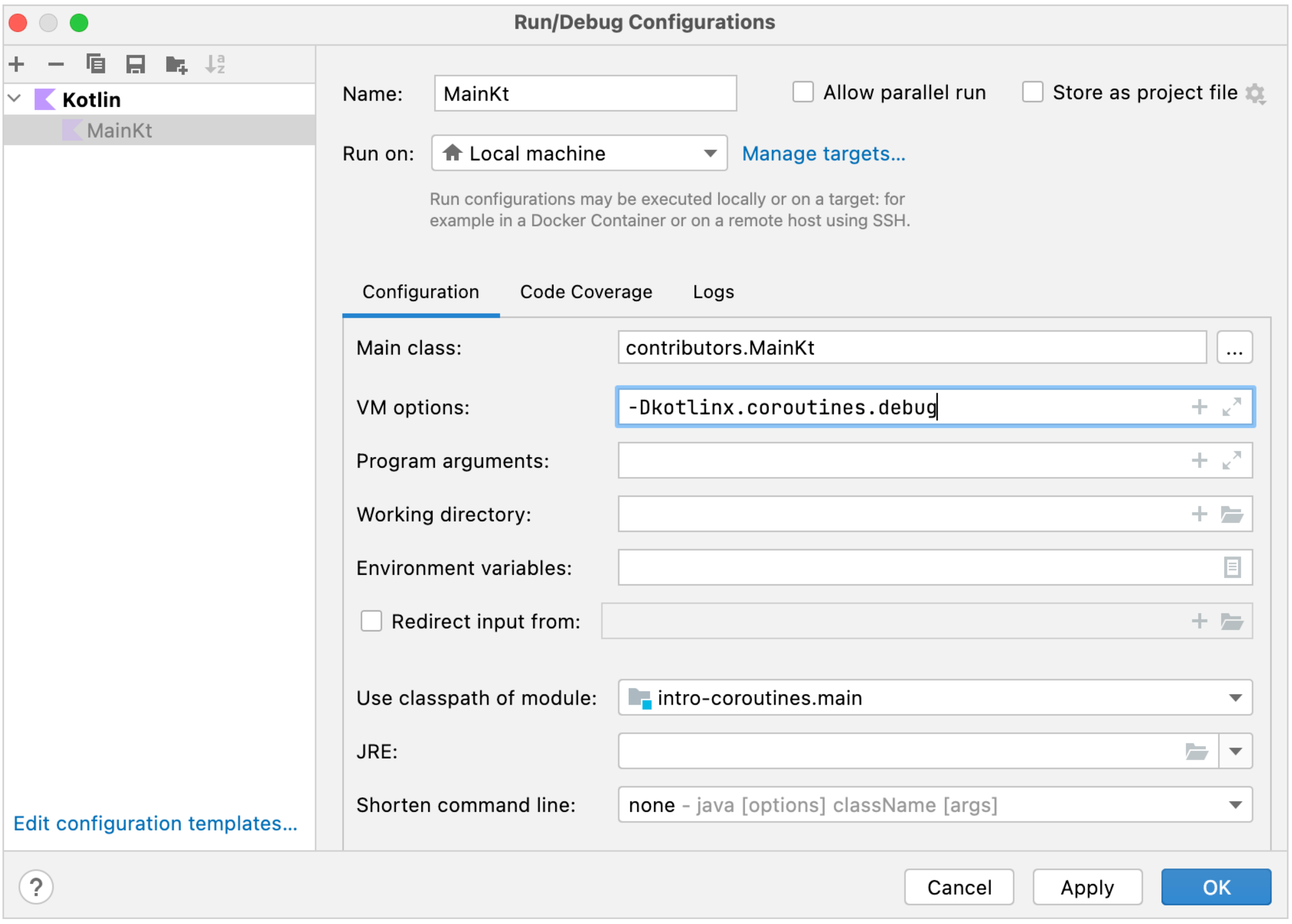
Suspending request

While the response is waiting to be received, the thread is free to be occupied by other tasks. The UI stays responsive, despite all the requests taking place on the main UI thread:

1. Run the program using the SUSPEND option. The log confirms that all of the requests are sent to the main UI thread:

```
2538 [AWT-EventQueue-0 @coroutine#1] INFO  Contributors - kotlin: loaded 30 repos
2729 [AWT-EventQueue-0 @coroutine#1] INFO  Contributors - ts2kt: loaded 11 contributors
3029 [AWT-EventQueue-0 @coroutine#1] INFO  Contributors - kotlin-koans: loaded 45 contributors
...
11252 [AWT-EventQueue-0 @coroutine#1] INFO  Contributors - kotlin-coroutines-workshop: loaded 1 contributors
```

2. The log can show you which coroutine the corresponding code is running on. To enable it, open Run | Edit configurations and add the -Dkotlinx.coroutines.debug VM option:



Name: MainKt
Allow parallel run
Store as project file
Run on: Local machine
Run configurations may be executed locally or on a target: for example in a Docker Container or on a remote host using SSH.

Main class: contributors.MainKt
VM options: -Dkotlinx.coroutines.debug
Program arguments:
Working directory:
Environment variables:
Redirect input from:
Use classpath of module: intro-coroutines.main
JRE:
Shorten command line: none - java [options] className [args]

Edit run configuration

The coroutine name will be attached to the thread name while main() is run with this option. You can also modify the template for running all of the Kotlin files and enable this option by default.

Now all of the code runs on one coroutine, the "load contributors" coroutine mentioned above, denoted as @coroutine#1. While waiting for the result, you shouldn't reuse the thread for sending other requests because the code is written sequentially. The new request is sent only when the previous result is received.

Suspending functions treat the thread fairly and don't block it for "waiting". However, this doesn't yet bring any concurrency into the picture.

Concurrency

Kotlin coroutines are much less resource-intensive than threads. Each time you want to start a new computation asynchronously, you can create a new coroutine instead.

To start a new coroutine, use one of the main coroutine builders: launch, async, or runBlocking. Different libraries can define additional coroutine builders.

async starts a new coroutine and returns a Deferred object. Deferred represents a concept known by other names such as Future or Promise. It stores a computation, but it defers the moment you get the final result; it promises the result sometime in the future.

The main difference between async and launch is that launch is used to start a computation that isn't expected to return a specific result. launch returns a Job that represents the coroutine. It is possible to wait until it completes by calling Job.join().

Deferred is a generic type that extends Job. An async call can return a Deferred<Int> or a Deferred<CustomType>, depending on what the lambda returns (the last expression inside the lambda is the result).

To get the result of a coroutine, you can call await() on the Deferred instance. While waiting for the result, the coroutine that this await() is called from is suspended:

```
import kotlinx.coroutines.*

fun main() = runBlocking {
    val deferred: Deferred<Int> = async {
        loadData()
    }
    println("waiting...")
    println(deferred.await())
}

suspend fun loadData(): Int {
    println("loading...")
    delay(1000L)
    println("loaded!")
    return 42
}
```

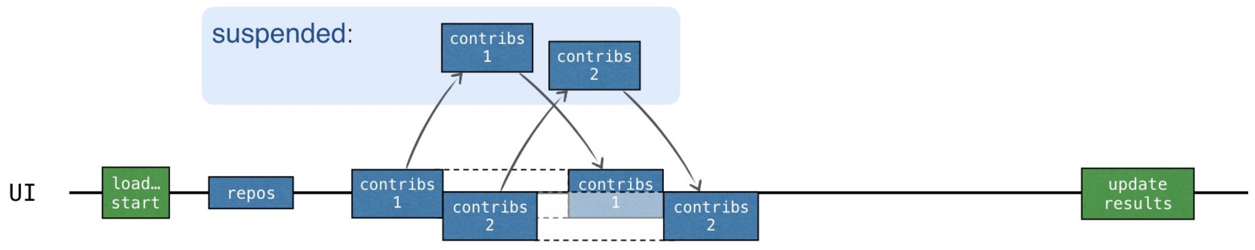
runBlocking is used as a bridge between regular and suspending functions, or between the blocking and non-blocking worlds. It works as an adaptor for starting the top-level main coroutine. It is intended primarily to be used in main() functions and tests.

> Watch this video for a better understanding of coroutines.

If there is a list of deferred objects, you can call awaitAll() to await the results of all of them:

```
import kotlinx.coroutines.*

fun main() = runBlocking {
    val deferreds: List<Deferred<Int>> = (1..3).map {
        async {
            delay(1000L * it)
            println("Loading $it")
            it
        }
    }
    val sum = deferreds.awaitAll().sum()
    println("$sum")
}
```

When each "contributors" request is started in a new coroutine, all of the requests are started asynchronously. A new request can be sent before the result for the previous one is received:



Concurrent coroutines

The total loading time is approximately the same as in the CALLBACKS version, but it doesn't need any callbacks. What's more, async explicitly emphasizes which parts run concurrently in the code.

Task 5

In the Request5Concurrent.kt file, implement a loadContributorsConcurrent() function by using the previous loadContributorsSuspend() function.

Tip for task 5

You can only start a new coroutine inside a coroutine scope. Copy the content from loadContributorsSuspend() to the coroutineScope call so that you can call async functions there:

```
suspend fun loadContributorsConcurrent(
    service: GitHubService,
    req: RequestData
): List<User> = coroutineScope {
    // ...
}
```

Base your solution on the following scheme:

```
val deferreds: List<Deferred<List<User>>> = repos.map { repo ->
    async {
        // load contributors for each repo
    }
}
deferreds.awaitAll() // List<List<User>>
```

Solution for task 5

Wrap each "contributors" request with async to create as many coroutines as there are repositories. async returns Deferred<List<User>>. This is not an issue because creating new coroutines is not very resource-intensive, so you can create as many as you need.

1. You can no longer use flatMap because the map result is now a list of Deferred objects, not a list of lists. awaitAll() returns List<List<User>>, so call flatten().aggregate() to get the result:

```
suspend fun loadContributorsConcurrent(
    service: GitHubService,
    req: RequestData
): List<User> = coroutineScope {
    val repos = service
        .getOrgRepos(req.org)
        .also { logRepos(req, it) }
        .bodyList()

    val deferreds: List<Deferred<List<User>>> = repos.map { repo ->
        async {
            service.getRepoContributors(req.org, repo.name)
                .also { logUsers(repo, it) }
                .bodyList()
        }
    }
    deferreds.awaitAll().flatten().aggregate()
}
```

2. Run the code and check the log. All of the coroutines still run on the main UI thread because multithreading hasn't been employed yet, but you can already see the benefits of running coroutines concurrently.

3. To change this code to run "contributors" coroutines on different threads from the common thread pool, specify Dispatchers.Default as the context argument for the async function:

```
async(Dispatchers.Default) { }
```

- CoroutineDispatcher determines what thread or threads the corresponding coroutine should be run on. If you don't specify one as an argument, async will use the dispatcher from the outer scope.
- Dispatchers.Default represents a shared pool of threads on the JVM. This pool provides a means for parallel execution. It consists of as many threads as there are CPU cores available, but it will still have two threads if there's only one core.

4. Modify the code in the loadContributorsConcurrent() function to start new coroutines on different threads from the common thread pool. Also, add additional logging before sending the request:

```
async(Dispatchers.Default) {
    log("starting loading for ${repo.name}")
    service.getRepoContributors(req.org, repo.name)
        .also { logUsers(repo, it) }
        .bodyList()
}
```

5. Run the program once again. In the log, you can see that each coroutine can be started on one thread from the thread pool and resumed on another:

```
1946 [DefaultDispatcher-worker-2 @coroutine#4] INFO  Contributors - starting loading for kotlin-koans
1946 [DefaultDispatcher-worker-3 @coroutine#5] INFO  Contributors - starting loading for dokka
```

```
1946 [DefaultDispatcher-worker-1 @coroutine#3] INFO  Contributors - starting loading for ts2kt
...
2178 [DefaultDispatcher-worker-1 @coroutine#4] INFO  Contributors - kotlin-koans: loaded 45 contributors
2569 [DefaultDispatcher-worker-1 @coroutine#5] INFO  Contributors - dokka: loaded 36 contributors
2821 [DefaultDispatcher-worker-2 @coroutine#3] INFO  Contributors - ts2kt: loaded 11 contributors
```

For instance, in this log excerpt, coroutine#4 is started on the worker-2 thread and continued on the worker-1 thread.

In src/contributors/Contributors.kt, check the implementation of the CONCURRENT option:

1. To run the coroutine only on the main UI thread, specify Dispatchers.Main as an argument:

   ```
   launch(Dispatchers.Main) {
       updateResults()
   }
   ```

   - If the main thread is busy when you start a new coroutine on it, the coroutine becomes suspended and scheduled for execution on this thread. The coroutine will only resume when the thread becomes free.
   - It's considered good practice to use the dispatcher from the outer scope rather than explicitly specifying it on each end-point. If you define loadContributorsConcurrent() without passing Dispatchers.Default as an argument, you can call this function in any context: with a Default dispatcher, with the main UI thread, or with a custom dispatcher.
   - As you'll see later, when calling loadContributorsConcurrent() from tests, you can call it in the context with TestDispatcher, which simplifies testing. That makes this solution much more flexible.

2. To specify the dispatcher on the caller side, apply the following change to the project while letting loadContributorsConcurrent start coroutines in the inherited context:

   ```
   launch(Dispatchers.Default) {
       val users = loadContributorsConcurrent(service, req)
       withContext(Dispatchers.Main) {
           updateResults(users, startTime)
       }
   }
   ```

   - updateResults() should be called on the main UI thread, so you call it with the context of Dispatchers.Main.
   - withContext() calls the given code with the specified coroutine context, is suspended until it completes, and returns the result. An alternative but more verbose way to express this would be to start a new coroutine and explicitly wait (by suspending) until it completes: launch(context) { ... }.join().

3. Run the code and ensure that the coroutines are executed on the threads from the thread pool.

Structured concurrency

- The coroutine scope is responsible for the structure and parent-child relationships between different coroutines. New coroutines usually need to be started inside a scope.
- The coroutine context stores additional technical information used to run a given coroutine, like the coroutine custom name, or the dispatcher specifying the threads the coroutine should be scheduled on.

When launch, async, or runBlocking are used to start a new coroutine, they automatically create the corresponding scope. All of these functions take a lambda with a receiver as an argument, and CoroutineScope is the implicit receiver type:

```
launch { /* this: CoroutineScope */ }
```

- New coroutines can only be started inside a scope.
- launch and async are declared as extensions to CoroutineScope, so an implicit or explicit receiver must always be passed when you call them.
- The coroutine started by runBlocking is the only exception because runBlocking is defined as a top-level function. But because it blocks the current thread, it's intended primarily to be used in main() functions and tests as a bridge function.

A new coroutine inside runBlocking, launch, or async is started automatically inside the scope:

```
import kotlinx.coroutines.*
```

```
fun main() = runBlocking { /* this: CoroutineScope */
    launch { /* ... */ }
    // the same as:
    this.launch { /* ... */ }
}
```

When you call launch inside runBlocking, it's called as an extension to the implicit receiver of the CoroutineScope type. Alternatively, you could explicitly write this.launch.

The nested coroutine (started by launch in this example) can be considered as a child of the outer coroutine (started by runBlocking). This "parent-child" relationship works through scopes; the child coroutine is started from the scope corresponding to the parent coroutine.

It's possible to create a new scope without starting a new coroutine, by using the coroutineScope function. To start new coroutines in a structured way inside a suspend function without access to the outer scope, you can create a new coroutine scope that automatically becomes a child of the outer scope that this suspend function is called from. loadContributorsConcurrent()is a good example.

You can also start a new coroutine from the global scope using GlobalScope.async or GlobalScope.launch. This will create a top-level "independent" coroutine.

The mechanism behind the structure of the coroutines is called structured concurrency. It provides the following benefits over global scopes:

- The scope is generally responsible for child coroutines, whose lifetime is attached to the lifetime of the scope.
- The scope can automatically cancel child coroutines if something goes wrong or a user changes their mind and decides to revoke the operation.
- The scope automatically waits for the completion of all child coroutines. Therefore, if the scope corresponds to a coroutine, the parent coroutine does not complete until all the coroutines launched in its scope have completed.

When using GlobalScope.async, there is no structure that binds several coroutines to a smaller scope. Coroutines started from the global scope are all independent – their lifetime is limited only by the lifetime of the whole application. It's possible to store a reference to the coroutine started from the global scope and wait for its completion or cancel it explicitly, but that won't happen automatically as it would with structured concurrency.

Canceling the loading of contributors

Create two versions of the function that loads the list of contributors. Compare how both versions behave when you try to cancel the parent coroutine. The first version will use coroutineScope to start all of the child coroutines, whereas the second will use GlobalScope.

1. In Request5Concurrent.kt, add a 3-second delay to the loadContributorsConcurrent() function:

   ```
   suspend fun loadContributorsConcurrent(
       service: GitHubService,
       req: RequestData
   ): List<User> = coroutineScope {
       // ...
       async {
           log("starting loading for ${repo.name}")
           delay(3000)
           // load repo contributors
       }
       // ...
   }
   ```

   The delay affects all of the coroutines that send requests, so that there's enough time to cancel the loading after the coroutines are started but before the requests are sent.

2. Create the second version of the loading function: copy the implementation of loadContributorsConcurrent() to loadContributorsNotCancellable() in Request5NotCancellable.kt and then remove the creation of a new coroutineScope.

3. The async calls now fail to resolve, so start them by using GlobalScope.async:

   ```
   suspend fun loadContributorsNotCancellable(
       service: GitHubService,
       req: RequestData
   ): List<User> {   // #1
       // ...
       GlobalScope.async {   // #2
           log("starting loading for ${repo.name}")
           // load repo contributors
       }
       // ...
       return deferreds.awaitAll().flatten().aggregate()  // #3
   ```

```
}
```

- The function now returns the result directly, not as the last expression inside the lambda (lines #1 and #3).
- All of the "contributors" coroutines are started inside the GlobalScope, not as children of the coroutine scope (line #2).

4. Run the program and choose the CONCURRENT option to load the contributors.
5. Wait until all of the "contributors" coroutines are started, and then click Cancel. The log shows no new results, which means that all of the requests were indeed canceled:

```
2896 [AWT-EventQueue-0 @coroutine#1] INFO  Contributors - kotlin: loaded 40 repos
2901 [DefaultDispatcher-worker-2 @coroutine#4] INFO  Contributors - starting loading for kotlin-koans
...
2909 [DefaultDispatcher-worker-5 @coroutine#36] INFO  Contributors - starting loading for mpp-example
/* click on 'cancel' */
/* no requests are sent */
```

6. Repeat step 5, but this time choose the NOT_CANCELLABLE option:

```
2570 [AWT-EventQueue-0 @coroutine#1] INFO  Contributors - kotlin: loaded 30 repos
2579 [DefaultDispatcher-worker-1 @coroutine#4] INFO  Contributors - starting loading for kotlin-koans
...
2586 [DefaultDispatcher-worker-6 @coroutine#36] INFO  Contributors - starting loading for mpp-example
/* click on 'cancel' */
/* but all the requests are still sent: */
6402 [DefaultDispatcher-worker-5 @coroutine#4] INFO  Contributors - kotlin-koans: loaded 45 contributors
...
9555 [DefaultDispatcher-worker-8 @coroutine#36] INFO  Contributors - mpp-example: loaded 8 contributors
```

In this case, no coroutines are canceled, and all the requests are still sent.

7. Check how the cancellation is triggered in the "contributors" program. When the Cancel button is clicked, the main "loading" coroutine is explicitly canceled and the child coroutines are canceled automatically:

```
interface Contributors {

    fun loadContributors() {
        // ...
        when (getSelectedVariant()) {
            CONCURRENT -> {
                launch {
                    val users = loadContributorsConcurrent(service, req)
                    updateResults(users, startTime)
                }.setUpCancellation()      // #1
            }
        }
    }

    private fun Job.setUpCancellation() {
        val loadingJob = this              // #2

        // cancel the loading job if the 'cancel' button was clicked:
        val listener = ActionListener {
            loadingJob.cancel()            // #3
            updateLoadingStatus(CANCELED)
        }
        // add a listener to the 'cancel' button:
        addCancelListener(listener)

        // update the status and remove the listener
        // after the loading job is completed
    }
}
```

The launch function returns an instance of Job. Job stores a reference to the "loading coroutine", which loads all of the data and updates the results. You can call the setUpCancellation() extension function on it (line #1), passing an instance of Job as a receiver.

Another way you could express this would be to explicitly write:

```
val job = launch { }
job.setUpCancellation()
```

- For readability, you could refer to the setUpCancellation() function receiver inside the function with the new loadingJob variable (line #2).
- Then you could add a listener to the Cancel button so that when it's clicked, the loadingJob is canceled (line #3).

With structured concurrency, you only need to cancel the parent coroutine and this automatically propagates cancellation to all of the child coroutines.

Using the outer scope's context

When you start new coroutines inside the given scope, it's much easier to ensure that all of them run with the same context. It is also much easier to replace the context if needed.

Now it's time to learn how using the dispatcher from the outer scope works. The new scope created by the coroutineScope or by the coroutine builders always inherits the context from the outer scope. In this case, the outer scope is the scope the suspend loadContributorsConcurrent() function was called from:

```
launch(Dispatchers.Default) {  // outer scope
    val users = loadContributorsConcurrent(service, req)
    // ...
}
```

All of the nested coroutines are automatically started with the inherited context. The dispatcher is a part of this context. That's why all of the coroutines started by async are started with the context of the default dispatcher:

```
suspend fun loadContributorsConcurrent(
    service: GitHubService, req: RequestData
): List<User> = coroutineScope {
    // this scope inherits the context from the outer scope
    // ...
    async {   // nested coroutine started with the inherited context
        // ...
    }
    // ...
}
```

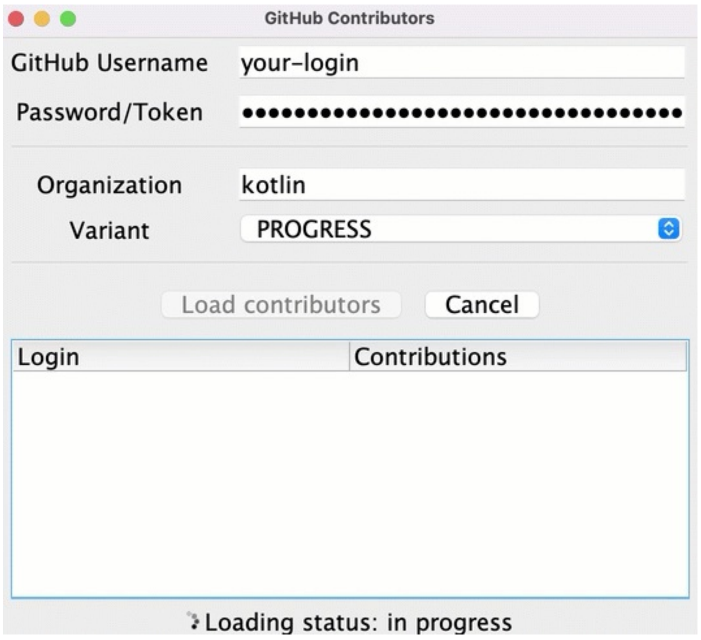
With structured concurrency, you can specify the major context elements (like dispatcher) once, when creating the top-level coroutine. All the nested coroutines then inherit the context and modify it only if needed.

> When you write code with coroutines for UI applications, for example Android ones, it's a common practice to use CoroutineDispatchers.Main by default for the top coroutine and then to explicitly put a different dispatcher when you need to run the code on a different thread.

Showing progress

Despite the information for some repositories being loaded rather quickly, the user only sees the resulting list after all of the data has been loaded. Until then, the loader icon runs showing the progress, but there's no information about the current state or what contributors are already loaded.

You can show the intermediate results earlier and display all of the contributors after loading the data for each of the repositories:



GitHub Username: your-login
Password/Token: ••••••••••••••••••••••••••••••••••
Organization: kotlin
Variant: PROGRESS
Loading status: in progress

To implement this functionality, in the src/tasks/Request6Progress.kt, you'll need to pass the logic updating the UI as a callback, so that it's called on each intermediate state:

```kotlin
suspend fun loadContributorsProgress(
    service: GitHubService,
    req: RequestData,
    updateResults: suspend (List<User>, completed: Boolean) -> Unit
) {
    // loading the data
    // calling `updateResults()` on intermediate states
}
```

On the call site in Contributors.kt, the callback is passed to update the results from the Main thread for the PROGRESS option:

```kotlin
launch(Dispatchers.Default) {
    loadContributorsProgress(service, req) { users, completed ->
        withContext(Dispatchers.Main) {
            updateResults(users, startTime, completed)
        }
    }
}
```

- The updateResults() parameter is declared as suspend in loadContributorsProgress(). It's necessary to call withContext, which is a suspend function inside the corresponding lambda argument.
- updateResults() callback takes an additional Boolean parameter as an argument specifying whether the loading has completed and the results are final.

Task 6

In the Request6Progress.kt file, implement the loadContributorsProgress() function that shows the intermediate progress. Base it on the loadContributorsSuspend() function from Request4Suspend.kt.

- Use a simple version without concurrency; you'll add it later in the next section.
- The intermediate list of contributors should be shown in an "aggregated" state, not just the list of users loaded for each repository.
- The total number of contributions for each user should be increased when the data for each new repository is loaded.

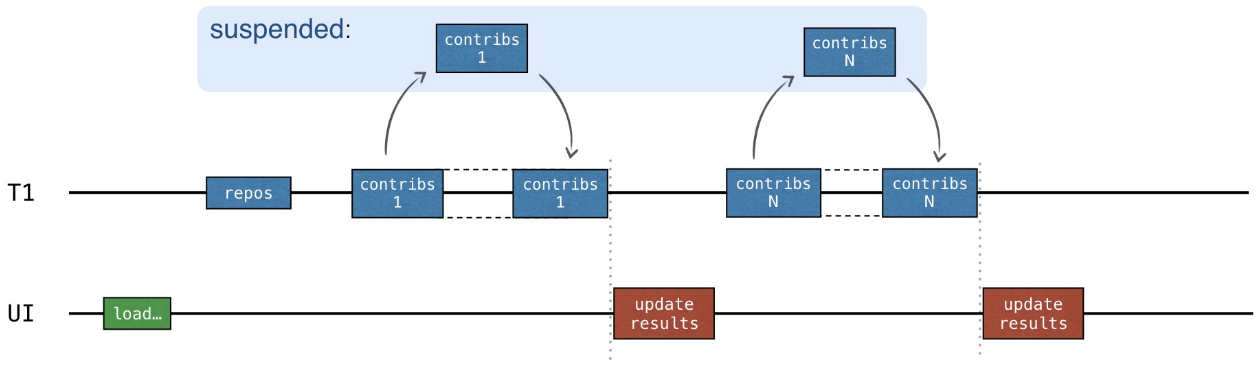
Solution for task 6

To store the intermediate list of loaded contributors in the "aggregated" state, define an allUsers variable which stores the list of users, and then update it after contributors for each new repository are loaded:

```
suspend fun loadContributorsProgress(
    service: GitHubService,
    req: RequestData,
    updateResults: suspend (List<User>, completed: Boolean) -> Unit
) {
    val repos = service
        .getOrgRepos(req.org)
        .also { logRepos(req, it) }
        .bodyList()

    var allUsers = emptyList<User>()
    for ((index, repo) in repos.withIndex()) {
        val users = service.getRepoContributors(req.org, repo.name)
            .also { logUsers(repo, it) }
            .bodyList()

        allUsers = (allUsers + users).aggregate()
        updateResults(allUsers, index == repos.lastIndex)
    }
}
```

Consecutive vs concurrent

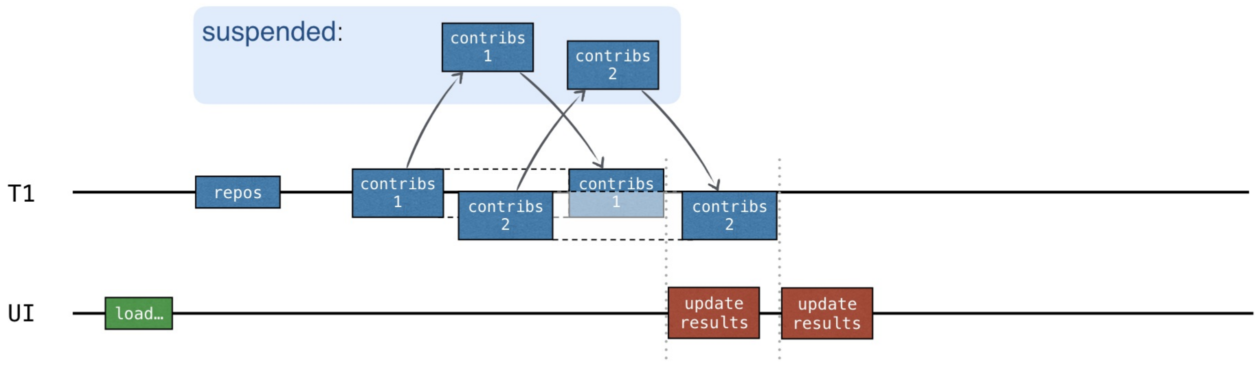
An updateResults() callback is called after each request is completed:



Progress on requests

This code doesn't include concurrency. It's sequential, so you don't need synchronization.

The best option would be to send requests concurrently and update the intermediate results after getting the response for each repository:



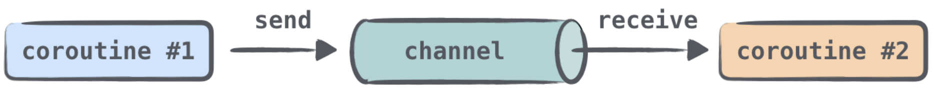
Concurrent requests

To add concurrency, use channels.

Channels

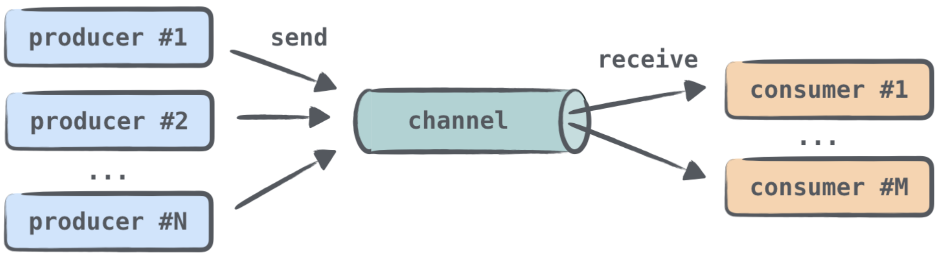
Writing code with a shared mutable state is quite difficult and error-prone (like in the solution using callbacks). A simpler way is to share information by communication rather than by using a common mutable state. Coroutines can communicate with each other through channels.

Channels are communication primitives that allow data to be passed between coroutines. One coroutine can send some information to a channel, while another can receive that information from it:



Using channels

A coroutine that sends (produces) information is often called a producer, and a coroutine that receives (consumes) information is called a consumer. One or multiple coroutines can send information to the same channel, and one or multiple coroutines can receive data from it:



Using channels with many coroutines

When many coroutines receive information from the same channel, each element is handled only once by one of the consumers. Once an element is handled, it is immediately removed from the channel.

You can think of a channel as similar to a collection of elements, or more precisely, a queue, in which elements are added to one end and received from the other. However, there's an important difference: unlike collections, even in their synchronized versions, a channel can suspend send()and receive() operations. This happens when the channel is empty or full. The channel can be full if the channel size has an upper bound.

Channel is represented by three different interfaces: SendChannel, ReceiveChannel, and Channel, with the latter extending the first two. You usually create a channel and give it to producers as a SendChannel instance so that only they can send information to the channel. You give a channel to consumers as a ReceiveChannel instance so that only they can receive from it. Both send and receive methods are declared as suspend:

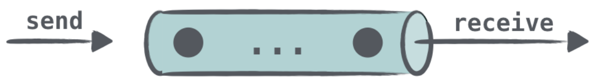
```
interface SendChannel<in E> {
    suspend fun send(element: E)
    fun close(): Boolean
}

interface ReceiveChannel<out E> {
    suspend fun receive(): E
}

interface Channel<E> : SendChannel<E>, ReceiveChannel<E>
```

The producer can close a channel to indicate that no more elements are coming.

Several types of channels are defined in the library. They differ in how many elements they can internally store and whether the send() call can be suspended or not. For all of the channel types, the receive() call behaves similarly: it receives an element if the channel is not empty; otherwise, it is suspended.

Unlimited channel

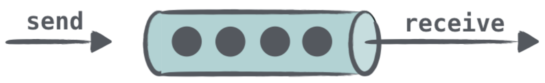
An unlimited channel is the closest analog to a queue: producers can send elements to this channel and it will keep growing indefinitely. The send() call will never be suspended. If the program runs out of memory, you'll get an OutOfMemoryException. The difference between an unlimited channel and a queue is that when a consumer tries to receive from an empty channel, it becomes suspended until some new elements are sent.



Unlimited channel

Buffered channel

The size of a buffered channel is constrained by the specified number. Producers can send elements to this channel until the size limit is reached. All of the elements are internally stored. When the channel is full, the next `send` call on it is suspended until more free space becomes available.



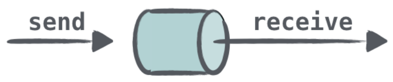
Buffered channel

Rendezvous channel

The "Rendezvous" channel is a channel without a buffer, the same as a buffered channel with zero size. One of the functions (send() or receive()) is always suspended until the other is called.

If the send() function is called and there's no suspended receive() call ready to process the element, then send() is suspended. Similarly, if the receive() function is called and the channel is empty or, in other words, there's no suspended send() call ready to send the element, the receive() call is suspended.

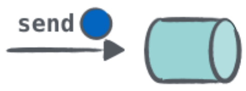
The "rendezvous" name ("a meeting at an agreed time and place") refers to the fact that send() and receive() should "meet on time".



Rendezvous channel

Conflated channel

A new element sent to the conflated channel will overwrite the previously sent element, so the receiver will always get only the latest element. The send() call is never suspended.



When you create a channel, specify its type or the buffer size (if you need a buffered one):

```
val rendezvousChannel = Channel<String>()
val bufferedChannel = Channel<String>(10)
val conflatedChannel = Channel<String>(CONFLATED)
val unlimitedChannel = Channel<String>(UNLIMITED)
```

By default, a "Rendezvous" channel is created.

In the following task, you'll create a "Rendezvous" channel, two producer coroutines, and a consumer coroutine:

```
import kotlinx.coroutines.channels.Channel
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> {
    val channel = Channel<String>()
    launch {
        channel.send("A1")
        channel.send("A2")
        log("A done")
    }
    launch {
        channel.send("B1")
        log("B done")
    }
    launch {
        repeat(3) {
            val x = channel.receive()
            log(x)
        }
    }
}

fun log(message: Any?) {
    println("[${Thread.currentThread().name}] $message")
}
```

Watch this video for a better understanding of channels.

Task 7

In src/tasks/Request7Channels.kt, implement the function loadContributorsChannels() that requests all of the GitHub contributors concurrently and shows intermediate progress at the same time.

Use the previous functions, loadContributorsConcurrent() from Request5Concurrent.kt and loadContributorsProgress() from Request6Progress.kt.

Tip for task 7

Different coroutines that concurrently receive contributor lists for different repositories can send all of the received results to the same channel:

```
val channel = Channel<List<User>>()
for (repo in repos) {
    launch {
        val users = TODO()
        // ...
        channel.send(users)
    }
}
```

Then the elements from this channel can be received one by one and processed:

```
repeat(repos.size) {
    val users = channel.receive()
    // ...
}
```

Since the receive() calls are sequential, no additional synchronization is needed.

Solution for task 7

As with the loadContributorsProgress() function, you can create an allUsers variable to store the intermediate states of the "all contributors" list. Each new list received from the channel is added to the list of all users. You aggregate the result and update the state using the updateResults callback:

```
suspend fun loadContributorsChannels(
    service: GitHubService,
    req: RequestData,
    updateResults: suspend (List<User>, completed: Boolean) -> Unit
) = coroutineScope {

    val repos = service
        .getOrgRepos(req.org)
        .also { logRepos(req, it) }
        .bodyList()
    val channel = Channel<List<User>>()
    for (repo in repos) {
        launch {
            val users = service.getRepoContributors(req.org, repo.name)
                .also { logUsers(repo, it) }
                .bodyList()
            channel.send(users)
        }
    }
    var allUsers = emptyList<User>()
    repeat(repos.size) {
        val users = channel.receive()
        allUsers = (allUsers + users).aggregate()
        updateResults(allUsers, it == repos.lastIndex)
    }
}
```

- Results for different repositories are added to the channel as soon as they are ready. At first, when all of the requests are sent, and no data is received, the receive() call is suspended. In this case, the whole "load contributors" coroutine is suspended.
- Then, when the list of users is sent to the channel, the "load contributors" coroutine resumes, the receive() call returns this list, and the results are immediately updated.

You can now run the program and choose the CHANNELS option to load the contributors and see the result.

Although neither coroutines nor channels completely remove the complexity that comes with concurrency, they make life easier when you need to understand what's going on.

Testing coroutines

Let's now test all solutions to check that the solution with concurrent coroutines is faster than the solution with the suspend functions, and check that the solution with channels is faster than the simple "progress" one.

In the following task, you'll compare the total running time of the solutions. You'll mock a GitHub service and make this service return results after the given timeouts:

```
repos request - returns an answer within 1000 ms delay
repo-1 - 1000 ms delay
repo-2 - 1200 ms delay
repo-3 - 800 ms delay
```

The sequential solution with the suspend functions should take around 4000 ms (4000 = 1000 + (1000 + 1200 + 800)). The concurrent solution should take around 2200 ms (2200 = 1000 + max(1000, 1200, 800)).

For the solutions that show progress, you can also check the intermediate results with timestamps.

The corresponding test data is defined in test/contributors/testData.kt, and the files Request4SuspendKtTest, Request7ChannelsKtTest, and so on contain the straightforward tests that use mock service calls.

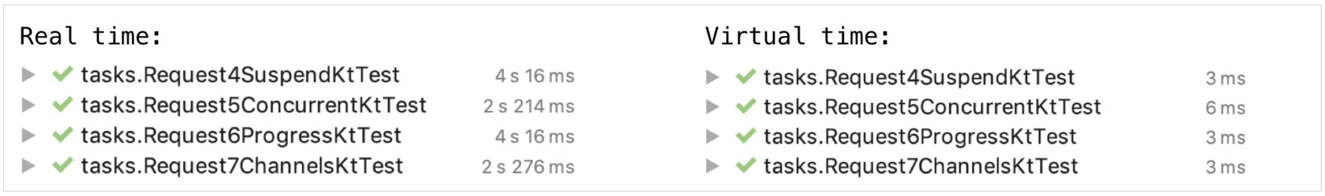
However, there are two problems here:

- These tests take too long to run. Each test takes around 2 to 4 seconds, and you need to wait for the results each time. It's not very efficient.
- You can't rely on the exact time the solution runs because it still takes additional time to prepare and run the code. You could add a constant, but then the time would differ from machine to machine. The mock service delays should be higher than this constant so you can see a difference. If the constant is 0.5 sec, making the delays 0.1 sec won't be enough.

A better way would be to use special frameworks to test the timing while running the same code several times (which increases the total time even more), but that is complicated to learn and set up.

To solve these problems and make sure that solutions with provided test delays behave as expected, one faster than the other, use virtual time with a special test dispatcher. This dispatcher keeps track of the virtual time passed from the start and runs everything immediately in real time. When you run coroutines on this dispatcher, the delay will return immediately and advance the virtual time.

Tests that use this mechanism run fast, but you can still check what happens at different moments in virtual time. The total running time drastically decreases:


Real time:

✓ tasks.Request4SuspendKtTest	4 s 16 ms
✓ tasks.Request5ConcurrentKtTest	2 s 214 ms
✓ tasks.Request6ProgressKtTest	4 s 16 ms
✓ tasks.Request7ChannelsKtTest	2 s 276 ms

Virtual time:

✓ tasks.Request4SuspendKtTest	3 ms
✓ tasks.Request5ConcurrentKtTest	6 ms
✓ tasks.Request6ProgressKtTest	3 ms
✓ tasks.Request7ChannelsKtTest	3 ms

Comparison for total running time

To use virtual time, replace the runBlocking invocation with a runTest. runTest takes an extension lambda to TestScope as an argument. When you call delay in a suspend function inside this special scope, delay will increase the virtual time instead of delaying in real time:

```kotlin
@Test
fun testDelayInSuspend() = runTest {
    val realStartTime = System.currentTimeMillis()
    val virtualStartTime = currentTime

    foo()
    println("${System.currentTimeMillis() - realStartTime} ms") // ~ 6 ms
    println("${currentTime - virtualStartTime} ms")            // 1000 ms
}

suspend fun foo() {
    delay(1000)    // auto-advances without delay
    println("foo") // executes eagerly when foo() is called
}
```

You can check the current virtual time using the currentTime property of TestScope.

The actual running time in this example is several milliseconds, whereas virtual time equals the delay argument, which is 1000 milliseconds.

To get the full effect of "virtual" delay in child coroutines, start all of the child coroutines with TestDispatcher. Otherwise, it won't work. This dispatcher is automatically inherited from the other TestScope, unless you provide a different dispatcher:

```kotlin
@Test
fun testDelayInLaunch() = runTest {
    val realStartTime = System.currentTimeMillis()
    val virtualStartTime = currentTime

    bar()

    println("${System.currentTimeMillis() - realStartTime} ms") // ~ 11 ms
    println("${currentTime - virtualStartTime} ms")            // 1000 ms
}

suspend fun bar() = coroutineScope {
    launch {
        delay(1000)    // auto-advances without delay
        println("bar") // executes eagerly when bar() is called
    }
}
```

If launch is called with the context of Dispatchers.Default in the example above, the test will fail. You'll get an exception saying that the job has not been completed yet.

You can test the loadContributorsConcurrent() function this way only if it starts the child coroutines with the inherited context, without modifying it using the Dispatchers.Default dispatcher.

You can specify the context elements like the dispatcher when calling a function rather than when defining it, which allows for more flexibility and easier testing.

The testing API that supports virtual time is Experimental and may change in the future.

By default, the compiler shows warnings if you use the experimental testing API. To suppress these warnings, annotate the test function or the whole class containing the tests with @OptIn(ExperimentalCoroutinesApi::class). Add the compiler argument instructing the compiler that you're using the experimental API:

```kotlin
compileTestKotlin {
    kotlinOptions {
        freeCompilerArgs += "-Xuse-experimental=kotlin.Experimental"
    }
}
```

In the project corresponding to this tutorial, the compiler argument has already been added to the Gradle script.

Task 8

Refactor the following tests in tests/tasks/ to use virtual time instead of real time:

- Request4SuspendKtTest.kt
- Request5ConcurrentKtTest.kt
- Request6ProgressKtTest.kt
- Request7ChannelsKtTest.kt

Compare the total running times before and after applying your refactoring.

Tip for task 8

1. Replace the runBlocking invocation with runTest, and replace System.currentTimeMillis() with currentTime:

```
@Test
fun test() = runTest {
    val startTime = currentTime
    // action
    val totalTime = currentTime - startTime
    // testing result
}
```

2. Uncomment the assertions that check the exact virtual time.

3. Don't forget to add @UseExperimental(ExperimentalCoroutinesApi::class).

Solution for task 8

Here are the solutions for the concurrent and channels cases:

```
fun testConcurrent() = runTest {
    val startTime = currentTime
    val result = loadContributorsConcurrent(MockGithubService, testRequestData)
    Assert.assertEquals("Wrong result for 'loadContributorsConcurrent'", expectedConcurrentResults.users, result)
    val totalTime = currentTime - startTime

    Assert.assertEquals(
        "The calls run concurrently, so the total virtual time should be 2200 ms: " +
                "1000 for repos request plus max(1000, 1200, 800) = 1200 for concurrent contributors requests)",
        expectedConcurrentResults.timeFromStart, totalTime
    )
}
```

First, check that the results are available exactly at the expected virtual time, and then check the results themselves:

```
fun testChannels() = runTest {
    val startTime = currentTime
    var index = 0
    loadContributorsChannels(MockGithubService, testRequestData) { users, _ ->
        val expected = concurrentProgressResults[index++]
        val time = currentTime - startTime
        Assert.assertEquals(
            "Expected intermediate results after ${expected.timeFromStart} ms:",
            expected.timeFromStart, time
        )
        Assert.assertEquals("Wrong intermediate results after $time:", expected.users, users)
    }
}
```

The first intermediate result for the last version with channels becomes available sooner than the progress version, and you can see the difference in tests that use virtual time.

> The tests for the remaining "suspend" and "progress" tasks are very similar – you can find them in the project's solutions branch.

What's next

- Check out the Asynchronous Programming with Kotlin workshop at KotlinConf.
- Find out more about using virtual time and the experimental testing package.

Cancellation and timeouts

This section covers coroutine cancellation and timeouts.

Cancelling coroutine execution

In a long-running application, you might need fine-grained control on your background coroutines. For example, a user might have closed the page that launched a coroutine, and now its result is no longer needed and its operation can be cancelled. The launch function returns a Job that can be used to cancel the running coroutine:

```
import kotlinx.coroutines.*

fun main() = runBlocking {
    val job = launch {
        repeat(1000) { i ->
            println("job: I'm sleeping $i ...")
            delay(500L)
        }
    }
    delay(1300L) // delay a bit
    println("main: I'm tired of waiting!")
    job.cancel() // cancels the job
    job.join() // waits for job's completion
    println("main: Now I can quit.")
}
```

> You can get the full code here.

It produces the following output:

```
job: I'm sleeping 0 ...
job: I'm sleeping 1 ...
job: I'm sleeping 2 ...
main: I'm tired of waiting!
main: Now I can quit.
```

As soon as main invokes job.cancel, we don't see any output from the other coroutine because it was cancelled. There is also a Job extension function cancelAndJoin that combines cancel and join invocations.

Cancellation is cooperative

Coroutine cancellation is cooperative. A coroutine code has to cooperate to be cancellable. All the suspending functions in kotlinx.coroutines are cancellable. They check for cancellation of coroutine and throw CancellationException when cancelled. However, if a coroutine is working in a computation and does not check for cancellation, then it cannot be cancelled, like the following example shows:

```
import kotlinx.coroutines.*
```

```
fun main() = runBlocking {
    val startTime = System.currentTimeMillis()
    val job = launch(Dispatchers.Default) {
        var nextPrintTime = startTime
        var i = 0
        while (i < 5) { // computation loop, just wastes CPU
            // print a message twice a second
            if (System.currentTimeMillis() >= nextPrintTime) {
                println("job: I'm sleeping ${i++} ...")
                nextPrintTime += 500L
            }
        }
    }
    delay(1300L) // delay a bit
    println("main: I'm tired of waiting!")
    job.cancelAndJoin() // cancels the job and waits for its completion
    println("main: Now I can quit.")
}
```

You can get the full code here.

Run it to see that it continues to print "I'm sleeping" even after cancellation until the job completes by itself after five iterations.

The same problem can be observed by catching a CancellationException and not rethrowing it:

```
import kotlinx.coroutines.*

fun main() = runBlocking {
    val job = launch(Dispatchers.Default) {
        repeat(5) { i ->
            try {
                // print a message twice a second
                println("job: I'm sleeping $i ...")
                delay(500)
            } catch (e: Exception) {
                // log the exception
                println(e)
            }
        }
    }
    delay(1300L) // delay a bit
    println("main: I'm tired of waiting!")
    job.cancelAndJoin() // cancels the job and waits for its completion
    println("main: Now I can quit.")
}
```

You can get the full code here.

While catching Exception is an anti-pattern, this issue may surface in more subtle ways, like when using the runCatching function, which does not rethrow CancellationException.

Making computation code cancellable

There are two approaches to making computation code cancellable. The first one is periodically invoking a suspending function that checks for cancellation. There are the yield and ensureActive functions, which are great choices for that purpose. The other one is explicitly checking the cancellation status using isActive. Let us try the latter approach.

Replace while (i < 5) in the previous example with while (isActive) and rerun it.

```
import kotlinx.coroutines.*

fun main() = runBlocking {
    val startTime = System.currentTimeMillis()
    val job = launch(Dispatchers.Default) {
        var nextPrintTime = startTime
        var i = 0
        while (isActive) { // cancellable computation loop
            // prints a message twice a second
            if (System.currentTimeMillis() >= nextPrintTime) {
                println("job: I'm sleeping ${i++} ...")
                nextPrintTime += 500L
            }
        }
    }
    delay(1300L) // delay a bit
    println("main: I'm tired of waiting!")
    job.cancelAndJoin() // cancels the job and waits for its completion
    println("main: Now I can quit.")
}
```

You can get the full code here.

As you can see, now this loop is cancelled. isActive is an extension property available inside the coroutine via the CoroutineScope object.

Closing resources with finally

Cancellable suspending functions throw CancellationException on cancellation, which can be handled in the usual way. For example, the try {...} finally {...} expression and Kotlin's use function execute their finalization actions normally when a coroutine is cancelled:

```
import kotlinx.coroutines.*

fun main() = runBlocking {
    val job = launch {
        try {
            repeat(1000) { i ->
                println("job: I'm sleeping $i ...")
                delay(500L)
            }
        } finally {
            println("job: I'm running finally")
        }
    }
    delay(1300L) // delay a bit
    println("main: I'm tired of waiting!")
    job.cancelAndJoin() // cancels the job and waits for its completion
    println("main: Now I can quit.")
}
```

You can get the full code here.

Both join and cancelAndJoin wait for all finalization actions to complete, so the example above produces the following output:

```
job: I'm sleeping 0 ...
job: I'm sleeping 1 ...
job: I'm sleeping 2 ...
main: I'm tired of waiting!
job: I'm running finally
main: Now I can quit.
```

Run non-cancellable block

Any attempt to use a suspending function in the finally block of the previous example causes CancellationException, because the coroutine running this code is cancelled. Usually, this is not a problem, since all well-behaved closing operations (closing a file, cancelling a job, or closing any kind of communication channel) are usually non-blocking and do not involve any suspending functions. However, in the rare case when you need to suspend in a cancelled coroutine you can wrap the corresponding code in withContext(NonCancellable) {...} using withContext function and NonCancellable context as the following example shows:

```
import kotlinx.coroutines.*

fun main() = runBlocking {
    val job = launch {
        try {
            repeat(1000) { i ->
                println("job: I'm sleeping $i ...")
                delay(500L)
            }
        } finally {
            withContext(NonCancellable) {
                println("job: I'm running finally")
                delay(1000L)
                println("job: And I've just delayed for 1 sec because I'm non-cancellable")
            }
        }
    }
    delay(1300L) // delay a bit
    println("main: I'm tired of waiting!")
    job.cancelAndJoin() // cancels the job and waits for its completion
    println("main: Now I can quit.")
}
```

You can get the full code here.

Timeout

The most obvious practical reason to cancel execution of a coroutine is because its execution time has exceeded some timeout. While you can manually track the reference to the corresponding Job and launch a separate coroutine to cancel the tracked one after delay, there is a ready to use withTimeout function that does it. Look at the following example:

```
import kotlinx.coroutines.*

fun main() = runBlocking {
    withTimeout(1300L) {
        repeat(1000) { i ->
            println("I'm sleeping $i ...")
            delay(500L)
        }
    }
}
```

You can get the full code here.

It produces the following output:

```
I'm sleeping 0 ...
I'm sleeping 1 ...
I'm sleeping 2 ...
Exception in thread "main" kotlinx.coroutines.TimeoutCancellationException: Timed out waiting for 1300 ms
```

The TimeoutCancellationException that is thrown by withTimeout is a subclass of CancellationException. We have not seen its stack trace printed on the console before. That is because inside a cancelled coroutine CancellationException is considered to be a normal reason for coroutine completion. However, in this example we have used withTimeout right inside the main function.

Since cancellation is just an exception, all resources are closed in the usual way. You can wrap the code with timeout in a try {...} catch (e: TimeoutCancellationException) {...} block if you need to do some additional action specifically on any kind of timeout or use the withTimeoutOrNull function that is similar to withTimeout but returns null on timeout instead of throwing an exception:

```
import kotlinx.coroutines.*

fun main() = runBlocking {
    val result = withTimeoutOrNull(1300L) {
        repeat(1000) { i ->
            println("I'm sleeping $i ...")
            delay(500L)
        }
        "Done" // will get cancelled before it produces this result
    }
    println("Result is $result")
}
```

You can get the full code here.

There is no longer an exception when running this code:

```
I'm sleeping 0 ...
I'm sleeping 1 ...
I'm sleeping 2 ...
Result is null
```

Asynchronous timeout and resources

The timeout event in withTimeout is asynchronous with respect to the code running in its block and may happen at any time, even right before the return from inside of the timeout block. Keep this in mind if you open or acquire some resource inside the block that needs closing or release outside of the block.

For example, here we imitate a closeable resource with the Resource class that simply keeps track of how many times it was created by incrementing the acquired counter and decrementing the counter in its close function. Now let us create a lot of coroutines, each of which creates a Resource at the end of the withTimeout block and releases the resource outside the block. We add a small delay so that it is more likely that the timeout occurs right when the withTimeout block is already finished, which will cause a resource leak.

```kotlin
import kotlinx.coroutines.*

var acquired = 0

class Resource {
    init { acquired++ } // Acquire the resource
    fun close() { acquired-- } // Release the resource
}

fun main() {
    runBlocking {
        repeat(10_000) { // Launch 10K coroutines
            launch {
                val resource = withTimeout(60) { // Timeout of 60 ms
                    delay(50) // Delay for 50 ms
                    Resource() // Acquire a resource and return it from withTimeout block
                }
                resource.close() // Release the resource
            }
        }
    }
    // Outside of runBlocking all coroutines have completed
    println(acquired) // Print the number of resources still acquired
}
```

You can get the full code here.

If you run the above code, you'll see that it does not always print zero, though it may depend on the timings of your machine. You may need to tweak the timeout in this example to actually see non-zero values.

Note that incrementing and decrementing acquired counter here from 10K coroutines is completely thread-safe, since it always happens from the same thread, the one used by runBlocking. More on that will be explained in the chapter on coroutine context.

To work around this problem you can store a reference to the resource in a variable instead of returning it from the withTimeout block.

```kotlin
import kotlinx.coroutines.*

var acquired = 0

class Resource {
    init { acquired++ } // Acquire the resource
    fun close() { acquired-- } // Release the resource
}

fun main() {
    runBlocking {
        repeat(10_000) { // Launch 10K coroutines
            launch {
                var resource: Resource? = null // Not acquired yet
                try {
                    withTimeout(60) { // Timeout of 60 ms
                        delay(50) // Delay for 50 ms
                        resource = Resource() // Store a resource to the variable if acquired
                    }
                    // We can do something else with the resource here
                } finally {
                    resource?.close() // Release the resource if it was acquired
                }
            }
        }
    }
    // Outside of runBlocking all coroutines have completed
    println(acquired) // Print the number of resources still acquired
}
```

You can get the full code here.

This example always prints zero. Resources do not leak.

Composing suspending functions

This section covers various approaches to composition of suspending functions.

Sequential by default

Assume that we have two suspending functions defined elsewhere that do something useful like some kind of remote service call or computation. We just pretend they are useful, but actually each one just delays for a second for the purpose of this example:

```
suspend fun doSomethingUsefulOne(): Int {
    delay(1000L) // pretend we are doing something useful here
    return 13
}

suspend fun doSomethingUsefulTwo(): Int {
    delay(1000L) // pretend we are doing something useful here, too
    return 29
}
```

What do we do if we need them to be invoked sequentially — first doSomethingUsefulOne and then doSomethingUsefulTwo, and compute the sum of their results? In practice, we do this if we use the result of the first function to make a decision on whether we need to invoke the second one or to decide on how to invoke it.

We use a normal sequential invocation, because the code in the coroutine, just like in the regular code, is sequential by default. The following example demonstrates it by measuring the total time it takes to execute both suspending functions:

```
import kotlinx.coroutines.*
import kotlin.system.*

fun main() = runBlocking<Unit> {
    val time = measureTimeMillis {
        val one = doSomethingUsefulOne()
        val two = doSomethingUsefulTwo()
        println("The answer is ${one + two}")
    }
    println("Completed in $time ms")
}

suspend fun doSomethingUsefulOne(): Int {
    delay(1000L) // pretend we are doing something useful here
    return 13
}
```

```
suspend fun doSomethingUsefulTwo(): Int {
    delay(1000L) // pretend we are doing something useful here, too
    return 29
}
```

You can get the full code here.

It produces something like this:

```
The answer is 42
Completed in 2017 ms
```

Concurrent using async

What if there are no dependencies between invocations of doSomethingUsefulOne and doSomethingUsefulTwo and we want to get the answer faster, by doing both concurrently? This is where async comes to help.

Conceptually, async is just like launch. It starts a separate coroutine which is a light-weight thread that works concurrently with all the other coroutines. The difference is that launch returns a Job and does not carry any resulting value, while async returns a Deferred — a light-weight non-blocking future that represents a promise to provide a result later. You can use .await() on a deferred value to get its eventual result, but Deferred is also a Job, so you can cancel it if needed.

```
import kotlinx.coroutines.*
import kotlin.system.*

fun main() = runBlocking<Unit> {
    val time = measureTimeMillis {
        val one = async { doSomethingUsefulOne() }
        val two = async { doSomethingUsefulTwo() }
        println("The answer is ${one.await() + two.await()}")
    }
    println("Completed in $time ms")
}

suspend fun doSomethingUsefulOne(): Int {
    delay(1000L) // pretend we are doing something useful here
    return 13
}

suspend fun doSomethingUsefulTwo(): Int {
    delay(1000L) // pretend we are doing something useful here, too
    return 29
}
```

You can get the full code here.

It produces something like this:

```
The answer is 42
Completed in 1017 ms
```

This is twice as fast, because the two coroutines execute concurrently. Note that concurrency with coroutines is always explicit.

Lazily started async

Optionally, async can be made lazy by setting its start parameter to CoroutineStart.LAZY. In this mode it only starts the coroutine when its result is required by await, or if its Job's start function is invoked. Run the following example:

```
import kotlinx.coroutines.*
import kotlin.system.*
```

```
fun main() = runBlocking<Unit> {
    val time = measureTimeMillis {
        val one = async(start = CoroutineStart.LAZY) { doSomethingUsefulOne() }
        val two = async(start = CoroutineStart.LAZY) { doSomethingUsefulTwo() }
        // some computation
        one.start() // start the first one
        two.start() // start the second one
        println("The answer is ${one.await() + two.await()}")
    }
    println("Completed in $time ms")
}

suspend fun doSomethingUsefulOne(): Int {
    delay(1000L) // pretend we are doing something useful here
    return 13
}

suspend fun doSomethingUsefulTwo(): Int {
    delay(1000L) // pretend we are doing something useful here, too
    return 29
}
```

You can get the full code here.

It produces something like this:

```
The answer is 42
Completed in 1017 ms
```

So, here the two coroutines are defined but not executed as in the previous example, but the control is given to the programmer on when exactly to start the execution by calling start. We first start one, then start two, and then await for the individual coroutines to finish.

Note that if we just call await in println without first calling start on individual coroutines, this will lead to sequential behavior, since await starts the coroutine execution and waits for its finish, which is not the intended use-case for laziness. The use-case for async(start = CoroutineStart.LAZY) is a replacement for the standard lazy function in cases when computation of the value involves suspending functions.

Async-style functions

This programming style with async functions is provided here only for illustration, because it is a popular style in other programming languages. Using this style with Kotlin coroutines is strongly discouraged for the reasons explained below.

We can define async-style functions that invoke doSomethingUsefulOne and doSomethingUsefulTwo asynchronously using the async coroutine builder using a GlobalScope reference to opt-out of the structured concurrency. We name such functions with the "...Async" suffix to highlight the fact that they only start asynchronous computation and one needs to use the resulting deferred value to get the result.

GlobalScope is a delicate API that can backfire in non-trivial ways, one of which will be explained below, so you must explicitly opt-in into using GlobalScope with @OptIn(DelicateCoroutinesApi::class).

```
// The result type of somethingUsefulOneAsync is Deferred<Int>
@OptIn(DelicateCoroutinesApi::class)
fun somethingUsefulOneAsync() = GlobalScope.async {
    doSomethingUsefulOne()
}

// The result type of somethingUsefulTwoAsync is Deferred<Int>
@OptIn(DelicateCoroutinesApi::class)
fun somethingUsefulTwoAsync() = GlobalScope.async {
    doSomethingUsefulTwo()
}
```

Note that these xxxAsync functions are not suspending functions. They can be used from anywhere. However, their use always implies asynchronous (here meaning concurrent) execution of their action with the invoking code.

The following example shows their use outside of coroutine:

```
import kotlinx.coroutines.*
import kotlin.system.*

// note that we don't have `runBlocking` to the right of `main` in this example
fun main() {
    val time = measureTimeMillis {
        // we can initiate async actions outside of a coroutine
        val one = somethingUsefulOneAsync()
        val two = somethingUsefulTwoAsync()
        // but waiting for a result must involve either suspending or blocking.
        // here we use `runBlocking { ... }` to block the main thread while waiting for the result
        runBlocking {
            println("The answer is ${one.await() + two.await()}")
        }
    }
    println("Completed in $time ms")
}

@OptIn(DelicateCoroutinesApi::class)
fun somethingUsefulOneAsync() = GlobalScope.async {
    doSomethingUsefulOne()
}

@OptIn(DelicateCoroutinesApi::class)
fun somethingUsefulTwoAsync() = GlobalScope.async {
    doSomethingUsefulTwo()
}

suspend fun doSomethingUsefulOne(): Int {
    delay(1000L) // pretend we are doing something useful here
    return 13
}

suspend fun doSomethingUsefulTwo(): Int {
    delay(1000L) // pretend we are doing something useful here, too
    return 29
}
```

You can get the full code here.

Consider what happens if between the val one = somethingUsefulOneAsync() line and one.await() expression there is some logic error in the code, and the program throws an exception, and the operation that was being performed by the program aborts. Normally, a global error-handler could catch this exception, log and report the error for developers, but the program could otherwise continue doing other operations. However, here we have somethingUsefulOneAsync still running in the background, even though the operation that initiated it was aborted. This problem does not happen with structured concurrency, as shown in the section below.

Structured concurrency with async

Let's refactor the Concurrent using async example into a function that runs doSomethingUsefulOne and doSomethingUsefulTwo concurrently and returns their combined results. Since async is a CoroutineScope extension, we'll use the coroutineScope function to provide the necessary scope:

```
suspend fun concurrentSum(): Int = coroutineScope {
    val one = async { doSomethingUsefulOne() }
    val two = async { doSomethingUsefulTwo() }
    one.await() + two.await()
}
```

This way, if something goes wrong inside the code of the concurrentSum function, and it throws an exception, all the coroutines that were launched in its scope will be cancelled.

```
import kotlinx.coroutines.*
import kotlin.system.*

fun main() = runBlocking<Unit> {
    val time = measureTimeMillis {
        println("The answer is ${concurrentSum()}")
    }
    println("Completed in $time ms")
}
```

```kotlin
suspend fun concurrentSum(): Int = coroutineScope {
    val one = async { doSomethingUsefulOne() }
    val two = async { doSomethingUsefulTwo() }
    one.await() + two.await()
}

suspend fun doSomethingUsefulOne(): Int {
    delay(1000L) // pretend we are doing something useful here
    return 13
}

suspend fun doSomethingUsefulTwo(): Int {
    delay(1000L) // pretend we are doing something useful here, too
    return 29
}
```

You can get the full code here.

We still have concurrent execution of both operations, as evident from the output of the above main function:

```
The answer is 42
Completed in 1017 ms
```

Cancellation is always propagated through coroutines hierarchy:

```kotlin
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> {
    try {
        failedConcurrentSum()
    } catch(e: ArithmeticException) {
        println("Computation failed with ArithmeticException")
    }
}

suspend fun failedConcurrentSum(): Int = coroutineScope {
    val one = async<Int> {
        try {
            delay(Long.MAX_VALUE) // Emulates very long computation
            42
        } finally {
            println("First child was cancelled")
        }
    }
    val two = async<Int> {
        println("Second child throws an exception")
        throw ArithmeticException()
    }
    one.await() + two.await()
}
```

You can get the full code here.

Note how both the first async and the awaiting parent are cancelled on failure of one of the children (namely, two):

```
Second child throws an exception
First child was cancelled
Computation failed with ArithmeticException
```

Coroutine context and dispatchers

Coroutines always execute in some context represented by a value of the CoroutineContext type, defined in the Kotlin standard library.

The coroutine context is a set of various elements. The main elements are the Job of the coroutine, which we've seen before, and its dispatcher, which is covered in this section.

Dispatchers and threads

The coroutine context includes a coroutine dispatcher (see CoroutineDispatcher) that determines what thread or threads the corresponding coroutine uses for its execution. The coroutine dispatcher can confine coroutine execution to a specific thread, dispatch it to a thread pool, or let it run unconfined.

All coroutine builders like launch and async accept an optional CoroutineContext parameter that can be used to explicitly specify the dispatcher for the new coroutine and other context elements.

Try the following example:

```
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> {
    launch { // context of the parent, main runBlocking coroutine
        println("main runBlocking      : I'm working in thread ${Thread.currentThread().name}")
    }
    launch(Dispatchers.Unconfined) { // not confined -- will work with main thread
        println("Unconfined            : I'm working in thread ${Thread.currentThread().name}")
    }
    launch(Dispatchers.Default) { // will get dispatched to DefaultDispatcher
        println("Default               : I'm working in thread ${Thread.currentThread().name}")
    }
    launch(newSingleThreadContext("MyOwnThread")) { // will get its own new thread
        println("newSingleThreadContext: I'm working in thread ${Thread.currentThread().name}")
    }
}
```

You can get the full code here.

It produces the following output (maybe in different order):

```
Unconfined            : I'm working in thread main
Default               : I'm working in thread DefaultDispatcher-worker-1
newSingleThreadContext: I'm working in thread MyOwnThread
main runBlocking      : I'm working in thread main
```

When launch { ... } is used without parameters, it inherits the context (and thus dispatcher) from the CoroutineScope it is being launched from. In this case, it inherits the context of the main runBlocking coroutine which runs in the main thread.

Dispatchers.Unconfined is a special dispatcher that also appears to run in the main thread, but it is, in fact, a different mechanism that is explained later.

The default dispatcher is used when no other dispatcher is explicitly specified in the scope. It is represented by Dispatchers.Default and uses a shared background pool of threads.

newSingleThreadContext creates a thread for the coroutine to run. A dedicated thread is a very expensive resource. In a real application it must be either released, when no longer needed, using the close function, or stored in a top-level variable and reused throughout the application.

Unconfined vs confined dispatcher

The Dispatchers.Unconfined coroutine dispatcher starts a coroutine in the caller thread, but only until the first suspension point. After suspension it resumes the coroutine in the thread that is fully determined by the suspending function that was invoked. The unconfined dispatcher is appropriate for coroutines which neither consume CPU time nor update any shared data (like UI) confined to a specific thread.

On the other side, the dispatcher is inherited from the outer CoroutineScope by default. The default dispatcher for the runBlocking coroutine, in particular, is confined to the invoker thread, so inheriting it has the effect of confining execution to this thread with predictable FIFO scheduling.

```
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> {
    launch(Dispatchers.Unconfined) { // not confined -- will work with main thread
        println("Unconfined      : I'm working in thread ${Thread.currentThread().name}")
        delay(500)
        println("Unconfined      : After delay in thread ${Thread.currentThread().name}")
    }
    launch { // context of the parent, main runBlocking coroutine
        println("main runBlocking: I'm working in thread ${Thread.currentThread().name}")
        delay(1000)
        println("main runBlocking: After delay in thread ${Thread.currentThread().name}")
    }
}
```

> You can get the full code here.

Produces the output:

```
Unconfined      : I'm working in thread main
main runBlocking: I'm working in thread main
Unconfined      : After delay in thread kotlinx.coroutines.DefaultExecutor
main runBlocking: After delay in thread main
```

So, the coroutine with the context inherited from runBlocking {...} continues to execute in the main thread, while the unconfined one resumes in the default executor thread that the delay function is using.

> The unconfined dispatcher is an advanced mechanism that can be helpful in certain corner cases where dispatching of a coroutine for its execution later is not needed or produces undesirable side-effects, because some operation in a coroutine must be performed right away. The unconfined dispatcher should not be used in general code.

Debugging coroutines and threads

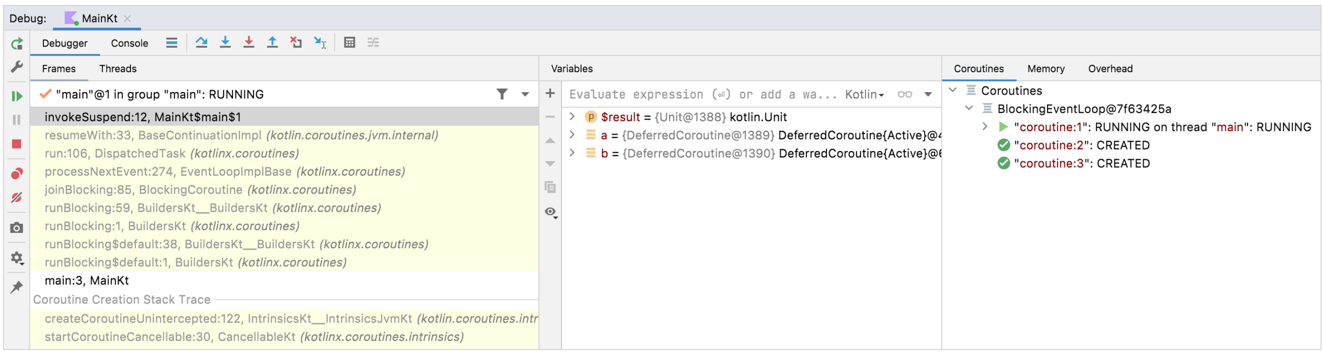
Coroutines can suspend on one thread and resume on another thread. Even with a single-threaded dispatcher it might be hard to figure out what the coroutine was doing, where, and when if you don't have special tooling.

Debugging with IDEA

The Coroutine Debugger of the Kotlin plugin simplifies debugging coroutines in IntelliJ IDEA.

> Debugging works for versions 1.3.8 or later of kotlinx-coroutines-core.

The Debug tool window contains the Coroutines tab. In this tab, you can find information about both currently running and suspended coroutines. The coroutines are grouped by the dispatcher they are running on.



```
"main"@1 in group "main": RUNNING
invokeSuspend:12, MainKt$main$1
resumeWith:33, BaseContinuationImpl (kotlin.coroutines.jvm.internal)
run:106, DispatchedTask (kotlinx.coroutines)
processNextEvent:274, EventLoopImplBase (kotlinx.coroutines)
joinBlocking:85, BlockingCoroutine (kotlinx.coroutines)
runBlocking:59, BuildersKt__BuildersKt (kotlinx.coroutines)
runBlocking:1, BuildersKt (kotlinx.coroutines)
runBlocking$default:38, BuildersKt__BuildersKt (kotlinx.coroutines)
runBlocking$default:1, BuildersKt (kotlinx.coroutines)
main:3, MainKt
Coroutine Creation Stack Trace
createCoroutineUnintercepted:122, IntrinsicsKt__IntrinsicsJvmKt (kotlin.coroutines.intr
startCoroutineCancellable:30, CancellableKt (kotlinx.coroutines.intrinsics)
```

```
$result = {Unit@1388} kotlin.Unit
a = {DeferredCoroutine@1389} DeferredCoroutine{Active}@4
b = {DeferredCoroutine@1390} DeferredCoroutine{Active}@6
```

```
Coroutines
  BlockingEventLoop@7f63425a
    "coroutine:1": RUNNING on thread "main": RUNNING
    "coroutine:2": CREATED
    "coroutine:3": CREATED
```

Debugging coroutines

With the coroutine debugger, you can:

- Check the state of each coroutine.
- See the values of local and captured variables for both running and suspended coroutines.

- See a full coroutine creation stack, as well as a call stack inside the coroutine. The stack includes all frames with variable values, even those that would be lost during standard debugging.
- Get a full report that contains the state of each coroutine and its stack. To obtain it, right-click inside the Coroutines tab, and then click Get Coroutines Dump.

To start coroutine debugging, you just need to set breakpoints and run the application in debug mode.

Learn more about coroutines debugging in the tutorial.

Debugging using logging

Another approach to debugging applications with threads without Coroutine Debugger is to print the thread name in the log file on each log statement. This feature is universally supported by logging frameworks. When using coroutines, the thread name alone does not give much of a context, so kotlinx.coroutines includes debugging facilities to make it easier.

Run the following code with -Dkotlinx.coroutines.debug JVM option:

```kotlin
import kotlinx.coroutines.*

fun log(msg: String) = println("[${Thread.currentThread().name}] $msg")

fun main() = runBlocking<Unit> {
    val a = async {
        log("I'm computing a piece of the answer")
        6
    }
    val b = async {
        log("I'm computing another piece of the answer")
        7
    }
    log("The answer is ${a.await() * b.await()}")
}
```

You can get the full code here.

There are three coroutines. The main coroutine (#1) inside runBlocking and two coroutines computing the deferred values a (#2) and b (#3). They are all executing in the context of runBlocking and are confined to the main thread. The output of this code is:

```
[main @coroutine#2] I'm computing a piece of the answer
[main @coroutine#3] I'm computing another piece of the answer
[main @coroutine#1] The answer is 42
```

The log function prints the name of the thread in square brackets, and you can see that it is the main thread with the identifier of the currently executing coroutine appended to it. This identifier is consecutively assigned to all created coroutines when the debugging mode is on.

Debugging mode is also turned on when JVM is run with -ea option. You can read more about debugging facilities in the documentation of the DEBUG_PROPERTY_NAME property.

Jumping between threads

Run the following code with the -Dkotlinx.coroutines.debug JVM option (see debug):

```kotlin
import kotlinx.coroutines.*

fun log(msg: String) = println("[${Thread.currentThread().name}] $msg")

fun main() {
    newSingleThreadContext("Ctx1").use { ctx1 ->
        newSingleThreadContext("Ctx2").use { ctx2 ->
            runBlocking(ctx1) {
                log("Started in ctx1")
                withContext(ctx2) {
                    log("Working in ctx2")
                }
                log("Back to ctx1")
            }
        }
    }
}
```

You can get the full code here.

The example above demonstrates new techniques in coroutine usage.

The first technique shows how to use runBlocking with a specified context.
The second technique involves calling withContext, which may suspend the current coroutine and switch to a new context—provided the new context differs from the existing one. Specifically, if you specify a different CoroutineDispatcher, extra dispatches are required: the block is scheduled on the new dispatcher, and once it finishes, execution returns to the original dispatcher.

As a result, the output of the above code is:

```
[Ctx1 @coroutine#1] Started in ctx1
[Ctx2 @coroutine#1] Working in ctx2
[Ctx1 @coroutine#1] Back to ctx1
```

The example above uses the use function from the Kotlin standard library to properly release thread resources created by newSingleThreadContext when they're no longer needed.

Job in the context

The coroutine's Job is part of its context, and can be retrieved from it using the coroutineContext[Job] expression:

```
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> {
    println("My job is ${coroutineContext[Job]}")
}
```

You can get the full code here.

In debug mode, it outputs something like this:

```
My job is "coroutine#1":BlockingCoroutine{Active}@6d311334
```

Note that isActive in CoroutineScope is just a convenient shortcut for coroutineContext[Job]?.isActive == true.

Children of a coroutine

When a coroutine is launched in the CoroutineScope of another coroutine, it inherits its context via CoroutineScope.coroutineContext and the Job of the new coroutine becomes a child of the parent coroutine's job. When the parent coroutine is cancelled, all its children are recursively cancelled, too.

However, this parent-child relation can be explicitly overridden in one of two ways:

1. When a different scope is explicitly specified when launching a coroutine (for example, GlobalScope.launch), it does not inherit a Job from the parent scope.

2. When a different Job object is passed as the context for the new coroutine (as shown in the example below), it overrides the Job of the parent scope.

In both cases, the launched coroutine is not tied to the scope it was launched from and operates independently.

```
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> {
    // launch a coroutine to process some kind of incoming request
    val request = launch {
        // it spawns two other jobs
        launch(Job()) {
            println("job1: I run in my own Job and execute independently!")
            delay(1000)
            println("job1: I am not affected by cancellation of the request")
        }
        // and the other inherits the parent context
        launch {
            delay(100)
            println("job2: I am a child of the request coroutine")
            delay(1000)
            println("job2: I will not execute this line if my parent request is cancelled")
        }
    }
    delay(500)
    request.cancel() // cancel processing of the request
    println("main: Who has survived request cancellation?")
    delay(1000) // delay the main thread for a second to see what happens
}
```

You can get the full code here.

The output of this code is:

```
job1: I run in my own Job and execute independently!
job2: I am a child of the request coroutine
main: Who has survived request cancellation?
job1: I am not affected by cancellation of the request
```

Parental responsibilities

A parent coroutine always waits for the completion of all its children. A parent does not have to explicitly track all the children it launches, and it does not have to use Job.join to wait for them at the end:

```
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> {
    // launch a coroutine to process some kind of incoming request
    val request = launch {
        repeat(3) { i -> // launch a few children jobs
            launch  {
                delay((i + 1) * 200L) // variable delay 200ms, 400ms, 600ms
                println("Coroutine $i is done")
            }
        }
        println("request: I'm done and I don't explicitly join my children that are still active")
    }
    request.join() // wait for completion of the request, including all its children
    println("Now processing of the request is complete")
}
```

You can get the full code here.

The result is going to be:

```
request: I'm done and I don't explicitly join my children that are still active
Coroutine 0 is done
Coroutine 1 is done
Coroutine 2 is done
Now processing of the request is complete
```

Naming coroutines for debugging

Automatically assigned ids are good when coroutines log often and you just need to correlate log records coming from the same coroutine. However, when a coroutine is tied to the processing of a specific request or doing some specific background task, it is better to name it explicitly for debugging purposes. The CoroutineName context element serves the same purpose as the thread name. It is included in the thread name that is executing this coroutine when the debugging mode is turned on.

The following example demonstrates this concept:

```
import kotlinx.coroutines.*

fun log(msg: String) = println("[${Thread.currentThread().name}] $msg")

fun main() = runBlocking(CoroutineName("main")) {
    log("Started main coroutine")
    // run two background value computations
    val v1 = async(CoroutineName("v1coroutine")) {
        delay(500)
        log("Computing v1")
        6
    }
    val v2 = async(CoroutineName("v2coroutine")) {
        delay(1000)
        log("Computing v2")
        7
    }
    log("The answer for v1 * v2 = ${v1.await() * v2.await()}")
}
```

You can get the full code here.

The output it produces with -Dkotlinx.coroutines.debug JVM option is similar to:

```
[main @main#1] Started main coroutine
[main @v1coroutine#2] Computing v1
[main @v2coroutine#3] Computing v2
[main @main#1] The answer for v1 * v2 = 42
```

Combining context elements

Sometimes we need to define multiple elements for a coroutine context. We can use the + operator for that. For example, we can launch a coroutine with an explicitly specified dispatcher and an explicitly specified name at the same time:

```
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> {
    launch(Dispatchers.Default + CoroutineName("test")) {
        println("I'm working in thread ${Thread.currentThread().name}")
    }
}
```

You can get the full code here.

The output of this code with the -Dkotlinx.coroutines.debug JVM option is:

```
I'm working in thread DefaultDispatcher-worker-1 @test#2
```

Coroutine scope

Let us put our knowledge about contexts, children, and jobs together. Assume that our application has an object with a lifecycle, but that object is not a coroutine. For example, we are writing an Android application, and launching various coroutines in the context of an Android activity to perform asynchronous operations to fetch and update data, do animations, etc. These coroutines must be cancelled when the activity is destroyed to avoid memory leaks. We, of course, can manipulate contexts and jobs manually to tie the lifecycles of the activity and its coroutines, but kotlinx.coroutines provides an abstraction encapsulating that:

CoroutineScope. You should be already familiar with the coroutine scope as all coroutine builders are declared as extensions on it.

We manage the lifecycles of our coroutines by creating an instance of CoroutineScope tied to the lifecycle of our activity. A CoroutineScope instance can be created by the CoroutineScope() or MainScope() factory functions. The former creates a general-purpose scope, while the latter creates a scope for UI applications and uses Dispatchers.Main as the default dispatcher:

```kotlin
class Activity {
    private val mainScope = MainScope()

    fun destroy() {
        mainScope.cancel()
    }
    // to be continued ...
```

Now, we can launch coroutines in the scope of this Activity using the defined mainScope. For the demo, we launch ten coroutines that delay for a different time:

```kotlin
// class Activity continues
    fun doSomething() {
        // launch ten coroutines for a demo, each working for a different time
        repeat(10) { i ->
            mainScope.launch {
                delay((i + 1) * 200L) // variable delay 200ms, 400ms, ... etc
                println("Coroutine $i is done")
            }
        }
    }
} // class Activity ends
```

In our main function we create the activity, call our test doSomething function, and destroy the activity after 500ms. This cancels all the coroutines that were launched from doSomething. We can see that because after the destruction of the activity, no more messages are printed, even if we wait a little longer.

```kotlin
import kotlinx.coroutines.*

class Activity {
    private val mainScope = CoroutineScope(Dispatchers.Default) // use Default for test purposes

    fun destroy() {
        mainScope.cancel()
    }

    fun doSomething() {
        // launch ten coroutines for a demo, each working for a different time
        repeat(10) { i ->
            mainScope.launch {
                delay((i + 1) * 200L) // variable delay 200ms, 400ms, ... etc
                println("Coroutine $i is done")
            }
        }
    }
} // class Activity ends

fun main() = runBlocking<Unit> {
    val activity = Activity()
    activity.doSomething() // run test function
    println("Launched coroutines")
    delay(500L) // delay for half a second
    println("Destroying activity!")
    activity.destroy() // cancels all coroutines
    delay(1000) // visually confirm that they don't work
}
```

You can get the full code here.

The output of this example is:

```
Launched coroutines
Coroutine 0 is done
Coroutine 1 is done
Destroying activity!
```

As you can see, only the first two coroutines print a message and the others are cancelled by a single invocation of mainScope.cancel() in Activity.destroy().

Note that Android has first-party support for coroutine scope in all entities with the lifecycle. See the corresponding documentation.

Thread-local data

Sometimes it is convenient to be able to pass some thread-local data to or between coroutines. However, since they are not bound to any particular thread, this will likely lead to boilerplate if done manually.

For ThreadLocal, the asContextElement extension function is here for the rescue. It creates an additional context element which keeps the value of the given ThreadLocal and restores it every time the coroutine switches its context.

It is easy to demonstrate it in action:

```kotlin
import kotlinx.coroutines.*

val threadLocal = ThreadLocal<String?>() // declare thread-local variable

fun main() = runBlocking<Unit> {
    threadLocal.set("main")
    println("Pre-main, current thread: ${Thread.currentThread()}, thread local value: '${threadLocal.get()}'")
    val job = launch(Dispatchers.Default + threadLocal.asContextElement(value = "launch")) {
        println("Launch start, current thread: ${Thread.currentThread()}, thread local value: '${threadLocal.get()}'")
        yield()
        println("After yield, current thread: ${Thread.currentThread()}, thread local value: '${threadLocal.get()}'")
    }
    job.join()
    println("Post-main, current thread: ${Thread.currentThread()}, thread local value: '${threadLocal.get()}'")
}
```

You can get the full code here.

In this example, we launch a new coroutine in a background thread pool using Dispatchers.Default, so it works on different threads from the thread pool, but it still has the value of the thread local variable that we specified using threadLocal.asContextElement(value = "launch"), no matter which thread the coroutine is executed on. Thus, the output (with debug) is:

```
Pre-main, current thread: Thread[main @coroutine#1,5,main], thread local value: 'main'
Launch start, current thread: Thread[DefaultDispatcher-worker-1 @coroutine#2,5,main], thread local value: 'launch'
After yield, current thread: Thread[DefaultDispatcher-worker-2 @coroutine#2,5,main], thread local value: 'launch'
Post-main, current thread: Thread[main @coroutine#1,5,main], thread local value: 'main'
```

It's easy to forget to set the corresponding context element. The thread-local variable accessed from the coroutine may then have an unexpected value if the thread running the coroutine is different. To avoid such situations, it is recommended to use the ensurePresent method and fail-fast on improper usages.

ThreadLocal has first-class support and can be used with any primitive kotlinx.coroutines provides. It has one key limitation, though: when a thread-local is mutated, a new value is not propagated to the coroutine caller (because a context element cannot track all ThreadLocal object accesses), and the updated value is lost on the next suspension. Use withContext to update the value of the thread-local in a coroutine, see asContextElement for more details.

Alternatively, a value can be stored in a mutable box like class Counter(var i: Int), which is, in turn, stored in a thread-local variable. However, in this case, you are fully responsible to synchronize potentially concurrent modifications to the variable in this mutable box.

For advanced usage, for example, for integration with logging MDC, transactional contexts or any other libraries that internally use thread-locals for passing data, see the documentation of the ThreadContextElement interface that should be implemented.

Asynchronous Flow

A suspending function asynchronously returns a single value, but how can we return multiple asynchronously computed values? This is where Kotlin Flows come in.

Representing multiple values

Multiple values can be represented in Kotlin using collections. For example, we can have a simple function that returns a List of three numbers and then print them all using forEach:

```
fun simple(): List<Int> = listOf(1, 2, 3)

fun main() {
    simple().forEach { value -> println(value) }
}
```

You can get the full code here.

This code outputs:

```
1
2
3
```

Sequences

If we are computing the numbers with some CPU-consuming blocking code (each computation taking 100ms), then we can represent the numbers using a Sequence:

```
fun simple(): Sequence<Int> = sequence { // sequence builder
    for (i in 1..3) {
        Thread.sleep(100) // pretend we are computing it
        yield(i) // yield next value
    }
}

fun main() {
    simple().forEach { value -> println(value) }
}
```

You can get the full code here.

This code outputs the same numbers, but it waits 100ms before printing each one.

Suspending functions

However, this computation blocks the main thread that is running the code. When these values are computed by asynchronous code we can mark the simple function with a suspend modifier, so that it can perform its work without blocking and return the result as a list:

```
import kotlinx.coroutines.*

suspend fun simple(): List<Int> {
    delay(1000) // pretend we are doing something asynchronous here
    return listOf(1, 2, 3)
}

fun main() = runBlocking<Unit> {
    simple().forEach { value -> println(value) }
}
```

You can get the full code here.

This code prints the numbers after waiting for a second.

Flows

Using the List<Int> result type, means we can only return all the values at once. To represent the stream of values that are being computed asynchronously, we can use a Flow<Int> type just like we would use a Sequence<Int> type for synchronously computed values:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

//sampleStart
fun simple(): Flow<Int> = flow { // flow builder
    for (i in 1..3) {
        delay(100) // pretend we are doing something useful here
        emit(i) // emit next value
    }
}

fun main() = runBlocking<Unit> {
    // Launch a concurrent coroutine to check if the main thread is blocked
    launch {
        for (k in 1..3) {
            println("I'm not blocked $k")
            delay(100)
        }
    }
    // Collect the flow
    simple().collect { value -> println(value) }
}
```

You can get the full code here.

This code waits 100ms before printing each number without blocking the main thread. This is verified by printing "I'm not blocked" every 100ms from a separate coroutine that is running in the main thread:

```
I'm not blocked 1
1
I'm not blocked 2
2
I'm not blocked 3
3
```

Notice the following differences in the code with the Flow from the earlier examples:

- A builder function of Flow type is called flow.
- Code inside a flow { ... } builder block can suspend.
- The simple function is no longer marked with a suspend modifier.
- Values are emitted from the flow using an emit function.
- Values are collected from the flow using a collect function.

We can replace delay with Thread.sleep in the body of simple's flow { ... } and see that the main thread is blocked in this case.

Flows are cold

Flows are cold streams similar to sequences — the code inside a flow builder does not run until the flow is collected. This becomes clear in the following example:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

//sampleStart
fun simple(): Flow<Int> = flow {
    println("Flow started")
    for (i in 1..3) {
        delay(100)
        emit(i)
    }
}
```

```
fun main() = runBlocking<Unit> {
    println("Calling simple function...")
    val flow = simple()
    println("Calling collect...")
    flow.collect { value -> println(value) }
    println("Calling collect again...")
    flow.collect { value -> println(value) }
}
```

You can get the full code here.

Which prints:

```
Calling simple function...
Calling collect...
Flow started
1
2
3
Calling collect again...
Flow started
1
2
3
```

This is a key reason the simple function (which returns a flow) is not marked with suspend modifier. The simple() call itself returns quickly and does not wait for anything. The flow starts afresh every time it is collected and that is why we see "Flow started" every time we call collect again.

Flow cancellation basics

Flows adhere to the general cooperative cancellation of coroutines. As usual, flow collection can be cancelled when the flow is suspended in a cancellable suspending function (like delay). The following example shows how the flow gets cancelled on a timeout when running in a withTimeoutOrNull block and stops executing its code:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

//sampleStart
fun simple(): Flow<Int> = flow {
    for (i in 1..3) {
        delay(100)
        println("Emitting $i")
        emit(i)
    }
}

fun main() = runBlocking<Unit> {
    withTimeoutOrNull(250) { // Timeout after 250ms
        simple().collect { value -> println(value) }
    }
    println("Done")
}
```

You can get the full code here.

Notice how only two numbers get emitted by the flow in the simple function, producing the following output:

```
Emitting 1
1
Emitting 2
2
Done
```

See Flow cancellation checks section for more details.

Flow builders

The flow { ... } builder from the previous examples is the most basic one. There are other builders that allow flows to be declared:

- The flowOf builder defines a flow that emits a fixed set of values.
- Various collections and sequences can be converted to flows using the .asFlow() extension function.

For example, the snippet that prints the numbers 1 to 3 from a flow can be rewritten as follows:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun main() = runBlocking<Unit> {
    // Convert an integer range to a flow
    (1..3).asFlow().collect { value -> println(value) }
}
```

You can get the full code here.

Intermediate flow operators

Flows can be transformed using operators, in the same way as you would transform collections and sequences. Intermediate operators are applied to an upstream flow and return a downstream flow. These operators are cold, just like flows are. A call to such an operator is not a suspending function itself. It works quickly, returning the definition of a new transformed flow.

The basic operators have familiar names like map and filter. An important difference of these operators from sequences is that blocks of code inside these operators can call suspending functions.

For example, a flow of incoming requests can be mapped to its results with a map operator, even when performing a request is a long-running operation that is implemented by a suspending function:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

//sampleStart
suspend fun performRequest(request: Int): String {
    delay(1000) // imitate long-running asynchronous work
    return "response $request"
}

fun main() = runBlocking<Unit> {
    (1..3).asFlow() // a flow of requests
        .map { request -> performRequest(request) }
        .collect { response -> println(response) }
}
```

You can get the full code here.

It produces the following three lines, each appearing one second after the previous:

```
response 1
response 2
response 3
```

Transform operator

Among the flow transformation operators, the most general one is called transform. It can be used to imitate simple transformations like map and filter, as well as implement more complex transformations. Using the transform operator, we can emit arbitrary values an arbitrary number of times.

For example, using transform we can emit a string before performing a long-running asynchronous request and follow it with a response:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

suspend fun performRequest(request: Int): String {
    delay(1000) // imitate long-running asynchronous work
    return "response $request"
}

fun main() = runBlocking<Unit> {
    (1..3).asFlow() // a flow of requests
        .transform { request ->
            emit("Making request $request")
            emit(performRequest(request))
        }
        .collect { response -> println(response) }
}
```

You can get the full code here.

The output of this code is:

```
Making request 1
response 1
Making request 2
response 2
Making request 3
response 3
```

Size-limiting operators

Size-limiting intermediate operators like take cancel the execution of the flow when the corresponding limit is reached. Cancellation in coroutines is always performed by throwing an exception, so that all the resource-management functions (like try { ... } finally { ... } blocks) operate normally in case of cancellation:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun numbers(): Flow<Int> = flow {
    try {
        emit(1)
        emit(2)
        println("This line will not execute")
        emit(3)
    } finally {
        println("Finally in numbers")
    }
}

fun main() = runBlocking<Unit> {
    numbers()
        .take(2) // take only the first two
        .collect { value -> println(value) }
}
```

You can get the full code here.

The output of this code clearly shows that the execution of the flow { ... } body in the numbers() function stopped after emitting the second number:

```
1
2
Finally in numbers
```

Terminal flow operators

Terminal operators on flows are suspending functions that start a collection of the flow. The collect operator is the most basic one, but there are other terminal operators, which can make it easier:

- Conversion to various collections like toList and toSet.
- Operators to get the first value and to ensure that a flow emits a single value.
- Reducing a flow to a value with reduce and fold.

For example:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun main() = runBlocking<Unit> {
//sampleStart
    val sum = (1..5).asFlow()
        .map { it * it } // squares of numbers from 1 to 5
        .reduce { a, b -> a + b } // sum them (terminal operator)
    println(sum)
}
```

You can get the full code here.

Prints a single number:

```
55
```

Flows are sequential

Each individual collection of a flow is performed sequentially unless special operators that operate on multiple flows are used. The collection works directly in the coroutine that calls a terminal operator. No new coroutines are launched by default. Each emitted value is processed by all the intermediate operators from upstream to downstream and is then delivered to the terminal operator after.

See the following example that filters the even integers and maps them to strings:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun main() = runBlocking<Unit> {
//sampleStart
    (1..5).asFlow()
        .filter {
            println("Filter $it")
            it % 2 == 0
        }
        .map {
            println("Map $it")
            "string $it"
        }.collect {
            println("Collect $it")
        }
}
```

You can get the full code here.

Producing:

```
Filter 1
Filter 2
Map 2
Collect string 2
Filter 3
Filter 4
Map 4
Collect string 4
```

```
Filter 5
```

Flow context

Collection of a flow always happens in the context of the calling coroutine. For example, if there is a simple flow, then the following code runs in the context specified by the author of this code, regardless of the implementation details of the simple flow:

```
withContext(context) {
    simple().collect { value ->
        println(value) // run in the specified context
    }
}
```

This property of a flow is called context preservation.

So, by default, code in the flow { ... } builder runs in the context that is provided by a collector of the corresponding flow. For example, consider the implementation of a simple function that prints the thread it is called on and emits three numbers:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun log(msg: String) = println("[${Thread.currentThread().name}] $msg")

fun simple(): Flow<Int> = flow {
    log("Started simple flow")
    for (i in 1..3) {
        emit(i)
    }
}

fun main() = runBlocking<Unit> {
    simple().collect { value -> log("Collected $value") }
}
```

You can get the full code here.

Running this code produces:

```
[main @coroutine#1] Started simple flow
[main @coroutine#1] Collected 1
[main @coroutine#1] Collected 2
[main @coroutine#1] Collected 3
```

Since simple().collect is called from the main thread, the body of simple's flow is also called in the main thread. This is the perfect default for fast-running or asynchronous code that does not care about the execution context and does not block the caller.

A common pitfall when using withContext

However, the long-running CPU-consuming code might need to be executed in the context of Dispatchers.Default and UI-updating code might need to be executed in the context of Dispatchers.Main. Usually, withContext is used to change the context in the code using Kotlin coroutines, but code in the flow { ... } builder has to honor the context preservation property and is not allowed to emit from a different context.

Try running the following code:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun simple(): Flow<Int> = flow {
    // The WRONG way to change context for CPU-consuming code in flow builder
    kotlinx.coroutines.withContext(Dispatchers.Default) {
        for (i in 1..3) {
            Thread.sleep(100) // pretend we are computing it in CPU-consuming way
            emit(i) // emit next value
        }
    }
}

fun main() = runBlocking<Unit> {
    simple().collect { value -> println(value) }
}
```

You can get the full code here.

This code produces the following exception:

```
Exception in thread "main" java.lang.IllegalStateException: Flow invariant is violated:
  Flow was collected in [CoroutineId(1), "coroutine#1":BlockingCoroutine{Active}@5511c7f8, BlockingEventLoop@2eac3323],
  but emission happened in [CoroutineId(1), "coroutine#1":DispatchedCoroutine{Active}@2dae0000, Dispatchers.Default].
  Please refer to 'flow' documentation or use 'flowOn' instead
 at ...
```

flowOn operator

The exception refers to the flowOn function that shall be used to change the context of the flow emission. The correct way to change the context of a flow is shown in the example below, which also prints the names of the corresponding threads to show how it all works:

```kotlin
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun log(msg: String) = println("[${Thread.currentThread().name}] $msg")

fun simple(): Flow<Int> = flow {
    for (i in 1..3) {
        Thread.sleep(100) // pretend we are computing it in CPU-consuming way
        log("Emitting $i")
        emit(i) // emit next value
    }
}.flowOn(Dispatchers.Default) // RIGHT way to change context for CPU-consuming code in flow builder

fun main() = runBlocking<Unit> {
    simple().collect { value ->
        log("Collected $value")
    }
}
```

You can get the full code here.

Notice how flow { ... } works in the background thread, while collection happens in the main thread:

```
[DefaultDispatcher-worker-1 @coroutine#2] Emitting 1
[main @coroutine#1] Collected 1
[DefaultDispatcher-worker-1 @coroutine#2] Emitting 2
[main @coroutine#1] Collected 2
[DefaultDispatcher-worker-1 @coroutine#2] Emitting 3
[main @coroutine#1] Collected 3
```

Another thing to observe here is that the flowOn operator has changed the default sequential nature of the flow. Now collection happens in one coroutine ("coroutine#1") and emission happens in another coroutine ("coroutine#2") that is running in another thread concurrently with the collecting coroutine. The flowOn operator creates another coroutine for an upstream flow when it has to change the CoroutineDispatcher in its context.

Buffering

Running different parts of a flow in different coroutines can be helpful from the standpoint of the overall time it takes to collect the flow, especially when long-running asynchronous operations are involved. For example, consider a case when the emission by a simple flow is slow, taking 100 ms to produce an element; and collector is also slow, taking 300 ms to process an element. Let's see how long it takes to collect such a flow with three numbers:

```kotlin
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*
import kotlin.system.*

fun simple(): Flow<Int> = flow {
    for (i in 1..3) {
        delay(100) // pretend we are asynchronously waiting 100 ms
        emit(i) // emit next value
    }
}

fun main() = runBlocking<Unit> {
    val time = measureTimeMillis {
        simple().collect { value ->
            delay(300) // pretend we are processing it for 300 ms
            println(value)
        }
    }
    println("Collected in $time ms")
}
```

You can get the full code here.

It produces something like this, with the whole collection taking around 1200 ms (three numbers, 400 ms for each):

```
1
2
3
Collected in 1220 ms
```

We can use a buffer operator on a flow to run emitting code of the simple flow concurrently with collecting code, as opposed to running them sequentially:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*
import kotlin.system.*

fun simple(): Flow<Int> = flow {
    for (i in 1..3) {
        delay(100) // pretend we are asynchronously waiting 100 ms
        emit(i) // emit next value
    }
}

fun main() = runBlocking<Unit> {
    val time = measureTimeMillis {
        simple()
            .buffer() // buffer emissions, don't wait
            .collect { value ->
                delay(300) // pretend we are processing it for 300 ms
                println(value)
            }
    }
    println("Collected in $time ms")
}
```

You can get the full code here.

It produces the same numbers just faster, as we have effectively created a processing pipeline, having to only wait 100 ms for the first number and then spending only 300 ms to process each number. This way it takes around 1000 ms to run:

```
1
2
3
Collected in 1071 ms
```

Note that the flowOn operator uses the same buffering mechanism when it has to change a CoroutineDispatcher, but here we explicitly request buffering without changing the execution context.

Conflation

When a flow represents partial results of the operation or operation status updates, it may not be necessary to process each value, but instead, only most recent ones. In this case, the conflate operator can be used to skip intermediate values when a collector is too slow to process them. Building on the previous example:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*
import kotlin.system.*

fun simple(): Flow<Int> = flow {
    for (i in 1..3) {
        delay(100) // pretend we are asynchronously waiting 100 ms
        emit(i) // emit next value
    }
}

fun main() = runBlocking<Unit> {
    val time = measureTimeMillis {
        simple()
            .conflate() // conflate emissions, don't process each one
            .collect { value ->
                delay(300) // pretend we are processing it for 300 ms
                println(value)
            }
    }
    println("Collected in $time ms")
}
```

You can get the full code here.

We see that while the first number was still being processed the second, and third were already produced, so the second one was conflated and only the most recent (the third one) was delivered to the collector:

```
1
3
Collected in 758 ms
```

Processing the latest value

Conflation is one way to speed up processing when both the emitter and collector are slow. It does it by dropping emitted values. The other way is to cancel a slow collector and restart it every time a new value is emitted. There is a family of xxxLatest operators that perform the same essential logic of a xxx operator, but cancel the code in their block on a new value. Let's try changing conflate to collectLatest in the previous example:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*
import kotlin.system.*

fun simple(): Flow<Int> = flow {
    for (i in 1..3) {
        delay(100) // pretend we are asynchronously waiting 100 ms
        emit(i) // emit next value
    }
}

fun main() = runBlocking<Unit> {
    val time = measureTimeMillis {
        simple()
            .collectLatest { value -> // cancel & restart on the latest value
                println("Collecting $value")
                delay(300) // pretend we are processing it for 300 ms
                println("Done $value")
            }
    }
    println("Collected in $time ms")
}
```

You can get the full code here.

Since the body of collectLatest takes 300 ms, but new values are emitted every 100 ms, we see that the block is run on every value, but completes only for the last value:

```
Collecting 1
Collecting 2
Collecting 3
Done 3
Collected in 741 ms
```

Composing multiple flows

There are lots of ways to compose multiple flows.

Zip

Just like the Sequence.zip extension function in the Kotlin standard library, flows have a zip operator that combines the corresponding values of two flows:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun main() = runBlocking<Unit> {
//sampleStart
    val nums = (1..3).asFlow() // numbers 1..3
    val strs = flowOf("one", "two", "three") // strings
    nums.zip(strs) { a, b -> "$a -> $b" } // compose a single string
        .collect { println(it) } // collect and print
}
```

You can get the full code here.

This example prints:

```
1 -> one
2 -> two
3 -> three
```

Combine

When flow represents the most recent value of a variable or operation (see also the related section on conflation), it might be needed to perform a computation that depends on the most recent values of the corresponding flows and to recompute it whenever any of the upstream flows emit a value. The corresponding family of operators is called combine.

For example, if the numbers in the previous example update every 300ms, but strings update every 400 ms, then zipping them using thezip operator will still produce the same result, albeit results that are printed every 400 ms:

We use a onEach intermediate operator in this example to delay each element and make the code that emits sample flows more declarative and shorter.

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun main() = runBlocking<Unit> {
//sampleStart
    val nums = (1..3).asFlow().onEach { delay(300) } // numbers 1..3 every 300 ms
    val strs = flowOf("one", "two", "three").onEach { delay(400) } // strings every 400 ms
    val startTime = System.currentTimeMillis() // remember the start time
    nums.zip(strs) { a, b -> "$a -> $b" } // compose a single string with "zip"
        .collect { value -> // collect and print
            println("$value at ${System.currentTimeMillis() - startTime} ms from start")
        }
}
```

You can get the full code here.

However, when using a combine operator here instead of a zip:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun main() = runBlocking<Unit> {
//sampleStart
    val nums = (1..3).asFlow().onEach { delay(300) } // numbers 1..3 every 300 ms
    val strs = flowOf("one", "two", "three").onEach { delay(400) } // strings every 400 ms
    val startTime = System.currentTimeMillis() // remember the start time
    nums.combine(strs) { a, b -> "$a -> $b" } // compose a single string with "combine"
        .collect { value -> // collect and print
            println("$value at ${System.currentTimeMillis() - startTime} ms from start")
        }
}
```

You can get the full code here.

We get quite a different output, where a line is printed at each emission from either nums or strs flows:

```
1 -> one at 452 ms from start
2 -> one at 651 ms from start
2 -> two at 854 ms from start
3 -> two at 952 ms from start
3 -> three at 1256 ms from start
```

Flattening flows

Flows represent asynchronously received sequences of values, and so it is quite easy to get into a situation where each value triggers a request for another sequence of values. For example, we can have the following function that returns a flow of two strings 500 ms apart:

```
fun requestFlow(i: Int): Flow<String> = flow {
    emit("$i: First")
    delay(500) // wait 500 ms
    emit("$i: Second")
}
```

Now if we have a flow of three integers and call requestFlow on each of them like this:

```
(1..3).asFlow().map { requestFlow(it) }
```

Then we will end up with a flow of flows (Flow<Flow<String>>) that needs to be flattened into a single flow for further processing. Collections and sequences have flatten and flatMap operators for this. However, due to the asynchronous nature of flows they call for different modes of flattening, and hence, a family of flattening operators on flows exists.

flatMapConcat

Concatenation of flows of flows is provided by the flatMapConcat and flattenConcat operators. They are the most direct analogues of the corresponding sequence operators. They wait for the inner flow to complete before starting to collect the next one as the following example shows:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun requestFlow(i: Int): Flow<String> = flow {
    emit("$i: First")
    delay(500) // wait 500 ms
    emit("$i: Second")
}

fun main() = runBlocking<Unit> {
    val startTime = System.currentTimeMillis() // remember the start time
    (1..3).asFlow().onEach { delay(100) } // emit a number every 100 ms
        .flatMapConcat { requestFlow(it) }
        .collect { value -> // collect and print
            println("$value at ${System.currentTimeMillis() - startTime} ms from start")
        }
}
```

You can get the full code here.

The sequential nature of flatMapConcat is clearly seen in the output:

```
1: First at 121 ms from start
1: Second at 622 ms from start
2: First at 727 ms from start
2: Second at 1227 ms from start
3: First at 1328 ms from start
3: Second at 1829 ms from start
```

flatMapMerge

Another flattening operation is to concurrently collect all the incoming flows and merge their values into a single flow so that values are emitted as soon as possible. It is implemented by flatMapMerge and flattenMerge operators. They both accept an optional concurrency parameter that limits the number of concurrent flows that are collected at the same time (it is equal to DEFAULT_CONCURRENCY by default).

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun requestFlow(i: Int): Flow<String> = flow {
    emit("$i: First")
    delay(500) // wait 500 ms
    emit("$i: Second")
}

fun main() = runBlocking<Unit> {
    val startTime = System.currentTimeMillis() // remember the start time
    (1..3).asFlow().onEach { delay(100) } // a number every 100 ms
        .flatMapMerge { requestFlow(it) }
        .collect { value -> // collect and print
            println("$value at ${System.currentTimeMillis() - startTime} ms from start")
        }
}
```

You can get the full code here.

The concurrent nature of flatMapMerge is obvious:

```
1: First at 136 ms from start
2: First at 231 ms from start
3: First at 333 ms from start
1: Second at 639 ms from start
2: Second at 732 ms from start
3: Second at 833 ms from start
```

Note that the flatMapMerge calls its block of code ({ requestFlow(it) } in this example) sequentially, but collects the resulting flows concurrently, it is the equivalent of performing a sequential map { requestFlow(it) } first and then calling flattenMerge on the result.

flatMapLatest

In a similar way to the collectLatest operator, that was described in the section "Processing the latest value", there is the corresponding "Latest" flattening mode where the collection of the previous flow is cancelled as soon as new flow is emitted. It is implemented by the flatMapLatest operator.

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun requestFlow(i: Int): Flow<String> = flow {
    emit("$i: First")
    delay(500) // wait 500 ms
    emit("$i: Second")
}

fun main() = runBlocking<Unit> {
    val startTime = System.currentTimeMillis() // remember the start time
    (1..3).asFlow().onEach { delay(100) } // a number every 100 ms
        .flatMapLatest { requestFlow(it) }
        .collect { value -> // collect and print
            println("$value at ${System.currentTimeMillis() - startTime} ms from start")
        }
}
```

You can get the full code here.

The output here in this example is a good demonstration of how flatMapLatest works:

```
1: First at 142 ms from start
2: First at 322 ms from start
3: First at 425 ms from start
3: Second at 931 ms from start
```

Note that flatMapLatest cancels all the code in its block ({ requestFlow(it) } in this example) when a new value is received. It makes no difference in this particular example, because the call to requestFlow itself is fast, not-suspending, and cannot be cancelled. However, a differnce in output would be visible if we were to use suspending functions like delay in requestFlow.

Flow exceptions

Flow collection can complete with an exception when an emitter or code inside the operators throw an exception. There are several ways to handle these exceptions.

Collector try and catch

A collector can use Kotlin's try/catch block to handle exceptions:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun simple(): Flow<Int> = flow {
    for (i in 1..3) {
        println("Emitting $i")
        emit(i) // emit next value
    }
}

fun main() = runBlocking<Unit> {
    try {
        simple().collect { value ->
            println(value)
            check(value <= 1) { "Collected $value" }
        }
    } catch (e: Throwable) {
        println("Caught $e")
    }
}
```

You can get the full code here.

This code successfully catches an exception in collect terminal operator and, as we see, no more values are emitted after that:

```
Emitting 1
1
Emitting 2
2
Caught java.lang.IllegalStateException: Collected 2
```

Everything is caught

The previous example actually catches any exception happening in the emitter or in any intermediate or terminal operators. For example, let's change the code so that emitted values are mapped to strings, but the corresponding code produces an exception:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun simple(): Flow<String> =
    flow {
        for (i in 1..3) {
            println("Emitting $i")
            emit(i) // emit next value
        }
    }
    .map { value ->
        check(value <= 1) { "Crashed on $value" }
        "string $value"
    }

fun main() = runBlocking<Unit> {
    try {
        simple().collect { value -> println(value) }
    } catch (e: Throwable) {
        println("Caught $e")
    }
}
```

You can get the full code here.

This exception is still caught and collection is stopped:

```
Emitting 1
string 1
Emitting 2
Caught java.lang.IllegalStateException: Crashed on 2
```

Exception transparency

But how can code of the emitter encapsulate its exception handling behavior?

Flows must be transparent to exceptions and it is a violation of the exception transparency to emit values in the flow { ... } builder from inside of a try/catch block. This guarantees that a collector throwing an exception can always catch it using try/catch as in the previous example.

The emitter can use a catch operator that preserves this exception transparency and allows encapsulation of its exception handling. The body of the catch operator can analyze an exception and react to it in different ways depending on which exception was caught:

- Exceptions can be rethrown using throw.
- Exceptions can be turned into emission of values using emit from the body of catch.
- Exceptions can be ignored, logged, or processed by some other code.

For example, let us emit the text on catching an exception:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*
```

```
fun simple(): Flow<String> =
    flow {
        for (i in 1..3) {
            println("Emitting $i")
            emit(i) // emit next value
        }
    }
    .map { value ->
        check(value <= 1) { "Crashed on $value" }
        "string $value"
    }

fun main() = runBlocking<Unit> {
    simple()
        .catch { e -> emit("Caught $e") } // emit on exception
        .collect { value -> println(value) }
}
```

You can get the full code here.

The output of the example is the same, even though we do not have try/catch around the code anymore.

Transparent catch

The catch intermediate operator, honoring exception transparency, catches only upstream exceptions (that is an exception from all the operators above catch, but not below it). If the block in collect { ... } (placed below catch) throws an exception then it escapes:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun simple(): Flow<Int> = flow {
    for (i in 1..3) {
        println("Emitting $i")
        emit(i)
    }
}

fun main() = runBlocking<Unit> {
    simple()
        .catch { e -> println("Caught $e") } // does not catch downstream exceptions
        .collect { value ->
            check(value <= 1) { "Collected $value" }
            println(value)
        }
}
```

You can get the full code here.

A "Caught ..." message is not printed despite there being a catch operator:

```
Emitting 1
1
Emitting 2
Exception in thread "main" java.lang.IllegalStateException: Collected 2
 at ...
```

Catching declaratively

We can combine the declarative nature of the catch operator with a desire to handle all the exceptions, by moving the body of the collect operator into onEach and putting it before the catch operator. Collection of this flow must be triggered by a call to collect() without parameters:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun simple(): Flow<Int> = flow {
    for (i in 1..3) {
        println("Emitting $i")
        emit(i)
    }
}

fun main() = runBlocking<Unit> {
    simple()
        .onEach { value ->
            check(value <= 1) { "Collected $value" }
            println(value)
        }
        .catch { e -> println("Caught $e") }
        .collect()
}
```

You can get the full code here.

Now we can see that a "Caught ..." message is printed and so we can catch all the exceptions without explicitly using a try/catch block:

```
Emitting 1
1
Emitting 2
Caught java.lang.IllegalStateException: Collected 2
```

Flow completion

When flow collection completes (normally or exceptionally) it may need to execute an action. As you may have already noticed, it can be done in two ways: imperative or declarative.

Imperative finally block

In addition to try/catch, a collector can also use a finally block to execute an action upon collect completion.

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun simple(): Flow<Int> = (1..3).asFlow()

fun main() = runBlocking<Unit> {
    try {
        simple().collect { value -> println(value) }
    } finally {
        println("Done")
    }
}
```

You can get the full code here.

This code prints three numbers produced by the simple flow followed by a "Done" string:

```
1
2
3
Done
```

Declarative handling

For the declarative approach, flow has onCompletion intermediate operator that is invoked when the flow has completely collected.

The previous example can be rewritten using an onCompletion operator and produces the same output:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun simple(): Flow<Int> = (1..3).asFlow()

fun main() = runBlocking<Unit> {
    simple()
        .onCompletion { println("Done") }
        .collect { value -> println(value) }
}
```

You can get the full code here.

The key advantage of onCompletion is a nullable Throwable parameter of the lambda that can be used to determine whether the flow collection was completed normally or exceptionally. In the following example the simple flow throws an exception after emitting the number 1:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun simple(): Flow<Int> = flow {
    emit(1)
    throw RuntimeException()
}

fun main() = runBlocking<Unit> {
    simple()
        .onCompletion { cause -> if (cause != null) println("Flow completed exceptionally") }
        .catch { cause -> println("Caught exception") }
        .collect { value -> println(value) }
}
```

You can get the full code here.

As you may expect, it prints:

```
1
Flow completed exceptionally
Caught exception
```

The onCompletion operator, unlike catch, does not handle the exception. As we can see from the above example code, the exception still flows downstream. It will be delivered to further onCompletion operators and can be handled with a catch operator.

Successful completion

Another difference with catch operator is that onCompletion sees all exceptions and receives a null exception only on successful completion of the upstream flow (without cancellation or failure).

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

fun simple(): Flow<Int> = (1..3).asFlow()

fun main() = runBlocking<Unit> {
    simple()
        .onCompletion { cause -> println("Flow completed with $cause") }
        .collect { value ->
            check(value <= 1) { "Collected $value" }
            println(value)
        }
}
```

You can get the full code here.

We can see the completion cause is not null, because the flow was aborted due to downstream exception:

```
1
Flow completed with java.lang.IllegalStateException: Collected 2
Exception in thread "main" java.lang.IllegalStateException: Collected 2
```

Imperative versus declarative

Now we know how to collect flow, and handle its completion and exceptions in both imperative and declarative ways. The natural question here is, which approach is preferred and why? As a library, we do not advocate for any particular approach and believe that both options are valid and should be selected according to your own preferences and code style.

Launching flow

It is easy to use flows to represent asynchronous events that are coming from some source. In this case, we need an analogue of the addEventListener function that registers a piece of code with a reaction for incoming events and continues further work. The onEach operator can serve this role. However, onEach is an intermediate operator. We also need a terminal operator to collect the flow. Otherwise, just calling onEach has no effect.

If we use the collect terminal operator after onEach, then the code after it will wait until the flow is collected:

```kotlin
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

// Imitate a flow of events
fun events(): Flow<Int> = (1..3).asFlow().onEach { delay(100) }

fun main() = runBlocking<Unit> {
    events()
        .onEach { event -> println("Event: $event") }
        .collect() // <--- Collecting the flow waits
    println("Done")
}
```

You can get the full code here.

As you can see, it prints:

```
Event: 1
Event: 2
Event: 3
Done
```

The launchIn terminal operator comes in handy here. By replacing collect with launchIn we can launch a collection of the flow in a separate coroutine, so that execution of further code immediately continues:

```kotlin
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

// Imitate a flow of events
fun events(): Flow<Int> = (1..3).asFlow().onEach { delay(100) }

fun main() = runBlocking<Unit> {
    events()
        .onEach { event -> println("Event: $event") }
        .launchIn(this) // <--- Launching the flow in a separate coroutine
    println("Done")
}
```

You can get the full code here.

It prints:

```
Done
Event: 1
Event: 2
Event: 3
```

The required parameter to launchIn must specify a CoroutineScope in which the coroutine to collect the flow is launched. In the above example this scope comes from the runBlocking coroutine builder, so while the flow is running, this runBlocking scope waits for completion of its child coroutine and keeps the main function from returning and terminating this example.

In actual applications a scope will come from an entity with a limited lifetime. As soon as the lifetime of this entity is terminated the corresponding scope is cancelled, cancelling the collection of the corresponding flow. This way the pair of onEach { ... }.launchIn(scope) works like the addEventListener. However, there is no need for the corresponding removeEventListener function, as cancellation and structured concurrency serve this purpose.

Note that launchIn also returns a Job, which can be used to cancel the corresponding flow collection coroutine only without cancelling the whole scope or to join it.

Flow cancellation checks

For convenience, the flow builder performs additional ensureActive checks for cancellation on each emitted value. It means that a busy loop emitting from a flow { ... } is cancellable:

```kotlin
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

//sampleStart
fun foo(): Flow<Int> = flow {
    for (i in 1..5) {
        println("Emitting $i")
        emit(i)
    }
}

fun main() = runBlocking<Unit> {
    foo().collect { value ->
        if (value == 3) cancel()
        println(value)
    }
}
```

You can get the full code here.

We get only numbers up to 3 and a CancellationException after trying to emit number 4:

```
Emitting 1
1
Emitting 2
2
Emitting 3
3
Emitting 4
Exception in thread "main" kotlinx.coroutines.JobCancellationException: BlockingCoroutine was cancelled;
job="coroutine#1":BlockingCoroutine{Cancelled}@6d7b4f4c
```

However, most other flow operators do not do additional cancellation checks on their own for performance reasons. For example, if you use IntRange.asFlow extension to write the same busy loop and don't suspend anywhere, then there are no checks for cancellation:

```kotlin
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

//sampleStart
fun main() = runBlocking<Unit> {
    (1..5).asFlow().collect { value ->
        if (value == 3) cancel()
        println(value)
    }
}
```

You can get the full code here.

All numbers from 1 to 5 are collected and cancellation gets detected only before return from runBlocking:

```
1
2
3
4
5
Exception in thread "main" kotlinx.coroutines.JobCancellationException: BlockingCoroutine was cancelled;
job="coroutine#1":BlockingCoroutine{Cancelled}@3327bd23
```

Making busy flow cancellable

In the case where you have a busy loop with coroutines you must explicitly check for cancellation. You can add .onEach { currentCoroutineContext().ensureActive() }, but there is a ready-to-use cancellable operator provided to do that:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*

//sampleStart
fun main() = runBlocking<Unit> {
    (1..5).asFlow().cancellable().collect { value ->
        if (value == 3) cancel()
        println(value)
    }
}
```

You can get the full code here.

With the cancellable operator only the numbers from 1 to 3 are collected:

```
1
2
3
Exception in thread "main" kotlinx.coroutines.JobCancellationException: BlockingCoroutine was cancelled;
job="coroutine#1":BlockingCoroutine{Cancelled}@5ec0a365
```

Flow and Reactive Streams

For those who are familiar with Reactive Streams or reactive frameworks such as RxJava and project Reactor, design of the Flow may look very familiar.

Indeed, its design was inspired by Reactive Streams and its various implementations. But Flow main goal is to have as simple design as possible, be Kotlin and suspension friendly and respect structured concurrency. Achieving this goal would be impossible without reactive pioneers and their tremendous work. You can read the complete story in Reactive Streams and Kotlin Flows article.

While being different, conceptually, Flow is a reactive stream and it is possible to convert it to the reactive (spec and TCK compliant) Publisher and vice versa. Such converters are provided by kotlinx.coroutines out-of-the-box and can be found in corresponding reactive modules (kotlinx-coroutines-reactive for Reactive Streams, kotlinx-coroutines-reactor for Project Reactor and kotlinx-coroutines-rx2/kotlinx-coroutines-rx3 for RxJava2/RxJava3). Integration modules include conversions from and to Flow, integration with Reactor's Context and suspension-friendly ways to work with various reactive entities.

Channels

Deferred values provide a convenient way to transfer a single value between coroutines. Channels provide a way to transfer a stream of values.

Channel basics

A Channel is conceptually very similar to BlockingQueue. One key difference is that instead of a blocking put operation it has a suspending send, and instead of a blocking take operation it has a suspending receive.

```kotlin
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*

fun main() = runBlocking {
    val channel = Channel<Int>()
    launch {
        // this might be heavy CPU-consuming computation or async logic,
        // we'll just send five squares
        for (x in 1..5) channel.send(x * x)
    }
    // here we print five received integers:
    repeat(5) { println(channel.receive()) }
    println("Done!")
}
```

You can get the full code here.

The output of this code is:

```
1
4
9
16
25
Done!
```

Closing and iteration over channels

Unlike a queue, a channel can be closed to indicate that no more elements are coming. On the receiver side it is convenient to use a regular for loop to receive elements from the channel.

Conceptually, a close is like sending a special close token to the channel. The iteration stops as soon as this close token is received, so there is a guarantee that all previously sent elements before the close are received:

```kotlin
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*

fun main() = runBlocking {
    val channel = Channel<Int>()
    launch {
        for (x in 1..5) channel.send(x * x)
        channel.close() // we're done sending
    }
    // here we print received values using `for` loop (until the channel is closed)
    for (y in channel) println(y)
    println("Done!")
}
```

You can get the full code here.

Building channel producers

The pattern where a coroutine is producing a sequence of elements is quite common. This is a part of producer-consumer pattern that is often found in concurrent code. You could abstract such a producer into a function that takes channel as its parameter, but this goes contrary to common sense that results must be returned from functions.

There is a convenient coroutine builder named produce that makes it easy to do it right on producer side, and an extension function consumeEach, that replaces a for loop on the consumer side:

```kotlin
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*
```

```
fun CoroutineScope.produceSquares(): ReceiveChannel<Int> = produce {
    for (x in 1..5) send(x * x)
}

fun main() = runBlocking {
    val squares = produceSquares()
    squares.consumeEach { println(it) }
    println("Done!")
}
```

You can get the full code here.

Pipelines

A pipeline is a pattern where one coroutine is producing, possibly infinite, stream of values:

```
fun CoroutineScope.produceNumbers() = produce<Int> {
    var x = 1
    while (true) send(x++) // infinite stream of integers starting from 1
}
```

And another coroutine or coroutines are consuming that stream, doing some processing, and producing some other results. In the example below, the numbers are just squared:

```
fun CoroutineScope.square(numbers: ReceiveChannel<Int>): ReceiveChannel<Int> = produce {
    for (x in numbers) send(x * x)
}
```

The main code starts and connects the whole pipeline:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*

fun main() = runBlocking {
    val numbers = produceNumbers() // produces integers from 1 and on
    val squares = square(numbers) // squares integers
    repeat(5) {
        println(squares.receive()) // print first five
    }
    println("Done!") // we are done
    coroutineContext.cancelChildren() // cancel children coroutines
}

fun CoroutineScope.produceNumbers() = produce<Int> {
    var x = 1
    while (true) send(x++) // infinite stream of integers starting from 1
}

fun CoroutineScope.square(numbers: ReceiveChannel<Int>): ReceiveChannel<Int> = produce {
    for (x in numbers) send(x * x)
}
```

You can get the full code here.

All functions that create coroutines are defined as extensions on CoroutineScope, so that we can rely on structured concurrency to make sure that we don't have lingering global coroutines in our application.

Prime numbers with pipeline

Let's take pipelines to the extreme with an example that generates prime numbers using a pipeline of coroutines. We start with an infinite sequence of numbers.

```
fun CoroutineScope.numbersFrom(start: Int) = produce<Int> {
    var x = start
    while (true) send(x++) // infinite stream of integers from start
}
```

The following pipeline stage filters an incoming stream of numbers, removing all the numbers that are divisible by the given prime number:

```
fun CoroutineScope.filter(numbers: ReceiveChannel<Int>, prime: Int) = produce<Int> {
    for (x in numbers) if (x % prime != 0) send(x)
}
```

Now we build our pipeline by starting a stream of numbers from 2, taking a prime number from the current channel, and launching new pipeline stage for each prime number found:

```
numbersFrom(2) -> filter(2) -> filter(3) -> filter(5) -> filter(7) ...
```

The following example prints the first ten prime numbers, running the whole pipeline in the context of the main thread. Since all the coroutines are launched in the scope of the main runBlocking coroutine we don't have to keep an explicit list of all the coroutines we have started. We use cancelChildren extension function to cancel all the children coroutines after we have printed the first ten prime numbers.

```
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*

fun main() = runBlocking {
    var cur = numbersFrom(2)
    repeat(10) {
        val prime = cur.receive()
        println(prime)
        cur = filter(cur, prime)
    }
    coroutineContext.cancelChildren() // cancel all children to let main finish
}

fun CoroutineScope.numbersFrom(start: Int) = produce<Int> {
    var x = start
    while (true) send(x++) // infinite stream of integers from start
}

fun CoroutineScope.filter(numbers: ReceiveChannel<Int>, prime: Int) = produce<Int> {
    for (x in numbers) if (x % prime != 0) send(x)
}
```

You can get the full code here.

The output of this code is:

```
2
3
5
7
11
13
17
19
23
29
```

Note that you can build the same pipeline using iterator coroutine builder from the standard library. Replace produce with iterator, send with yield, receive with next, ReceiveChannel with Iterator, and get rid of the coroutine scope. You will not need runBlocking either. However, the benefit of a pipeline that uses channels as shown above is that it can actually use multiple CPU cores if you run it in Dispatchers.Default context.

Anyway, this is an extremely impractical way to find prime numbers. In practice, pipelines do involve some other suspending invocations (like asynchronous calls to remote services) and these pipelines cannot be built using sequence/iterator, because they do not allow arbitrary suspension, unlike produce, which is fully asynchronous.

Fan-out

Multiple coroutines may receive from the same channel, distributing work between themselves. Let us start with a producer coroutine that is periodically producing integers (ten numbers per second):

```
fun CoroutineScope.produceNumbers() = produce<Int> {
    var x = 1 // start from 1
    while (true) {
        send(x++) // produce next
        delay(100) // wait 0.1s
    }
}
```

Then we can have several processor coroutines. In this example, they just print their id and received number:

```
fun CoroutineScope.launchProcessor(id: Int, channel: ReceiveChannel<Int>) = launch {
    for (msg in channel) {
        println("Processor #$id received $msg")
    }
}
```

Now let us launch five processors and let them work for almost a second. See what happens:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*

fun main() = runBlocking<Unit> {
    val producer = produceNumbers()
    repeat(5) { launchProcessor(it, producer) }
    delay(950)
    producer.cancel() // cancel producer coroutine and thus kill them all
}

fun CoroutineScope.produceNumbers() = produce<Int> {
    var x = 1 // start from 1
    while (true) {
        send(x++) // produce next
        delay(100) // wait 0.1s
    }
}

fun CoroutineScope.launchProcessor(id: Int, channel: ReceiveChannel<Int>) = launch {
    for (msg in channel) {
        println("Processor #$id received $msg")
    }
}
```

You can get the full code here.

The output will be similar to the following one, albeit the processor ids that receive each specific integer may be different:

```
Processor #2 received 1
Processor #4 received 2
Processor #0 received 3
Processor #1 received 4
Processor #3 received 5
Processor #2 received 6
Processor #4 received 7
Processor #0 received 8
Processor #1 received 9
Processor #3 received 10
```

Note that cancelling a producer coroutine closes its channel, thus eventually terminating iteration over the channel that processor coroutines are doing.

Also, pay attention to how we explicitly iterate over channel with for loop to perform fan-out in launchProcessor code. Unlike consumeEach, this for loop pattern is perfectly safe to use from multiple coroutines. If one of the processor coroutines fails, then others would still be processing the channel, while a processor that is written via consumeEach always consumes (cancels) the underlying channel on its normal or abnormal completion.

Fan-in

Multiple coroutines may send to the same channel. For example, let us have a channel of strings, and a suspending function that repeatedly sends a specified string to this channel with a specified delay:

```
suspend fun sendString(channel: SendChannel<String>, s: String, time: Long) {
    while (true) {
        delay(time)
        channel.send(s)
    }
}
```

Now, let us see what happens if we launch a couple of coroutines sending strings (in this example we launch them in the context of the main thread as main coroutine's children):

```
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*

fun main() = runBlocking {
    val channel = Channel<String>()
    launch { sendString(channel, "foo", 200L) }
    launch { sendString(channel, "BAR!", 500L) }
    repeat(6) { // receive first six
        println(channel.receive())
    }
    coroutineContext.cancelChildren() // cancel all children to let main finish
}

suspend fun sendString(channel: SendChannel<String>, s: String, time: Long) {
    while (true) {
        delay(time)
        channel.send(s)
    }
}
```

You can get the full code here.

The output is:

```
foo
foo
BAR!
foo
foo
BAR!
```

Buffered channels

The channels shown so far had no buffer. Unbuffered channels transfer elements when sender and receiver meet each other (aka rendezvous). If send is invoked first, then it is suspended until receive is invoked, if receive is invoked first, it is suspended until send is invoked.

Both Channel() factory function and produce builder take an optional capacity parameter to specify buffer size. Buffer allows senders to send multiple elements before suspending, similar to the BlockingQueue with a specified capacity, which blocks when buffer is full.

Take a look at the behavior of the following code:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*

fun main() = runBlocking<Unit> {
    val channel = Channel<Int>(4) // create buffered channel
    val sender = launch { // launch sender coroutine
        repeat(10) {
            println("Sending $it") // print before sending each element
            channel.send(it) // will suspend when buffer is full
        }
    }
    // don't receive anything... just wait....
    delay(1000)
    sender.cancel() // cancel sender coroutine
}
```

You can get the full code here.

It prints "sending" five times using a buffered channel with capacity of four:

```
Sending 0
Sending 1
Sending 2
Sending 3
Sending 4
```

The first four elements are added to the buffer and the sender suspends when trying to send the fifth one.

Channels are fair

Send and receive operations to channels are fair with respect to the order of their invocation from multiple coroutines. They are served in first-in first-out order, e.g. the first coroutine to invoke receive gets the element. In the following example two coroutines "ping" and "pong" are receiving the "ball" object from the shared "table" channel.

```
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*

data class Ball(var hits: Int)

fun main() = runBlocking {
    val table = Channel<Ball>() // a shared table
    launch { player("ping", table) }
    launch { player("pong", table) }
    table.send(Ball(0)) // serve the ball
    delay(1000) // delay 1 second
    coroutineContext.cancelChildren() // game over, cancel them
}

suspend fun player(name: String, table: Channel<Ball>) {
    for (ball in table) { // receive the ball in a loop
        ball.hits++
        println("$name $ball")
        delay(300) // wait a bit
        table.send(ball) // send the ball back
    }
}
```

You can get the full code here.

The "ping" coroutine is started first, so it is the first one to receive the ball. Even though "ping" coroutine immediately starts receiving the ball again after sending it back to the table, the ball gets received by the "pong" coroutine, because it was already waiting for it:

```
ping Ball(hits=1)
pong Ball(hits=2)
ping Ball(hits=3)
pong Ball(hits=4)
```

Note that sometimes channels may produce executions that look unfair due to the nature of the executor that is being used. See this issue for details.

Ticker channels

Ticker channel is a special rendezvous channel that produces Unit every time given delay passes since last consumption from this channel. Though it may seem to be useless standalone, it is a useful building block to create complex time-based produce pipelines and operators that do windowing and other time-dependent processing. Ticker channel can be used in select to perform "on tick" action.

To create such channel use a factory method ticker. To indicate that no further elements are needed use ReceiveChannel.cancel method on it.

Now let's see how it works in practice:

```kotlin
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*

fun main() = runBlocking<Unit> {
    val tickerChannel = ticker(delayMillis = 200, initialDelayMillis = 0) // create a ticker channel
    var nextElement = withTimeoutOrNull(1) { tickerChannel.receive() }
    println("Initial element is available immediately: $nextElement") // no initial delay

    nextElement = withTimeoutOrNull(100) { tickerChannel.receive() } // all subsequent elements have 200ms delay
    println("Next element is not ready in 100 ms: $nextElement")

    nextElement = withTimeoutOrNull(120) { tickerChannel.receive() }
    println("Next element is ready in 200 ms: $nextElement")

    // Emulate large consumption delays
    println("Consumer pauses for 300ms")
    delay(300)
    // Next element is available immediately
    nextElement = withTimeoutOrNull(1) { tickerChannel.receive() }
    println("Next element is available immediately after large consumer delay: $nextElement")
    // Note that the pause between `receive` calls is taken into account and next element arrives faster
    nextElement = withTimeoutOrNull(120) { tickerChannel.receive() }
    println("Next element is ready in 100ms after consumer pause in 300ms: $nextElement")

    tickerChannel.cancel() // indicate that no more elements are needed
}
```

You can get the full code here.

It prints following lines:

```
Initial element is available immediately: kotlin.Unit
Next element is not ready in 100 ms: null
Next element is ready in 200 ms: kotlin.Unit
Consumer pauses for 300ms
Next element is available immediately after large consumer delay: kotlin.Unit
Next element is ready in 100ms after consumer pause in 300ms: kotlin.Unit
```

Note that ticker is aware of possible consumer pauses and, by default, adjusts next produced element delay if a pause occurs, trying to maintain a fixed rate of produced elements.

Optionally, a mode parameter equal to TickerMode.FIXED_DELAY can be specified to maintain a fixed delay between elements.

Coroutine exceptions handling

This section covers exception handling and cancellation on exceptions. We already know that a cancelled coroutine throws CancellationException in suspension points and that it is ignored by the coroutines' machinery. Here we look at what happens if an exception is thrown during cancellation or multiple children of the same coroutine throw an exception.

Exception propagation

Coroutine builders come in two flavors: propagating exceptions automatically (launch) or exposing them to users (async and produce). When these builders are used to create a root coroutine, that is not a child of another coroutine, the former builders treat exceptions as uncaught exceptions, similar to Java's Thread.uncaughtExceptionHandler, while the latter are relying on the user to consume the final exception, for example via await or receive (produce and receive are covered in Channels section).

It can be demonstrated by a simple example that creates root coroutines using the GlobalScope:

GlobalScope is a delicate API that can backfire in non-trivial ways. Creating a root coroutine for the whole application is one of the rare legitimate uses for GlobalScope, so you must explicitly opt-in into using GlobalScope with @OptIn(DelicateCoroutinesApi::class).

```
import kotlinx.coroutines.*

@OptIn(DelicateCoroutinesApi::class)
fun main() = runBlocking {
    val job = GlobalScope.launch { // root coroutine with launch
        println("Throwing exception from launch")
        throw IndexOutOfBoundsException() // Will be printed to the console by Thread.defaultUncaughtExceptionHandler
    }
    job.join()
    println("Joined failed job")
    val deferred = GlobalScope.async { // root coroutine with async
        println("Throwing exception from async")
        throw ArithmeticException() // Nothing is printed, relying on user to call await
    }
    try {
        deferred.await()
        println("Unreached")
    } catch (e: ArithmeticException) {
        println("Caught ArithmeticException")
    }
}
```

You can get the full code here.

The output of this code is (with debug):

```
Throwing exception from launch
Exception in thread "DefaultDispatcher-worker-1 @coroutine#2" java.lang.IndexOutOfBoundsException
Joined failed job
Throwing exception from async
Caught ArithmeticException
```

CoroutineExceptionHandler

It is possible to customize the default behavior of printing uncaught exceptions to the console. CoroutineExceptionHandler context element on a root coroutine can be used as a generic catch block for this root coroutine and all its children where custom exception handling may take place. It is similar to Thread.uncaughtExceptionHandler. You cannot recover from the exception in the CoroutineExceptionHandler. The coroutine had already completed with the corresponding exception when the handler is called. Normally, the handler is used to log the exception, show some kind of error message, terminate, and/or restart the application.

CoroutineExceptionHandler is invoked only on uncaught exceptions — exceptions that were not handled in any other way. In particular, all children coroutines (coroutines created in the context of another Job) delegate handling of their exceptions to their parent coroutine, which also delegates to the parent, and so on until the root, so the CoroutineExceptionHandler installed in their context is never used. In addition to that, async builder always catches all exceptions and represents them in the resulting Deferred object, so its CoroutineExceptionHandler has no effect either.

Coroutines running in supervision scope do not propagate exceptions to their parent and are excluded from this rule. A further Supervision section of this document gives more details.

```
import kotlinx.coroutines.*

@OptIn(DelicateCoroutinesApi::class)
fun main() = runBlocking {
    val handler = CoroutineExceptionHandler { _, exception ->
        println("CoroutineExceptionHandler got $exception")
    }
    val job = GlobalScope.launch(handler) { // root coroutine, running in GlobalScope
        throw AssertionError()
    }
    val deferred = GlobalScope.async(handler) { // also root, but async instead of launch
        throw ArithmeticException() // Nothing will be printed, relying on user to call deferred.await()
    }
    joinAll(job, deferred)
}
```

You can get the full code here.

The output of this code is:

```
CoroutineExceptionHandler got java.lang.AssertionError
```

Cancellation and exceptions

Cancellation is closely related to exceptions. Coroutines internally use CancellationException for cancellation, these exceptions are ignored by all handlers, so they should be used only as the source of additional debug information, which can be obtained by catch block. When a coroutine is cancelled using Job.cancel, it terminates, but it does not cancel its parent.

```
import kotlinx.coroutines.*

fun main() = runBlocking {
    val job = launch {
        val child = launch {
            try {
                delay(Long.MAX_VALUE)
            } finally {
                println("Child is cancelled")
            }
        }
        yield()
        println("Cancelling child")
        child.cancel()
        child.join()
        yield()
        println("Parent is not cancelled")
    }
    job.join()
}
```

You can get the full code here.

The output of this code is:

```
Cancelling child
Child is cancelled
Parent is not cancelled
```

If a coroutine encounters an exception other than CancellationException, it cancels its parent with that exception. This behaviour cannot be overridden and is used to provide stable coroutines hierarchies for structured concurrency. CoroutineExceptionHandler implementation is not used for child coroutines.

In these examples, CoroutineExceptionHandler is always installed to a coroutine that is created in GlobalScope. It does not make sense to install an exception handler to a coroutine that is launched in the scope of the main runBlocking, since the main coroutine is going to be always cancelled when its child completes with exception despite the installed handler.

The original exception is handled by the parent only when all its children terminate, which is demonstrated by the following example.

```
import kotlinx.coroutines.*

@OptIn(DelicateCoroutinesApi::class)
fun main() = runBlocking {
    val handler = CoroutineExceptionHandler { _, exception ->
        println("CoroutineExceptionHandler got $exception")
    }
    val job = GlobalScope.launch(handler) {
        launch { // the first child
            try {
                delay(Long.MAX_VALUE)
            } finally {
                withContext(NonCancellable) {
                    println("Children are cancelled, but exception is not handled until all children terminate")
                    delay(100)
                    println("The first child finished its non cancellable block")
                }
            }
        }
        launch { // the second child
            delay(10)
            println("Second child throws an exception")
            throw ArithmeticException()
        }
    }
    job.join()
}
```

You can get the full code here.

The output of this code is:

```
Second child throws an exception
Children are cancelled, but exception is not handled until all children terminate
The first child finished its non cancellable block
CoroutineExceptionHandler got java.lang.ArithmeticException
```

Exceptions aggregation

When multiple children of a coroutine fail with an exception, the general rule is "the first exception wins", so the first exception gets handled. All additional exceptions that happen after the first one are attached to the first exception as suppressed ones.

```
import kotlinx.coroutines.*
import java.io.*

@OptIn(DelicateCoroutinesApi::class)
fun main() = runBlocking {
    val handler = CoroutineExceptionHandler { _, exception ->
        println("CoroutineExceptionHandler got $exception with suppressed ${exception.suppressed.contentToString()}")
    }
    val job = GlobalScope.launch(handler) {
        launch {
            try {
                delay(Long.MAX_VALUE) // it gets cancelled when another sibling fails with IOException
            } finally {
                throw ArithmeticException() // the second exception
            }
        }
        launch {
            delay(100)
            throw IOException() // the first exception
        }
        delay(Long.MAX_VALUE)
    }
    job.join()
}
```

You can get the full code here.

The output of this code is:

```
CoroutineExceptionHandler got java.io.IOException with suppressed [java.lang.ArithmeticException]
```

Note that this mechanism currently only works on Java version 1.7+. The JS and Native restrictions are temporary and will be lifted in the future.

Cancellation exceptions are transparent and are unwrapped by default:

```kotlin
import kotlinx.coroutines.*
import java.io.*

@OptIn(DelicateCoroutinesApi::class)
fun main() = runBlocking {
    val handler = CoroutineExceptionHandler { _, exception ->
        println("CoroutineExceptionHandler got $exception")
    }
    val job = GlobalScope.launch(handler) {
        val innerJob = launch { // all this stack of coroutines will get cancelled
            launch {
                launch {
                    throw IOException() // the original exception
                }
            }
        }
        try {
            innerJob.join()
        } catch (e: CancellationException) {
            println("Rethrowing CancellationException with original cause")
            throw e // cancellation exception is rethrown, yet the original IOException gets to the handler
        }
    }
    job.join()
}
```

You can get the full code here.

The output of this code is:

```
Rethrowing CancellationException with original cause
CoroutineExceptionHandler got java.io.IOException
```

Supervision

As we have studied before, cancellation is a bidirectional relationship propagating through the whole hierarchy of coroutines. Let us take a look at the case when unidirectional cancellation is required.

A good example of such a requirement is a UI component with the job defined in its scope. If any of the UI's child tasks have failed, it is not always necessary to cancel (effectively kill) the whole UI component, but if the UI component is destroyed (and its job is cancelled), then it is necessary to cancel all child jobs as their results are no longer needed.

Another example is a server process that spawns multiple child jobs and needs to supervise their execution, tracking their failures and only restarting the failed ones.

Supervision job

The SupervisorJob can be used for these purposes. It is similar to a regular Job with the only exception that cancellation is propagated only downwards. This can easily be demonstrated using the following example:

```kotlin
import kotlinx.coroutines.*

fun main() = runBlocking {
    val supervisor = SupervisorJob()
    with(CoroutineScope(coroutineContext + supervisor)) {
        // launch the first child -- its exception is ignored for this example (don't do this in practice!)
        val firstChild = launch(CoroutineExceptionHandler { _, _ ->  }) {
            println("The first child is failing")
            throw AssertionError("The first child is cancelled")
        }
        // launch the second child
        val secondChild = launch {
            firstChild.join()
            // Cancellation of the first child is not propagated to the second child
            println("The first child is cancelled: ${firstChild.isCancelled}, but the second one is still active")
            try {
                delay(Long.MAX_VALUE)
            } finally {
                // But cancellation of the supervisor is propagated
                println("The second child is cancelled because the supervisor was cancelled")
            }
        }
        // wait until the first child fails & completes
        firstChild.join()
        println("Cancelling the supervisor")
        supervisor.cancel()
        secondChild.join()
    }
}
```

You can get the full code here.

The output of this code is:

```
The first child is failing
The first child is cancelled: true, but the second one is still active
Cancelling the supervisor
The second child is cancelled because the supervisor was cancelled
```

Supervision scope

Instead of coroutineScope, we can use supervisorScope for scoped concurrency. It propagates the cancellation in one direction only and cancels all its children only if it failed itself. It also waits for all children before completion just like coroutineScope does.

```
import kotlin.coroutines.*
import kotlinx.coroutines.*

fun main() = runBlocking {
    try {
        supervisorScope {
            val child = launch {
                try {
                    println("The child is sleeping")
                    delay(Long.MAX_VALUE)
                } finally {
                    println("The child is cancelled")
                }
            }
            // Give our child a chance to execute and print using yield
            yield()
            println("Throwing an exception from the scope")
            throw AssertionError()
        }
    } catch(e: AssertionError) {
        println("Caught an assertion error")
    }
}
```

You can get the full code here.

The output of this code is:

```
The child is sleeping
Throwing an exception from the scope
The child is cancelled
Caught an assertion error
```

Exceptions in supervised coroutines

Another crucial difference between regular and supervisor jobs is exception handling. Every child should handle its exceptions by itself via the exception handling mechanism. This difference comes from the fact that child's failure does not propagate to the parent. It means that coroutines launched directly inside the supervisorScope do use the CoroutineExceptionHandler that is installed in their scope in the same way as root coroutines do (see the CoroutineExceptionHandler section for details).

```
import kotlin.coroutines.*
import kotlinx.coroutines.*

fun main() = runBlocking {
    val handler = CoroutineExceptionHandler { _, exception ->
        println("CoroutineExceptionHandler got $exception")
    }
    supervisorScope {
        val child = launch(handler) {
            println("The child throws an exception")
            throw AssertionError()
        }
        println("The scope is completing")
    }
    println("The scope is completed")
}
```

You can get the full code here.

The output of this code is:

```
The scope is completing
The child throws an exception
CoroutineExceptionHandler got java.lang.AssertionError
The scope is completed
```

Shared mutable state and concurrency

Coroutines can be executed parallelly using a multi-threaded dispatcher like the Dispatchers.Default. It presents all the usual parallelism problems. The main problem being synchronization of access to shared mutable state. Some solutions to this problem in the land of coroutines are similar to the solutions in the multi-threaded world, but others are unique.

The problem

Let us launch a hundred coroutines all doing the same action a thousand times. We'll also measure their completion time for further comparisons:

```
suspend fun massiveRun(action: suspend () -> Unit) {
    val n = 100  // number of coroutines to launch
    val k = 1000 // times an action is repeated by each coroutine
    val time = measureTimeMillis {
        coroutineScope { // scope for coroutines
            repeat(n) {
                launch {
                    repeat(k) { action() }
                }
            }
        }
    }
    println("Completed ${n * k} actions in $time ms")
}
```

We start with a very simple action that increments a shared mutable variable using multi-threaded Dispatchers.Default.

```
import kotlinx.coroutines.*
import kotlin.system.*

suspend fun massiveRun(action: suspend () -> Unit) {
    val n = 100  // number of coroutines to launch
    val k = 1000 // times an action is repeated by each coroutine
    val time = measureTimeMillis {
        coroutineScope { // scope for coroutines
            repeat(n) {
                launch {
                    repeat(k) { action() }
                }
            }
        }
    }
    println("Completed ${n * k} actions in $time ms")
}

var counter = 0

fun main() = runBlocking {
    withContext(Dispatchers.Default) {
        massiveRun {
            counter++
        }
    }
    println("Counter = $counter")
}
```

You can get the full code here.

What does it print at the end? It is highly unlikely to ever print "Counter = 100000", because a hundred coroutines increment the counter concurrently from multiple threads without any synchronization.

Volatiles are of no help

There is a common misconception that making a variable volatile solves concurrency problem. Let us try it:

```
import kotlinx.coroutines.*
import kotlin.system.*

suspend fun massiveRun(action: suspend () -> Unit) {
    val n = 100  // number of coroutines to launch
    val k = 1000 // times an action is repeated by each coroutine
    val time = measureTimeMillis {
        coroutineScope { // scope for coroutines
            repeat(n) {
                launch {
                    repeat(k) { action() }
                }
            }
        }
    }
    println("Completed ${n * k} actions in $time ms")
}

@Volatile // in Kotlin `volatile` is an annotation
var counter = 0

fun main() = runBlocking {
    withContext(Dispatchers.Default) {
        massiveRun {
            counter++
        }
    }
    println("Counter = $counter")
}
```

You can get the full code here.

This code works slower, but we still don't always get "Counter = 100000" at the end, because volatile variables guarantee linearizable (this is a technical term for "atomic") reads and writes to the corresponding variable, but do not provide atomicity of larger actions (increment in our case).

Thread-safe data structures

The general solution that works both for threads and for coroutines is to use a thread-safe (aka synchronized, linearizable, or atomic) data structure that provides all the necessary synchronization for the corresponding operations that needs to be performed on a shared state. In the case of a simple counter we can use AtomicInteger class which has atomic incrementAndGet operations:

```
import kotlinx.coroutines.*
import java.util.concurrent.atomic.*
import kotlin.system.*

suspend fun massiveRun(action: suspend () -> Unit) {
    val n = 100  // number of coroutines to launch
    val k = 1000 // times an action is repeated by each coroutine
    val time = measureTimeMillis {
        coroutineScope { // scope for coroutines
            repeat(n) {
                launch {
                    repeat(k) { action() }
                }
            }
        }
    }
    println("Completed ${n * k} actions in $time ms")
}

val counter = AtomicInteger()

fun main() = runBlocking {
    withContext(Dispatchers.Default) {
        massiveRun {
            counter.incrementAndGet()
        }
    }
    println("Counter = $counter")
}
```

You can get the full code here.

This is the fastest solution for this particular problem. It works for plain counters, collections, queues and other standard data structures and basic operations on them. However, it does not easily scale to complex state or to complex operations that do not have ready-to-use thread-safe implementations.

Thread confinement fine-grained

Thread confinement is an approach to the problem of shared mutable state where all access to the particular shared state is confined to a single thread. It is typically used in UI applications, where all UI state is confined to the single event-dispatch/application thread. It is easy to apply with coroutines by using a single-threaded context.

```
import kotlinx.coroutines.*
import kotlin.system.*

suspend fun massiveRun(action: suspend () -> Unit) {
    val n = 100  // number of coroutines to launch
    val k = 1000 // times an action is repeated by each coroutine
    val time = measureTimeMillis {
        coroutineScope { // scope for coroutines
            repeat(n) {
                launch {
                    repeat(k) { action() }
                }
            }
        }
    }
    println("Completed ${n * k} actions in $time ms")
}

val counterContext = newSingleThreadContext("CounterContext")
var counter = 0

fun main() = runBlocking {
    withContext(Dispatchers.Default) {
        massiveRun {
            // confine each increment to a single-threaded context
            withContext(counterContext) {
                counter++
            }
        }
    }
    println("Counter = $counter")
}
```

You can get the full code here.

This code works very slowly, because it does fine-grained thread-confinement. Each individual increment switches from multi-threaded Dispatchers.Default context to the single-threaded context using withContext(counterContext) block.

Thread confinement coarse-grained

In practice, thread confinement is performed in large chunks, e.g. big pieces of state-updating business logic are confined to the single thread. The following example does it like that, running each coroutine in the single-threaded context to start with.

```
import kotlinx.coroutines.*
import kotlin.system.*

suspend fun massiveRun(action: suspend () -> Unit) {
    val n = 100  // number of coroutines to launch
    val k = 1000 // times an action is repeated by each coroutine
    val time = measureTimeMillis {
        coroutineScope { // scope for coroutines
            repeat(n) {
                launch {
                    repeat(k) { action() }
                }
            }
        }
    }
    println("Completed ${n * k} actions in $time ms")
}

val counterContext = newSingleThreadContext("CounterContext")
var counter = 0

fun main() = runBlocking {
    // confine everything to a single-threaded context
    withContext(counterContext) {
        massiveRun {
            counter++
        }
    }
    println("Counter = $counter")
}
```

You can get the full code here.

This now works much faster and produces correct result.

Mutual exclusion

Mutual exclusion solution to the problem is to protect all modifications of the shared state with a critical section that is never executed concurrently. In a blocking world you'd typically use synchronized or ReentrantLock for that. Coroutine's alternative is called Mutex. It has lock and unlock functions to delimit a critical section. The key difference is that Mutex.lock() is a suspending function. It does not block a thread.

There is also withLock extension function that conveniently represents mutex.lock(); try { ... } finally { mutex.unlock() } pattern:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.sync.*
import kotlin.system.*
```

```
suspend fun massiveRun(action: suspend () -> Unit) {
    val n = 100  // number of coroutines to launch
    val k = 1000 // times an action is repeated by each coroutine
    val time = measureTimeMillis {
        coroutineScope { // scope for coroutines
            repeat(n) {
                launch {
                    repeat(k) { action() }
                }
            }
        }
    }
    println("Completed ${n * k} actions in $time ms")
}

val mutex = Mutex()
var counter = 0

fun main() = runBlocking {
    withContext(Dispatchers.Default) {
        massiveRun {
            // protect each increment with lock
            mutex.withLock {
                counter++
            }
        }
    }
    println("Counter = $counter")
}
```

You can get the full code here.

The locking in this example is fine-grained, so it pays the price. However, it is a good choice for some situations where you absolutely must modify some shared state periodically, but there is no natural thread that this state is confined to.

Select expression (experimental)

Select expression makes it possible to await multiple suspending functions simultaneously and select the first one that becomes available.

Select expressions are an experimental feature of kotlinx.coroutines. Their API is expected to evolve in the upcoming updates of the kotlinx.coroutines library with potentially breaking changes.

Selecting from channels

Let us have two producers of strings: fizz and buzz. The fizz produces "Fizz" string every 500 ms:

```
fun CoroutineScope.fizz() = produce<String> {
    while (true) { // sends "Fizz" every 500 ms
        delay(500)
        send("Fizz")
    }
}
```

And the buzz produces "Buzz!" string every 1000 ms:

```
fun CoroutineScope.buzz() = produce<String> {
    while (true) { // sends "Buzz!" every 1000 ms
        delay(1000)
        send("Buzz!")
    }
}
```

Using receive suspending function we can receive either from one channel or the other. But select expression allows us to receive from both simultaneously using its onReceive clauses:

```
suspend fun selectFizzBuzz(fizz: ReceiveChannel<String>, buzz: ReceiveChannel<String>) {
    select<Unit> { // <Unit> means that this select expression does not produce any result
        fizz.onReceive { value ->  // this is the first select clause
            println("fizz -> '$value'")
        }
        buzz.onReceive { value ->  // this is the second select clause
            println("buzz -> '$value'")
        }
    }
}
```

Let us run it all seven times:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*
import kotlinx.coroutines.selects.*

fun CoroutineScope.fizz() = produce<String> {
    while (true) { // sends "Fizz" every 500 ms
        delay(500)
        send("Fizz")
    }
}

fun CoroutineScope.buzz() = produce<String> {
    while (true) { // sends "Buzz!" every 1000 ms
        delay(1000)
        send("Buzz!")
    }
}

suspend fun selectFizzBuzz(fizz: ReceiveChannel<String>, buzz: ReceiveChannel<String>) {
    select<Unit> { // <Unit> means that this select expression does not produce any result
        fizz.onReceive { value ->  // this is the first select clause
            println("fizz -> '$value'")
        }
        buzz.onReceive { value ->  // this is the second select clause
            println("buzz -> '$value'")
        }
    }
}

fun main() = runBlocking<Unit> {
    val fizz = fizz()
    val buzz = buzz()
    repeat(7) {
        selectFizzBuzz(fizz, buzz)
    }
    coroutineContext.cancelChildren() // cancel fizz & buzz coroutines
}
```

You can get the full code here.

The result of this code is:

```
fizz -> 'Fizz'
buzz -> 'Buzz!'
fizz -> 'Fizz'
fizz -> 'Fizz'
buzz -> 'Buzz!'
fizz -> 'Fizz'
fizz -> 'Fizz'
```

Selecting on close

The onReceive clause in select fails when the channel is closed causing the corresponding select to throw an exception. We can use onReceiveCatching clause to perform a specific action when the channel is closed. The following example also shows that select is an expression that returns the result of its selected clause:

```
suspend fun selectAorB(a: ReceiveChannel<String>, b: ReceiveChannel<String>): String =
    select<String> {
        a.onReceiveCatching { it ->
            val value = it.getOrNull()
            if (value != null) {
                "a -> '$value'"
            } else {
                "Channel 'a' is closed"
            }
        }
        b.onReceiveCatching { it ->
            val value = it.getOrNull()
            if (value != null) {
                "b -> '$value'"
            } else {
                "Channel 'b' is closed"
            }
        }
    }
```

Let's use it with channel a that produces "Hello" string four times and channel b that produces "World" four times:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*
import kotlinx.coroutines.selects.*

suspend fun selectAorB(a: ReceiveChannel<String>, b: ReceiveChannel<String>): String =
    select<String> {
        a.onReceiveCatching { it ->
            val value = it.getOrNull()
            if (value != null) {
                "a -> '$value'"
            } else {
                "Channel 'a' is closed"
            }
        }
        b.onReceiveCatching { it ->
            val value = it.getOrNull()
            if (value != null) {
                "b -> '$value'"
            } else {
                "Channel 'b' is closed"
            }
        }
    }

fun main() = runBlocking<Unit> {
    val a = produce<String> {
        repeat(4) { send("Hello $it") }
    }
    val b = produce<String> {
        repeat(4) { send("World $it") }
    }
    repeat(8) { // print first eight results
        println(selectAorB(a, b))
    }
    coroutineContext.cancelChildren()
}
```

You can get the full code here.

The result of this code is quite interesting, so we'll analyze it in more detail:

```
a -> 'Hello 0'
a -> 'Hello 1'
b -> 'World 0'
a -> 'Hello 2'
a -> 'Hello 3'
b -> 'World 1'
Channel 'a' is closed
Channel 'a' is closed
```

There are a couple of observations to make out of it.

First of all, select is biased to the first clause. When several clauses are selectable at the same time, the first one among them gets selected. Here, both channels are constantly producing strings, so a channel, being the first clause in select, wins. However, because we are using unbuffered channel, the a gets suspended from time to time on its send invocation and gives a chance for b to send, too.

The second observation, is that onReceiveCatching gets immediately selected when the channel is already closed.

Selecting to send

Select expression has onSend clause that can be used for a great good in combination with a biased nature of selection.

Let us write an example of a producer of integers that sends its values to a side channel when the consumers on its primary channel cannot keep up with it:

```
fun CoroutineScope.produceNumbers(side: SendChannel<Int>) = produce<Int> {
    for (num in 1..10) { // produce 10 numbers from 1 to 10
        delay(100) // every 100 ms
        select<Unit> {
            onSend(num) {} // Send to the primary channel
            side.onSend(num) {} // or to the side channel
        }
    }
}
```

Consumer is going to be quite slow, taking 250 ms to process each number:

```
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*
import kotlinx.coroutines.selects.*

fun CoroutineScope.produceNumbers(side: SendChannel<Int>) = produce<Int> {
    for (num in 1..10) { // produce 10 numbers from 1 to 10
        delay(100) // every 100 ms
        select<Unit> {
            onSend(num) {} // Send to the primary channel
            side.onSend(num) {} // or to the side channel
        }
    }
}

fun main() = runBlocking<Unit> {
    val side = Channel<Int>() // allocate side channel
    launch { // this is a very fast consumer for the side channel
        side.consumeEach { println("Side channel has $it") }
    }
    produceNumbers(side).consumeEach {
        println("Consuming $it")
        delay(250) // let us digest the consumed number properly, do not hurry
    }
    println("Done consuming")
    coroutineContext.cancelChildren()
}
```

You can get the full code here.

So let us see what happens:

```
Consuming 1
Side channel has 2
Side channel has 3
Consuming 4
Side channel has 5
Side channel has 6
Consuming 7
Side channel has 8
Side channel has 9
Consuming 10
Done consuming
```

Selecting deferred values

Deferred values can be selected using onAwait clause. Let us start with an async function that returns a deferred string value after a random delay:

```kotlin
fun CoroutineScope.asyncString(time: Int) = async {
    delay(time.toLong())
    "Waited for $time ms"
}
```

Let us start a dozen of them with a random delay.

```kotlin
fun CoroutineScope.asyncStringsList(): List<Deferred<String>> {
    val random = Random(3)
    return List(12) { asyncString(random.nextInt(1000)) }
}
```

Now the main function awaits for the first of them to complete and counts the number of deferred values that are still active. Note that we've used here the fact that select expression is a Kotlin DSL, so we can provide clauses for it using an arbitrary code. In this case we iterate over a list of deferred values to provide onAwait clause for each deferred value.

```kotlin
import kotlinx.coroutines.*
import kotlinx.coroutines.selects.*
import java.util.*

fun CoroutineScope.asyncString(time: Int) = async {
    delay(time.toLong())
    "Waited for $time ms"
}

fun CoroutineScope.asyncStringsList(): List<Deferred<String>> {
    val random = Random(3)
    return List(12) { asyncString(random.nextInt(1000)) }
}

fun main() = runBlocking<Unit> {
    val list = asyncStringsList()
    val result = select<String> {
        list.withIndex().forEach { (index, deferred) ->
            deferred.onAwait { answer ->
                "Deferred $index produced answer '$answer'"
            }
        }
    }
    println(result)
    val countActive = list.count { it.isActive }
    println("$countActive coroutines are still active")
}
```

You can get the full code here.

The output is:

```
Deferred 4 produced answer 'Waited for 128 ms'
11 coroutines are still active
```

Switch over a channel of deferred values

Let us write a channel producer function that consumes a channel of deferred string values, waits for each received deferred value, but only until the next deferred value comes over or the channel is closed. This example puts together onReceiveCatching and onAwait clauses in the same select:

```kotlin
fun CoroutineScope.switchMapDeferreds(input: ReceiveChannel<Deferred<String>>) = produce<String> {
    var current = input.receive() // start with first received deferred value
    while (isActive) { // loop while not cancelled/closed
        val next = select<Deferred<String>?> { // return next deferred value from this select or null
            input.onReceiveCatching { update ->
                update.getOrNull()
            }
            current.onAwait { value ->
                send(value) // send value that current deferred has produced
                input.receiveCatching().getOrNull() // and use the next deferred from the input channel
            }
        }
        if (next == null) {
            println("Channel was closed")
            break // out of loop
        } else {
            current = next
        }
    }
}
```

To test it, we'll use a simple async function that resolves to a specified string after a specified time:

```kotlin
fun CoroutineScope.asyncString(str: String, time: Long) = async {
    delay(time)
    str
}
```

The main function just launches a coroutine to print results of switchMapDeferreds and sends some test data to it:

```kotlin
import kotlinx.coroutines.*
import kotlinx.coroutines.channels.*
import kotlinx.coroutines.selects.*

fun CoroutineScope.switchMapDeferreds(input: ReceiveChannel<Deferred<String>>) = produce<String> {
    var current = input.receive() // start with first received deferred value
    while (isActive) { // loop while not cancelled/closed
        val next = select<Deferred<String>?> { // return next deferred value from this select or null
            input.onReceiveCatching { update ->
                update.getOrNull()
            }
            current.onAwait { value ->
                send(value) // send value that current deferred has produced
                input.receiveCatching().getOrNull() // and use the next deferred from the input channel
            }
        }
        if (next == null) {
            println("Channel was closed")
            break // out of loop
        } else {
            current = next
        }
    }
}

fun CoroutineScope.asyncString(str: String, time: Long) = async {
    delay(time)
    str
}

fun main() = runBlocking<Unit> {
    val chan = Channel<Deferred<String>>() // the channel for test
    launch { // launch printing coroutine
        for (s in switchMapDeferreds(chan))
            println(s) // print each received string
    }
    chan.send(asyncString("BEGIN", 100))
    delay(200) // enough time for "BEGIN" to be produced
    chan.send(asyncString("Slow", 500))
    delay(100) // not enough time to produce slow
    chan.send(asyncString("Replace", 100))
    delay(500) // give it time before the last one
    chan.send(asyncString("END", 500))
    delay(1000) // give it time to process
    chan.close() // close the channel ...
    delay(500) // and wait some time to let it finish
}
```

You can get the full code here.

The result of this code:

```
BEGIN
Replace
END
Channel was closed
```

Debug coroutines using IntelliJ IDEA – tutorial

This tutorial demonstrates how to create Kotlin coroutines and debug them using IntelliJ IDEA.

The tutorial assumes you have prior knowledge of the coroutines concept.

Create coroutines

1. Open a Kotlin project in IntelliJ IDEA. If you don't have a project, create one.

2. To use the kotlinx.coroutines library in a Gradle project, add the following dependency to build.gradle(.kts):

   Kotlin

   ```
   dependencies {
       implementation("org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2")
   }
   ```

   Groovy

   ```
   dependencies {
       implementation 'org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2'
   }
   ```

   For other build systems, see instructions in the kotlinx.coroutines README.

3. Open the Main.kt file in src/main/kotlin.

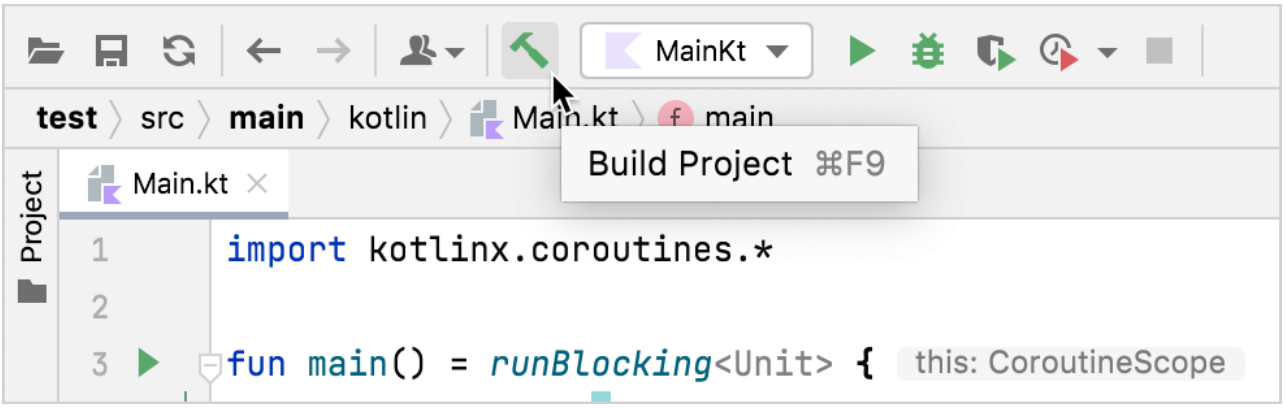
   The src directory contains Kotlin source files and resources. The Main.kt file contains sample code that will print Hello World!.

4. Change code in the main() function:

   - Use the runBlocking() block to wrap a coroutine.
   - Use the async() function to create coroutines that compute deferred values a and b.
   - Use the await() function to await the computation result.
   - Use the println() function to print computing status and the result of multiplication to the output.

   ```
   import kotlinx.coroutines.*

   fun main() = runBlocking<Unit> {
       val a = async {
           println("I'm computing part of the answer")
           6
       }
       val b = async {
           println("I'm computing another part of the answer")
           7
       }
       println("The answer is ${a.await() * b.await()}")
   }
   ```

5. Build the code by clicking Build Project.

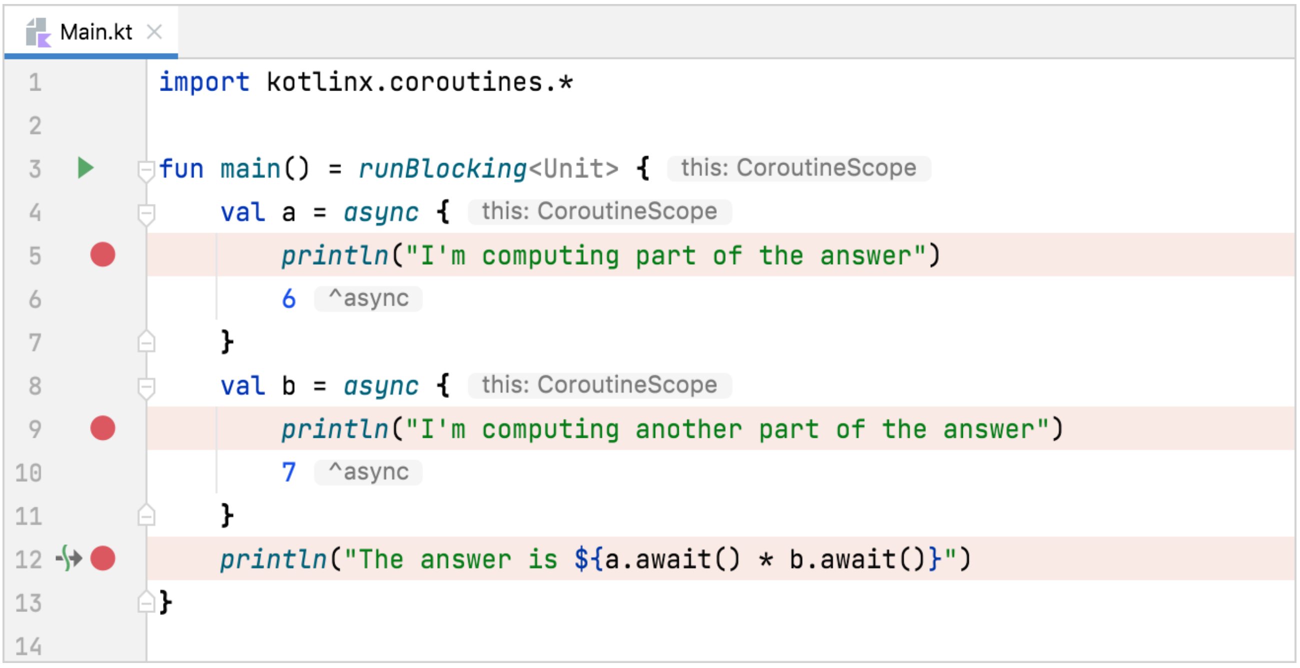


```
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> { this: CoroutineScope
```

Build an application

Debug coroutines

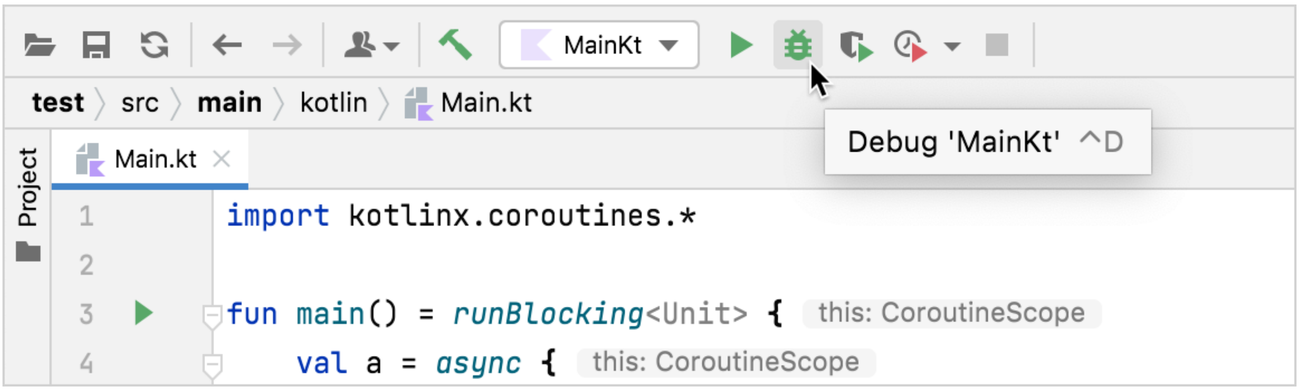
1. Set breakpoints at the lines with the println() function call:



```
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> { this: CoroutineScope
    val a = async { this: CoroutineScope
        println("I'm computing part of the answer")
        6 ^async
    }
    val b = async { this: CoroutineScope
        println("I'm computing another part of the answer")
        7 ^async
    }
    println("The answer is ${a.await() * b.await()}")
}
```

Build a console application

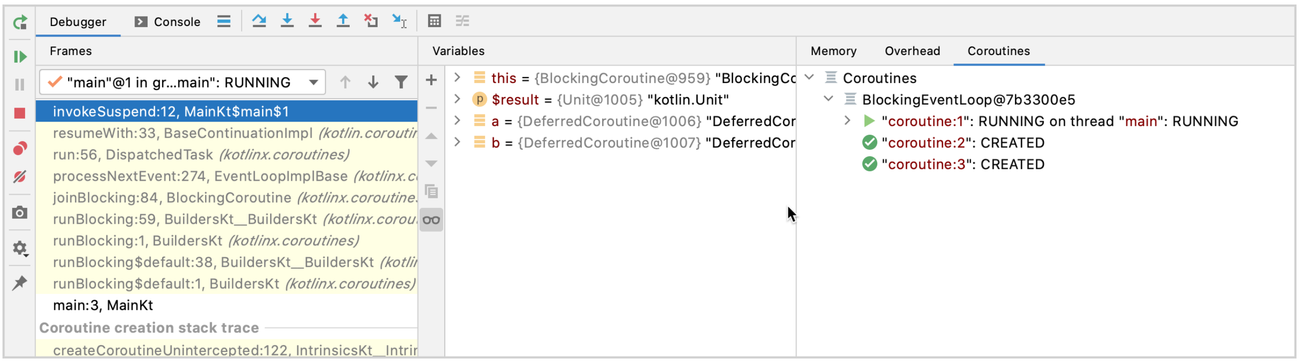
2. Run the code in debug mode by clicking Debug next to the run configuration at the top of the screen.



```
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> { this: CoroutineScope
    val a = async { this: CoroutineScope
```

The Debug tool window appears:

- The Frames tab contains the call stack.
- The Variables tab contains variables in the current context.
- The Coroutines tab contains information on running or suspended coroutines. It shows that there are three coroutines. The first one has the RUNNING status, and the other two have the CREATED status.



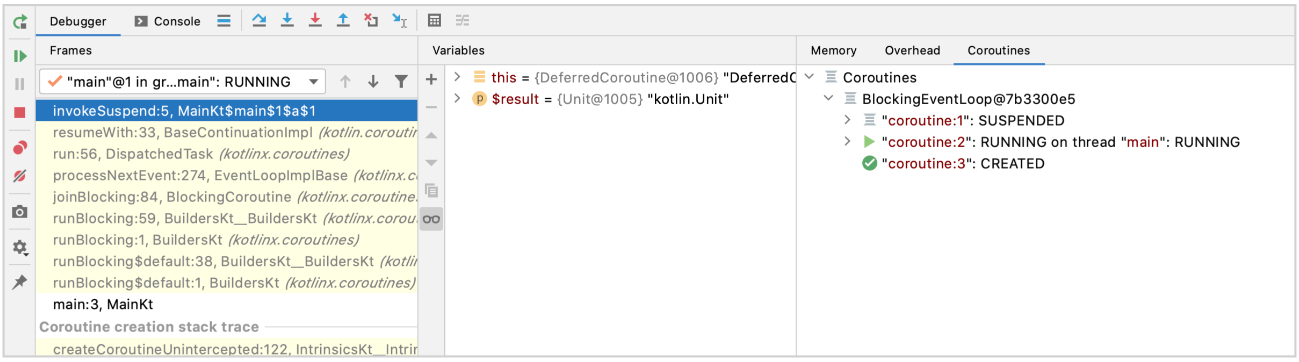
```
"main"@1 in gr...main": RUNNING
invokeSuspend:12, MainKt$main$1
resumeWith:33, BaseContinuationImpl (kotlin.corouti
run:56, DispatchedTask (kotlinx.coroutines)
processNextEvent:274, EventLoopImplBase (kotlinx.c
joinBlocking:84, BlockingCoroutine (kotlinx.coroutine.
runBlocking:59, BuildersKt__BuildersKt (kotlinx.corou
runBlocking:1, BuildersKt (kotlinx.coroutines)
runBlocking$default:38, BuildersKt__BuildersKt (kotli
runBlocking$default:1, BuildersKt (kotlinx.coroutines)
main:3, MainKt
Coroutine creation stack trace
createCoroutineUnintercepted:122, IntrinsicsKt__Intrir
```

```
this = {BlockingCoroutine@959} "BlockingCc
$result = {Unit@1005} "kotlin.Unit"
a = {DeferredCoroutine@1006} "DeferredCor
b = {DeferredCoroutine@1007} "DeferredCor
```

```
Coroutines
  BlockingEventLoop@7b3300e5
    "coroutine:1": RUNNING on thread "main": RUNNING
    "coroutine:2": CREATED
    "coroutine:3": CREATED
```

Debug the coroutine

3. Resume the debugger session by clicking Resume Program in the Debug tool window:



```
"main"@1 in gr...main": RUNNING
invokeSuspend:5, MainKt$main$1$a$1
resumeWith:33, BaseContinuationImpl (kotlin.corouti
run:56, DispatchedTask (kotlinx.coroutines)
processNextEvent:274, EventLoopImplBase (kotlinx.c
joinBlocking:84, BlockingCoroutine (kotlinx.coroutine.
runBlocking:59, BuildersKt__BuildersKt (kotlinx.corou
runBlocking:1, BuildersKt (kotlinx.coroutines)
runBlocking$default:38, BuildersKt__BuildersKt (kotli
runBlocking$default:1, BuildersKt (kotlinx.coroutines)
main:3, MainKt
Coroutine creation stack trace
createCoroutineUnintercepted:122, IntrinsicsKt__Intrir
```

```
this = {DeferredCoroutine@1006} "DeferredC
$result = {Unit@1005} "kotlin.Unit"
```

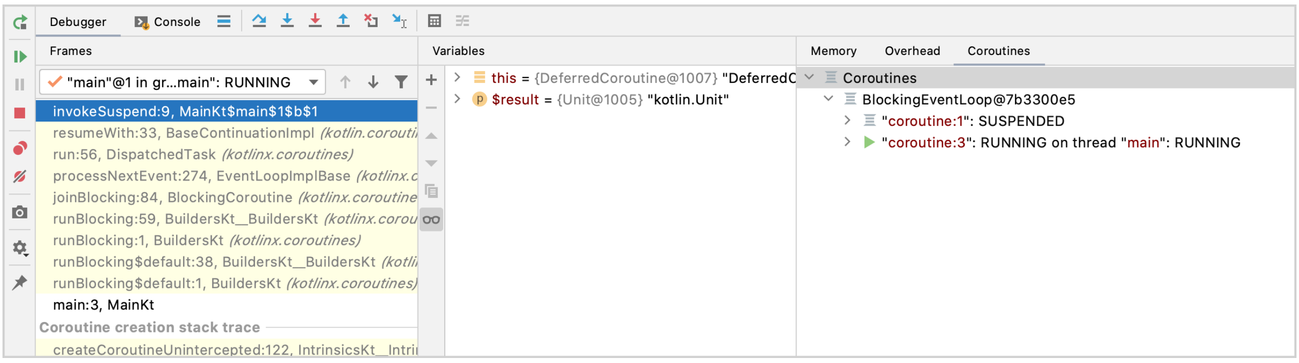
```
Coroutines
  BlockingEventLoop@7b3300e5
    "coroutine:1": SUSPENDED
    "coroutine:2": RUNNING on thread "main": RUNNING
    "coroutine:3": CREATED
```

Debug the coroutine

Now the Coroutines tab shows the following:

- The first coroutine has the SUSPENDED status – it is waiting for the values so it can multiply them.
- The second coroutine is calculating the a value – it has the RUNNING status.
- The third coroutine has the CREATED status and isn't calculating the value of b.

4. Resume the debugger session by clicking Resume Program in the Debug tool window:



```
"main"@1 in gr...main": RUNNING
invokeSuspend:9, MainKt$main$1$b$1
resumeWith:33, BaseContinuationImpl (kotlin.corouti
run:56, DispatchedTask (kotlinx.coroutines)
processNextEvent:274, EventLoopImplBase (kotlinx.c
joinBlocking:84, BlockingCoroutine (kotlinx.coroutine
runBlocking:59, BuildersKt__BuildersKt (kotlinx.corou
runBlocking:1, BuildersKt (kotlinx.coroutines)
runBlocking$default:38, BuildersKt__BuildersKt (kotli
runBlocking$default:1, BuildersKt (kotlinx.coroutines)
main:3, MainKt
Coroutine creation stack trace
createCoroutineUnintercepted:122, IntrinsicsKt__Intri
```

```
> this = {DeferredCoroutine@1007} "DeferredC
> $result = {Unit@1005} "kotlin.Unit"
```

```
Coroutines
  BlockingEventLoop@7b3300e5
    > "coroutine:1": SUSPENDED
    > "coroutine:3": RUNNING on thread "main": RUNNING
```

Build a console application

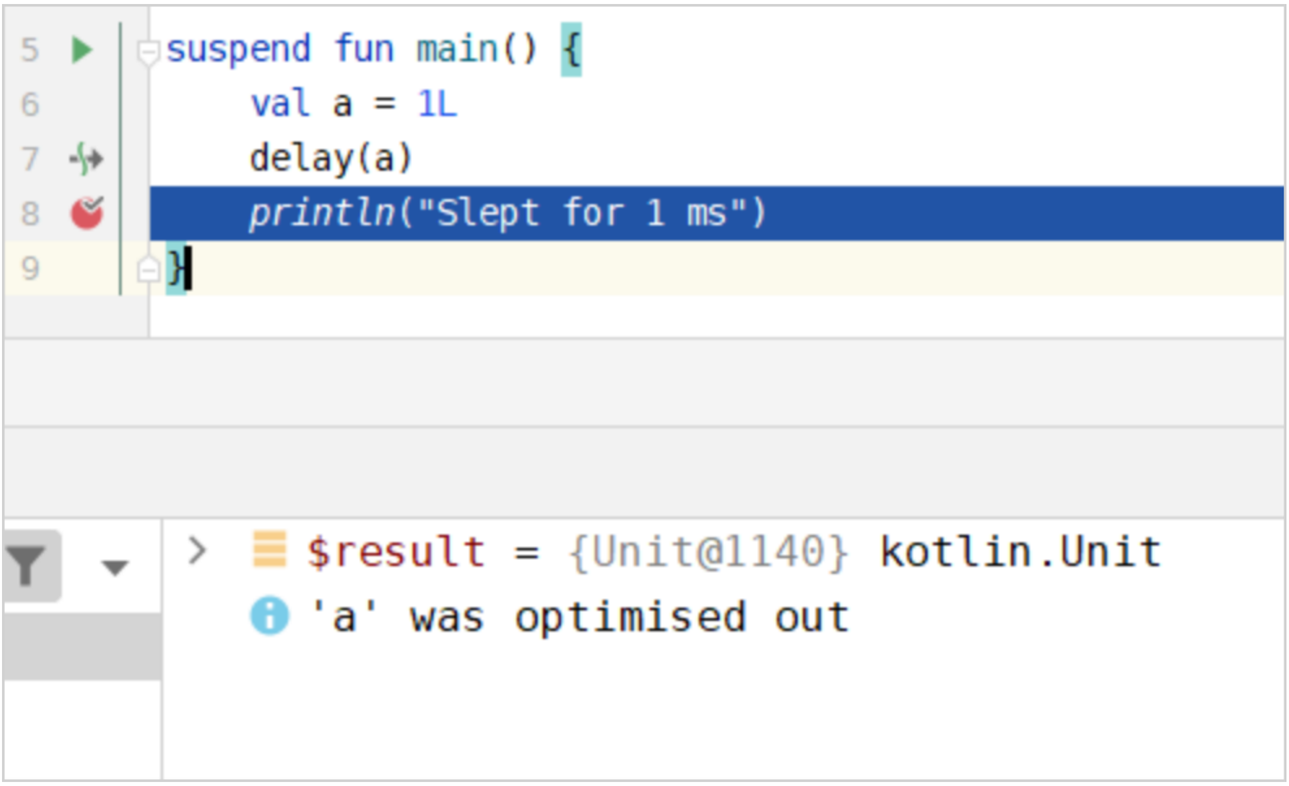
Now the Coroutines tab shows the following:

- The first coroutine has the SUSPENDED status – it is waiting for the values so it can multiply them.
- The second coroutine has computed its value and disappeared.
- The third coroutine is calculating the value of b – it has the RUNNING status.

Using IntelliJ IDEA debugger, you can dig deeper into each coroutine to debug your code.

Optimized-out variables

If you use suspend functions, in the debugger, you might see the "was optimized out" text next to a variable's name:



```kotlin
suspend fun main() {
    val a = 1L
    delay(a)
    println("Slept for 1 ms")
}
```

```
> $result = {Unit@1140} kotlin.Unit
  'a' was optimised out
```

Variable "a" was optimized out

This text means that the variable's lifetime was decreased, and the variable doesn't exist anymore. It is difficult to debug code with optimized variables because you don't see their values. You can disable this behavior with the -Xdebug compiler option.

Never use this flag in production: -Xdebug can cause memory leaks.

Debug Kotlin Flow using IntelliJ IDEA – tutorial

This tutorial demonstrates how to create Kotlin Flow and debug it using IntelliJ IDEA.

The tutorial assumes you have prior knowledge of the coroutines and Kotlin Flow concepts.

Create a Kotlin flow

Create a Kotlin flow with a slow emitter and a slow collector:

1. Open a Kotlin project in IntelliJ IDEA. If you don't have a project, create one.
2. To use the kotlinx.coroutines library in a Gradle project, add the following dependency to build.gradle(.kts):

   Kotlin

   ```
   dependencies {
       implementation("org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2")
   }
   ```

   Groovy

   ```
   dependencies {
       implementation 'org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2'
   }
   ```

   For other build systems, see instructions in the kotlinx.coroutines README.
3. Open the Main.kt file in src/main/kotlin.

   The src directory contains Kotlin source files and resources. The Main.kt file contains sample code that will print Hello World!.
4. Create the simple() function that returns a flow of three numbers:

   - Use the delay() function to imitate CPU-consuming blocking code. It suspends the coroutine for 100 ms without blocking the thread.
   - Produce the values in the for loop using the emit() function.

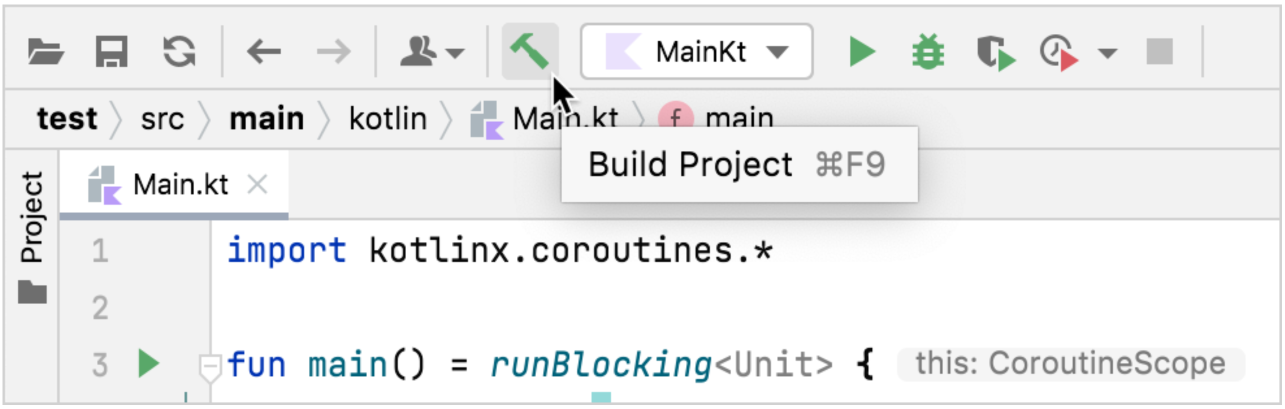
   ```
   import kotlinx.coroutines.*
   import kotlinx.coroutines.flow.*
   import kotlin.system.*

   fun simple(): Flow<Int> = flow {
       for (i in 1..3) {
           delay(100)
           emit(i)
       }
   }
   ```
5. Change the code in the main() function:

   - Use the runBlocking() block to wrap a coroutine.
   - Collect the emitted values using the collect() function.
   - Use the delay() function to imitate CPU-consuming code. It suspends the coroutine for 300 ms without blocking the thread.
   - Print the collected value from the flow using the println() function.

   ```
   fun main() = runBlocking {
       simple()
   ```

```
            .collect { value ->
                delay(300)
                println(value)
            }
    }
```

6. Build the code by clicking Build Project.

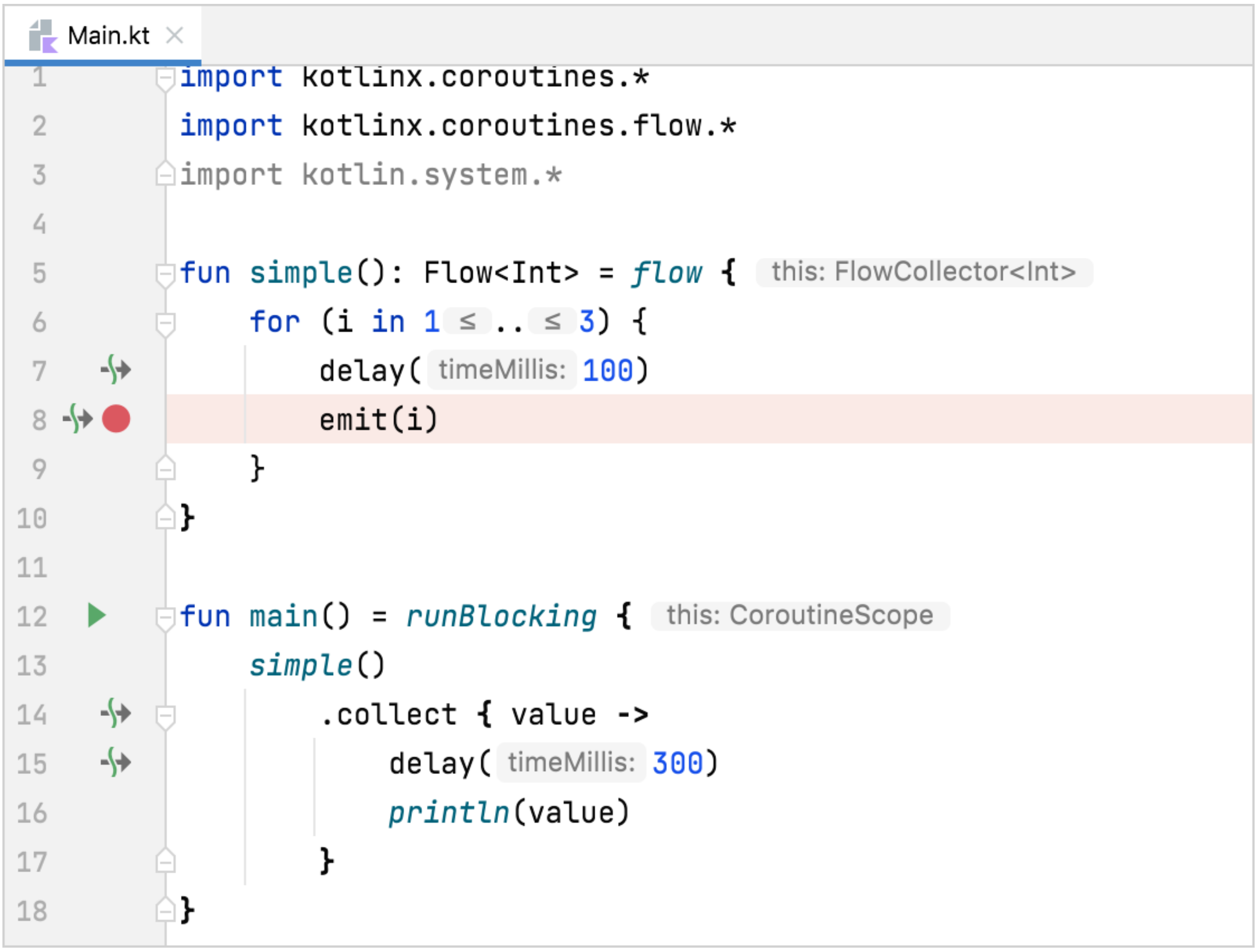


```
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> { this: CoroutineScope
```

Build an application

Debug the coroutine

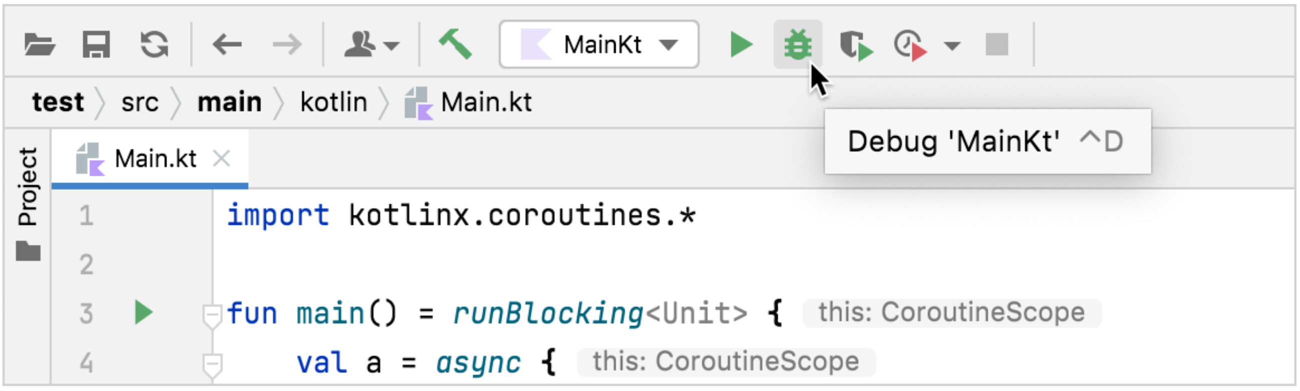
1. Set a breakpoint at the line where the emit() function is called:



```
import kotlinx.coroutines.*
import kotlinx.coroutines.flow.*
import kotlin.system.*

fun simple(): Flow<Int> = flow { this: FlowCollector<Int>
    for (i in 1 ≤ .. ≤ 3) {
        delay( timeMillis: 100)
        emit(i)
    }
}

fun main() = runBlocking { this: CoroutineScope
    simple()
        .collect { value ->
            delay( timeMillis: 300)
            println(value)
        }
}
```

Build a console application

2. Run the code in debug mode by clicking Debug next to the run configuration at the top of the screen.

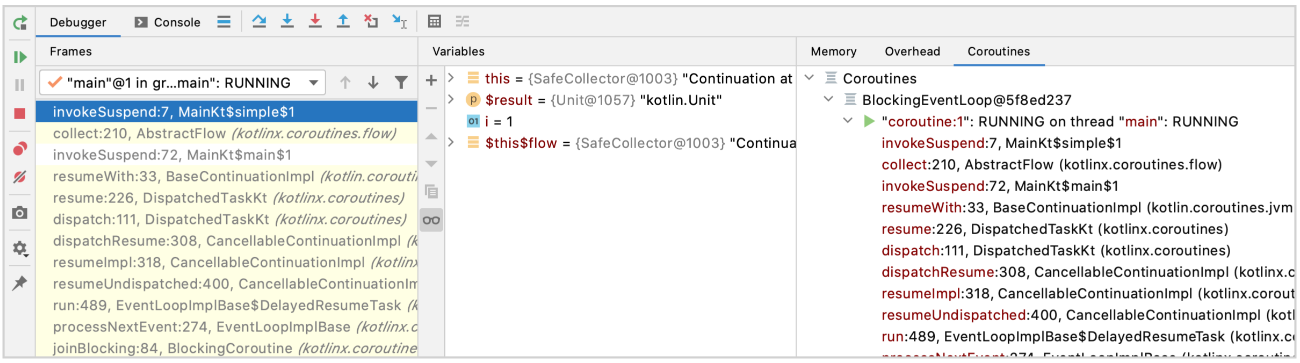


```
import kotlinx.coroutines.*

fun main() = runBlocking<Unit> { this: CoroutineScope
    val a = async { this: CoroutineScope
```

Build a console application

The Debug tool window appears:

- The Frames tab contains the call stack.
- The Variables tab contains variables in the current context. It tells us that the flow is emitting the first value.
- The Coroutines tab contains information on running or suspended coroutines.



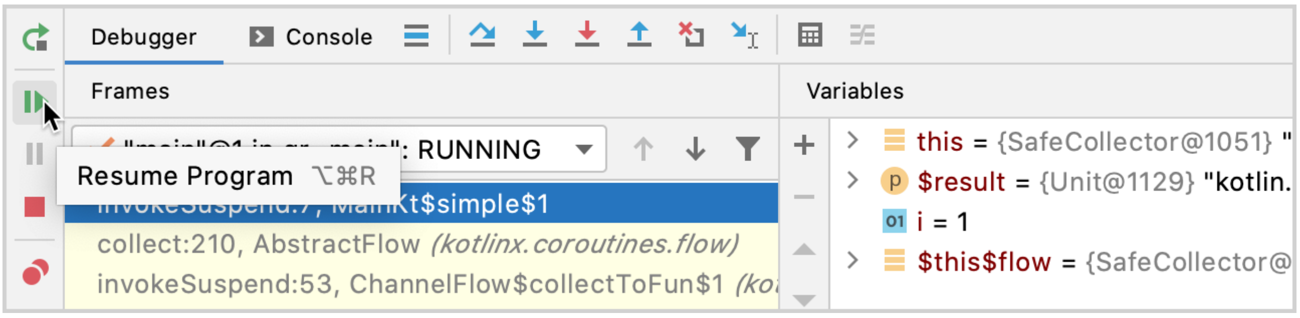
```
"main"@1 in gr...main": RUNNING
invokeSuspend:7, MainKt$simple$1
collect:210, AbstractFlow (kotlinx.coroutines.flow)
invokeSuspend:72, MainKt$main$1
resumeWith:33, BaseContinuationImpl (kotlin.corouti
resume:226, DispatchedTaskKt (kotlinx.coroutines)
dispatch:111, DispatchedTaskKt (kotlinx.coroutines)
dispatchResume:308, CancellableContinuationImpl (k
resumeImpl:318, CancellableContinuationImpl (kotlinx
resumeUndispatched:400, CancellableContinuationIm
run:489, EventLoopImplBase$DelayedResumeTask (k
processNextEvent:274, EventLoopImplBase (kotlinx.c
joinBlocking:84, BlockingCoroutine (kotlinx.coroutine
```

```
> this = {SafeCollector@1003} "Continuation at
> $result = {Unit@1057} "kotlin.Unit"
  i = 1
> $this$flow = {SafeCollector@1003} "Continua
```

```
Coroutines
  BlockingEventLoop@5f8ed237
    "coroutine:1": RUNNING on thread "main": RUNNING
      invokeSuspend:7, MainKt$simple$1
      collect:210, AbstractFlow (kotlinx.coroutines.flow)
      invokeSuspend:72, MainKt$main$1
      resumeWith:33, BaseContinuationImpl (kotlin.coroutines.jvm
      resume:226, DispatchedTaskKt (kotlinx.coroutines)
      dispatch:111, DispatchedTaskKt (kotlinx.coroutines)
      dispatchResume:308, CancellableContinuationImpl (kotlinx.c
      resumeImpl:318, CancellableContinuationImpl (kotlinx.corout
      resumeUndispatched:400, CancellableContinuationImpl (kotl
      run:489, EventLoopImplBase$DelayedResumeTask (kotlinx.c
```

Debug the coroutine

3. Resume the debugger session by clicking Resume Program in the Debug tool window. The program stops at the same breakpoint.

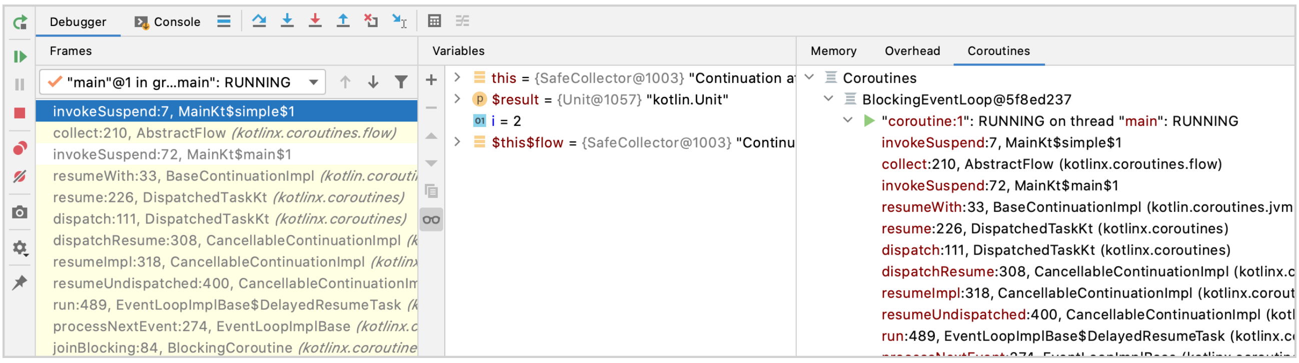


```
"main"@1 in gr...main": RUNNING
invokeSuspend:7, MainKt$simple$1
collect:210, AbstractFlow (kotlinx.coroutines.flow)
invokeSuspend:53, ChannelFlow$collectToFun$1 (ko
```

```
> this = {SafeCollector@1051} "
> $result = {Unit@1129} "kotlin.
  i = 1
> $this$flow = {SafeCollector@
```

Debug the coroutine

Now the flow emits the second value.



```
"main"@1 in gr...main": RUNNING
invokeSuspend:7, MainKt$simple$1
collect:210, AbstractFlow (kotlinx.coroutines.flow)
invokeSuspend:72, MainKt$main$1
resumeWith:33, BaseContinuationImpl (kotlin.corouti
resume:226, DispatchedTaskKt (kotlinx.coroutines)
dispatch:111, DispatchedTaskKt (kotlinx.coroutines)
dispatchResume:308, CancellableContinuationImpl (k
resumeImpl:318, CancellableContinuationImpl (kotlinx
resumeUndispatched:400, CancellableContinuationIm
run:489, EventLoopImplBase$DelayedResumeTask (k
processNextEvent:274, EventLoopImplBase (kotlinx.c
joinBlocking:84, BlockingCoroutine (kotlinx.coroutine
```

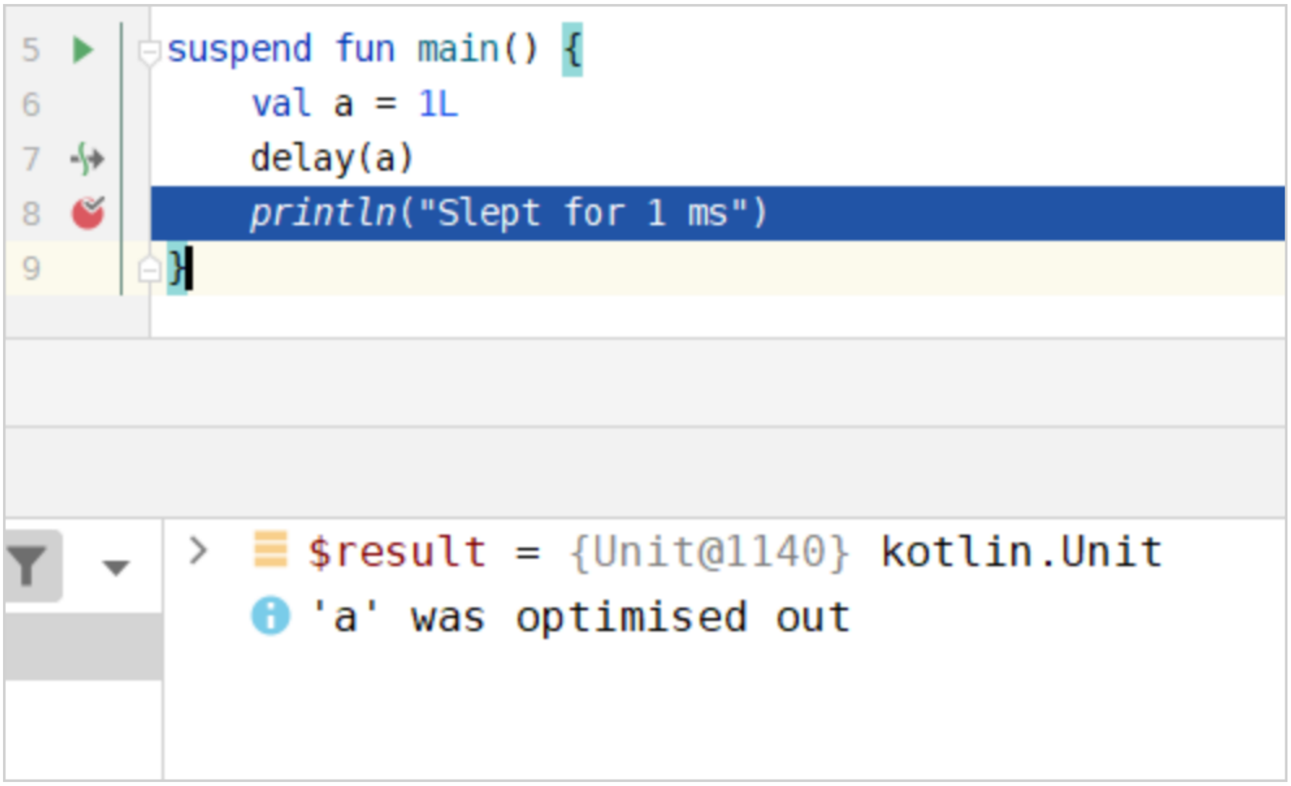
```
> this = {SafeCollector@1003} "Continuation a
> $result = {Unit@1057} "kotlin.Unit"
  i = 2
> $this$flow = {SafeCollector@1003} "Continu
```

```
Coroutines
  BlockingEventLoop@5f8ed237
    "coroutine:1": RUNNING on thread "main": RUNNING
      invokeSuspend:7, MainKt$simple$1
      collect:210, AbstractFlow (kotlinx.coroutines.flow)
      invokeSuspend:72, MainKt$main$1
      resumeWith:33, BaseContinuationImpl (kotlin.coroutines.jvm
      resume:226, DispatchedTaskKt (kotlinx.coroutines)
      dispatch:111, DispatchedTaskKt (kotlinx.coroutines)
      dispatchResume:308, CancellableContinuationImpl (kotlinx.c
      resumeImpl:318, CancellableContinuationImpl (kotlinx.corout
      resumeUndispatched:400, CancellableContinuationImpl (kotl
      run:489, EventLoopImplBase$DelayedResumeTask (kotlinx.c
```

Debug the coroutine

Optimized-out variables

If you use suspend functions, in the debugger, you might see the "was optimized out" text next to a variable's name:



```kotlin
suspend fun main() {
    val a = 1L
    delay(a)
    println("Slept for 1 ms")
}
```

```
> $result = {Unit@1140} kotlin.Unit
  'a' was optimised out
```

Variable "a" was optimized out

This text means that the variable's lifetime was decreased, and the variable doesn't exist anymore. It is difficult to debug code with optimized variables because you don't see their values. You can disable this behavior with the -Xdebug compiler option.

Never use this flag in production: -Xdebug can cause memory leaks.

Add a concurrently running coroutine

1. Open the Main.kt file in src/main/kotlin.

2. Enhance the code to run the emitter and collector concurrently:

- Add a call to the buffer() function to run the emitter and collector concurrently. buffer() stores emitted values and runs the flow collector in a separate coroutine.

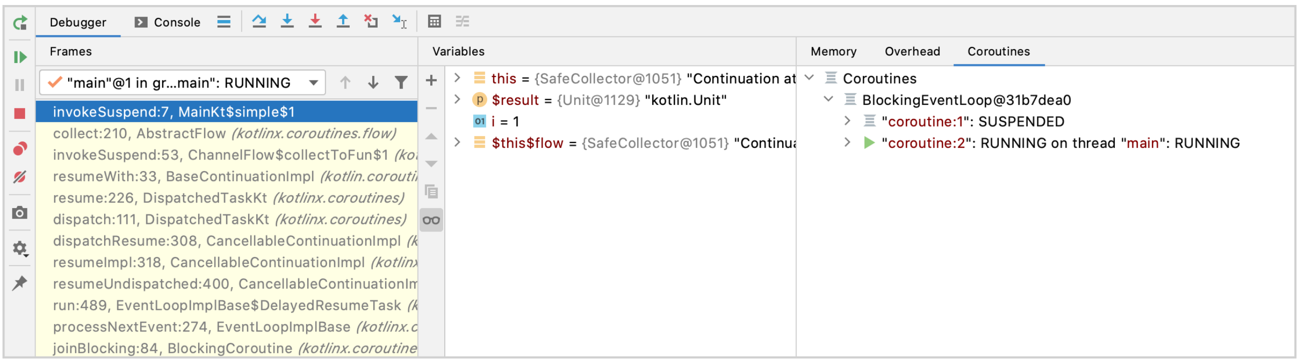
```kotlin
fun main() = runBlocking<Unit> {
    simple()
        .buffer()
        .collect { value ->
            delay(300)
            println(value)
        }
}
```

3. Build the code by clicking Build Project.

Debug a Kotlin flow with two coroutines

1. Set a new breakpoint at println(value).

2. Run the code in debug mode by clicking Debug next to the run configuration at the top of the screen.



```
"main"@1 in gr...main": RUNNING
invokeSuspend:7, MainKt$simple$1
collect:210, AbstractFlow (kotlinx.coroutines.flow)
invokeSuspend:53, ChannelFlow$collectToFun$1 (ko
resumeWith:33, BaseContinuationImpl (kotlin.corouti
resume:226, DispatchedTaskKt (kotlinx.coroutines)
dispatch:111, DispatchedTaskKt (kotlinx.coroutines)
dispatchResume:308, CancellableContinuationImpl (k
resumeImpl:318, CancellableContinuationImpl (kotlinx
resumeUndispatched:400, CancellableContinuationIm
run:489, EventLoopImplBase$DelayedResumeTask (k
processNextEvent:274, EventLoopImplBase (kotlinx.c
joinBlocking:84, BlockingCoroutine (kotlinx.coroutine
```

```
> this = {SafeCollector@1051} "Continuation at
> $result = {Unit@1129} "kotlin.Unit"
  i = 1
> $this$flow = {SafeCollector@1051} "Continua
```

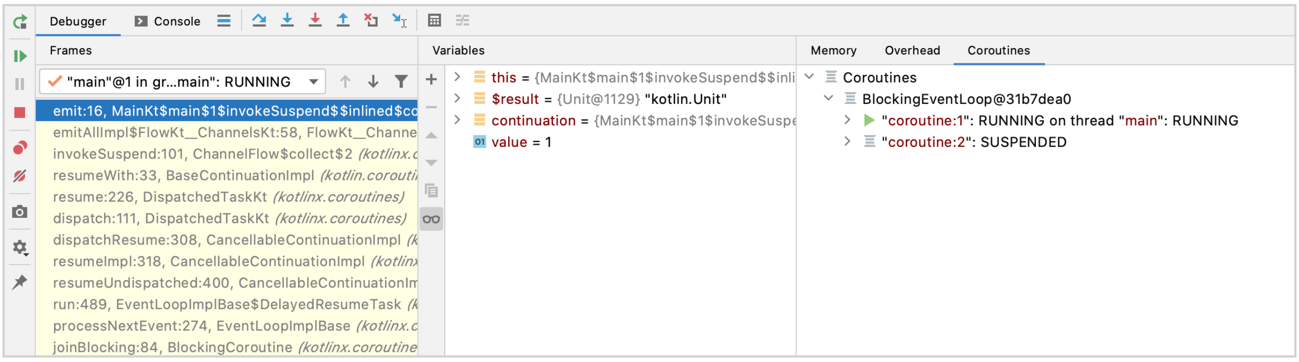
```
v Coroutines
  v BlockingEventLoop@31b7dea0
    > "coroutine:1": SUSPENDED
    > "coroutine:2": RUNNING on thread "main": RUNNING
```

Build a console application

The Debug tool window appears.

In the Coroutines tab, you can see that there are two coroutines running concurrently. The flow collector and emitter run in separate coroutines because of the buffer() function. The buffer() function buffers emitted values from the flow. The emitter coroutine has the RUNNING status, and the collector coroutine has the SUSPENDED status.

3. Resume the debugger session by clicking Resume Program in the Debug tool window.



```
"main"@1 in gr...main": RUNNING
emit:16, MainKt$main$1$invokeSuspend$$inlined$co
emitAllImpl$FlowKt__ChannelsKt:58, FlowKt__Channe
invokeSuspend:101, ChannelFlow$collect$2 (kotlinx.c
resumeWith:33, BaseContinuationImpl (kotlin.corouti
resume:226, DispatchedTaskKt (kotlinx.coroutines)
dispatch:111, DispatchedTaskKt (kotlinx.coroutines)
dispatchResume:308, CancellableContinuationImpl (k
resumeImpl:318, CancellableContinuationImpl (kotlinx
resumeUndispatched:400, CancellableContinuationIm
run:489, EventLoopImplBase$DelayedResumeTask (k
processNextEvent:274, EventLoopImplBase (kotlinx.c
joinBlocking:84, BlockingCoroutine (kotlinx.coroutine
```

```
> this = {MainKt$main$1$invokeSuspend$$inli
> $result = {Unit@1129} "kotlin.Unit"
> continuation = {MainKt$main$1$invokeSuspe
  value = 1
```

```
v Coroutines
  v BlockingEventLoop@31b7dea0
    > "coroutine:1": RUNNING on thread "main": RUNNING
    > "coroutine:2": SUSPENDED
```

Debugging coroutines

Now the collector coroutine has the RUNNING status, while the emitter coroutine has the SUSPENDED status.

You can dig deeper into each coroutine to debug your code.

Serialization

Serialization is the process of converting data used by an application to a format that can be transferred over a network or stored in a database or a file. In turn, deserialization is the opposite process of reading data from an external source and converting it into a runtime object. Together, they are essential to most applications that exchange data with third parties.

Some data serialization formats, such as JSON and protocol buffers are particularly common. Being language-neutral and platform-neutral, they enable data exchange between systems written in any modern language.

In Kotlin, data serialization tools are available in a separate component, kotlinx.serialization. It consists of several parts: the org.jetbrains.kotlin.plugin.serialization Gradle plugin, runtime libraries, and compiler plugins.

Compiler plugins, kotlinx-serialization-compiler-plugin and kotlinx-serialization-compiler-plugin-embeddable, are published directly to Maven Central. The second plugin is designed for working with the kotlin-compiler-embeddable artifact, which is the default option for scripting artifacts. Gradle adds compiler plugins to your projects as compiler arguments.

Libraries

kotlinx.serialization provides sets of libraries for all supported platforms – JVM, JavaScript, Native – and for various serialization formats – JSON, CBOR, protocol buffers, and others. You can find the complete list of supported serialization formats below.

All Kotlin serialization libraries belong to the org.jetbrains.kotlinx: group. Their names start with kotlinx-serialization- and have suffixes that reflect the serialization format. Examples:

- org.jetbrains.kotlinx:kotlinx-serialization-json provides JSON serialization for Kotlin projects.
- org.jetbrains.kotlinx:kotlinx-serialization-cbor provides CBOR serialization.

Platform-specific artifacts are handled automatically; you don't need to add them manually. Use the same dependencies in JVM, JS, Native, and multiplatform projects.

Note that the kotlinx.serialization libraries use their own versioning structure, which doesn't match Kotlin's versioning. Check out the releases on GitHub to find the latest versions.

Formats

kotlinx.serialization includes libraries for various serialization formats:

- JSON: kotlinx-serialization-json
- Protocol buffers: kotlinx-serialization-protobuf
- CBOR: kotlinx-serialization-cbor
- Properties: kotlinx-serialization-properties
- HOCON: kotlinx-serialization-hocon (only on JVM)

Note that all libraries except JSON serialization (kotlinx-serialization-json) are Experimental, which means their API can be changed without notice.

There are also community-maintained libraries that support more serialization formats, such as YAML or Apache Avro. For detailed information about available serialization formats, see the kotlinx.serialization documentation.

Example: JSON serialization

Let's take a look at how to serialize Kotlin objects into JSON.

Add plugins and dependencies

Before starting, you must configure your build script so that you can use Kotlin serialization tools in your project:

1. Apply the Kotlin serialization Gradle plugin org.jetbrains.kotlin.plugin.serialization (or kotlin("plugin.serialization") in the Kotlin Gradle DSL).

Kotlin

```kotlin
plugins {
    kotlin("jvm") version "2.2.0"
    kotlin("plugin.serialization") version "2.2.0"
}
```

Groovy

```groovy
plugins {
    id 'org.jetbrains.kotlin.jvm' version '2.2.0'
    id 'org.jetbrains.kotlin.plugin.serialization' version '2.2.0'
}
```

2. Add the JSON serialization library dependency: org.jetbrains.kotlinx:kotlinx-serialization-json:1.8.1

Kotlin

```kotlin
dependencies {
    implementation("org.jetbrains.kotlinx:kotlinx-serialization-json:1.8.1")
}
```

Groovy

```groovy
dependencies {
    implementation 'org.jetbrains.kotlinx:kotlinx-serialization-json:1.8.1'
}
```

Now you're ready to use the serialization API in your code. The API is located in the kotlinx.serialization package and its format-specific subpackages, such as kotlinx.serialization.json.

Serialize and deserialize JSON

1. Make a class serializable by annotating it with @Serializable.

```kotlin
import kotlinx.serialization.Serializable

@Serializable
data class Data(val a: Int, val b: String)
```

2. Serialize an instance of this class by calling Json.encodeToString().

```kotlin
import kotlinx.serialization.Serializable
import kotlinx.serialization.json.Json
import kotlinx.serialization.encodeToString

@Serializable
data class Data(val a: Int, val b: String)

fun main() {
   val json = Json.encodeToString(Data(42, "str"))
}
```

As a result, you get a string containing the state of this object in the JSON format: {"a": 42, "b": "str"}

You can also serialize object collections, such as lists, in a single call:

```kotlin
val dataList = listOf(Data(42, "str"), Data(12, "test"))
val jsonList = Json.encodeToString(dataList)
```

3. Use the decodeFromString() function to deserialize an object from JSON:

```kotlin
import kotlinx.serialization.Serializable
import kotlinx.serialization.json.Json
import kotlinx.serialization.decodeFromString

@Serializable
data class Data(val a: Int, val b: String)

fun main() {
   val obj = Json.decodeFromString<Data>("""{"a":42, "b": "str"}""")
}
```

That's it! You have successfully serialized objects into JSON strings and deserialized them back into objects.

What's next

For more information about serialization in Kotlin, see the Kotlin Serialization Guide.

You can explore different aspects of Kotlin serialization in the following resources:

- Learn more about Kotlin serialization and its core concepts
- Explore the built-in serializable classes of Kotlin
- Look at serializers in more detail and learn how to create custom serializers
- Discover how polymorphic serialization is handled in Kotlin
- Look into the various JSON features handling Kotlin serialization
- Learn more about the experimental serialization formats supported by Kotlin

Kotlin Metadata JVM library

The kotlin-metadata-jvm library provides tools to read, modify, and generate metadata from Kotlin classes compiled for the JVM. This metadata, stored in the @Metadata annotation within .class files, is used by libraries and tools such as kotlin-reflect to inspect Kotlin-specific constructs such as properties, functions, and classes at runtime.

> The kotlin-reflect library relies on metadata to retrieve Kotlin-specific class details at runtime. Any inconsistencies between the metadata and the actual .class file may lead to incorrect behavior when using reflection.

You can also use the Kotlin Metadata JVM library to inspect various declaration attributes such as visibility or modality, or to generate and embed metadata into .class files.

Add the library to your project

To include the Kotlin Metadata JVM library in your project, add the corresponding dependency configuration based on your build tool.

> The Kotlin Metadata JVM library follows the same versioning as the Kotlin compiler and standard library. Ensure that the version you use matches your project's Kotlin version.

Gradle

Add the following dependency to your build.gradle(.kts) file:

Kotlin

```
// build.gradle.kts
repositories {
    mavenCentral()
}

dependencies {
    implementation("org.jetbrains.kotlin:kotlin-metadata-jvm:2.2.0")
}
```

Groovy

```
// build.gradle
repositories {
    mavenCentral()
}

dependencies {
    implementation 'org.jetbrains.kotlin:kotlin-metadata-jvm:2.2.0'
}
```

Maven

Add the following dependency to your pom.xml file.

```
<project>
    <dependencies>
        <dependency>
            <groupId>org.jetbrains.kotlin</groupId>
            <artifactId>kotlin-metadata-jvm</artifactId>
            <version>2.2.0</version>
        </dependency>
    </dependencies>
    ...
</project>
```

Read and parse metadata

The kotlin-metadata-jvm library extracts structured information from compiled Kotlin .class files, such as class names, visibility, and signatures. You can use it in projects that need to analyze compiled Kotlin declarations. For example, the Binary Compatibility Validator (BCV) relies on kotlin-metadata-jvm to print public API declarations.

You can start exploring Kotlin class metadata by retrieving the @Metadata annotation from a compiled class using reflection:

```
fun main() {
    // Specifies the fully qualified name of the class
    val clazz = Class.forName("org.example.SampleClass")

    // Retrieves the @Metadata annotation
    val metadata = clazz.getAnnotation(Metadata::class.java)

    // Checks if the metadata is present
    if (metadata != null) {
        println("This is a Kotlin class with metadata.")
    } else {
        println("This is not a Kotlin class.")
    }
}
```

After retrieving the @Metadata annotation, use either the readLenient() or the readStrict() function from the KotlinClassMetadata API to parse it. These functions extract detailed information about classes or files, while addressing different compatibility requirements:

- readLenient(): Use this function to read metadata, including metadata generated by newer Kotlin compiler versions. This function doesn't support modifying or writing metadata.
- readStrict(): Use this function when you need to modify and write metadata. The readStrict() function only works with metadata generated by Kotlin compiler versions fully supported by your project.

The readStrict() function supports metadata formats up to one version beyond JvmMetadataVersion.LATEST_STABLE_SUPPORTED, which corresponds to the latest Kotlin version used in the project. For example, if your project depends on kotlin-metadata-jvm:2.1.0, readStrict() can process metadata up to Kotlin 2.2.x; otherwise, it throws an error to prevent mishandling unknown formats.

For more information, see the Kotlin Metadata GitHub repository.

When parsing metadata, the KotlinClassMetadata instance provides structured information about class or file-level declarations. For classes, use the kmClass property to analyze detailed class-level metadata, such as the class name, functions, properties, and attributes like visibility. For file-level declarations, the metadata is represented by the kmPackage property, which includes top-level functions and properties from file facades generated by the Kotlin compiler.

The following code example demonstrates how to use readLenient() to parse metadata, analyze class-level details with kmClass, and retrieve file-level declarations with kmPackage:

```kotlin
// Imports the necessary libraries
import kotlin.metadata.jvm.*
import kotlin.metadata.*

fun main() {
    // Specifies the fully qualified class name
    val className = "org.example.SampleClass"

    try {
        // Retrieves the class object for the specified name
        val clazz = Class.forName(className)

        // Retrieves the @Metadata annotation
        val metadataAnnotation = clazz.getAnnotation(Metadata::class.java)
        if (metadataAnnotation != null) {
            println("Kotlin Metadata found for class: $className")

            // Parses metadata using the readLenient() function
            val metadata = KotlinClassMetadata.readLenient(metadataAnnotation)
            when (metadata) {
                is KotlinClassMetadata.Class -> {
                    val kmClass = metadata.kmClass
                    println("Class name: ${kmClass.name}")

                    // Iterates over functions and checks visibility
                    kmClass.functions.forEach { function ->
                        val visibility = function.visibility
                        println("Function: ${function.name}, Visibility: $visibility")
                    }
                }
                is KotlinClassMetadata.FileFacade -> {
                    val kmPackage = metadata.kmPackage

                    // Iterates over functions and checks visibility
                    kmPackage.functions.forEach { function ->
                        val visibility = function.visibility
                        println("Function: ${function.name}, Visibility: $visibility")
                    }
                }
                else -> {
                    println("Unsupported metadata type: $metadata")
                }
            }
        } else {
            println("No Kotlin Metadata found for class: $className")
        }
    } catch (e: ClassNotFoundException) {
        println("Class not found: $className")
    } catch (e: Exception) {
        println("Error processing metadata: ${e.message}")
        e.printStackTrace()
    }
}
```

Write and read annotations in metadata

You can store annotations in Kotlin metadata and access them using the kotlin-metadata-jvm library. This removes the need to match annotations by signature, making access more reliable for overloaded declarations.

To make annotations available in the metadata of your compiled files, add the following compiler option:

```
-Xannotations-in-metadata
```

Alternatively, add it to the compilerOptions {} block of your Gradle build file:

```
// build.gradle.kts
kotlin {
    compilerOptions {
        freeCompilerArgs.add("-Xannotations-in-metadata")
    }
}
```

When you enable this option, the Kotlin compiler writes annotations into metadata alongside the JVM bytecode, making them accessible to the kotlin-metadata-jvm library.

The library provides the following APIs for accessing annotations:

- KmClass.annotations
- KmFunction.annotations
- KmProperty.annotations
- KmConstructor.annotations
- KmPropertyAccessorAttributes.annotations
- KmValueParameter.annotations
- KmFunction.extensionReceiverAnnotations
- KmProperty.extensionReceiverAnnotations
- KmProperty.backingFieldAnnotations
- KmProperty.delegateFieldAnnotations
- KmEnumEntry.annotations

These APIs are Experimental. To opt in, use the @OptIn(ExperimentalAnnotationsInMetadata::class) annotation.

Here's an example of reading annotations from Kotlin metadata:

```
@file:OptIn(ExperimentalAnnotationsInMetadata::class)

import kotlin.metadata.ExperimentalAnnotationsInMetadata
import kotlin.metadata.jvm.KotlinClassMetadata

annotation class Label(val value: String)

@Label("Message class")
class Message

fun main() {
    val metadata = Message::class.java.getAnnotation(Metadata::class.java)
    val kmClass = (KotlinClassMetadata.readStrict(metadata) as KotlinClassMetadata.Class).kmClass
    println(kmClass.annotations)
    // [@Label(value = StringValue("Message class"))]
}
```

If you use the kotlin-metadata-jvm library in your projects, we recommend updating and testing your code to support annotations. Otherwise, when annotations in metadata become enabled by default in a future Kotlin version, your projects may produce invalid or incomplete metadata.

If you experience any problems, please report them in our issue tracker.

Extract metadata from bytecode

While you can retrieve metadata using reflection, another approach is to extract it from bytecode using a bytecode manipulation framework such as ASM.

You can do this by following these steps:

1. Read the bytecode of a .class file using the ASM library's ClassReader class. This class processes the compiled file and populates a ClassNode object, which represents the class structure.
2. Extract the @Metadata from the ClassNode object. The example below uses a custom extension function findAnnotation() for this.
3. Parse the extracted metadata using the KotlinClassMetadata.readLenient() function.
4. Inspect the parsed metadata with the kmClass and kmPackage properties.

Here's an example:

```kotlin
// Imports the necessary libraries
import kotlin.metadata.jvm.*
import kotlin.metadata.*
import org.objectweb.asm.*
import org.objectweb.asm.tree.*
import java.io.File

// Checks if an annotation refers to a specific name
fun AnnotationNode.refersToName(name: String) =
    desc.startsWith('L') && desc.endsWith(';') && desc.regionMatches(1, name, 0, name.length)

// Retrieves annotation values by key
private fun List<Any>.annotationValue(key: String): Any? {
    for (index in (0 until size / 2)) {
        if (this[index * 2] == key) {
            return this[index * 2 + 1]
        }
    }
    return null
}

// Defines a custom extension function to locate an annotation by its name in a ClassNode
fun ClassNode.findAnnotation(annotationName: String, includeInvisible: Boolean = false): AnnotationNode? {
    val visible = visibleAnnotations?.firstOrNull { it.refersToName(annotationName) }
    if (!includeInvisible) return visible
    return visible ?: invisibleAnnotations?.firstOrNull { it.refersToName(annotationName) }
}

// Operator to simplify retrieving annotation values
operator fun AnnotationNode.get(key: String): Any? = values.annotationValue(key)

// Extracts Kotlin metadata from a class node
fun ClassNode.readMetadataLenient(): KotlinClassMetadata? {
    val metadataAnnotation = findAnnotation("kotlin/Metadata", false) ?: return null
    @Suppress("UNCHECKED_CAST")
    val metadata = Metadata(
        kind = metadataAnnotation["k"] as Int?,
        metadataVersion = (metadataAnnotation["mv"] as List<Int>?)?.toIntArray(),
        data1 = (metadataAnnotation["d1"] as List<String>?)?.toTypedArray(),
        data2 = (metadataAnnotation["d2"] as List<String>?)?.toTypedArray(),
        extraString = metadataAnnotation["xs"] as String?,
        packageName = metadataAnnotation["pn"] as String?,
        extraInt = metadataAnnotation["xi"] as Int?
    )
    return KotlinClassMetadata.readLenient(metadata)
}

// Converts a file to a ClassNode for bytecode inspection
fun File.toClassNode(): ClassNode {
    val node = ClassNode()
    this.inputStream().use { ClassReader(it).accept(node, ClassReader.SKIP_CODE) }
    return node
}

fun main() {
    val classFilePath = "build/classes/kotlin/main/org/example/SampleClass.class"
    val classFile = File(classFilePath)

    // Reads the bytecode and processes it into a ClassNode object
    val classNode = classFile.toClassNode()

    // Locates the @Metadata annotation and reads it leniently
    val metadata = classNode.readMetadataLenient()
    if (metadata != null && metadata is KotlinClassMetadata.Class) {
        // Inspects the parsed metadata
        val kmClass = metadata.kmClass

        // Prints class details
        println("Class name: ${kmClass.name}")
        println("Functions:")
        kmClass.functions.forEach { function ->
            println("- ${function.name}, Visibility: ${function.visibility}")
        }
    }
}
```

Modify metadata

When using tools like ProGuard to shrink and optimize bytecode, some declarations may be removed from .class files. ProGuard automatically updates metadata to keep it consistent with the modified bytecode.

However, if you're developing a custom tool that modifies Kotlin bytecode in a similar way, you need to ensure that metadata is adjusted accordingly. With the kotlin-metadata-jvm library, you can update declarations, adjust attributes, and remove specific elements.

For example, if you use a JVM tool that deletes private methods from Java class files, you must also delete private functions from Kotlin metadata to maintain consistency:

1. Parse the metadata by using the readStrict() function to load the @Metadata annotation into a structured KotlinClassMetadata object.
2. Apply modifications by adjusting the metadata, such as filtering functions or altering attributes, directly within kmClass or other metadata structures.
3. Use the write() function to encode the modified metadata into a new @Metadata annotation.

Here's an example where private functions are removed from a class's metadata:

```kotlin
// Imports the necessary libraries
import kotlin.metadata.jvm.*
import kotlin.metadata.*

fun main() {
    // Specifies the fully qualified class name
    val className = "org.example.SampleClass"

    try {
        // Retrieves the class object for the specified name
        val clazz = Class.forName(className)

        // Retrieves the @Metadata annotation
        val metadataAnnotation = clazz.getAnnotation(Metadata::class.java)
        if (metadataAnnotation != null) {
            println("Kotlin Metadata found for class: $className")

            // Parses metadata using the readStrict() function
            val metadata = KotlinClassMetadata.readStrict(metadataAnnotation)
            if (metadata is KotlinClassMetadata.Class) {
                val kmClass = metadata.kmClass

                // Removes private functions from the class metadata
                kmClass.functions.removeIf { it.visibility == Visibility.PRIVATE }
                println("Removed private functions. Remaining functions: ${kmClass.functions.map { it.name }}")

                // Serializes the modified metadata back
                val newMetadata = metadata.write()
                // After modifying the metadata, you need to write it into the class file
                // To do so, you can use a bytecode manipulation framework such as ASM

                println("Modified metadata: ${newMetadata}")
            } else {
                println("The metadata is not a class.")
            }
        } else {
            println("No Kotlin Metadata found for class: $className")
        }
    } catch (e: ClassNotFoundException) {
        println("Class not found: $className")
    } catch (e: Exception) {
        println("Error processing metadata: ${e.message}")
        e.printStackTrace()
    }
}
```

Instead of separately calling readStrict() and write(), you can use the transform() function. This function parses metadata, applies transformations through a lambda, and writes the modified metadata automatically.

Create metadata from scratch

To create metadata for a Kotlin class file from scratch using the Kotlin Metadata JVM library:

1. Create an instance of KmClass, KmPackage, or KmLambda, depending on the type of metadata you want to generate.
2. Add attributes to the instance, such as the class name, visibility, constructors, and function signatures.

   You can use the apply() scope function to reduce boilerplate code while setting properties.

3. Use the instance to create a KotlinClassMetadata object, which can generate a @Metadata annotation.
4. Specify the metadata version, such as JvmMetadataVersion.LATEST_STABLE_SUPPORTED, and set flags (0 for no flags, or copy flags from existing files if necessary).
5. Use the ClassWriter class from ASM to embed metadata fields, such as kind, data1 and data2 into a .class file.

The following example demonstrates how to create metadata for a simple Kotlin class:

```kotlin
// Imports the necessary libraries
import kotlin.metadata.*
import kotlin.metadata.jvm.*
import org.objectweb.asm.*

fun main() {
    // Creates a KmClass instance
    val klass = KmClass().apply {
        name = "Hello"
        visibility = Visibility.PUBLIC
        constructors += KmConstructor().apply {
            visibility = Visibility.PUBLIC
            signature = JvmMethodSignature("<init>", "()V")
        }
        functions += KmFunction("hello").apply {
            visibility = Visibility.PUBLIC
            returnType = KmType().apply {
                classifier = KmClassifier.Class("kotlin/String")
            }
            signature = JvmMethodSignature("hello", "()Ljava/lang/String;")
        }
    }

    // Serializes a KotlinClassMetadata.Class instance, including the version and flags, into a @kotlin.Metadata annotation
    val annotationData = KotlinClassMetadata.Class(
        klass, JvmMetadataVersion.LATEST_STABLE_SUPPORTED, 0
    ).write()

    // Generates a .class file with ASM
    val classBytes = ClassWriter(0).apply {
        visit(Opcodes.V1_6, Opcodes.ACC_PUBLIC, "Hello", null, "java/lang/Object", null)
        // Writes @kotlin.Metadata instance to the .class file
        visitAnnotation("Lkotlin/Metadata;", true).apply {
            visit("mv", annotationData.metadataVersion)
            visit("k", annotationData.kind)
            visitArray("d1").apply {
                annotationData.data1.forEach { visit(null, it) }
                visitEnd()
            }
            visitArray("d2").apply {
                annotationData.data2.forEach { visit(null, it) }
                visitEnd()
            }
            visitEnd()
        }
        visitEnd()
    }.toByteArray()

    // Writes the generated class file to disk
    java.io.File("Hello.class").writeBytes(classBytes)
    println("Metadata and .class file created successfully.")
}
```

For a more detailed example, see the Kotlin Metadata JVM GitHub repository.

What's next

- See the API reference for the Kotlin Metadata JVM library.
- Check out the Kotlin Metadata JVM GitHub repository.
- Learn about module metadata and working with .kotlin_module files.

Lincheck guide

Lincheck is a practical and user-friendly framework for testing concurrent algorithms on the JVM. It provides a simple and declarative way to write concurrent tests.

With the Lincheck framework, instead of describing how to perform tests, you can specify what to test by declaring all the operations to examine and the required correctness property. As a result, a typical concurrent Lincheck test contains only about 15 lines.

When given a list of operations, Lincheck automatically:

- Generates a set of random concurrent scenarios.
- Examines them using either stress-testing or bounded model checking.
- Verifies that the results of each invocation satisfy the required correctness property (linearizability is the default one).

Add Lincheck to your project

To enable the Lincheck support, include the corresponding repository and dependency to the Gradle configuration. In your build.gradle(.kts) file, add the following:

Kotlin

```kotlin
repositories {
    mavenCentral()
}

dependencies {
    testImplementation("org.jetbrains.kotlinx:lincheck:2.39")
}
```

Groovy

```groovy
repositories {
    mavenCentral()
}

dependencies {
    testImplementation "org.jetbrains.kotlinx:lincheck:2.39"
}
```

Explore Lincheck

This guide will help you get in touch with the framework and try the most useful features with examples. Learn the Lincheck features step-by-step:

1. Write your first test with Lincheck
2. Choose your testing strategy

3. Configure operation arguments
4. Consider popular algorithm constraints
5. Check the algorithm for non-blocking progress guarantees
6. Define sequential specification of the algorithm

Additional references

- "How we test concurrent algorithms in Kotlin Coroutines" by Nikita Koval: Video. KotlinConf 2023
- "Lincheck: Testing concurrency on the JVM" workshop by Maria Sokolova: Part 1, Part 2. Hydra 2021

Write your first test with Lincheck

This tutorial demonstrates how to write your first Lincheck test, set up the Lincheck framework, and use its basic API. You will create a new IntelliJ IDEA project with an incorrect concurrent counter implementation and write a test for it, finding and analyzing the bug afterward.

Create a project

Open an existing Kotlin project in IntelliJ IDEA or create a new one. When creating a project, use the Gradle build system.

Add required dependencies

1. Open the build.gradle(.kts) file and make sure that mavenCentral() is added to the repository list.
2. Add the following dependencies to the Gradle configuration:

   Kotlin

```kotlin
repositories {
    mavenCentral()
}

dependencies {
    // Lincheck dependency
    testImplementation("org.jetbrains.kotlinx:lincheck:2.39")
    // This dependency allows you to work with kotlin.test and JUnit:
    testImplementation("junit:junit:4.13")
}
```

   Groovy

```groovy
repositories {
    mavenCentral()
}

dependencies {
    // Lincheck dependency
    testImplementation "org.jetbrains.kotlinx:lincheck:2.39"
    // This dependency allows you to work with kotlin.test and JUnit:
    testImplementation "junit:junit:4.13"
}
```

Write a concurrent counter and run the test

1. In the src/test/kotlin directory, create a BasicCounterTest.kt file and add the following code with a buggy concurrent counter and a Lincheck test for it:

```kotlin
import org.jetbrains.kotlinx.lincheck.annotations.*
import org.jetbrains.kotlinx.lincheck.*
import org.jetbrains.kotlinx.lincheck.strategy.stress.*
import org.junit.*

class Counter {
    @Volatile
    private var value = 0

    fun inc(): Int = ++value
    fun get() = value
}

class BasicCounterTest {
    private val c = Counter() // Initial state

    // Operations on the Counter
    @Operation
    fun inc() = c.inc()

    @Operation
    fun get() = c.get()

    @Test // JUnit
    fun stressTest() = StressOptions().check(this::class) // The magic button
}
```

This Lincheck test automatically:

- Generates several random concurrent scenarios with the specified inc() and get() operations.
- Performs a lot of invocations for each of the generated scenarios.
- Verifies that each invocation result is correct.

2. Run the test above, and you will see the following error:

```
= Invalid execution results =
| ------------------- |
| Thread 1 | Thread 2 |
| ------------------- |
| inc(): 1 | inc(): 1 |
| ------------------- |
```

Here, Lincheck found an execution that violates the counter atomicity – two concurrent increments ended with the same result 1. It means that one increment has been lost, and the behavior of the counter is incorrect.

Trace the invalid execution

Besides showing invalid execution results, Lincheck can also provide an interleaving that leads to the error. This feature is accessible with the model checking testing strategy, which examines numerous executions with a bounded number of context switches.

1. To switch the testing strategy, replace the options type from StressOptions() to ModelCheckingOptions(). The updated BasicCounterTest class will look like this:

```
import org.jetbrains.kotlinx.lincheck.annotations.*
import org.jetbrains.kotlinx.lincheck.check
import org.jetbrains.kotlinx.lincheck.strategy.managed.modelchecking.*
import org.junit.*

class Counter {
    @Volatile
    private var value = 0

    fun inc(): Int = ++value
    fun get() = value
}

class BasicCounterTest {
    private val c = Counter()

    @Operation
    fun inc() = c.inc()

    @Operation
    fun get() = c.get()
    @Test
    fun modelCheckingTest() = ModelCheckingOptions().check(this::class)
}
```

2. Run the test again. You will get the execution trace that leads to incorrect results:

```
= Invalid execution results =
| ------------------- |
| Thread 1 | Thread 2 |
| ------------------- |
| inc(): 1 | inc(): 1 |
| ------------------- |

The following interleaving leads to the error:
| --------------------------------------------------------------------- |
| Thread 1 |                          Thread  2                         |
| --------------------------------------------------------------------- |
|          | inc()                                                      |
|          |   inc(): 1 at BasicCounterTest.inc(BasicCounterTest.kt:18) |
|          |     value.READ: 0 at Counter.inc(BasicCounterTest.kt:10)   |
|          |     switch                                                 |
| inc(): 1 |                                                            |
|          |     value.WRITE(1) at Counter.inc(BasicCounterTest.kt:10)  |
|          |     value.READ: 1 at Counter.inc(BasicCounterTest.kt:10)   |
|          |   result: 1                                                |
| --------------------------------------------------------------------- |
```

According to the trace, the following events have occurred:

- T2: The second thread starts the inc() operation, reading the current counter value (value.READ: 0) and pausing.
- T1: The first thread executes inc(), which returns 1, and finishes.
- T2: The second thread resumes and increments the previously obtained counter value, incorrectly updating the counter to 1.

Get the full code.

Test the Java standard library

Let's now find a bug in the standard Java's ConcurrentLinkedDeque class. The Lincheck test below finds a race between removing and adding an element to the head of the deque:

```
import org.jetbrains.kotlinx.lincheck.*
import org.jetbrains.kotlinx.lincheck.annotations.*
import org.jetbrains.kotlinx.lincheck.strategy.managed.modelchecking.*
import org.junit.*
import java.util.concurrent.*

class ConcurrentDequeTest {
    private val deque = ConcurrentLinkedDeque<Int>()

    @Operation
    fun addFirst(e: Int) = deque.addFirst(e)

    @Operation
    fun addLast(e: Int) = deque.addLast(e)

    @Operation
    fun pollFirst() = deque.pollFirst()

    @Operation
    fun pollLast() = deque.pollLast()

    @Operation
    fun peekFirst() = deque.peekFirst()

    @Operation
    fun peekLast() = deque.peekLast()

    @Test
    fun modelCheckingTest() = ModelCheckingOptions().check(this::class)
}
```

Run modelCheckingTest(). The test will fail with the following output:

```
= Invalid execution results =
| --------------------------------------- |
|      Thread 1     |       Thread 2      |
| --------------------------------------- |
| addLast(22): void |                     |
| --------------------------------------- |
| pollFirst(): 22   | addFirst(8): void   |
|                   | peekLast(): 22 [-,1] |
| --------------------------------------- |

---
All operations above the horizontal line | ----- | happen before those below the line
---
Values in "[..]" brackets indicate the number of completed operations
in each of the parallel threads seen at the beginning of the current operation
---

The following interleaving leads to the error:
| ----------------------------------------------------------------------------------------------------------------------------
---- |
|                                                 Thread 1                                                      |       Thread 2
|
| ----------------------------------------------------------------------------------------------------------------------------
---- |
| pollFirst()                                                                                                   |
|
|   pollFirst(): 22 at ConcurrentDequeTest.pollFirst(ConcurrentDequeTest.kt:17)                                 |
|
|     first(): Node@1 at ConcurrentLinkedDeque.pollFirst(ConcurrentLinkedDeque.java:915)                        |
|
|     item.READ: null at ConcurrentLinkedDeque.pollFirst(ConcurrentLinkedDeque.java:917)                        |
|
|     next.READ: Node@2 at ConcurrentLinkedDeque.pollFirst(ConcurrentLinkedDeque.java:925)                      |
|
|     item.READ: 22 at ConcurrentLinkedDeque.pollFirst(ConcurrentLinkedDeque.java:917)                          |
|
|     prev.READ: null at ConcurrentLinkedDeque.pollFirst(ConcurrentLinkedDeque.java:919)                        |
|
|     switch                                                                                                    |
|
|                                                                                                               | addFirst(8): void
|
|                                                                                                               | peekLast(): 22
|
|     compareAndSet(Node@2,22,null): true at ConcurrentLinkedDeque.pollFirst(ConcurrentLinkedDeque.java:920) |
|
|     unlink(Node@2) at ConcurrentLinkedDeque.pollFirst(ConcurrentLinkedDeque.java:921)                         |
|
|   result: 22                                                                                                  |
|
| ----------------------------------------------------------------------------------------------------------------------------
---- |
```

Get the full code.

Next step

Choose your testing strategy and configure test execution.

See also

- How to generate operation arguments
- Popular algorithm constraints
- Checking for non-blocking progress guarantees

- Define sequential specification of the algorithm

Stress testing and model checking

Lincheck offers two testing strategies: stress testing and model checking. Learn what happens under the hood of both approaches using the Counter we coded in the BasicCounterTest.kt file in the previous step:

```
class Counter {
    @Volatile
    private var value = 0

    fun inc(): Int = ++value
    fun get() = value
}
```

Stress testing

Write a stress test

Create a concurrent stress test for the Counter, following these steps:

1. Create the CounterTest class.
2. In this class, add the field c of the Counter type, creating an instance in the constructor.
3. List the counter operations and mark them with the @Operation annotation, delegating their implementations to c.
4. Specify the stress testing strategy using StressOptions().
5. Invoke the StressOptions.check() function to run the test.

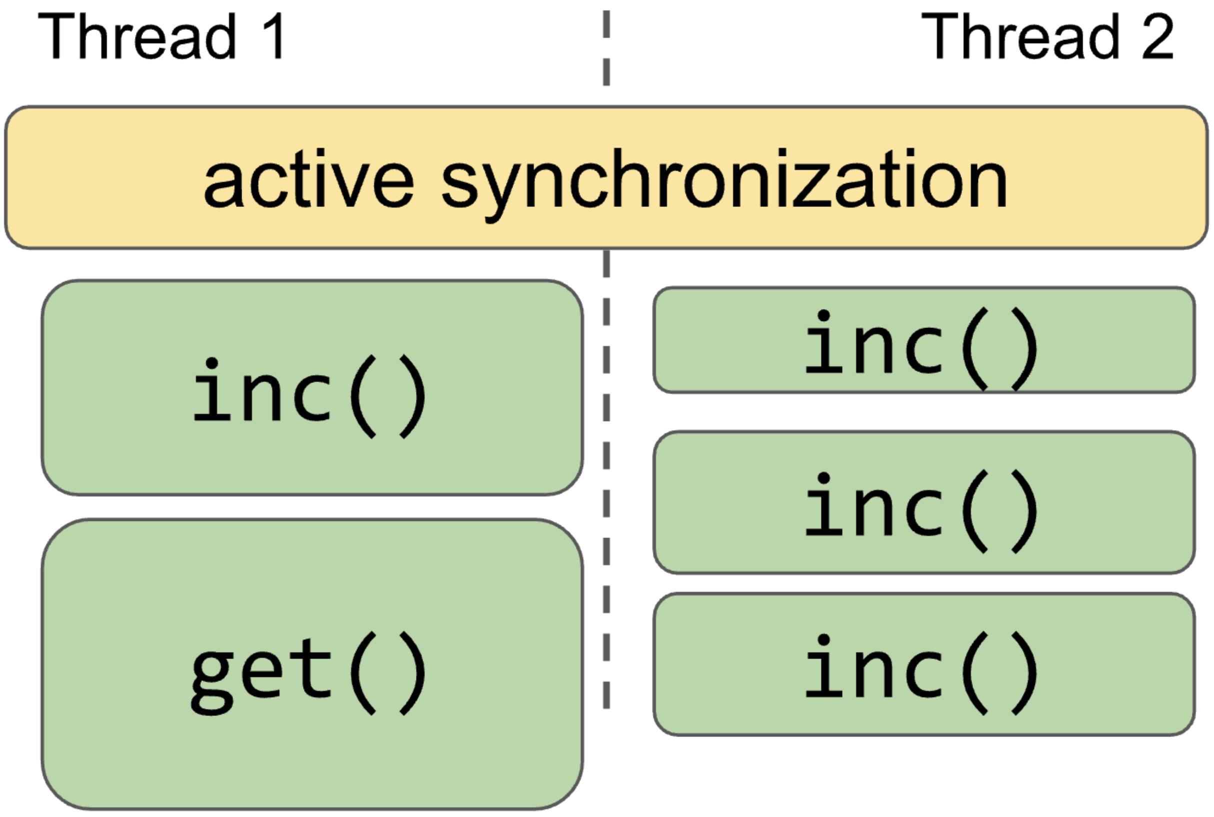
The resulting code will look like this:

```
import org.jetbrains.kotlinx.lincheck.annotations.*
import org.jetbrains.kotlinx.lincheck.check
import org.jetbrains.kotlinx.lincheck.strategy.stress.*
import org.junit.*

class CounterTest {
    private val c = Counter() // Initial state

    // Operations on the Counter
    @Operation
    fun inc() = c.inc()

    @Operation
    fun get() = c.get()

    @Test // Run the test
    fun stressTest() = StressOptions().check(this::class)
}
```

How stress testing works

At first, Lincheck generates a set of concurrent scenarios using the operations marked with @Operation. Then it launches native threads, synchronizing them at the beginning to guarantee that operations start simultaneously. Finally, Lincheck executes each scenario on these native threads multiple times, expecting to hit an interleaving that produces incorrect results.

The figure below shows a high-level scheme of how Lincheck may execute generated scenarios:



Stress execution of the Counter

Model checking

The main concern regarding stress testing is that you may spend hours trying to understand how to reproduce the found bug. To help you with that, Lincheck supports bounded model checking, which automatically provides an interleaving for reproducing bugs.

A model checking test is constructed the same way as the stress test. Just replace the StressOptions() that specify the testing strategy with ModelCheckingOptions().

Write a model checking test

To change the stress testing strategy to model checking, replace StressOptions() with ModelCheckingOptions() in your test:

```
import org.jetbrains.kotlinx.lincheck.annotations.*
import org.jetbrains.kotlinx.lincheck.check
import org.jetbrains.kotlinx.lincheck.strategy.managed.modelchecking.*
import org.junit.*

class CounterTest {
    private val c = Counter() // Initial state

    // Operations on the Counter
    @Operation
    fun inc() = c.inc()

    @Operation
    fun get() = c.get()

    @Test // Run the test
    fun modelCheckingTest() = ModelCheckingOptions().check(this::class)
}
```

How model checking works

Most bugs in complicated concurrent algorithms can be reproduced with classic interleavings, switching the execution from one thread to another. Besides, model checkers for weak memory models are very complicated, so Lincheck uses a bounded model checking under the sequential consistency memory model.

In short, Lincheck analyzes all interleavings, starting with one context switch, then two, continuing the process until the specified number of interleaving is examined. This strategy allows finding an incorrect schedule with the lowest possible number of context switches, making further bug investigation easier.

To control the execution, Lincheck inserts special switch points into the testing code. These points identify where a context switch can be performed. Essentially, these are shared memory accesses, such as field and array element reads or updates in the JVM, as well as wait/notify and park/unpark calls. To insert a switch point, Lincheck transforms the testing code on the fly using the ASM framework, adding internal function invocations to the existing code.

As the model checking strategy controls the execution, Lincheck can provide the trace that leads to the invalid interleaving, which is extremely helpful in practice. You can see the example of trace for the incorrect execution of the Counter in the Write your first test with Lincheck tutorial.

Which testing strategy is better?

The model checking strategy is preferable for finding bugs under the sequentially consistent memory model since it ensures better coverage and provides a failing execution trace if an error is found.

Although stress testing doesn't guarantee any coverage, checking algorithms for bugs introduced by low-level effects, such as a missed volatile modifier, is still helpful. Stress testing is also a great help in discovering rare bugs that require many context switches to reproduce, and it's impossible to analyze them all due to the current restrictions in the model checking strategy.

Configure the testing strategy

To configure the testing strategy, set options in the <TestingMode>Options class.

1. Set the options for scenario generation and execution for the CounterTest:

```kotlin
import org.jetbrains.kotlinx.lincheck.annotations.*
import org.jetbrains.kotlinx.lincheck.check
import org.jetbrains.kotlinx.lincheck.strategy.stress.*
import org.junit.*

class CounterTest {
    private val c = Counter()

    @Operation
    fun inc() = c.inc()

    @Operation
    fun get() = c.get()

    @Test
    fun stressTest() = StressOptions() // Stress testing options:
        .actorsBefore(2) // Number of operations before the parallel part
        .threads(2) // Number of threads in the parallel part
        .actorsPerThread(2) // Number of operations in each thread of the parallel part
        .actorsAfter(1) // Number of operations after the parallel part
        .iterations(100) // Generate 100 random concurrent scenarios
        .invocationsPerIteration(1000) // Run each generated scenario 1000 times
        .check(this::class) // Run the test
}
```

2. Run stressTest() again, Lincheck will generate scenarios similar to the one below:

```
| ------------------- |
| Thread 1 | Thread 2 |
| ------------------- |
| inc()    |          |
| inc()    |          |
| ------------------- |
| get()    | inc()    |
| inc()    | get()    |
| ------------------- |
| inc()    |          |
| ------------------- |
```

Here, there are two operations before the parallel part, two threads for each of the two operations, followed after that by a single operation in the end.

You can configure your model checking tests in the same way.

Scenario minimization

You may already have noticed that detected errors are usually represented with a scenario smaller than the specified in the test configuration. Lincheck tries to minimize the error, actively removing an operation while it's possible to keep the test from failing.

Here's the minimized scenario for the counter test above:

```
= Invalid execution results =
| ------------------- |
| Thread 1 | Thread 2 |
| ------------------- |
| inc()    | inc()    |
| ------------------- |
```

As it's easier to analyze smaller scenarios, scenario minimization is enabled by default. To disable this feature, add minimizeFailedScenario(false) to the [Stress, ModelChecking]Options configuration.

Logging data structure states

Another useful feature for debugging is state logging. When analyzing an interleaving that leads to an error, you usually draw the data structure changes on a sheet of paper, changing the state after each event. To automize this procedure, you can provide a special method that returns a String representation of the data structure, so Lincheck prints the state representation after each event in the interleaving that modifies the data structure.

For this, define a method that doesn't take arguments and is marked with the @StateRepresentation annotation. The method should be thread-safe, non-blocking, and never modify the data structure.

1. In the Counter example, the String representation is simply the value of the counter. Thus, to print the counter states in the trace, add the stateRepresentation() function to the CounterTest:

```
import org.jetbrains.kotlinx.lincheck.annotations.*
import org.jetbrains.kotlinx.lincheck.check
import org.jetbrains.kotlinx.lincheck.strategy.managed.modelchecking.*
import org.junit.Test

class CounterTest {
    private val c = Counter()

    @Operation
    fun inc() = c.inc()

    @Operation
    fun get() = c.get()

    @StateRepresentation
    fun stateRepresentation() = c.get().toString()

    @Test
    fun modelCheckingTest() = ModelCheckingOptions().check(this::class)
}
```

2. Run the modelCheckingTest() now and check the states of the Counter printed at the switch points that modify the counter state (they start with STATE:):

```
= Invalid execution results =
| ------------------- |
| Thread 1 | Thread 2 |
| ------------------- |
| STATE: 0            |
| ------------------- |
| inc(): 1 | inc(): 1 |
| ------------------- |
| STATE: 1            |
| ------------------- |

The following interleaving leads to the error:
| -------------------------------------------------------------------- |
| Thread 1 |                         Thread 2                            |
| ------------------------------------------------------------------- |
|          | inc()                                                     |
|          |   inc(): 1 at CounterTest.inc(CounterTest.kt:10)          |
|          |     value.READ: 0 at Counter.inc(BasicCounterTest.kt:10)  |
|          |     switch                                                |
| inc(): 1 |                                                           |
| STATE: 1 |                                                           |
|          |     value.WRITE(1) at Counter.inc(BasicCounterTest.kt:10) |
|          |     STATE: 1                                              |
|          |     value.READ: 1 at Counter.inc(BasicCounterTest.kt:10)  |
|          |   result: 1                                               |
| ------------------------------------------------------------------- |
```

In case of stress testing, Lincheck prints the state representation right before and after the parallel part of the scenario, as well as at the end.

- Get the full code of these examples
- See more test examples

Next step

Learn how to configure arguments passed to the operations and when it can be useful.

Operation arguments

In this tutorial, you'll learn how to configure operation arguments.

Consider this straightforward MultiMap implementation below. It's based on the ConcurrentHashMap, internally storing a list of values:

```kotlin
import java.util.concurrent.*

class MultiMap<K, V> {
    private val map = ConcurrentHashMap<K, List<V>>()

    // Maintains a list of values
    // associated with the specified key.
    fun add(key: K, value: V) {
        val list = map[key]
        if (list == null) {
            map[key] = listOf(value)
        } else {
            map[key] = list + value
        }
    }

    fun get(key: K): List<V> = map[key] ?: emptyList()
}
```

Is this MultiMap implementation linearizable? If not, an incorrect interleaving is more likely to be detected when accessing a small range of keys, thus, increasing the possibility of processing the same key concurrently.

For this, configure the generator for a key: Int parameter:

1. Declare the @Param annotation.
2. Specify the integer generator class: @Param(gen = IntGen::class). Lincheck supports random parameter generators for almost all primitives and strings out of the box.
3. Define the range of values generated with the string configuration @Param(conf = "1:2").
4. Specify the parameter configuration name (@Param(name = "key")) to share it for several operations.

   Below is the stress test for MultiMap that generates keys for add(key, value) and get(key) operations in the range of [1..2]:

   ```kotlin
   import java.util.concurrent.*
   ```

```
import org.jetbrains.kotlinx.lincheck.annotations.*
import org.jetbrains.kotlinx.lincheck.check
import org.jetbrains.kotlinx.lincheck.paramgen.*
import org.jetbrains.kotlinx.lincheck.strategy.stress.*
import org.jetbrains.kotlinx.lincheck.strategy.managed.modelchecking.*
import org.junit.*

class MultiMap<K, V> {
    private val map = ConcurrentHashMap<K, List<V>>()

    // Maintains a list of values
    // associated with the specified key.
    fun add(key: K, value: V) {
        val list = map[key]
        if (list == null) {
            map[key] = listOf(value)
        } else {
            map[key] = list + value
        }
    }

    fun get(key: K): List<V> = map[key] ?: emptyList()
}

@Param(name = "key", gen = IntGen::class, conf = "1:2")
class MultiMapTest {
    private val map = MultiMap<Int, Int>()

    @Operation
    fun add(@Param(name = "key") key: Int, value: Int) = map.add(key, value)

    @Operation
    fun get(@Param(name = "key") key: Int) = map.get(key)

    @Test
    fun stressTest() = StressOptions().check(this::class)

    @Test
    fun modelCheckingTest() = ModelCheckingOptions().check(this::class)
}
```

5. Run the stressTest() and see the following output:

```
= Invalid execution results =
| ---------------------------------- |
|    Thread 1     |      Thread 2     |
| ---------------------------------- |
| add(2, 0): void | add(2, -1): void |
| ---------------------------------- |
| get(2): [0]     |                  |
| ---------------------------------- |
```

6. Finally, run modelCheckingTest(). It fails with the following output:

```
= Invalid execution results =
| ---------------------------------- |
|    Thread 1     |      Thread 2     |
| ---------------------------------- |
| add(2, 0): void | add(2, -1): void |
| ---------------------------------- |
| get(2): [-1]    |                  |
| ---------------------------------- |

---
All operations above the horizontal line | ----- | happen before those below the line
---

The following interleaving leads to the error:
| ---------------------------------------------------------------------- |
|    Thread 1     |                       Thread 2                        |
| ---------------------------------------------------------------------- |
|                 | add(2, -1)                                           |
|                 |   add(2,-1) at MultiMapTest.add(MultiMap.kt:31)      |
|                 |     get(2): null at MultiMap.add(MultiMap.kt:15)     |
|                 |     switch                                           |
| add(2, 0): void |                                                      |
|                 |     put(2,[-1]): [0] at MultiMap.add(MultiMap.kt:17) |
|                 |   result: void                                       |
| ---------------------------------------------------------------------- |
```

Due to the small range of keys, Lincheck quickly reveals the race: when two values are being added concurrently by the same key, one of the values may be overwritten and lost.

Next step

Learn how to test data structures that set access constraints on the execution, such as single-producer single-consumer queues.

Data structure constraints

Some data structures may require a part of operations not to be executed concurrently, such as single-producer single-consumer queues. Lincheck provides out-of-the-box support for such contracts, generating concurrent scenarios according to the restrictions.

Consider the single-consumer queue from the JCTools library. Let's write a test to check correctness of its poll(), peek(), and offer(x) operations.

In your build.gradle(.kts) file, add the JCTools dependency:

Kotlin

```
dependencies {
    // jctools dependency
    testImplementation("org.jctools:jctools-core:3.3.0")
}
```

Groovy

```
dependencies {
    // jctools dependency
    testImplementation "org.jctools:jctools-core:3.3.0"
}
```

To meet the single-consumer restriction, ensure that all poll() and peek() consuming operations are called from a single thread. For that, we can set the nonParallelGroup parameter of the corresponding @Operation annotations to the same value, e.g. "consumers".

Here is the resulting test:

```
import org.jctools.queues.atomic.*
import org.jetbrains.kotlinx.lincheck.annotations.*
import org.jetbrains.kotlinx.lincheck.check
import org.jetbrains.kotlinx.lincheck.strategy.managed.modelchecking.*
import org.jetbrains.kotlinx.lincheck.strategy.stress.*
import org.junit.*

class MPSCQueueTest {
    private val queue = MpscLinkedAtomicQueue<Int>()

    @Operation
    fun offer(x: Int) = queue.offer(x)

    @Operation(nonParallelGroup = "consumers")
    fun poll(): Int? = queue.poll()

    @Operation(nonParallelGroup = "consumers")
    fun peek(): Int? = queue.peek()

    @Test
    fun stressTest() = StressOptions().check(this::class)

    @Test
    fun modelCheckingTest() = ModelCheckingOptions().check(this::class)
}
```

Here is an example of the scenario generated for this test:

```
= Iteration 15 / 100 =
| -------------------- |
| Thread 1  | Thread 2  |
| -------------------- |
| poll()    |           |
| poll()    |           |
| peek()    |           |
| peek()    |           |
| peek()    |           |
| -------------------- |
| offer(-1) | offer(0)  |
| offer(0)  | offer(-1) |
| peek()    | offer(-1) |
| offer(1)  | offer(1)  |
| peek()    | offer(1)  |
| -------------------- |
| peek()    |           |
| offer(-2) |           |
| offer(-2) |           |
| offer(2)  |           |
| offer(-2) |           |
| -------------------- |
```

Note that all consuming poll() and peek() invocations are performed from a single thread, thus satisfying the "single-consumer" restriction.

Get the full code.

Next step

Learn how to check your algorithm for progress guarantees with the model checking strategy.

Progress guarantees

Many concurrent algorithms provide non-blocking progress guarantees, such as lock-freedom and wait-freedom. As they are usually non-trivial, it's easy to add a bug that blocks the algorithm. Lincheck can help you find liveness bugs using the model checking strategy.

To check the progress guarantee of the algorithm, enable the checkObstructionFreedom option in ModelCheckingOptions():

```
ModelCheckingOptions().checkObstructionFreedom()
```

Create a ConcurrentMapTest.kt file. Then add the following test to detect that ConcurrentHashMap::put(key: K, value: V) from the Java standard library is a blocking operation:

```
import org.jetbrains.kotlinx.lincheck.*
import org.jetbrains.kotlinx.lincheck.annotations.*
import org.jetbrains.kotlinx.lincheck.strategy.managed.modelchecking.*
import org.junit.*
import java.util.concurrent.*

class ConcurrentHashMapTest {
    private val map = ConcurrentHashMap<Int, Int>()

    @Operation
    fun put(key: Int, value: Int) = map.put(key, value)

    @Test
    fun modelCheckingTest() = ModelCheckingOptions()
        .actorsBefore(1) // To init the HashMap
        .actorsPerThread(1)
        .actorsAfter(0)
        .minimizeFailedScenario(false)
        .checkObstructionFreedom()
        .check(this::class)
}
```

Run the modelCheckingTest(). You should get the following result:

```
= Obstruction-freedom is required but a lock has been found =
| ---------------------- |
|  Thread 1  | Thread 2  |
| ---------------------- |
| put(1, -1) |           |
| ---------------------- |
| put(2, -2) | put(3, 2) |
| ---------------------- |

---
All operations above the horizontal line | ----- | happen before those below the line
---

The following interleaving leads to the error:
| ----------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------- |
|                                         Thread 1                                         |
Thread 2                                        |
| ----------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------- |
|                                                                                          | put(3, 2)
|
|                                                                                          |   put(3,2) at
ConcurrentHashMapTest.put(ConcurrentMapTest.kt:11)                        |
|                                                                                          |     putVal(3,2,false) at
ConcurrentHashMap.put(ConcurrentHashMap.java:1006)             |
|                                                                                          |       table.READ: Node[]@1 at
ConcurrentHashMap.putVal(ConcurrentHashMap.java:1014)      |
|                                                                                          |       tabAt(Node[]@1,0): Node@1 at
ConcurrentHashMap.putVal(ConcurrentHashMap.java:1018) |
|                                                                                          |       MONITORENTER at
ConcurrentHashMap.putVal(ConcurrentHashMap.java:1031)              |
|                                                                                          |       tabAt(Node[]@1,0): Node@1 at
ConcurrentHashMap.putVal(ConcurrentHashMap.java:1032) |
|                                                                                          |       next.READ: null at
ConcurrentHashMap.putVal(ConcurrentHashMap.java:1046)           |
|                                                                                          |       switch
|
| put(2, -2)                                                                               |
|
|   put(2,-2) at ConcurrentHashMapTest.put(ConcurrentMapTest.kt:11)                        |
|
|     putVal(2,-2,false) at ConcurrentHashMap.put(ConcurrentHashMap.java:1006)             |
|
|       table.READ: Node[]@1 at ConcurrentHashMap.putVal(ConcurrentHashMap.java:1014)      |
|
|       tabAt(Node[]@1,0): Node@1 at ConcurrentHashMap.putVal(ConcurrentHashMap.java:1018) |
|
|       MONITORENTER at ConcurrentHashMap.putVal(ConcurrentHashMap.java:1031)              |
|
| ----------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------- |
```

Now let's add a test for the non-blocking ConcurrentSkipListMap<K, V>, expecting the test to pass successfully:

```kotlin
class ConcurrentSkipListMapTest {
    private val map = ConcurrentSkipListMap<Int, Int>()

    @Operation
    fun put(key: Int, value: Int) = map.put(key, value)

    @Test
    fun modelCheckingTest() = ModelCheckingOptions()
        .checkObstructionFreedom()
        .check(this::class)
}
```

The common non-blocking progress guarantees are (from strongest to weakest):

- wait-freedom, when each operation is completed in a bounded number of steps no matter what other threads do.
- lock-freedom, which guarantees system-wide progress so that at least one operation is completed in a bounded number of steps while a particular operation may be stuck.
- obstruction-freedom, when any operation is completed in a bounded number of steps if all the other threads pause.

At the moment, Lincheck supports only the obstruction-freedom progress guarantees. However, most real-life liveness bugs add unexpected blocking code, so the obstruction-freedom check will also help with lock-free and wait-free algorithms.

- Get the full code of the example.
- See another example where the Michael-Scott queue implementation is tested for progress guarantees.

Next step

Learn how to specify the sequential specification of the testing algorithm explicitly, improving the Lincheck tests robustness.

Sequential specification

To be sure that the algorithm provides correct sequential behavior, you can define its sequential specification by writing a straightforward sequential implementation of the testing data structure.

> This feature also allows you to write a single test instead of two separate sequential and concurrent tests.

To provide a sequential specification of the algorithm for verification:

1. Implement a sequential version of all the testing methods.
2. Pass the class with sequential implementation to the sequentialSpecification() option:

```
StressOptions().sequentialSpecification(SequentialQueue::class)
```

For example, here is the test to check correctness of j.u.c.ConcurrentLinkedQueue from the Java standard library.

```
import org.jetbrains.kotlinx.lincheck.*
import org.jetbrains.kotlinx.lincheck.annotations.*
import org.jetbrains.kotlinx.lincheck.strategy.stress.*
import org.junit.*
import java.util.*
import java.util.concurrent.*

class ConcurrentLinkedQueueTest {
    private val s = ConcurrentLinkedQueue<Int>()

    @Operation
    fun add(value: Int) = s.add(value)

    @Operation
    fun poll(): Int? = s.poll()

    @Test
    fun stressTest() = StressOptions()
        .sequentialSpecification(SequentialQueue::class.java)
        .check(this::class)
}

class SequentialQueue {
    private val s = LinkedList<Int>()

    fun add(x: Int) = s.add(x)
    fun poll(): Int? = s.poll()
}
```

> Get the full code of the examples.

Keywords and operators

Hard keywords

The following tokens are always interpreted as keywords and cannot be used as identifiers:

- as
  - is used for type casts.
  - specifies an alias for an import
- as? is used for safe type casts.
- break terminates the execution of a loop.
- class declares a class.
- continue proceeds to the next step of the nearest enclosing loop.
- do begins a do/while loop (a loop with a postcondition).
- else defines the branch of an if expression that is executed when the condition is false.
- false specifies the 'false' value of the Boolean type.
- for begins a for loop.
- fun declares a function.
- if begins an if expression.
- in
  - specifies the object being iterated in a for loop.
  - is used as an infix operator to check that a value belongs to a range, a collection, or another entity that defines a 'contains' method.
  - is used in when expressions for the same purpose.
  - marks a type parameter as contravariant.
- !in
  - is used as an operator to check that a value does NOT belong to a range, a collection, or another entity that defines a 'contains' method.
  - is used in when expressions for the same purpose.
- interface declares an interface.
- is
  - checks that a value has a certain type.
  - is used in when expressions for the same purpose.
- !is
  - checks that a value does NOT have a certain type.
  - is used in when expressions for the same purpose.
- null is a constant representing an object reference that doesn't point to any object.
- object declares a class and its instance at the same time.
- package specifies the package for the current file.
- return returns from the nearest enclosing function or anonymous function.
- super

  - refers to the superclass implementation of a method or property.
  - calls the superclass constructor from a secondary constructor.
- this
  - refers to the current receiver.
  - calls another constructor of the same class from a secondary constructor.
- throw throws an exception.
- true specifies the 'true' value of the Boolean type.
- try begins an exception-handling block.
- typealias declares a type alias.
- typeof is reserved for future use.
- val declares a read-only property or local variable.
- var declares a mutable property or local variable.
- when begins a when expression (executes one of the given branches).
- while begins a while loop (a loop with a precondition).

Soft keywords

The following tokens act as keywords in the context in which they are applicable, and they can be used as identifiers in other contexts:

- by
  - delegates the implementation of an interface to another object.
  - delegates the implementation of the accessors for a property to another object.
- catch begins a block that handles a specific exception type.
- constructor declares a primary or secondary constructor.
- delegate is used as an annotation use-site target.
- dynamic references a dynamic type in Kotlin/JS code.
- field is used as an annotation use-site target.
- file is used as an annotation use-site target.
- finally begins a block that is always executed when a try block exits.
- get
  - declares the getter of a property.
  - is used as an annotation use-site target.
- import imports a declaration from another package into the current file.
- init begins an initializer block.
- param is used as an annotation use-site target.
- property is used as an annotation use-site target.
- receiver is used as an annotation use-site target.
- set
  - declares the setter of a property.

  - is used as an annotation use-site target.

- setparam is used as an annotation use-site target.

- value with the class keyword declares an inline class.

- where specifies the constraints for a generic type parameter.

Modifier keywords

The following tokens act as keywords in modifier lists of declarations, and they can be used as identifiers in other contexts:

- abstract marks a class or member as abstract.

- actual denotes a platform-specific implementation in multiplatform projects.

- annotation declares an annotation class.

- companion declares a companion object.

- const marks a property as a compile-time constant.

- crossinline forbids non-local returns in a lambda passed to an inline function.

- data instructs the compiler to generate canonical members for a class.

- enum declares an enumeration.

- expect marks a declaration as platform-specific, expecting an implementation in platform modules.

- external marks a declaration as implemented outside of Kotlin (accessible through JNI or in JavaScript).

- final forbids overriding a member.

- infix allows calling a function using infix notation.

- inline tells the compiler to inline a function and the lambdas passed to it at the call site.

- inner allows referring to an outer class instance from a nested class.

- internal marks a declaration as visible in the current module.

- lateinit allows initializing a non-nullable property outside of a constructor.

- noinline turns off inlining of a lambda passed to an inline function.

- open allows subclassing a class or overriding a member.

- operator marks a function as overloading an operator or implementing a convention.

- out marks a type parameter as covariant.

- override marks a member as an override of a superclass member.

- private marks a declaration as visible in the current class or file.

- protected marks a declaration as visible in the current class and its subclasses.

- public marks a declaration as visible anywhere.

- reified marks a type parameter of an inline function as accessible at runtime.

- sealed declares a sealed class (a class with restricted subclassing).

- suspend marks a function or lambda as suspending (usable as a coroutine).

- tailrec marks a function as tail-recursive (allowing the compiler to replace recursion with iteration).

- vararg allows passing a variable number of arguments for a parameter.

Special identifiers

The following identifiers are defined by the compiler in specific contexts, and they can be used as regular identifiers in other contexts:

- field is used inside a property accessor to refer to the backing field of the property.
- it is used inside a lambda to refer to its parameter implicitly.

Operators and special symbols

Kotlin supports the following operators and special symbols:

- +, -, *, /, % - mathematical operators
  - * is also used to pass an array to a vararg parameter.
- =
  - assignment operator.
  - is used to specify default values for parameters.
- +=, -=, *=, /=, %= - augmented assignment operators.
- ++, -- - increment and decrement operators.
- &&, ||, ! - logical 'and', 'or', 'not' operators (for bitwise operations, use the corresponding infix functions instead).
- ==, != - equality operators (translated to calls of equals() for non-primitive types).
- ===, !== - referential equality operators.
- <, >, <=, >= - comparison operators (translated to calls of compareTo() for non-primitive types).
- [,] - indexed access operator (translated to calls of get and set).
- !! asserts that an expression is non-nullable.
- ?. performs a safe call (calls a method or accesses a property if the receiver is non-nullable).
- ?: takes the right-hand value if the left-hand value is null (the elvis operator).
- :: creates a member reference or a class reference.
- .., ..< create ranges.
- : separates a name from a type in a declaration.
- ? marks a type as nullable.
- ->
  - separates the parameters and body of a lambda expression.
  - separates the parameters and return type declaration in a function type.
  - separates the condition and body of a when expression branch.
- @
  - introduces an annotation.
  - introduces or references a loop label.
  - introduces or references a lambda label.
  - references a 'this' expression from an outer scope.
  - references an outer superclass.
- ; separates multiple statements on the same line.

- $ references a variable or expression in a string template.
- _
  - substitutes an unused parameter in a lambda expression.
  - substitutes an unused parameter in a destructuring declaration.

For operator precedence, see this reference in Kotlin grammar.

Gradle

Gradle is a build system that helps to automate and manage your building process. It downloads required dependencies, packages your code, and prepares it for compilation. Learn about Gradle basics and specifics on the Gradle website.

You can set up your own project with these instructions for different platforms or pass a small step-by-step tutorial that will show you how to create a simple backend "Hello World" application in Kotlin.

> You can find information about the compatibility of Kotlin, Gradle, and Android Gradle plugin versions here.

In this chapter, you can also learn about:

- Compiler options and how to pass them.
- Incremental compilation, caches support, build reports, and the Kotlin daemon.
- Support for Gradle plugin variants.

What's next?

Learn about:

- Gradle Kotlin DSL. The Gradle Kotlin DSL is a domain specific language that you can use to write build scripts quickly and efficiently.
- Annotation processing. Kotlin supports annotation processing via the Kotlin Symbol processing API.
- Generating documentation. To generate documentation for Kotlin projects, use Dokka; please refer to the Dokka README for configuration instructions. Dokka supports mixed-language projects and can generate output in multiple formats, including standard Javadoc.
- OSGi. For OSGi support see the Kotlin OSGi page.

Get started with Gradle and Kotlin/JVM

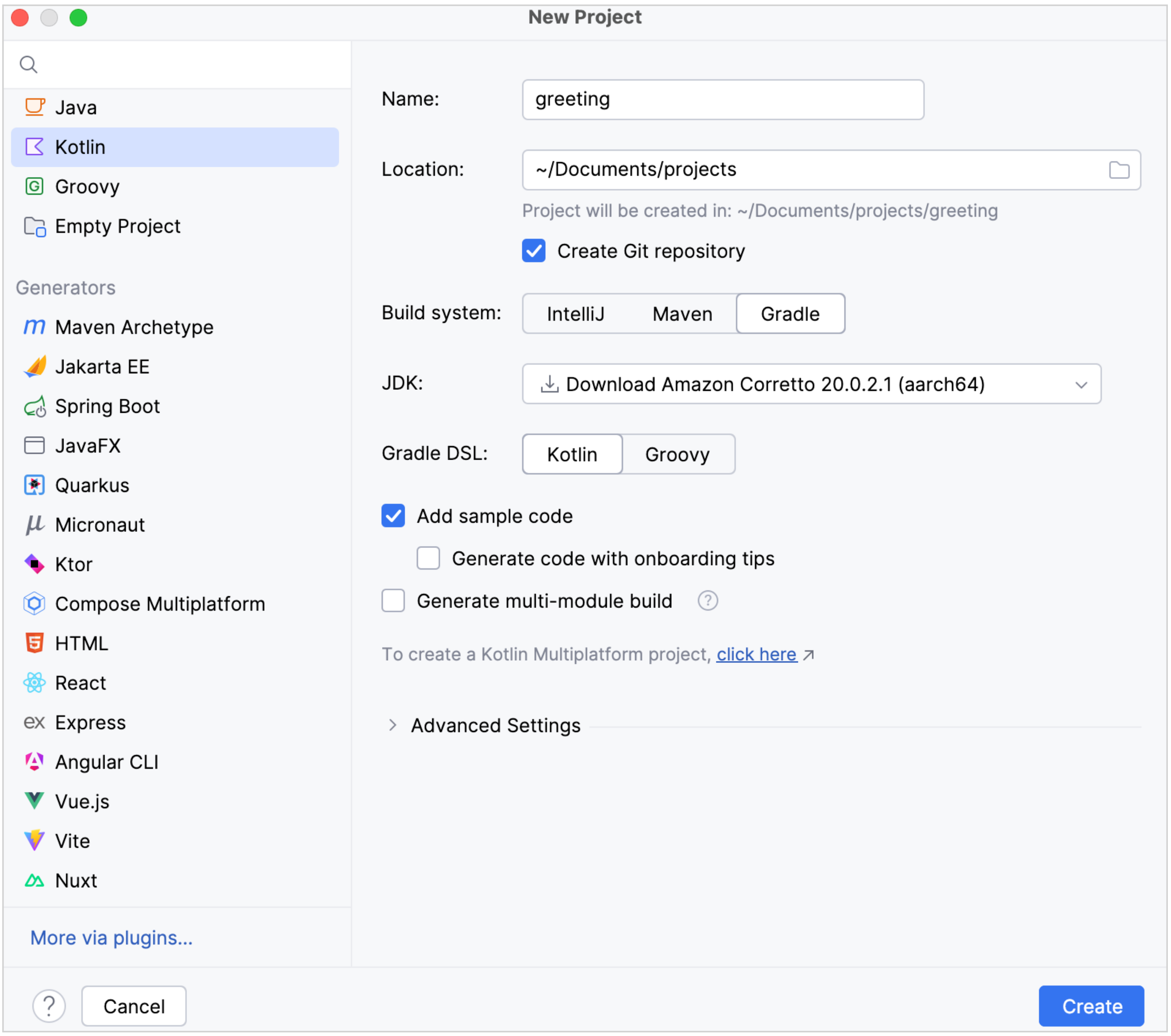
This tutorial demonstrates how to use IntelliJ IDEA and Gradle to create a JVM console application.

To get started, first download and install the latest version of IntelliJ IDEA.

Create a project

1. In IntelliJ IDEA, select File | New | Project.
2. In the panel on the left, select Kotlin.
3. Name the new project and change its location, if necessary.

   > Select the Create Git repository checkbox to place the new project under version control. You will be able to do it later at any time.



Name: greeting

Location: ~/Documents/projects

Project will be created in: ~/Documents/projects/greeting

[✓] Create Git repository

Build system: IntelliJ Maven [✓ Gradle]

JDK: Download Amazon Corretto 20.0.2.1 (aarch64)

Gradle DSL: [✓ Kotlin] Groovy

[✓] Add sample code

[ ] Generate code with onboarding tips

[ ] Generate multi-module build

To create a Kotlin Multiplatform project, click here ↗

Advanced Settings

Create a console application

4. Select the Gradle build system.
5. From the JDK list, select the JDK that you want to use in your project.
   - If the JDK is installed on your computer, but not defined in the IDE, select Add JDK and specify the path to the JDK home directory.
   - If you don't have the necessary JDK on your computer, select Download JDK.
6. Select the Kotlin DSL for Gradle.
7. Select the Add sample code checkbox to create a file with a sample "Hello World!" application.

> You can also enable the Generate code with onboarding tips option to add some additional useful comments to your sample code.

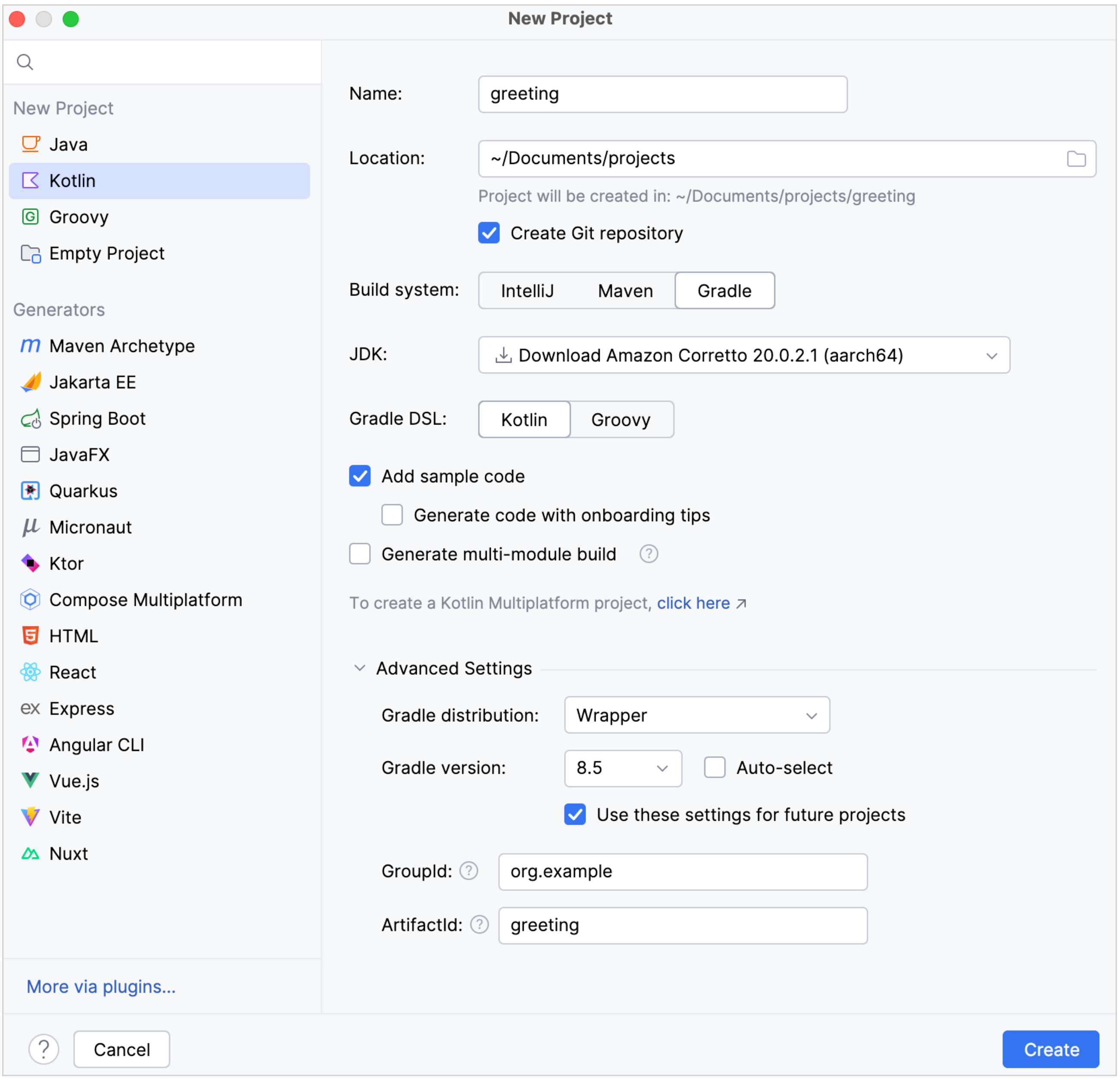
8. Click Create.

You have successfully created a project with Gradle!

Specify a Gradle version for your project

You can explicitly specify a Gradle version for your project under the Advanced Settings section, either by using the Gradle Wrapper or a local installation of Gradle:

* Gradle Wrapper:
  1. From the Gradle distribution list, select Wrapper.
  2. Disable the Auto-select checkbox.
  3. From the Gradle version list, select your Gradle version.
* Local installation:
  1. From the Gradle distribution list, select Local installation.
  2. For Gradle location, specify the path of your local Gradle version.



New Project

Name: greeting

Location: ~/Documents/projects

Project will be created in: ~/Documents/projects/greeting

☑ Create Git repository

Build system: IntelliJ | Maven | [✓ Gradle]

JDK: Download Amazon Corretto 20.0.2.1 (aarch64)

Gradle DSL: [✓ Kotlin] | Groovy

☑ Add sample code

☐ Generate code with onboarding tips

☐ Generate multi-module build

To create a Kotlin Multiplatform project, click here ↗

Advanced Settings

Gradle distribution: Wrapper

Gradle version: 8.5 ☐ Auto-select

☑ Use these settings for future projects

GroupId: org.example

ArtifactId: greeting

Advanced settings

Explore the build script

Open the build.gradle.kts file. This is the Gradle Kotlin build script, which contains Kotlin-related artifacts and other parts required for the application:

```
plugins {
    kotlin("jvm") version "2.2.0" // Kotlin version to use
}

group = "org.example" // A company name, for example, `org.jetbrains`
version = "1.0-SNAPSHOT" // Version to assign to the built artifact

repositories { // Sources of dependencies. See
    mavenCentral() // Maven Central Repository. See
}

dependencies { // All the libraries you want to use. See
    // Copy dependencies' names after you find them in a repository
    testImplementation(kotlin("test")) // The Kotlin test library
}

tasks.test { // See
    useJUnitPlatform() // JUnitPlatform for tests. See
}
```

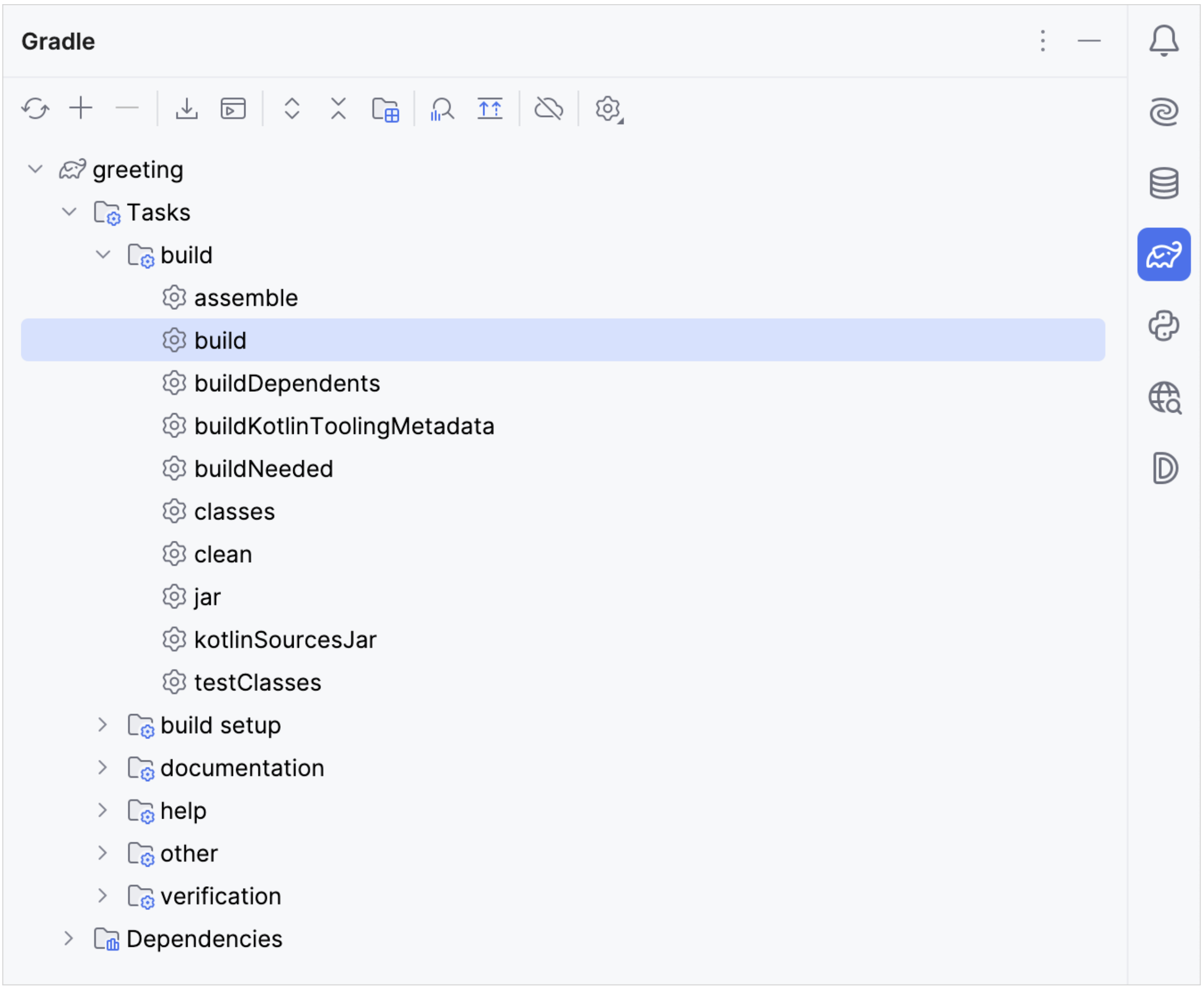
- Lean more about sources of dependencies.
- The Maven Central Repository. It can also be Google's Maven repository or your company's private repository.
- Learn more about declaring dependencies.
- Learn more about tasks.
- JUnitPlatform for tests.

As you can see, there are a few Kotlin-specific artifacts added to the Gradle build file:

1. In the plugins {} block, there is the kotlin("jvm") artifact. This plugin defines the version of Kotlin to be used in the project.
2. In the dependencies {} block, there is testImplementation(kotlin("test")). Learn more about setting dependencies on test libraries.

Run the application

1. Open the Gradle window by selecting View | Tool Windows | Gradle:



Main.kt with main fun

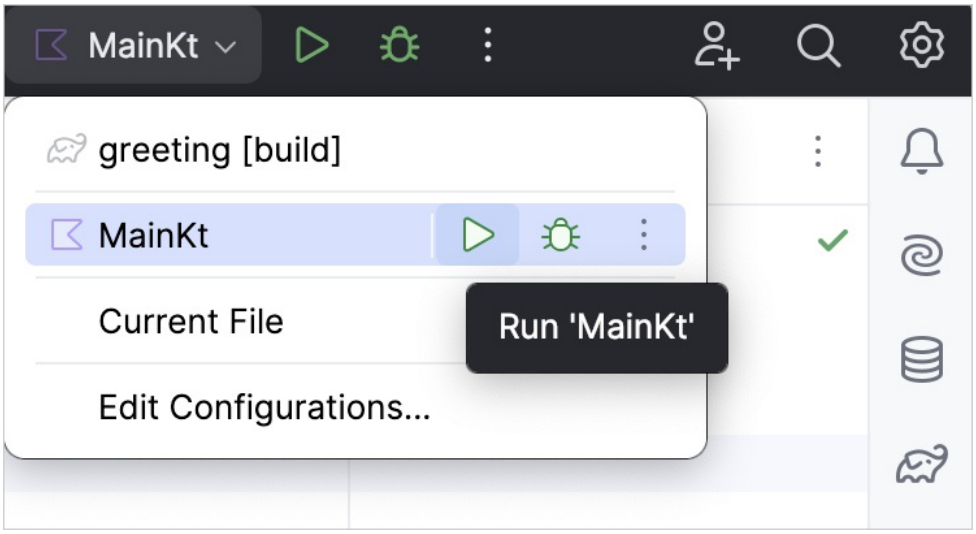
2. Execute the build Gradle task in Tasks\build\. In the Build window, BUILD SUCCESSFUL appears. It means that Gradle built the application successfully.

3. In src/main/kotlin, open the Main.kt file:

   - src directory contains Kotlin source files and resources.

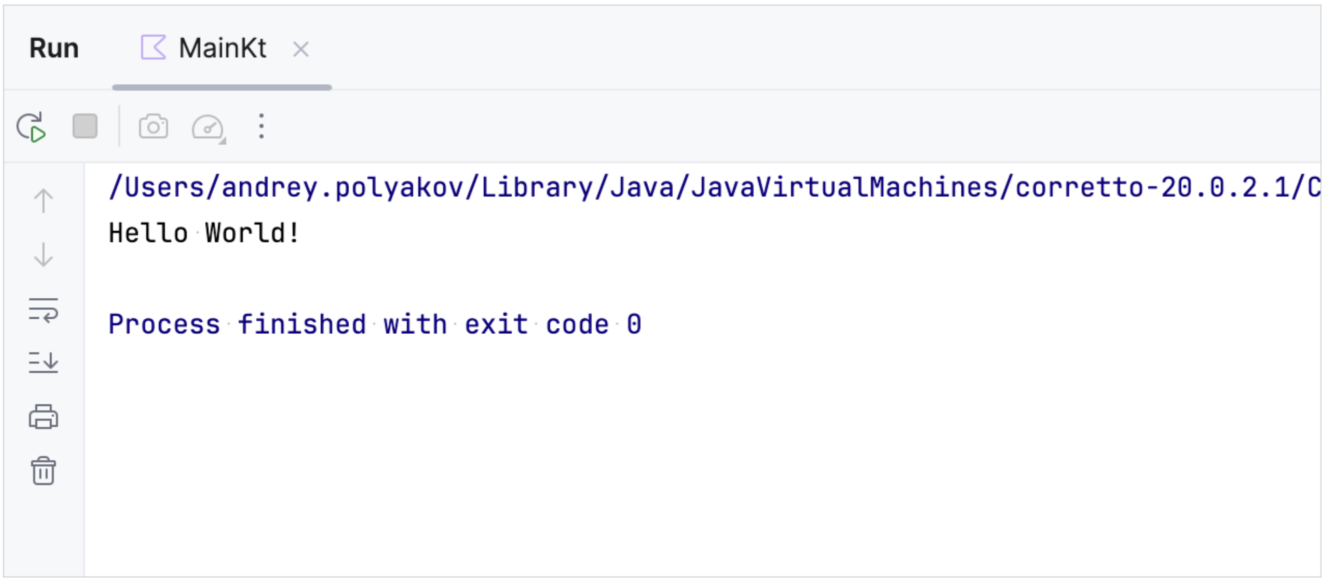
   - Main.kt file contains sample code that will print Hello World!.

4. Run the application by clicking the green Run icon in the gutter and select Run 'MainKt'.



Running a console app

You can see the result in the Run tool window:



```
/Users/andrey.polyakov/Library/Java/JavaVirtualMachines/corretto-20.0.2.1/C
Hello World!

Process finished with exit code 0
```

Kotlin run output

Congratulations! You have just run your first Kotlin application.

What's next?

Learn more about:

- Gradle build file properties.
- Targeting different platforms and setting library dependencies.
- Compiler options and how to pass them.
- Incremental compilation, caches support, build reports, and the Kotlin daemon.

Configure a Gradle project

To build a Kotlin project with Gradle, you need to add the Kotlin Gradle plugin to your build script file build.gradle(.kts) and configure the project's dependencies there.

> To learn more about the contents of a build script, visit the Explore the build script section.

Apply the plugin

To apply the Kotlin Gradle plugin, use the plugins{} block from the Gradle plugins DSL:

Kotlin

```
plugins {
    // Replace `<...>` with the plugin name appropriate for your target environment
    kotlin("<...>") version "2.2.0"
    // For example, if your target environment is JVM:
    // kotlin("jvm") version "2.2.0"
}
```

Groovy

```
plugins {
    // Replace `<...>` with the plugin name appropriate for your target environment
    id 'org.jetbrains.kotlin.<...>' version '2.2.0'
    // For example, if your target environment is JVM:
    // id 'org.jetbrains.kotlin.jvm' version '2.2.0'
}
```

> The Kotlin Gradle plugin (KGP) and Kotlin share the same version numbering.

When configuring your project, check the Kotlin Gradle plugin (KGP) compatibility with available Gradle versions. In the following table, there are the minimum and maximum fully supported versions of Gradle and Android Gradle plugin (AGP):

KGP version	Gradle min and max versions	AGP min and max versions
2.2.0	7.6.3–8.14	7.3.1–8.10.0
2.1.20-2.1.21	7.6.3–8.12.1	7.3.1–8.7.2
2.1.0–2.1.10	7.6.3–8.10*	7.3.1–8.7.2
2.0.20–2.0.21	6.8.3–8.8*	7.1.3–8.5
2.0.0	6.8.3–8.5	7.1.3–8.3.1
1.9.20–1.9.25	6.8.3–8.1.1	4.2.2–8.1.0
1.9.0–1.9.10	6.8.3–7.6.0	4.2.2–7.4.0
1.8.20–1.8.22	6.8.3–7.6.0	4.1.3–7.4.0

KGP version	Gradle min and max versions	AGP min and max versions
1.8.0–1.8.11	6.8.3–7.3.3	4.1.3–7.2.1
1.7.20–1.7.22	6.7.1–7.1.1	3.6.4–7.0.4
1.7.0–1.7.10	6.7.1–7.0.2	3.4.3–7.0.2
1.6.20–1.6.21	6.1.1–7.0.2	3.4.3–7.0.2

*Kotlin 2.0.20–2.0.21 and Kotlin 2.1.0–2.1.10 are fully compatible with Gradle up to 8.6. Gradle versions 8.7–8.10 are also supported, with only one exception: If you use the Kotlin Multiplatform Gradle plugin, you may see deprecation warnings in your multiplatform projects calling the withJava() function in the JVM target. For more information, see Java source sets created by default.

You can also use Gradle and AGP versions up to the latest releases, but if you do, keep in mind that you might encounter deprecation warnings or some new features might not work.

For example, the Kotlin Gradle plugin and the kotlin-multiplatform plugin 2.2.0 require the minimum Gradle version of 7.6.3 for your project to compile.

Similarly, the maximum fully supported version is 8.14. It doesn't have deprecated Gradle methods and properties, and supports all the current Gradle features.

Kotlin Gradle plugin data in a project

By default, the Kotlin Gradle plugin stores persistent project-specific data at the root of the project, in the .kotlin directory.

Do not commit the .kotlin directory to version control. For example, if you are using Git, add .kotlin to your project's .gitignore file.

There are properties you can add to the gradle.properties file of your project to configure this behavior:

Gradle property	Description
kotlin.project.persistent.dir	Configures the location where your project-level data is stored. Default: <project-root-directory>/.kotlin
kotlin.project.persistent.dir.gradle.disableWrite	Controls whether writing Kotlin data to the .gradle directory is disabled (for backward compatibility with older IDEA versions). Default: false

Targeting the JVM

To target the JVM, apply the Kotlin JVM plugin.

Kotlin

```kotlin
plugins {
    kotlin("jvm") version "2.2.0"
}
```

Groovy

```
plugins {
    id "org.jetbrains.kotlin.jvm" version "2.2.0"
}
```

The version should be literal in this block, and it cannot be applied from another build script.

Kotlin and Java sources

Kotlin sources and Java sources can be stored in the same directory, or they can be placed in different directories.

The default convention is to use different directories:

```
project
    - src
        - main (root)
            - kotlin
            - java
```

> Do not store Java .java files in the src/*/kotlin directory, as the .java files will not be compiled.
>
> Instead, you can use src/main/java.

The corresponding sourceSets property should be updated if you are not using the default convention:

Kotlin

```kotlin
sourceSets.main {
    java.srcDirs("src/main/myJava", "src/main/myKotlin")
}
```

Groovy

```groovy
sourceSets {
    main.kotlin.srcDirs += 'src/main/myKotlin'
    main.java.srcDirs += 'src/main/myJava'
}
```

Check for JVM target compatibility of related compile tasks

In the build module, you may have related compile tasks, for example:

- compileKotlin and compileJava
- compileTestKotlin and compileTestJava

> main and test source set compile tasks are not related.

For related tasks like these, the Kotlin Gradle plugin checks for JVM target compatibility. Different values of the jvmTarget attribute in the kotlin extension or task and targetCompatibility in the java extension or task cause JVM target incompatibility. For example: the compileKotlin task has jvmTarget=1.8, and the compileJava task has (or inherits) targetCompatibility=15.

Configure the behavior of this check for the whole project by setting the kotlin.jvm.target.validation.mode property in the gradle.properties file to:

- error – the plugin fails the build; the default value for projects on Gradle 8.0+.
- warning – the plugin prints a warning message; the default value for projects on Gradle less than 8.0.
- ignore – the plugin skips the check and doesn't produce any messages.

You can also configure it at task level in your build.gradle(kts) file:

Kotlin

```
tasks.withType<org.jetbrains.kotlin.gradle.tasks.KotlinJvmCompile>().configureEach {
    jvmTargetValidationMode.set(org.jetbrains.kotlin.gradle.dsl.jvm.JvmTargetValidationMode.WARNING)
}
```

Groovy

```
tasks.withType(org.jetbrains.kotlin.gradle.tasks.KotlinJvmCompile.class).configureEach {
    jvmTargetValidationMode = org.jetbrains.kotlin.gradle.dsl.jvm.JvmTargetValidationMode.WARNING
}
```

To avoid JVM target incompatibility, configure a toolchain or align JVM versions manually.

What can go wrong if targets are incompatible

There are two ways of manually setting JVM targets for Kotlin and Java source sets:

- The implicit way via setting up a Java toolchain.
- The explicit way via setting the jvmTarget attribute in the kotlin extension or task and targetCompatibility in the java extension or task.

JVM target incompatibility occurs if you:

- Explicitly set different values of jvmTarget and targetCompatibility.
- Have a default configuration, and your JDK is not equal to 1.8.

Let's consider a default configuration of JVM targets when you have only the Kotlin JVM plugin in your build script and no additional settings for JVM targets:

Kotlin

```
plugins {
    kotlin("jvm") version "2.2.0"
}
```

Groovy

```
plugins {
    id "org.jetbrains.kotlin.jvm" version "2.2.0"
}
```

When there is no explicit information about the jvmTarget value in the build script, its default value is null, and the compiler translates it to the default value 1.8. The targetCompatibility equals the current Gradle's JDK version, which is equal to your JDK version (unless you use a Java toolchain approach). Assuming that your JDK version is 17, your published library artifact will declare itself compatible with JDK 17+: org.gradle.jvm.version=17, which is wrong. In this case, you have to use Java 17 in your main project to add this library, even though the bytecode's version is 1.8. Configure a toolchain to solve this issue.

Gradle Java toolchains support

A warning for Android users. To use Gradle toolchain support, use the Android Gradle plugin (AGP) version 8.1.0-alpha09 or higher.

Gradle Java toolchain support is available only from AGP 7.4.0. Nevertheless, because of this issue, AGP did not set targetCompatibility to be equal to the toolchain's JDK until the version 8.1.0-alpha09. If you use versions less than 8.1.0-alpha09, you need to configure targetCompatibility manually via compileOptions. Replace the placeholder <MAJOR_JDK_VERSION> with the JDK version you would like to use:

```
android {
    compileOptions {
        sourceCompatibility = <MAJOR_JDK_VERSION>
        targetCompatibility = <MAJOR_JDK_VERSION>
    }
}
```

Gradle 6.7 introduced Java toolchains support. Using this feature, you can:

- Use a JDK and a JRE that are different from the ones in Gradle to run compilations, tests, and executables.
- Compile and test code with a not-yet-released language version.

With toolchains support, Gradle can autodetect local JDKs and install missing JDKs that Gradle requires for the build. Now Gradle itself can run on any JDK and still reuse the remote build cache feature for tasks that depend on a major JDK version.

The Kotlin Gradle plugin supports Java toolchains for Kotlin/JVM compilation tasks. JS and Native tasks don't use toolchains. The Kotlin compiler always runs on the JDK the Gradle daemon is running on. A Java toolchain:

- Sets the -jdk-home option available for JVM targets.
- Sets the compilerOptions.jvmTarget to the toolchain's JDK version if the user doesn't set the jvmTarget option explicitly. If the user doesn't configure the toolchain, the jvmTarget field uses the default value. Learn more about JVM target compatibility.
- Sets the toolchain to be used by any Java compile, test and javadoc tasks.
- Affects which JDK kapt workers are running on.

Use the following code to set a toolchain. Replace the placeholder <MAJOR_JDK_VERSION> with the JDK version you would like to use:

Kotlin

```
kotlin {
    jvmToolchain {
        languageVersion.set(JavaLanguageVersion.of(<MAJOR_JDK_VERSION>))
    }
    // Or shorter:
    jvmToolchain(<MAJOR_JDK_VERSION>)
    // For example:
    jvmToolchain(17)
}
```

Groovy

```
kotlin {
    jvmToolchain {
        languageVersion = JavaLanguageVersion.of(<MAJOR_JDK_VERSION>)
    }
    // Or shorter:
    jvmToolchain(<MAJOR_JDK_VERSION>)
    // For example:
    jvmToolchain(17)
}
```

Note that setting a toolchain via the kotlin extension updates the toolchain for Java compile tasks as well.

You can set a toolchain via the java extension, and Kotlin compilation tasks will use it:

Kotlin

```
java {
    toolchain {
        languageVersion.set(JavaLanguageVersion.of(<MAJOR_JDK_VERSION>))
    }
}
```

Groovy

```
java {
    toolchain {
        languageVersion = JavaLanguageVersion.of(<MAJOR_JDK_VERSION>)
    }
}
```

If you use Gradle 8.0.2 or higher, you also need to add a toolchain resolver plugin. This type of plugin manages which repositories to download a toolchain from. As an example, add to your settings.gradle(.kts) the following plugin:

Kotlin

```
plugins {
    id("org.gradle.toolchains.foojay-resolver-convention") version("0.9.0")
}
```

Groovy

```
plugins {
    id 'org.gradle.toolchains.foojay-resolver-convention' version '0.9.0'
}
```

Check that the version of foojay-resolver-convention corresponds to your Gradle version on the Gradle site.

To understand which toolchain Gradle uses, run your Gradle build with the log level --info and find a string in the output starting with [KOTLIN] Kotlin compilation 'jdkHome' argument:. The part after the colon will be the JDK version from the toolchain.

To set any JDK (even local) for a specific task, use the Task DSL.

Learn more about Gradle JVM toolchain support in the Kotlin plugin.

Set JDK version with the Task DSL

The Task DSL allows setting any JDK version for any task implementing the UsesKotlinJavaToolchain interface. At the moment, these tasks are KotlinCompile and KaptTask. If you want Gradle to search for the major JDK version, replace the <MAJOR_JDK_VERSION> placeholder in your build script:

Kotlin

```
val service = project.extensions.getByType<JavaToolchainService>()
val customLauncher = service.launcherFor {
    languageVersion.set(JavaLanguageVersion.of(<MAJOR_JDK_VERSION>))
}
project.tasks.withType<UsesKotlinJavaToolchain>().configureEach {
    kotlinJavaToolchain.toolchain.use(customLauncher)
}
```

Groovy

```
JavaToolchainService service = project.getExtensions().getByType(JavaToolchainService.class)
Provider<JavaLauncher> customLauncher = service.launcherFor {
    it.languageVersion = JavaLanguageVersion.of(<MAJOR_JDK_VERSION>)
}
tasks.withType(UsesKotlinJavaToolchain::class).configureEach { task ->
    task.kotlinJavaToolchain.toolchain.use(customLauncher)
}
```

Or you can specify the path to your local JDK and replace the placeholder <LOCAL_JDK_VERSION> with this JDK version:

```
tasks.withType<UsesKotlinJavaToolchain>().configureEach {
    kotlinJavaToolchain.jdk.use(
        "/path/to/local/jdk", // Put a path to your JDK
        JavaVersion.<LOCAL_JDK_VERSION> // For example, JavaVersion.17
    )
}
```

Associate compiler tasks

You can associate compilations by setting up such a relationship between them that one compilation uses the compiled outputs of the other. Associating compilations establishes internal visibility between them.

The Kotlin compiler associates some compilations by default, such as the test and main compilations of each target. If you need to express that one of your custom compilations is connected to another, create your own associated compilation.

To make the IDE support associated compilations for inferring visibility between source sets, add the following code to your build.gradle(.kts):

Kotlin

```
val integrationTestCompilation = kotlin.target.compilations.create("integrationTest") {
    associateWith(kotlin.target.compilations.getByName("main"))
}
```

Groovy

```
integrationTestCompilation {
    kotlin.target.compilations.create("integrationTest") {
        associateWith(kotlin.target.compilations.getByName("main"))
    }
}
```

Here, the integrationTest compilation is associated with the main compilation that gives access to internal objects from functional tests.

Configure with Java Modules (JPMS) enabled

To make the Kotlin Gradle plugin work with Java Modules, add the following lines to your build script and replace YOUR_MODULE_NAME with a reference to your JPMS module, for example, org.company.module:

Kotlin

```
// Add the following three lines if you use a Gradle version less than 7.0
java {
    modularity.inferModulePath.set(true)
}

tasks.named("compileJava", JavaCompile::class.java) {
    options.compilerArgumentProviders.add(CommandLineArgumentProvider {
        // Provide compiled Kotlin classes to javac – needed for Java/Kotlin mixed sources to work
        listOf("--patch-module", "YOUR_MODULE_NAME=${sourceSets["main"].output.asPath}")
    })
}
```

Groovy

```
// Add the following three lines if you use a Gradle version less than 7.0
java {
    modularity.inferModulePath = true
}

tasks.named("compileJava", JavaCompile.class) {
    options.compilerArgumentProviders.add(new CommandLineArgumentProvider() {
        @Override
        Iterable<String> asArguments() {
            // Provide compiled Kotlin classes to javac – needed for Java/Kotlin mixed sources to work
            return ["--patch-module", "YOUR_MODULE_NAME=${sourceSets["main"].output.asPath}"]
        }
    })
}
```

Put module-info.java into the src/main/java directory as usual.

For a module, a package name in Kotlin files should be equal to the package name from module-info.java to avoid a "package is empty or does not exist" build failure.

Learn more about:

- Building modules for the Java Module System
- Building applications using the Java Module System
- What "module" means in Kotlin

Other details

Learn more about Kotlin/JVM.

Disable use of artifact in compilation task

In some rare scenarios, you can experience a build failure caused by a circular dependency error. For example, when you have multiple compilations where one compilation can see all internal declarations of another, and the generated artifact relies on the output of both compilation tasks:

```
FAILURE: Build failed with an exception.

What went wrong:
Circular dependency between the following tasks:
:lib:compileKotlinJvm
--- :lib:jvmJar
     \--- :lib:compileKotlinJvm (*)
(*) - details omitted (listed previously)
```

To fix this circular dependency error, we've added a Gradle property: archivesTaskOutputAsFriendModule. This property controls the use of artifact inputs in the compilation task and determines if a task dependency is created as a result.

By default, this property is set to true to track the task dependency. If you encounter a circular dependency error, you can disable the use of the artifact in the compilation task to remove the task dependency and avoid the circular dependency error.

To disable the use of the artifact in the compilation task, add the following to your gradle.properties file:

```
kotlin.build.archivesTaskOutputAsFriendModule=false
```

Lazy Kotlin/JVM task creation

Starting from Kotlin 1.8.20, the Kotlin Gradle plugin registers all tasks and doesn't configure them on a dry run.

Non-default location of compile tasks' destinationDirectory

If you override the Kotlin/JVM KotlinJvmCompile/KotlinCompile task's destinationDirectory location, update your build script. You need to explicitly add sourceSets.main.kotlin.classesDirectories to sourceSets.main.outputs in your JAR file:

```
tasks.jar(type: Jar) {
    from sourceSets.main.outputs
    from sourceSets.main.kotlin.classesDirectories
}
```

Targeting multiple platforms

Projects targeting multiple platforms, called multiplatform projects, require the kotlin-multiplatform plugin.

> The kotlin-multiplatform plugin works with Gradle 7.6.3 or later.

Kotlin

```
plugins {
    kotlin("multiplatform") version "2.2.0"
}
```

Groovy

```
plugins {
    id 'org.jetbrains.kotlin.multiplatform' version '2.2.0'
}
```

Learn more about Kotlin Multiplatform for different platforms and Kotlin Multiplatform for iOS and Android.

Targeting Android

It's recommended to use Android Studio for creating Android applications. Learn how to use the Android Gradle plugin.

Targeting JavaScript

When targeting JavaScript, use the kotlin-multiplatform plugin as well. Learn more about setting up a Kotlin/JS project

Kotlin

```
plugins {
    kotlin("multiplatform") version "2.2.0"
}
```

Groovy

```
plugins {
    id 'org.jetbrains.kotlin.multiplatform' version '2.2.0'
}
```

Kotlin and Java sources for JavaScript

This plugin only works for Kotlin files, so it is recommended that you keep Kotlin and Java files separate (if the project contains Java files). If you don't store them separately, specify the source folder in the sourceSets{} block:

Kotlin

```
kotlin {
    sourceSets["main"].apply {
        kotlin.srcDir("src/main/myKotlin")
    }
}
```

Groovy

```
kotlin {
    sourceSets {
        main.kotlin.srcDirs += 'src/main/myKotlin'
    }
}
```

Triggering configuration actions with the KotlinBasePlugin interface

To trigger some configuration action whenever any Kotlin Gradle plugin (JVM, JS, Multiplatform, Native, and others) is applied, use the KotlinBasePlugin interface that all Kotlin plugins inherit from:

Kotlin

```kotlin
import org.jetbrains.kotlin.gradle.plugin.KotlinBasePlugin

// ...

project.plugins.withType<KotlinBasePlugin>() {
    // Configure your action here
}
```

Groovy

```groovy
import org.jetbrains.kotlin.gradle.plugin.KotlinBasePlugin

// ...

project.plugins.withType(KotlinBasePlugin.class) {
    // Configure your action here
}
```

Configure dependencies

To add a dependency on a library, set the dependency of the required type (for example, implementation) in the dependencies{} block of the source sets DSL.

Kotlin

```kotlin
kotlin {
    sourceSets {
        commonMain.dependencies {
            implementation("com.example:my-library:1.0")
        }
    }
}
```

Groovy

```groovy
kotlin {
    sourceSets {
        commonMain {
            dependencies {
                implementation 'com.example:my-library:1.0'
            }
        }
    }
}
```

Alternatively, you can set dependencies at top level.

Dependency types

Choose the dependency type based on your requirements.

Type	Description	When to use
api	Used both during compilation and at runtime and is exported to library consumers.	If any type from a dependency is used in the public API of the current module, use an api dependency.
implementation	Used during compilation and at runtime for the current module, but is not exposed for compilation of other modules depending on the one with the `implementation` dependency.	Use for dependencies needed for the internal logic of a module. If a module is an endpoint application which is not published, use implementation dependencies instead of api dependencies.
compileOnly	Used for compilation of the current module and is not available at runtime nor during compilation of other modules.	Use for APIs which have a third-party implementation available at runtime.
runtimeOnly	Available at runtime but is not visible during compilation of any module.	

Dependency on the standard library

A dependency on the standard library (stdlib) is added automatically to each source set. The version of the standard library used is the same as the version of the Kotlin Gradle plugin.

For platform-specific source sets, the corresponding platform-specific variant of the library is used, while a common standard library is added to the rest. The Kotlin Gradle plugin selects the appropriate JVM standard library depending on the compilerOptions.jvmTarget compiler option of your Gradle build script.

If you declare a standard library dependency explicitly (for example, if you need a different version), the Kotlin Gradle plugin won't override it or add a second standard library.

If you don't need a standard library at all, you can add the following Gradle property to your gradle.properties file:

```
kotlin.stdlib.default.dependency=false
```

Versions alignment of transitive dependencies

From Kotlin standard library version 1.9.20, Gradle uses metadata included in the standard library to automatically align transitive kotlin-stdlib-jdk7 and kotlin-stdlib-jdk8 dependencies.

If you add a dependency for any Kotlin standard library version between 1.8.0 – 1.9.10, for example: implementation("org.jetbrains.kotlin:kotlin-stdlib:1.8.0"), then the Kotlin Gradle Plugin uses this Kotlin version for transitive kotlin-stdlib-jdk7 and kotlin-stdlib-jdk8 dependencies. This avoids class duplication from different standard library versions. Learn more about merging kotlin-stdlib-jdk7 and kotlin-stdlib-jdk8 into kotlin-stdlib. You can disable this behavior with the kotlin.stdlib.jdk.variants.version.alignment Gradle property in your gradle.properties file:

```
kotlin.stdlib.jdk.variants.version.alignment=false
```

Other ways to align versions

- If you have issues with version alignment, you can align all versions via the Kotlin BOM. Declare a platform dependency on kotlin-bom in your build script:

  Kotlin

  ```
  implementation(platform("org.jetbrains.kotlin:kotlin-bom:2.2.0"))
  ```

  Groovy

```
implementation platform('org.jetbrains.kotlin:kotlin-bom:2.2.0')
```

- If you don't add a dependency for a standard library version, but you have two different dependencies that transitively bring different old versions of the Kotlin standard library, then you can explicitly require 2.2.0 versions of these transitive libraries:

Kotlin

```
dependencies {
    constraints {
        add("implementation", "org.jetbrains.kotlin:kotlin-stdlib-jdk7") {
            version {
                require("2.2.0")
            }
        }
        add("implementation", "org.jetbrains.kotlin:kotlin-stdlib-jdk8") {
            version {
                require("2.2.0")
            }
        }
    }
}
```

Groovy

```
dependencies {
    constraints {
        add("implementation", "org.jetbrains.kotlin:kotlin-stdlib-jdk7") {
            version {
                require("2.2.0")
            }
        }
        add("implementation", "org.jetbrains.kotlin:kotlin-stdlib-jdk8") {
            version {
                require("2.2.0")
            }
        }
    }
}
```

- If you add a dependency for Kotlin standard library version 2.2.0: implementation("org.jetbrains.kotlin:kotlin-stdlib:2.2.0"), and an old version (earlier than 1.8.0) of the Kotlin Gradle plugin, update the Kotlin Gradle plugin to match the standard library version:

Kotlin

```
plugins {
    // replace `<...>` with the plugin name
    kotlin("<...>") version "2.2.0"
}
```

Groovy

```
plugins {
    // replace `<...>` with the plugin name
    id "org.jetbrains.kotlin.<...>" version "2.2.0"
}
```

- If you use versions prior to 1.8.0 of kotlin-stdlib-jdk7/kotlin-stdlib-jdk8, for example, implementation("org.jetbrains.kotlin:kotlin-stdlib-jdk7:SOME_OLD_KOTLIN_VERSION"), and a dependency that transitively brings kotlin-stdlib:1.8+, replace your kotlin-stdlib-jdk<7/8>:SOME_OLD_KOTLIN_VERSION with kotlin-stdlib-jdk*:2.2.0 or exclude the transitive kotlin-stdlib:1.8+ from the library that brings it:

Kotlin

```
dependencies {
    implementation("com.example:lib:1.0") {
        exclude(group = "org.jetbrains.kotlin", module = "kotlin-stdlib")
    }
}
```

Groovy

```
dependencies {
    implementation("com.example:lib:1.0") {
        exclude group: "org.jetbrains.kotlin", module: "kotlin-stdlib"
    }
}
```

Set dependencies on test libraries

The kotlin.test API is available for testing Kotlin projects on all supported platforms. Add the kotlin-test dependency to the commonTest source set, so that the Gradle plugin can infer the corresponding test dependencies for each test source set.

Kotlin/Native targets do not require additional test dependencies, and the kotlin.test API implementations are built-in.

Kotlin

```
kotlin {
    sourceSets {
         commonTest.dependencies {
             implementation(kotlin("test")) // This brings all the platform dependencies automatically
        }
    }
}
```

Groovy

```
kotlin {
    sourceSets {
        commonTest {
            dependencies {
                implementation kotlin("test") // This brings all the platform dependencies automatically
            }
        }
    }
}
```

You can use shorthand for a dependency on a Kotlin module, for example, kotlin("test") for "org.jetbrains.kotlin:kotlin-test".

You can use the kotlin-test dependency in any shared or platform-specific source set as well.

JVM variants of kotlin-test

For Kotlin/JVM, Gradle uses JUnit 4 by default. Therefore, the kotlin("test") dependency resolves to the variant for JUnit 4, namely kotlin-test-junit.

You can choose JUnit 5 or TestNG by calling useJUnitPlatform() or useTestNG() in the test task of your build script. The following example is for a Kotlin Multiplatform project:

Kotlin

```
kotlin {
    jvm {
        testRuns["test"].executionTask.configure {
            useJUnitPlatform()
        }
    }
    sourceSets {
        commonTest.dependencies {
            implementation(kotlin("test"))
        }
    }
}
```

Groovy

```
kotlin {
    jvm {
        testRuns["test"].executionTask.configure {
            useJUnitPlatform()
        }
    }
    sourceSets {
        commonTest {
            dependencies {
                implementation kotlin("test")
            }
        }
    }
}
```

The following example is for a JVM project:

Kotlin

```
dependencies {
    testImplementation(kotlin("test"))
}

tasks {
    test {
        useTestNG()
    }
}
```

Groovy

```
dependencies {
    testImplementation 'org.jetbrains.kotlin:kotlin-test'
}

test {
    useTestNG()
}
```

Learn how to test code using JUnit on the JVM.

Automatic JVM variant resolution can sometimes cause problems for your configuration. In that case, you can specify the necessary framework explicitly and disable the automatic resolution by adding this line to the project gradle.properties file:

```
kotlin.test.infer.jvm.variant=false
```

If you have used a variant of kotlin("test") in your build script explicitly and your project build stopped working with a compatibility conflict, see this issue in the Compatibility guide.

Set a dependency on a kotlinx library

If you use a multiplatform library and need to depend on the shared code, set the dependency only once in the shared source set. Use the library's base artifact name, such as kotlinx-coroutines-core or ktor-client-core:

Kotlin

```
kotlin {
    sourceSets {
        commonMain.dependencies {
            implementation("org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2")
        }
    }
}
```

Groovy

```
kotlin {
    sourceSets {
        commonMain {
            dependencies {
                implementation 'org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2'
            }
        }
    }
}
```

If you need a kotlinx library for a platform-specific dependency, you can still use the library's base artifact name in the corresponding platform source set:

Kotlin

```
kotlin {
    sourceSets {
        jvmMain.dependencies {
            implementation("org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2")
        }
    }
}
```

Groovy

```
kotlin {
    sourceSets {
        jvmMain {
            dependencies {
                implementation 'org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2'
            }
        }
    }
}
```

Set dependencies at top level

Alternatively, you can specify the dependencies at top level, using the following pattern for the configuration names: <sourceSetName><DependencyType>. This can be helpful for some Gradle built-in dependencies, like gradleApi(), localGroovy(), or gradleTestKit(), which are not available in the source sets' dependency DSL.

Kotlin

```
dependencies {
    "commonMainImplementation"("com.example:my-library:1.0")
}
```

Groovy

```
dependencies {
    commonMainImplementation 'com.example:my-library:1.0'
}
```

Declare repositories

You can declare a publicly-available repository to use its open source dependencies. In the repositories{} block, set the name of the repository:

Kotlin

```
repositories {
    mavenCentral()
}
```

Groovy

```
repositories {
    mavenCentral()
}
```

Popular repositories are Maven Central and Google's Maven repository.

> If you also work with Maven projects, we recommend avoiding adding mavenLocal() as a repository because you may experience problems when switching between Gradle and Maven projects. If you must add the mavenLocal() repository, add it as the last repository in your repositories{} block. For more information, see The case for mavenLocal().

If you need to declare the same repositories in more than one subproject, declare the repositories centrally in the dependencyResolutionManagement{} block in your settings.gradle(.kts) file:

Kotlin

```
dependencyResolutionManagement {
    repositories {
        mavenCentral()
    }
}
```

Groovy

```
dependencyResolutionManagement {
    repositories {
        mavenCentral()
    }
}
```

Any declared repositories in subprojects override repositories declared centrally. For more information on how to control this behavior and what options are available, see Gradle's documentation.

What's next?

Learn more about:

- Compiler options and how to pass them.
- Incremental compilation, caches support, build reports, and the Kotlin daemon.
- Gradle basics and specifics.
- Support for Gradle plugin variants.

Gradle best practices

Gradle is a build system used by many Kotlin projects to automate and manage the build process.

Getting the best out of Gradle is essential to help you spend less time managing and waiting for builds, and more time coding. Here we provide a set of best practices split into two key areas: organizing and optimizing your projects.

Organize

This section focuses on structuring your Gradle projects to improve clarity, maintainability, and scalability.

Use Kotlin DSL

Use Kotlin DSL instead of the traditional Groovy DSL. You avoid learning another language and gain the benefits of strict typing. Strict typing lets IDEs provide better support for refactoring and auto-completion, making development more efficient.

Find more information in Gradle’s Kotlin DSL primer.

Read Gradle's blog about Kotlin DSL becoming the default for Gradle builds.

Use a version catalog

Use a version catalog in a libs.versions.toml file to centralize dependency management. This enables you to define and reuse versions, libraries, and plugins consistently across projects.

```
[versions]
kotlinxCoroutines = "1.10.2"

[libraries]
kotlinxCoroutines = { module = "org.jetbrains.kotlinx:kotlinx-coroutines-core", version.ref = "kotlinxCoroutines" }
```

With the following dependency added to your build.gradle.kts file:

```
dependencies {
    implementation(libs.kotlinxCoroutines)
}
```

Learn more in Gradle's documentation about Dependency management basics.

Use convention plugins

Use convention plugins to encapsulate and reuse common build logic across multiple build files. Moving a shared configuration into a plugin helps simplify and modularize your build scripts.

Although the initial setup may be time-consuming, it's easy to maintain and add new build logic once you complete it.

Learn more in Gradle's documentation about Convention plugins.

Optimize

This section provides strategies to enhance the performance and efficiency of your Gradle builds.

Use local build cache

Use a local build cache to save time by reusing outputs produced by other builds. The build cache can retrieve outputs from any earlier build that you have already created.

Learn more in Gradle's documentation about their Build cache.

Use configuration cache

The configuration cache doesn't support all core Gradle plugins yet. For the latest information, see Gradle's table of supported plugins.

Use the configuration cache to significantly improve build performance by caching the result of the configuration phase and reusing it for subsequent builds. If Gradle detects no changes in the build configuration or related dependencies, it skips the configuration phase.

Learn more in Gradle's documentation about their Configuration cache.

Improve build times for multiple targets

When your multiplatform project includes multiple targets, tasks like build and assemble can compile the same code multiple times for each target, leading to longer compilation times.

If you're actively developing and testing a specific platform, run the corresponding linkDebug* task instead.

For more information, see Tips for improving compilation time.

Migrate from kapt to KSP

If you're using a library that relies on the kapt compiler plugin, check whether you can switch to using the Kotlin Symbol Processing (KSP) API instead. The KSP API improves build performance by reducing annotation processing time. KSP is faster and more efficient than kapt, as it processes source code directly without generating intermediary Java stubs.

For guidance on the migration steps, see Google's migration guide.

To learn more about how KSP compares to kapt, check out why KSP.

Use modularization

Modularization only benefits projects of moderate to large size. It doesn't provide advantages for projects based on a microservices architecture.

Use a modularized project structure to increase build speed and enable easier parallel development. Structure your project into one root project and one or more subprojects. If changes only affect one of the subprojects, Gradle rebuilds only that specific subproject.

```
.
└── root-project/
    ├── settings.gradle.kts
    ├── app subproject/
    │   └── build.gradle.kts
    └── lib subproject/
        └── build.gradle.kts
```

Learn more in Gradle's documentation about Structuring projects with Gradle.

Set up CI/CD

Set up a CI/CD process to significantly reduce build time by using incremental builds and caching dependencies. Add persistent storage or use a remote build cache to see these benefits. This process doesn't have to be time-consuming, as some providers, like GitHub, offer this service almost out of the box.

Explore Gradle's community cookbook on Using Gradle with Continuous Integration systems.

Use remote build cache

Like the local build cache, the remote build cache helps you save time by reusing outputs from other builds. It can retrieve task outputs from any earlier build that anyone has already run, not just the last one.

The remote build cache uses a cache server to share task outputs across builds. For example, in a development environment with a CI/CD server, all builds on the server populate the remote cache. When you check out the main branch to start a new feature, you can immediately access incremental builds.

Keep in mind that a slow internet connection might make transferring cached results slower than running tasks locally.

Learn more in Gradle's documentation about their Build cache.

Compiler options in the Kotlin Gradle plugin

Each release of Kotlin includes compilers for the supported targets: JVM, JavaScript, and native binaries for supported platforms.

These compilers are used by:

- The IDE, when you click the Compile or Run button for your Kotlin project.
- Gradle, when you call gradle build in a console or in the IDE.
- Maven, when you call mvn compile or mvn test-compile in a console or in the IDE.

You can also run Kotlin compilers manually from the command line as described in the Working with command-line compiler tutorial.

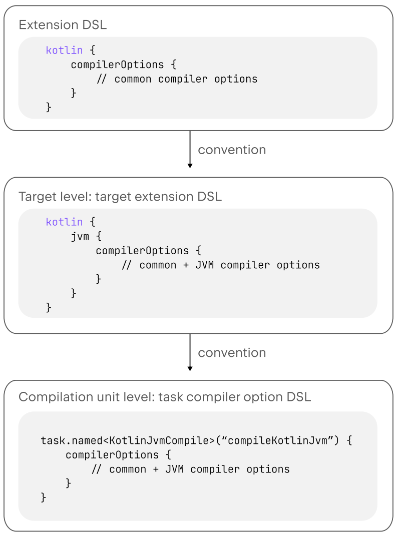
How to define options

Kotlin compilers have a number of options for tailoring the compiling process.

The Gradle DSL allows comprehensive configuration of compiler options. It is available for Kotlin Multiplatform and JVM/Android projects.

With the Gradle DSL, you can configure compiler options within the build script at three levels:

- Extension level, in the kotlin {} block for all targets and shared source sets.
- Target level, in the block for a specific target.
- Compilation unit level, usually in a specific compilation task.


Extension DSL
convention
Target level: target extension DSL
convention
Compilation unit level: task compiler option DSL

```
kotlin {
    compilerOptions {
        // common compiler options
    }
}
```

```
kotlin {
    jvm {
        compilerOptions {
            // common + JVM compiler options
        }
    }
}
```

```
task.named<KotlinJvmCompile>("compileKotlinJvm") {
    compilerOptions {
        // common + JVM compiler options
    }
}
```

Kotlin compiler options levels

The settings at a higher level are used as a convention (default) for a lower level:

- Compiler options set at the extension level are the default for target-level options, including shared source sets like commonMain, nativeMain, and commonTest.
- Compiler options set at the target level are the default for options at the compilation unit (task) level, like compileKotlinJvm and compileTestKotlinJvm tasks.

In turn, configurations made at a lower level override related settings at a higher level:

- Task-level compiler options override related configurations at the target or the extension level.
- Target-level compiler options override related configurations at the extension level.

To find out which level of compiler arguments is applied to the compilation, use the DEBUG level of Gradle logging. For JVM and JS/WASM tasks, search for the "Kotlin compiler args:" string within the logs; for Native tasks, search for the "Arguments =" string.

If you're a third-party plugin author, it's best to apply your configuration on the project level to avoid overriding issues. You can use the new Kotlin plugin DSL extension types for this. It's recommended that you document this configuration on your side explicitly.

Extension level

You can configure common compiler options for all the targets and shared source sets in the compilerOptions {} block at the top level:

```
kotlin {
    compilerOptions {
        optIn.add("kotlin.RequiresOptIn")
    }
}
```

Target level

You can configure compiler options for the JVM/Android target in the compilerOptions {} block inside the target {} block:

```
kotlin {
    target {
        compilerOptions {
            optIn.add("kotlin.RequiresOptIn")
        }
    }
}
```

In Kotlin Multiplatform projects, you can configure compiler options inside the specific target. For example, jvm { compilerOptions {}}. For more information, see Multiplatform Gradle DSL reference.

Compilation unit level

You can configure compiler options for a specific compilation unit or task in a compilerOptions {} block inside the task configuration:

```
tasks.named<KotlinJvmCompile>("compileKotlin"){
    compilerOptions {
        optIn.add("kotlin.RequiresOptIn")
    }
}
```

You can also access and configure compiler options at a compilation unit level via KotlinCompilation:

```
kotlin {
    target {
        val main by compilations.getting {
            compileTaskProvider.configure {
                compilerOptions {
                    optIn.add("kotlin.RequiresOptIn")
                }
            }
        }
    }
}
```

If you want to configure a plugin of a target different from JVM/Android and Kotlin Multiplatform, use the compilerOptions {} property of the corresponding Kotlin compilation task. The following examples show how to set this configuration up in both Kotlin and Groovy DSLs:

Kotlin

```
tasks.named("compileKotlin", org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask::class.java) {
    compilerOptions {
        apiVersion.set(org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_2_0)
    }
}
```

Groovy

```
tasks.named('compileKotlin', org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask.class) {
    compilerOptions {
        apiVersion.set(org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_2_0)
    }
}
```

Migrate from kotlinOptions {} to compilerOptions {}

Before Kotlin 2.2.0, you could configure compiler options using the kotlinOptions {} block. Since the kotlinOptions {} block is deprecated from Kotlin 2.0.0, this section provides guidance and recommendations for migrating your build scripts to use the compilerOptions {} block instead:

- Centralize compiler options and use types
- Migrate away from android.kotlinOptions
- Migrate freeCompilerArgs

Centralize compiler options and use types

Whenever possible, configure compiler options at the extension level, and override them for specific tasks at the compilation unit level.

You can't use raw strings in the compilerOptions {} block, so convert them to typed values. For example, if you have:

Kotlin

```kotlin
plugins {
    kotlin("jvm") version "2.2.0"
}

tasks.withType<KotlinCompile>().configureEach {
    kotlinOptions {
        jvmTarget = "17"
        languageVersion = "2.1"
        apiVersion = "2.1"
    }
}
```

Groovy

```groovy
plugins {
    id 'org.jetbrains.kotlin.jvm' version '2.2.0'
}

tasks.withType(KotlinCompile).configureEach {
    kotlinOptions {
        jvmTarget = '17'
        languageVersion = '2.1'
        apiVersion = '2.1'
    }
}
```

After migration, it should be:

Kotlin

```kotlin
plugins {
    kotlin("jvm") version "2.2.0"
}

kotlin {
    // Extension level
    compilerOptions {
        jvmTarget = JvmTarget.fromTarget("17")
        languageVersion = KotlinVersion.fromVersion("2.1")
        apiVersion = KotlinVersion.fromVersion("2.1")
    }
}
```

```
// Example of overriding at compilation unit level
tasks.named<KotlinJvmCompile>("compileKotlin"){
    compilerOptions {
        apiVersion = KotlinVersion.fromVersion("2.1")
    }
}
```

Groovy

```
plugins {
    id 'org.jetbrains.kotlin.jvm' version '2.2.0'
}

kotlin {
  // Extension level
    compilerOptions {
        jvmTarget = JvmTarget.fromTarget("17")
        languageVersion = KotlinVersion.fromVersion("2.1")
        apiVersion = KotlinVersion.fromVersion("2.1")
    }
}

// Example of overriding at compilation unit level
tasks.named("compileKotlin", KotlinJvmCompile).configure {
    compilerOptions {
        apiVersion = KotlinVersion.fromVersion("2.1")
    }
}
```

Migrate away from android.kotlinOptions

If your build script previously used android.kotlinOptions, migrate to kotlin.compilerOptions instead. Either at the extension level or the target level.

For example, if you have an Android project:

Kotlin

```
plugins {
    id("com.android.application")
    kotlin("android")
}

android {
    kotlinOptions {
        jvmTarget = "17"
    }
}
```

Groovy

```
plugins {
    id 'com.android.application'
    id 'org.jetbrains.kotlin.android'
}

android {
    kotlinOptions {
        jvmTarget = '17'
    }
}
```

Update it to:

Kotlin

```
plugins {
  id("com.android.application")
  kotlin("android")
}

kotlin {
    compilerOptions {
        jvmTarget = JvmTarget.fromTarget("17")
    }
}
```

Groovy

```
plugins {
    id 'com.android.application'
    id 'org.jetbrains.kotlin.android'
}

kotlin {
    compilerOptions {
        jvmTarget = JvmTarget.fromTarget("17")
    }
}
```

And for example, if you have a Kotlin Multiplatform project with an Android target:

Kotlin

```
plugins {
    kotlin("multiplatform")
    id("com.android.application")
}

kotlin {
    androidTarget {
        compilations.all {
            kotlinOptions.jvmTarget = "17"
        }
    }
}
```

Groovy

```
plugins {
    id 'org.jetbrains.kotlin.multiplatform'
    id 'com.android.application'
}

kotlin {
    androidTarget {
        compilations.all {
            kotlinOptions {
                jvmTarget = '17'
            }
        }
    }
}
```

Update it to:

Kotlin

```
plugins {
    kotlin("multiplatform")
    id("com.android.application")
}

kotlin {
    androidTarget {
        compilerOptions {
            jvmTarget = JvmTarget.fromTarget("17")
        }
    }
}
```

Groovy

```
plugins {
    id 'org.jetbrains.kotlin.multiplatform'
    id 'com.android.application'
}

kotlin {
    androidTarget {
        compilerOptions {
            jvmTarget = JvmTarget.fromTarget("17")
        }
    }
}
```

Migrate freeCompilerArgs

- Replace all += operations with add() or addAll() functions.
- If you use the -opt-in compiler option, check whether a specialized DSL already is available in the KGP API reference and use that instead.
- Migrate any use of the -progressive compiler option to use the dedicated DSL: progressiveMode.set(true).
- Migrate any use of the -Xjvm-default compiler option to use the dedicated DSL: jvmDefault.set(). Use the following mapping for the options:

Before	After
-Xjvm-default=all-compatibility	jvmDefault.set(JvmDefaultMode.ENABLE)
-Xjvm-default=all	jvmDefault.set(JvmDefaultMode.NO_COMPATIBILITY)
-Xjvm-default=disable	jvmDefault.set(JvmDefaultMode.DISABLE)

For example, if you have:

Kotlin

```
kotlinOptions {
    freeCompilerArgs += "-opt-in=kotlin.RequiresOptIn"
    freeCompilerArgs += listOf("-Xcontext-receivers", "-Xinline-classes", "-progressive", "-Xjvm-default=all")
}
```

Groovy

```
kotlinOptions {
    freeCompilerArgs += "-opt-in=kotlin.RequiresOptIn"
    freeCompilerArgs += ["-Xcontext-receivers", "-Xinline-classes", "-progressive", "-Xjvm-default=all"]
}
```

Migrate to:

Kotlin

```
kotlin {
    compilerOptions {
        optIn.add("kotlin.RequiresOptIn")
        freeCompilerArgs.addAll(listOf("-Xcontext-receivers", "-Xinline-classes"))
        progressiveMode.set(true)
        jvmDefault.set(JvmDefaultMode.NO_COMPATIBILITY)
    }
}
```

Groovy

```
kotlin {
    compilerOptions {
        optIn.add("kotlin.RequiresOptIn")
        freeCompilerArgs.addAll(["-Xcontext-receivers", "-Xinline-classes"])
        progressiveMode.set(true)
        jvmDefault.set(JvmDefaultMode.NO_COMPATIBILITY)
    }
}
```

Target the JVM

As explained before, you can define compiler options for your JVM/Android projects at the extension, target, and compilation unit levels (tasks).

Default JVM compilation tasks are called compileKotlin for production code and compileTestKotlin for test code. The tasks for custom source sets are named according to their compile<Name>Kotlin patterns.

You can see the list of Android compilation tasks by running the gradlew tasks --all command in the terminal and searching for compile*Kotlin task names in the Other tasks group.

Some important details to be aware of:

- kotlin.compilerOptions configures every Kotlin compilation task in the project.
- You can override the configuration applied by kotlin.compilerOptions DSL using the tasks.named<KotlinJvmCompile>("compileKotlin") { } (or tasks.withType<KotlinJvmCompile>().configureEach { }) approach.

Target JavaScript

JavaScript compilation tasks are called compileKotlinJs for production code, compileTestKotlinJs for test code, and compile<Name>KotlinJs for custom source sets.

To configure a single task, use its name:

Kotlin

```
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask
// ...

val compileKotlin: KotlinCompilationTask<*> by tasks

compileKotlin.compilerOptions.suppressWarnings.set(true)
```

Groovy

```
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask
// ...

tasks.named('compileKotlin', KotlinCompilationTask) {
    compilerOptions {
        suppressWarnings = true
    }
}
```

Note that with the Gradle Kotlin DSL, you should get the task from the project's tasks first.

Use the Kotlin2JsCompile and KotlinCompileCommon types for JS and common targets, respectively.

You can see the list of JavaScript compilation tasks by running the gradlew tasks --all command in the terminal and searching for compile*KotlinJS task names in the Other tasks group.

All Kotlin compilation tasks

It is also possible to configure all the Kotlin compilation tasks in the project:

Kotlin

```kotlin
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask
// ...

tasks.named<KotlinCompilationTask<*>>("compileKotlin").configure {
    compilerOptions { /*...*/ }
}
```

Groovy

```groovy
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask
// ...

tasks.named('compileKotlin', KotlinCompilationTask) {
    compilerOptions { /*...*/ }
}
```

All compiler options

Here is a complete list of options for the Gradle compiler:

Common attributes

Name	Description	Possible values	Default value
optIn	A property for configuring a list of opt-in compiler arguments	listOf(/* opt-ins */)	emptyList()
progressiveMode	Enables the progressive compiler mode	true, false	false
extraWarnings	Enables additional declaration, expression, and type compiler checks that emit warnings if true	true, false	false

Attributes specific to JVM

Name	Description	Possible values	Default value
javaParameters	Generate metadata for Java 1.8 reflection on method parameters		false
jvmTarget	Target version of the generated JVM bytecode	"1.8", "9", "10", ..., "23", "24". Also, see Types for compiler options	"1.8"
noJdk	Don't automatically include the Java runtime into the classpath		false

Name	Description	Possible values	Default value
jvmTargetValidationMode	• Validation of the JVM target compatibility between Kotlin and Java • A property for tasks of the KotlinCompile type.	WARNING, ERROR, IGNORE	ERROR
jvmDefault	Control how functions declared in interfaces are compiled to default methods on the JVM	ENABLE, NO_COMPATIBILITY, DISABLE	ENABLE

Attributes common to JVM and JavaScript

Name	Description	Possible values	Default value
allWarningsAsErrors	Report an error if there are any warnings		false
suppressWarnings	Don't generate warnings		false
verbose	Enable verbose logging output. Works only when the Gradle debug log level enabled		false
freeCompilerArgs	A list of additional compiler arguments. You can use experimental -X arguments here too. See an example		[]
apiVersion	Restrict the use of declarations to those from the specified version of bundled libraries	"1.8", "1.9", "2.0", "2.1", "2.2" (EXPERIMENTAL)	
languageVersion	Provide source compatibility with the specified version of Kotlin	"1.8", "1.9", "2.0", "2.1", "2.2" (EXPERIMENTAL)	

We are going to deprecate the attribute freeCompilerArgs in future releases. If you miss some option in the Kotlin Gradle DSL, please, file an issue.

Example of additional arguments usage via freeCompilerArgs

Use the freeCompilerArgs attribute to supply additional (including experimental) compiler arguments. You can add a single argument to this attribute or a list of arguments:

Kotlin

```kotlin
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask
// ...

kotlin {
    compilerOptions {
        // Specifies the version of the Kotlin API and the JVM target
        apiVersion.set(KotlinVersion.KOTLIN_2_1)
        jvmTarget.set(JvmTarget.JVM_1_8)

        // Single experimental argument
        freeCompilerArgs.add("-Xexport-kdoc")
        // Single additional argument
        freeCompilerArgs.add("-Xno-param-assertions")

        // List of arguments
        freeCompilerArgs.addAll(
            listOf(
                "-Xno-receiver-assertions",
                "-Xno-call-assertions"
            )
        )
    }
}
```

Groovy

```
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask
// ...

tasks.named('compileKotlin', KotlinCompilationTask) {
    compilerOptions {
        // Specifies the version of the Kotlin API and the JVM target
        apiVersion = KotlinVersion.KOTLIN_2_1
        jvmTarget = JvmTarget.JVM_1_8

        // Single experimental argument
        freeCompilerArgs.add("-Xexport-kdoc")

        // Single additional argument, can be a key-value pair
        freeCompilerArgs.add("-Xno-param-assertions")

        // List of arguments
        freeCompilerArgs.addAll(["-Xno-receiver-assertions", "-Xno-call-assertions"])
    }
}
```

The freeCompilerArgs attribute is available at the extension, target, and compilation unit (task) levels.

Example of setting languageVersion

To set a language version, use the following syntax:

Kotlin

```
kotlin {
    compilerOptions {
        languageVersion.set(org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_2_1)
    }
}
```

Groovy

```
tasks
    .withType(org.jetbrains.kotlin.gradle.tasks.KotlinCompilationTask.class)
    .configureEach {
        compilerOptions.languageVersion =
            org.jetbrains.kotlin.gradle.dsl.KotlinVersion.KOTLIN_2_1
    }
```

Also, see Types for compiler options.

Attributes specific to JavaScript

Name	Description	Possible values	Default value

Name	Description	Possible values	Default value
friendModulesDisabled	Disable internal declaration export		false
main	Specify whether the main function should be called upon execution	JsMainFunctionExecutionMode.CALL, JsMainFunctionExecutionMode.NO_CALL	JsMainFunctionExecutionMode.CALL
moduleKind	The kind of JS module generated by the compiler	JsModuleKind.MODULE_AMD, JsModuleKind.MODULE_PLAIN, JsModuleKind.MODULE_ES, JsModuleKind.MODULE_COMMONJS, JsModuleKind.MODULE_UMD	null
sourceMap	Generate source map		false
sourceMapEmbedSources	Embed source files into the source map	JsSourceMapEmbedMode.SOURCE_MAP_SOURCE_CONTENT_INLINING, JsSourceMapEmbedMode.SOURCE_MAP_SOURCE_CONTENT_NEVER, JsSourceMapEmbedMode.SOURCE_MAP_SOURCE_CONTENT_ALWAYS	null
sourceMapNamesPolicy	Add variable and function names that you declared in Kotlin code into the source map. For more information on the behavior, see our compiler reference	JsSourceMapNamesPolicy.SOURCE_MAP_NAMES_POLICY_FQ_NAMES, JsSourceMapNamesPolicy.SOURCE_MAP_NAMES_POLICY_SIMPLE_NAMES, JsSourceMapNamesPolicy.SOURCE_MAP_NAMES_POLICY_NO	null
sourceMapPrefix	Add the specified prefix to paths in the source map		null

Name	Description	Possible values	Default value
target	Generate JS files for specific ECMA version	"es5", "es2015"	"es5"
useEsClasses	Let generated JavaScript code use ES2015 classes. Enabled by default in case of ES2015 target usage		null

Types for compiler options

Some of the compilerOptions use the new types instead of the String type:

Option	Type	Example
jvmTarget	JvmTarget	compilerOptions.jvmTarget.set(JvmTarget.JVM_11)
apiVersion and languageVersion	KotlinVersion	compilerOptions.languageVersion.set(KotlinVersion.KOTLIN_2_1)
main	JsMainFunctionExecutionMode	compilerOptions.main.set(JsMainFunctionExecutionMode.NO_CALL)
moduleKind	JsModuleKind	compilerOptions.moduleKind.set(JsModuleKind.MODULE_ES)
sourceMapEmbedSources	JsSourceMapEmbedMode	compilerOptions.sourceMapEmbedSources.set(JsSourceMapEmbedMode.SOURCE_MAP_SOURCE_CO
sourceMapNamesPolicy	JsSourceMapNamesPolicy	compilerOptions.sourceMapNamesPolicy.set(JsSourceMapNamesPolicy.SOURCE_MAP_NAMES_POLIC

What's next?

Learn more about:

- Kotlin Multiplatform DSL reference.
- Incremental compilation, caches support, build reports, and the Kotlin daemon.
- Gradle basics and specifics.

- Support for Gradle plugin variants.

Compilation and caches in the Kotlin Gradle plugin

On this page, you can learn about the following topics:

- Incremental compilation
- Gradle build cache support
- Gradle configuration cache support
- The Kotlin daemon and how to use it with Gradle
- Rolling back to the previous compiler
- Defining Kotlin compiler execution strategy
- Kotlin compiler fallback strategy
- Trying the latest language version
- Build reports

Incremental compilation

The Kotlin Gradle plugin supports incremental compilation, which is enabled by default for Kotlin/JVM and Kotlin/JS projects. Incremental compilation tracks changes to files in the classpath between builds so that only the files affected by these changes are compiled. This approach works with Gradle's build cache and supports compilation avoidance.

For Kotlin/JVM, incremental compilation relies on classpath snapshots, which capture the API structure of modules to determine when recompilation is necessary. To optimize the overall pipeline, the Kotlin compiler uses two types of classpath snapshots:

- Fine-grained snapshots: include detailed information about class members, such as properties or functions. When member-level changes are detected, the Kotlin compiler recompiles only the classes that depend on the modified members. To maintain performance, the Kotlin Gradle plugin creates coarse-grained snapshots for .jar files in the Gradle cache.
- Coarse-grained snapshots: only contain the class ABI hash. When a part of ABI changes, the Kotlin compiler recompiles all classes that depend on the changed class. This is useful for classes that change infrequently, such as external libraries.

> Kotlin/JS projects use a different incremental compilation approach based on history files.

There are several ways to disable incremental compilation:

- Set kotlin.incremental=false for Kotlin/JVM.
- Set kotlin.incremental.js=false for Kotlin/JS projects.
- Use -Pkotlin.incremental=false or -Pkotlin.incremental.js=false as a command line parameter.

  The parameter should be added to each subsequent build.

When you disable incremental compilation, incremental caches become invalid after the build. The first build is never incremental.

> Sometimes problems with incremental compilation become visible several rounds after the failure occurs. Use build reports to track the history of changes and compilations. This can help you to provide reproducible bug reports.

To learn more about how our current incremental compilation approach works and compares to the previous one, see our blog post.

Gradle build cache support

The Kotlin plugin uses the Gradle build cache, which stores the build outputs for reuse in future builds.

To disable caching for all Kotlin tasks, set the system property kotlin.caching.enabled to false (run the build with the argument -Dkotlin.caching.enabled=false).

Gradle configuration cache support

The Kotlin plugin uses the Gradle configuration cache, which speeds up the build process by reusing the results of the configuration phase for subsequent builds.

See the Gradle documentation to learn how to enable the configuration cache. After you enable this feature, the Kotlin Gradle plugin automatically starts using it.

The Kotlin daemon and how to use it with Gradle

The Kotlin daemon:

- Runs with the Gradle daemon to compile the project.
- Runs separately from the Gradle daemon when you compile the project with an IntelliJ IDEA built-in build system.

The Kotlin daemon starts at the Gradle execution stage when one of the Kotlin compile tasks starts to compile sources. The Kotlin daemon stops either with the Gradle daemon or after two idle hours with no Kotlin compilation.

The Kotlin daemon uses the same JDK that the Gradle daemon does.

Setting Kotlin daemon's JVM arguments

Each of the following ways to set arguments overrides the ones that came before it:

- Gradle daemon arguments inheritance
- kotlin.daemon.jvm.options system property
- kotlin.daemon.jvmargs property
- kotlin extension
- Specific task definition

Gradle daemon arguments inheritance

By default, the Kotlin daemon inherits a specific set of arguments from the Gradle daemon but overwrites them with any JVM arguments specified directly for the Kotlin daemon. For example, if you add the following JVM arguments in the gradle.properties file:

```
org.gradle.jvmargs=-Xmx1500m -Xms500m -XX:MaxMetaspaceSize=1g
```

These arguments are then added to the Kotlin daemon's JVM arguments:

```
-Xmx1500m -XX:ReservedCodeCacheSize=320m -XX:MaxMetaspaceSize=1g -XX:UseParallelGC -ea -XX:+UseCodeCacheFlushing -
XX:+HeapDumpOnOutOfMemoryError -Djava.awt.headless=true -Djava.rmi.server.hostname=127.0.0.1 --add-exports=java.base/sun.nio.ch=ALL-
UNNAMED
```

To learn more about the Kotlin daemon's default behavior with JVM arguments, see Kotlin daemon's behavior with JVM arguments.

kotlin.daemon.jvm.options system property

If the Gradle daemon's JVM arguments have the kotlin.daemon.jvm.options system property – use it in the gradle.properties file:

```
org.gradle.jvmargs=-Dkotlin.daemon.jvm.options=-Xmx1500m,Xms500m
```

When passing arguments, follow these rules:

- Use the minus sign - only before the arguments Xmx, XX:MaxMetaspaceSize, and XX:ReservedCodeCacheSize.
- Separate arguments with commas (,) without spaces. Arguments that come after a space will be used for the Gradle daemon, not for the Kotlin daemon.

Gradle ignores these properties if all the following conditions are satisfied:

- Gradle is using JDK 1.9 or higher.
- The version of Gradle is between 7.0 and 7.1.1 inclusively.
- Gradle is compiling Kotlin DSL scripts.
- The Kotlin daemon isn't running.

To overcome this, upgrade Gradle to the version 7.2 (or higher) or use the kotlin.daemon.jvmargs property – see the following section.

kotlin.daemon.jvmargs property

You can add the kotlin.daemon.jvmargs property in the gradle.properties file:

```
kotlin.daemon.jvmargs=-Xmx1500m -Xms500m
```

Note that if you don't specify the ReservedCodeCacheSize argument here or in Gradle's JVM arguments, the Kotlin Gradle plugin applies a default value of 320m:

```
-Xmx1500m -XX:ReservedCodeCacheSize=320m -Xms500m
```

kotlin extension

You can specify arguments in the kotlin extension:

Kotlin

```kotlin
kotlin {
    kotlinDaemonJvmArgs = listOf("-Xmx486m", "-Xms256m", "-XX:+UseParallelGC")
}
```

Groovy

```groovy
kotlin {
    kotlinDaemonJvmArgs = ["-Xmx486m", "-Xms256m", "-XX:+UseParallelGC"]
}
```

Specific task definition

You can specify arguments for a specific task:

Kotlin

```kotlin
tasks.withType<CompileUsingKotlinDaemon>().configureEach {
    kotlinDaemonJvmArguments.set(listOf("-Xmx486m", "-Xms256m", "-XX:+UseParallelGC"))
}
```

Groovy

```groovy
tasks.withType(CompileUsingKotlinDaemon).configureEach { task ->
    task.kotlinDaemonJvmArguments = ["-Xmx1g", "-Xms512m"]
}
```

In this case a new Kotlin daemon instance can start on task execution. Learn more about Kotlin daemon's behavior with JVM arguments.

Kotlin daemon's behavior with JVM arguments

When configuring the Kotlin daemon's JVM arguments, note that:

- It is expected to have multiple instances of the Kotlin daemon running at the same time when different subprojects or tasks have different sets of JVM arguments.
- A new Kotlin daemon instance starts only when Gradle runs a related compilation task and existing Kotlin daemons do not have the same set of JVM arguments. Imagine that your project has a lot of subprojects. Most of them require some heap memory for a Kotlin daemon, but one module requires a lot (though it is rarely compiled). In this case, you should provide a different set of JVM arguments for such a module, so a Kotlin daemon with a larger heap size would start only for developers who touch this specific module.

  If you are already running a Kotlin daemon that has enough heap size to handle the compilation request, even if other requested JVM arguments are different, this daemon will be reused instead of starting a new one.

If the following arguments aren't specified, the Kotlin daemon inherits them from the Gradle daemon:

- -Xmx
- -XX:MaxMetaspaceSize
- -XX:ReservedCodeCacheSize. If not specified or inherited, the default value is 320m.

The Kotlin daemon has the following default JVM arguments:

- -XX:UseParallelGC. This argument is only applied if no other garbage collector is specified.
- -ea
- -XX:+UseCodeCacheFlushing
- -Djava.awt.headless=true
- -D{java.servername.property}={localhostip}
- --add-exports=java.base/sun.nio.ch=ALL-UNNAMED. This argument is only applied for JDK versions 16 or higher.

The list of default JVM arguments for the Kotlin daemon may vary between versions. You can use a tool like VisualVM to check the actual settings of a running JVM process, like the Kotlin daemon.

Rolling back to the previous compiler

From Kotlin 2.0.0, the K2 compiler is used by default.

To use the previous compiler from Kotlin 2.0.0 onwards, either:

- In your build.gradle.kts file, set your language version to 1.9.

  OR

- Use the following compiler option: -language-version 1.9.

To learn more about the benefits of the K2 compiler, see the K2 compiler migration guide.

Defining Kotlin compiler execution strategy

Kotlin compiler execution strategy defines where the Kotlin compiler is executed and if incremental compilation is supported in each case.

There are three compiler execution strategies:

Strategy	Where Kotlin compiler is executed	Incremental compilation	Other characteristics and notes
Daemon	Inside its own daemon process	Yes	The default and fastest strategy. Can be shared between different Gradle daemons and multiple parallel compilations.
In process	Inside the Gradle daemon process	No	May share the heap with the Gradle daemon. The "In process" execution strategy is slower than the "Daemon" execution strategy. Each worker creates a separate Kotlin compiler classloader for each compilation.
Out of process	In a separate process for each compilation	No	The slowest execution strategy. Similar to the "In process", but additionally creates a separate Java process within a Gradle worker for each compilation.

To define a Kotlin compiler execution strategy, you can use one of the following properties:

- The kotlin.compiler.execution.strategy Gradle property.
- The compilerExecutionStrategy compile task property.

The task property compilerExecutionStrategy takes priority over the Gradle property kotlin.compiler.execution.strategy.

The available values for the kotlin.compiler.execution.strategy property are:

1. daemon (default)
2. in-process
3. out-of-process

Use the Gradle property kotlin.compiler.execution.strategy in gradle.properties:

```
kotlin.compiler.execution.strategy=out-of-process
```

The available values for the compilerExecutionStrategy task property are:

1. org.jetbrains.kotlin.gradle.tasks.KotlinCompilerExecutionStrategy.DAEMON (default)
2. org.jetbrains.kotlin.gradle.tasks.KotlinCompilerExecutionStrategy.IN_PROCESS
3. org.jetbrains.kotlin.gradle.tasks.KotlinCompilerExecutionStrategy.OUT_OF_PROCESS

Use the task property compilerExecutionStrategy in your build scripts:

Kotlin

```kotlin
import org.jetbrains.kotlin.gradle.tasks.CompileUsingKotlinDaemon
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilerExecutionStrategy

// ...

tasks.withType<CompileUsingKotlinDaemon>().configureEach {
    compilerExecutionStrategy.set(KotlinCompilerExecutionStrategy.IN_PROCESS)
}
```

Groovy

```groovy
import org.jetbrains.kotlin.gradle.tasks.CompileUsingKotlinDaemon
import org.jetbrains.kotlin.gradle.tasks.KotlinCompilerExecutionStrategy

// ...

tasks.withType(CompileUsingKotlinDaemon)
    .configureEach {
        compilerExecutionStrategy = KotlinCompilerExecutionStrategy.IN_PROCESS
    }
```

Kotlin compiler fallback strategy

The Kotlin compiler's fallback strategy is to run a compilation outside a Kotlin daemon if the daemon somehow fails. If the Gradle daemon is on, the compiler uses the "In process" strategy. If the Gradle daemon is off, the compiler uses the "Out of process" strategy.

When this fallback happens, you have the following warning lines in your Gradle's build output:

```
Failed to compile with Kotlin daemon: java.lang.RuntimeException: Could not connect to Kotlin compile daemon
[exception stacktrace]
Using fallback strategy: Compile without Kotlin daemon
Try ./gradlew --stop if this issue persists.
```

However, a silent fallback to another strategy can consume a lot of system resources or lead to non-deterministic builds. Read more about this in this YouTrack issue. To avoid this, there is a Gradle property kotlin.daemon.useFallbackStrategy, whose default value is true. When the value is false, builds fail on problems with the daemon's startup or communication. Declare this property in gradle.properties:

```
kotlin.daemon.useFallbackStrategy=false
```

There is also a useDaemonFallbackStrategy property in Kotlin compile tasks, which takes priority over the Gradle property if you use both.

Kotlin

```kotlin
tasks {
    compileKotlin {
        useDaemonFallbackStrategy.set(false)
    }
}
```

Groovy

```groovy
tasks.named("compileKotlin").configure {
    useDaemonFallbackStrategy = false
}
```

If there is insufficient memory to run the compilation, you can see a message about it in the logs.

Trying the latest language version

Starting with Kotlin 2.0.0, to try the latest language version, set the kotlin.experimental.tryNext property in your gradle.properties file. When you use this property, the Kotlin Gradle plugin increments the language version to one above the default value for your Kotlin version. For example, in Kotlin 2.0.0, the default language version is 2.0, so the property configures language version 2.1.

Alternatively, you can run the following command:

```
./gradlew assemble -Pkotlin.experimental.tryNext=true
```

In build reports, you can find the language version used to compile each task.

Build reports

Build reports contain the durations of different compilation phases and any reasons why compilation couldn't be incremental. Use build reports to investigate performance issues when the compilation time is too long or when it differs for the same project.

Kotlin build reports help you to investigate problems with build performance more efficiently than with Gradle build scans that have a single Gradle task as the unit of granularity.

There are two common cases that analyzing build reports for long-running compilations can help you resolve:

- The build wasn't incremental. Analyze the reasons and fix underlying problems.
- The build was incremental but took too much time. Try reorganizing source files — split big files, save separate classes in different files, refactor large classes, declare top-level functions in different files, and so on.

Build reports also show the Kotlin version used in the project. In addition, starting with Kotlin 1.9.0, you can see which compiler was used to compile the code in your Gradle build scans.

Learn how to read build reports and about how JetBrains uses build reports.

Enabling build reports

To enable build reports, declare where to save the build report output in gradle.properties:

```
kotlin.build.report.output=file
```

The following values and their combinations are available for the output:

Option	Description
file	Saves build reports in a human-readable format to a local file. By default, it's ${project_folder}/build/reports/kotlin-build/${project_name}-timestamp.txt
single_file	Saves build reports in a format of an object to a specified local file.
build_scan	Saves build reports in the custom values section of the build scan. Note that the Gradle Enterprise plugin limits the number of custom values and their length. In big projects, some values could be lost.
http	Posts build reports using HTTP(S). The POST method sends metrics in JSON format. You can see the current version of the sent data in the Kotlin repository. You can find samples of HTTP endpoints in this blog post
json	Saves build reports in JSON format to a local file. Set the location for your build reports in kotlin.build.report.json.directory (see below). By default, it's name is ${project_name}-build-<date-time>-<index>.json.

Here's a list of available options for kotlin.build.report:

```
# Required outputs. Any combination is allowed
kotlin.build.report.output=file,single_file,http,build_scan,json

# Mandatory if single_file output is used. Where to put reports
# Use instead of the deprecated `kotlin.internal.single.build.metrics.file` property
kotlin.build.report.single_file=some_filename

# Mandatory if json output is used. Where to put reports
kotlin.build.report.json.directory=my/directory/path

# Optional. Output directory for file-based reports. Default: build/reports/kotlin-build/
kotlin.build.report.file.output_dir=kotlin-reports

# Optional. Label for marking your build report (for example, debug parameters)
kotlin.build.report.label=some_label
```

Options, applicable only to HTTP:

```
# Mandatory. Where to post HTTP(S)-based reports
kotlin.build.report.http.url=http://127.0.0.1:8080

# Optional. User and password if the HTTP endpoint requires authentication
kotlin.build.report.http.user=someUser
kotlin.build.report.http.password=somePassword

# Optional. Add a Git branch name of a build to a build report
kotlin.build.report.http.include_git_branch.name=true|false

# Optional. Add compiler arguments to a build report
# If a project contains many modules, its compiler arguments in the report can be very heavy and not that helpful
kotlin.build.report.include_compiler_arguments=true|false
```

Limit of custom values

To collect build scans' statistics, Kotlin build reports use Gradle's custom values. Both you and different Gradle plugins can write data to custom values. The number of custom values has a limit. See the current maximum custom value count in the Build scan plugin docs.

If you have a big project, a number of such custom values may be quite big. If this number exceeds the limit, you can see the following message in the logs:

```
Maximum number of custom values (1,000) exceeded
```

To reduce the number of custom values the Kotlin plugin produces, you can use the following property in gradle.properties:

```
kotlin.build.report.build_scan.custom_values_limit=500
```

Switching off collecting project and system properties

HTTP build statistic logs can contain some project and system properties. These properties can change builds' behavior, so it's useful to log them in build statistics. These properties can store sensitive data, for example, passwords or a project's full path.

You can disable collection of these statistics by adding the kotlin.build.report.http.verbose_environment property to your gradle.properties.

> JetBrains doesn't collect these statistics. You choose a place where to store your reports.

What's next?

Learn more about:

- Gradle basics and specifics.
- Support for Gradle plugin variants.

Binary compatibility validation in the Kotlin Gradle plugin

Binary compatibility validation helps library authors ensure that users don't break their code when upgrading to newer versions. It's important not only for delivering a smooth upgrade experience, but also for building long-term trust with users and encouraging continued adoption of the library.

> Binary compatibility means that the compiled bytecode of two versions of a library can run interchangeably without needing recompilation.

Starting with version 2.2.0, the Kotlin Gradle plugin supports binary compatibility validation. When enabled, it generates Application Binary Interface (ABI) dumps from the current code and compares them with previous dumps to highlight differences. You can review these changes to find any potentially binary-incompatible modifications and take action to address them.

How to enable

To enable binary compatibility validation, add the following to the kotlin{} block in your build.gradle.kts file:

Kotlin

```kotlin
kotlin {
    @OptIn(org.jetbrains.kotlin.gradle.dsl.abi.ExperimentalAbiValidation::class)
    abiValidation {
        // Use the set() function to ensure compatibility with older Gradle versions
        enabled.set(true)
    }
}
```

Groovy

```groovy
kotlin {
    abiValidation {
        enabled = true
    }
}
```

If your project has multiple modules where you want to check for binary compatibility, configure each module separately.

Check for binary compatibility issues

To check for potentially binary incompatible issues after making changes to your code, run the checkLegacyAbi Gradle task in IntelliJ IDEA or use the following command in your project directory:

```
./gradlew checkLegacyAbi
```

The task compares ABI dumps and prints any detected differences as errors. Check the output carefully to see if you need to make changes to your code to preserve binary compatibility.

Update reference ABI dump

To update the reference ABI dump that Gradle uses to check your latest changes, run the updateLegacyAbi task in IntelliJ IDEA or use the following command in your project directory:

```
./gradlew updateLegacyAbi
```

Only update the reference dump when you're confident your changes maintain binary compatibility with the previous version.

Configure filters

You can define filters to control which classes, properties, and functions the ABI dump includes. Use the filters {} block to add exclusion and inclusion rules with excluded {} and included {} blocks respectively.

Gradle includes a declaration in the ABI dump only if it doesn't match any exclusion rule. When inclusion rules are defined, the declaration must either match one of them or have at least one member that does.

A rule can be based on:

- The fully qualified name of a class, property, or function (byNames).
- The name of an annotation that has BINARY or RUNTIME retention (annotatedWith).

> You can use wildcards **, *, and ? in your rules for names:
>
> - ** matches zero or more characters, including periods.
> - * matches zero or more characters excluding periods. Use this to specify a single class name.
> - ? matches exactly one character.

For example:

Kotlin

```
kotlin {
    @OptIn(org.jetbrains.kotlin.gradle.dsl.abi.ExperimentalAbiValidation::class)
    abiValidation {
        filters {
            excluded {
                byNames.add("**.InternalUtils")
                annotatedWith.add("com.example.annotations.InternalApi")
            }

            included {
                byNames.add("com.example.api.**")
                annotatedWith.add("com.example.annotations.PublicApi")
            }
        }
    }
}
```

Groovy

```
kotlin {
    abiValidation {
        filters {
            excluded {
                byNames.add("**.InternalUtils")
                annotatedWith.add("com.example.annotations.InternalApi")
            }

            included {
                byNames.add("com.example.api.**")
                annotatedWith.add("com.example.annotations.PublicApi")
            }
        }
    }
}
```

This example:

- Excludes:
  - The InternalUtils class.
  - Declarations annotated with @InternalApi.
- Includes:
  - Everything in the com.example.api package.
  - Declarations annotated with @PublicApi.

To learn more about filtering, see the Kotlin Gradle plugin API reference.

Prevent inferred changes for unsupported targets

In multiplatform projects, if your host system can't compile all targets, the Kotlin Gradle plugin tries to infer ABI changes from the available targets. This helps avoid false failures when you later switch to a host that supports more targets.

To disable this behavior, add the following to your build.gradle.kts file:

Kotlin

```
kotlin {
    @OptIn(org.jetbrains.kotlin.gradle.dsl.abi.ExperimentalAbiValidation::class)
    abiValidation {
        klib {
            keepUnsupportedTargets.set(false)
        }
    }
}
```

Groovy

```
kotlin {
    abiValidation {
        klib {
            keepUnsupportedTargets = false
        }
    }
}
```

If a target is unsupported and inference is disabled, the checkLegacyAbi task fails because it can't generate a complete ABI dump. This behavior may be useful if you'd prefer the task to fail rather than risk missing a binary-incompatible change.

Support for Gradle plugin variants

Gradle 7.0 introduced a new feature for Gradle plugin authors — plugins with variants. This feature makes it easier to add support for latest Gradle features while maintaining compatibility with older Gradle versions. Learn more about variant selection in Gradle.

With Gradle plugin variants, the Kotlin team can ship different Kotlin Gradle plugin (KGP) variants for different Gradle versions. The goal is to support the base Kotlin compilation in the main variant, which corresponds to the oldest supported versions of Gradle. Each variant will have implementations for Gradle features from a corresponding release. The latest variant will support the latest Gradle feature set. With this approach, it is possible to extend support for older Gradle versions with limited functionality.

Currently, there are the following variants of the Kotlin Gradle plugin:

Variant's name	Corresponding Gradle versions
main	7.6.0–7.6.3
gradle80	8.0–8.0.2
gradle81	8.1.1
gradle82	8.2.1–8.4
gradle85	8.5
gradle86	8.6-8.7
gradle88	8.8-8.10
gradle811	8.11-8.12
gradle813	8.13 and higher

In future Kotlin releases, more variants will be added.

To check which variant your build uses, enable the --info log level and find a string in the output starting with Using Kotlin Gradle plugin, for example, Using Kotlin Gradle plugin main variant.

Troubleshooting

Here are workarounds for some known issues with variant selection in Gradle:

- ResolutionStrategy in pluginManagement is not working for plugins with multivariants
- Plugin variants are ignored when a plugin is added as the buildSrc common dependency

Gradle can't select a KGP variant in a custom configuration

This is an expected situation that Gradle can't select a KGP variant in a custom configuration. If you use a custom Gradle configuration:

Kotlin

```
configurations.register("customConfiguration") {
    // ...
}
```

Groovy

```
configurations.register("customConfiguration") {
    // ...
}
```

And want to add a dependency on the Kotlin Gradle plugin, for example:

Kotlin

```
dependencies {
    customConfiguration("org.jetbrains.kotlin:kotlin-gradle-plugin:2.2.0")
}
```

Groovy

```
dependencies {
    customConfiguration 'org.jetbrains.kotlin:kotlin-gradle-plugin:2.2.0'
}
```

You need to add the following attributes to your customConfiguration:

Kotlin

```
configurations {
    customConfiguration {
        attributes {
            attribute(
                Usage.USAGE_ATTRIBUTE,
                project.objects.named(Usage.class, Usage.JAVA_RUNTIME)
            )
            attribute(
                Category.CATEGORY_ATTRIBUTE,
                project.objects.named(Category.class, Category.LIBRARY)
            )
            // If you want to depend on a specific KGP variant:
            attribute(
                GradlePluginApiVersion.GRADLE_PLUGIN_API_VERSION_ATTRIBUTE,
                project.objects.named("7.0")
            )
        }
    }
}
```

Groovy

```
configurations {
    customConfiguration {
        attributes {
            attribute(
                Usage.USAGE_ATTRIBUTE,
                project.objects.named(Usage, Usage.JAVA_RUNTIME)
            )
            attribute(
                Category.CATEGORY_ATTRIBUTE,
                project.objects.named(Category, Category.LIBRARY)
            )
            // If you want to depend on a specific KGP variant:
            attribute(
                GradlePluginApiVersion.GRADLE_PLUGIN_API_VERSION_ATTRIBUTE,
                project.objects.named('7.0')
            )
        }
    }
}
```

Otherwise, you will receive an error similar to this:

```
> Could not resolve all files for configuration ':customConfiguration'.
      > Could not resolve org.jetbrains.kotlin:kotlin-gradle-plugin:1.7.0.
        Required by:
            project :
         > Cannot choose between the following variants of org.jetbrains.kotlin:kotlin-gradle-plugin:1.7.0:
             - gradle70RuntimeElements
             - runtimeElements
           All of them match the consumer attributes:
             - Variant 'gradle70RuntimeElements' capability org.jetbrains.kotlin:kotlin-gradle-plugin:1.7.0:
                 - Unmatched attributes:
```

What's next?

Learn more about Gradle basics and specifics.

Maven

Maven is a build system that you can use to build and manage any Java-based project.

Configure and enable the plugin

The kotlin-maven-plugin compiles Kotlin sources and modules. Currently, only Maven v3 is supported.

In your pom.xml file, define the version of Kotlin you want to use in the kotlin.version property:

```
<properties>
    <kotlin.version>2.2.0</kotlin.version>
</properties>
```

To enable kotlin-maven-plugin, update your pom.xml file:

```
<plugins>
    <plugin>
        <artifactId>kotlin-maven-plugin</artifactId>
        <groupId>org.jetbrains.kotlin</groupId>
        <version>2.2.0</version>
    </plugin>
</plugins>
```

Use JDK 17

To use JDK 17, in your .mvn/jvm.config file, add:

```
--add-opens=java.base/java.lang=ALL-UNNAMED
--add-opens=java.base/java.io=ALL-UNNAMED
```

Declare repositories

By default, the mavenCentral repository is available for all Maven projects. To access artifacts in other repositories, specify the ID and URL of each repository in the <repositories> element:

```
<repositories>
    <repository>
        <id>spring-repo</id>
        <url>https://repo.spring.io/release</url>
    </repository>
</repositories>
```

If you declare mavenLocal() as a repository in a Gradle project, you may experience problems when switching between Gradle and Maven projects. For more information, see Declare repositories.

Set dependencies

Kotlin has an extensive standard library that can be used in your applications. To use the standard library in your project, add the following dependency to your pom.xml file:

```
<dependencies>
    <dependency>
        <groupId>org.jetbrains.kotlin</groupId>
        <artifactId>kotlin-stdlib</artifactId>
        <version>${kotlin.version}</version>
    </dependency>
</dependencies>
```

If you're targeting JDK 7 or 8 with Kotlin versions older than:

- 1.8, use kotlin-stdlib-jdk7 or kotlin-stdlib-jdk8, respectively.
- 1.2, use kotlin-stdlib-jre7 or kotlin-stdlib-jre8, respectively.

If your project uses Kotlin reflection or testing facilities, you need to add the corresponding dependencies as well. The artifact IDs are kotlin-reflect for the reflection library, and kotlin-test and kotlin-test-junit for the testing libraries.

Compile Kotlin-only source code

To compile source code, specify the source directories in the <build> tag:

```
<build>
    <sourceDirectory>${project.basedir}/src/main/kotlin</sourceDirectory>
    <testSourceDirectory>${project.basedir}/src/test/kotlin</testSourceDirectory>
</build>
```

The Kotlin Maven Plugin needs to be referenced to compile the sources:

```
<build>
    <plugins>
        <plugin>
            <groupId>org.jetbrains.kotlin</groupId>
            <artifactId>kotlin-maven-plugin</artifactId>
            <version>${kotlin.version}</version>

            <executions>
                <execution>
                    <id>compile</id>
                    <goals>
                        <goal>compile</goal>
                    </goals>
                </execution>

                <execution>
                    <id>test-compile</id>
                    <goals>
                        <goal>test-compile</goal>
                    </goals>
                </execution>
            </executions>
        </plugin>
    </plugins>
</build>
```

Starting from Kotlin 1.8.20, you can replace the whole <executions> element above with <extensions>true</extensions>. Enabling extensions automatically adds the compile, test-compile, kapt, and test-kapt executions to your build, bound to their appropriate lifecycle phases. If you need to configure an execution, you need to specify its ID. You can find an example of this in the next section.

> If several build plugins overwrite the default lifecycle and you have also enabled the extensions option, the last plugin in the <build> section has priority in terms of lifecycle settings. All earlier changes to lifecycle settings are ignored.

Compile Kotlin and Java sources

To compile projects that include Kotlin and Java source code, invoke the Kotlin compiler before the Java compiler. In Maven terms it means that kotlin-maven-plugin should be run before maven-compiler-plugin using the following method, making sure that the kotlin plugin comes before the maven-compiler-plugin in your pom.xml file:

```
<build>
    <plugins>
        <plugin>
            <groupId>org.jetbrains.kotlin</groupId>
            <artifactId>kotlin-maven-plugin</artifactId>
            <version>${kotlin.version}</version>
            <extensions>true</extensions> <!-- You can set this option
            to automatically take information about lifecycles -->
            <executions>
                <execution>
                    <id>compile</id>
                    <goals>
                        <goal>compile</goal> <!-- You can skip the <goals> element
                        if you enable extensions for the plugin -->
                    </goals>
                    <configuration>
                        <sourceDirs>
                            <sourceDir>${project.basedir}/src/main/kotlin</sourceDir>
                            <sourceDir>${project.basedir}/src/main/java</sourceDir>
                        </sourceDirs>
                    </configuration>
                </execution>
                <execution>
                    <id>test-compile</id>
                    <goals>
                        <goal>test-compile</goal> <!-- You can skip the <goals> element
                    if you enable extensions for the plugin -->
                    </goals>
                    <configuration>
                        <sourceDirs>
                            <sourceDir>${project.basedir}/src/test/kotlin</sourceDir>
                            <sourceDir>${project.basedir}/src/test/java</sourceDir>
                        </sourceDirs>
                    </configuration>
                </execution>
            </executions>
        </plugin>
        <plugin>
            <groupId>org.apache.maven.plugins</groupId>
            <artifactId>maven-compiler-plugin</artifactId>
            <version>3.5.1</version>
            <executions>
                <!-- Replacing default-compile as it is treated specially by Maven -->
                <execution>
                    <id>default-compile</id>
                    <phase>none</phase>
                </execution>
                <!-- Replacing default-testCompile as it is treated specially by Maven -->
                <execution>
                    <id>default-testCompile</id>
                    <phase>none</phase>
                </execution>
                <execution>
                    <id>java-compile</id>
                    <phase>compile</phase>
                    <goals>
                        <goal>compile</goal>
                    </goals>
                </execution>
                <execution>
                    <id>java-test-compile</id>
                    <phase>test-compile</phase>
                    <goals>
                        <goal>testCompile</goal>
                    </goals>
                </execution>
            </executions>
        </plugin>
    </plugins>
</build>
```

Enable incremental compilation

To make your builds faster, you can enable incremental compilation by adding the kotlin.compiler.incremental property:

```
<properties>
    <kotlin.compiler.incremental>true</kotlin.compiler.incremental>
</properties>
```

Alternatively, run your build with the -Dkotlin.compiler.incremental=true option.

Configure annotation processing

See kapt – Using in Maven.

Create JAR file

To create a small JAR file containing just the code from your module, include the following under build->plugins in your Maven pom.xml file, where main.class is defined as a property and points to the main Kotlin or Java class:

```
<plugin>
    <groupId>org.apache.maven.plugins</groupId>
    <artifactId>maven-jar-plugin</artifactId>
    <version>2.6</version>
    <configuration>
        <archive>
            <manifest>
                <addClasspath>true</addClasspath>
                <mainClass>${main.class}</mainClass>
            </manifest>
        </archive>
    </configuration>
</plugin>
```

Create a self-contained JAR file

To create a self-contained JAR file containing the code from your module along with its dependencies, include the following under build->plugins in your Maven pom.xml file, where main.class is defined as a property and points to the main Kotlin or Java class:

```
<plugin>
    <groupId>org.apache.maven.plugins</groupId>
    <artifactId>maven-assembly-plugin</artifactId>
    <version>2.6</version>
    <executions>
        <execution>
            <id>make-assembly</id>
            <phase>package</phase>
            <goals> <goal>single</goal> </goals>
            <configuration>
                <archive>
                    <manifest>
                        <mainClass>${main.class}</mainClass>
                    </manifest>
                </archive>
                <descriptorRefs>
                    <descriptorRef>jar-with-dependencies</descriptorRef>
                </descriptorRefs>
            </configuration>
        </execution>
    </executions>
</plugin>
```

This self-contained JAR file can be passed directly to a JRE to run your application:

```
java -jar target/mymodule-0.0.1-SNAPSHOT-jar-with-dependencies.jar
```

Specify compiler options

Additional options and arguments for the compiler can be specified as tags under the <configuration> element of the Maven plugin node:

```
<plugin>
    <groupId>org.jetbrains.kotlin</groupId>
    <artifactId>kotlin-maven-plugin</artifactId>
    <version>${kotlin.version}</version>
    <extensions>true</extensions> <!-- If you want to enable automatic addition of executions to your build -->
    <executions>...</executions>
    <configuration>
        <nowarn>true</nowarn>  <!-- Disable warnings -->
        <args>
            <arg>-Xjsr305=strict</arg> <!-- Enable strict mode for JSR-305 annotations -->
            ...
        </args>
    </configuration>
</plugin>
```

Many of the options can also be configured through properties:

```
<project ...>
    <properties>
        <kotlin.compiler.languageVersion>2.1</kotlin.compiler.languageVersion>
    </properties>
</project>
```

The following attributes are supported:

Attributes specific to JVM

Name	Property name	Description	Possible values	Default value
nowarn		Generate no warnings	true, false	false
languageVersion	kotlin.compiler.languageVersion	Provide source compatibility with the specified version of Kotlin	"1.8", "1.9", "2.0", "2.1", "2.2" (EXPERIMENTAL)	
apiVersion	kotlin.compiler.apiVersion	Allow using declarations only from the specified version of bundled libraries	"1.8", "1.9", "2.0", "2.1", "2.2" (EXPERIMENTAL)	
sourceDirs		The directories containing the source files to compile		The project source roots
compilerPlugins		Enabled compiler plugins		[]
pluginOptions		Options for compiler plugins		[]
args		Additional compiler arguments		[]
jvmTarget	kotlin.compiler.jvmTarget	Target version of the generated JVM bytecode	"1.8", "9", "10", ..., "24"	"1.8"
jdkHome	kotlin.compiler.jdkHome	Include a custom JDK from the specified location into the classpath instead of the default JAVA_HOME		

Use BOM

To use a Kotlin Bill of Materials (BOM), write a dependency on kotlin-bom:

```
<dependencyManagement>
    <dependencies>
        <dependency>
            <groupId>org.jetbrains.kotlin</groupId>
            <artifactId>kotlin-bom</artifactId>
            <version>2.2.0</version>
            <type>pom</type>
            <scope>import</scope>
        </dependency>
    </dependencies>
</dependencyManagement>
```

Generate documentation

The standard Javadoc generation plugin (maven-javadoc-plugin) doesn't support Kotlin code. To generate documentation for Kotlin projects, use Dokka. Dokka supports mixed-language projects and can generate output in multiple formats, including standard Javadoc. For more information about how to configure Dokka in your Maven project, see Maven.

Enable OSGi support

Learn how to enable OSGi support in your Maven project.

Build tools API

Kotlin 2.2.0 introduces an experimental Build tools API (BTA) that simplifies how build systems integrate with the Kotlin compiler.

Previously, adding full Kotlin support to a build system (like incremental compilation, Kotlin compiler plugins, daemons, and Kotlin Multiplatform) required significant effort. The BTA aims to reduce this complexity by providing a unified API between build systems and the Kotlin compiler ecosystem.

The BTA defines a single entry point that build systems can implement. This removes the need to deeply integrate with internal compiler details.

> The BTA itself is not yet publicly available for direct use in your own build tool integrations. If you're interested in the proposal or want to share feedback, see the KEEP. Follow the status of its implementation in YouTrack.

Integration with Gradle

The Kotlin Gradle plugin (KGP) has experimental support for the BTA, and you need to opt in to use it.

> We'd appreciate your feedback on your experience with the KGP in YouTrack.

How to enable

Add the following property to your gradle.properties file:

```
kotlin.compiler.runViaBuildToolsApi=true
```

Configure different compiler versions

With the BTA, you can now use a different Kotlin compiler version than the version used by the KGP. This is useful when:

- You want to try new Kotlin features but haven't updated your build scripts yet.
- You need the latest plugin fixes but want to stay on an older compiler version for now.

Here's an example of how to configure this in your build.gradle.kts file:

```kotlin
import org.jetbrains.kotlin.buildtools.api.ExperimentalBuildToolsApi
import org.jetbrains.kotlin.gradle.ExperimentalKotlinGradlePluginApi

plugins {
 kotlin("jvm") version "2.2.0"
}

group = "org.jetbrains.example"
version = "1.0-SNAPSHOT"

repositories {
 mavenCentral()
}

kotlin {
 jvmToolchain(8)
 @OptIn(ExperimentalBuildToolsApi::class, ExperimentalKotlinGradlePluginApi::class)
 compilerVersion.set("2.1.21") // <-- different version than 2.2.0
}
```

Compatible Kotlin compiler and KGP versions

The BTA supports:

- The three previous major Kotlin compiler versions.
- One major version forward.

For example, in KGP 2.2.0, the supported Kotlin compiler versions are:

- 1.9.25
- 2.0.x
- 2.1.x
- 2.2.x
- 2.3.x

Limitations

Using different compiler versions together with compiler plugins may lead to Kotlin compiler exceptions. The Kotlin team plans to address this in future Kotlin releases.

Enable incremental compilation with "in process" strategy

The KGP supports three compiler execution strategies. Ordinarily, the "in-process" strategy (which runs the compiler in the Gradle daemon) doesn't support incremental compilation.

With the BTA, the "in-process" strategy now supports incremental compilation. To enable it, add the following property to your gradle.properties file:

```
kotlin.compiler.execution.strategy=in-process
```

Integration with Maven

From Kotlin 2.2.0, the BTA is enabled by default in the kotlin-maven-plugin.

Although the BTA doesn't give direct benefits for Maven users yet, it provides a solid foundation for developing features like:

- Kotlin daemon support
- Incremental compilation stabilization

Ant

> Starting with Kotlin 2.2.0, support for the Ant build system in Kotlin is deprecated. We plan to remove Ant support in Kotlin 2.3.0.
>
> However, if you're interested in becoming an external maintainer for Ant, leave a comment in this YouTrack issue.

Getting the Ant tasks

Kotlin provides three tasks for Ant:

- kotlinc: Kotlin compiler targeting the JVM
- kotlin2js: Kotlin compiler targeting JavaScript
- withKotlin: Task to compile Kotlin files when using the standard javac Ant task

These tasks are defined in the kotlin-ant.jar library which is located in the lib folder in the Kotlin Compiler archive. Ant version 1.8.2+ is required.

Targeting JVM with Kotlin-only source

When the project consists of exclusively Kotlin source code, the easiest way to compile the project is to use the kotlinc task:

```
<project name="Ant Task Test" default="build">
```

```
    <typedef resource="org/jetbrains/kotlin/ant/antlib.xml" classpath="${kotlin.lib}/kotlin-ant.jar"/>

    <target name="build">
        <kotlinc src="hello.kt" output="hello.jar"/>
    </target>
</project>
```

where ${kotlin.lib} points to the folder where the Kotlin standalone compiler was unzipped.

Targeting JVM with Kotlin-only source and multiple roots

If a project consists of multiple source roots, use src as elements to define paths:

```
<project name="Ant Task Test" default="build">
    <typedef resource="org/jetbrains/kotlin/ant/antlib.xml" classpath="${kotlin.lib}/kotlin-ant.jar"/>

    <target name="build">
        <kotlinc output="hello.jar">
            <src path="root1"/>
            <src path="root2"/>
        </kotlinc>
    </target>
</project>
```

Targeting JVM with Kotlin and Java source

If a project consists of both Kotlin and Java source code, while it is possible to use kotlinc, to avoid repetition of task parameters, it is recommended to use withKotlin task:

```
<project name="Ant Task Test" default="build">
    <typedef resource="org/jetbrains/kotlin/ant/antlib.xml" classpath="${kotlin.lib}/kotlin-ant.jar"/>

    <target name="build">
        <delete dir="classes" failonerror="false"/>
        <mkdir dir="classes"/>
        <javac destdir="classes" includeAntRuntime="false" srcdir="src">
            <withKotlin/>
        </javac>
        <jar destfile="hello.jar">
            <fileset dir="classes"/>
        </jar>
    </target>
</project>
```

You can also specify the name of the module being compiled as the moduleName attribute:

```
<withKotlin moduleName="myModule"/>
```

Targeting JavaScript with single source folder

```
<project name="Ant Task Test" default="build">
    <typedef resource="org/jetbrains/kotlin/ant/antlib.xml" classpath="${kotlin.lib}/kotlin-ant.jar"/>

    <target name="build">
        <kotlin2js src="root1" output="out.js"/>
    </target>
</project>
```

Targeting JavaScript with Prefix, PostFix and sourcemap options

```
<project name="Ant Task Test" default="build">
    <taskdef resource="org/jetbrains/kotlin/ant/antlib.xml" classpath="${kotlin.lib}/kotlin-ant.jar"/>
    <target name="build">
        <kotlin2js src="root1" output="out.js" outputPrefix="prefix" outputPostfix="postfix" sourcemap="true"/>
    </target>
</project>
```

Targeting JavaScript with single source folder and metaInfo option

The metaInfo option is useful, if you want to distribute the result of translation as a Kotlin/JavaScript library. If metaInfo was set to true, then during compilation additional JS file with binary metadata will be created. This file should be distributed together with the result of translation:

```
<project name="Ant Task Test" default="build">
    <typedef resource="org/jetbrains/kotlin/ant/antlib.xml" classpath="${kotlin.lib}/kotlin-ant.jar"/>

    <target name="build">
        <!-- out.meta.js will be created, which contains binary metadata -->
        <kotlin2js src="root1" output="out.js" metaInfo="true"/>
    </target>
</project>
```

References

Complete list of elements and attributes are listed below:

Attributes common for kotlinc and kotlin2js

Name	Description	Required	Default Value
src	Kotlin source file or directory to compile	Yes	
nowarn	Suppresses all compilation warnings	No	false
noStdlib	Does not include the Kotlin standard library into the classpath	No	false
failOnError	Fails the build if errors are detected during the compilation	No	true

kotlinc attributes

Name	Description	Required	Default Value
output	Destination directory or .jar file name	Yes	
classpath	Compilation class path	No	
classpathref	Compilation class path reference	No	
includeRuntime	If output is a .jar file, whether Kotlin runtime library is included in the jar	No	true

Name	Description	Required	Default Value
moduleName	Name of the module being compiled	No	The name of the target (if specified) or the project

kotlin2js attributes

Name	Description	Required
output	Destination file	Yes
libraries	Paths to Kotlin libraries	No
outputPrefix	Prefix to use for generated JavaScript files	No
outputSuffix	Suffix to use for generated JavaScript files	No
sourcemap	Whether sourcemap file should be generated	No
metaInfo	Whether metadata file with binary descriptors should be generated	No
main	Should compiler generated code call the main function	No

Passing raw compiler arguments

To pass custom raw compiler arguments, you can use <compilerarg> elements with either value or line attributes. This can be done within the <kotlinc>, <kotlin2js>, and <withKotlin> task elements, as follows:

```
<kotlinc src="${test.data}/hello.kt" output="${temp}/hello.jar">
    <compilerarg value="-Xno-inline"/>
    <compilerarg line="-Xno-call-assertions -Xno-param-assertions"/>
    <compilerarg value="-Xno-optimize"/>
</kotlinc>
```

The full list of arguments that can be used is shown when you run kotlinc -help.

Introduction

Dokka is an API documentation engine for Kotlin.

Just like Kotlin itself, Dokka supports mixed-language projects. It understands Kotlin's KDoc comments and Java's Javadoc comments.

Dokka can generate documentation in multiple formats, including its own modern HTML format, multiple flavors of Markdown, and Java's Javadoc HTML.

Here are some libraries that use Dokka for their API reference documentation:

- kotlinx.coroutines
- Bitmovin
- Hexagon

- Ktor
- OkHttp

You can run Dokka using Gradle, Maven or from the command line. It is also highly pluggable.

See Get started with Dokka to take your first steps in using Dokka.

Community

Dokka has a dedicated #dokka channel in Kotlin Community Slack where you can chat about Dokka, its plugins and how to develop them, as well as get in touch with maintainers.

Get started with Dokka

Below you can find simple instructions to help you get started with Dokka.

Gradle Kotlin DSL

Apply the Gradle plugin for Dokka in the root build script of your project:

```
plugins {
    id("org.jetbrains.dokka") version "2.0.0"
}
```

When documenting multi-project builds, you need to apply the Gradle plugin within subprojects as well:

```
subprojects {
    apply(plugin = "org.jetbrains.dokka")
}
```

To generate documentation, run the following Gradle tasks:

- dokkaHtml for single-project builds
- dokkaHtmlMultiModule for multi-project builds

By default, the output directory is set to /build/dokka/html and /build/dokka/htmlMultiModule.

To learn more about using Dokka with Gradle, see Gradle.

Gradle Groovy DSL

Apply the Gradle plugin for Dokka in the root build script of your project:

```
plugins {
    id 'org.jetbrains.dokka' version '2.0.0'
}
```

When documenting multi-project builds, you need to apply the Gradle plugin within subprojects as well:

```
subprojects {
    apply plugin: 'org.jetbrains.dokka'
}
```

To generate documentation, run the following Gradle tasks:

- dokkaHtml for single-project builds
- dokkaHtmlMultiModule for multi-project builds

By default, the output directory is set to /build/dokka/html and /build/dokka/htmlMultiModule.

To learn more about using Dokka with Gradle, see Gradle.

Maven

Add the Maven plugin for Dokka to the plugins section of your POM file:

```
<build>
    <plugins>
        <plugin>
            <groupId>org.jetbrains.dokka</groupId>
            <artifactId>dokka-maven-plugin</artifactId>
            <version>2.0.0</version>
            <executions>
                <execution>
                    <phase>pre-site</phase>
                    <goals>
                        <goal>dokka</goal>
                    </goals>
                </execution>
            </executions>
        </plugin>
    </plugins>
</build>
```

To generate documentation, run the dokka:dokka goal.

By default, the output directory is set to target/dokka.

To learn more about using Dokka with Maven, see Maven.

In Dokka 2.0.0, several steps and tasks for getting started have been updated, including:

- Configure multi-project builds
- Generate documentation with the updated tasks
- Specify an output directory

For more details and the full list of changes, see the Migration guide.

Gradle

To generate documentation for a Gradle-based project, you can use the Gradle plugin for Dokka.

It comes with basic autoconfiguration for your project, has convenient Gradle tasks for generating documentation, and provides a great deal of configuration options to customize the output.

You can play around with Dokka and see how it can be configured for various projects by visiting our Gradle example projects.

Apply Dokka

The recommended way of applying the Gradle plugin for Dokka is with the plugins DSL:

Kotlin

```kotlin
plugins {
    id("org.jetbrains.dokka") version "2.0.0"
}
```

Groovy

```groovy
plugins {
    id 'org.jetbrains.dokka' version '2.0.0'
}
```

When documenting multi-project builds, you need to apply the Gradle plugin for Dokka within subprojects as well. You can use allprojects {} or subprojects {} Gradle configurations to achieve that:

Gradle Kotlin DSL

```
subprojects {
    apply(plugin = "org.jetbrains.dokka")
}
```

Gradle Groovy DSL

```
subprojects {
    apply plugin: 'org.jetbrains.dokka'
}
```

See Configuration examples if you are not sure where to apply Dokka.

> Under the hood, Dokka uses the Kotlin Gradle plugin to perform autoconfiguration of source sets for which documentation is to be generated. Make sure to apply the Kotlin Gradle Plugin or configure source sets manually.

> If you are using Dokka in a precompiled script plugin, you need to add the Kotlin Gradle plugin as a dependency for it to work properly.

If you cannot use the plugins DSL for some reason, you can use the legacy method of applying plugins.

Generate documentation

The Gradle plugin for Dokka comes with HTML, Markdown and Javadoc output formats built in. It adds a number of tasks for generating documentation, both for single and multi-project builds.

Single-project builds

Use the following tasks to build documentation for simple, single-project applications and libraries:

Task	Description
dokkaHtml	Generates documentation in HTML format.

Experimental formats

Task	Description
dokkaGfm	Generates documentation in GitHub Flavored Markdown format.
dokkaJavadoc	Generates documentation in Javadoc format.
dokkaJekyll	Generates documentation in Jekyll compatible Markdown format.

By default, generated documentation is located in the build/dokka/{format} directory of your project. The output location, among other things, can be configured.

Multi-project builds

For documenting multi-project builds, make sure that you apply the Gradle plugin for Dokka within subprojects that you want to generate documentation for, as well as in their parent project.

MultiModule tasks

MultiModule tasks generate documentation for each subproject individually via Partial tasks, collect and process all outputs, and produce complete documentation with a common table of contents and resolved cross-project references.

Dokka creates the following tasks for parent projects automatically:

Task	Description
dokkaHtmlMultiModule	Generates multi-module documentation in HTML output format.

Experimental formats (multi-module)

Task	Description
dokkaGfmMultiModule	Generates multi-module documentation in GitHub Flavored Markdown output format.
dokkaJekyllMultiModule	Generates multi-module documentation in Jekyll compatible Markdown output format.

The Javadoc output format does not have a MultiModule task, but a Collector task can be used instead.

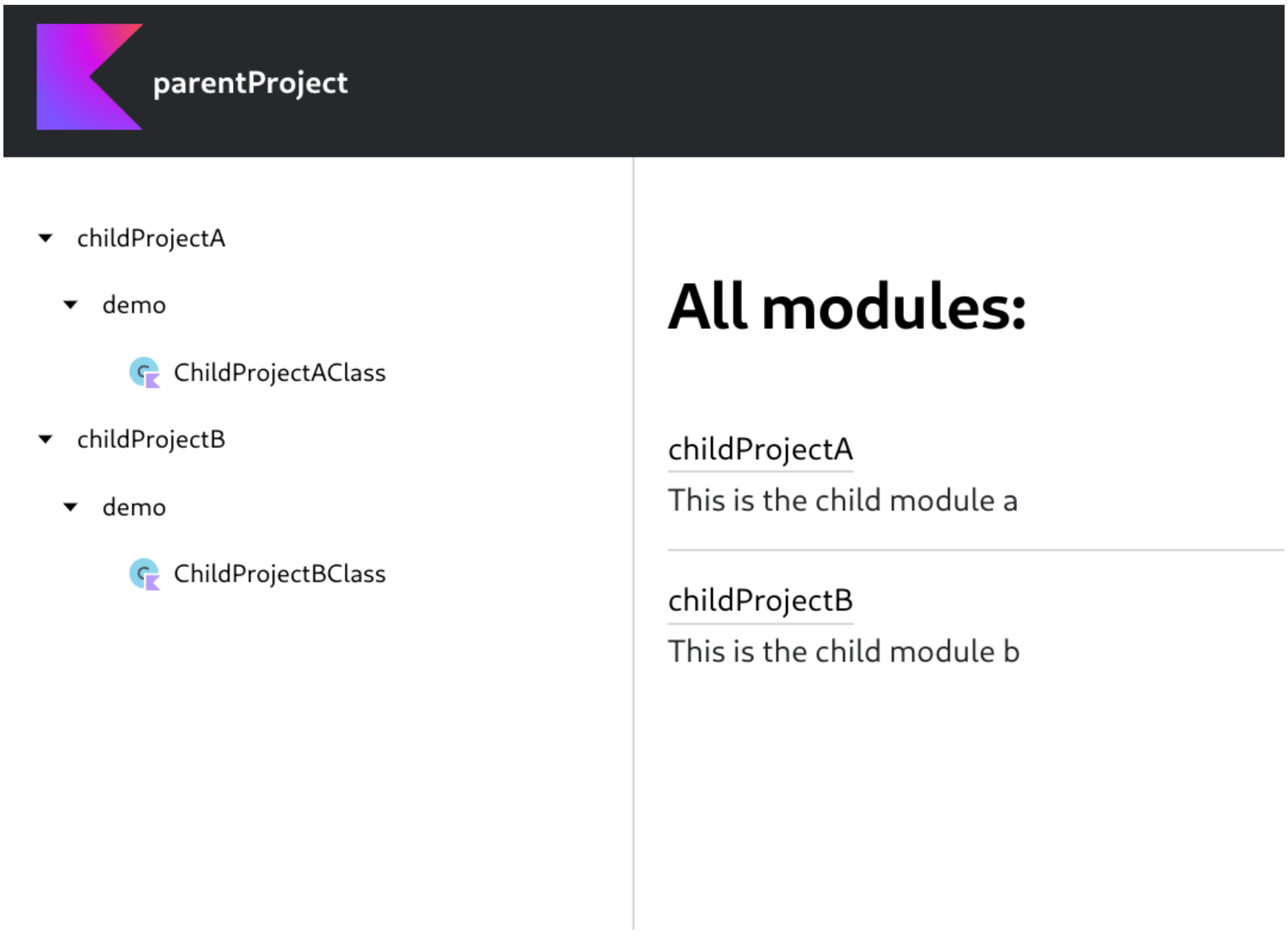
By default, you can find ready-to-use documentation under {parentProject}/build/dokka/{format}MultiModule directory.

MultiModule results

Given a project with the following structure:

```
.
└── parentProject/
    ├── childProjectA/
    │   └── demo/
    │       └── ChildProjectAClass
    └── childProjectB/
        └── demo/
            └── ChildProjectBClass
```

These pages are generated after running dokkaHtmlMultiModule:


parentProject

- childProjectA
  - demo
    - ChildProjectAClass
- childProjectB
  - demo
    - ChildProjectBClass

All modules:

childProjectA
This is the child module a

childProjectB
This is the child module b

Screenshot for output of dokkaHtmlMultiModule task

See our multi-module project example for more details.

Collector tasks

Similar to MultiModule tasks, Collector tasks are created for each parent project: dokkaHtmlCollector, dokkaGfmCollector, dokkaJavadocCollector and dokkaJekyllCollector.

A Collector task executes the corresponding single-project task for each subproject (for example, dokkaHtml), and merges all outputs into a single virtual project.

The resulting documentation looks as if you have a single-project build that contains all declarations from the subprojects.

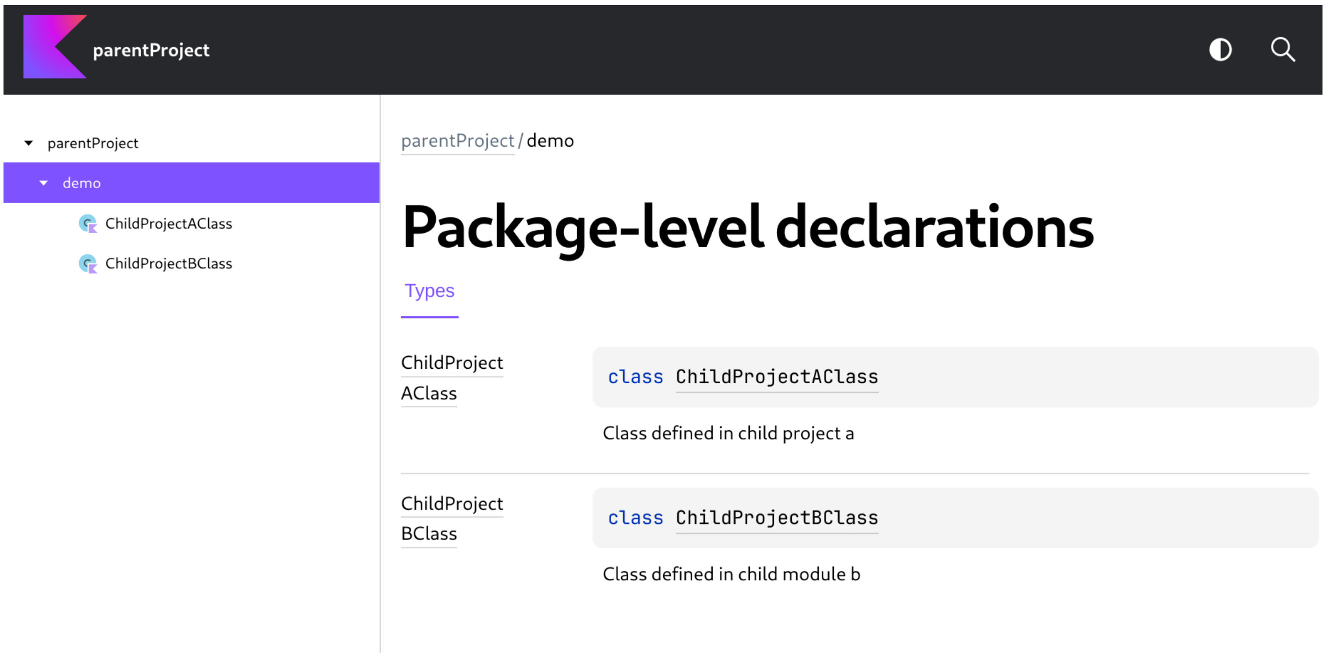
> Use the dokkaJavadocCollector task if you need to create Javadoc documentation for your multi-project build.

Collector results

Given a project with the following structure:

```
.
└── parentProject/
    ├── childProjectA/
    │   └── demo/
    │       └── ChildProjectAClass
    └── childProjectB/
        └── demo/
            └── ChildProjectBClass
```

These pages are generated after running dokkaHtmlCollector:


parentProject

parentProject
demo
ChildProjectAClass
ChildProjectBClass

parentProject / demo

Package-level declarations

Types

ChildProjectAClass	`class ChildProjectAClass` Class defined in child project a
ChildProjectBClass	`class ChildProjectBClass` Class defined in child module b

Screenshot for output of dokkaHtmlCollector task

See our multi-module project example for more details.

Partial tasks

Each subproject has Partial tasks created for it: dokkaHtmlPartial, dokkaGfmPartial, and dokkaJekyllPartial.

These tasks are not intended to be run independently, they are called by the parent's MultiModule task.

However, you can configure Partial tasks to customize Dokka for your subprojects.

> Output generated by Partial tasks contains unresolved HTML templates and references, so it cannot be used on its own without post-processing done by the parent's MultiModule task.

> If you want to generate documentation for a single subproject only, use single-project tasks. For example, :subprojectName:dokkaHtml.

Build javadoc.jar

If you want to publish your library to a repository, you may need to provide a javadoc.jar file that contains API reference documentation of your library.

For example, if you want to publish to Maven Central, you must supply a javadoc.jar alongside your project. However, not all repositories have that rule.

The Gradle plugin for Dokka does not provide any way to do this out of the box, but it can be achieved with custom Gradle tasks. One for generating documentation in HTML format and another one for Javadoc format:

Kotlin

```
tasks.register<Jar>("dokkaHtmlJar") {
    dependsOn(tasks.dokkaHtml)
    from(tasks.dokkaHtml.flatMap { it.outputDirectory })
    archiveClassifier.set("html-docs")
}

tasks.register<Jar>("dokkaJavadocJar") {
    dependsOn(tasks.dokkaJavadoc)
    from(tasks.dokkaJavadoc.flatMap { it.outputDirectory })
    archiveClassifier.set("javadoc")
}
```

Groovy

```groovy
tasks.register('dokkaHtmlJar', Jar.class) {
    dependsOn(dokkaHtml)
    from(dokkaHtml)
    archiveClassifier.set("html-docs")
}

tasks.register('dokkaJavadocJar', Jar.class) {
    dependsOn(dokkaJavadoc)
    from(dokkaJavadoc)
    archiveClassifier.set("javadoc")
}
```

> If you publish your library to Maven Central, you can use services like javadoc.io to host your library's API documentation for free and without any setup. It takes documentation pages straight from the javadoc.jar. It works well with the HTML format as demonstrated in this example.

Configuration examples

Depending on the type of project that you have, the way you apply and configure Dokka differs slightly. However, configuration options themselves are the same, regardless of the type of your project.

For simple and flat projects with a single build.gradle.kts or build.gradle file found in the root of your project, see Single-project configuration.

For a more complex build with subprojects and multiple nested build.gradle.kts or build.gradle files, see Multi-project configuration.

Single-project configuration

Single-project builds usually have only one build.gradle.kts or build.gradle file in the root of the project, and typically have the following structure:

Kotlin

Single platform:

```
.
├── build.gradle.kts
└── src/
    └── main/
        └── kotlin/
            └── HelloWorld.kt
```

Multiplatform:

```
.
├── build.gradle.kts
└── src/
    ├── commonMain/
    │   └── kotlin/
    │       └── Common.kt
    ├── jvmMain/
    │   └── kotlin/
    │       └── JvmUtils.kt
    └── nativeMain/
        └── kotlin/
            └── NativeUtils.kt
```

Groovy

Single platform:

```
.
├── build.gradle
└── src/
    └── main/
```

```
        └── kotlin/
            └── HelloWorld.kt
```

Multiplatform:

```
.
├── build.gradle
└── src/
    ├── commonMain/
    │   └── kotlin/
    │       └── Common.kt
    ├── jvmMain/
    │   └── kotlin/
    │       └── JvmUtils.kt
    └── nativeMain/
        └── kotlin/
            └── NativeUtils.kt
```

In such projects, you need to apply Dokka and its configuration in the root build.gradle.kts or build.gradle file.

You can configure tasks and output formats individually:

Kotlin

Inside ./build.gradle.kts:

```kotlin
plugins {
    id("org.jetbrains.dokka") version "2.0.0"
}

tasks.dokkaHtml {
    outputDirectory.set(layout.buildDirectory.dir("documentation/html"))
}

tasks.dokkaGfm {
    outputDirectory.set(layout.buildDirectory.dir("documentation/markdown"))
}
```

Groovy

Inside ./build.gradle:

```groovy
plugins {
    id 'org.jetbrains.dokka' version '2.0.0'
}

dokkaHtml {
    outputDirectory.set(file("build/documentation/html"))
}

dokkaGfm {
    outputDirectory.set(file("build/documentation/markdown"))
}
```

Or you can configure all tasks and output formats at the same time:

Kotlin

Inside ./build.gradle.kts:

```kotlin
import org.jetbrains.dokka.gradle.DokkaTask
import org.jetbrains.dokka.gradle.DokkaTaskPartial
import org.jetbrains.dokka.DokkaConfiguration.Visibility

plugins {
    id("org.jetbrains.dokka") version "2.0.0"
}

// Configure all single-project Dokka tasks at the same time,
// such as dokkaHtml, dokkaJavadoc and dokkaGfm.
tasks.withType<DokkaTask>().configureEach {
    dokkaSourceSets.configureEach {
        documentedVisibilities.set(
            setOf(
                Visibility.PUBLIC,
                Visibility.PROTECTED,
            )
        )

        perPackageOption {
            matchingRegex.set(".*internal.*")
            suppress.set(true)
        }
    }
}
```

Groovy

Inside ./build.gradle:

```
import org.jetbrains.dokka.gradle.DokkaTask
import org.jetbrains.dokka.gradle.DokkaTaskPartial
import org.jetbrains.dokka.DokkaConfiguration.Visibility

plugins {
    id 'org.jetbrains.dokka' version '2.0.0'
}

// Configure all single-project Dokka tasks at the same time,
// such as dokkaHtml, dokkaJavadoc and dokkaGfm.
tasks.withType(DokkaTask.class) {
    dokkaSourceSets.configureEach {
        documentedVisibilities.set([
                Visibility.PUBLIC,
                Visibility.PROTECTED
        ])

        perPackageOption {
            matchingRegex.set(".*internal.*")
            suppress.set(true)
        }
    }
}
```

Multi-project configuration

Gradle's multi-project builds are more complex in structure and configuration. They usually have multiple nested build.gradle.kts or build.gradle files, and typically have the following structure:

Kotlin

```
.
├── build.gradle.kts
├── settings.gradle.kts
├── subproject-A/
│   ├── build.gradle.kts
│   └── src/
│       └── main/
│           └── kotlin/
│               └── HelloFromA.kt
└── subproject-B/
    ├── build.gradle.kts
    └── src/
        └── main/
            └── kotlin/
                └── HelloFromB.kt
```

Groovy

```
.
├── build.gradle
├── settings.gradle
├── subproject-A/
│   ├── build.gradle
│   └── src/
│       └── main/
│           └── kotlin/
│               └── HelloFromA.kt
└── subproject-B/
    ├── build.gradle
    └── src/
        └── main/
            └── kotlin/
                └── HelloFromB.kt
```

In this case, there are multiple ways of applying and configuring Dokka.

Subproject configuration

To configure subprojects in a multi-project build, you need to configure Partial tasks.

You can configure all subprojects at the same time in the root build.gradle.kts or build.gradle file, using Gradle's allprojects {} or subprojects {} configuration blocks:

Kotlin

In the root ./build.gradle.kts:

```kotlin
import org.jetbrains.dokka.gradle.DokkaTaskPartial

plugins {
    id("org.jetbrains.dokka") version "2.0.0"
}

subprojects {
    apply(plugin = "org.jetbrains.dokka")

    // configure only the HTML task
    tasks.dokkaHtmlPartial {
        outputDirectory.set(layout.buildDirectory.dir("docs/partial"))
    }

    // configure all format tasks at once
    tasks.withType<DokkaTaskPartial>().configureEach {
        dokkaSourceSets.configureEach {
            includes.from("README.md")
        }
    }
}
```

Groovy

In the root ./build.gradle:

```groovy
import org.jetbrains.dokka.gradle.DokkaTaskPartial

plugins {
    id 'org.jetbrains.dokka' version '2.0.0'
}

subprojects {
    apply plugin: 'org.jetbrains.dokka'

    // configure only the HTML task
    dokkaHtmlPartial {
        outputDirectory.set(file("build/docs/partial"))
    }

    // configure all format tasks at once
    tasks.withType(DokkaTaskPartial.class) {
        dokkaSourceSets.configureEach {
            includes.from("README.md")
        }
    }
}
```

Alternatively, you can apply and configure Dokka within subprojects individually.

For example, to have specific settings for the subproject-A subproject only, you need to apply the following code inside ./subproject-A/build.gradle.kts:

Kotlin

Inside ./subproject-A/build.gradle.kts:

```kotlin
apply(plugin = "org.jetbrains.dokka")

// configuration for subproject-A only.
tasks.dokkaHtmlPartial {
    outputDirectory.set(layout.buildDirectory.dir("docs/partial"))
}
```

Groovy

Inside ./subproject-A/build.gradle:

```groovy
apply plugin: 'org.jetbrains.dokka'

// configuration for subproject-A only.
dokkaHtmlPartial {
    outputDirectory.set(file("build/docs/partial"))
}
```

Parent project configuration

If you want to configure something which is universal across all documentation and does not belong to the subprojects - in other words, it's a property of the parent project - you need to configure the MultiModule tasks.

For example, if you want to change the name of your project which is used in the header of the HTML documentation, you need to apply the following inside the root build.gradle.kts or build.gradle file:

Kotlin

In the root ./build.gradle.kts file:

```kotlin
plugins {
    id("org.jetbrains.dokka") version "2.0.0"
}

tasks.dokkaHtmlMultiModule {
    moduleName.set("WHOLE PROJECT NAME USED IN THE HEADER")
}
```

Groovy

In the root ./build.gradle file:

```groovy
plugins {
    id 'org.jetbrains.dokka' version '2.0.0'
}

dokkaHtmlMultiModule {
    moduleName.set("WHOLE PROJECT NAME USED IN THE HEADER")
}
```

Configuration options

Dokka has many configuration options to tailor your and your reader's experience.

Below are some examples and detailed descriptions for each configuration section. You can also find an example with all configuration options applied at the bottom of the page.

See Configuration examples for more details on where to apply configuration blocks and how.

General configuration

Here is an example of general configuration of any Dokka task, regardless of source set or package:

Kotlin

```kotlin
import org.jetbrains.dokka.gradle.DokkaTask

// Note: To configure multi-project builds, you need
//       to configure Partial tasks of the subprojects.
//       See "Configuration example" section of documentation.
tasks.withType<DokkaTask>().configureEach {
    moduleName.set(project.name)
    moduleVersion.set(project.version.toString())
    outputDirectory.set(layout.buildDirectory.dir("dokka/$name"))
    failOnWarning.set(false)
    suppressObviousFunctions.set(true)
    suppressInheritedMembers.set(false)
    offlineMode.set(false)

    // ..
    // source set configuration section
    // ..
}
```

Groovy

```groovy
import org.jetbrains.dokka.gradle.DokkaTask

// Note: To configure multi-project builds, you need
//       to configure Partial tasks of the subprojects.
//       See "Configuration example" section of documentation.
tasks.withType(DokkaTask.class) {
    moduleName.set(project.name)
    moduleVersion.set(project.version.toString())
    outputDirectory.set(file("build/dokka/$name"))
    failOnWarning.set(false)
    suppressObviousFunctions.set(true)
    suppressInheritedMembers.set(false)
    offlineMode.set(false)

    // ..
    // source set configuration section
    // ..
}
```

moduleName

The display name used to refer to the module. It is used for the table of contents, navigation, logging, etc.

If set for a single-project build or a MultiModule task, it is used as the project name.

Default: Gradle project name

moduleVersion

The module version. If set for a single-project build or a MultiModule task, it is used as the project version.

Default: Gradle project version

outputDirectory

The directory to where documentation is generated, regardless of format. It can be set on a per-task basis.

The default is {project}/{buildDir}/{format}, where {format} is the task name with the "dokka" prefix removed. For the dokkaHtmlMultiModule task, it is project/buildDir/htmlMultiModule.

failOnWarning

Whether to fail documentation generation if Dokka has emitted a warning or an error. The process waits until all errors and warnings have been emitted first.

This setting works well with reportUndocumented.

Default: false

suppressObviousFunctions

Whether to suppress obvious functions.

A function is considered to be obvious if it is:

- Inherited from kotlin.Any, Kotlin.Enum, java.lang.Object or java.lang.Enum, such as equals, hashCode, toString.
- Synthetic (generated by the compiler) and does not have any documentation, such as dataClass.componentN or dataClass.copy.

Default: true

suppressInheritedMembers
Whether to suppress inherited members that aren't explicitly overridden in a given class.

Note: This can suppress functions such as equals/hashCode/toString, but cannot suppress synthetic functions such as dataClass.componentN and dataClass.copy. Use suppressObviousFunctions for that.

Default: false

offlineMode
Whether to resolve remote files/links over your network.

This includes package-lists used for generating external documentation links. For example, to make classes from the standard library clickable.

Setting this to true can significantly speed up build times in certain cases, but can also worsen documentation quality and user experience. For example, by not resolving class/member links from your dependencies, including the standard library.

Note: You can cache fetched files locally and provide them to Dokka as local paths. See externalDocumentationLinks section.

Default: false

Source set configuration

Dokka allows configuring some options for Kotlin source sets:

Kotlin

```kotlin
import org.jetbrains.dokka.DokkaConfiguration.Visibility
import org.jetbrains.dokka.gradle.DokkaTask
import org.jetbrains.dokka.Platform
import java.net.URL

// Note: To configure multi-project builds, you need
//       to configure Partial tasks of the subprojects.
//       See "Configuration example" section of documentation.
tasks.withType<DokkaTask>().configureEach {
    // ..
    // general configuration section
    // ..

    dokkaSourceSets {
        // configuration exclusive to the 'linux' source set
        named("linux") {
            dependsOn("native")
            sourceRoots.from(file("linux/src"))
        }
        configureEach {
            suppress.set(false)
            displayName.set(name)
            documentedVisibilities.set(setOf(Visibility.PUBLIC))
            reportUndocumented.set(false)
            skipEmptyPackages.set(true)
            skipDeprecated.set(false)
            suppressGeneratedFiles.set(true)
            jdkVersion.set(8)
            languageVersion.set("1.7")
            apiVersion.set("1.7")
            noStdlibLink.set(false)
            noJdkLink.set(false)
            noAndroidSdkLink.set(false)
            includes.from(project.files(), "packages.md", "extra.md")
            platform.set(Platform.DEFAULT)
            sourceRoots.from(file("src"))
            classpath.from(project.files(), file("libs/dependency.jar"))
            samples.from(project.files(), "samples/Basic.kt", "samples/Advanced.kt")

            sourceLink {
                // Source link section
            }
            externalDocumentationLink {
                // External documentation link section
            }
            perPackageOption {
                // Package options section
            }
        }
    }
}
```

Groovy

```
import org.jetbrains.dokka.DokkaConfiguration.Visibility
import org.jetbrains.dokka.gradle.DokkaTask
import org.jetbrains.dokka.Platform
import java.net.URL

// Note: To configure multi-project builds, you need
//       to configure Partial tasks of the subprojects.
//       See "Configuration example" section of documentation.
tasks.withType(DokkaTask.class) {
    // ..
    // general configuration section
    // ..

    dokkaSourceSets {
        // configuration exclusive to the 'linux' source set
        named("linux") {
            dependsOn("native")
            sourceRoots.from(file("linux/src"))
        }
        configureEach {
            suppress.set(false)
            displayName.set(name)
            documentedVisibilities.set([Visibility.PUBLIC])
            reportUndocumented.set(false)
            skipEmptyPackages.set(true)
            skipDeprecated.set(false)
            suppressGeneratedFiles.set(true)
            jdkVersion.set(8)
            languageVersion.set("1.7")
            apiVersion.set("1.7")
            noStdlibLink.set(false)
            noJdkLink.set(false)
            noAndroidSdkLink.set(false)
            includes.from(project.files(), "packages.md", "extra.md")
            platform.set(Platform.DEFAULT)
            sourceRoots.from(file("src"))
            classpath.from(project.files(), file("libs/dependency.jar"))
            samples.from(project.files(), "samples/Basic.kt", "samples/Advanced.kt")

            sourceLink {
                // Source link section
            }
            externalDocumentationLink {
                // External documentation link section
            }
            perPackageOption {
                // Package options section
            }
        }
    }
}
```

suppress
Whether this source set should be skipped when generating documentation.

Default: false

displayName
The display name used to refer to this source set.

The name is used both externally (for example, as source set name visible to documentation readers) and internally (for example, for logging messages of reportUndocumented).

By default, the value is deduced from information provided by the Kotlin Gradle plugin.

documentedVisibilities

The set of visibility modifiers that should be documented.

This can be used if you want to document protected/internal/private declarations, as well as if you want to exclude public declarations and only document internal API.

This can be configured on per-package basis.

Default: DokkaConfiguration.Visibility.PUBLIC

reportUndocumented

Whether to emit warnings about visible undocumented declarations, that is declarations without KDocs after they have been filtered by documentedVisibilities and other filters.

This setting works well with failOnWarning.

This can be configured on per-package basis.

Default: false

skipEmptyPackages

Whether to skip packages that contain no visible declarations after various filters have been applied.

For example, if skipDeprecated is set to true and your package contains only deprecated declarations, it is considered to be empty.

Default: true

skipDeprecated

Whether to document declarations annotated with @Deprecated.

This can be configured on per-package basis.

Default: false

suppressGeneratedFiles

Whether to document/analyze generated files.

Generated files are expected to be present under the {project}/{buildDir}/generated directory.

If set to true, it effectively adds all files from that directory to the suppressedFiles option, so you can configure it manually.

Default: true

jdkVersion

The JDK version to use when generating external documentation links for Java types.

For example, if you use java.util.UUID in some public declaration signature, and this option is set to 8, Dokka generates an external documentation link to JDK 8 Javadocs for it.

Default: JDK 8

languageVersion

The Kotlin language version used for setting up analysis and @sample environment.

By default, the latest language version available to Dokka's embedded compiler is used.

apiVersion

The Kotlin API version used for setting up analysis and @sample environment.

By default, it is deduced from languageVersion.

noStdlibLink

Whether to generate external documentation links that lead to the API reference documentation of Kotlin's standard library.

Note: Links are generated when noStdLibLink is set to false.

Default: false

noJdkLink

Whether to generate external documentation links to JDK's Javadocs.

The version of JDK Javadocs is determined by the jdkVersion option.

Note: Links are generated when noJdkLink is set to false.

Default: false

noAndroidSdkLink

Whether to generate external documentation links to the Android SDK API reference.

This is only relevant in Android projects, ignored otherwise.

Note: Links are generated when noAndroidSdkLink is set to false.

Default: false

includes

A list of Markdown files that contain module and package documentation.

The contents of the specified files are parsed and embedded into documentation as module and package descriptions.

See Dokka gradle example for an example of what it looks like and how to use it.

platform

The platform to be used for setting up code analysis and @sample environment.

The default value is deduced from information provided by the Kotlin Gradle plugin.

sourceRoots

The source code roots to be analyzed and documented. Acceptable inputs are directories and individual .kt/.java files.

By default, source roots are deduced from information provided by the Kotlin Gradle plugin.

classpath

The classpath for analysis and interactive samples.

This is useful if some types that come from dependencies are not resolved/picked up automatically.

This option accepts both .jar and .klib files.

By default, classpath is deduced from information provided by the Kotlin Gradle plugin.

samples

A list of directories or files that contain sample functions which are referenced via the @sample KDoc tag.

Source link configuration

The sourceLinks configuration block allows you to add a source link to each signature that leads to the remoteUrl with a specific line number. (The line number is configurable by setting remoteLineSuffix).

This helps readers to find the source code for each declaration.

For an example, see the documentation for the count() function in kotlinx.coroutines.

Kotlin

```kotlin
import org.jetbrains.dokka.gradle.DokkaTask
import java.net.URL

// Note: To configure multi-project builds, you need
//       to configure Partial tasks of the subprojects.
//       See "Configuration example" section of documentation.
tasks.withType<DokkaTask>().configureEach {
    // ..
    // general configuration section
    // ..

    dokkaSourceSets.configureEach {
        // ..
        // source set configuration section
        // ..

        sourceLink {
            localDirectory.set(projectDir.resolve("src"))
            remoteUrl.set(URL("https://github.com/kotlin/dokka/tree/master/src"))
            remoteLineSuffix.set("#L")
        }
    }
}
```

Groovy

```groovy
import org.jetbrains.dokka.gradle.DokkaTask
import java.net.URL

// Note: To configure multi-project builds, you need
//       to configure Partial tasks of the subprojects.
//       See "Configuration example" section of documentation.
tasks.withType(DokkaTask.class) {
    // ..
    // general configuration section
    // ..

    dokkaSourceSets.configureEach {
        // ..
        // source set configuration section
        // ..

        sourceLink {
            localDirectory.set(file("src"))
            remoteUrl.set(new URL("https://github.com/kotlin/dokka/tree/master/src"))
            remoteLineSuffix.set("#L")
        }
    }
}
```

localDirectory
The path to the local source directory. The path must be relative to the root of the current project.

remoteUrl
The URL of the source code hosting service that can be accessed by documentation readers, like GitHub, GitLab, Bitbucket, etc. This URL is used to generate source code links of declarations.

remoteLineSuffix
The suffix used to append the source code line number to the URL. This helps readers navigate not only to the file, but to the specific line number of the declaration.

The number itself is appended to the specified suffix. For example, if this option is set to #L and the line number is 10, the resulting URL suffix is #L10.

Suffixes used by popular services:

- GitHub: #L
- GitLab: #L
- Bitbucket: #lines-

Default: #L

Package options

The perPackageOption configuration block allows setting some options for specific packages matched by matchingRegex.

Kotlin

```kotlin
import org.jetbrains.dokka.DokkaConfiguration.Visibility
import org.jetbrains.dokka.gradle.DokkaTask

// Note: To configure multi-project builds, you need
//       to configure Partial tasks of the subprojects.
//       See "Configuration example" section of documentation.
tasks.withType<DokkaTask>().configureEach {
    // ..
    // general configuration section
    // ..

    dokkaSourceSets.configureEach {
        // ..
        // source set configuration section
        // ..

        perPackageOption {
            matchingRegex.set(".*api.*")
            suppress.set(false)
            skipDeprecated.set(false)
            reportUndocumented.set(false)
            documentedVisibilities.set(setOf(Visibility.PUBLIC))
        }
    }
}
```

Groovy

```
import org.jetbrains.dokka.DokkaConfiguration.Visibility
import org.jetbrains.dokka.gradle.DokkaTask

// Note: To configure multi-project builds, you need
//       to configure Partial tasks of the subprojects.
//       See "Configuration example" section of documentation.
tasks.withType(DokkaTask.class) {
    // ..
    // general configuration section
    // ..

    dokkaSourceSets.configureEach {
        // ..
        // Source set configuration section
        // ..

        perPackageOption {
            matchingRegex.set(".*api.*")
            suppress.set(false)
            skipDeprecated.set(false)
            reportUndocumented.set(false)
            documentedVisibilities.set([Visibility.PUBLIC])
        }
    }
}
```

matchingRegex
The regular expression that is used to match the package.

Default: .*

suppress
Whether this package should be skipped when generating documentation.

Default: false

skipDeprecated
Whether to document declarations annotated with @Deprecated.

This can be configured on source set level.

Default: false

reportUndocumented
Whether to emit warnings about visible undocumented declarations, that is declarations without KDocs after they have been filtered by documentedVisibilities and other filters.

This setting works well with failOnWarning.

This can be configured on source set level.

Default: false

documentedVisibilities
The set of visibility modifiers that should be documented.

This can be used if you want to document protected/internal/private declarations within this package, as well as if you want to exclude public declarations and only document internal API.

This can be configured on source set level.

Default: DokkaConfiguration.Visibility.PUBLIC

External documentation links configuration

The externalDocumentationLink block allows the creation of links that lead to the externally hosted documentation of your dependencies.

For example, if you are using types from kotlinx.serialization, by default they are unclickable in your documentation, as if they are unresolved. However, since the API reference documentation for kotlinx.serialization is built by Dokka and is published on kotlinlang.org, you can configure external documentation links for it. Thus allowing Dokka to generate links for types from the library, making them resolve successfully and clickable.

By default, external documentation links for Kotlin standard library, JDK, Android SDK and AndroidX are configured.

Kotlin

```kotlin
import org.jetbrains.dokka.gradle.DokkaTask
import java.net.URL

// Note: To configure multi-project builds, you need
//       to configure Partial tasks of the subprojects.
//       See "Configuration example" section of documentation.
tasks.withType<DokkaTask>().configureEach {
    // ..
    // general configuration section
    // ..

    dokkaSourceSets.configureEach {
        // ..
        // source set configuration section
        // ..

        externalDocumentationLink {
            url.set(URL("https://kotlinlang.org/api/kotlinx.serialization/"))
            packageListUrl.set(
                rootProject.projectDir.resolve("serialization.package.list").toURL()
            )
        }
    }
}
```

Groovy

```groovy
import org.jetbrains.dokka.gradle.DokkaTask
import java.net.URL

// Note: To configure multi-project builds, you need
//       to configure Partial tasks of the subprojects.
//       See "Configuration example" section of documentation.
tasks.withType(DokkaTask.class) {
    // ..
    // general configuration section
    // ..

    dokkaSourceSets.configureEach {
        // ..
        // source set configuration section
        // ..

        externalDocumentationLink {
            url.set(new URL("https://kotlinlang.org/api/kotlinx.serialization/"))
            packageListUrl.set(
                file("serialization.package.list").toURL()
            )
        }
    }
}
```

url

The root URL of documentation to link to. It must contain a trailing slash.

Dokka does its best to automatically find package-list for the given URL, and link declarations together.

If automatic resolution fails or if you want to use locally cached files instead, consider setting the packageListUrl option.

packageListUrl

The exact location of a package-list. This is an alternative to relying on Dokka automatically resolving it.

Package lists contain information about the documentation and the project itself, such as module and package names.

This can also be a locally cached file to avoid network calls.

Complete configuration

Below you can see all possible configuration options applied at the same time.

Kotlin

```kotlin
import org.jetbrains.dokka.DokkaConfiguration.Visibility
import org.jetbrains.dokka.gradle.DokkaTask
import org.jetbrains.dokka.Platform
import java.net.URL

// Note: To configure multi-project builds, you need
//       to configure Partial tasks of the subprojects.
//       See "Configuration example" section of documentation.
tasks.withType<DokkaTask>().configureEach {
    moduleName.set(project.name)
    moduleVersion.set(project.version.toString())
    outputDirectory.set(layout.buildDirectory.dir("dokka/$name"))
    failOnWarning.set(false)
    suppressObviousFunctions.set(true)
    suppressInheritedMembers.set(false)
    offlineMode.set(false)

    dokkaSourceSets {
        named("linux") {
            dependsOn("native")
            sourceRoots.from(file("linux/src"))
        }
        configureEach {
            suppress.set(false)
            displayName.set(name)
            documentedVisibilities.set(setOf(Visibility.PUBLIC))
            reportUndocumented.set(false)
            skipEmptyPackages.set(true)
            skipDeprecated.set(false)
            suppressGeneratedFiles.set(true)
            jdkVersion.set(8)
            languageVersion.set("1.7")
            apiVersion.set("1.7")
            noStdlibLink.set(false)
            noJdkLink.set(false)
            noAndroidSdkLink.set(false)
            includes.from(project.files(), "packages.md", "extra.md")
            platform.set(Platform.DEFAULT)
            sourceRoots.from(file("src"))
            classpath.from(project.files(), file("libs/dependency.jar"))
            samples.from(project.files(), "samples/Basic.kt", "samples/Advanced.kt")

            sourceLink {
                localDirectory.set(projectDir.resolve("src"))
                remoteUrl.set(URL("https://github.com/kotlin/dokka/tree/master/src"))
                remoteLineSuffix.set("#L")
            }

            externalDocumentationLink {
                url.set(URL("https://kotlinlang.org/api/core/kotlin-stdlib/"))
                packageListUrl.set(
                    rootProject.projectDir.resolve("stdlib.package.list").toURL()
                )
            }

            perPackageOption {
                matchingRegex.set(".*api.*")
                suppress.set(false)
                skipDeprecated.set(false)
                reportUndocumented.set(false)
                documentedVisibilities.set(
                    setOf(
                        Visibility.PUBLIC,
                        Visibility.PRIVATE,
                        Visibility.PROTECTED,
                        Visibility.INTERNAL,
                        Visibility.PACKAGE
                    )
                )
            }
        }
    }
}
```

Groovy

```
import org.jetbrains.dokka.DokkaConfiguration.Visibility
import org.jetbrains.dokka.gradle.DokkaTask
import org.jetbrains.dokka.Platform
import java.net.URL

// Note: To configure multi-project builds, you need
//       to configure Partial tasks of the subprojects.
//       See "Configuration example" section of documentation.
tasks.withType(DokkaTask.class) {
    moduleName.set(project.name)
    moduleVersion.set(project.version.toString())
    outputDirectory.set(file("build/dokka/$name"))
    failOnWarning.set(false)
    suppressObviousFunctions.set(true)
    suppressInheritedMembers.set(false)
    offlineMode.set(false)

    dokkaSourceSets {
        named("linux") {
            dependsOn("native")
            sourceRoots.from(file("linux/src"))
        }
        configureEach {
            suppress.set(false)
            displayName.set(name)
            documentedVisibilities.set([Visibility.PUBLIC])
            reportUndocumented.set(false)
            skipEmptyPackages.set(true)
            skipDeprecated.set(false)
            suppressGeneratedFiles.set(true)
            jdkVersion.set(8)
            languageVersion.set("1.7")
            apiVersion.set("1.7")
            noStdlibLink.set(false)
            noJdkLink.set(false)
            noAndroidSdkLink.set(false)
            includes.from(project.files(), "packages.md", "extra.md")
            platform.set(Platform.DEFAULT)
            sourceRoots.from(file("src"))
            classpath.from(project.files(), file("libs/dependency.jar"))
            samples.from(project.files(), "samples/Basic.kt", "samples/Advanced.kt")

            sourceLink {
                localDirectory.set(file("src"))
                remoteUrl.set(new URL("https://github.com/kotlin/dokka/tree/master/src"))
                remoteLineSuffix.set("#L")
            }

            externalDocumentationLink {
                url.set(new URL("https://kotlinlang.org/api/core/kotlin-stdlib/"))
                packageListUrl.set(
                        file("stdlib.package.list").toURL()
                )
            }

            perPackageOption {
                matchingRegex.set(".*api.*")
                suppress.set(false)
                skipDeprecated.set(false)
                reportUndocumented.set(false)
                documentedVisibilities.set([Visibility.PUBLIC])
            }
        }
    }
}
```

Migrate to Dokka Gradle plugin v2

The Dokka Gradle plugin v2 is an Experimental feature. It may be changed at any time. We appreciate your feedback on GitHub.

The Dokka Gradle plugin (DGP) is a tool for generating comprehensive API documentation for Kotlin projects built with Gradle.

DGP seamlessly processes both Kotlin's KDoc comments and Java's Javadoc comments to extract information and create structured documentation in HTML or Javadoc format.

Starting with Dokka 2.0.0, you can try the Dokka Gradle plugin v2, the new version of DGP. With Dokka 2.0.0, you can use the Dokka Gradle plugin either in v1 or v2 modes.

DGP v2 introduces significant improvements to DGP, aligning more closely with Gradle best practices:

- Adopts Gradle types, which leads to better performance.
- Uses an intuitive top-level DSL configuration instead of a low-level task-based setup, which simplifies the build scripts and their readability.
- Takes a more declarative approach to documentation aggregation, which makes multi-project documentation easier to manage.
- Uses a type-safe plugin configuration, which improves the reliability and maintainability of your build scripts.
- Fully supports Gradle configuration cache and build cache, which improves performance and simplifies build work.

Before you start

Before starting the migration, complete the following steps.

Verify supported versions

Ensure that your project meets the minimum version requirements:

Tool	Version
Gradle	7.6 or higher
Android Gradle plugin	7.0 or higher
Kotlin Gradle plugin	1.9 or higher

Enable DGP v2

Update the Dokka version to 2.0.0 in the plugins {} block of your project's build.gradle.kts file:

```
plugins {
    kotlin("jvm") version "2.1.10"
    id("org.jetbrains.dokka") version "2.0.0"
}
```

Alternatively, you can use version catalog to enable the Dokka Gradle plugin v2.

By default, DGP v2 generates documentation in HTML format. To generate Javadoc or both HTML and Javadoc formats, add the appropriate plugins. For more information about the plugins, see Select documentation output format.

Enable migration helpers

In the project's gradle.properties file, set the following Gradle property to activate DGP v2 with helpers:

```
org.jetbrains.dokka.experimental.gradle.pluginMode=V2EnabledWithHelpers
```

> If your project doesn't have a gradle.properties file, create one in the root directory of your project.

This property activates the DGP v2 plugin with migration helpers. These helpers prevent compilation errors when build scripts reference tasks from DGP v1 that are no longer available in DGP v2.

> Migration helpers do not actively assist with the migration. They only keep your build script from breaking while you transition to the new API.

After completing the migration, disable the migration helpers.

Sync your project with Gradle

After enabling DGP v2 and migration helpers, sync your project with Gradle to ensure DGP v2 is properly applied:

- If you use IntelliJ IDEA, click the Reload All Gradle Projects button in the Gradle tool window.
- If you use Android Studio, select File | Sync Project with Gradle Files.

Migrate your project

After updating the Dokka Gradle plugin to v2, follow the migration steps applicable to your project.

Adjust configuration options

DGP v2 introduces some changes in the Gradle configuration options. In the build.gradle.kts file, adjust the configuration options according to your project setup.

Top-level DSL configuration in DGP v2

Replace the configuration syntax of DGP v1 with the top-level dokka {} DSL configuration of DGP v2:

Configuration in DGP v1:

```
tasks.withType<DokkaTask>().configureEach {
    suppressInheritedMembers.set(true)
    failOnWarning.set(true)
    dokkaSourceSets {
        named("main") {
            moduleName.set("Project Name")
            includes.from("README.md")
            sourceLink {
                localDirectory.set(file("src/main/kotlin"))
                remoteUrl.set(URL("https://example.com/src"))
                remoteLineSuffix.set("#L")
            }
        }
    }
}

tasks.dokkaHtml {
    pluginConfiguration<DokkaBase, DokkaBaseConfiguration> {
        customStyleSheets.set(listOf("styles.css"))
        customAssets.set(listOf("logo.png"))
        footerMessage.set("(c) Your Company")
    }
}
```

Configuration in DGP v2:

The syntax of build.gradle.kts files differs from regular .kt files (such as those used for custom Gradle plugins) because Gradle's Kotlin DSL uses type-safe accessors.

Gradle configuration file

```
// build.gradle.kts

dokka {
    moduleName.set("Project Name")
    dokkaPublications.html {
        suppressInheritedMembers.set(true)
        failOnWarning.set(true)
    }
    dokkaSourceSets.main {
        includes.from("README.md")
        sourceLink {
            localDirectory.set(file("src/main/kotlin"))
            remoteUrl("https://example.com/src")
            remoteLineSuffix.set("#L")
        }
    }
    pluginsConfiguration.html {
        customStyleSheets.from("styles.css")
        customAssets.from("logo.png")
        footerMessage.set("(c) Your Company")
    }
}
```

Kotlin file

```
// CustomPlugin.kt

import org.gradle.api.Plugin
import org.gradle.api.Project
import org.jetbrains.dokka.gradle.DokkaExtension
import org.jetbrains.dokka.gradle.engine.plugins.DokkaHtmlPluginParameters

abstract class CustomPlugin : Plugin<Project> {
    override fun apply(project: Project) {
        project.plugins.apply("org.jetbrains.dokka")

        project.extensions.configure(DokkaExtension::class.java) { dokka ->

            dokka.dokkaPublications.named("html") { publication ->
                publication.suppressInheritedMembers.set(true)
                publication.failOnWarning.set(true)
            }

            dokka.dokkaSourceSets.named("main") { dss ->
                dss.includes.from("README.md")
                dss.sourceLink {
                    it.localDirectory.set(project.file("src/main/kotlin"))
                    it.remoteUrl("https://example.com/src")
                    it.remoteLineSuffix.set("#L")
                }
            }

            dokka.pluginsConfiguration.named("html", DokkaHtmlPluginParameters::class.java) { html ->
                html.customStyleSheets.from("styles.css")
                html.customAssets.from("logo.png")
                html.footerMessage.set("(c) Your Company")
            }
        }
    }
}
```

Visibility settings

Set the documentedVisibilities property from Visibility.PUBLIC to VisibilityModifier.Public.

Configuration in DGP v1:

```
import org.jetbrains.dokka.DokkaConfiguration.Visibility

// ...
documentedVisibilities.set(
    setOf(Visibility.PUBLIC)
)
```

Configuration in DGP v2:

```
import org.jetbrains.dokka.gradle.engine.parameters.VisibilityModifier

// ...
documentedVisibilities.set(
    setOf(VisibilityModifier.Public)
)

// OR

documentedVisibilities(VisibilityModifier.Public)
```

Additionally, use DGP v2's utility function to add documented visibilities:

```
fun documentedVisibilities(vararg visibilities: VisibilityModifier): Unit =
    documentedVisibilities.set(visibilities.asList())
```

Source links

Configure source links to allow navigation from the generated documentation to the corresponding source code in a remote repository. Use the dokkaSourceSets.main{} block for this configuration.

Configuration in DGP v1:

```
tasks.withType<DokkaTask>().configureEach {
    dokkaSourceSets {
        named("main") {
            sourceLink {
                localDirectory.set(file("src/main/kotlin"))
                remoteUrl.set(URL("https://github.com/your-repo"))
                remoteLineSuffix.set("#L")
            }
        }
    }
}
```

Configuration in DGP v2:

The syntax of build.gradle.kts files differs from regular .kt files (such as those used for custom Gradle plugins) because Gradle's Kotlin DSL uses type-safe accessors.

Gradle configuration file

```
// build.gradle.kts

dokka {
    dokkaSourceSets.main {
        sourceLink {
            localDirectory.set(file("src/main/kotlin"))
            remoteUrl("https://github.com/your-repo")
            remoteLineSuffix.set("#L")
        }
    }
}
```

Kotlin file

```
// CustomPlugin.kt

import org.gradle.api.Plugin
import org.gradle.api.Project
import org.jetbrains.dokka.gradle.DokkaExtension
```

```
abstract class CustomPlugin : Plugin<Project> {
    override fun apply(project: Project) {
        project.plugins.apply("org.jetbrains.dokka")
        project.extensions.configure(DokkaExtension::class.java) { dokka ->
            dokka.dokkaSourceSets.named("main") { dss ->
                dss.includes.from("README.md")
                dss.sourceLink {
                    it.localDirectory.set(project.file("src/main/kotlin"))
                    it.remoteUrl("https://example.com/src")
                    it.remoteLineSuffix.set("#L")
                }
            }
        }
    }
}
```

Since the source link configuration has changed, use the URI class instead of URL to specify the remote URL.

Configuration in DGP v1:

```
remoteUrl.set(URL("https://github.com/your-repo"))
```

Configuration in DGP v2:

```
remoteUrl.set(URI("https://github.com/your-repo"))

// or

remoteUrl("https://github.com/your-repo")
```

Additionally, DGP v2 has two utility functions for setting the URL:

```
fun remoteUrl(@Language("http-url-reference") value: String): Unit =
    remoteUrl.set(URI(value))

// and

fun remoteUrl(value: Provider<String>): Unit =
    remoteUrl.set(value.map(::URI))
```

External documentation links

Register external documentation links using the register() method to define each link. The externalDocumentationLinks API uses this method aligning with Gradle DSL conventions.

Configuration in DGP v1:

```
tasks.dokkaHtml {
    dokkaSourceSets {
        configureEach {
            externalDocumentationLink {
                url = URL("https://example.com/docs/")
                packageListUrl = File("/path/to/package-list").toURI().toURL()
            }
        }
    }
}
```

Configuration in DGP v2:

```
dokka {
    dokkaSourceSets.configureEach {
        externalDocumentationLinks.register("example-docs") {
            url("https://example.com/docs/")
            packageListUrl("https://example.com/docs/package-list")
        }
    }
}
```

Custom assets

Use the customAssets property with collections of files (FileCollection) instead of lists (var List<File>).

Configuration in DGP v1:

```
customAssets = listOf(file("example.png"), file("example2.png"))
```

Configuration in DGP v2:

```
customAssets.from("example.png", "example2.png")
```

Output directory

Use the dokka {} block to specify the output directory for the generated Dokka documentation.

Configuration in DGP v1:

```
tasks.dokkaHtml {
    outputDirectory.set(layout.buildDirectory.dir("dokkaDir"))
}
```

Configuration in DGP v2:

```
dokka {
    dokkaPublications.html {
        outputDirectory.set(layout.buildDirectory.dir("dokkaDir"))
    }
}
```

Output directory for additional files

Specify the output directory and include additional files for both single-module and multi-module projects inside the dokka {} block.

In DGP v2, the configuration for single-module and multi-module projects is unified. Instead of configuring dokkaHtml and dokkaHtmlMultiModule tasks separately, specify the settings in dokkaPublications.html {} within the dokka {} block.

For multi-module projects, set the output directory and include additional files (such as README.md) in the configuration of the root project.

Configuration in DGP v1:

```
tasks.dokkaHtmlMultiModule {
    outputDirectory.set(rootDir.resolve("docs/api/0.x"))
    includes.from(project.layout.projectDirectory.file("README.md"))
}
```

Configuration in DGP v2:

The syntax of build.gradle.kts files differs from regular .kt files (such as those used for custom Gradle plugins) because Gradle's Kotlin DSL uses type-safe accessors.

Gradle configuration file

```
// build.gradle.kts

dokka {
    dokkaPublications.html {
        outputDirectory.set(rootDir.resolve("docs/api/0.x"))
        includes.from(project.layout.projectDirectory.file("README.md"))
    }
}
```

Kotlin
file

```
// CustomPlugin.kt

import org.gradle.api.Plugin
import org.gradle.api.Project
import org.jetbrains.dokka.gradle.DokkaExtension

abstract class CustomPlugin : Plugin<Project> {
    override fun apply(project: Project) {
        project.plugins.apply("org.jetbrains.dokka")
        project.extensions.configure(DokkaExtension::class.java) { dokka ->
            dokka.dokkaPublications.named("html") { html ->
                html.outputDirectory.set(project.rootDir.resolve("docs/api/0.x"))
                html.includes.from(project.layout.projectDirectory.file("README.md"))
            }
        }
    }
}
```

Configure Dokka plugins

Configuring built-in Dokka plugins with JSON is deprecated in favor of a type-safe DSL. This change improves compatibility with Gradle's incremental build system and improves task input tracking.

Configuration in DGP v1:

In DGP v1, Dokka plugins were configured manually using JSON. This approach caused issues with registering task inputs for Gradle up-to-date checks.

Here is an example of the deprecated JSON-based configuration for the Dokka Versioning plugin:

```
tasks.dokkaHtmlMultiModule {
    pluginsMapConfiguration.set(
        mapOf(
            "org.jetbrains.dokka.versioning.VersioningPlugin" to """
                { "version": "1.2", "olderVersionsDir": "$projectDir/dokka-docs" }
                """.trimIndent()
        )
    )
}
```

Configuration in DGP v2:

In DGP v2, Dokka plugins are configured using type-safe DSL. To configure Dokka plugins in a type-safe way, use the pluginsConfiguration{} block:

```
dokka {
    pluginsConfiguration {
        versioning {
            version.set("1.2")
            olderVersionsDir.set(projectDir.resolve("dokka-docs"))
        }
    }
}
```

For an example of the DGP v2 configuration, see the Dokka's versioning plugin.

Dokka 2.0.0 allows you to extend its functionality by configuring custom plugins. Custom plugins enable additional processing or modifications to the documentation generation process.

Share Dokka configuration across modules

DPG v2 moves away from using subprojects {} or allprojects {} to share configuration across modules. In future Gradle versions, using these approaches will lead to errors.

Follow the steps below to properly share Dokka configuration in multi-module projects with existing convention plugins or without convention plugins.

After sharing the Dokka configuration, you can aggregate the documentation from multiple modules into a single output. For more information, see Update documentation aggregation in multi-module projects.

For a multi-module project example, see the Dokka GitHub repository.

Multi-module projects without convention plugins

If your project doesn't use convention plugins, you can still share Dokka configurations by directly configuring each module. This involves manually setting up the shared configuration in each module's build.gradle.kts file. While this approach is less centralized, it avoids the need for additional setups like convention plugins.

Otherwise, if your project uses convention plugins, you can also share the Dokka configuration in multi-module projects by creating a convention plugin in the buildSrc directory, and then applying the plugin to your modules (subprojects).

Set up the buildSrc directory

1. In your project root, create a buildSrc directory containing two files:

   - settings.gradle.kts

   - build.gradle.kts

2. In the buildSrc/settings.gradle.kts file, add the following snippet:

   ```
   rootProject.name = "buildSrc"
   ```

3. In the buildSrc/build.gradle.kts file, add the following snippet:

   ```
   plugins {
       `kotlin-dsl`
   }

   repositories {
       mavenCentral()
       gradlePluginPortal()
   }

   dependencies {
       implementation("org.jetbrains.dokka:dokka-gradle-plugin:2.0.0")
   }
   ```

Set up the Dokka convention plugin

After setting up the buildSrc directory:

1. Create a buildSrc/src/main/kotlin/dokka-convention.gradle.kts file to host the convention plugin.

2. In the dokka-convention.gradle.kts file, add the following snippet:

   ```
   plugins {
       id("org.jetbrains.dokka")
   }

   dokka {
       // The shared configuration goes here
   }
   ```

   You need to add the shared Dokka configuration common to all subprojects within the dokka {} block. Also, you don't need to specify a Dokka version. The version is already set in the buildSrc/build.gradle.kts file.

Apply the convention plugin to your modules

Apply the Dokka convention plugin across your modules (subprojects) by adding it to each subproject's build.gradle.kts file:

```
plugins {
    id("dokka-convention")
}
```

Multi-module projects with convention plugins

If you already have convention plugins, create a dedicated Dokka convention plugin following Gradle's documentation.

Then, follow the steps to set up the Dokka convention plugin and apply it across your modules.

Update documentation aggregation in multi-module projects

Dokka can aggregate the documentation from multiple modules (subprojects) into a single output or publication.

As explained, apply the Dokka plugin to all documentable subprojects before aggregating the documentation.

Aggregation in DGP v2 uses the dependencies {} block instead of tasks and can be added in any build.gradle.kts file.

In DGP v1, aggregation was implicitly created in the root project. To replicate this behavior in DGP v2, add the dependencies {} block in the build.gradle.kts file of the root project.

Aggregation in DGP v1:

```
tasks.dokkaHtmlMultiModule {
        // ...
    }
```

Aggregation in DGP v2:

```
dependencies {
    dokka(project(":some-subproject:"))
    dokka(project(":another-subproject:"))
}
```

Change directory of aggregated documentation

When DGP aggregates modules, each subproject has its own subdirectory within the aggregated documentation.

In DGP v2, the aggregation mechanism has been updated to better align with Gradle conventions. DGP v2 now preserves the full subproject directory to prevent conflicts when aggregating documentation in any location.

Aggregation directory in DGP v1:

In DGP v1, aggregated documentation was placed in a collapsed directory structure. For example, given a project with an aggregation in :turbo-lib and a nested subproject :turbo-lib:maths, the generated documentation was placed under:

```
turbo-lib/build/dokka/html/maths/
```

Aggregation directory in DGP v2:

DGP v2 ensures each subproject has a unique directory by retaining the full project structure. The same aggregated documentation now follows this structure:

```
turbo-lib/build/dokka/html/turbo-lib/maths/
```

This change prevents subprojects with the same name from clashing. However, since the directory structure has changed, external links may become outdated, potentially causing 404 errors.

Revert to the DGP v1 directory behavior

If your project depends on the directory structure used in DGP v1, you can revert this behavior by manually specifying the module directory. Add the following configuration to the build.gradle.kts file of each subproject:

```
// /turbo-lib/maths/build.gradle.kts

plugins {
    id("org.jetbrains.dokka")
}

dokka {
    // Overrides the module directory to match the V1 structure
    modulePath.set("maths")
}
```

Generate documentation with the updated task

DGP v2 has renamed the Gradle tasks that generate the API documentation.

Task in DGP v1:

```
./gradlew dokkaHtml

// or

./gradlew dokkaHtmlMultiModule
```

Task in DGP v2:

```
./gradlew :dokkaGenerate
```

The dokkaGenerate task generates the API documentation in the build/dokka/ directory.

In the DGP v2 version, the dokkaGenerate task name works for both single and multi-module projects. You can use different tasks to generate output in HTML, Javadoc or both HTML and Javadoc. For more information, see Select documentation output format.

Select documentation output format

The Javadoc output format is in Alpha. You may find bugs and experience migration issues when using it. Successful integration with tools that accept Javadoc as input is not guaranteed. Use it at your own risk.

The default output format for DGP v2 is HTML. However, you can choose to generate the API documentation in HTML, Javadoc, or both formats at the same time:

1. Place the corresponding plugin id in the plugins {} block of your project's build.gradle.kts file:

```
plugins {
    // Generates HTML documentation
    id("org.jetbrains.dokka") version "2.0.0"

    // Generates Javadoc documentation
    id("org.jetbrains.dokka-javadoc") version "2.0.0"

    // Keeping both plugin IDs generates both formats
}
```

2. Run the corresponding Gradle task.

Here is a list of the plugin id and Gradle task that correspond to each format:

	HTML	Javadoc	Both
Plugin id	id("org.jetbrains.dokka")	id("org.jetbrains.dokka-javadoc")	Use both HTML and Javadoc plugins
Gradle task	./gradlew :dokkaGeneratePublicationHtml	./gradlew :dokkaGeneratePublicationJavadoc	./gradlew :dokkaGenerate

The dokkaGenerate task generates documentation in all available formats based on the applied plugins. If both the HTML and Javadoc plugins are applied, you can choose to generate only HTML by running the dokkaGeneratePublicationHtml task, or only Javadoc by running the dokkaGeneratePublicationJavadoc task.

Address deprecations and removals

- Output format support: Dokka 2.0.0 only supports HTML and Javadoc output. Experimental formats like Markdown and Jekyll are no longer supported.
- Collector task: DokkaCollectorTask has been removed. Now, you need to generate the documentation separately for each subproject and then aggregate the documentation if necessary.

Finalize your migration

After you've migrated your project, perform these steps to wrap up and improve performance.

Set the opt-in flag

After successful migration, set the following opt-in flag without helpers in the project's gradle.properties file:

```
org.jetbrains.dokka.experimental.gradle.pluginMode=V2Enabled
```

If you removed references to Gradle tasks from DGP v1 that are no longer available in DGP v2, you shouldn't see compilation errors related to it.

Enable build cache and configuration cache

DGP v2 now supports Gradle build cache and configuration cache, improving build performance.

- To enable build cache, follow instructions in the Gradle build cache documentation.
- To enable configuration cache, follow instructions in the Gradle configuration cache documentation.

Troubleshooting

In large projects, Dokka can consume a significant amount of memory to generate documentation. This can exceed Gradle’s memory limits, especially when processing large volumes of data.

When Dokka generation runs out of memory, the build fails, and Gradle can throw exceptions like java.lang.OutOfMemoryError: Metaspace.

Active efforts are underway to improve Dokka's performance, although some limitations stem from Gradle.

If you encounter memory issues, try these workarounds:

- Increasing heap space
- Running Dokka within the Gradle process

Increase heap space

One way to resolve memory issues is to increase the amount of Java heap memory for the Dokka generator process. In the build.gradle.kts file, adjust the following configuration option:

```
dokka {
        // Dokka generates a new process managed by Gradle
        dokkaGeneratorIsolation = ProcessIsolation {
            // Configures heap size
            maxHeapSize = "4g"
        }
    }
```

In this example, the maximum heap size is set to 4 GB ("4g"). Adjust and test the value to find the optimal setting for your build.

If you find that Dokka requires a considerably expanded heap size, for example, significantly higher than Gradle's own memory usage, create an issue on Dokka's GitHub repository.

You have to apply this configuration to each subproject. It is recommended that you configure Dokka in a convention plugin applied to all subprojects.

Run Dokka within the Gradle process

When both the Gradle build and Dokka generation require a lot of memory, they may run as separate processes, consuming significant memory on a single machine.

To optimize memory usage, you can run Dokka within the same Gradle process instead of as a separate process. This allows you to configure the memory for Gradle once instead of allocating it separately for each process.

To run Dokka within the same Gradle process, adjust the following configuration option in the build.gradle.kts file:

```
dokka {
        // Runs Dokka in the current Gradle process
        dokkaGeneratorIsolation = ClassLoaderIsolation()
    }
```

As with increasing heap space, test this configuration to confirm it works well for your project.

For more details on configuring Gradle's JVM memory, see the Gradle documentation.

> Changing the Java options for Gradle launches a new Gradle daemon, which may stay alive for a long time. You can manually stop any other Gradle processes.
>
> Additionally, Gradle issues with the ClassLoaderIsolation() configuration may cause memory leaks.

What's next

- Explore more DGP v2 project examples.
- Get started with Dokka.
- Learn more about Dokka plugins.

Maven

To generate documentation for a Maven-based project, you can use the Maven plugin for Dokka.

> Compared to the Gradle plugin for Dokka, the Maven plugin has only basic features and does not provide support for multi-module builds.

You can play around with Dokka and see how it can be configured for a Maven project by visiting our Maven example project.

Apply Dokka

To apply Dokka, you need to add dokka-maven-plugin to the plugins section of your POM file:

```
<build>
    <plugins>
        <plugin>
            <groupId>org.jetbrains.dokka</groupId>
            <artifactId>dokka-maven-plugin</artifactId>
            <version>2.0.0</version>
            <executions>
                <execution>
                    <phase>pre-site</phase>
                    <goals>
                        <goal>dokka</goal>
                    </goals>
                </execution>
            </executions>
        </plugin>
    </plugins>
</build>
```

Generate documentation

The following goals are provided by the Maven plugin:

Goal	Description
dokka:dokka	Generates documentation with Dokka plugins applied. HTML format by default.

Experimental

Goal	Description
dokka:javadoc	Generates documentation in Javadoc format.
dokka:javadocJar	Generates a javadoc.jar file that contains documentation in Javadoc format.

Other output formats

By default, the Maven plugin for Dokka builds documentation in HTML output format.

All other output formats are implemented as Dokka plugins. In order to generate documentation in the desired format, you have to add it as a Dokka plugin to the configuration.

For example, to use the experimental GFM format, you have to add gfm-plugin artifact:

```
<plugin>
    <groupId>org.jetbrains.dokka</groupId>
    <artifactId>dokka-maven-plugin</artifactId>
    ...
    <configuration>
        <dokkaPlugins>
            <plugin>
                <groupId>org.jetbrains.dokka</groupId>
                <artifactId>gfm-plugin</artifactId>
                <version>2.0.0</version>
            </plugin>
        </dokkaPlugins>
    </configuration>
</plugin>
```

With this configuration, running the dokka:dokka goal produces documentation in GFM format.

To learn more about Dokka plugins, see Dokka plugins.

Build javadoc.jar

If you want to publish your library to a repository, you may need to provide a javadoc.jar file that contains API reference documentation of your library.

For example, if you want to publish to Maven Central, you must supply a javadoc.jar alongside your project. However, not all repositories have that rule.

Unlike the Gradle plugin for Dokka, the Maven plugin comes with a ready-to-use dokka:javadocJar goal. By default, it generates documentation in Javadoc output format in thetarget folder.

If you are not satisfied with the built-in goal or want to customize the output (for example, you want to generate documentation inHTML format instead of Javadoc), similar behavior can be achieved by adding the Maven JAR plugin with the following configuration:

```
<plugin>
    <groupId>org.apache.maven.plugins</groupId>
    <artifactId>maven-jar-plugin</artifactId>
    <version>3.3.0</version>
    <executions>
        <execution>
            <goals>
                <goal>test-jar</goal>
            </goals>
        </execution>
        <execution>
            <id>dokka-jar</id>
            <phase>package</phase>
            <goals>
                <goal>jar</goal>
            </goals>
            <configuration>
                <classifier>dokka</classifier>
                <classesDirectory>${project.build.directory}/dokka</classesDirectory>
                <skipIfEmpty>true</skipIfEmpty>
            </configuration>
        </execution>
    </executions>
</plugin>
```

The documentation and the .jar archive for it are then generated by running dokka:dokka and jar:jar@dokka-jar goals:

```
mvn dokka:dokka jar:jar@dokka-jar
```

> If you publish your library to Maven Central, you can use services like javadoc.io to host your library's API documentation for free and without any setup. It takes documentation pages straight from the javadoc.jar. It works well with the HTML format as demonstrated in this example.

Configuration example

Maven's plugin configuration block can be used to configure Dokka.

Here is an example of a basic configuration that only changes the output location of your documentation:

```
<plugin>
    <groupId>org.jetbrains.dokka</groupId>
    <artifactId>dokka-maven-plugin</artifactId>
    ...
    <configuration>
        <outputDir>${project.basedir}/target/documentation/dokka</outputDir>
    </configuration>
</plugin>
```

Configuration options

Dokka has many configuration options to tailor your and your reader's experience.

Below are some examples and detailed descriptions for each configuration section. You can also find an example with all configuration options applied at the bottom of the page.

General configuration

```
<plugin>
    <groupId>org.jetbrains.dokka</groupId>
    <artifactId>dokka-maven-plugin</artifactId>
    <!--  ...  -->
    <configuration>
        <skip>false</skip>
        <moduleName>${project.artifactId}</moduleName>
        <outputDir>${project.basedir}/target/documentation</outputDir>
        <failOnWarning>false</failOnWarning>
        <suppressObviousFunctions>true</suppressObviousFunctions>
        <suppressInheritedMembers>false</suppressInheritedMembers>
        <offlineMode>false</offlineMode>
        <sourceDirectories>
            <dir>${project.basedir}/src</dir>
        </sourceDirectories>
        <documentedVisibilities>
            <visibility>PUBLIC</visibility>
            <visibility>PROTECTED</visibility>
        </documentedVisibilities>
        <reportUndocumented>false</reportUndocumented>
        <skipDeprecated>false</skipDeprecated>
        <skipEmptyPackages>true</skipEmptyPackages>
        <suppressedFiles>
            <file>/path/to/dir</file>
            <file>/path/to/file</file>
        </suppressedFiles>
        <jdkVersion>8</jdkVersion>
        <languageVersion>1.7</languageVersion>
        <apiVersion>1.7</apiVersion>
        <noStdlibLink>false</noStdlibLink>
        <noJdkLink>false</noJdkLink>
        <includes>
            <include>packages.md</include>
            <include>extra.md</include>
        </includes>
        <classpath>${project.compileClasspathElements}</classpath>
        <samples>
            <dir>${project.basedir}/samples</dir>
        </samples>
        <sourceLinks>
            <!-- Separate section -->
        </sourceLinks>
        <externalDocumentationLinks>
            <!-- Separate section -->
        </externalDocumentationLinks>
        <perPackageOptions>
            <!-- Separate section -->
        </perPackageOptions>
    </configuration>
</plugin>
```

skip
Whether to skip documentation generation.

Default: false

moduleName
The display name used to refer to the project/module. It's used for the table of contents, navigation, logging, etc.

Default: {project.artifactId}

outputDir
The directory to where documentation is generated, regardless of format.

Default: {project.basedir}/target/dokka

failOnWarning
Whether to fail documentation generation if Dokka has emitted a warning or an error. The process waits until all errors and warnings have been emitted first.

This setting works well with reportUndocumented.

Default: false

suppressObviousFunctions
Whether to suppress obvious functions.

A function is considered to be obvious if it is:

- Inherited from kotlin.Any, Kotlin.Enum, java.lang.Object or java.lang.Enum, such as equals, hashCode, toString.
- Synthetic (generated by the compiler) and does not have any documentation, such as dataClass.componentN or dataClass.copy.

Default: true

suppressInheritedMembers
Whether to suppress inherited members that aren't explicitly overridden in a given class.

Note: This can suppress functions such as equals/hashCode/toString, but cannot suppress synthetic functions such as dataClass.componentN and dataClass.copy. Use suppressObviousFunctions for that.

Default: false

offlineMode

Whether to resolve remote files/links over your network.

This includes package-lists used for generating external documentation links. For example, to make classes from the standard library clickable.

Setting this to true can significantly speed up build times in certain cases, but can also worsen documentation quality and user experience. For example, by not resolving class/member links from your dependencies, including the standard library.

Note: You can cache fetched files locally and provide them to Dokka as local paths. See externalDocumentationLinks section.

Default: false

sourceDirectories

The source code roots to be analyzed and documented. Acceptable inputs are directories and individual .kt/.java files.

Default: {project.compileSourceRoots}

documentedVisibilities

The set of visibility modifiers that should be documented.

This can be used if you want to document protected/internal/private declarations, as well as if you want to exclude public declarations and only document internal API.

Can be configured on per-package basis.

Default: PUBLIC

reportUndocumented

Whether to emit warnings about visible undocumented declarations, that is declarations without KDocs after they have been filtered by documentedVisibilities and other filters.

This setting works well with failOnWarning.

This can be overridden at package level.

Default: false

skipDeprecated

Whether to document declarations annotated with @Deprecated.

This can be overridden at package level.

Default: false

skipEmptyPackages

Whether to skip packages that contain no visible declarations after various filters have been applied.

For example, if skipDeprecated is set to true and your package contains only deprecated declarations, it is considered to be empty.

Default: true

suppressedFiles

The directories or individual files that should be suppressed, meaning that declarations from them are not documented.

jdkVersion

The JDK version to use when generating external documentation links for Java types.

For example, if you use java.util.UUID in some public declaration signature, and this option is set to 8, Dokka generates an external documentation link to JDK 8 Javadocs for it.

Default: JDK 8

languageVersion

The Kotlin language version used for setting up analysis and @sample environment.

By default, the latest language version available to Dokka's embedded compiler is used.

apiVersion

The Kotlin API version used for setting up analysis and @sample environment.

By default, it is deduced from languageVersion.

noStdlibLink

Whether to generate external documentation links that lead to the API reference documentation of Kotlin's standard library.

Note: Links are generated when noStdLibLink is set to false.

Default: false

noJdkLink
Whether to generate external documentation links to JDK's Javadocs.

The version of JDK Javadocs is determined by the jdkVersion option.

Note: Links are generated when noJdkLink is set to false.

Default: false

includes
A list of Markdown files that contain module and package documentation

The contents of specified files are parsed and embedded into documentation as module and package descriptions.

classpath
The classpath for analysis and interactive samples.

This is useful if some types that come from dependencies are not resolved/picked up automatically. This option accepts both .jar and .klib files.

Default: {project.compileClasspathElements}

samples
A list of directories or files that contain sample functions which are referenced via @sample KDoc tag.

Source link configuration

The sourceLinks configuration block allows you to add a source link to each signature that leads to the url with a specific line number. (The line number is configurable by setting lineSuffix).

This helps readers to find the source code for each declaration.

For an example, see the documentation for the count() function in kotlinx.coroutines.

```
<plugin>
    <groupId>org.jetbrains.dokka</groupId>
    <artifactId>dokka-maven-plugin</artifactId>
    <!--  ...  -->
    <configuration>
        <sourceLinks>
            <link>
                <path>src</path>
                <url>https://github.com/kotlin/dokka/tree/master/src</url>
                <lineSuffix>#L</lineSuffix>
            </link>
        </sourceLinks>
    </configuration>
</plugin>
```

path
The path to the local source directory. The path must be relative to the root of the current module.

Note: Only Unix based paths are allowed, Windows-style paths will throw an error.

url
The URL of the source code hosting service that can be accessed by documentation readers, like GitHub, GitLab, Bitbucket, etc. This URL is used to generate source code links of declarations.

lineSuffix
The suffix used to append source code line number to the URL. This helps readers navigate not only to the file, but to the specific line number of the declaration.

The number itself is appended to the specified suffix. For example, if this option is set to #L and the line number is 10, the resulting URL suffix is #L10.

Suffixes used by popular services:

- GitHub: #L
- GitLab: #L
- Bitbucket: #lines-

External documentation links configuration

The externalDocumentationLinks block allows the creation of links that lead to the externally hosted documentation of your dependencies.

For example, if you are using types from kotlinx.serialization, by default they are unclickable in your documentation, as if they are unresolved. However, since the API reference documentation for kotlinx.serialization is built by Dokka and is published on kotlinlang.org, you can configure external documentation links for it. Thus allowing Dokka to generate links for types from the library, making them resolve successfully and clickable.

By default, external documentation links for Kotlin standard library and JDK are configured.

```
<plugin>
    <groupId>org.jetbrains.dokka</groupId>
    <artifactId>dokka-maven-plugin</artifactId>
    <!--  ...  -->
    <configuration>
        <externalDocumentationLinks>
            <link>
                <url>https://kotlinlang.org/api/kotlinx.serialization/</url>
                <packageListUrl>file:/${project.basedir}/serialization.package.list</packageListUrl>
            </link>
        </externalDocumentationLinks>
    </configuration>
</plugin>
```

url
The root URL of documentation to link to. It must contain a trailing slash.

Dokka does its best to automatically find the package-list for the given URL, and link declarations together.

If automatic resolution fails or if you want to use locally cached files instead, consider setting the packageListUrl option.

packageListUrl
The exact location of a package-list. This is an alternative to relying on Dokka automatically resolving it.

Package lists contain information about the documentation and the project itself, such as module and package names.

This can also be a locally cached file to avoid network calls.

Package options

The perPackageOptions configuration block allows setting some options for specific packages matched by matchingRegex.

```
<plugin>
    <groupId>org.jetbrains.dokka</groupId>
    <artifactId>dokka-maven-plugin</artifactId>
    <!--  ...  -->
    <configuration>
        <perPackageOptions>
            <packageOptions>
                <matchingRegex>.*api.*</matchingRegex>
                <suppress>false</suppress>
                <reportUndocumented>false</reportUndocumented>
                <skipDeprecated>false</skipDeprecated>
                <documentedVisibilities>
                    <visibility>PUBLIC</visibility>
                    <visibility>PRIVATE</visibility>
                    <visibility>PROTECTED</visibility>
                    <visibility>INTERNAL</visibility>
                    <visibility>PACKAGE</visibility>
                </documentedVisibilities>
            </packageOptions>
        </perPackageOptions>
    </configuration>
</plugin>
```

matchingRegex
The regular expression that is used to match the package.

Default: .*

suppress
Whether this package should be skipped when generating documentation.

Default: false

documentedVisibilities

The set of visibility modifiers that should be documented.

This can be used if you want to document protected/internal/private declarations within this package, as well as if you want to exclude public declarations and only document internal API.

Default: PUBLIC

skipDeprecated

Whether to document declarations annotated with @Deprecated.

This can be set on project/module level.

Default: false

reportUndocumented

Whether to emit warnings about visible undocumented declarations, that is declarations without KDocs after they have been filtered by documentedVisibilities and other filters.

This setting works well with failOnWarning.

Default: false

Complete configuration

Below you can see all the possible configuration options applied at the same time.

```
<plugin>
    <groupId>org.jetbrains.dokka</groupId>
    <artifactId>dokka-maven-plugin</artifactId>
    <!--  ...  -->
    <configuration>
        <skip>false</skip>
        <moduleName>${project.artifactId}</moduleName>
        <outputDir>${project.basedir}/target/documentation</outputDir>
        <failOnWarning>false</failOnWarning>
        <suppressObviousFunctions>true</suppressObviousFunctions>
        <suppressInheritedMembers>false</suppressInheritedMembers>
        <offlineMode>false</offlineMode>
        <sourceDirectories>
            <dir>${project.basedir}/src</dir>
        </sourceDirectories>
        <documentedVisibilities>
            <visibility>PUBLIC</visibility>
            <visibility>PRIVATE</visibility>
            <visibility>PROTECTED</visibility>
            <visibility>INTERNAL</visibility>
            <visibility>PACKAGE</visibility>
        </documentedVisibilities>
        <reportUndocumented>false</reportUndocumented>
        <skipDeprecated>false</skipDeprecated>
        <skipEmptyPackages>true</skipEmptyPackages>
        <suppressedFiles>
            <file>/path/to/dir</file>
            <file>/path/to/file</file>
        </suppressedFiles>
        <jdkVersion>8</jdkVersion>
        <languageVersion>1.7</languageVersion>
        <apiVersion>1.7</apiVersion>
        <noStdlibLink>false</noStdlibLink>
        <noJdkLink>false</noJdkLink>
        <includes>
            <include>packages.md</include>
            <include>extra.md</include>
        </includes>
        <classpath>${project.compileClasspathElements}</classpath>
        <samples>
            <dir>${project.basedir}/samples</dir>
        </samples>
        <sourceLinks>
            <link>
                <path>src</path>
                <url>https://github.com/kotlin/dokka/tree/master/src</url>
                <lineSuffix>#L</lineSuffix>
            </link>
        </sourceLinks>
        <externalDocumentationLinks>
```

```
            <link>
                <url>https://kotlinlang.org/api/core/kotlin-stdlib/</url>
                <packageListUrl>file:/${project.basedir}/stdlib.package.list</packageListUrl>
            </link>
        </externalDocumentationLinks>
        <perPackageOptions>
            <packageOptions>
                <matchingRegex>.*api.*</matchingRegex>
                <suppress>false</suppress>
                <reportUndocumented>false</reportUndocumented>
                <skipDeprecated>false</skipDeprecated>
                <documentedVisibilities>
                    <visibility>PUBLIC</visibility>
                    <visibility>PRIVATE</visibility>
                    <visibility>PROTECTED</visibility>
                    <visibility>INTERNAL</visibility>
                    <visibility>PACKAGE</visibility>
                </documentedVisibilities>
            </packageOptions>
        </perPackageOptions>
    </configuration>
</plugin>
```

CLI

If for some reason you cannot use Gradle or Maven build tools, Dokka has a command line (CLI) runner for generating documentation.

In comparison, it has the same, if not more, capabilities as the Gradle plugin for Dokka. Although it is considerably more difficult to set up as there is no autoconfiguration, especially in multiplatform and multi-module environments.

Get started

The CLI runner is published to Maven Central as a separate runnable artifact.

You can find it on Maven Central or download it directly.

With the dokka-cli-2.0.0.jar file saved on your computer, run it with the -help option to see all available configuration options and their description:

```
java -jar dokka-cli-2.0.0.jar -help
```

It also works for some nested options, such as -sourceSet:

```
java -jar dokka-cli-2.0.0.jar -sourceSet -help
```

Generate documentation

Prerequisites

Since there is no build tool to manage dependencies, you have to provide dependency .jar files yourself.

Listed below are the dependencies that you need for any output format:

Group	Artifact	Version	Link
org.jetbrains.dokka	dokka-base	2.0.0	download
org.jetbrains.dokka	analysis-kotlin-descriptors	2.0.0	download

Below are the additional dependencies that you need for HTML output format:

Group	Artifact	Version	Link
org.jetbrains.kotlinx	kotlinx-html-jvm	0.8.0	download
org.freemarker	freemarker	2.3.31	download

Run with command line options

You can pass command line options to configure the CLI runner.

At the very least you need to provide the following options:

- -pluginsClasspath - a list of absolute/relative paths to downloaded dependencies, separated by semi-colons ;
- -sourceSet - an absolute path to code sources to generate documentation for
- -outputDir - an absolute/relative path of the documentation output directory

```
java -jar dokka-cli-2.0.0.jar \
     -pluginsClasspath "./dokka-base-2.0.0.jar;./analysis-kotlin-descriptors-2.0.0.jar;./kotlinx-html-jvm-0.8.0.jar;./freemarker-
2.3.31.jar" \
     -sourceSet "-src /home/myCoolProject/src/main/kotlin" \
     -outputDir "./dokka/html"
```

Executing the given example generates documentation in HTML output format.

See Command line options for more configuration details.

Run with JSON configuration

It's possible to configure the CLI runner with JSON. In this case, you need to provide an absolute/relative path to the JSON configuration file as the first and only argument. All other configuration options are parsed from it.

```
java -jar dokka-cli-2.0.0.jar dokka-configuration.json
```

At the very least, you need the following JSON configuration file:

```
{
  "outputDir": "./dokka/html",
  "sourceSets": [
    {
      "sourceSetID": {
        "scopeId": "moduleName",
        "sourceSetName": "main"
      },
      "sourceRoots": [
        "/home/myCoolProject/src/main/kotlin"
      ]
    }
  ],
  "pluginsClasspath": [
    "./dokka-base-2.0.0.jar",
    "./kotlinx-html-jvm-0.8.0.jar",
    "./analysis-kotlin-descriptors-2.0.0.jar",
    "./freemarker-2.3.31.jar"
  ]
}
```

See JSON configuration options for more details.

Other output formats

By default, the dokka-base artifact contains the HTML output format only.

All other output formats are implemented as Dokka plugins. In order to use them, you have to put them on the plugins classpath.

For example, if you want to generate documentation in the experimental GFM output format, you need to download and pass gfm-plugin's JAR (download) into the pluginsClasspath configuration option.

Via command line options:

```
java -jar dokka-cli-2.0.0.jar \
     -pluginsClasspath "./dokka-base-2.0.0.jar;...;./gfm-plugin-2.0.0.jar" \
     ...
```

Via JSON configuration:

```
{
  ...
  "pluginsClasspath": [
    "./dokka-base-2.0.0.jar",
    "...",
    "./gfm-plugin-2.0.0.jar"
  ],
  ...
}
```

With the GFM plugin passed to pluginsClasspath, the CLI runner generates documentation in the GFM output format.

For more information, see Markdown and Javadoc pages.

Command line options

To see the list of all possible command line options and their detailed description, run:

```
java -jar dokka-cli-2.0.0.jar -help
```

Short summary:

Option	Description
moduleName	Name of the project/module.
moduleVersion	Documented version.
outputDir	Output directory path, ./dokka by default.
sourceSet	Configuration for a Dokka source set. Contains nested configuration options.
pluginsConfiguration	Configuration for Dokka plugins.
pluginsClasspath	List of jars with Dokka plugins and their dependencies. Accepts multiple paths separated by semicolons.
offlineMode	Whether to resolve remote files/links over network.
failOnWarning	Whether to fail documentation generation if Dokka has emitted a warning or an error.

Option	Description
delayTemplateSubstitution	Whether to delay substitution of some elements. Used in incremental builds of multi-module projects.
noSuppressObviousFunctions	Whether to suppress obvious functions such as those inherited from kotlin.Any and java.lang.Object.
includes	Markdown files that contain module and package documentation. Accepts multiple values separated by semicolons.
suppressInheritedMembers	Whether to suppress inherited members that aren't explicitly overridden in a given class.
globalPackageOptions	Global list of package configuration options in format "matchingRegex,-deprecated,-privateApi,+warnUndocumented,+suppress;+visibility:PUBLIC;...". Accepts multiple values separated by semicolons.
globalLinks	Global external documentation links in format {url}^{packageListUrl}. Accepts multiple values separated by ^^.
globalSrcLink	Global mapping between a source directory and a Web service for browsing the code. Accepts multiple paths separated by semicolons.
helpSourceSet	Prints help for the nested -sourceSet configuration.
loggingLevel	Logging level, possible values: DEBUG, PROGRESS, INFO, WARN, ERROR.
help, h	Usage info.

Source set options

To see the list of command line options for the nested -sourceSet configuration, run:

```
java -jar dokka-cli-2.0.0.jar -sourceSet -help
```

Short summary:

Option	Description
sourceSetName	Name of the source set.
displayName	Display name of the source set, used both internally and externally.
classpath	Classpath for analysis and interactive samples. Accepts multiple paths separated by semicolons.
src	Source code roots to be analyzed and documented. Accepts multiple paths separated by semicolons.

Option	Description
dependentSourceSets	Names of the dependent source sets in format moduleName/sourceSetName. Accepts multiple values separated by semicolons.
samples	List of directories or files that contain sample functions. Accepts multiple paths separated by semicolons.
includes	Markdown files that contain module and package documentation. Accepts multiple paths separated by semicolons.
documentedVisibilities	Visibilities to be documented. Accepts multiple values separated by semicolons. Possible values: PUBLIC, PRIVATE, PROTECTED, INTERNAL, PACKAGE.
reportUndocumented	Whether to report undocumented declarations.
noSkipEmptyPackages	Whether to create pages for empty packages.
skipDeprecated	Whether to skip deprecated declarations.
jdkVersion	Version of JDK to use for linking to JDK Javadocs.
languageVersion	Language version used for setting up analysis and samples.
apiVersion	Kotlin API version used for setting up analysis and samples.
noStdlibLink	Whether to generate links to the Kotlin standard library.
noJdkLink	Whether to generate links to JDK Javadocs.
suppressedFiles	Paths to files to be suppressed. Accepts multiple paths separated by semicolons.
analysisPlatform	Platform used for setting up analysis.
perPackageOptions	List of package source set configurations in format matchingRegexp,-deprecated,-privateApi,+warnUndocumented,+suppress;.... Accepts multiple values separated by semicolons.
externalDocumentationLinks	External documentation links in format {url}^{packageListUrl}. Accepts multiple values separated by ^^.
srcLink	Mapping between a source directory and a Web service for browsing the code. Accepts multiple paths separated by semicolons.

JSON configuration

Below are some examples and detailed descriptions for each configuration section. You can also find an example with all configuration options applied at the bottom of the page.

General configuration

```
{
  "moduleName": "Dokka Example",
  "moduleVersion": null,
  "outputDir": "./build/dokka/html",
  "failOnWarning": false,
  "suppressObviousFunctions": true,
  "suppressInheritedMembers": false,
  "offlineMode": false,
  "includes": [
    "module.md"
  ],
  "sourceLinks":  [
    { "_comment": "Options are described in a separate section" }
  ],
  "perPackageOptions": [
    { "_comment": "Options are described in a separate section" }
  ],
  "externalDocumentationLinks":  [
    { "_comment": "Options are described in a separate section" }
  ],
  "sourceSets": [
    { "_comment": "Options are described in a separate section" }
  ],
  "pluginsClasspath": [
    "./dokka-base-2.0.0.jar",
    "./kotlinx-html-jvm-0.8.0.jar",
    "./analysis-kotlin-descriptors-2.0.0.jar",
    "./freemarker-2.3.31.jar"
  ]
}
```

moduleName
The display name used to refer to the module. It is used for the table of contents, navigation, logging, etc.

Default: root

moduleVersion
The module version.

Default: empty

outputDirectory
The directory to where documentation is generated, regardless of output format.

Default: ./dokka

failOnWarning
Whether to fail documentation generation if Dokka has emitted a warning or an error. The process waits until all errors and warnings have been emitted first.

This setting works well with reportUndocumented

Default: false

suppressObviousFunctions
Whether to suppress obvious functions.

A function is considered to be obvious if it is:

- Inherited from kotlin.Any, Kotlin.Enum, java.lang.Object or java.lang.Enum, such as equals, hashCode, toString.
- Synthetic (generated by the compiler) and does not have any documentation, such as dataClass.componentN or dataClass.copy.

Default: true

suppressInheritedMembers
Whether to suppress inherited members that aren't explicitly overridden in a given class.

Note: This can suppress functions such as equals/hashCode/toString, but cannot suppress synthetic functions such as dataClass.componentN and dataClass.copy. Use suppressObviousFunctions for that.

Default: false

offlineMode

Whether to resolve remote files/links over your network.

This includes package-lists used for generating external documentation links. For example, to make classes from the standard library clickable.

Setting this to true can significantly speed up build times in certain cases, but can also worsen documentation quality and user experience. For example, by not resolving class/member links from your dependencies, including the standard library.

Note: You can cache fetched files locally and provide them to Dokka as local paths. See externalDocumentationLinks section.

Default: false

includes

A list of Markdown files that contain module and package documentation.

The contents of specified files are parsed and embedded into documentation as module and package descriptions.

This can be configured on per-package basis.

sourceSets

Individual and additional configuration of Kotlin source sets.

For a list of possible options, see source set configuration.

sourceLinks

The global configuration of source links that is applied for all source sets.

For a list of possible options, see source link configuration.

perPackageOptions

The global configuration of matched packages, regardless of the source set they are in.

For a list of possible options, see per-package configuration.

externalDocumentationLinks

The global configuration of external documentation links, regardless of the source set they are used in.

For a list of possible options, see external documentation links configuration.

pluginsClasspath

A list of JAR files with Dokka plugins and their dependencies.

Source set configuration

How to configure Kotlin source sets:

```
{
  "sourceSets": [
    {
      "displayName": "jvm",
      "sourceSetID": {
        "scopeId": "moduleName",
        "sourceSetName": "main"
      },
      "dependentSourceSets": [
        {
          "scopeId": "dependentSourceSetScopeId",
          "sourceSetName": "dependentSourceSetName"
        }
      ],
      "documentedVisibilities": ["PUBLIC", "PRIVATE", "PROTECTED", "INTERNAL", "PACKAGE"],
      "reportUndocumented": false,
      "skipEmptyPackages": true,
      "skipDeprecated": false,
      "jdkVersion": 8,
      "languageVersion": "1.7",
      "apiVersion": "1.7",
      "noStdlibLink": false,
      "noJdkLink": false,
      "includes": [
        "module.md"
      ],
      "analysisPlatform": "jvm",
      "sourceRoots": [
        "/home/ignat/IdeaProjects/dokka-debug-mvn/src/main/kotlin"
      ],
      "classpath": [
        "libs/kotlin-stdlib-2.2.0.jar",
        "libs/kotlin-stdlib-common-2.2.0.jar"
      ],
      "samples": [
        "samples/basic.kt"
      ],
      "suppressedFiles": [
        "src/main/kotlin/org/jetbrains/dokka/Suppressed.kt"
      ],
      "sourceLinks":  [
        { "_comment": "Options are described in a separate section" }
      ],
      "perPackageOptions": [
        { "_comment": "Options are described in a separate section" }
      ],
      "externalDocumentationLinks":  [
        { "_comment": "Options are described in a separate section" }
      ]
    }
  ]
}
```

displayName

The display name used to refer to this source set.

The name is used both externally (for example, the source set name is visible to documentation readers) and internally (for example, for logging messages of reportUndocumented).

The platform name can be used if you don't have a better alternative.

sourceSetID

The technical ID of the source set

documentedVisibilities

The set of visibility modifiers that should be documented.

This can be used if you want to document protected/internal/private declarations, as well as if you want to exclude public declarations and only document internal API.

This can be configured on per-package basis.

Possible values:

- PUBLIC
- PRIVATE
- PROTECTED
- INTERNAL
- PACKAGE

Default: PUBLIC

reportUndocumented

Whether to emit warnings about visible undocumented declarations, that is declarations without KDocs after they have been filtered by documentedVisibilities and other filters.

This setting works well with failOnWarning.

This can be configured on per-package basis.

Default: false

skipEmptyPackages

Whether to skip packages that contain no visible declarations after various filters have been applied.

For example, if skipDeprecated is set to true and your package contains only deprecated declarations, it is considered to be empty.

Default for CLI runner is false.

skipDeprecated

Whether to document declarations annotated with @Deprecated.

This can be configured on per-package basis.

Default: false

jdkVersion
The JDK version to use when generating external documentation links for Java types.

For example, if you use java.util.UUID in some public declaration signature, and this option is set to 8, Dokka generates an external documentation link to JDK 8 Javadocs for it.

languageVersion
The Kotlin language version used for setting up analysis and @sample environment.

apiVersion
The Kotlin API version used for setting up analysis and @sample environment.

noStdlibLink
Whether to generate external documentation links that lead to the API reference documentation of Kotlin's standard library.

Note: Links are generated when noStdLibLink is set to false.

Default: false

noJdkLink
Whether to generate external documentation links to JDK's Javadocs.

The version of JDK Javadocs is determined by the jdkVersion option.

Note: Links are generated when noJdkLink is set to false.

Default: false

includes
A list of Markdown files that contain module and package documentation.

The contents of the specified files are parsed and embedded into documentation as module and package descriptions.

analysisPlatform
Platform to be used for setting up code analysis and @sample environment.

Possible values:

- jvm
- common
- js
- native

sourceRoots
The source code roots to be analyzed and documented. Acceptable inputs are directories and individual .kt/.java files.

classpath
The classpath for analysis and interactive samples.

This is useful if some types that come from dependencies are not resolved/picked up automatically.

This option accepts both .jar and .klib files.

samples
A list of directories or files that contain sample functions which are referenced via the @sample KDoc tag.

suppressedFiles
The files to be suppressed when generating documentation.

sourceLinks
A set of parameters for source links that is applied only for this source set.

For a list of possible options, see source link configuration.

perPackageOptions
A set of parameters specific to matched packages within this source set.

For a list of possible options, see per-package configuration.

externalDocumentationLinks
A set of parameters for external documentation links that is applied only for this source set.

For a list of possible options, see external documentation links configuration.

Source link configuration

The sourceLinks configuration block allows you to add a source link to each signature that leads to the remoteUrl with a specific line number. (The line number is configurable by setting remoteLineSuffix).

This helps readers to find the source code for each declaration.

For an example, see the documentation for the count() function in kotlinx.coroutines.

You can configure source links for all source sets together at the same time, or individually:

```
{
  "sourceLinks": [
    {
      "localDirectory": "src/main/kotlin",
      "remoteUrl": "https://github.com/Kotlin/dokka/tree/master/src/main/kotlin",
      "remoteLineSuffix": "#L"
    }
  ]
}
```

localDirectory
The path to the local source directory.

remoteUrl
The URL of the source code hosting service that can be accessed by documentation readers, like GitHub, GitLab, Bitbucket, etc. This URL is used to generate source code links of declarations.

remoteLineSuffix
The suffix used to append the source code line number to the URL. This helps readers navigate not only to the file, but to the specific line number of the declaration.

The number itself is appended to the specified suffix. For example, if this option is set to #L and the line number is 10, the resulting URL suffix is #L10.

Suffixes used by popular services:

- GitHub: #L
- GitLab: #L
- Bitbucket: #lines-

Default: empty (no suffix)

Per-package configuration

The perPackageOptions configuration block allows setting some options for specific packages matched by matchingRegex.

You can add package configurations for all source sets together at the same time, or individually:

```
{
  "perPackageOptions": [
    {
      "matchingRegex": ".*internal.*",
      "suppress": false,
      "skipDeprecated": false,
      "reportUndocumented": false,
      "documentedVisibilities": ["PUBLIC", "PRIVATE", "PROTECTED", "INTERNAL", "PACKAGE"]
    }
  ]
}
```

matchingRegex
The regular expression that is used to match the package.

suppress
Whether this package should be skipped when generating documentation.

Default: false

skipDeprecated

Whether to document declarations annotated with @Deprecated.

This can be set on project/module level.

Default: false

reportUndocumented

Whether to emit warnings about visible undocumented declarations, that is declarations without KDocs after they have been filtered by documentedVisibilities and other filters.

This setting works well with failOnWarning.

This can be configured on source set level.

Default: false

documentedVisibilities

The set of visibility modifiers that should be documented.

This can be used if you want to document protected/internal/private declarations within this package, as well as if you want to exclude public declarations and only document internal API.

Can be configured on source set level.

Default: PUBLIC

External documentation links configuration

The externalDocumentationLinks block allows the creation of links that lead to the externally hosted documentation of your dependencies.

For example, if you are using types from kotlinx.serialization, by default they are unclickable in your documentation, as if they are unresolved. However, since the API reference documentation for kotlinx.serialization is built by Dokka and is published on kotlinlang.org, you can configure external documentation links for it. Thus allowing Dokka to generate links for types from the library, making them resolve successfully and clickable.

You can configure external documentation links for all source sets together at the same time, or individually:

```
{
  "externalDocumentationLinks": [
    {
      "url": "https://kotlinlang.org/api/kotlinx.serialization/",
      "packageListUrl": "https://kotlinlang.org/api/kotlinx.serialization/package-list"
    }
  ]
}
```

url

The root URL of documentation to link to. It must contain a trailing slash.

Dokka does its best to automatically find package-list for the given URL, and link declarations together.

If automatic resolution fails or if you want to use locally cached files instead, consider setting the packageListUrl option.

packageListUrl

The exact location of a package-list. This is an alternative to relying on Dokka automatically resolving it.

Package lists contain information about the documentation and the project itself, such as module and package names.

This can also be a locally cached file to avoid network calls.

Complete configuration

Below you can see all possible configuration options applied at the same time.

```
{
  "moduleName": "Dokka Example",
  "moduleVersion": null,
  "outputDir": "./build/dokka/html",
  "failOnWarning": false,
  "suppressObviousFunctions": true,
  "suppressInheritedMembers": false,
  "offlineMode": false,
  "sourceLinks": [
    {
      "localDirectory": "src/main/kotlin",
      "remoteUrl": "https://github.com/Kotlin/dokka/tree/master/src/main/kotlin",
      "remoteLineSuffix": "#L"
    }
  ],
  "externalDocumentationLinks": [
    {
      "url": "https://docs.oracle.com/javase/8/docs/api/",
      "packageListUrl": "https://docs.oracle.com/javase/8/docs/api/package-list"
    },
    {
      "url": "https://kotlinlang.org/api/core/kotlin-stdlib/",
      "packageListUrl": "https://kotlinlang.org/api/core/kotlin-stdlib/package-list"
    }
  ],
  "perPackageOptions": [
    {
      "matchingRegex": ".*internal.*",
      "suppress": false,
      "reportUndocumented": false,
      "skipDeprecated": false,
      "documentedVisibilities": ["PUBLIC", "PRIVATE", "PROTECTED", "INTERNAL", "PACKAGE"]
    }
  ],
  "sourceSets": [
    {
      "displayName": "jvm",
      "sourceSetID": {
        "scopeId": "moduleName",
        "sourceSetName": "main"
      },
      "dependentSourceSets": [
        {
          "scopeId": "dependentSourceSetScopeId",
          "sourceSetName": "dependentSourceSetName"
        }
      ],
      "documentedVisibilities": ["PUBLIC", "PRIVATE", "PROTECTED", "INTERNAL", "PACKAGE"],
      "reportUndocumented": false,
      "skipEmptyPackages": true,
      "skipDeprecated": false,
      "jdkVersion": 8,
      "languageVersion": "1.7",
      "apiVersion": "1.7",
      "noStdlibLink": false,
      "noJdkLink": false,
      "includes": [
        "module.md"
      ],
      "analysisPlatform": "jvm",
      "sourceRoots": [
        "/home/ignat/IdeaProjects/dokka-debug-mvn/src/main/kotlin"
      ],
      "classpath": [
        "libs/kotlin-stdlib-2.2.0.jar",
        "libs/kotlin-stdlib-common-2.2.0.jar"
      ],
      "samples": [
        "samples/basic.kt"
      ],
      "suppressedFiles": [
        "src/main/kotlin/org/jetbrains/dokka/Suppressed.kt"
      ],
      "sourceLinks": [
        {
          "localDirectory": "src/main/kotlin",
          "remoteUrl": "https://github.com/Kotlin/dokka/tree/master/src/main/kotlin",
          "remoteLineSuffix": "#L"
        }
      ],
      "externalDocumentationLinks": [
        {
          "url": "https://docs.oracle.com/javase/8/docs/api/",
          "packageListUrl": "https://docs.oracle.com/javase/8/docs/api/package-list"
        },
        {
          "url": "https://kotlinlang.org/api/core/kotlin-stdlib/",
          "packageListUrl": "https://kotlinlang.org/api/core/kotlin-stdlib/package-list"
        }
      ],
      "perPackageOptions": [
        {
          "matchingRegex": ".*internal.*",
          "suppress": false,
          "reportUndocumented": false,
          "skipDeprecated": false,
          "documentedVisibilities": ["PUBLIC", "PRIVATE", "PROTECTED", "INTERNAL", "PACKAGE"]
        }
      ]
    }
  ],
  "pluginsClasspath": [
    "./dokka-base-2.0.0.jar",
    "./kotlinx-html-jvm-0.8.0.jar",
    "./analysis-kotlin-descriptors-2.0.0.jar",
    "./freemarker-2.3.31.jar"
  ],
  "pluginsConfiguration": [
    {
      "fqPluginName": "org.jetbrains.dokka.base.DokkaBase",
      "serializationFormat": "JSON",
      "values": "{\"separateInheritedMembers\":false,\"footerMessage\":\"© 2021 pretty good Copyright\"}"
    }
  ],
  "includes": [
    "module.md"
  ]
}
```

HTML

HTML is Dokka's default and recommended output format. It is currently in Beta and approaching the Stable release.

You can see an example of the output by browsing documentation for kotlinx.coroutines.

Generate HTML documentation

HTML as an output format is supported by all runners. To generate HTML documentation, follow these steps depending on your build tool or runner:

- For Gradle, run dokkaHtml or dokkaHtmlMultiModule tasks.
- For Maven, run the dokka:dokka goal.
- For CLI runner, run with HTML dependencies set.

HTML pages generated by this format need to be hosted on a web server in order to render everything correctly.

You can use any free static site hosting service, such as GitHub Pages.

Locally, you can use the built-in IntelliJ web server.

Configuration

HTML format is Dokka's base format, so it is configurable through DokkaBase and DokkaBaseConfiguration classes:

Kotlin

Via type-safe Kotlin DSL:

```
import org.jetbrains.dokka.base.DokkaBase
import org.jetbrains.dokka.gradle.DokkaTask
import org.jetbrains.dokka.base.DokkaBaseConfiguration

buildscript {
    dependencies {
        classpath("org.jetbrains.dokka:dokka-base:2.0.0")
    }
}

tasks.withType<DokkaTask>().configureEach {
    pluginConfiguration<DokkaBase, DokkaBaseConfiguration> {
        customAssets = listOf(file("my-image.png"))
        customStyleSheets = listOf(file("my-styles.css"))
        footerMessage = "(c) 2022 MyOrg"
        separateInheritedMembers = false
        templatesDir = file("dokka/templates")
        mergeImplicitExpectActualDeclarations = false
    }
}
```

Via JSON:

```
import org.jetbrains.dokka.gradle.DokkaTask

tasks.withType<DokkaTask>().configureEach {
    val dokkaBaseConfiguration = """
    {
      "customAssets": ["${file("assets/my-image.png")}"],
      "customStyleSheets": ["${file("assets/my-styles.css")}"],
      "footerMessage": "(c) 2022 MyOrg",
      "separateInheritedMembers": false,
      "templatesDir": "${file("dokka/templates")}",
      "mergeImplicitExpectActualDeclarations": false
    }
    """
    pluginsMapConfiguration.set(
        mapOf(
            // fully qualified plugin name to json configuration
            "org.jetbrains.dokka.base.DokkaBase" to dokkaBaseConfiguration
        )
    )
}
```

Groovy

```
import org.jetbrains.dokka.gradle.DokkaTask

tasks.withType(DokkaTask.class) {
    String dokkaBaseConfiguration = """
    {
      "customAssets": ["${file("assets/my-image.png")}"],
      "customStyleSheets": ["${file("assets/my-styles.css")}"],
      "footerMessage": "(c) 2022 MyOrg"
      "separateInheritedMembers": false,
      "templatesDir": "${file("dokka/templates")}",
      "mergeImplicitExpectActualDeclarations": false
    }
    """
    pluginsMapConfiguration.set(
            // fully qualified plugin name to json configuration
            ["org.jetbrains.dokka.base.DokkaBase": dokkaBaseConfiguration]
    )
}
```

Maven

```
<plugin>
    <groupId>org.jetbrains.dokka</groupId>
    <artifactId>dokka-maven-plugin</artifactId>
    ...
    <configuration>
        <pluginsConfiguration>
            <!-- Fully qualified plugin name -->
            <org.jetbrains.dokka.base.DokkaBase>
                <!-- Options by name -->
                <customAssets>
                    <asset>${project.basedir}/my-image.png</asset>
                </customAssets>
                <customStyleSheets>
                    <stylesheet>${project.basedir}/my-styles.css</stylesheet>
                </customStyleSheets>
                <footerMessage>(c) MyOrg 2022 Maven</footerMessage>
                <separateInheritedMembers>false</separateInheritedMembers>
                <templatesDir>${project.basedir}/dokka/templates</templatesDir>
                <mergeImplicitExpectActualDeclarations>false</mergeImplicitExpectActualDeclarations>
            </org.jetbrains.dokka.base.DokkaBase>
        </pluginsConfiguration>
    </configuration>
</plugin>
```

CLI

Via command line options:

```
java -jar dokka-cli-2.0.0.jar \
     ...
     -pluginsConfiguration "org.jetbrains.dokka.base.DokkaBase={\"customAssets\": [\"my-image.png\"], \"customStyleSheets\": [\"my-styles.css\"], \"footerMessage\": \"(c) 2022 MyOrg\", \"separateInheritedMembers\": false, \"templatesDir\": \"dokka/templates\", \"mergeImplicitExpectActualDeclarations\": false}
"
```

Via JSON configuration:

```
{
  "moduleName": "Dokka Example",
  "pluginsConfiguration": [
    {
      "fqPluginName": "org.jetbrains.dokka.base.DokkaBase",
      "serializationFormat": "JSON",
      "values": "{\"customAssets\": [\"my-image.png\"], \"customStyleSheets\": [\"my-styles.css\"], \"footerMessage\": \"(c) 2022 MyOrg\", \"separateInheritedMembers\": false, \"templatesDir\": \"dokka/templates\", \"mergeImplicitExpectActualDeclarations\": false}"
    }
  ]
}
```

Configuration options

The table below contains all of the possible configuration options and their purpose.

Option	Description
customAssets	List of paths for image assets to be bundled with documentation. The image assets can have any file extension. For more information, see Customizing assets.
customStyleSheets	List of paths for .css stylesheets to be bundled with documentation and used for rendering. For more information, see Customizing styles.
templatesDir	Path to the directory containing custom HTML templates. For more information, see Templates.
footerMessage	The text displayed in the footer.
separateInheritedMembers	This is a boolean option. If set to true, Dokka renders properties/functions and inherited properties/inherited functions separately. This is disabled by default.
mergeImplicitExpectActualDeclarations	This is a boolean option. If set to true, Dokka merges declarations that are not declared as expect/actual, but have the same fully qualified name. This can be useful for legacy codebases. This is disabled by default.

For more information about configuring Dokka plugins, see Configuring Dokka plugins.

Customization

To help you add your own look and feel to your documentation, the HTML format supports a number of customization options.

Customize styles

You can use your own stylesheets by using the customStyleSheets configuration option. These are applied to every page.

It's also possible to override Dokka's default stylesheets by providing files with the same name:

Stylesheet name	Description
style.css	Main stylesheet, contains most of the styles used across all pages
logo-styles.css	Header logo styling
prism.css	Styles for PrismJS syntax highlighter

The source code for all of Dokka's stylesheets is available on GitHub.

Customize assets

You can provide your own images to be bundled with documentation by using the customAssets configuration option.

These files are copied to the <output>/images directory.

It's possible to override Dokka's images and icons by providing files with the same name. The most useful and relevant one being logo-icon.svg, which is the image that's used in the header. The rest is mostly icons.

You can find all images used by Dokka on GitHub.

Change the logo

To customize the logo, you can begin by providing your own asset for logo-icon.svg.

If you don't like how it looks, or you want to use a .png file instead of the default .svg file, you can override the logo-styles.css stylesheet to customize it.

For an example of how to do this, see our custom format example project.

The maximum supported logo dimensions are 120 pixels in width and 36 pixels in height. If you use a larger image, it will be automatically resized.

Modify the footer

You can modify text in the footer by using the footerMessage configuration option.

Templates

Dokka provides the ability to modify FreeMarker templates used for generating documentation pages.

You can change the header completely, add your own banners/menus/search, load analytics, change body styling and so on.

Dokka uses the following templates:

Template	Description
base.ftl	Defines the general design of all pages to be rendered.

Template	Description
includes/header.ftl	The page header that by default contains the logo, version, source set selector, light/dark theme switch, and search.
includes/footer.ftl	The page footer that contains the footerMessage configuration option and copyright.
includes/page_metadata.ftl	Metadata used within <head> container.
includes/source_set_selector.ftl	The source set selector in the header.

The base template is base.ftl and it includes all of the remaining listed templates. You can find the source code for all of Dokka's templates on GitHub.

You can override any template by using the templatesDir configuration option. Dokka searches for the exact template names within the given directory. If it fails to find user-defined templates, it uses the default templates.

Variables

The following variables are available inside all templates:

Variable	Description
${pageName}	The page name
${footerMessage}	The text which is set by the footerMessage configuration option
${sourceSets}	A nullable list of source sets for multi-platform pages. Each item has name, platform, and filter properties.
${projectName}	The project name. It's available only within the template_cmd directive.
${pathToRoot}	The path to root from the current page. It's useful for locating assets and is available only within the template_cmd directive.

Variables projectName and pathToRoot are available only within the template_cmd directive as they require more context and thus they need to be resolved at later stages by the MultiModule task:

```
<@template_cmd name="projectName">
   <span>${projectName}</span>
</@template_cmd>
```

Directives

You can also use the following Dokka-defined directives:

Variable	Description
<@content/>	The main page content.

Variable	Description
<@resources/>	Resources such as scripts and stylesheets.
<@version/>	The module version taken from configuration. If the versioning plugin is applied, it is replaced with a version navigator.

Markdown

The Markdown output formats are still in Alpha, so you may find bugs and experience migration issues when using them. You use them at your own risk.

Dokka is able to generate documentation in GitHub Flavored and Jekyll compatible Markdown.

These formats give you more freedom in terms of hosting documentation as the output can be embedded right into your documentation website. For example, see OkHttp's API reference pages.

Markdown output formats are implemented as Dokka plugins, maintained by the Dokka team, and they are open source.

GFM

The GFM output format generates documentation in GitHub Flavored Markdown.

Gradle

The Gradle plugin for Dokka comes with the GFM output format included. You can use the following tasks with it:

Task	Description
dokkaGfm	Generates GFM documentation for a single project.
dokkaGfmMultiModule	A MultiModule task created only for parent projects in multi-project builds. It generates documentation for subprojects and collects all outputs in a single place with a common table of contents.
dokkaGfmCollector	A Collector task created only for parent projects in multi-project builds. It callsdokkaGfm for every subproject and merges all outputs into a single virtual project.

Maven

Since GFM format is implemented as a Dokka plugin, you need to apply it as a plugin dependency:

```
<plugin>
    <groupId>org.jetbrains.dokka</groupId>
    <artifactId>dokka-maven-plugin</artifactId>
    ...
    <configuration>
        <dokkaPlugins>
            <plugin>
                <groupId>org.jetbrains.dokka</groupId>
                <artifactId>gfm-plugin</artifactId>
                <version>2.0.0</version>
            </plugin>
        </dokkaPlugins>
    </configuration>
</plugin>
```

After configuring this, running the dokka:dokka goal produces documentation in GFM format.

For more information, see the Maven plugin documentation for Other output formats.

CLI

Since GFM format is implemented as a Dokka plugin, you need to download the JAR file and pass it to pluginsClasspath.

Via command line options:

```
java -jar dokka-cli-2.0.0.jar \
     -pluginsClasspath "./dokka-base-2.0.0.jar;...;./gfm-plugin-2.0.0.jar" \
     ...
```

Via JSON configuration:

```
{
  ...
  "pluginsClasspath": [
    "./dokka-base-2.0.0.jar",
    "...",
    "./gfm-plugin-2.0.0.jar"
  ],
  ...
}
```

For more information, see the CLI runner's documentation for Other output formats.

You can find the source code on GitHub.

Jekyll

The Jekyll output format generates documentation in Jekyll compatible Markdown.

Gradle

The Gradle plugin for Dokka comes with the Jekyll output format included. You can use the following tasks with it:

Task	Description
dokkaJekyll	Generates Jekyll documentation for a single project.
dokkaJekyllMultiModule	A MultiModule task created only for parent projects in multi-project builds. It generates documentation for subprojects and collects all outputs in a single place with a common table of contents.
dokkaJekyllCollector	A Collector task created only for parent projects in multi-project builds. It calls dokkaJekyll for every subproject and merges all outputs into a single virtual project.

Maven

Since Jekyll format is implemented as a Dokka plugin, you need to apply it as a plugin dependency:

```
<plugin>
    <groupId>org.jetbrains.dokka</groupId>
    <artifactId>dokka-maven-plugin</artifactId>
    ...
    <configuration>
        <dokkaPlugins>
            <plugin>
                <groupId>org.jetbrains.dokka</groupId>
                <artifactId>jekyll-plugin</artifactId>
                <version>2.0.0</version>
            </plugin>
        </dokkaPlugins>
    </configuration>
</plugin>
```

After configuring this, running the dokka:dokka goal produces documentation in GFM format.

For more information, see the Maven plugin's documentation for Other output formats.

CLI

Since Jekyll format is implemented as a Dokka plugin, you need to download the JAR file. This format is also based on GFM format, so you need to provide it as a dependency as well. Both JARs need to be passed to pluginsClasspath:

Via command line options:

```
java -jar dokka-cli-2.0.0.jar \
     -pluginsClasspath "./dokka-base-2.0.0.jar;...;./gfm-plugin-2.0.0.jar;./jekyll-plugin-2.0.0.jar" \
     ...
```

Via JSON configuration:

```
{
  ...
  "pluginsClasspath": [
    "./dokka-base-2.0.0.jar",
    "...",
    "./gfm-plugin-2.0.0.jar",
    "./jekyll-plugin-2.0.0.jar"
  ],
  ...
}
```

For more information, see the CLI runner's documentation for Other output formats.

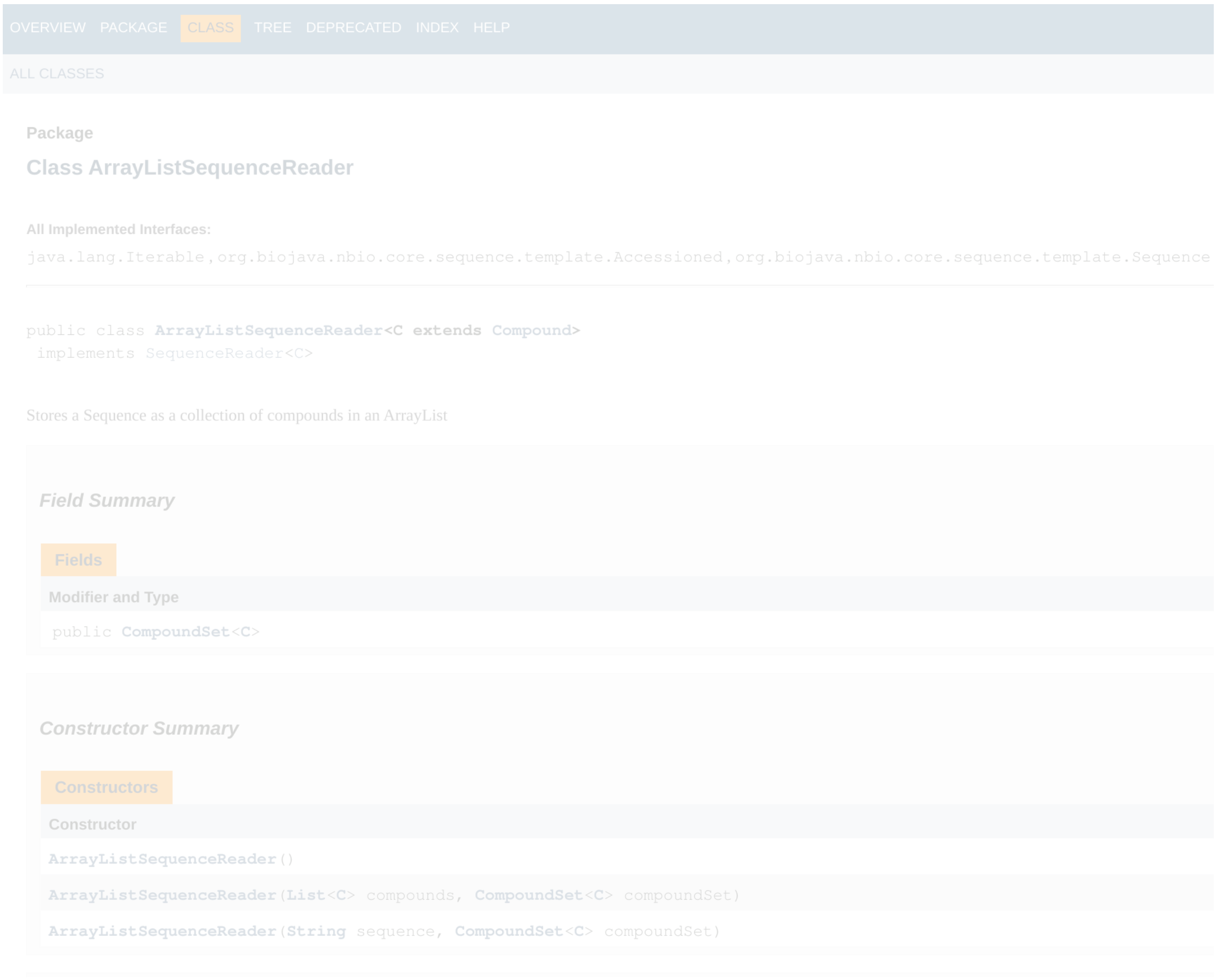
You can find the source code on GitHub.

Javadoc

The Javadoc output format is still in Alpha, so you may find bugs and experience migration issues when using it. Successful integration with tools that accept Java's Javadoc HTML as input is not guaranteed. You use it at your own risk.

Dokka's Javadoc output format is a lookalike of Java's Javadoc HTML format.

It tries to visually mimic HTML pages generated by the Javadoc tool, but it's not a direct implementation or an exact copy.


OVERVIEW PACKAGE CLASS TREE DEPRECATED INDEX HELP

ALL CLASSES

Package

Class ArrayListSequenceReader

All Implemented Interfaces:

java.lang.Iterable,org.biojava.nbio.core.sequence.template.Accessioned,org.biojava.nbio.core.sequence.template.Sequence

```
public class ArrayListSequenceReader<C extends Compound>
 implements SequenceReader<C>
```

Stores a Sequence as a collection of compounds in an ArrayList

Field Summary

Fields

Modifier and Type
`public CompoundSet<C>`

Constructor Summary

Constructors

Constructor
`ArrayListSequenceReader()`
`ArrayListSequenceReader(List<C> compounds, CompoundSet<C> compoundSet)`
`ArrayListSequenceReader(String sequence, CompoundSet<C> compoundSet)`

Screenshot of javadoc output format

All Kotlin code and signatures are rendered as seen from Java's perspective. This is achieved with our Kotlin as Java Dokka plugin, which comes bundled and applied by default for this format.

The Javadoc output format is implemented as a Dokka plugin, and it is maintained by the Dokka team. It is open source and you can find the source code on GitHub.

Generate Javadoc documentation

The Javadoc format does not support multiplatform projects.

Gradle

The Gradle plugin for Dokka comes with the Javadoc output format included. You can use the following tasks:

Task	Description
dokkaJavadoc	Generates Javadoc documentation for a single project.

Task	Description
dokkaJavadocCollector	A Collector task created only for parent projects in multi-project builds. It callsdokkaJavadoc for every subproject and merges all outputs into a single virtual project.

The javadoc.jar file can be generated separately. For more information, seeBuilding javadoc.jar.

Maven

The Maven plugin for Dokka comes with the Javadoc output format built in. You can generate documentation by using the following goals:

Goal	Description
dokka:javadoc	Generates documentation in Javadoc format
dokka:javadocJar	Generates a javadoc.jar file that contains documentation in Javadoc format

CLI

Since the Javadoc output format is a Dokka plugin, you need to download the plugin's JAR file.

The Javadoc output format has two dependencies that you need to provide as additional JAR files:

- kotlin-as-java plugin
- korte-jvm

Via command line options:

```
java -jar dokka-cli-2.0.0.jar \
     -pluginsClasspath "./dokka-base-2.0.0.jar;...;./javadoc-plugin-2.0.0.jar" \
     ...
```

Via JSON configuration:

```
{
  ...
  "pluginsClasspath": [
    "./dokka-base-2.0.0.jar",
    "...",
    "./kotlin-as-java-plugin-2.0.0.jar",
    "./korte-jvm-3.3.0.jar",
    "./javadoc-plugin-2.0.0.jar"
  ],
  ...
}
```

For more information, see Other output formats in the CLI runner's documentation.

Dokka plugins

Dokka was built from the ground up to be easily extensible and highly customizable, which allows the community to implement plugins for missing or very specific features that are not provided out of the box.

Dokka plugins range anywhere from supporting other programming language sources to exotic output formats. You can add support for your own KDoc tags or annotations, teach Dokka how to render different DSLs that are found in KDoc descriptions, visually redesign Dokka's pages to be seamlessly integrated into your company's website, integrate it with other tools and so much more.

If you want to learn how to create Dokka plugins, see Developer guides.

Apply Dokka plugins

Dokka plugins are published as separate artifacts, so to apply a Dokka plugin you only need to add it as a dependency. From there, the plugin extends Dokka by itself - no further action is needed.

> Plugins that use the same extension points or work in a similar way can interfere with each other. This may lead to visual bugs, general undefined behaviour or even failed builds. However, it should not lead to concurrency issues since Dokka does not expose any mutable data structures or objects.
>
> If you notice problems like this, it's a good idea to check which plugins are applied and what they do.

Let's have a look at how you can apply the mathjax plugin to your project:

Kotlin

The Gradle plugin for Dokka creates convenient dependency configurations that allow you to apply plugins universally or for a specific output format only.

```
dependencies {
    // Is applied universally
    dokkaPlugin("org.jetbrains.dokka:mathjax-plugin:2.0.0")

    // Is applied for the single-module dokkaHtml task only
    dokkaHtmlPlugin("org.jetbrains.dokka:kotlin-as-java-plugin:2.0.0")

    // Is applied for HTML format in multi-project builds
    dokkaHtmlPartialPlugin("org.jetbrains.dokka:kotlin-as-java-plugin:2.0.0")
}
```

> When documenting multi-project builds, you need to apply Dokka plugins within subprojects as well as in their parent project.

Groovy

The Gradle plugin for Dokka creates convenient dependency configurations that allow you to apply Dokka plugins universally or for a specific output format only.

```
dependencies {
    // Is applied universally
    dokkaPlugin 'org.jetbrains.dokka:mathjax-plugin:2.0.0'

    // Is applied for the single-module dokkaHtml task only
    dokkaHtmlPlugin 'org.jetbrains.dokka:kotlin-as-java-plugin:2.0.0'

    // Is applied for HTML format in multi-project builds
    dokkaHtmlPartialPlugin 'org.jetbrains.dokka:kotlin-as-java-plugin:2.0.0'
}
```

> When documenting multi-project builds, you need to apply Dokka plugins within subprojects as well as in their parent project.

Maven

```
<plugin>
    <groupId>org.jetbrains.dokka</groupId>
    <artifactId>dokka-maven-plugin</artifactId>
    ...
    <configuration>
        <dokkaPlugins>
            <plugin>
                <groupId>org.jetbrains.dokka</groupId>
                <artifactId>mathjax-plugin</artifactId>
                <version>2.0.0</version>
            </plugin>
        </dokkaPlugins>
    </configuration>
</plugin>
```

CLI

If you are using the CLI runner with command line options, Dokka plugins should be passed as .jar files to -pluginsClasspath:

```
java -jar dokka-cli-2.0.0.jar \
     -pluginsClasspath "./dokka-base-2.0.0.jar;...;./mathjax-plugin-2.0.0.jar" \
     ...
```

If you are using JSON configuration, Dokka plugins should be specified under pluginsClasspath.

```
{
  ...
  "pluginsClasspath": [
    "./dokka-base-2.0.0.jar",
    "...",
    "./mathjax-plugin-2.0.0.jar"
  ],
  ...
}
```

Configure Dokka plugins

Dokka plugins can also have configuration options of their own. To see which options are available, consult the documentation of the plugins you are using.

Let's have a look at how you can configure the DokkaBase plugin, which is responsible for generating HTML documentation, by adding a custom image to the assets (customAssets option), by adding custom style sheets (customStyleSheets option), and by modifying the footer message (footerMessage option):

Kotlin

Gradle's Kotlin DSL allows for type-safe plugin configuration. This is achievable by adding the plugin's artifact to the classpath dependencies in the buildscript block, and then importing plugin and configuration classes:

```
import org.jetbrains.dokka.base.DokkaBase
import org.jetbrains.dokka.gradle.DokkaTask
import org.jetbrains.dokka.base.DokkaBaseConfiguration

buildscript {
    dependencies {
        classpath("org.jetbrains.dokka:dokka-base:2.0.0")
    }
}

tasks.withType<DokkaTask>().configureEach {
    pluginConfiguration<DokkaBase, DokkaBaseConfiguration> {
        customAssets = listOf(file("my-image.png"))
        customStyleSheets = listOf(file("my-styles.css"))
        footerMessage = "(c) 2022 MyOrg"
    }
}
```

Alternatively, plugins can be configured via JSON. With this method, no additional dependencies are needed.

```
import org.jetbrains.dokka.gradle.DokkaTask

tasks.withType<DokkaTask>().configureEach {
    val dokkaBaseConfiguration = """
    {
      "customAssets": ["${file("assets/my-image.png")}"],
      "customStyleSheets": ["${file("assets/my-styles.css")}"],
      "footerMessage": "(c) 2022 MyOrg"
    }
    """
    pluginsMapConfiguration.set(
        mapOf(
            // fully qualified plugin name to json configuration
            "org.jetbrains.dokka.base.DokkaBase" to dokkaBaseConfiguration
        )
    )
}
```

Groovy

```
import org.jetbrains.dokka.gradle.DokkaTask

tasks.withType(DokkaTask.class) {
    String dokkaBaseConfiguration = """
    {
      "customAssets": ["${file("assets/my-image.png")}"],
      "customStyleSheets": ["${file("assets/my-styles.css")}"],
      "footerMessage": "(c) 2022 MyOrg"
    }
    """
    pluginsMapConfiguration.set(
            // fully qualified plugin name to json configuration
            ["org.jetbrains.dokka.base.DokkaBase": dokkaBaseConfiguration]
    )
}
```

Maven

```
<plugin>
    <groupId>org.jetbrains.dokka</groupId>
    <artifactId>dokka-maven-plugin</artifactId>
    ...
    <configuration>
        <pluginsConfiguration>
            <!-- Fully qualified plugin name -->
            <org.jetbrains.dokka.base.DokkaBase>
                <!-- Options by name -->
                <customAssets>
                    <asset>${project.basedir}/my-image.png</asset>
                </customAssets>
                <customStyleSheets>
                    <stylesheet>${project.basedir}/my-styles.css</stylesheet>
                </customStyleSheets>
                <footerMessage>(c) MyOrg 2022 Maven</footerMessage>
            </org.jetbrains.dokka.base.DokkaBase>
        </pluginsConfiguration>
    </configuration>
</plugin>
```

CLI

If you are using the CLI runner with command line options, use the -pluginsConfiguration option that accepts JSON configuration in the form offullyQualifiedPluginName=json.

If you need to configure multiple plugins, you can pass multiple values separated by^^.

```
java -jar dokka-cli-2.0.0.jar \
     ...
     -pluginsConfiguration "org.jetbrains.dokka.base.DokkaBase={\"customAssets\": [\"my-image.png\"], \"customStyleSheets\": [\"my-
styles.css\"], \"footerMessage\": \"(c) 2022 MyOrg CLI\"}"
```

If you are using JSON configuration, there exists a similarpluginsConfiguration array that accepts JSON configuration invalues.

```
{
  "moduleName": "Dokka Example",
  "pluginsConfiguration": [
    {
      "fqPluginName": "org.jetbrains.dokka.base.DokkaBase",
      "serializationFormat": "JSON",
      "values": "{\"customAssets\": [\"my-image.png\"], \"customStyleSheets\": [\"my-styles.css\"], \"footerMessage\": \"(c) 2022
MyOrg\"}"
    }
  ]
}
```

Notable plugins

Here are some notable Dokka plugins that you might find useful:

Name	Description

Name	Description
Android documentation plugin	Improves the documentation experience on Android
Versioning plugin	Adds version selector and helps to organize documentation for different versions of your application/library
MermaidJS HTML plugin	Renders MermaidJS diagrams and visualizations found in KDocs
Mathjax HTML plugin	Pretty prints mathematics found in KDocs
Kotlin as Java plugin	Renders Kotlin signatures as seen from Java's perspective

If you are a Dokka plugin author and would like to add your plugin to this list, get in touch with maintainers via Slack or GitHub.

Module documentation

Documentation for a module as a whole, as well as packages in that module, can be provided as separate Markdown files.

File format

Inside the Markdown file, the documentation for the module as a whole and for individual packages is introduced by the corresponding first-level headings. The text of the heading must be Module <module name> for a module, and Package <package qualified name> for a package.

The file doesn't have to contain both module and package documentation. You can have files that contain only package or module documentation. You can even have a Markdown file per module or package.

Using Markdown syntax, you can add:

- Headings up to level 6
- Emphasis with bold or italic formatting
- Links
- Inline code
- Code blocks
- Blockquotes

Here's an example file containing both module and package documentation:

```
# Module kotlin-demo

This content appears under your module name.

# Package org.jetbrains.kotlin.demo

This content appears under your package name in the packages list.
It also appears under the first-level heading on your package's page.

## Level 2 heading for package org.jetbrains.kotlin.demo

Content after this heading is also part of documentation for `org.jetbrains.kotlin.demo`

# Package org.jetbrains.kotlin.demo2

This content appears under your package name in the packages list.
```

```
It also appears under the first-level heading on your package's page.

## Level 2 heading for package org.jetbrains.kotlin.demo2

Content after this heading is also part of documentation for `org.jetbrains.kotlin.demo2`
```

To explore an example project with Gradle, see Dokka gradle example.

Pass files to Dokka

To pass these files to Dokka, you need to use the relevant includes option for Gradle, Maven, or CLI:

Gradle

Use the includes option in Source set configuration.

Maven

Use the includes option in General configuration.

CLI

If you are using command line configuration, use the includes option in Source set options.

If you are using JSON configuration, use the includes option in General configuration.

IDEs for Kotlin development

JetBrains provides the official Kotlin support for the following IDEs and code editors: IntelliJ IDEA and Android Studio.

Other IDEs and code editors only have Kotlin community-supported plugins.

IntelliJ IDEA

IntelliJ IDEA is an IDE designed for JVM languages, such as Kotlin and Java, to maximize developer productivity. It does the routine and repetitive tasks for you by providing clever code completion, static code analysis, and refactorings. It lets you focus on the bright side of software development, making it not only productive but also an enjoyable experience.

The Kotlin plugin is bundled with each IntelliJ IDEA release. Each IDEA release introduces new features and upgrades that improve the experience for Kotlin developers in the IDE. See What's new in IntelliJ IDEA for the latest updates and improvements for Kotlin.

Read more about IntelliJ IDEA in the official documentation.

Android Studio

Android Studio is the official IDE for Android app development, based on IntelliJ IDEA. On top of IntelliJ's powerful code editor and developer tools, Android Studio offers even more features that enhance your productivity when building Android apps.

Kotlin plugin is bundled with each Android Studio release.

Read more about Android Studio in the official documentation.

Eclipse

Eclipse allows developers to write their applications in different programming languages, including Kotlin. It also has the Kotlin plugin: originally developed by JetBrains, now the Kotlin plugin is supported by the Kotlin community contributors.

You can install the Kotlin plugin manually from the Marketplace.

The Kotlin team manages the development and contribution process to the Kotlin plugin for Eclipse. If you want to contribute to the plugin, send a pull request to its repository on GitHub.

Compatibility with the Kotlin language versions

For IntelliJ IDEA and Android Studio, the Kotlin plugin is bundled with each release. When the new Kotlin version is released, these tools will suggest updating Kotlin to the latest version automatically. See the latest supported language version in Kotlin releases.

Other IDEs support

JetBrains doesn't provide Kotlin plugins for other IDEs. However, some of the other IDEs and source editors, such as Eclipse, Visual Studio Code, and Atom, have their own Kotlin plugins supported by the Kotlin community.

You can use any text editor to write the Kotlin code, but without IDE-related features: code formatting, debugging tools, and so on. To use Kotlin in text editors, you can download the latest Kotlin command-line compiler (kotlin-compiler-2.2.0.zip) from Kotlin GitHub Releases and install it manually. Also, you could use package managers, such as Homebrew, SDKMAN!, and Snap package.

What's next?

- Start your first project using IntelliJ IDEA IDE
- Create your first cross-platform mobile app using Android Studio

Migrate to Kotlin code style

Kotlin coding conventions and IntelliJ IDEA formatter

Kotlin coding conventions affect several aspects of writing idiomatic Kotlin, and a set of formatting recommendations aimed at improving Kotlin code readability is among them.

Unfortunately, the code formatter built into IntelliJ IDEA had to work long before this document was released and now has a default setup that produces different formatting from what is now recommended.

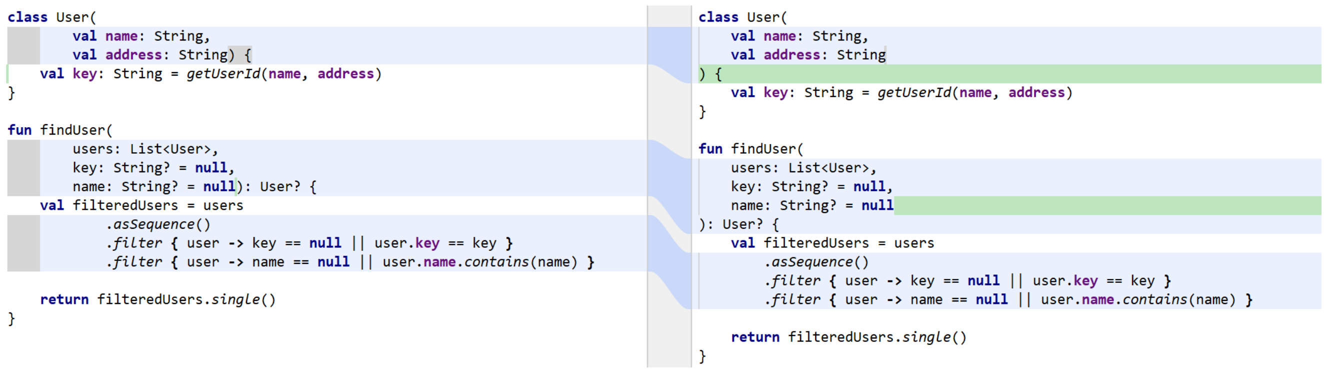
It may seem a logical next step to remove this obscurity by switching the defaults in IntelliJ IDEA and make formatting consistent with the Kotlin coding conventions. But this would mean that all the existing Kotlin projects will have a new code style enabled the moment the Kotlin plugin is installed. Not really the expected result for plugin update, right?

That's why we have the following migration plan instead:

- Enable the official code style formatting by default starting from Kotlin 1.3 and only for new projects (old formatting can be enabled manually)
- Authors of existing projects may choose to migrate to the Kotlin coding conventions
- Authors of existing projects may choose to explicitly declare using the old code style in a project (this way the project won't be affected by switching to the defaults in the future)
- Switch to the default formatting and make it consistent with Kotlin coding conventions in Kotlin 1.4

Differences between "Kotlin coding conventions" and "IntelliJ IDEA default code style"

The most notable change is in the continuation indentation policy. There's a nice idea to use the double indent for showing that a multi-line expression hasn't ended on the previous line. This is a very simple and general rule, but several Kotlin constructions look a bit awkward when they are formatted this way. In Kotlin coding conventions, it's recommended to use a single indent in cases where the long continuation indent has been forced before.



```
class User(
        val name: String,
        val address: String) {
    val key: String = getUserId(name, address)
}

fun findUser(
        users: List<User>,
        key: String? = null,
        name: String? = null): User? {
    val filteredUsers = users
            .asSequence()
            .filter { user -> key == null || user.key == key }
            .filter { user -> name == null || user.name.contains(name) }

    return filteredUsers.single()
}
```

```
class User(
    val name: String,
    val address: String
) {
    val key: String = getUserId(name, address)
}

fun findUser(
    users: List<User>,
    key: String? = null,
    name: String? = null
): User? {
    val filteredUsers = users
        .asSequence()
        .filter { user -> key == null || user.key == key }
        .filter { user -> name == null || user.name.contains(name) }

    return filteredUsers.single()
}
```

Code formatting

In practice, quite a bit of code is affected, so this can be considered a major code style update.

Migration to a new code style discussion

A new code style adoption might be a very natural process if it starts with a new project, when there's no code formatted in the old way. That is why starting from version 1.3, the Kotlin IntelliJ Plugin creates new projects with formatting from the Coding conventions document which is enabled by default.

Changing formatting in an existing project is a far more demanding task, and should probably be started with discussing all the caveats with the team.

The main disadvantage of changing the code style in an existing project is that the blame/annotate VCS feature will point to irrelevant commits more often. While each VCS has some kind of way to deal with this problem ("Annotate Previous Revision" can be used in IntelliJ IDEA), it's important to decide if a new style is worth all the effort. The practice of separating reformatting commits from meaningful changes can help a lot with later investigations.

Also migrating can be harder for larger teams because committing a lot of files in several subsystems may produce merging conflicts in personal branches. And while each conflict resolution is usually trivial, it's still wise to know if there are large feature branches currently in work.

In general, for small projects, we recommend converting all the files at once.

For medium and large projects the decision may be tough. If you are not ready to update many files right away you may decide to migrate module by module, or continue with gradual migration for modified files only.

Migration to a new code style

Switching to the Kotlin Coding Conventions code style can be done in Settings/Preferences | Editor | Code Style | Kotlin dialog. Switch scheme to Project and activate Set from... | Kotlin style guide.

In order to share those changes for all project developers .idea/codeStyle folder have to be committed to VCS.

If an external build system is used for configuring the project, and it's been decided not to share .idea/codeStyle folder, Kotlin coding conventions can be forced with an additional property:

In Gradle

Add kotlin.code.style=official property to the gradle.properties file at the project root and commit the file to VCS.

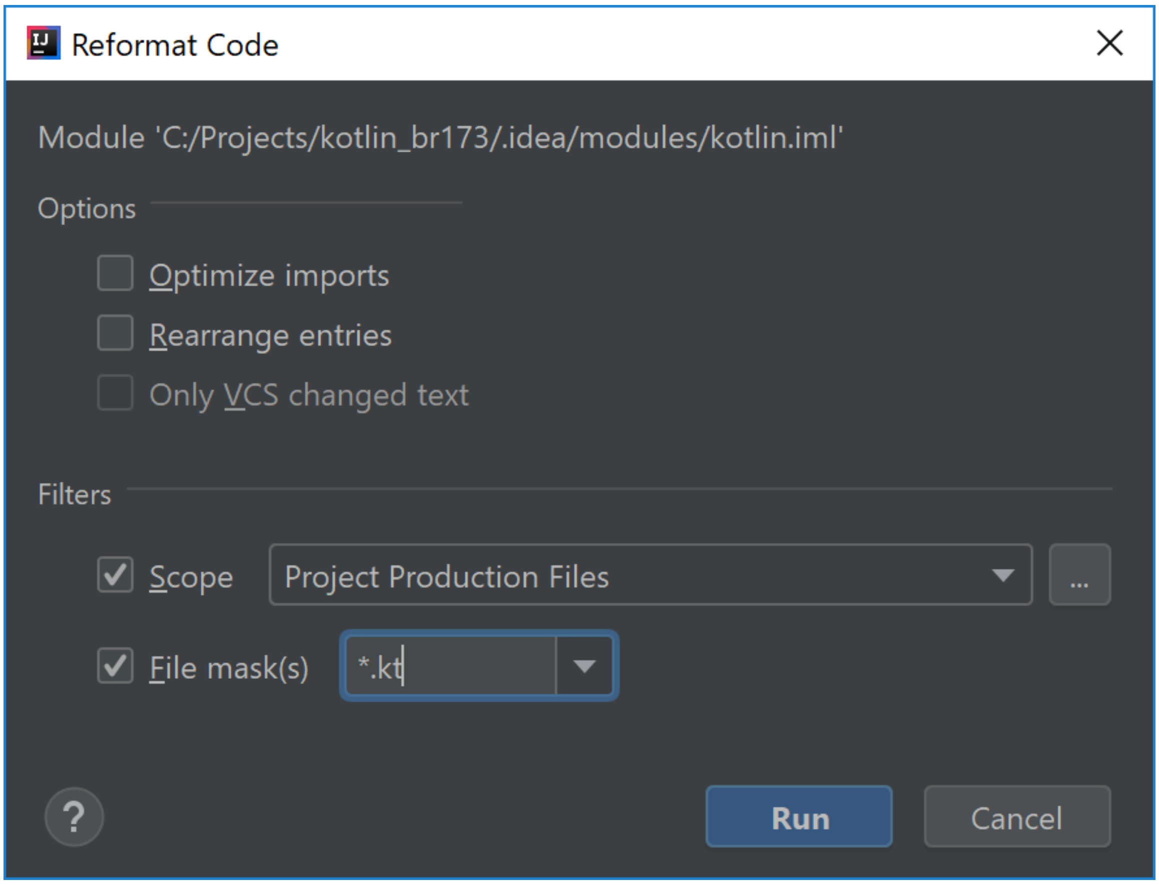
In Maven

Add kotlin.code.style official property to root pom.xml project file.

```
<properties>
  <kotlin.code.style>official</kotlin.code.style>
</properties>
```

Having the kotlin.code.style option set may modify the code style scheme during a project import and may change the code style settings.

After updating your code style settings, activate Reformat Code in the project view on the desired scope.


Reformat Code

Module 'C:/Projects/kotlin_br173/.idea/modules/kotlin.iml'

Options

☐ Optimize imports

☐ Rearrange entries

☐ Only VCS changed text

Filters

✓ Scope: Project Production Files

✓ File mask(s): *.kt

Reformat code

For a gradual migration, it's possible to enable the File is not formatted according to project settings inspection. It will highlight the places that should be reformatted. After enabling the Apply only to modified files option, inspection will show formatting problems only in modified files. Such files are probably going to be committed soon anyway.

Store old code style in project

It's always possible to explicitly set the IntelliJ IDEA code style as the correct code style for the project:

1. In Settings/Preferences | Editor | Code Style | Kotlin, switch to the Project scheme.
2. Open the Load/Save tab and in the Use defaults from select Kotlin obsolete IntelliJ IDEA codestyle.

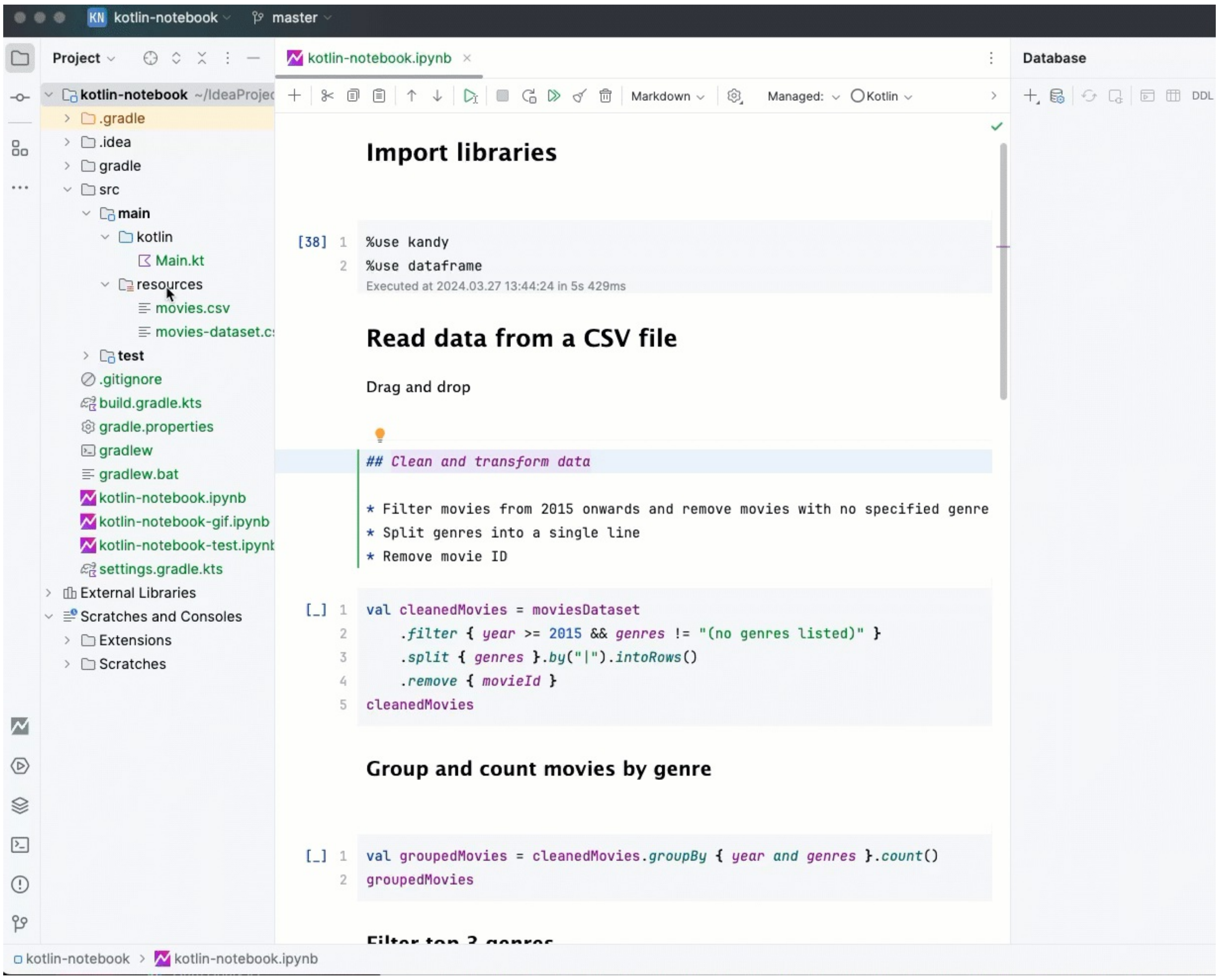
In order to share the changes across the project developers .idea/codeStyle folder, it has to be committed to VCS. Alternatively, kotlin.code.style=obsolete can be used for projects configured with Gradle or Maven.

Kotlin Notebook

Kotlin Notebook provides an interactive environment to create and edit notebooks, leveraging the full potential of Kotlin's capabilities.

Kotlin Notebook relies on the Kotlin Notebook plugin, which is bundled and enabled in IntelliJ IDEA by default.

Get ready for a seamless coding experience where you can develop and experiment with Kotlin code, receive immediate outputs, and integrate code, visuals, and text within the IntelliJ IDEA ecosystem.



Import libraries

```
[38]
%use kandy
%use dataframe
Executed at 2024.03.27 13:44:24 in 5s 429ms
```

Read data from a CSV file

Drag and drop

```
## Clean and transform data

* Filter movies from 2015 onwards and remove movies with no specified genre
* Split genres into a single line
* Remove movie ID
```

```
[_]
val cleanedMovies = moviesDataset
    .filter { year >= 2015 && genres != "(no genres listed)" }
    .split { genres }.by("|").intoRows()
    .remove { movieId }
cleanedMovies
```

Group and count movies by genre

```
[_]
val groupedMovies = cleanedMovies.groupBy { year and genres }.count()
groupedMovies
```

The Kotlin Notebook plugin comes with various features to boost your development process, such as:

- Accessing APIs within cells
- Importing and exporting files with a few clicks
- Using REPL commands for a quick project exploration
- Getting a rich set of output formats
- Managing dependencies intuitively with annotations or Gradle-like syntax
- Importing various libraries with a single line of code or even adding new libraries to your project
- Getting insights for debugging with error messages and traceback

Kotlin Notebook is based on our Kotlin Kernel for Jupyter Notebooks, making it easy to integrate with other Kotlin notebook solutions. Without compatibility issues, you can effortlessly share your work among Kotlin Notebook, Datalore, and Kotlin-Jupyter Notebook.

With these capabilities, you can embark on a wide range of tasks, from simple code experiments to comprehensive data projects.

Dive deeper into the sections below to discover what you can achieve with Kotlin Notebook!

Data analytics and visualization

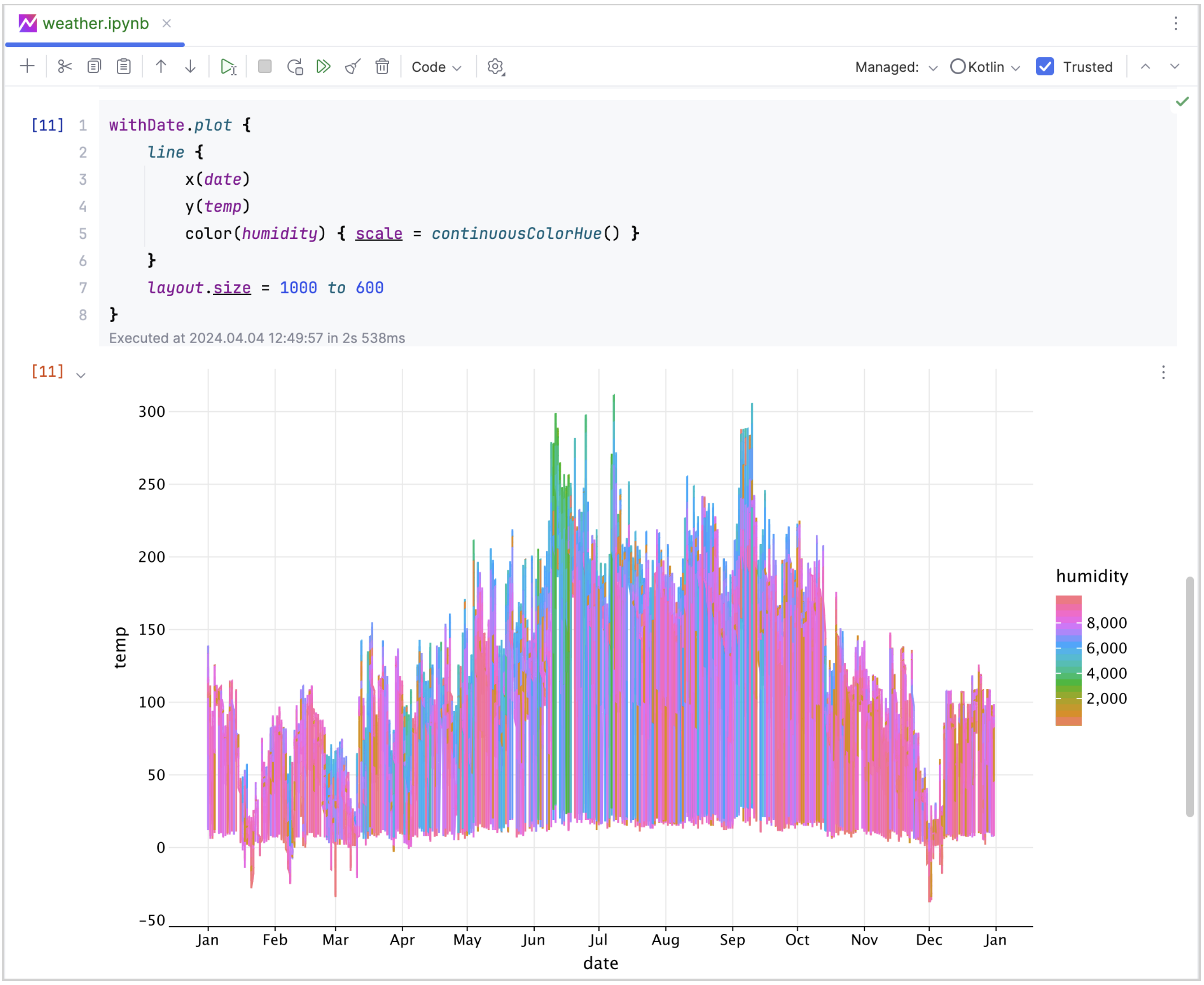
Whether you're conducting preliminary data exploration or completing an end-to-end data analysis project, Kotlin Notebook has the right tools for you.

Within Kotlin Notebook, you can intuitively integrate libraries that let you retrieve, transform, plot, and model your data while getting immediate outputs of your operations.

For analytics-related tasks, the Kotlin DataFrame library provides robust solutions. This library facilitates loading, creating, filtering, and cleaning structured data.

Kotlin DataFrame also supports seamless connection with SQL databases and reads data right in the IDE from different file formats, including CSV, JSON, and TXT.

Kandy, an open-source Kotlin library, allows you to create charts of various types. Kandy's idiomatic, readable, and type-safe features let you visualize data effectively and gain valuable insights.



```
withDate.plot {
    line {
        x(date)
        y(temp)
        color(humidity) { scale = continuousColorHue() }
    }
    layout.size = 1000 to 600
}
```

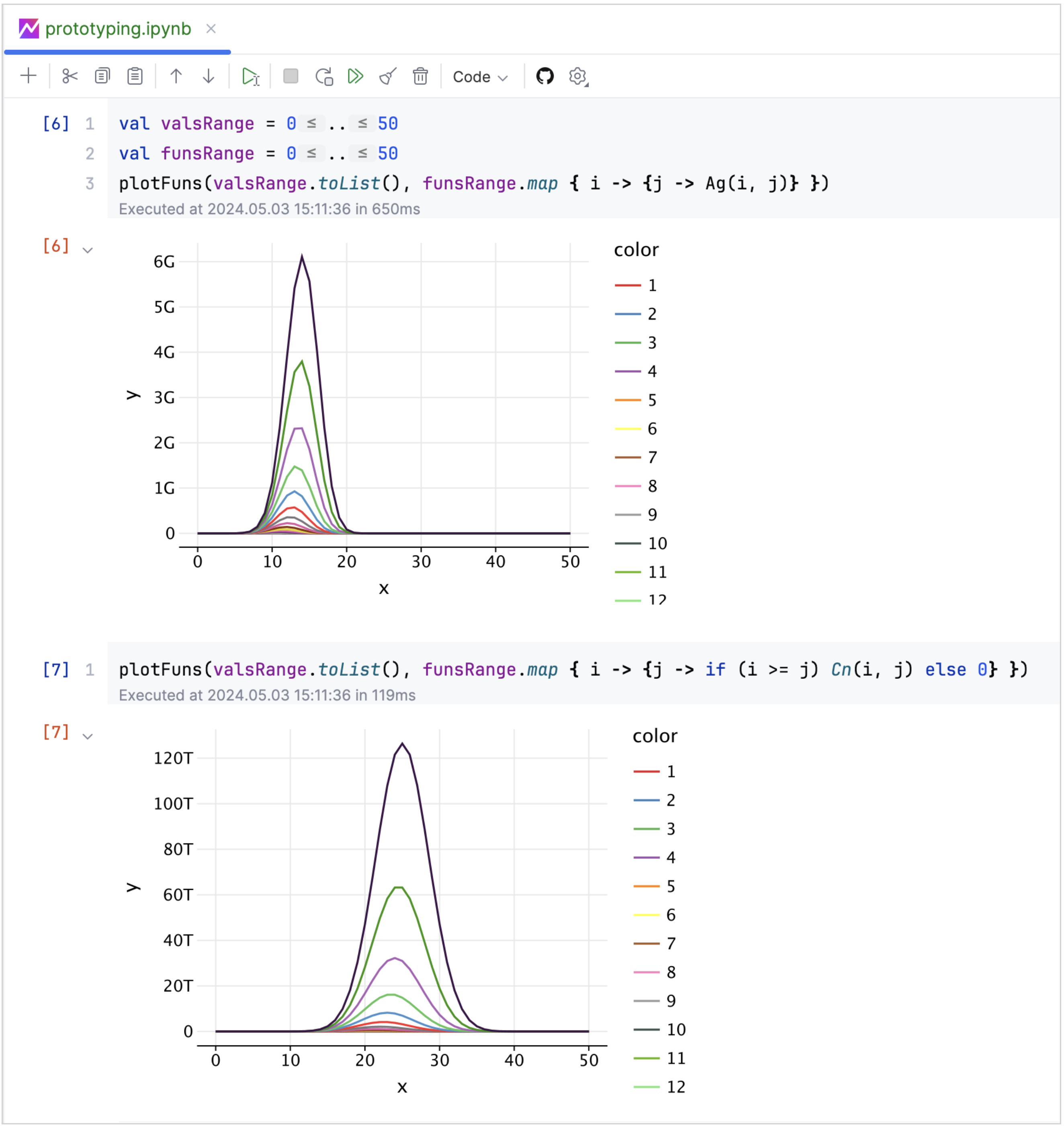
Executed at 2024.04.04 12:49:57 in 2s 538ms

data-analytics-and-visualization

Prototyping

Kotlin Notebook provides an interactive environment for running code in small chunks and seeing the results in real-time. This hands-on approach enables rapid experimentation and iteration during the prototyping phase.

With the help of Kotlin Notebook, you can test the concepts of solutions early in the ideation stage. Additionally, Kotlin Notebook supports both collaborative and reproducible work, enabling the generation and assessment of new ideas.



```
val valsRange = 0 ≤ .. ≤ 50
val funsRange = 0 ≤ .. ≤ 50
plotFuns(valsRange.toList(), funsRange.map { i -> {j -> Ag(i, j)} })
```

Executed at 2024.05.03 15:11:36 in 650ms

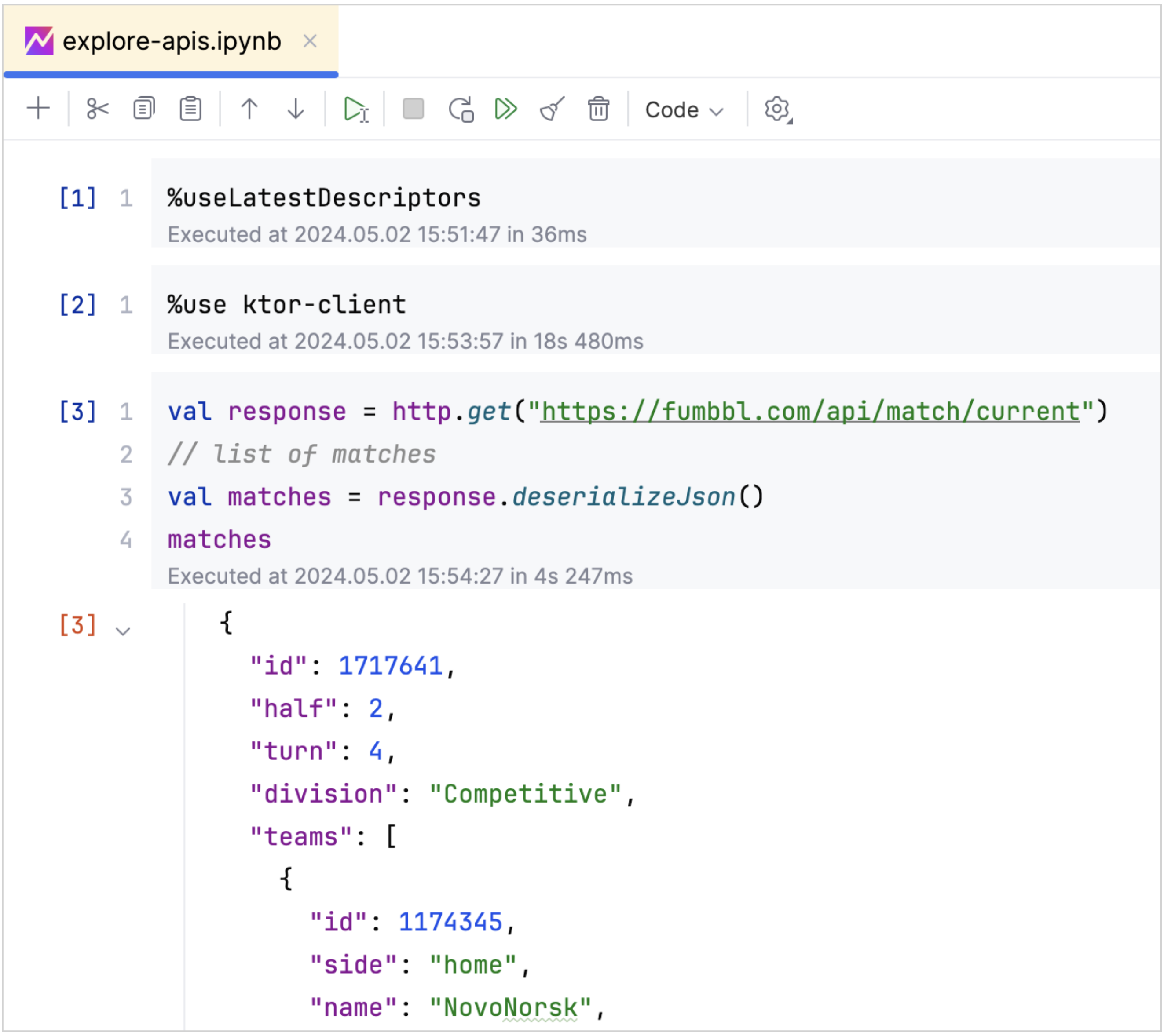
```
plotFuns(valsRange.toList(), funsRange.map { i -> {j -> if (i >= j) Cn(i, j) else 0} })
```

Executed at 2024.05.03 15:11:36 in 119ms

kotlin-notebook-prototyping

Backend development

Kotlin Notebook offers the ability to call APIs within cells and work with protocols like OpenAPI. Its capability to interact with external services and APIs makes it useful for certain backend development scenarios, such as retrieving information and reading JSON files directly within your notebook environment.



```
[1] %useLatestDescriptors
Executed at 2024.05.02 15:51:47 in 36ms

[2] %use ktor-client
Executed at 2024.05.02 15:53:57 in 18s 480ms

[3] val response = http.get("https://fumbbl.com/api/match/current")
    // list of matches
    val matches = response.deserializeJson()
    matches
Executed at 2024.05.02 15:54:27 in 4s 247ms
```

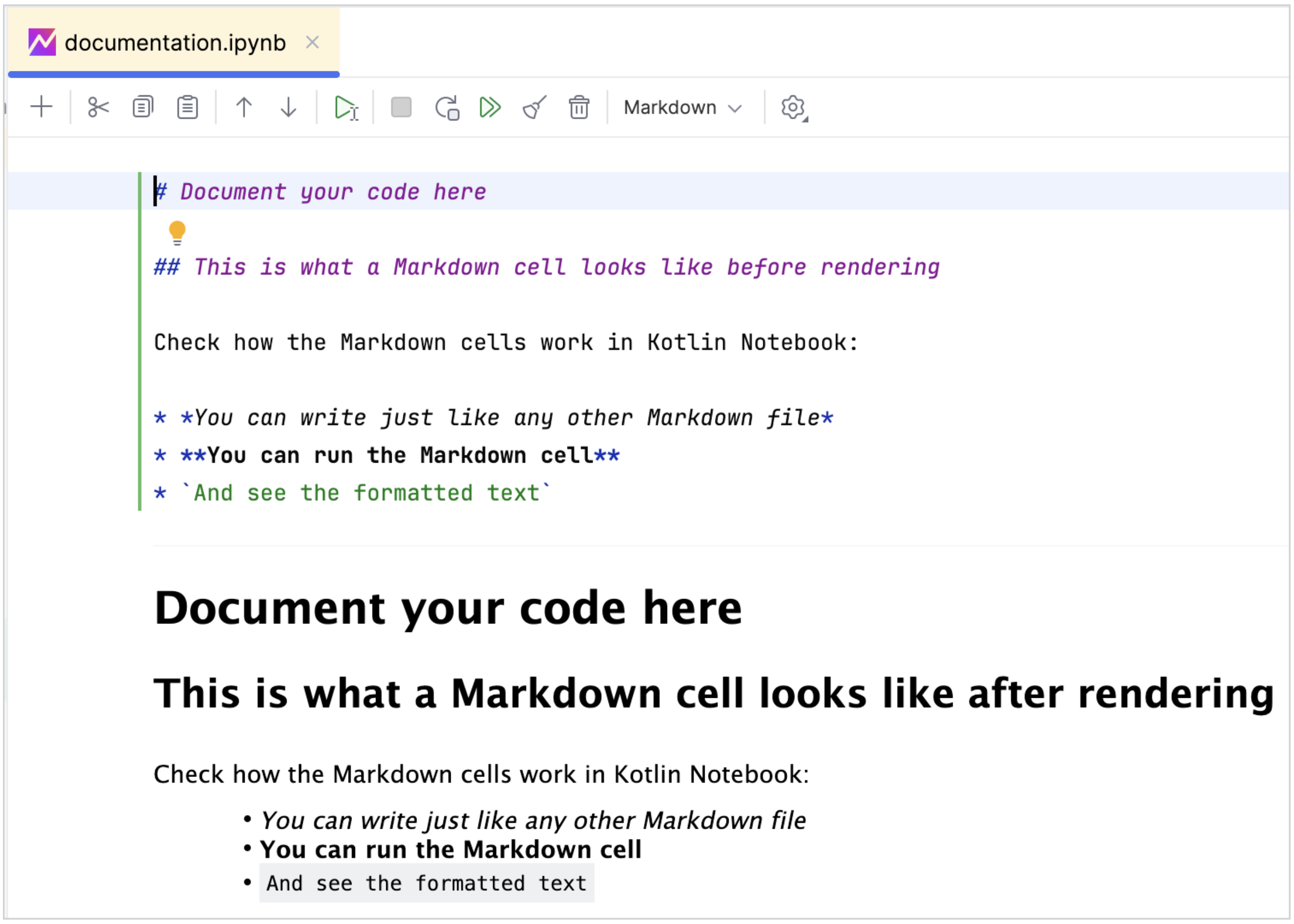
```
[3]  {
       "id": 1717641,
       "half": 2,
       "turn": 4,
       "division": "Competitive",
       "teams": [
         {
           "id": 1174345,
           "side": "home",
           "name": "NovoNorsk",
```

kotlin-notebook-backend-development

Code documentation

In Kotlin Notebook, you can include inline comments and text annotations within code cells to provide additional context, explanations, and instructions relevant to the code snippets.

You can also write text in Markdown cells, which support rich formatting options such as headers, lists, links, images, and more. To render a Markdown cell and see the formatted text, simply run it as you would a code cell.



```
# Document your code here

## This is what a Markdown cell looks like before rendering

Check how the Markdown cells work in Kotlin Notebook:

* *You can write just like any other Markdown file*
* **You can run the Markdown cell**
* `And see the formatted text`
```

Document your code here

This is what a Markdown cell looks like after rendering

Check how the Markdown cells work in Kotlin Notebook:

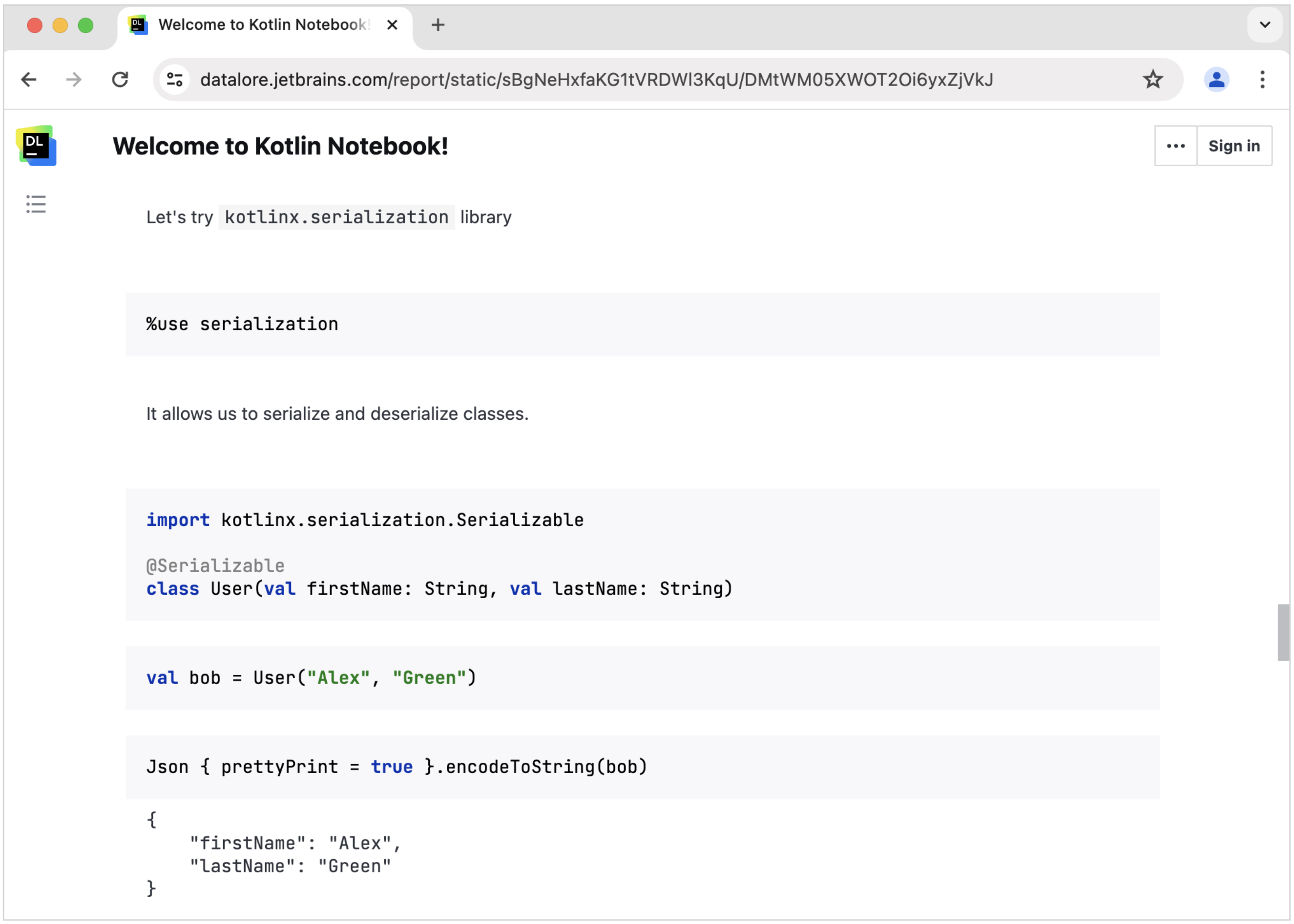
* *You can write just like any other Markdown file*
* **You can run the Markdown cell**
* `And see the formatted text`

kotlin-notebook-documenting

Sharing code and outputs

Given Kotlin Notebook's adherence to the universal Jupyter format, it's possible to share your code and outputs across different notebooks. You can open, edit, anc run your Kotlin Notebook with any Jupyter client, such as Jupyter Notebook or Jupyter Lab.

You can also distribute your work by sharing the .ipynb notebook file with any notebook web viewer. One option is GitHub, which natively renders this format. Another option is JetBrain's Datalore platform, which facilitates sharing, running, and editing notebooks with advanced features like scheduled notebook runs.


Welcome to Kotlin Notebook!
datalore.jetbrains.com/report/static/sBgNeHxfaKG1tVRDWI3KqU/DMtWM05XWOT2Oi6yxZjVkJ
Sign in

Welcome to Kotlin Notebook!

Let's try `kotlinx.serialization` library

```
%use serialization
```

It allows us to serialize and deserialize classes.

```
import kotlinx.serialization.Serializable

@Serializable
class User(val firstName: String, val lastName: String)
```

```
val bob = User("Alex", "Green")
```

```
Json { prettyPrint = true }.encodeToString(bob)
```

```
{
    "firstName": "Alex",
    "lastName": "Green"
}
```

kotlin-notebook-sharing-datalore

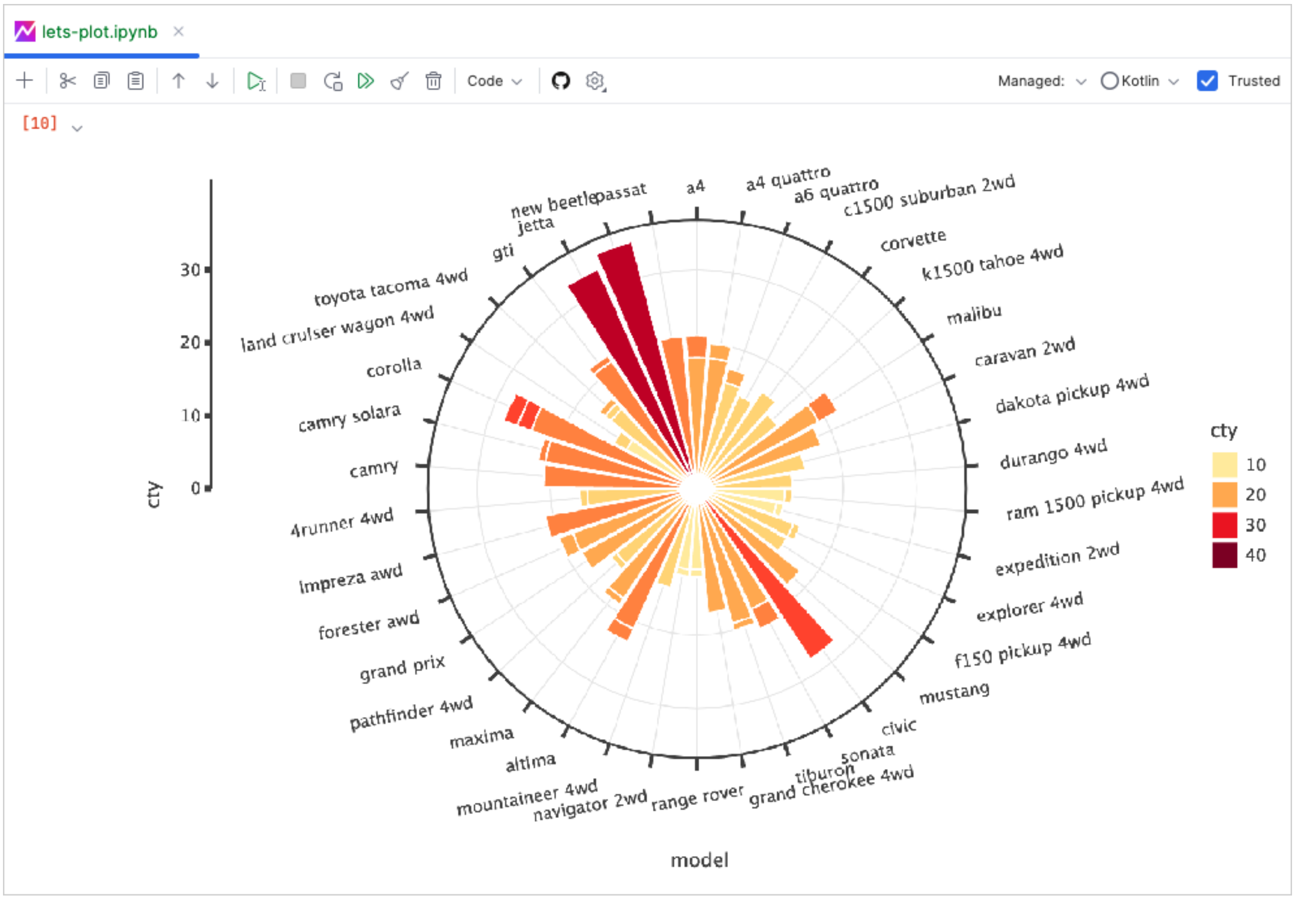
What's next

- Learn about the Kotlin Notebook's usage and key features.
- Try out Kotlin Notebook.
- Deep dive into Kotlin for data analysis.

Data visualization with Lets-Plot for Kotlin

Lets-Plot for Kotlin (LPK) is a multiplatform plotting library that ports the R's ggplot2 library to Kotlin. LPK brings the feature-rich ggplot2 API to the Kotlin ecosystem, making it suitable for scientists and statisticians who require sophisticated data visualization capabilities.

LPK targets various platforms, including Kotlin notebooks, Kotlin/JS, JVM's Swing, JavaFX, and Compose Multiplatform. Additionally, LPK has seamless integration with IntelliJ, DataGrip, DataSpell, and PyCharm.



Lets-Plot

This tutorial demonstrates how to create different plot types with the LPK and Kotlin DataFrame libraries using Kotlin Notebook in IntelliJ IDEA.

Before you start

Kotlin Notebook relies on the Kotlin Notebook plugin, which is bundled and enabled in IntelliJ IDEA by default.

If the Kotlin Notebook features are not available, ensure the plugin is enabled. For more information, see Set up an environment.

Create a new Kotlin Notebook to work with Lets-Plot:

1. Select File | New | Kotlin Notebook.

2. In your notebook, import the LPK and Kotlin DataFrame libraries by running the following command:

```
%use lets-plot
%use dataframe
```

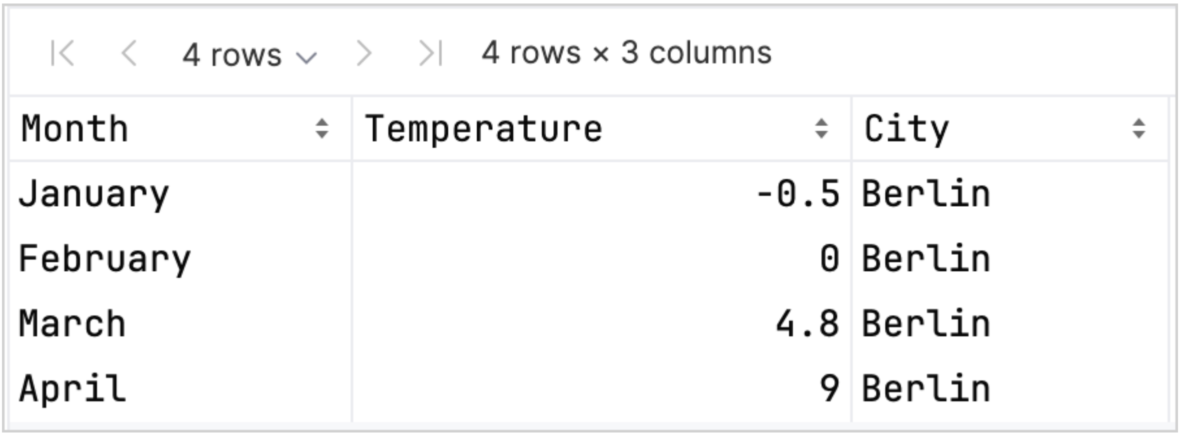
Prepare the data

Let's create a DataFrame that stores simulated numbers of the monthly average temperature in three cities: Berlin, Madrid, and Caracas.

Use the dataFrameOf() function from the Kotlin DataFrame library to generate the DataFrame. Paste and run the following code snippet in your Kotlin Notebook:

```
// The months variable stores a list with 12 months of the year
val months = listOf(
    "January", "February",
    "March", "April", "May",
    "June", "July", "August",
    "September", "October", "November",
    "December"
)
// The tempBerlin, tempMadrid, and tempCaracas variables store a list with temperature values for each month
val tempBerlin =
    listOf(-0.5, 0.0, 4.8, 9.0, 14.3, 17.5, 19.2, 18.9, 14.5, 9.7, 4.7, 1.0)
val tempMadrid =
    listOf(6.3, 7.9, 11.2, 12.9, 16.7, 21.1, 24.7, 24.2, 20.3, 15.4, 9.9, 6.6)
val tempCaracas =
    listOf(27.5, 28.9, 29.6, 30.9, 31.7, 35.1, 33.8, 32.2, 31.3, 29.4, 28.9, 27.6)

// The df variable stores a DataFrame of three columns, including monthly records, temperature, and cities
val df = dataFrameOf(
    "Month" to months + months + months,
    "Temperature" to tempBerlin + tempMadrid + tempCaracas,
    "City" to List(12) { "Berlin" } + List(12) { "Madrid" } + List(12) { "Caracas" }
)
df.head(4)
```

You can see that the DataFrame has three columns: Month, Temperature, and City. The first four rows of the DataFrame contain records of the temperature in Berlin from January to April:


4 rows
4 rows × 3 columns

Month	Temperature	City
January	-0.5	Berlin
February	0	Berlin
March	4.8	Berlin
April	9	Berlin

Dataframe exploration

To create a plot using the LPK library, you need to convert your data (df) into a Map type that stores the data in key-value pairs. You can easily convert a DataFrame into a Map using the .toMap() function:

```
val data = df.toMap()
```

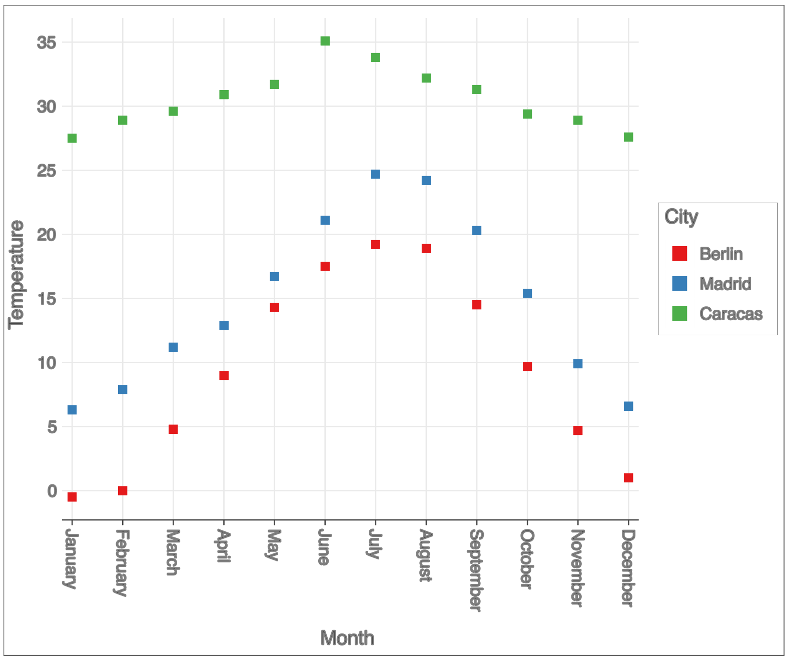
Create a scatter plot

Let's create a scatter plot in Kotlin Notebook with the LPK library.

Once you have your data in the Map format, use the geomPoint() function from the LPK library to generate the scatter plot. You can specify the values for the X and Y axes, as well as define categories and their color. Additionally, you can customize the plot's size and point shapes to suit your needs:

```
// Specifies X and Y axes, categories and their color, plot size, and plot type
val scatterPlot =
    letsPlot(data) { x = "Month"; y = "Temperature"; color = "City" } + ggsize(600, 500) + geomPoint(shape = 15)
scatterPlot
```

Here's the result:



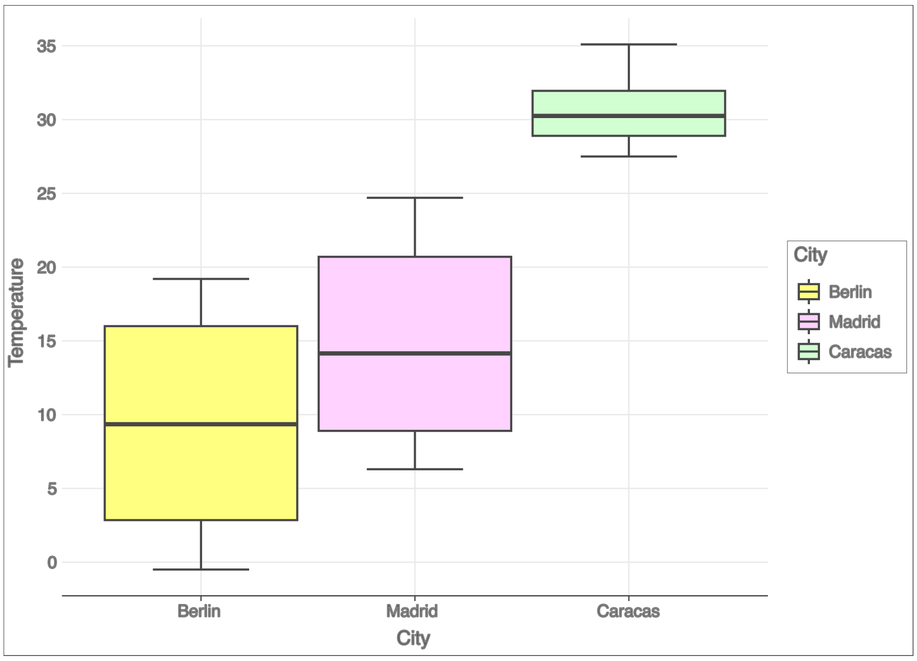
Scatter plot

Create a box plot

Let's visualize the data in a box plot. Use the geomBoxplot() function from the LPK library to generate the plot and customize colors with the scaleFillManual() function:

```
// Specifies X and Y axes, categories, plot size, and plot type
val boxPlot = ggplot(data) { x = "City"; y = "Temperature" } + ggsize(700, 500) + geomBoxplot { fill = "City" } +
    // Customizes colors
    scaleFillManual(values = listOf("light_yellow", "light_magenta", "light_green"))
boxPlot
```

Here's the result:



Box plot

Create a 2D density plot

Now, let's create a 2D density plot to visualize the distribution and concentration of some random data.

Prepare the data for the 2D density plot

1. Import the dependencies to process the data and generate the plot:

```
%use lets-plot

@file:DependsOn("org.apache.commons:commons-math3:3.6.1")
import org.apache.commons.math3.distribution.MultivariateNormalDistribution
```

> For more information about importing dependencies to Kotlin Notebook, see the Kotlin Notebook documentation.

2. Paste and run the following code snippet in your Kotlin Notebook to create sets of 2D data points:

```
// Defines covariance matrices for three distributions
val cov0: Array<DoubleArray> = arrayOf(
    doubleArrayOf(1.0, -.8),
    doubleArrayOf(-.8, 1.0)
)

val cov1: Array<DoubleArray> = arrayOf(
    doubleArrayOf(1.0, .8),
    doubleArrayOf(.8, 1.0)
)

val cov2: Array<DoubleArray> = arrayOf(
    doubleArrayOf(10.0, .1),
    doubleArrayOf(.1, .1)
)

// Defines the number of samples
val n = 400

// Defines means for three distributions
val means0: DoubleArray = doubleArrayOf(-2.0, 0.0)
val means1: DoubleArray = doubleArrayOf(2.0, 0.0)
val means2: DoubleArray = doubleArrayOf(0.0, 1.0)

// Generates random samples from three multivariate normal distributions
val xy0 = MultivariateNormalDistribution(means0, cov0).sample(n)
val xy1 = MultivariateNormalDistribution(means1, cov1).sample(n)
val xy2 = MultivariateNormalDistribution(means2, cov2).sample(n)
```

From the code above, the xy0, xy1, and xy2 variables store arrays with 2D (x, y) data points.

3. Convert your data into a Map type:

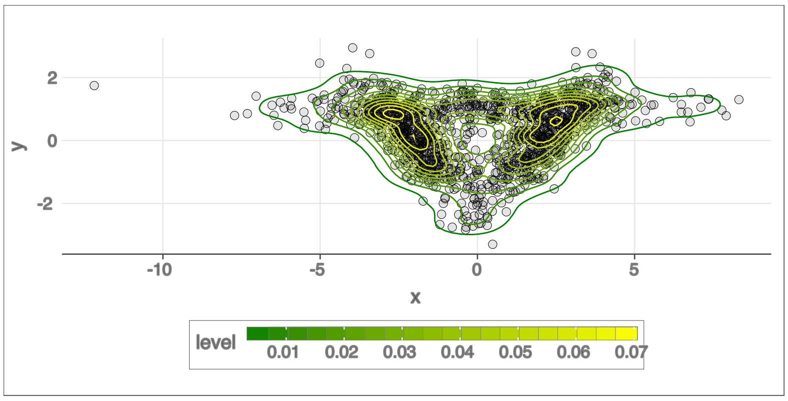
```
val data = mapOf(
    "x" to (xy0.map { it[0] } + xy1.map { it[0] } + xy2.map { it[0] }).toList(),
    "y" to (xy0.map { it[1] } + xy1.map { it[1] } + xy2.map { it[1] }).toList()
)
```

Generate the 2D density plot

Using the Map from the previous step, create a 2D density plot (geomDensity2D) with a scatter plot (geomPoint) in the background to better visualize the data points and outliers. You can use the scaleColorGradient() function to customize the scale of colors:

```
val densityPlot = letsPlot(data) { x = "x"; y = "y" } + ggsize(600, 300) + geomPoint(
    color = "black",
    alpha = .1
) + geomDensity2D { color = "..level.." } +
        scaleColorGradient(low = "dark_green", high = "yellow", guide = guideColorbar(barHeight = 10, barWidth = 300)) +
        theme().legendPositionBottom()
densityPlot
```

Here's the result:



2D density plot

What's next

- Explore more plot examples in the Lets-Plot for Kotlin's documentation.
- Check the Lets-Plot for Kotlin's API reference.
- Learn about transforming and visualizing data with Kotlin in the Kotlin DataFrame and Kandy library documentation.
- Find additional information about the Kotlin Notebook's usage and key features.

Run code snippets

Kotlin code is typically organized into projects with which you work in an IDE, a text editor, or another tool. However, if you want to quickly see how a function works or find an expression's value, there's no need to create a new project and build it. Check out these three handy ways to run Kotlin code instantly in different environments:

- Scratch files and worksheets in the IDE.
- Kotlin Playground in the browser.
- ki shell in the command line.

IDE: scratches and worksheets

IntelliJ IDEA and Android Studio support Kotlin scratch files and worksheets.

- Scratch files (or just scratches) let you create code drafts in the same IDE window as your project and run them on the fly. Scratches are not tied to projects; you can access and run all your scratches from any IntelliJ IDEA window on your OS.

  To create a Kotlin scratch, click File | New | Scratch File and select the Kotlin type.

- Worksheets are project files: they are stored in project directories and tied to the project modules. Worksheets are useful for writing pieces of code that don't actually make a software unit but should still be stored together in a project, such as educational or demo materials.

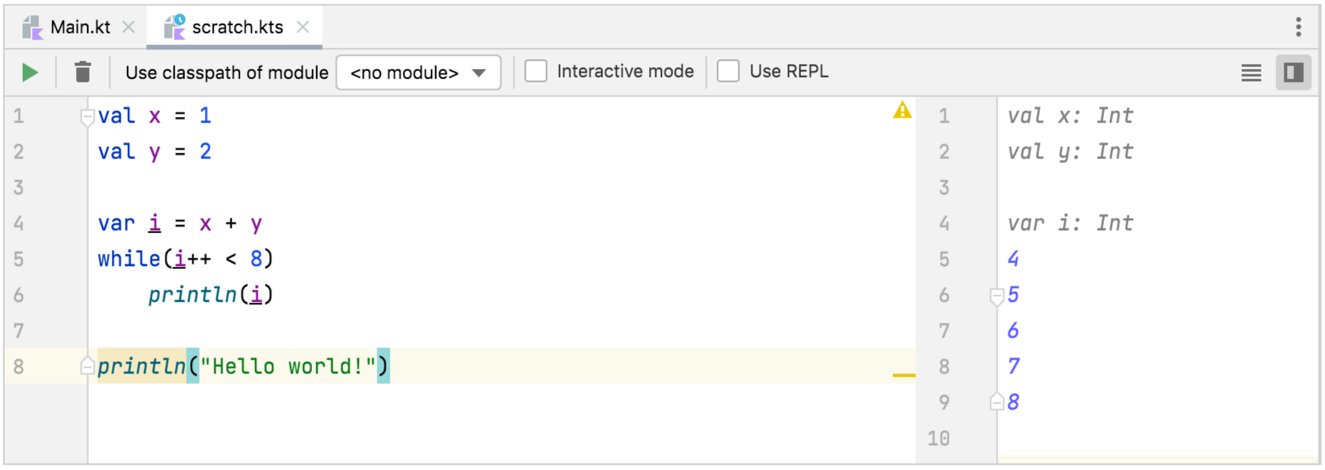
  To create a Kotlin worksheet in a project directory, right-click the directory in the project tree and select New | Kotlin Class/File | Kotlin Worksheet.

  Kotlin worksheets aren't supported in K2 mode. We're working on providing an alternative with similar functionality.

Syntax highlighting, auto-completion, and other IntelliJ IDEA code editing features are supported in scratches and worksheets. There's no need to declare the main()

function – all the code you write is executed as if it were in the body of main().

Once you have finished writing your code in a scratch or a worksheet, click Run. The execution results will appear in the lines opposite your code.



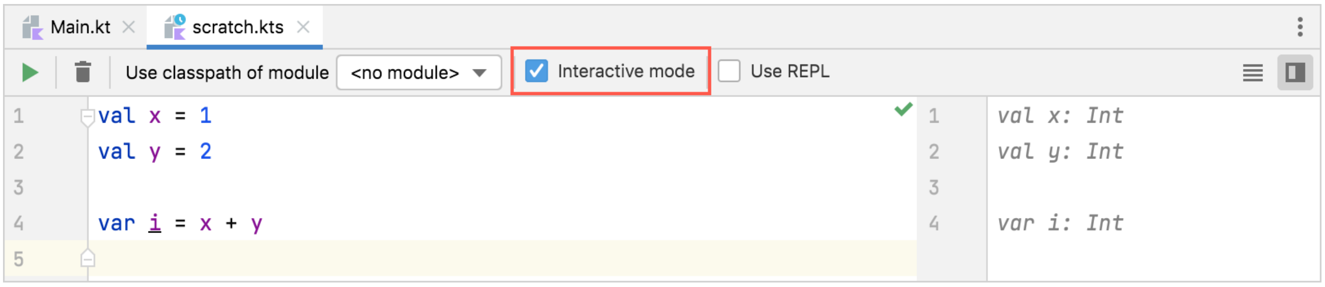
```kotlin
val x = 1
val y = 2

var i = x + y
while(i++ < 8)
    println(i)

println("Hello world!")
```

```
val x: Int
val y: Int

var i: Int
4
5
6
7
8
```

Run scratch

Interactive mode

The IDE can run code from scratches and worksheets automatically. To get execution results as soon as you stop typing, switch on Interactive mode.



```kotlin
val x = 1
val y = 2

var i = x + y
```

```
val x: Int
val y: Int

var i: Int
```

Scratch interactive mode

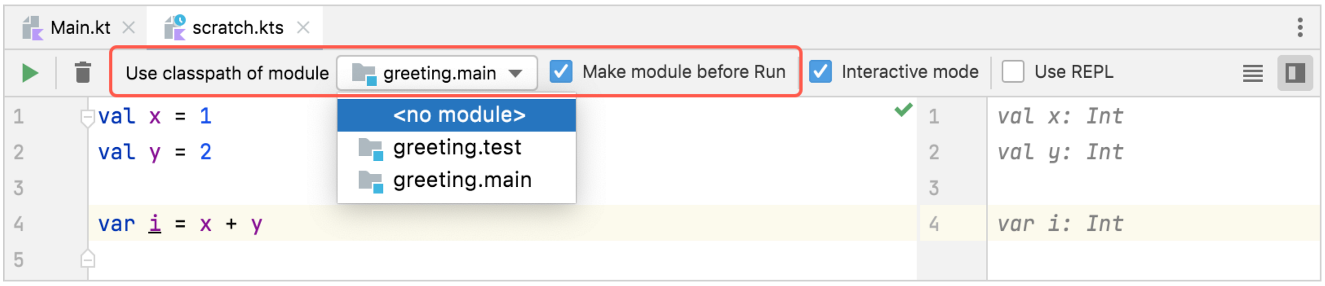
Use modules

You can use classes or functions from a Kotlin project in your scratches and worksheets.

Worksheets automatically have access to classes and functions from the module where they reside.

To use classes or functions from a project in a scratch, import them into the scratch file with the import statement, as usual. Then write your code and run it with the appropriate module selected in the Use classpath of module list.

Both scratches and worksheets use the compiled versions of connected modules. So, if you modify a module's source files, the changes will propagate to scratches and worksheets when you rebuild the module. To rebuild the module automatically before each run of a scratch or a worksheet, select Make module before Run.



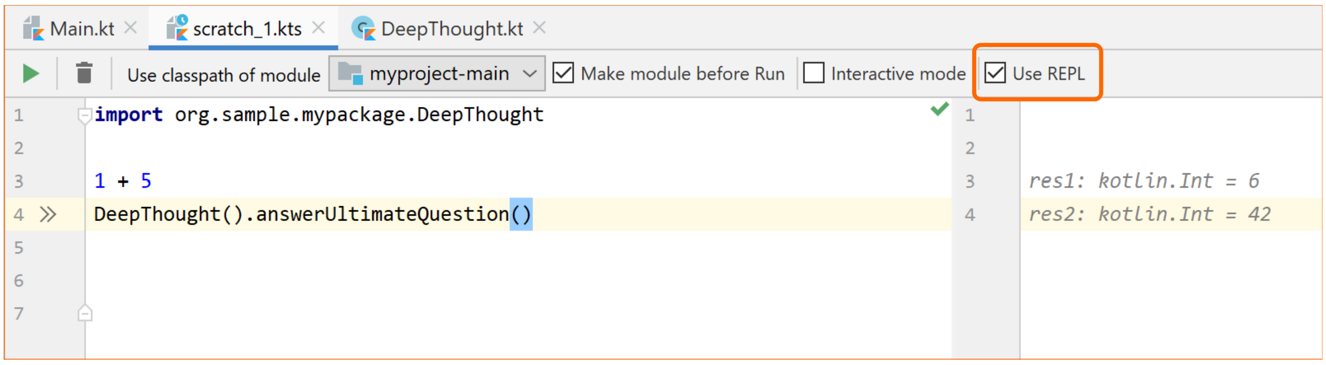
```
val x = 1
val y = 2

var i = x + y
```

```
val x: Int
val y: Int

var i: Int
```

Scratch select module

Run as REPL

To evaluate each particular expression in a scratch or a worksheet, run it with Use REPL selected. The code lines will run sequentially, providing the results of each call. You can later use the results in the same file by reffering to their auto-generated res* names (they are shown in the corresponding lines).



```
import org.sample.mypackage.DeepThought

1 + 5
DeepThought().answerUltimateQuestion()
```

```


res1: kotlin.Int = 6
res2: kotlin.Int = 42
```

Scratch REPL

Browser: Kotlin Playground

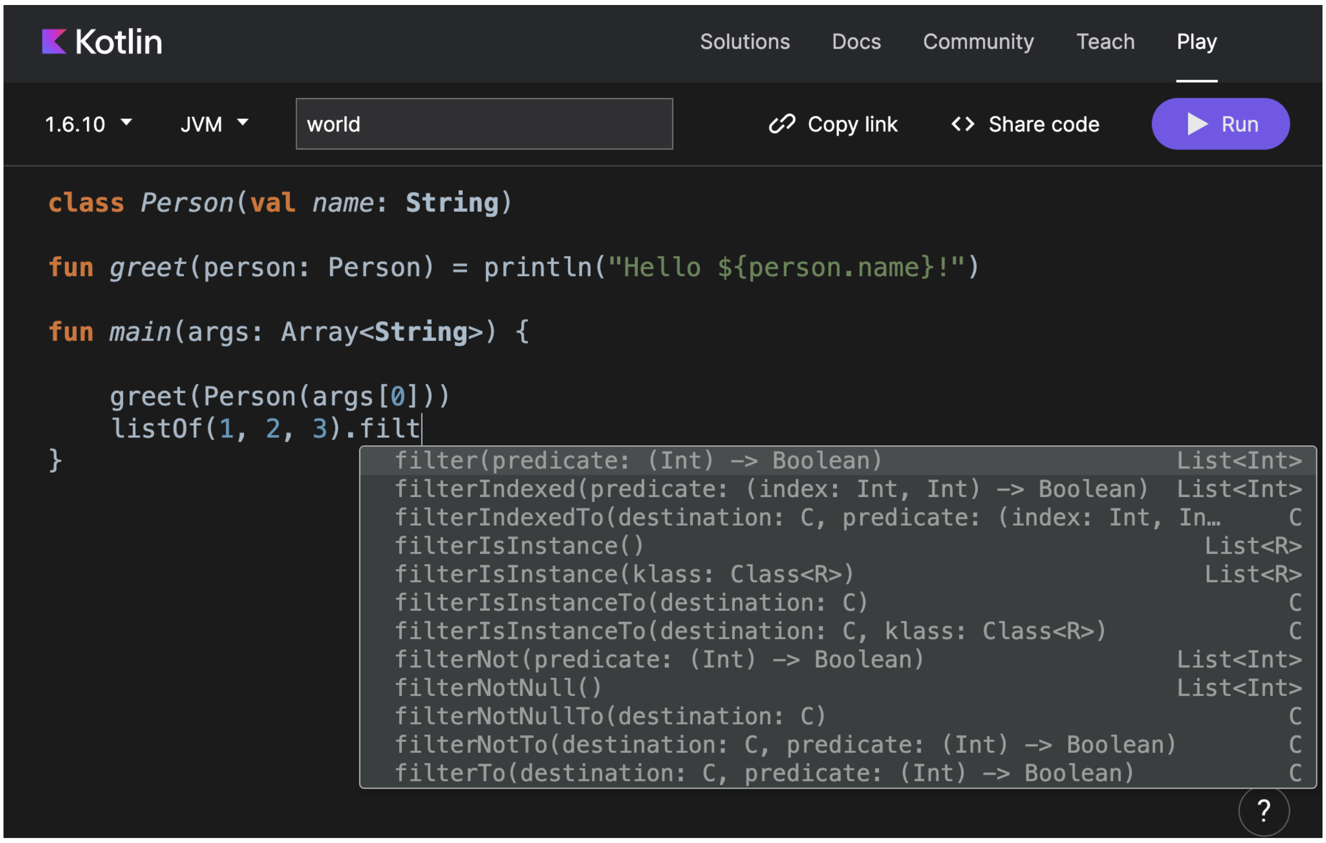
Kotlin Playground is an online application for writing, running, and sharing Kotlin code in your browser.

Write and edit code

In the Playground's editor area, you can write code just as you would in a source file:

- Add your own classes, functions, and top-level declarations in an arbitrary order.
- Write the executable part in the body of the main() function.

As in typical Kotlin projects, the main() function in the Playground can have the args parameter or no parameters at all. To pass program arguments upon execution, write them in the Program arguments field.



```
class Person(val name: String)

fun greet(person: Person) = println("Hello ${person.name}!")

fun main(args: Array<String>) {

    greet(Person(args[0]))
    listOf(1, 2, 3).filt
}
```

```
filter(predicate: (Int) -> Boolean)                        List<Int>
filterIndexed(predicate: (index: Int, Int) -> Boolean)     List<Int>
filterIndexedTo(destination: C, predicate: (index: Int, In…        C
filterIsInstance()                                           List<R>
filterIsInstance(klass: Class<R>)                            List<R>
filterIsInstanceTo(destination: C)                                 C
filterIsInstanceTo(destination: C, klass: Class<R>)                C
filterNot(predicate: (Int) -> Boolean)                     List<Int>
filterNotNull()                                            List<Int>
filterNotNullTo(destination: C)                                    C
filterNotTo(destination: C, predicate: (Int) -> Boolean)           C
filterTo(destination: C, predicate: (Int) -> Boolean)              C
```

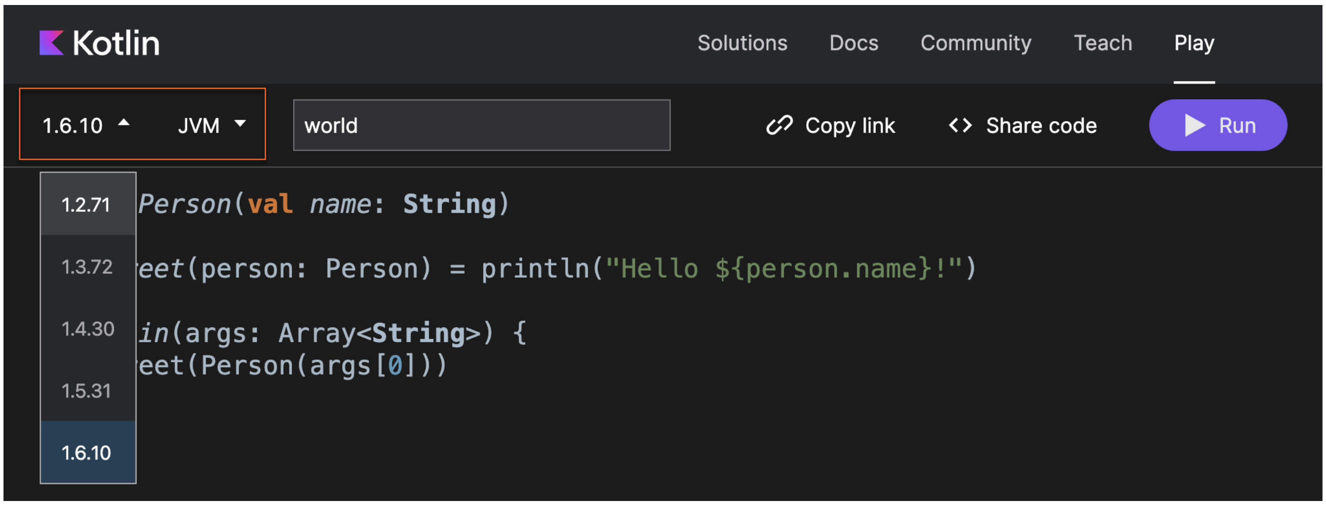
Playground: code completion

The Playground highlights the code and shows code completion options as you type. It automatically imports declarations from the standard library and kotlinx.coroutines.

Choose execution environment

The Playground provides ways to customize the execution environment:

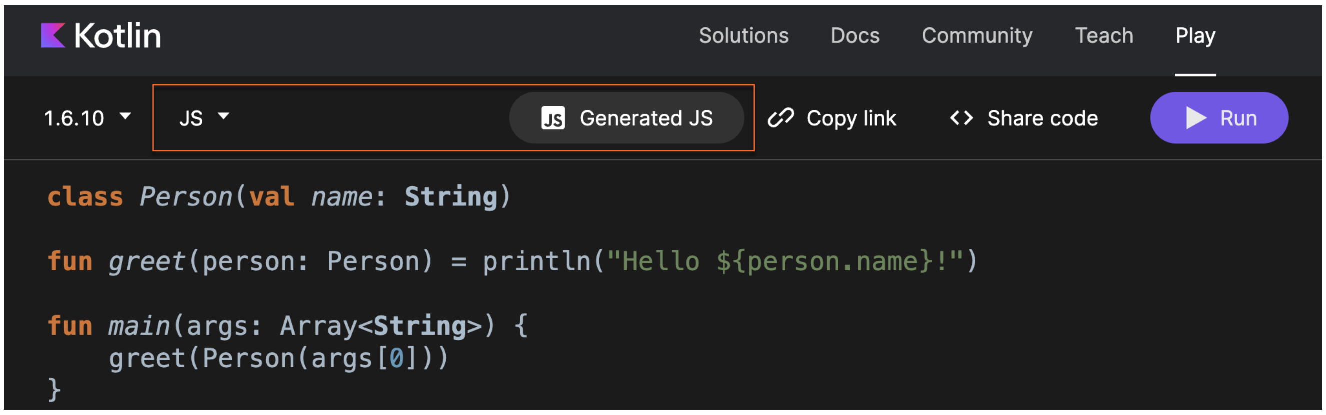
- Multiple Kotlin versions, including available previews of future versions.
- Multiple backends to run the code in: JVM, JS (legacy or IR compiler, or Canvas), or JUnit.



```
Person(val name: String)

eet(person: Person) = println("Hello ${person.name}!")

in(args: Array<String>) {
eet(Person(args[0]))
```

Playground: environment setup

For JS backends, you can also see the generated JS code.



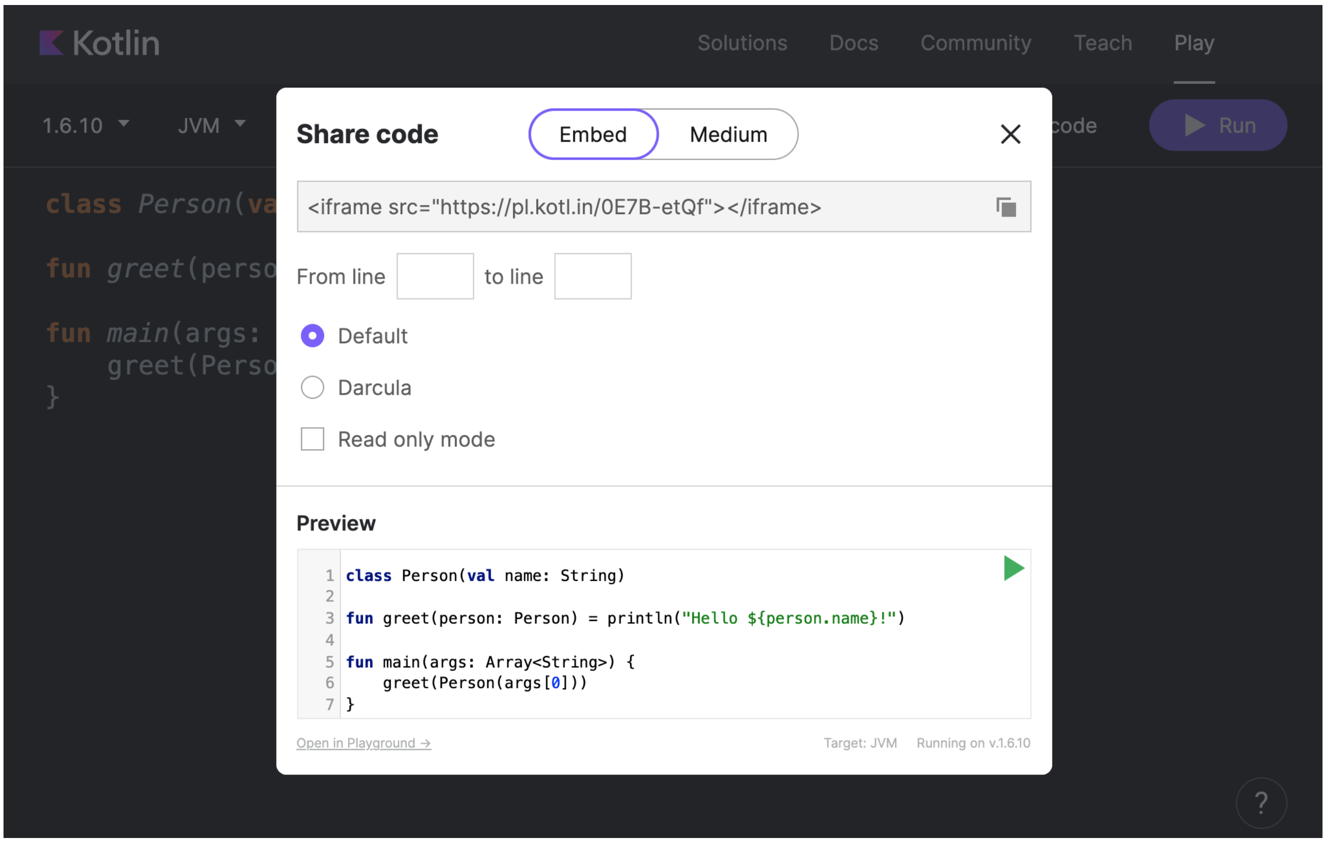
```kotlin
class Person(val name: String)

fun greet(person: Person) = println("Hello ${person.name}!")

fun main(args: Array<String>) {
    greet(Person(args[0]))
}
```

Playground: generated JS

Share code online

Use the Playground to share your code with others – click Copy link and send it to anyone you want to show the code to.

You can also embed code snippets from the Playground into other websites and even make them runnable. Click Share code to embed your sample into any web page or into a Medium article.



<iframe src="https://pl.kotl.in/0E7B-etQf"></iframe>

Default [✓]
Darcula
Read only mode

```kotlin
class Person(val name: String)

fun greet(person: Person) = println("Hello ${person.name}!")

fun main(args: Array<String>) {
    greet(Person(args[0]))
}
```

Playground: share code

Command line: ki shell

The ki shell (Kotlin Interactive Shell) is a command-line utility for running Kotlin code in the terminal. It's available for Linux, macOS, and Windows.

The ki shell provides basic code evaluation capabilities, along with advanced features such as:

- code completion
- type checks
- external dependencies
- paste mode for code snippets
- scripting support

See the ki shell GitHub repository for more details.

Install and run ki shell

To install the ki shell, download the latest version of it from GitHub and unzip it in the directory of your choice.

On macOS, you can also install the ki shell with Homebrew by running the following command:

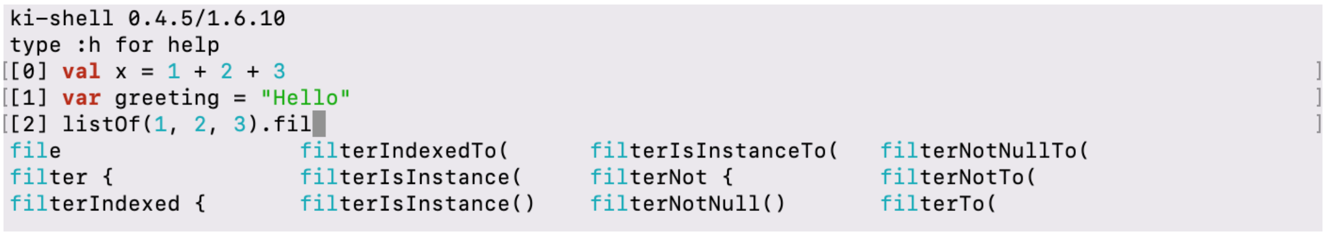
```
brew install ki
```

To start the ki shell, run bin/ki.sh on Linux and macOS (or just ki if the ki shell was installed with Homebrew) or bin\ki.bat on Windows.

Once the shell is running, you can immediately start writing Kotlin code in your terminal. Type :help (or :h) to see the commands that are available in the ki shell.

Code completion and highlighting

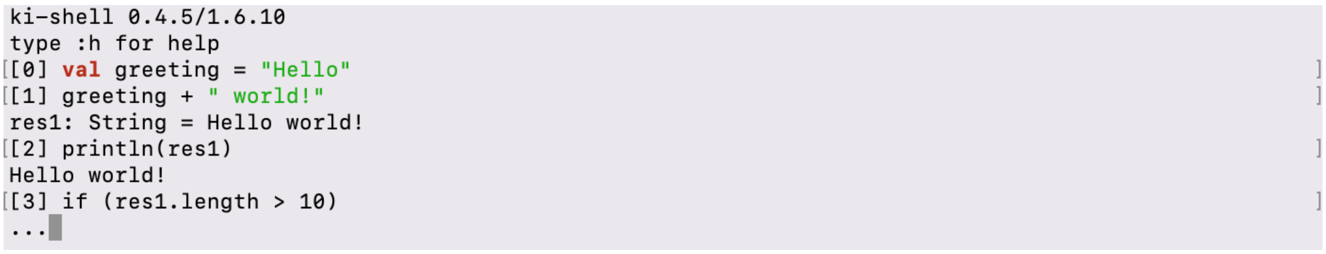
The ki shell shows code completion options when you press Tab. It also provides syntax highlighting as you type. You can disable this feature by entering :syntax off.



```
ki-shell 0.4.5/1.6.10
type :h for help
[0] val x = 1 + 2 + 3
[1] var greeting = "Hello"
[2] listOf(1, 2, 3).fil
file                   filterIndexedTo(      filterIsInstanceTo(    filterNotNullTo(
filter {               filterIsInstance(     filterNot {            filterNotTo(
filterIndexed {        filterIsInstance()    filterNotNull()        filterTo(
```

ki shell highlighting and completion

When you press Enter, the ki shell evaluates the entered line and prints the result. Expression values are printed as variables with auto-generated names like res*. You can later use such variables in the code you run. If the construct entered is incomplete (for example, an if with a condition but without the body), the shell prints three dots and expects the remaining part.

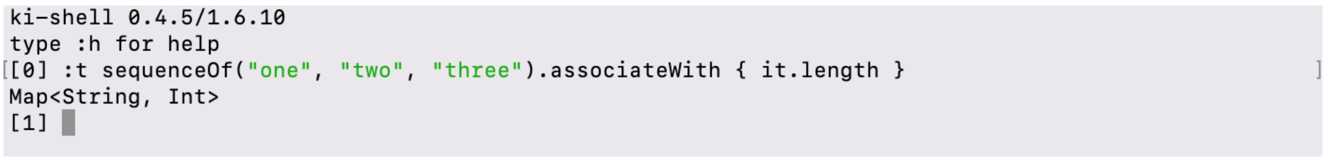


```
ki-shell 0.4.5/1.6.10
type :h for help
[0] val greeting = "Hello"
[1] greeting + " world!"
res1: String = Hello world!
[2] println(res1)
Hello world!
[3] if (res1.length > 10)
...
```

ki shell results

Check an expression's type

For complex expressions or APIs that you don't know well, the ki shell provides the :type (or :t) command, which shows the type of an expression:



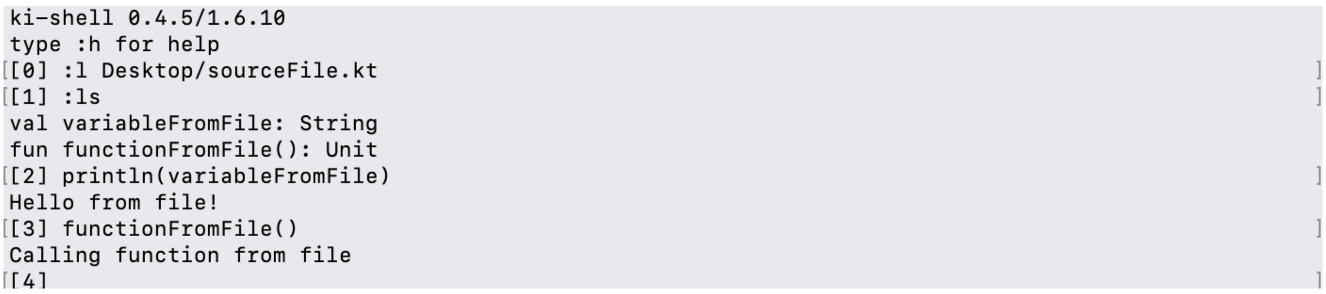
```
ki-shell 0.4.5/1.6.10
type :h for help
[0] :t sequenceOf("one", "two", "three").associateWith { it.length }
Map<String, Int>
[1]
```

ki shell type

Load code

If the code you need is stored somewhere else, there are two ways to load it and use it in the ki shell:

- Load a source file with the :load (or :l) command.
- Copy and paste the code snippet in paste mode with the :paste (or :p) command.



```
ki-shell 0.4.5/1.6.10
type :h for help
[0] :l Desktop/sourceFile.kt
[1] :ls
val variableFromFile: String
fun functionFromFile(): Unit
[2] println(variableFromFile)
Hello from file!
[3] functionFromFile()
Calling function from file
[4]
```

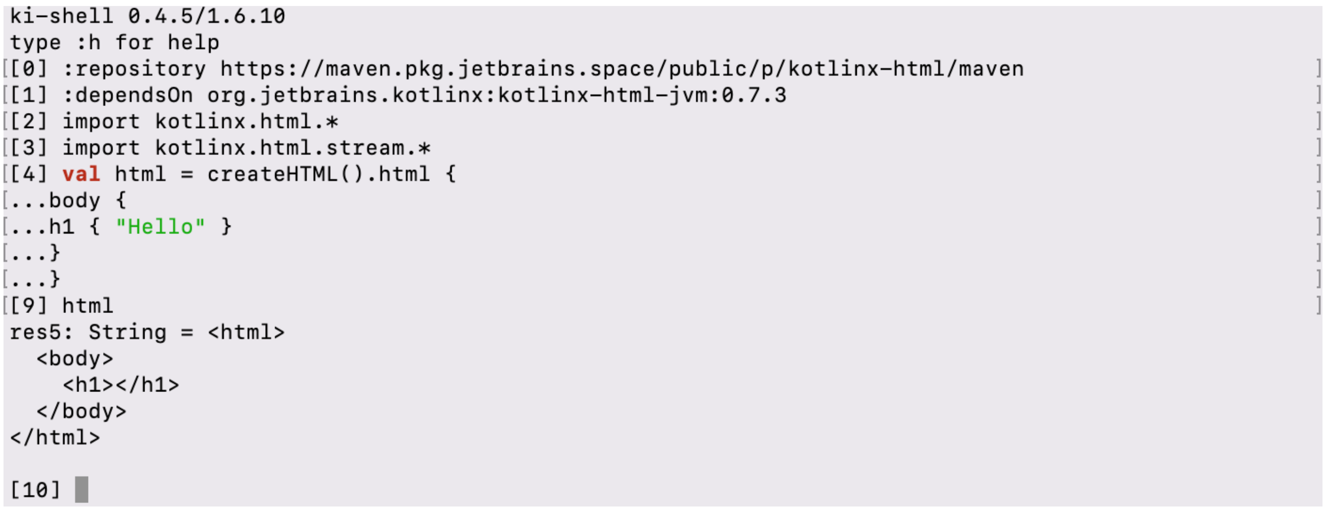
ki shell load file

The ls command shows available symbols (variables and functions).

Add external dependencies

Along with the standard library, the ki shell also supports external dependencies. This lets you try out third-party libraries in it without creating a whole project.

To add a third-party library in the ki shell, use the :dependsOn command. By default, the ki shell works with Maven Central, but you can use other repositories if you connect them using the :repository command:



```
ki-shell 0.4.5/1.6.10
type :h for help
[0] :repository https://maven.pkg.jetbrains.space/public/p/kotlinx-html/maven
[1] :dependsOn org.jetbrains.kotlinx:kotlinx-html-jvm:0.7.3
[2] import kotlinx.html.*
[3] import kotlinx.html.stream.*
[4] val html = createHTML().html {
[...body {
[...h1 { "Hello" }
[...}
[...}
[9] html
res5: String = <html>
  <body>
    <h1></h1>
  </body>
</html>

[10]
```

ki shell external dependency

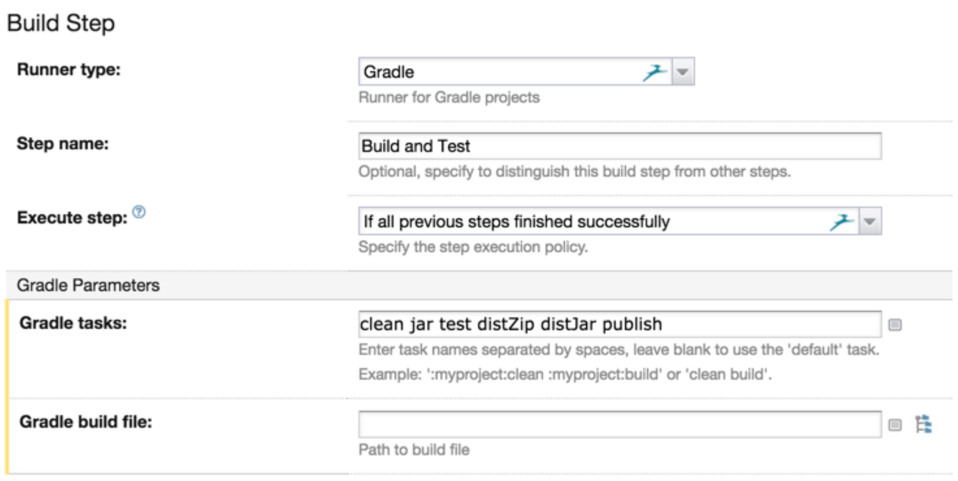
Kotlin and continuous integration with TeamCity

On this page, you'll learn how to set up TeamCity to build your Kotlin project. For more information and basics of TeamCity please check the Documentation page which contains information about installation, basic configuration, etc.

Kotlin works with different build tools, so if you're using a standard tool such as Ant, Maven or Gradle, the process for setting up a Kotlin project is no different to any other language or library that integrates with these tools. Where there are some minor requirements and differences is when using the internal build system of IntelliJ IDEA, which is also supported on TeamCity.

Gradle, Maven, and Ant

If using Ant, Maven or Gradle, the setup process is straightforward. All that is needed is to define the Build Step. For example, if using Gradle, simply define the required parameters such as the Step Name and Gradle tasks that need executing for the Runner Type.



Build Step

Runner type:	Gradle Runner for Gradle projects
Step name:	Build and Test Optional, specify to distinguish this build step from other steps.
Execute step:	If all previous steps finished successfully Specify the step execution policy.

Gradle Parameters

Gradle tasks:	clean jar test distZip distJar publish Enter task names separated by spaces, leave blank to use the 'default' task. Example: ':myproject:clean :myproject:build' or 'clean build'.
Gradle build file:	 Path to build file

Gradle Build Step

Since all the dependencies required for Kotlin are defined in the Gradle file, nothing else needs to be configured specifically for Kotlin to run correctly.

If using Ant or Maven, the same configuration applies. The only difference being that the Runner Type would be Ant or Maven respectively.

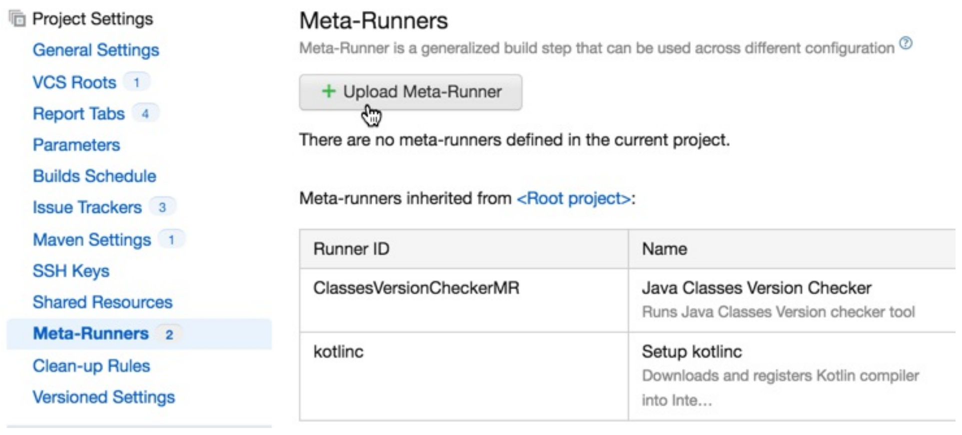
IntelliJ IDEA Build System

If using IntelliJ IDEA build system with TeamCity, make sure that the version of Kotlin being used by IntelliJ IDEA is the same as the one that TeamCity runs. You may need to download the specific version of the Kotlin plugin and install it on TeamCity.

Fortunately, there is a meta-runner already available that takes care of most of the manual work. If not familiar with the concept of TeamCity meta-runners, check the documentation. They are very easy and powerful way to introduce custom Runners without the need to write plugins.

Download and install the meta-runner

The meta-runner for Kotlin is available on GitHub. Download that meta-runner and import it from the TeamCity user interface


Project Settings
General Settings
VCS Roots 1
Report Tabs 4
Parameters
Builds Schedule
Issue Trackers 3
Maven Settings 1
SSH Keys
Shared Resources
Meta-Runners 2
Clean-up Rules
Versioned Settings

Meta-Runners

Meta-Runner is a generalized build step that can be used across different configuration

+ Upload Meta-Runner

There are no meta-runners defined in the current project.

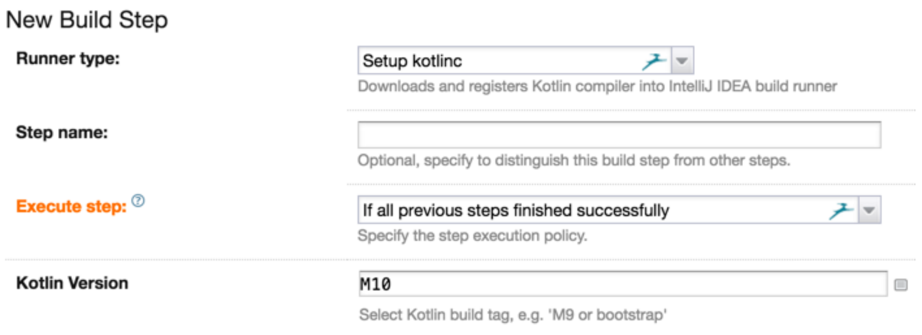
Meta-runners inherited from <Root project>:

Runner ID	Name
ClassesVersionCheckerMR	Java Classes Version Checker Runs Java Classes Version checker tool
kotlinc	Setup kotlinc Downloads and registers Kotlin compiler into Inte…

Meta-runner

Setup Kotlin compiler fetching step

Basically this step is limited to defining the Step Name and the version of Kotlin you need. Tags can be used.


New Build Step

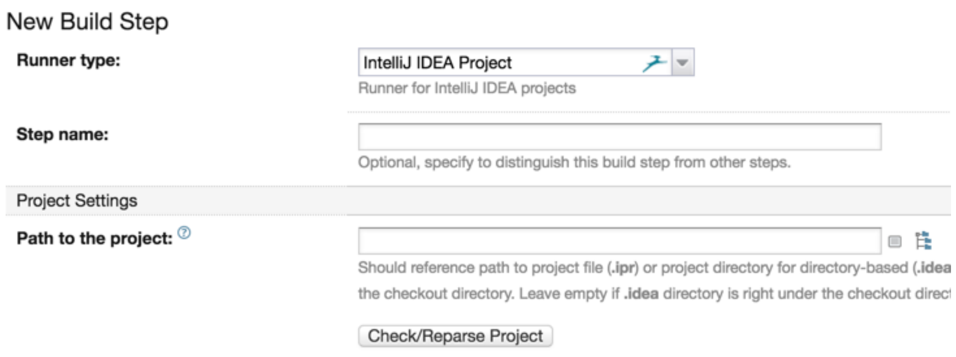
Runner type:	Setup kotlinc Downloads and registers Kotlin compiler into IntelliJ IDEA build runner
Step name:	 Optional, specify to distinguish this build step from other steps.
Execute step:	If all previous steps finished successfully Specify the step execution policy.
Kotlin Version	M10 Select Kotlin build tag, e.g. 'M9 or bootstrap'

Setup Kotlin Compiler

The runner will set the value for the property system.path.macro.KOTLIN.BUNDLED to the correct one based on the path settings from the IntelliJ IDEA project. However, this value needs to be defined in TeamCity (and can be set to any value). Therefore, you need to define it as a system variable.

Setup Kotlin compilation step

The final step is to define the actual compilation of the project, which uses the standard IntelliJ IDEA Runner Type.


New Build Step

Runner type:	IntelliJ IDEA Project Runner for IntelliJ IDEA projects
Step name:	 Optional, specify to distinguish this build step from other steps.
Project Settings	
Path to the project:	 Should reference path to project file (.ipr) or project directory for directory-based (.idea the checkout directory. Leave empty if .idea directory is right under the checkout direct

Check/Reparse Project

IntelliJ IDEA Runner

With that, our project should now build and produce the corresponding artifacts.

Other CI servers

If using a continuous integration tool different to TeamCity, as long as it supports any of the build tools, or calling command line tools, compiling Kotlin and automating things as part of a CI process should be possible.

Document Kotlin code: KDoc

The language used to document Kotlin code (the equivalent of Java's Javadoc) is called KDoc. In essence, KDoc combines Javadoc's syntax for block tags (extended to support Kotlin's specific constructs) and Markdown for inline markup.

> Kotlin's documentation engine: Dokka, understands KDoc and can be used to generate documentation in various formats. For more information, read our Dokka documentation.

KDoc syntax

Just like with Javadoc, KDoc comments start with /** and end with */. Every line of the comment may begin with an asterisk, which is not considered part of the contents of the comment.

By convention, the first paragraph of the documentation text (the block of text until the first blank line) is the summary description of the element, and the following text is the detailed description.

Every block tag begins on a new line and starts with the @ character.

Here's an example of a class documented using KDoc:

```
/**
 * A group of *members*.
 *
 * This class has no useful logic; it's just a documentation example.
 *
 * @param T the type of a member in this group.
 * @property name the name of this group.
 * @constructor Creates an empty group.
 */
class Group<T>(val name: String) {
    /**
     * Adds a [member] to this group.
     * @return the new size of the group.
     */
    fun add(member: T): Int { ... }
}
```

Block tags

KDoc currently supports the following block tags:

@param name

Documents a value parameter of a function or a type parameter of a class, property or function. To better separate the parameter name from the description, if you prefer, you can enclose the name of the parameter in brackets. The following two syntaxes are therefore equivalent:

```
@param name description.
@param[name] description.
```

@return

Documents the return value of a function.

@constructor

Documents the primary constructor of a class.

@receiver

Documents the receiver of an extension function.

@property name

Documents the property of a class which has the specified name. This tag can be used for documenting properties declared in the primary constructor, where putting a doc comment directly before the property definition would be awkward.

@throws class, @exception class

Documents an exception which can be thrown by a method. Since Kotlin does not have checked exceptions, there is also no expectation that all possible exceptions are documented, but you can still use this tag when it provides useful information for users of the class.

@sample identifier

Embeds the body of the function with the specified qualified name into the documentation for the current element, in order to show an example of how the element could be used.

@see identifier

Adds a link to the specified class or method to the See also block of the documentation.

@author

Specifies the author of the element being documented.

@since

Specifies the version of the software in which the element being documented was introduced.

@suppress

Excludes the element from the generated documentation. Can be used for elements which are not part of the official API of a module but still have to be visible externally.

> KDoc does not support the @deprecated tag. Instead, please use the @Deprecated annotation.

Inline markup

For inline markup, KDoc uses the regular Markdown syntax, extended to support a shorthand syntax for linking to other elements in the code.

Links to elements

To link to another element (class, method, property, or parameter), simply put its name in square brackets:

```
Use the method [foo] for this purpose.
```

If you want to specify a custom label for the link, add it in another set of square brackets before the element link:

```
Use [this method][foo] for this purpose.
```

You can also use qualified names in the element links. Note that, unlike Javadoc, qualified names always use the dot character to separate the components, even before a method name:

```
Use [kotlin.reflect.KClass.properties] to enumerate the properties of the class.
```

Names in element links are resolved using the same rules as if the name was used inside the element being documented. In particular, this means that if you have imported a name into the current file, you don't need to fully qualify it when you use it in a KDoc comment.

Note that KDoc does not have any syntax for resolving overloaded members in links. Since Kotlin's documentation generation tool puts the documentation for all overloads of a function on the same page, identifying a specific overloaded function is not required for the link to work.

External links

To add an external link, use the typical Markdown syntax:

```
For more information about KDoc syntax, see [KDoc](<example-URL>).
```

What's next?

Learn how to use Kotlin's documentation generation tool: Dokka.

Kotlin and OSGi

To enable Kotlin OSGi support in your Kotlin project, include kotlin-osgi-bundle instead of the regular Kotlin libraries. It is recommended to remove kotlin-runtime, kotlin-stdlib and kotlin-reflect dependencies as kotlin-osgi-bundle already contains all of them. You also should pay attention in case when external Kotlin libraries are included. Most regular Kotlin dependencies are not OSGi-ready, so you shouldn't use them and should remove them from your project.

Maven

To include the Kotlin OSGi bundle to a Maven project:

```
<dependencies>
    <dependency>
        <groupId>org.jetbrains.kotlin</groupId>
        <artifactId>kotlin-osgi-bundle</artifactId>
        <version>${kotlin.version}</version>
    </dependency>
</dependencies>
```

To exclude the standard library from external libraries (notice that "star exclusion" works in Maven 3 only):

```
<dependency>
    <groupId>some.group.id</groupId>
    <artifactId>some.library</artifactId>
    <version>some.library.version</version>

    <exclusions>
        <exclusion>
            <groupId>org.jetbrains.kotlin</groupId>
            <artifactId>*</artifactId>
        </exclusion>
    </exclusions>
</dependency>
```

Gradle

To include kotlin-osgi-bundle to a Gradle project:

Kotlin

```
dependencies {
    implementation(kotlin("osgi-bundle"))
}
```

Groovy

```
dependencies {
    implementation "org.jetbrains.kotlin:kotlin-osgi-bundle:2.2.0"
}
```

To exclude default Kotlin libraries that comes as transitive dependencies you can use the following approach:

Kotlin

```
dependencies {
    implementation("some.group.id:some.library:someversion") {
        exclude(group = "org.jetbrains.kotlin")
    }
}
```

Groovy

```
dependencies {
    implementation('some.group.id:some.library:someversion') {
        exclude group: 'org.jetbrains.kotlin'
    }
}
```

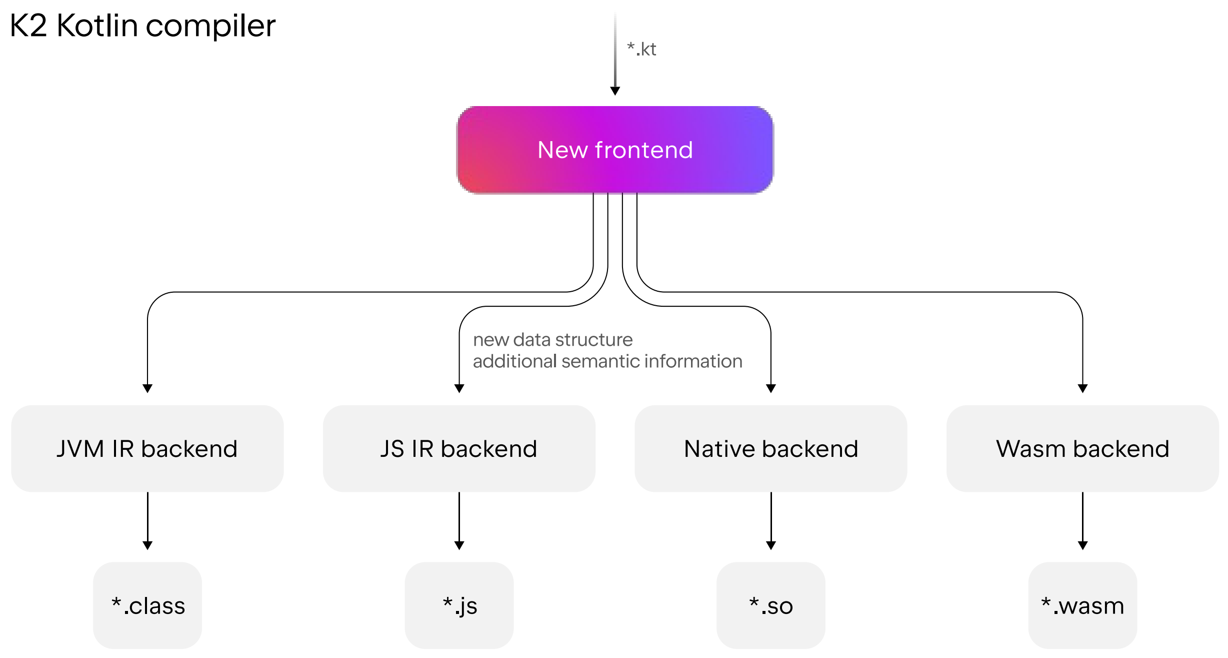
FAQ

Why not just add required manifest options to all Kotlin libraries

Even though it is the most preferred way to provide OSGi support, unfortunately it couldn't be done for now due to so called "package split" issue that couldn't be easily eliminated and such a big change is not planned for now. There is Require-Bundle feature but it is not the best option too and not recommended to use. So it was decided to make a separate artifact for OSGi.

K2 compiler migration guide

As the Kotlin language and ecosystem have continued to evolve, so has the Kotlin compiler. The first step was the introduction of the new JVM and JS IR (Intermediate Representation) backends that share logic, simplifying code generation for targets on different platforms. Now, the next stage of its evolution brings a new frontend known as K2.



Kotlin K2 compiler architecture

With the arrival of the K2 compiler, the Kotlin frontend has been completely rewritten and features a new, more efficient architecture. The fundamental change the new compiler brings is the use of one unified data structure that contains more semantic information. This frontend is responsible for performing semantic analysis, call resolution, and type inference.

The new architecture and enriched data structure enables the K2 compiler to provide the following benefits:

- Improved call resolution and type inference. The compiler behaves more consistently and understands your code better.
- Easier introduction of syntactic sugar for new language features. In the future, you'll be able to use more concise, readable code when new features are introduced.
- Faster compilation times. Compilation times can be significantly faster.
- Enhanced IDE performance. Starting with 2025.1, IntelliJ IDEA uses K2 mode to analyze your Kotlin code, increasing stability and providing performance improvements. For more information, see Support in IDEs.

This guide:

- Explains the benefits of the new K2 compiler.
- Highlights changes you might encounter during migration and how to adapt your code accordingly.
- Describes how you can roll back to the previous version.

The new K2 compiler is enabled by default starting with 2.0.0. For more information on the new features provided in Kotlin 2.0.0, as well as the new K2 compiler, see What's new in Kotlin 2.0.0.

Performance improvements

To evaluate the performance of the K2 compiler, we ran performance tests on two open-source projects: Anki-Android and Exposed. Here are the key performance improvements that we found:

- The K2 compiler brings up to 94% compilation speed gains. For example, in the Anki-Android project, clean build times were reduced from 57.7 seconds in Kotlin 1.9.23 to 29.7 seconds in Kotlin 2.0.0.

- The initialization phase is up to 488% faster with the K2 compiler. For example, in the Anki-Android project, the initialization phase for incremental builds was cut from 0.126 seconds in Kotlin 1.9.23 to just 0.022 seconds in Kotlin 2.0.0.
- The Kotlin K2 compiler is up to 376% quicker in the analysis phase compared to the previous compiler. For example, in the Anki-Android project, analysis times for incremental builds were slashed from 0.581 seconds in Kotlin 1.9.23 to only 0.122 seconds in Kotlin 2.0.0.

For more details on these improvements and to learn more about how we analyzed the performance of the K2 compiler, see our blog post.

Language feature improvements

The Kotlin K2 compiler improves language features related to smart-casting and Kotlin Multiplatform.

Smart casts

The Kotlin compiler can automatically cast an object to a type in specific cases, saving you the trouble of having to explicitly specify it yourself. This is called smart-casting. The Kotlin K2 compiler now performs smart casts in even more scenarios than before.

In Kotlin 2.0.0, we've made improvements related to smart casts in the following areas:

- Local variables and further scopes
- Type checks with the logical or operator
- Inline functions
- Properties with function types
- Exception handling
- Increment and decrement operators

Local variables and further scopes

Previously, if a variable was evaluated as not null within an if condition, the variable would be smart-cast. Information about this variable would then be shared further within the scope of the if block.

However, if you declared the variable outside the if condition, no information about the variable would be available within the if condition, so it couldn't be smart-cast. This behavior was also seen with when expressions and while loops.

From Kotlin 2.0.0, if you declare a variable before using it in your if, when, or while condition, then any information collected by the compiler about the variable will be accessible in the corresponding block for smart-casting.

This can be useful when you want to do things like extract boolean conditions into variables. Then, you can give the variable a meaningful name, which will improve your code readability and make it possible to reuse the variable later in your code. For example:

```kotlin
class Cat {
    fun purr() {
        println("Purr purr")
    }
}

fun petAnimal(animal: Any) {
    val isCat = animal is Cat
    if (isCat) {
        // In Kotlin 2.0.0, the compiler can access
        // information about isCat, so it knows that
        // animal was smart-cast to the type Cat.
        // Therefore, the purr() function can be called.
        // In Kotlin 1.9.20, the compiler doesn't know
        // about the smart cast, so calling the purr()
        // function triggers an error.
        animal.purr()
    }
}

fun main(){
    val kitty = Cat()
    petAnimal(kitty)
    // Purr purr
}
```

Type checks with the logical or operator

In Kotlin 2.0.0, if you combine type checks for objects with an or operator (||), a smart cast is made to their closest common supertype. Before this change, a smart cast was always made to the Any type.

In this case, you still had to manually check the object type afterward before you could access any of its properties or call its functions. For example:

```kotlin
interface Status {
    fun signal() {}
}

interface Ok : Status
interface Postponed : Status
interface Declined : Status

fun signalCheck(signalStatus: Any) {
    if (signalStatus is Postponed || signalStatus is Declined) {
        // signalStatus is smart-cast to a common supertype Status
        signalStatus.signal()
        // Prior to Kotlin 2.0.0, signalStatus is smart cast
        // to type Any, so calling the signal() function triggered an
        // Unresolved reference error. The signal() function can only
        // be called successfully after another type check:

        // check(signalStatus is Status)
        // signalStatus.signal()
    }
}
```

The common supertype is an approximation of a union type. Union types are not currently supported in Kotlin.

Inline functions

In Kotlin 2.0.0, the K2 compiler treats inline functions differently, allowing it to determine in combination with other compiler analyses whether it's safe to smart-cast.

Specifically, inline functions are now treated as having an implicit callsInPlace contract. This means that any lambda functions passed to an inline function are called in place. Since lambda functions are called in place, the compiler knows that a lambda function can't leak references to any variables contained within its function body.

The compiler uses this knowledge along with other compiler analyses to decide whether it's safe to smart-cast any of the captured variables. For example:

```kotlin
interface Processor {
    fun process()
}

inline fun inlineAction(f: () -> Unit) = f()

fun nextProcessor(): Processor? = null

fun runProcessor(): Processor? {
    var processor: Processor? = null
    inlineAction {
        // In Kotlin 2.0.0, the compiler knows that processor
        // is a local variable and inlineAction() is an inline function, so
        // references to processor can't be leaked. Therefore, it's safe
        // to smart-cast processor.

        // If processor isn't null, processor is smart-cast
        if (processor != null) {
            // The compiler knows that processor isn't null, so no safe call
            // is needed
            processor.process()

            // In Kotlin 1.9.20, you have to perform a safe call:
            // processor?.process()
        }

        processor = nextProcessor()
    }
    return processor
}
```

Properties with function types

In previous versions of Kotlin, there was a bug that meant that class properties with a function type weren't smart-cast. We fixed this behavior in Kotlin 2.0.0 and the K2 compiler. For example:

```
class Holder(val provider: (() -> Unit)?) {
    fun process() {
        // In Kotlin 2.0.0, if provider isn't null,
        // it is smart-cast
        if (provider != null) {
            // The compiler knows that provider isn't null
            provider()

            // In 1.9.20, the compiler doesn't know that provider isn't
            // null, so it triggers an error:
            // Reference has a nullable type '(() -> Unit)?', use explicit '?.invoke()' to make a function-like call instead
        }
    }
}
```

This change also applies if you overload your invoke operator. For example:

```
interface Provider {
    operator fun invoke()
}

interface Processor : () -> String

class Holder(val provider: Provider?, val processor: Processor?) {
    fun process() {
        if (provider != null) {
            provider()
            // In 1.9.20, the compiler triggers an error:
            // Reference has a nullable type 'Provider?', use explicit '?.invoke()' to make a function-like call instead
        }
    }
}
```

Exception handling

In Kotlin 2.0.0, we've made improvements to exception handling so that smart cast information can be passed on to catch and finally blocks. This change makes your code safer as the compiler keeps track of whether your object has a nullable type. For example:

```
fun testString() {
    var stringInput: String? = null
    // stringInput is smart-cast to String type
    stringInput = ""
    try {
        // The compiler knows that stringInput isn't null
        println(stringInput.length)
        // 0

        // The compiler rejects previous smart cast information for
        // stringInput. Now stringInput has the String? type.
        stringInput = null

        // Trigger an exception
        if (2 > 1) throw Exception()
        stringInput = ""
    } catch (exception: Exception) {
        // In Kotlin 2.0.0, the compiler knows stringInput
        // can be null, so stringInput stays nullable.
        println(stringInput?.length)
        // null

        // In Kotlin 1.9.20, the compiler says that a safe call isn't
        // needed, but this is incorrect.
    }
}
```

```
fun main() {
    testString()
}
```

Increment and decrement operators

Prior to Kotlin 2.0.0, the compiler didn't understand that the type of an object can change after using an increment or decrement operator. As the compiler couldn't accurately track the object type, your code could lead to unresolved reference errors. In Kotlin 2.0.0, this has been fixed:

```kotlin
interface Rho {
    operator fun inc(): Sigma = TODO()
}

interface Sigma : Rho {
    fun sigma() = Unit
}

interface Tau {
    fun tau() = Unit
}

fun main(input: Rho) {
    var unknownObject: Rho = input

    // Check if unknownObject inherits from the Tau interface
    // Note, it's possible that unknownObject inherits from both
    // Rho and Tau interfaces.
    if (unknownObject is Tau) {

        // Use the overloaded inc() operator from interface Rho.
        // In Kotlin 2.0.0, the type of unknownObject is smart-cast to
        // Sigma.
        ++unknownObject

        // In Kotlin 2.0.0, the compiler knows unknownObject has type
        // Sigma, so the sigma() function can be called successfully.
        unknownObject.sigma()

        // In Kotlin 1.9.20, the compiler doesn't perform a smart cast
        // when inc() is called so the compiler still thinks that
        // unknownObject has type Tau. Calling the sigma() function
        // throws a compile-time error.

        // In Kotlin 2.0.0, the compiler knows unknownObject has type
        // Sigma, so calling the tau() function throws a compile-time
        // error.
        unknownObject.tau()
        // Unresolved reference 'tau'

        // In Kotlin 1.9.20, since the compiler mistakenly thinks that
        // unknownObject has type Tau, the tau() function can be called,
        // but it throws a ClassCastException.
    }
}
```

Kotlin Multiplatform

There are improvements in the K2 compiler related to Kotlin Multiplatform in the following areas:

- Separation of common and platform sources during compilation
- Different visibility levels of expected and actual declarations

Separation of common and platform sources during compilation

Previously, the design of the Kotlin compiler prevented it from keeping common and platform source sets separate at compile time. As a consequence, common code could access platform code, which resulted in different behavior between platforms. In addition, some compiler settings and dependencies from common code used to leak into platform code.

In Kotlin 2.0.0, our implementation of the new Kotlin K2 compiler included a redesign of the compilation scheme to ensure strict separation between common and platform source sets. This change is most noticeable when you use expected and actual functions. Previously, it was possible for a function call in your common code to resolve to a function in platform code. For example:

Common code

```kotlin
fun foo(x: Any) = println("common foo")

fun exampleFunction() {
    foo(42)
}
```

Platform code

```kotlin
// JVM
fun foo(x: Int) = println("platform foo")

// JavaScript
// There is no foo() function overload on the JavaScript platform
```

In this example, the common code has different behavior depending on which platform it is run on:

- On the JVM platform, calling the foo() function in the common code results in the foo() function from the platform code being called as platform foo.
- On the JavaScript platform, calling the foo() function in the common code results in the foo() function from the common code being called as common foo, as there is no such function available in the platform code.

In Kotlin 2.0.0, common code doesn't have access to platform code, so both platforms successfully resolve the foo() function to the foo() function in the common code: common foo.

In addition to the improved consistency of behavior across platforms, we also worked hard to fix cases where there was conflicting behavior between IntelliJ IDEA or Android Studio and the compiler. For instance, when you used expected and actual classes, the following would happen:

Common code

```kotlin
expect class Identity {
    fun confirmIdentity(): String
}

fun common() {
    // Before 2.0.0, it triggers an IDE-only error
    Identity().confirmIdentity()
    // RESOLUTION_TO_CLASSIFIER : Expected class Identity has no default
constructor.
}
```

Platform code

```kotlin
actual class Identity {
    actual fun confirmIdentity() = "expect class
fun: jvm"
}
```

In this example, the expected class Identity has no default constructor, so it can't be called successfully in common code. Previously, an error was only reported by the IDE, but the code still compiled successfully on the JVM. However, now the compiler correctly reports an error:

```
Expected class 'expect class Identity : Any' does not have default constructor
```

When resolution behavior doesn't change

We're still in the process of migrating to the new compilation scheme, so the resolution behavior is still the same when you call functions that aren't within the same source set. You'll notice this difference mainly when you use overloads from a multiplatform library in your common code.

Suppose you have a library, which has two whichFun() functions with different signatures:

```kotlin
// Example library

// MODULE: common
fun whichFun(x: Any) = println("common function")

// MODULE: JVM
fun whichFun(x: Int) = println("platform function")
```

If you call the whichFun() function in your common code, the function that has the most relevant argument type in the library will be resolved:

```kotlin
// A project that uses the example library for the JVM target

// MODULE: common
fun main(){
    whichFun(2)
    // platform function
}
```

In comparison, if you declare the overloads for whichFun() within the same source set, the function from the common code will be resolved because your code doesn't have access to the platform-specific version:

```
// Example library isn't used

// MODULE: common
fun whichFun(x: Any) = println("common function")

fun main(){
    whichFun(2)
    // common function
}

// MODULE: JVM
fun whichFun(x: Int) = println("platform function")
```

Similar to multiplatform libraries, since the commonTest module is in a separate source set, it also still has access to platform-specific code. Therefore, the resolution of calls to functions in the commonTest module exhibits the same behavior as in the old compilation scheme.

In the future, these remaining cases will be more consistent with the new compilation scheme.

Different visibility levels of expected and actual declarations

Before Kotlin 2.0.0, if you used expected and actual declarations in your Kotlin Multiplatform project, they had to have the same visibility level. Kotlin 2.0.0 now also supports different visibility levels but only if the actual declaration is more permissive than the expected declaration. For example:

```
expect internal class Attribute // Visibility is internal
actual class Attribute          // Visibility is public by default,
                                // which is more permissive
```

Similarly, if you are using a type alias in your actual declaration, the visibility of the underlying type should be the same or more permissive than the expected declaration. For example:

```
expect internal class Attribute                 // Visibility is internal
internal actual typealias Attribute = Expanded

class Expanded                                  // Visibility is public by default,
                                                // which is more permissive
```

How to enable the Kotlin K2 compiler

Starting with Kotlin 2.0.0, the Kotlin K2 compiler is enabled by default.

To upgrade the Kotlin version, change it to 2.0.0 or a later release in your Gradle and Maven build scripts.

To have the best experience with IntelliJ IDEA or Android Studio, consider enabling K2 mode in your IDE.

Use Kotlin build reports with Gradle

Kotlin build reports provide information about the time spent in different compilation phases for Kotlin compiler tasks, as well as which compiler and Kotlin version were used, and whether the compilation was incremental. These build reports are useful for assessing your build performance. They offer more insight into the Kotlin compilation pipeline than Gradle build scans do because they give you an overview of the performance of all Gradle tasks.

How to enable build reports

To enable build reports, declare where you'd like to save the build report output in your gradle.properties file:

```
kotlin.build.report.output=file
```

The following values and their combinations are available for the output:

Option	Description
file	Saves build reports in a human-readable format to a local file. By default, it's ${project_folder}/build/reports/kotlin-build/${project_name}-timestamp.txt
single_file	Saves build reports in a format of an object to a specified local file.
build_scan	Saves build reports in the custom values section of the build scan. Note that the Gradle Enterprise plugin limits the number of custom values and their length. In big projects, some values could be lost.
http	Posts build reports using HTTP(S). The POST method sends metrics in JSON format. You can see the current version of the sent data in the Kotlin repository. You can find samples of HTTP endpoints in this blog post
json	Saves build reports in JSON format to a local file. Set the location for your build reports in kotlin.build.report.json.directory. By default, it's name is ${project_name}-build-<date-time>-<index>.json.

For more information on what is possible with build reports, see Build reports.

Support in IDEs

K2 mode in IntelliJ IDEA and Android Studio uses the K2 compiler to improve code analysis, code completion, and highlighting.

Starting with IntelliJ IDEA 2025.1, K2 mode is enabled by default.

In Android Studio, you can enable K2 mode starting with 2024.1 by following these steps:

1. Go to Settings | Languages & Frameworks | Kotlin.
2. Select the Enable K2 mode option.

Previous IDE behavior

If you want to go back to the previous IDE behavior, you can disable K2 mode:

1. Go to Settings | Languages & Frameworks | Kotlin.
2. Deselect the Enable K2 mode option.

We plan to introduce Stable language features after Kotlin 2.1.0. Until then, you can continue to use the previous IDE features for code analysis, and you won't encounter any code highlighting issues due to unrecognized language features.

Try the Kotlin K2 compiler in the Kotlin Playground

The Kotlin Playground supports Kotlin 2.0.0 and later releases. Check it out!

How to roll back to the previous compiler

To use the previous compiler in Kotlin 2.0.0 and later releases, either:

- In your build.gradle.kts file, set your language version to 1.9.

  OR

- Use the following compiler option: -language-version 1.9.

Changes

With the introduction of the new frontend, the Kotlin compiler has undergone several changes. Let's start by highlighting the most significant modifications affecting your code, explaining what has changed and detailing best practices going forward. If you'd like to learn more, we've organized these changes into subject areas to facilitate your further reading.

This section highlights the following modifications:

- Immediate initialization of open properties with backing fields
- Deprecated synthetic setters on a projected receiver
- Forbidden use of inaccessible generic types
- Consistent resolution order of Kotlin properties and Java fields with the same name
- Improved null safety for Java primitive arrays
- Stricter rules for abstract members in expected classes

Immediate initialization of open properties with backing fields

What's changed?

In Kotlin 2.0, all open properties with backing fields must be immediately initialized; otherwise, you'll get a compilation error. Previously, only open var properties needed to be initialized right away, but now this extends to open val properties with backing fields too:

```
open class Base {
    open val a: Int
    open var b: Int

    init {
        // Error starting with Kotlin 2.0 that earlier compiled successfully
        this.a = 1 //Error: open val must have initializer
        // Always an error
        this.b = 1 // Error: open var must have initializer
    }
}

class Derived : Base() {
    override val a: Int = 2
    override var b = 2
}
```

This change makes the compiler's behavior more predictable. Consider an example where an open val property is overridden by a var property with a custom setter.

If a custom setter is used, deferred initialization can lead to confusion because it's unclear whether you want to initialize the backing field or to invoke the setter. In the past, if you wanted to invoke the setter, the old compiler couldn't guarantee that the setter would then initialize the backing field.

What's the best practice now?

We encourage you to always initialize open properties with backing fields, as we believe this practice is both more efficient and less error-prone.

However, if you don't want to immediately initialize a property, you can:

- Make the property final.
- Use a private backing property that allows for deferred initialization.

For more information, see the corresponding issue in YouTrack.

Deprecated synthetics setter on a projected receiver

What's changed?

If you use the synthetic setter of a Java class to assign a type that conflicts with the class's projected type, an error is triggered.

Suppose you have a Java class named Container that contains the getFoo() and setFoo() methods:

```
public class Container<E> {
    public E getFoo() {
        return null;
    }
    public void setFoo(E foo) {}
}
```

If you have the following Kotlin code, where instances of the Container class have projected types, using the setFoo() method will always generate an error. However, only from Kotlin 2.0.0 will the synthetic foo property trigger an error:

```
fun exampleFunction(starProjected: Container<*>, inProjected: Container<in Number>, sampleString: String) {
    starProjected.setFoo(sampleString)
    // Error since Kotlin 1.0

    // Synthetic setter `foo` is resolved to the `setFoo()` method
    starProjected.foo = sampleString
    // Error since Kotlin 2.0.0

    inProjected.setFoo(sampleString)
    // Error since Kotlin 1.0

    // Synthetic setter `foo` is resolved to the `setFoo()` method
    inProjected.foo = sampleString
    // Error since Kotlin 2.0.0
}
```

What's the best practice now?

If you see that this change introduces errors in your code, you might wish to reconsider how you structure your type declarations. It could be that you don't need to use type projections, or perhaps you need to remove any assignments from your code.

For more information, see the corresponding issue in YouTrack.

Forbidden use of inaccessible generic types

What's changed?

Due to the new architecture of our K2 compiler, we've changed how we handle inaccessible generic types. Generally, you should never rely on inaccessible generic types in your code because this indicates a misconfiguration in your project's build configuration, preventing the compiler from accessing the necessary information to compile. In Kotlin 2.0.0, you can't declare or call a function literal with an inaccessible generic type, nor use a generic type with inaccessible generic type arguments. This restriction helps you avoid compiler errors later in your code.

For example, let's say that you declared a generic class in one module:

```
// Module one
class Node<V>(val value: V)
```

If you have another module (module two) with a dependency configured on module one, your code can access the Node<V> class and use it as a type in function types:

```
// Module two
fun execute(func: (Node<Int>) -> Unit) {}
// Function compiles successfully
```

However, if your project is misconfigured such that you have a third module (module three) that depends only on module two, the Kotlin compiler won't be able to access the Node<V> class in module one when compiling the third module. Now, any lambdas or anonymous functions in module three that use the Node<V> type trigger errors in Kotlin 2.0.0, thus preventing avoidable compiler errors, crashes, and run-time exceptions later in your code:

```
// Module three
fun test() {
    // Triggers an error in Kotlin 2.0.0, as the type of the implicit
    // lambda parameter (it) resolves to Node, which is inaccessible
    execute {}

    // Triggers an error in Kotlin 2.0.0, as the type of the unused
    // lambda parameter (_) resolves to Node, which is inaccessible
    execute { _ -> }

    // Triggers an error in Kotlin 2.0.0, as the type of the unused
    // anonymous function parameter (_) resolves to Node, which is inaccessible
    execute(fun (_) {})
}
```

In addition to function literals triggering errors when they contain value parameters of inaccessible generic types, errors also occur when a type has an inaccessible generic type argument.

For example, you have the same generic class declaration in module one. In module two, you declare another generic class: Container<C>. In addition, you declare functions in module two that use Container<C> with generic class Node<V> as a type argument:

Module one

```
// Module one
class Node<V>(val value: V)
```

Module two

```
// Module two
class Container<C>(vararg val content: C)

// Functions with generic class type that
// also have a generic class type argument
fun produce(): Container<Node<Int>> = Container(Node(42))
fun consume(arg: Container<Node<Int>>) {}
```

If you try to call these functions in module three, an error is triggered in Kotlin 2.0.0 because the generic class Node<V> is inaccessible from module three:

```
// Module three
fun test() {
    // Triggers an error in Kotlin 2.0.0, as generic class Node<V> is
    // inaccessible
    consume(produce())
}
```

In future releases we will continue to deprecate the use of inaccessible types in general. We have already started in Kotlin 2.0.0 by adding warnings for some scenarios with inaccessible types, including non-generic ones.

For example, let's use the same module setup as the previous examples, but turn the generic class Node<V> into a non-generic class IntNode, with all functions declared in module two:

Module one

```
// Module one
class IntNode(val value: Int)
```

Module two

```
// Module two
// A function that contains a lambda
// parameter with `IntNode` type
fun execute(func: (IntNode) -> Unit) {}

class Container<C>(vararg val content: C)

// Functions with generic class type
// that has `IntNode` as a type argument
fun produce(): Container<IntNode> = Container(IntNode(42))
fun consume(arg: Container<IntNode>) {}
```

If you call these functions in module three, some warnings are triggered:

```
// Module three
fun test() {
    // Triggers warnings in Kotlin 2.0.0, as class IntNode is
    // inaccessible.

    execute {}
    // Class 'IntNode' of the parameter 'it' is inaccessible.

    execute { _ -> }
    execute(fun (_) {})
    // Class 'IntNode' of the parameter '_' is inaccessible.

    // Will trigger a warning in future Kotlin releases, as IntNode is
    // inaccessible.
    consume(produce())
}
```

What's the best practice now?

If you encounter new warnings regarding inaccessible generic types, it's highly likely that there's an issue with your build system configuration. We recommend checking your build scripts and configuration.

As a last resort, you can configure a direct dependency for module three on module one. Alternatively, you can modify your code to make the types accessible within the same module.

For more information, see the corresponding issue in YouTrack.

Consistent resolution order of Kotlin properties and Java fields with the same name

What's changed?

Before Kotlin 2.0.0, if you worked with Java and Kotlin classes that inherited from each other and contained Kotlin properties and Java fields with the same name, the resolution behavior of the duplicated name was inconsistent. There was also conflicting behavior between IntelliJ IDEA and the compiler. When developing the new resolution behavior for Kotlin 2.0.0, we aimed to cause the least impact to users.

For example, suppose there is a Java class Base:

```
public class Base {
    public String a = "a";

    public String b = "b";
}
```

Let's say there is also a Kotlin class Derived that inherits from the aforementioned Base class:

```
class Derived : Base() {
    val a = "aa"

    // Declares custom get() function
    val b get() = "bb"
}

fun main() {
    // Resolves Derived.a
    println(a)
    // aa

    // Resolves Base.b
    println(b)
    // b
}
```

Prior to Kotlin 2.0.0, a resolves to the Kotlin property within the Derived Kotlin class, whereas b resolves to the Java field in the Base Java class.

In Kotlin 2.0.0, the resolution behavior in the example is consistent, ensuring that the Kotlin property supersedes the Java field of the same name. Now, b resolves to: Derived.b.

Prior to Kotlin 2.0.0, if you used IntelliJ IDEA to go to the declaration or usage of a, it would incorrectly navigate to the Java field when it should have navigated to the Kotlin property.

From Kotlin 2.0.0, IntelliJ IDEA correctly navigates to the same location as the compiler.

The general rule is that the subclass takes precedence. The previous example demonstrates this, as the Kotlin property a from the Derived class is resolved because Derived is a subclass of the Base Java class.

In the event that the inheritance is reversed and a Java class inherits from a Kotlin class, the Java field in the subclass takes precedence over the Kotlin property with the same name.

Consider this example:

Kotlin	Java
`open class Base { val a = "aa" }`	`public class Derived extends Base { public String a = "a"; }`

```kotlin
open class Base {
    val a = "aa"
}
```

```java
public class Derived extends Base {
    public String a = "a";
}
```

Now in the following code:

```kotlin
fun main() {
    // Resolves Derived.a
    println(a)
    // a
}
```

What's the best practice now?

If this change affects your code, consider whether you really need to use duplicate names. If you want to have Java or Kotlin classes that each contain a field or property with the same name and that each inherit from one another, keep in mind that the field or property in the subclass will take precedence.

For more information, see the corresponding issue in YouTrack.

Improved null safety for Java primitive arrays

What's changed?

Starting with Kotlin 2.0.0, the compiler correctly infers the nullability of Java primitive arrays imported to Kotlin. Now, it retains native nullability from the TYPE_USE annotations used with Java primitive arrays and emits errors when their values are not used according to annotations.

Usually, when Java types with @Nullable and @NotNull annotations are called from Kotlin, they receive the appropriate native nullability:

```java
interface DataService {
    @NotNull ResultContainer<@Nullable String> fetchData();
}
```

```kotlin
val dataService: DataService = ...
dataService.fetchData() // -> ResultContainer<String?>
```

Previously, however, when Java primitive arrays were imported to Kotlin, all TYPE_USE annotations were lost, resulting in platform nullability and possibly unsafe code:

```java
interface DataProvider {
    int @Nullable [] fetchData();
}
```

```kotlin
val dataService: DataProvider = ...
dataService.fetchData() // -> IntArray .. IntArray?
// No error, even though `dataService.fetchData()` might be `null` according to annotations
// This might result in a NullPointerException
dataService.fetchData()[0]
```

Note that this issue never affected nullability annotations on the declaration itself, only the TYPE_USE ones.

What's the best practice now?

In Kotlin 2.0.0, null safety for Java primitive arrays is now standard in Kotlin, so check your code for new warnings and errors if you use them:

- Any code that uses a @Nullable Java primitive array without an explicit nullability check or attempts to pass null to a Java method expecting a non-nullable primitive array will now fail to compile.
- Using a @NotNull primitive array with a nullability check now emits "Unnecessary safe call" or "Comparison with null always false" warnings.

For more information, see the corresponding issue in YouTrack.

Stricter rules for abstract members in expected classes

> Expected and actual classes are in Beta. They are almost stable, but you may need to perform migration steps in the future. We'll do our best to minimize any further changes for you to make.

What's changed?

Due to the separation of common and platform sources during compilation with the K2 compiler, we've implemented stricter rules for abstract members in expected classes.

With the previous compiler, it was possible for an expected non-abstract class to inherit an abstract function without overriding the function. Since the compiler could access both common and platform code at the same time, the compiler could see whether the abstract function had a corresponding override and definition in the actual class.

Now that common and platform sources are compiled separately, the inherited function must be explicitly overridden in the expected class so that the compiler knows the function is not abstract. Otherwise, the compiler reports an ABSTRACT_MEMBER_NOT_IMPLEMENTED error.

For example, let's say you have a common source set where you declare an abstract class called FileSystem that has an abstract function listFiles(). You define the listFiles() function in the platform source set as part of an actual declaration.

In your common code, if you have an expected non-abstract class called PlatformFileSystem that inherits from the FileSystem class, the PlatformFileSystem class inherits the abstract function listFiles(). However, you can't have an abstract function in a non-abstract class in Kotlin. To make the listFiles() function non-abstract, you must declare it as an override without the abstract keyword:

Common code

```kotlin
abstract class FileSystem {
    abstract fun listFiles()
}
expect open class PlatformFileSystem() : FileSystem {
    // In Kotlin 2.0.0, an explicit override is needed
    expect override fun listFiles()
    // Before Kotlin 2.0.0, an override wasn't needed
}
```

Platform code

```kotlin
actual open class PlatformFileSystem : FileSystem {
    actual override fun listFiles() {}
}
```

What's the best practice now?

If you inherit abstract functions in an expected non-abstract class, add a non-abstract override.

For more information, see the corresponding issue in YouTrack.

Per subject area

These subject areas list changes that are unlikely to affect your code but provide links to the relevant YouTrack issues for further reading. Changes listed with an asterisk (*) next to the Issue ID are explained at the beginning of the section.

Type inference

Issue ID	Title
KT-64189	Incorrect type in compiled function signature of property reference if the type is Normal explicitly
KT-47986	Forbid implicit inferring a type variable into an upper bound in the builder inference context

Issue ID	Title
KT-59275	K2: Require explicit type arguments for generic annotation calls in array literals
KT-53752	Missed subtyping check for an intersection type
KT-59138	Change Java type parameter based types default representation in Kotlin
KT-57178	Change inferred type of prefix increment to return type of getter instead of return type of inc() operator
KT-57609	K2: Stop relying on the presence of @UnsafeVariance using for contravariant parameters
KT-57620	K2: Forbid resolution to subsumed members for raw types
KT-64641	K2: Properly inferred type of callable reference to a callable with extension-function parameter
KT-57011	Make real type of a destructuring variable consistent with explicit type when specified
KT-38895	K2: Fix inconsistent behavior with integer literals overflow
KT-54862	Anonymous type can be exposed from anonymous function from type argument
KT-22379	Condition of while-loop with break can produce unsound smartcast
KT-62507	K2: Prohibit smart cast in common code for expect/actual top-level property
KT-65750	Increment and plus operators that change return type must affect smart casts
KT-65349	[LC] K2: specifying variable types explicitly breaks bound smart casts in some cases that worked in K1

Generics

Issue ID	Title
KT-54309*	Deprecate use of a synthetic setter on a projected receiver
KT-57600	Forbid overriding of Java method with raw-typed parameter with generic typed parameter

Issue ID	Title
KT-54663	Forbid passing possibly nullable type parameter to `in` projected DNN parameter
KT-54066	Deprecate upper bound violation in typealias constructors
KT-49404	Fix type unsoundness for contravariant captured type based on Java class
KT-61718	Forbid unsound code with self upper bounds and captured types
KT-61749	Forbid unsound bound violation in generic inner class of generic outer class
KT-62923	K2: Introduce PROJECTION_IN_IMMEDIATE_ARGUMENT_TO_SUPERTYPE for projections of outer super types of inner class
KT-63243	Report MANY_IMPL_MEMBER_NOT_IMPLEMENTED when inheriting from collection of primitives with an extra specialized implementation from another supertype
KT-60305	K2: Prohibit constructor call and inheritance on type alias that has variance modifiers in expanded type
KT-64965	Fix type hole caused by improper handling of captured types with self-upper bounds
KT-64966	Forbid generic delegating constructor calls with wrong type for generic parameter
KT-65712	Report missing upper bound violation when upper bound is captured type

Resolution

Issue ID	Title
KT-55017*	Choose Kotlin property from derived class during overload resolution with Java field from base class
KT-58260	Make invoke convention works consistently with expected desugaring

Issue ID	Title
KT-62866	K2: Change qualifier resolution behavior when companion object is preferred against static scope
KT-57750	Report ambiguity error when resolving types and having the same-named classes star imported
KT-63558	K2: migrate resolution around COMPATIBILITY_WARNING
KT-51194	False negative CONFLICTING_INHERITED_MEMBERS when dependency class contained in two different versions of the same dependency
KT-37592	Property invoke of a functional type with receiver is preferred over extension function invoke
KT-51666	Qualified this: introduce/prioritize this qualified with type case
KT-54166	Confirm unspecified behavior in case of FQ name conflicts in classpath
KT-64431	K2: forbid using typealiases as qualifier in imports
KT-56520	K1/K2: incorrect work of resolve tower for type references with ambiguity at lower level

Visibility

Issue ID	Title
KT-64474*	Declare usages of inaccessible types as unspecified behavior
KT-55179	False negative PRIVATE_CLASS_MEMBER_FROM_INLINE on calling private class companion object member from internal inline function
KT-58042	Make synthetic property invisible if equivalent getter is invisible even when overridden declaration is visible
KT-64255	Forbid accessing internal setter from a derived class in another module
KT-33917	Prohibit to expose anonymous types from private inline functions
KT-54997	Forbid implicit non-public-API accesses from public-API inline function
KT-56310	Smart casts should not affect visibility of protected members
KT-65494	Forbid access to overlooked private operator functions from public inline function

Issue ID	Title
KT-65004	K1: Setter of var, which overrides protected val, is generates as public
KT-64972	Forbid overriding by private members in link-time for Kotlin/Native

Annotations

Issue ID	Title
KT-58723	Forbid annotating statements with an annotation if it has no EXPRESSION target
KT-49930	Ignore parentheses expression during `REPEATED_ANNOTATION` checking
KT-57422	K2: Prohibit use-site 'get' targeted annotations on property getters
KT-46483	Prohibit annotation on type parameter in where clause
KT-64299	Companion scope is ignored for resolution of annotations on companion object
KT-64654	K2: Introduced ambiguity between user and compiler-required annotations
KT-64527	Annotations on enum values shouldn't be copied to enum value classes
KT-63389	K2: `WRONG_ANNOTATION_TARGET` is reported on incompatible annotations of a type wrapped into `()?`
KT-63388	K2: `WRONG_ANNOTATION_TARGET` is reported on catch parameter type's annotations

Null safety

Issue ID	Title
KT-54521*	Deprecate unsafe usages of array types annotated as Nullable in Java
KT-41034	K2: Change evaluation semantics for combination of safe calls and convention operators
KT-50850	Order of supertypes defines nullability parameters of inherited functions
KT-53982	Keep nullability when approximating local types in public signatures

Issue ID	Title
KT-62998	Forbid assignment of a nullable to a not-null Java field as a selector of unsafe assignment
KT-63209	Report missing errors for error-level nullable arguments of warning-level Java types

Java interoperability

Issue ID	Title
KT-53061	Forbid Java and Kotlin classes with the same FQ name in sources
KT-49882	Classes inherited from Java collections have inconsistent behavior depending on order of supertypes
KT-66324	K2: unspecified behavior in case of Java class inheritance from a Kotlin private class
KT-66220	Passing java vararg method to inline function leads to array of arrays in runtime instead of just an array
KT-66204	Allow to override internal members in K-J-K hierarchy

Properties

Issue ID	Title
KT-57555*	[LC] Forbid deferred initialization of open properties with backing field
KT-58589	Deprecate missed MUST_BE_INITIALIZED when no primary constructor is presented or when class is local
KT-64295	Forbid recursive resolve in case of potential invoke calls on properties
KT-57290	Deprecate smart cast on base class property from invisible derived class if base class is from another module
KT-62661	K2: Missed OPT_IN_USAGE_ERROR for data class properties

Control flow

Issue ID	Title
KT-56408	Inconsistent rules of CFA in class initialization block between K1 and K2

Issue ID	Title
KT-57871	K1/K2 inconsistency on if-conditional without else-branch in parenthesis
KT-42995	False negative "VAL_REASSIGNMENT" in try/catch block with initialization in scope function
KT-65724	Propagate data flow information from try block to catch and finally blocks

Enum classes

Issue ID	Title
KT-57608	Prohibit access to the companion object of enum class during initialization of enum entry
KT-34372	Report missed error for virtual inline method in enum classes
KT-52802	Report ambiguity resolving between property/field and enum entry
KT-47310	Change qualifier resolution behavior when companion property is preferred against enum entry

Functional (SAM) interfaces

Issue ID	Title
KT-52628	Deprecate SAM constructor usages which require OptIn without annotation
KT-57014	Prohibit returning values with incorrect nullability from lambda for SAM constructor of JDK function interfaces
KT-64342	SAM conversion of parameter types of callable references leads to CCE

Companion object

Issue ID	Title
KT-54316	Out-of-call reference to companion object's member has invalid signature
KT-47313	Change (V)::foo reference resolution when V has a companion

Miscellaneous

Issue ID	Title
KT-59739*	K2/MPP reports [ABSTRACT_MEMBER_NOT_IMPLEMENTED] for inheritor in common code when the implementation is located in the actual counterpart
KT-49015	Qualified this: change behavior in case of potential label conflicts
KT-56545	Fix incorrect functions mangling in JVM backend in case of accidental clashing overload in a Java subclass
KT-62019	[LC issue] Prohibit suspend-marked anonymous function declarations in statement positions
KT-55111	OptIn: forbid constructor calls with default arguments under marker
KT-61182	Unit conversion is accidentally allowed to be used for expressions on variables + invoke resolution
KT-55199	Forbid promoting callable references with adaptations to KFunction
KT-65776	[LC] K2 breaks \`false && ...\` and \`false || ...\`
KT-65682	[LC] Deprecate \`header\`/\`impl\` keywords
KT-45375	Generate all Kotlin lambdas via invokedynamic + LambdaMetafactory by default

Compatibility with Kotlin releases

The following Kotlin releases have support for the new K2 compiler:

Kotlin release	Stability level
2.0.0–2.2.0	Stable
1.9.20–1.9.25	Beta
1.9.0–1.9.10	JVM is Beta
1.7.0–1.8.22	Alpha

Compatibility with Kotlin libraries

If you're working with Kotlin/JVM, the K2 compiler works with libraries compiled with any version of Kotlin.

If you're working with Kotlin Multiplatform, the K2 compiler is guaranteed to work with libraries compiled with Kotlin version 1.9.20 and onwards.

Compiler plugins support

Currently, the Kotlin K2 compiler supports the following Kotlin compiler plugins:

- all-open
- AtomicFU
- jvm-abi-gen
- js-plain-objects
- kapt
- Lombok
- no-arg
- Parcelize
- SAM with receiver
- Serialization

In addition, the Kotlin K2 compiler supports:

- The Jetpack Compose 1.5.0 compiler plugin and later versions.
- Kotlin Symbol Processing (KSP) since KSP2.

> If you use any additional compiler plugins, check their documentation to see if they are compatible with K2.

Upgrade your custom compiler plugins

> Custom compiler plugins use the plugin API, which is Experimental. As a result, the API may change at any time, so we can't guarantee backward compatibility.

The upgrade process has two paths depending on the type of custom plugin you have.

Backend-only compiler plugins

If your plugin implements only IrGenerationExtension extension points, the process is the same as for any other new compiler release. Check if there are any changes to the API that you use and make changes if necessary.

Backend and frontend compiler plugins

If your plugin uses frontend-related extension points, you need to rewrite the plugin using the new K2 compiler API. For an introduction to the new API, see FIR Plugin API.

> If you have questions about upgrading your custom compiler plugin, join our #compiler Slack channel, and we will do our best to help you.

Share your feedback on the new K2 compiler

We would appreciate any feedback you may have!

- Report any problems you face migrating to the new K2 compiler in our issue tracker.
- Enable the Send usage statistics option to allow JetBrains to collect anonymous data about K2 usage.

Kotlin command-line compiler

Every Kotlin release ships with a standalone version of the compiler. You can download the latest version manually or via a package manager.

> Installing the command-line compiler is not an essential step to use Kotlin. The common approach is to write Kotlin applications using IDEs or code editors with official Kotlin support, such as IntelliJ IDEA or Android Studio. They provide full Kotlin support right out of the box.
>
> Learn how to get started with Kotlin in an IDE.

Install the compiler

Manual install

To install the Kotlin compiler manually:

1. Download the latest version (kotlin-compiler-2.2.0.zip) from GitHub Releases.
2. Unzip the standalone compiler into a directory and optionally add the bin directory to the system path. The bin directory contains the scripts needed to compile and run Kotlin on Windows, macOS, and Linux.

> If you want to use the Kotlin command-line compiler on Windows, we recommend installing it manually.

SDKMAN!

An easier way to install Kotlin on UNIX-based systems, such as macOS, Linux, Cygwin, FreeBSD, and Solaris, is SDKMAN!. It also works in Bash and ZSH shells. Learn how to install SDKMAN!.

To install the Kotlin compiler via SDKMAN!, run the following command in the terminal:

```
sdk install kotlin
```

Homebrew

Alternatively, on macOS you can install the compiler via Homebrew:

```
brew update
brew install kotlin
```

Snap package

If you use Snap on Ubuntu 16.04 or later, you can install the compiler from the command line:

```
sudo snap install --classic kotlin
```

Create and run an application

1. Create a simple console JVM application in Kotlin that displays "Hello, World!". In a code editor, create a new file called hello.kt with the following code:

   ```
   fun main() {
       println("Hello, World!")
   }
   ```

2. Compile the application using the Kotlin compiler:

```
kotlinc hello.kt -include-runtime -d hello.jar
```

- The -d option indicates the output path for generated class files, which may be either a directory or a .jar file.
- The -include-runtime option makes the resulting .jar file self-contained and runnable by including the Kotlin runtime library in it.

To see all available options, run:

```
kotlinc -help
```

3. Run the application:

```
java -jar hello.jar
```

Compile a library

If you're developing a library to be used by other Kotlin applications, you can build the .jar file without including the Kotlin runtime:

```
kotlinc hello.kt -d hello.jar
```

Since binaries compiled this way depend on the Kotlin runtime, you should ensure that it is present in the classpath whenever your compiled library is used.

You can also use the kotlin script to run binaries produced by the Kotlin compiler:

```
kotlin -classpath hello.jar HelloKt
```

HelloKt is the main class name that the Kotlin compiler generates for the file named hello.kt.

Run the REPL

Run the compiler with the -Xrepl compiler option to have an interactive shell. In this shell, you can type any valid Kotlin code and see the results.

Run scripts

You can use Kotlin as a scripting language. A Kotlin script is a Kotlin source file (.kts) with top-level executable code.

```
import java.io.File

// Get the passed in path, i.e. "-d some/path" or use the current path.
val path = if (args.contains("-d")) args[1 + args.indexOf("-d")]
           else "."

val folders = File(path).listFiles { file -> file.isDirectory() }
folders?.forEach { folder -> println(folder) }
```

To run a script, pass the -script option to the compiler with the corresponding script file:

```
kotlinc -script list_folders.kts -- -d <path_to_folder_to_inspect>
```

Kotlin provides experimental support for script customization, such as adding external properties, providing static or dynamic dependencies, and so on. Customizations are defined by so-called script definitions – annotated kotlin classes with the appropriate support code. The script filename extension is used to select the appropriate definition. Learn more about Kotlin custom scripting.

Properly prepared script definitions are detected and applied automatically when the appropriate jars are included in the compilation classpath. Alternatively, you can specify definitions manually by passing the -script-templates option to the compiler:

```
kotlinc -script-templates org.example.CustomScriptDefinition -script custom.script1.kts
```

For additional details, see the KEEP-75.

Kotlin compiler options

Each release of Kotlin includes compilers for the supported targets: JVM, JavaScript, and native binaries for supported platforms.

These compilers are used by:

- The IDE, when you click the Compile or Run button for your Kotlin project.
- Gradle, when you call gradle build in a console or in the IDE.
- Maven, when you call mvn compile or mvn test-compile in a console or in the IDE.

You can also run Kotlin compilers manually from the command line as described in the Working with command-line compiler tutorial.

Compiler options

Kotlin compilers have a number of options for tailoring the compiling process. Compiler options for different targets are listed on this page together with a description of each one.

There are several ways to set the compiler options and their values (compiler arguments):

- In IntelliJ IDEA, write in the compiler arguments in the Additional command line parameters text box in Settings/Preferences | Build, Execution, Deployment | Compiler | Kotlin Compiler.
- If you're using Gradle, specify the compiler arguments in the compilerOptions property of the Kotlin compilation task. For details, see Gradle compiler options.
- If you're using Maven, specify the compiler arguments in the <configuration> element of the Maven plugin node. For details, see Maven.
- If you run a command-line compiler, add the compiler arguments directly to the utility call or write them into an argfile.

  For example:

  ```
  $ kotlinc hello.kt -include-runtime -d hello.jar
  ```

  > On Windows, when you pass compiler arguments that contain delimiter characters (whitespace, =, ;, ,), surround these arguments with double quotes (").
  >
  > ```
  > $ kotlinc.bat hello.kt -include-runtime -d "My Folder\hello.jar"
  > ```

Common options

The following options are common for all Kotlin compilers.

-version

Display the compiler version.

-verbose

Enable verbose logging output which includes details of the compilation process.

-script

Evaluate a Kotlin script file. When called with this option, the compiler executes the first Kotlin script (*.kts) file among the given arguments.

-help (-h)

Display usage information and exit. Only standard options are shown. To show advanced options, use -X.

-X

Display information about the advanced options and exit. These options are currently unstable: their names and behavior may be changed without notice.

-kotlin-home path

Specify a custom path to the Kotlin compiler used for the discovery of runtime libraries.

-P plugin:pluginId:optionName=value

Pass an option to a Kotlin compiler plugin. Core plugins and their options are listed in the Core compiler plugins section of the documentation.

-language-version version

Provide source compatibility with the specified version of Kotlin.

-api-version version

Allow using declarations only from the specified version of Kotlin bundled libraries.

-progressive

Enable the progressive mode for the compiler.

In the progressive mode, deprecations and bug fixes for unstable code take effect immediately, instead of going through a graceful migration cycle. Code written in the progressive mode is backwards compatible; however, code written in a non-progressive mode may cause compilation errors in the progressive mode.

@argfile

Read the compiler options from the given file. Such a file can contain compiler options with values and paths to the source files. Options and paths should be separated by whitespaces. For example:

```
-include-runtime -d hello.jar hello.kt
```

To pass values that contain whitespaces, surround them with single (') or double (") quotes. If a value contains quotation marks in it, escape them with a backslash (\).

```
-include-runtime -d 'My folder'
```

You can also pass multiple argument files, for example, to separate compiler options from source files.

```
$ kotlinc @compiler.options @classes
```

If the files reside in locations different from the current directory, use relative paths.

```
$ kotlinc @options/compiler.options hello.kt
```

-opt-in annotation

Enable usages of API that requires opt-in with a requirement annotation with the given fully qualified name.

-Xrepl

Activates the Kotlin REPL.

```
kotlinc -Xrepl
```

-Xannotation-target-all

Enables the experimental all use-site target for annotations:

```
kotlinc -Xannotation-target-all
```

-Xannotation-default-target=param-property

Enables the new experimental defaulting rule for annotation use-site targets:

```
kotlinc -Xannotation-default-target=param-property
```

Warning management

-nowarn

Suppress all warnings during compilation.

-Werror

Treat all warnings as compilation errors.

-Wextra

Enable additional declaration, expression, and type compiler checks that emit warnings if true.

-Xwarning-level

Configure the severity level of specific compiler warnings:

```
kotlinc -Xwarning-level=DIAGNOSTIC_NAME:(error|warning|disabled)
```

- error: raises only the specified warning to an error.
- warning: emits a warning for the specified diagnostic and is enabled by default.
- disabled: suppresses only the specified warning module-wide.

You can adjust warning reporting in your project by combining module-wide rules with specific ones:

Command	Description
-nowarn -Xwarning-level=DIAGNOSTIC_NAME:warning	Suppress all warnings except for the specified ones.
-Werror -Xwarning-level=DIAGNOSTIC_NAME:warning	Raise all warnings to errors except for the specified ones.
-Wextra -Xwarning-level=DIAGNOSTIC_NAME:disabled	Enable all additional checks except for the specified ones.

If you have many warnings to exclude from the general rules, you can list them in a separate file using @argfile.

Kotlin/JVM compiler options

The Kotlin compiler for JVM compiles Kotlin source files into Java class files. The command-line tools for Kotlin to JVM compilation are kotlinc and kotlinc-jvm. You can also use them for executing Kotlin script files.

In addition to the common options, Kotlin/JVM compiler has the options listed below.

-classpath path (-cp path)

Search for class files in the specified paths. Separate elements of the classpath with system path separators (; on Windows, : on macOS/Linux). The classpath can contain file and directory paths, ZIP, or JAR files.

-d path

Place the generated class files into the specified location. The location can be a directory, a ZIP, or a JAR file.

-include-runtime

Include the Kotlin runtime into the resulting JAR file. Makes the resulting archive runnable on any Java-enabled environment.

-jdk-home path

Use a custom JDK home directory to include into the classpath if it differs from the default JAVA_HOME.

-Xjdk-release=version

Specify the target version of the generated JVM bytecode. Limit the API of the JDK in the classpath to the specified Java version. Automatically sets -jvm-target version. Possible values are 1.8, 9, 10, ..., 24.

> This option is not guaranteed to be effective for each JDK distribution.

-jvm-target version

Specify the target version of the generated JVM bytecode. Possible values are 1.8, 9, 10, ..., 24. The default value is 1.8.

-java-parameters

Generate metadata for Java 1.8 reflection on method parameters.

-module-name name (JVM)

Set a custom name for the generated .kotlin_module file.

-no-jdk

Don't automatically include the Java runtime into the classpath.

-no-reflect

Don't automatically include the Kotlin reflection (kotlin-reflect.jar) into the classpath.

-no-stdlib (JVM)

Don't automatically include the Kotlin/JVM stdlib (kotlin-stdlib.jar) and Kotlin reflection (kotlin-reflect.jar) into the classpath.

-script-templates classnames[,]

Script definition template classes. Use fully qualified class names and separate them with commas (,).

-Xjvm-expose-boxed

Generate boxed versions of all inline value classes in the module, along with boxed variants of functions that use them, making both accessible from Java. For more information, see Inline value classes in the guide to calling Kotlin from Java.

Kotlin/JS compiler options

The Kotlin compiler for JS compiles Kotlin source files into JavaScript code. The command-line tool for Kotlin to JS compilation is kotlinc-js.

In addition to the common options, Kotlin/JS compiler has the options listed below.

-target {es5|es2015}

Generate JS files for the specified ECMA version.

-libraries path

Paths to Kotlin libraries with .meta.js and .kjsm files, separated by the system path separator.

-main {call|noCall}

Define whether the main function should be called upon execution.

-meta-info

Generate .meta.js and .kjsm files with metadata. Use this option when creating a JS library.

-module-kind {umd|commonjs|amd|plain}

The kind of JS module generated by the compiler:

- umd - a Universal Module Definition module
- commonjs - a CommonJS module
- amd - an Asynchronous Module Definition module
- plain - a plain JS module

To learn more about the different kinds of JS module and the distinctions between them, see this article.

-no-stdlib (JS)

Don't automatically include the default Kotlin/JS stdlib into the compilation dependencies.

-output filepath

Set the destination file for the compilation result. The value must be a path to a .js file including its name.

-output-postfix filepath

Add the content of the specified file to the end of the output file.

-output-prefix filepath

Add the content of the specified file to the beginning of the output file.

-source-map

Generate the source map.

-source-map-base-dirs path

Use the specified paths as base directories. Base directories are used for calculating relative paths in the source map.

-source-map-embed-sources {always|never|inlining}

Embed source files into the source map.

-source-map-names-policy {simple-names|fully-qualified-names|no}

Add variable and function names that you declared in Kotlin code into the source map.

Setting	Description	Example output
simple-names	Variable names and simple function names are added. (Default)	main
fully-qualified-names	Variable names and fully qualified function names are added.	com.example.kjs.playground.main
no	No variable or function names are added.	N/A

-source-map-prefix

Add the specified prefix to paths in the source map.

Kotlin/Native compiler options

Kotlin/Native compiler compiles Kotlin source files into native binaries for the supported platforms. The command-line tool for Kotlin/Native compilation is kotlinc-native.

In addition to the common options, Kotlin/Native compiler has the options listed below.

-enable-assertions (-ea)

Enable runtime assertions in the generated code.

-g

Enable emitting debug information. This option lowers the optimization level and should not be combined with the -opt option.

-generate-test-runner (-tr)

Produce an application for running unit tests from the project.

-generate-no-exit-test-runner (-trn)

Produce an application for running unit tests without an explicit process exit.

-include-binary path (-ib path)

Pack external binary within the generated klib file.

-library path (-l path)

Link with the library. To learn about using libraries in Kotlin/native projects, see Kotlin/Native libraries.

-library-version version (-lv version)

Set the library version.

-list-targets

List the available hardware targets.

-manifest path

Provide a manifest addend file.

-module-name name (Native)

Specify a name for the compilation module. This option can also be used to specify a name prefix for the declarations exported to Objective-C: How do I specify a custom Objective-C prefix/name for my Kotlin framework?

-native-library path (-nl path)

Include the native bitcode library.

-no-default-libs

Disable linking user code with the prebuilt platform libraries distributed with the compiler.

-nomain

Assume the main entry point to be provided by external libraries.

-nopack

Don't pack the library into a klib file.

-linker-option

Pass an argument to the linker during binary building. This can be used for linking against some native library.

-linker-options args

Pass multiple arguments to the linker during binary building. Separate arguments with whitespaces.

-nostdlib

Don't link with stdlib.

-opt

Enable compilation optimizations and produce a binary with better runtime performance. It's not recommended to combine it with the -g option, which lowers the optimization level.

-output name (-o name)

Set the name for the output file.

-entry name (-e name)

Specify the qualified entry point name.

-produce output (-p output)

Specify output file kind:

- program
- static
- dynamic
- framework
- library
- bitcode

-repo path (-r path)

Library search path. For more information, see Library search sequence.

-target target

Set hardware target. To see the list of available targets, use the -list-targets option.

All-open compiler plugin

Kotlin has classes and their members final by default, which makes it inconvenient to use frameworks and libraries such as Spring AOP that require classes to be open. The all-open compiler plugin adapts Kotlin to the requirements of those frameworks and makes classes annotated with a specific annotation and their members open without the explicit open keyword.

For instance, when you use Spring, you don't need all the classes to be open, but only classes annotated with specific annotations like @Configuration or @Service. The all-open plugin allows you to specify such annotations.

Kotlin provides all-open plugin support both for Gradle and Maven with the complete IDE integration.

For Spring, you can use the kotlin-spring compiler plugin.

Gradle

Add the plugin in your build.gradle(.kts) file:

Kotlin

```
plugins {
    kotlin("plugin.allopen") version "2.2.0"
}
```

Groovy

```
plugins {
    id "org.jetbrains.kotlin.plugin.allopen" version "2.2.0"
}
```

Then specify the list of annotations that will make classes open:

Kotlin

```
allOpen {
    annotation("com.my.Annotation")
    // annotations("com.another.Annotation", "com.third.Annotation")
}
```

Groovy

```
allOpen {
    annotation("com.my.Annotation")
    // annotations("com.another.Annotation", "com.third.Annotation")
}
```

If the class (or any of its superclasses) is annotated with com.my.Annotation, the class itself and all its members will become open.

It also works with meta-annotations:

```
@com.my.Annotation
annotation class MyFrameworkAnnotation

@MyFrameworkAnnotation
class MyClass // will be all-open
```

MyFrameworkAnnotation is annotated with the all-open meta-annotation com.my.Annotation, so it becomes an all-open annotation as well.

Maven

Add the plugin in your pom.xml file:

```
<plugin>
    <artifactId>kotlin-maven-plugin</artifactId>
    <groupId>org.jetbrains.kotlin</groupId>
    <version>${kotlin.version}</version>

    <configuration>
        <compilerPlugins>
            <!-- Or "spring" for the Spring support -->
            <plugin>all-open</plugin>
        </compilerPlugins>

        <pluginOptions>
            <!-- Each annotation is placed on its own line -->
            <option>all-open:annotation=com.my.Annotation</option>
            <option>all-open:annotation=com.their.AnotherAnnotation</option>
        </pluginOptions>
    </configuration>

    <dependencies>
        <dependency>
            <groupId>org.jetbrains.kotlin</groupId>
            <artifactId>kotlin-maven-allopen</artifactId>
            <version>${kotlin.version}</version>
        </dependency>
    </dependencies>
</plugin>
```

Please refer to the Gradle section for the detailed information about how all-open annotations work.

Spring support

If you use Spring, you can enable the kotlin-spring compiler plugin instead of specifying Spring annotations manually. The kotlin-spring is a wrapper on top of all-open, and it behaves exactly the same way.

Add the spring plugin in your build.gradle(.kts) file:

Kotlin

```
plugins {
    id("org.jetbrains.kotlin.plugin.spring") version "2.2.0"
}
```

Groovy

```
plugins {
    id "org.jetbrains.kotlin.plugin.spring" version "2.2.0"
}
```

In Maven, the spring plugin is provided by the kotlin-maven-allopen plugin dependency, so to enable it in your pom.xml file:

```
<compilerPlugins>
    <plugin>spring</plugin>
</compilerPlugins>

<dependencies>
    <dependency>
        <groupId>org.jetbrains.kotlin</groupId>
        <artifactId>kotlin-maven-allopen</artifactId>
        <version>${kotlin.version}</version>
    </dependency>
</dependencies>
```

The plugin specifies the following annotations:

- @Component
- @Async
- @Transactional
- @Cacheable
- @SpringBootTest

Thanks to meta-annotations support, classes annotated with @Configuration, @Controller, @RestController, @Service or @Repository are automatically opened since these annotations are meta-annotated with @Component.

Of course, you can use both kotlin-allopen and kotlin-spring in the same project.

If you generate the project template by the start.spring.io service, the kotlin-spring plugin will be enabled by default.

Command-line compiler

All-open compiler plugin JAR is available in the binary distribution of the Kotlin compiler. You can attach the plugin by providing the path to its JAR file using the -Xplugin kotlinc option:

```
-Xplugin=$KOTLIN_HOME/lib/allopen-compiler-plugin.jar
```

You can specify all-open annotations directly, using the annotation plugin option, or enable the preset:

```
# The plugin option format is: "-P plugin:<plugin id>:<key>=<value>".
# Options can be repeated.

-P plugin:org.jetbrains.kotlin.allopen:annotation=com.my.Annotation
-P plugin:org.jetbrains.kotlin.allopen:preset=spring
```

Presets that available for the all-open plugin are: spring, micronaut, and quarkus.

No-arg compiler plugin

The no-arg compiler plugin generates an additional zero-argument constructor for classes with a specific annotation.

The generated constructor is synthetic, so it can't be directly called from Java or Kotlin, but it can be called using reflection.

This allows the Java Persistence API (JPA) to instantiate a class although it doesn't have the zero-parameter constructor from Kotlin or Java point of view (see the description of kotlin-jpa plugin below).

In your Kotlin file

Add new annotations to mark the code that needs a zero-argument constructor:

```
package com.my

annotation class Annotation
```

Gradle

Add the plugin using Gradle's plugins DSL:

Kotlin

```
plugins {
    kotlin("plugin.noarg") version "2.2.0"
}
```

Groovy

```
plugins {
    id "org.jetbrains.kotlin.plugin.noarg" version "2.2.0"
}
```

Then specify the list of no-arg annotations that must lead to generating a no-arg constructor for the annotated classes:

```
noArg {
    annotation("com.my.Annotation")
}
```

Enable invokeInitializers option if you want the plugin to run the initialization logic from the synthetic constructor. By default, it is disabled.

```
noArg {
    invokeInitializers = true
}
```

Maven

```
<plugin>
    <artifactId>kotlin-maven-plugin</artifactId>
    <groupId>org.jetbrains.kotlin</groupId>
    <version>${kotlin.version}</version>

    <configuration>
        <compilerPlugins>
```

```
            <!-- Or "jpa" for JPA support -->
            <plugin>no-arg</plugin>
        </compilerPlugins>

        <pluginOptions>
            <option>no-arg:annotation=com.my.Annotation</option>
            <!-- Call instance initializers in the synthetic constructor -->
            <!-- <option>no-arg:invokeInitializers=true</option> -->
        </pluginOptions>
    </configuration>

    <dependencies>
        <dependency>
            <groupId>org.jetbrains.kotlin</groupId>
            <artifactId>kotlin-maven-noarg</artifactId>
            <version>${kotlin.version}</version>
        </dependency>
    </dependencies>
</plugin>
```

JPA support

As with the kotlin-spring plugin wrapped on top of all-open, kotlin-jpa is wrapped on top of no-arg. The plugin specifies @Entity, @Embeddable, and @MappedSuperclass no-arg annotations automatically.

Add the plugin using the Gradle plugins DSL:

Kotlin

```kotlin
plugins {
    kotlin("plugin.jpa") version "2.2.0"
}
```

Groovy

```groovy
plugins {
    id "org.jetbrains.kotlin.plugin.jpa" version "2.2.0"
}
```

In Maven, enable the jpa plugin:

```xml
<compilerPlugins>
    <plugin>jpa</plugin>
</compilerPlugins>
```

Command-line compiler

Add the plugin JAR file to the compiler plugin classpath and specify annotations or presets:

```
-Xplugin=$KOTLIN_HOME/lib/noarg-compiler-plugin.jar
-P plugin:org.jetbrains.kotlin.noarg:annotation=com.my.Annotation
-P plugin:org.jetbrains.kotlin.noarg:preset=jpa
```

SAM-with-receiver compiler plugin

The sam-with-receiver compiler plugin makes the first parameter of the annotated Java "single abstract method" (SAM) interface method a receiver in Kotlin. This conversion only works when the SAM interface is passed as a Kotlin lambda, both for SAM adapters and SAM constructors (see the SAM conversions documentation for more details).

Here is an example:

```
public @interface SamWithReceiver {}

@SamWithReceiver
public interface TaskRunner {
    void run(Task task);
}
```

```
fun test(context: TaskContext) {
    val runner = TaskRunner {
        // Here 'this' is an instance of 'Task'

        println("$name is started")
        context.executeTask(this)
        println("$name is finished")
    }
}
```

Gradle

The usage is the same to all-open and no-arg, except the fact that sam-with-receiver does not have any built-in presets, and you need to specify your own list of special-treated annotations.

Kotlin

```
plugins {
    kotlin("plugin.sam.with.receiver") version "2.2.0"
}
```

Groovy

```
plugins {
    id "org.jetbrains.kotlin.plugin.sam.with.receiver" version "2.2.0"
}
```

Then specify the list of SAM-with-receiver annotations:

```
samWithReceiver {
    annotation("com.my.SamWithReceiver")
}
```

Maven

```
<plugin>
    <artifactId>kotlin-maven-plugin</artifactId>
    <groupId>org.jetbrains.kotlin</groupId>
    <version>${kotlin.version}</version>

    <configuration>
        <compilerPlugins>
            <plugin>sam-with-receiver</plugin>
        </compilerPlugins>

        <pluginOptions>
            <option>
                sam-with-receiver:annotation=com.my.SamWithReceiver
            </option>
        </pluginOptions>
    </configuration>

    <dependencies>
        <dependency>
            <groupId>org.jetbrains.kotlin</groupId>
            <artifactId>kotlin-maven-sam-with-receiver</artifactId>
            <version>${kotlin.version}</version>
        </dependency>
    </dependencies>
</plugin>
```

Command-line compiler

Add the plugin JAR file to the compiler plugin classpath and specify the list of sam-with-receiver annotations:

```
-Xplugin=$KOTLIN_HOME/lib/sam-with-receiver-compiler-plugin.jar
-P plugin:org.jetbrains.kotlin.samWithReceiver:annotation=com.my.SamWithReceiver
```

kapt compiler plugin

kapt is in maintenance mode. We are keeping it up-to-date with recent Kotlin and Java releases but have no plans to implement new features. Please use the Kotlin Symbol Processing API (KSP) for annotation processing. See the list of libraries supported by KSP.

Annotation processors (see JSR 269) are supported in Kotlin with the kapt compiler plugin.

In a nutshell, you can use libraries such as Dagger or Data Binding in your Kotlin projects.

Please read below about how to apply the kapt plugin to your Gradle/Maven build.

Use in Gradle

Follow these steps:

1. Apply the kotlin-kapt Gradle plugin:

   Kotlin

   ```
   plugins {
       kotlin("kapt") version "2.2.0"
   }
   ```

   Groovy

   ```
   plugins {
       id "org.jetbrains.kotlin.kapt" version "2.2.0"
   }
   ```

2. Add the respective dependencies using the kapt configuration in your dependencies block:

   Kotlin

   ```
   dependencies {
       kapt("groupId:artifactId:version")
   }
   ```

   Groovy

   ```
   dependencies {
       kapt 'groupId:artifactId:version'
   }
   ```

3. If you previously used the Android support for annotation processors, replace usages of the annotationProcessor configuration with kapt. If your project contains

Java classes, kapt will also take care of them.

If you use annotation processors for your androidTest or test sources, the respective kapt configurations are named kaptAndroidTest and kaptTest. Note that kaptAndroidTest and kaptTest extends kapt, so you can just provide the kapt dependency and it will be available both for production sources and tests.

Try Kotlin K2 compiler

Support for K2 in the kapt compiler plugin is Experimental. Opt-in is required (see details below), and you should use it only for evaluation purposes.

From Kotlin 1.9.20, you can try using the kapt compiler plugin with the K2 compiler, which brings performance improvements and many other benefits. To use the K2 compiler in your Gradle project, add the following option to your gradle.properties file:

```
kapt.use.k2=true
```

If you use the Maven build system, update your pom.xml file:

```
<configuration>
   ...
   <args>
      <arg>-Xuse-k2-kapt</arg>
   </args>
</configuration>
```

To enable the kapt plugin in your Maven project, see Use in Maven.

If you encounter any issues when using kapt with the K2 compiler, please report them to our issue tracker.

Annotation processor arguments

Use arguments {} block to pass arguments to annotation processors:

```
kapt {
    arguments {
        arg("key", "value")
    }
}
```

Gradle build cache support

The kapt annotation processing tasks are cached in Gradle by default. However, annotation processors run arbitrary code that may not necessarily transform the task inputs into the outputs, might access and modify the files that are not tracked by Gradle etc. If the annotation processors used in the build cannot be properly cached, it is possible to disable caching for kapt entirely by adding the following lines to the build script, in order to avoid false-positive cache hits for the kapt tasks:

```
kapt {
    useBuildCache = false
}
```

Improve the speed of builds that use kapt

Run kapt tasks in parallel

To improve the speed of builds that use kapt, you can enable the Gradle Worker API for kapt tasks. Using the Worker API lets Gradle run independent annotation processing tasks from a single project in parallel, which in some cases significantly decreases the execution time.

When you use the custom JDK home feature in the Kotlin Gradle plugin, kapt task workers use only process isolation mode. Note that the kapt.workers.isolation property is ignored.

If you want to provide additional JVM arguments for a kapt worker process, use the input kaptProcessJvmArgs of the KaptWithoutKotlincTask:

Kotlin

```
tasks.withType<org.jetbrains.kotlin.gradle.internal.KaptWithoutKotlincTask>()
    .configureEach {
        kaptProcessJvmArgs.add("-Xmx512m")
    }
```

Groovy

```
tasks.withType(org.jetbrains.kotlin.gradle.internal.KaptWithoutKotlincTask.class)
    .configureEach {
        kaptProcessJvmArgs.add('-Xmx512m')
    }
```

Caching for annotation processors' classloaders

Caching for annotation processors' classloaders in kapt is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

Caching for annotation processors' classloaders helps kapt perform faster if you run many Gradle tasks consecutively.

To enable this feature, use the following properties in your gradle.properties file:

```
# positive value will enable caching
# use the same value as the number of modules that use kapt
kapt.classloaders.cache.size=5

# disable for caching to work
kapt.include.compile.classpath=false
```

If you run into any problems with caching for annotation processors, disable caching for them:

```
# specify annotation processors' full names to disable caching for them
kapt.classloaders.cache.disableForProcessors=[annotation processors full names]
```

Measure performance of annotation processors

Get a performance statistics on the annotation processors execution using the -Kapt-show-processor-timings plugin option. An example output:

```
Kapt Annotation Processing performance report:
com.example.processor.TestingProcessor: total: 133 ms, init: 36 ms, 2 round(s): 97 ms, 0 ms
com.example.processor.AnotherProcessor: total: 100 ms, init: 6 ms, 1 round(s): 93 ms
```

You can dump this report into a file with the plugin option -Kapt-dump-processor-timings (org.jetbrains.kotlin.kapt3:dumpProcessorTimings). The following command will run kapt and dump the statistics to the ap-perf-report.file file:

```
kotlinc -cp $MY_CLASSPATH \
-Xplugin=kotlin-annotation-processing-SNAPSHOT.jar -P \
plugin:org.jetbrains.kotlin.kapt3:aptMode=stubsAndApt,\
plugin:org.jetbrains.kotlin.kapt3:apclasspath=processor/build/libs/processor.jar,\
plugin:org.jetbrains.kotlin.kapt3:dumpProcessorTimings=ap-perf-report.file \
-Xplugin=$JAVA_HOME/lib/tools.jar \
-d cli-tests/out \
-no-jdk -no-reflect -no-stdlib -verbose \
sample/src/main/
```

Measure the number of files generated with annotation processors

The kotlin-kapt Gradle plugin can report statistics on the number of generated files for each annotation processor.

This is useful to track if there are unused annotation processors as a part of the build. You can use the generated report to find modules that trigger unnecessary annotation processors and update the modules to prevent that.

Enable the statistics in two steps:

- Set the showProcessorStats flag to true in your build.gradle(.kts):

```
kapt {
    showProcessorStats = true
}
```

- Set the kapt.verbose Gradle property to true in your gradle.properties:

```
kapt.verbose=true
```

You can also enable verbose output via the command line option verbose.

The statistics will appear in the logs with the info level. You'll see the Annotation processor stats: line followed by statistics on the execution time of each annotation processor. After these lines, there will be the Generated files report: line followed by statistics on the number of generated files for each annotation processor. For example:

```
[INFO] Annotation processor stats:
[INFO] org.mapstruct.ap.MappingProcessor: total: 290 ms, init: 1 ms, 3 round(s): 289 ms, 0 ms, 0 ms
[INFO] Generated files report:
[INFO] org.mapstruct.ap.MappingProcessor: total sources: 2, sources per round: 2, 0, 0
```

Compile avoidance for kapt

To improve the times of incremental builds with kapt, it can use the Gradle compile avoidance. With compile avoidance enabled, Gradle can skip annotation processing when rebuilding a project. Particularly, annotation processing is skipped when:

- The project's source files are unchanged.
- The changes in dependencies are ABI compatible. For example, the only changes are in method bodies.

However, compile avoidance can't be used for annotation processors discovered in the compile classpath since any changes in them require running the annotation processing tasks.

To run kapt with compile avoidance:

- Add the annotation processor dependencies to the kapt* configurations manually as described above.
- Turn off the discovery of annotation processors in the compile classpath by adding this line to your gradle.properties file:

```
kapt.include.compile.classpath=false
```

Incremental annotation processing

kapt supports incremental annotation processing that is enabled by default. Currently, annotation processing can be incremental only if all annotation processors being used are incremental.

To disable incremental annotation processing, add this line to your gradle.properties file:

```
kapt.incremental.apt=false
```

Note that incremental annotation processing requires incremental compilation to be enabled as well.

Inherit annotation processors from superconfigurations

You can define a common set of annotation processors in a separate Gradle configuration as a superconfiguration and extend it further in kapt-specific configurations for your subprojects.

As an example, for a subproject using Dagger, in your build.gradle(.kts) file, use the following configuration:

```
val commonAnnotationProcessors by configurations.creating
configurations.named("kapt") { extendsFrom(commonAnnotationProcessors) }

dependencies {
    implementation("com.google.dagger:dagger:2.48.1")
    commonAnnotationProcessors("com.google.dagger:dagger-compiler:2.48.1")
}
```

In this example, the commonAnnotationProcessors Gradle configuration is your common superconfiguration for annotation processing that you want to be used for all your projects. You use the extendsFrom() method to add commonAnnotationProcessors as a superconfiguration. kapt sees that the commonAnnotationProcessors Gradle configuration has a dependency on the Dagger annotation processor. Therefore, kapt includes the Dagger annotation processor in its configuration for annotation processing.

Java compiler options

kapt uses Java compiler to run annotation processors.
Here is how you can pass arbitrary options to javac:

```
kapt {
    javacOptions {
        // Increase the max count of errors from annotation processors.
        // Default is 100.
        option("-Xmaxerrs", 500)
    }
}
```

Non-existent type correction

Some annotation processors (such as AutoFactory) rely on precise types in declaration signatures. By default, kapt replaces every unknown type (including types for the generated classes) to NonExistentClass, but you can change this behavior. Add the option to the build.gradle(.kts) file to enable error type inferring in stubs:

```
kapt {
    correctErrorTypes = true
}
```

Use in Maven

Add an execution of the kapt goal from kotlin-maven-plugin before compile:

```
<execution>
    <id>kapt</id>
    <goals>
        <goal>kapt</goal> <!-- You can skip the <goals> element
        if you enable extensions for the plugin -->
    </goals>
    <configuration>
        <sourceDirs>
            <sourceDir>src/main/kotlin</sourceDir>
            <sourceDir>src/main/java</sourceDir>
        </sourceDirs>
        <annotationProcessorPaths>
            <!-- Specify your annotation processors here -->
            <annotationProcessorPath>
                <groupId>com.google.dagger</groupId>
                <artifactId>dagger-compiler</artifactId>
                <version>2.9</version>
            </annotationProcessorPath>
        </annotationProcessorPaths>
    </configuration>
</execution>
```

To configure the level of annotation processing, set one of the following as the aptMode in the <configuration> block:

- stubs – only generate stubs needed for annotation processing.
- apt – only run annotation processing.
- stubsAndApt – (default) generate stubs and run annotation processing.

For example:

```
<configuration>
   ...
   <aptMode>stubs</aptMode>
</configuration>
```

To enable the kapt plugin with the K2 compiler, add the -Xuse-k2-kapt compiler option:

```
<configuration>
   ...
   <args>
      <arg>-Xuse-k2-kapt</arg>
   </args>
</configuration>
```

Use in IntelliJ build system

kapt is not supported for IntelliJ IDEA's own build system. Launch the build from the "Maven Projects" toolbar whenever you want to re-run the annotation processing.

Use in CLI

kapt compiler plugin is available in the binary distribution of the Kotlin compiler.

You can attach the plugin by providing the path to its JAR file using the Xplugin kotlinc option:

```
-Xplugin=$KOTLIN_HOME/lib/kotlin-annotation-processing.jar
```

Here is a list of the available options:

- sources (required): An output path for the generated files.
- classes (required): An output path for the generated class files and resources.
- stubs (required): An output path for the stub files. In other words, some temporary directory.
- incrementalData: An output path for the binary stubs.
- apclasspath (repeatable): A path to the annotation processor JAR. Pass as many apclasspath options as the number of JARs that you have.
- apoptions: A base64-encoded list of the annotation processor options. See AP/javac options encoding for more information.
- javacArguments: A base64-encoded list of the options passed to javac. See AP/javac options encoding for more information.
- processors: A comma-specified list of annotation processor qualified class names. If specified, kapt does not try to find annotation processors in apclasspath.
- verbose: Enable verbose output.
- aptMode (required)
  - stubs – only generate stubs needed for annotation processing.
  - apt – only run annotation processing.

    - stubsAndApt – generate stubs and run annotation processing.

- correctErrorTypes: For more information, see Non-existent type correction. Disabled by default.

- dumpFileReadHistory: An output path to dump for each file a list of classes used during annotation processing.

The plugin option format is: -P plugin:<plugin id>:<key>=<value>. Options can be repeated.

An example:

```
-P plugin:org.jetbrains.kotlin.kapt3:sources=build/kapt/sources
-P plugin:org.jetbrains.kotlin.kapt3:classes=build/kapt/classes
-P plugin:org.jetbrains.kotlin.kapt3:stubs=build/kapt/stubs

-P plugin:org.jetbrains.kotlin.kapt3:apclasspath=lib/ap.jar
-P plugin:org.jetbrains.kotlin.kapt3:apclasspath=lib/anotherAp.jar

-P plugin:org.jetbrains.kotlin.kapt3:correctErrorTypes=true
```

Generate Kotlin sources

kapt can generate Kotlin sources. Just write the generated Kotlin source files to the directory specified by processingEnv.options["kapt.kotlin.generated"], and these files will be compiled together with the main sources.

Note that kapt does not support multiple rounds for the generated Kotlin files.

AP/Javac options encoding

apoptions and javacArguments CLI options accept an encoded map of options.
Here is how you can encode options by yourself:

```kotlin
fun encodeList(options: Map<String, String>): String {
    val os = ByteArrayOutputStream()
    val oos = ObjectOutputStream(os)

    oos.writeInt(options.size)
    for ((key, value) in options.entries) {
        oos.writeUTF(key)
        oos.writeUTF(value)
    }

    oos.flush()
    return Base64.getEncoder().encodeToString(os.toByteArray())
}
```

Keep Java compiler's annotation processors

By default, kapt runs all annotation processors and disables annotation processing by javac. However, you may need some of javac's annotation processors working (for example, Lombok).

In the Gradle build file, use the option keepJavacAnnotationProcessors:

```kotlin
kapt {
    keepJavacAnnotationProcessors = true
}
```

If you use Maven, you need to specify concrete plugin settings. See this example of settings for the Lombok compiler plugin.

Lombok compiler plugin

The Lombok compiler plugin is Experimental. It may be dropped or changed at any time. Use it only for evaluation purposes. We would appreciate your feedback on it in YouTrack.

The Kotlin Lombok compiler plugin allows the generation and use of Java's Lombok declarations by Kotlin code in the same mixed Java/Kotlin module. If you call such declarations from another module, then you don't need to use this plugin for the compilation of that module.

The Lombok compiler plugin cannot replace Lombok, but it helps Lombok work in mixed Java/Kotlin modules. Thus, you still need to configure Lombok as usual when using this plugin. Learn more about how to configure the Lombok compiler plugin.

Supported annotations

The plugin supports the following annotations:

- @Getter, @Setter
- @Builder, @SuperBuilder
- @NoArgsConstructor, @RequiredArgsConstructor, and @AllArgsConstructor
- @Data
- @With
- @Value

We're continuing to work on this plugin. To find out the detailed current state, visit the Lombok compiler plugin's README.

Currently, we don't have plans to support the @Tolerate annotation. However, we can consider this if you vote for the @Tolerate issue in YouTrack.

Kotlin compiler ignores Lombok annotations if you use them in Kotlin code.

Gradle

Apply the kotlin-plugin-lombok Gradle plugin in the build.gradle(.kts) file:

Kotlin

```
plugins {
    kotlin("plugin.lombok") version "2.2.0"
    id("io.freefair.lombok") version "8.13.1"
}
```

Groovy

```
plugins {
    id 'org.jetbrains.kotlin.plugin.lombok' version '2.2.0'
    id 'io.freefair.lombok' version '8.13.1'
}
```

See this test project with examples of the Lombok compiler plugin in use.

Using the Lombok configuration file

If you use a Lombok configuration file lombok.config, you need to set the file's path so that the plugin can find it. The path must be relative to the module's directory. For example, add the following code to your build.gradle(.kts) file:

Kotlin

```
kotlinLombok {
    lombokConfigurationFile(file("lombok.config"))
}
```

Groovy

```
kotlinLombok {
    lombokConfigurationFile file("lombok.config")
}
```

See this test project with examples of the Lombok compiler plugin and lombok.config in use.

Maven

To use the Lombok compiler plugin, add the plugin lombok to the compilerPlugins section and the dependency kotlin-maven-lombok to the dependencies section. If you use a Lombok configuration file lombok.config, provide a path to it to the plugin in the pluginOptions. Add the following lines to the pom.xml file:

```
<plugin>
    <groupId>org.jetbrains.kotlin</groupId>
    <artifactId>kotlin-maven-plugin</artifactId>
    <version>${kotlin.version}</version>
    <configuration>
        <compilerPlugins>
            <plugin>lombok</plugin>
        </compilerPlugins>
        <pluginOptions>
            <option>lombok:config=${project.basedir}/lombok.config</option>
        </pluginOptions>
    </configuration>
    <dependencies>
        <dependency>
            <groupId>org.jetbrains.kotlin</groupId>
            <artifactId>kotlin-maven-lombok</artifactId>
            <version>${kotlin.version}</version>
        </dependency>
        <dependency>
            <groupId>org.projectlombok</groupId>
            <artifactId>lombok</artifactId>
            <version>1.18.20</version>
            <scope>provided</scope>
        </dependency>
    </dependencies>
</plugin>
```

See this test project example of the Lombok compiler plugin and lombok.config in use.

Using with kapt

By default, the kapt compiler plugin runs all annotation processors and disables annotation processing by javac. To run Lombok along with kapt, set up kapt to keep javac's annotation processors working.

If you use Gradle, add the option to the build.gradle(.kts) file:

```
kapt {
    keepJavacAnnotationProcessors = true
}
```

In Maven, use the following settings to launch Lombok with Java's compiler:

```
<plugin>
    <groupId>org.apache.maven.plugins</groupId>
    <artifactId>maven-compiler-plugin</artifactId>
    <version>3.5.1</version>
    <configuration>
        <source>1.8</source>
        <target>1.8</target>
        <annotationProcessorPaths>
```

```
            <annotationProcessorPath>
                <groupId>org.projectlombok</groupId>
                <artifactId>lombok</artifactId>
                <version>${lombok.version}</version>
            </annotationProcessorPath>
        </annotationProcessorPaths>
    </configuration>
</plugin>
```

The Lombok compiler plugin works correctly with kapt if annotation processors don't depend on the code generated by Lombok.

Look through the test project examples of kapt and the Lombok compiler plugin in use:

- Using Gradle.
- Using Maven

Command-line compiler

Lombok compiler plugin JAR is available in the binary distribution of the Kotlin compiler. You can attach the plugin by providing the path to its JAR file using the Xplugin kotlinc option:

```
-Xplugin=$KOTLIN_HOME/lib/lombok-compiler-plugin.jar
```

If you want to use the lombok.config file, replace <PATH_TO_CONFIG_FILE> with a path to your lombok.config:

```
# The plugin option format is: "-P plugin:<plugin id>:<key>=<value>".
# Options can be repeated.

-P plugin:org.jetbrains.kotlin.lombok:config=<PATH_TO_CONFIG_FILE>
```

Power-assert compiler plugin

The Power-assert compiler plugin is Experimental. It may be changed at any time. Use it only for evaluation purposes. We would appreciate your feedback in YouTrack.

The Kotlin Power-assert compiler plugin improves the debugging experience by providing detailed failure messages with contextual information. It simplifies the process of writing tests by automatically generating intermediate values in failure messages. It helps you understand why a test failed without needing complex assertion libraries.

This is an example message provided by the plugin:

```
Incorrect length
assert(hello.length == world.substring(1, 4).length) { "Incorrect length" }
       |     |      |  |     |                |
       |     |      |  |     |                3
       |     |      |  |     orl
       |     |      |  world!
       |     |      false
       |     5
       Hello
```

The Power-assert plugin key features:

- Enhanced error messages: The plugin captures and displays the values of variables and sub-expressions within the assertion to clearly identify the cause of failure.
- Simplified testing: Automatically generates informative failure messages, reducing the need for complex assertion libraries.
- Support for multiple functions: By default, it transforms assert() function calls but can also transform other functions, such as require(), check(), and assertTrue().

Apply the plugin

To enable the Power-assert plugin, configure your build.gradle(.kts) file as follows:

Kotlin

```kotlin
// build.gradle.kts
plugins {
    kotlin("multiplatform") version "2.0.0"
    kotlin("plugin.power-assert") version "2.0.0"
}
```

Groovy

```groovy
// build.gradle
plugins {
    id 'org.jetbrains.kotlin.multiplatform' version '2.0.0'
    id 'org.jetbrains.kotlin.plugin.power-assert' version '2.0.0'
}
```

Configure the plugin

The Power-assert plugin provides several options to customize its behavior:

- functions: A list of fully-qualified function paths. The Power-assert plugin will transform the calls to these functions. If not specified, only kotlin.assert() calls will be transformed by default.
- includedSourceSets: A list of Gradle source sets that the Power-assert plugin will transform. If not specified, all test source sets will be transformed by default.

To customize the behavior, add the powerAssert {} block to your build script file:

Kotlin

```kotlin
// build.gradle.kts
powerAssert {
    functions = listOf("kotlin.assert", "kotlin.test.assertTrue", "kotlin.test.assertEquals", "kotlin.test.assertNull")
    includedSourceSets = listOf("commonMain", "jvmMain", "jsMain", "nativeMain")
}
```

Groovy

```groovy
// build.gradle
powerAssert {
    functions = ["kotlin.assert", "kotlin.test.assertTrue", "kotlin.test.assertEquals", "kotlin.test.assertNull"]
    includedSourceSets = ["commonMain", "jvmMain", "jsMain", "nativeMain"]
}
```

Since the plugin is Experimental, you will see warnings every time you build your app. To exclude these warnings, add this @OptIn annotation before declaring the powerAssert {} block:

```kotlin
import org.jetbrains.kotlin.gradle.ExperimentalKotlinGradlePluginApi

@OptIn(ExperimentalKotlinGradlePluginApi::class)
powerAssert {
    ...
}
```

Use the plugin

This section provides examples of using the Power-assert compiler plugin.

See the complete code of the build script file build.gradle.kts for all these examples:

```
import org.jetbrains.kotlin.gradle.ExperimentalKotlinGradlePluginApi

plugins {
    kotlin("jvm") version "2.2.0"
    kotlin("plugin.power-assert") version "2.2.0"
}

group = "org.example"
version = "1.0-SNAPSHOT"

repositories {
    mavenCentral()
}

dependencies {
    testImplementation(kotlin("test"))
}

tasks.test {
    useJUnitPlatform()
}

@OptIn(ExperimentalKotlinGradlePluginApi::class)
powerAssert {
    functions = listOf("kotlin.assert", "kotlin.test.assertEquals", "kotlin.test.assertTrue", "kotlin.test.assertNull",
"kotlin.require", "org.example.AssertScope.assert")
}
```

Assert function

Consider the following test with the assert() function:

```
import kotlin.test.Test

class SampleTest {

    @Test
    fun testFunction() {
        val hello = "Hello"
        val world = "world!"
        assert(hello.length == world.substring(1, 4).length) { "Incorrect length" }
    }
}
```

If you run the testFunction() test with the Power-assert plugin enabled, you get the explicit failure message:

```
Incorrect length
assert(hello.length == world.substring(1, 4).length) { "Incorrect length" }
       |     |      |  |     |               |
       |     |      |  |     |               3
       |     |      |  |     orl
       |     |      |  world!
       |     |      false
       |     5
       Hello
```

To get a more complete error message, always inline the variable into the test function parameters. Consider the following test function:

```
class ComplexExampleTest {

    data class Person(val name: String, val age: Int)

    @Test
    fun testComplexAssertion() {
        val person = Person("Alice", 10)
        val isValidName = person.name.startsWith("A") && person.name.length > 3
        val isValidAge = person.age in 21..28
        assert(isValidName && isValidAge)
    }
}
```

The output of the executed code doesn't provide enough information to find the cause of the problem:

```
Assertion failed
assert(isValidName && isValidAge)
       |              |
       |              false
       true
```

Inline the variable into the assert() function:

```kotlin
class ComplexExampleTest {

    data class Person(val name: String, val age: Int)

    @Test
    fun testComplexAssertion() {
        val person = Person("Alice", 10)
        assert(person.name.startsWith("A") && person.name.length > 3 && person.age > 20 && person.age < 29)
    }
}
```

After execution, you get more explicit information about what went wrong:

```
Assertion failed
assert(person.name.startsWith("A") && person.name.length > 3 && person.age > 20 && person.age < 29)
       |      |    |                  |      |    |      |      |      |   |
       |      |    |                  |      |    |      |      |      |   false
       |      |    |                  |      |    |      |      |      10
       |      |    |                  |      |    |      |      Person(name=Alice, age=10)
       |      |    |                  |      |    |      true
       |      |    |                  |      |    5
       |      |    |                  |      Alice
       |      |    |                  Person(name=Alice, age=10)
       |      |    true
       |      Alice
       Person(name=Alice, age=10)
```

Beyond assert function

The Power-assert plugin can transform various functions beyond assert which is transformed by default. Functions like require(), check(), assertTrue(), assertEqual() and others can also be transformed, if they have a form that allows taking a String or () -> String value as the last parameter.

Before using a new function in a test, specify the function in the powerAssert {} block of your build script file. For example, the require() function:

```kotlin
// build.gradle.kts
import org.jetbrains.kotlin.gradle.ExperimentalKotlinGradlePluginApi

@OptIn(ExperimentalKotlinGradlePluginApi::class)
powerAssert {
    functions = listOf("kotlin.assert", "kotlin.require")
}
```

After adding the function, you can use it in your tests:

```kotlin
class RequireExampleTest {

    @Test
    fun testRequireFunction() {
        val value = ""
        require(value.isNotEmpty()) { "Value should not be empty" }
    }
}
```

The output for this example uses the Power-assert plugin to provide detailed information about the failed test:

```
Value should not be empty
require(value.isNotEmpty()) { "Value should not be empty" }
        |     |
        |     false
```

The message shows the intermediate values that lead to the failure, making it easier to debug.

Soft assertions

The Power-assert plugin supports soft assertions, which do not immediately fail the test but instead collect assertion failures and report them at the end of the test run. This can be useful when you want to see all assertion failures in a single run without stopping at the first failure.

To enable soft assertions, implement the way you will collect error messages:

```kotlin
fun <R> assertSoftly(block: AssertScope.() -> R): R {
    val scope = AssertScopeImpl()
    val result = scope.block()
    if (scope.errors.isNotEmpty()) {
        throw AssertionError(scope.errors.joinToString("\n"))
    }
    return result
}

interface AssertScope {
    fun assert(assertion: Boolean, message: (() -> String)? = null)
}

class AssertScopeImpl : AssertScope {
    val errors = mutableListOf<String>()
    override fun assert(assertion: Boolean, message: (() -> String)?) {
        if (!assertion) {
            errors.add(message?.invoke() ?: "Assertion failed")
        }
    }
}
```

Add these functions to the powerAssert {} block to make them available for the Power-assert plugin:

```kotlin
@OptIn(ExperimentalKotlinGradlePluginApi::class)
powerAssert {
    functions = listOf("kotlin.assert", "kotlin.test.assert", "org.example.AssertScope.assert")
}
```

You should specify the full name of the package where you declare the AssertScope.assert() function.

After that, you could use it in your test code:

```kotlin
// Import the assertSoftly() function
import org.example.assertSoftly

class SoftAssertExampleTest1 {

    data class Employee(val name: String, val age: Int, val salary: Int)

    @Test
    fun `test employees data`() {
        val employees = listOf(
            Employee("Alice", 30, 60000),
            Employee("Bob", 45, 80000),
            Employee("Charlie", 55, 40000),
            Employee("Dave", 150, 70000)
        )

        assertSoftly {
            for (employee in employees) {
                assert(employee.age < 100) { "${employee.name} has an invalid age: ${employee.age}" }
                assert(employee.salary > 50000) { "${employee.name} has an invalid salary: ${employee.salary}" }
            }
        }
    }
}
```

In the output, all the assert() function error messages will be printed one after another:

```
Charlie has an invalid salary: 40000
assert(employee.salary > 50000) { "${employee.name} has an invalid salary: ${employee.salary}" }
       |        |      |
       |        |      false
       |        40000
```

```
        Employee(name=Charlie, age=55, salary=40000)
Dave has an invalid age: 150
assert(employee.age < 100) { "${employee.name} has an invalid age: ${employee.age}" }
        |        |   |
        |        |   false
        |        150
        Employee(name=Dave, age=150, salary=70000)
```

What's next

- Look through a simple project with the plugin enabled and a more complex project with multiple source sets.

Compose compiler migration guide

The Compose compiler is supplemented by a Gradle plugin, which simplifies setup and offers easier access to compiler options. When applied with the Android Gradle plugin (AGP), this Compose compiler plugin will override the coordinates of the Compose compiler supplied automatically by AGP.

The Compose compiler has been merged into the Kotlin repository since Kotlin 2.0.0. This helps smooth the migration of your projects to Kotlin 2.0.0 and later, as the Compose compiler ships simultaneously with Kotlin and will always be compatible with Kotlin of the same version.

To use the new Compose compiler plugin in your project, apply it for each module that uses Compose. Read on for details on how to migrate a Jetpack Compose project. For a Compose Multiplatform project, refer to the multiplatform migration guide.

Migrating a Jetpack Compose project

When migrating to Kotlin 2.0.0 or newer from 1.9, you should adjust your project configuration depending on the way you deal with the Compose compiler. We recommend using the Kotlin Gradle plugin and the Compose compiler Gradle plugin to automate configuration management.

Managing the Compose compiler with Gradle plugins

For Android modules:

1. Add the Compose compiler Gradle plugin to the Gradle version catalog:

```
[versions]
# ...
kotlin = "2.2.0"

[plugins]
# ...
org-jetbrains-kotlin-android = { id = "org.jetbrains.kotlin.android", version.ref = "kotlin" }
compose-compiler = { id = "org.jetbrains.kotlin.plugin.compose", version.ref = "kotlin" }
```

2. Add the Gradle plugin to the root build.gradle.kts file:

```
plugins {
    // ...
    alias(libs.plugins.compose.compiler) apply false
}
```

3. Apply the plugin to every module that uses Jetpack Compose:

```
plugins {
    // ...
    alias(libs.plugins.compose.compiler)
}
```

4. If you are using compiler options for the Jetpack Compose compiler, set them in the composeCompiler {} block. See the list of compiler options for reference.

5. If you reference Compose compiler artifacts directly, you can remove these references and let the Gradle plugins take care of things.

Using Compose compiler without Gradle plugins

If you are not using Gradle plugins to manage the Compose compiler, update any direct references to old Maven artifacts in your project:

- Change androidx.compose.compiler:compiler to org.jetbrains.kotlin:kotlin-compose-compiler-plugin-embeddable
- Change androidx.compose.compiler:compiler-hosted to org.jetbrains.kotlin:kotlin-compose-compiler-plugin

What's next

- See Google's announcement about the Compose compiler moving to the Kotlin repository.
- If you are using Jetpack Compose to build an Android app, check out our guide on how to make it multiplatform.

Compose compiler options DSL

The Compose compiler Gradle plugin offers a DSL for various compiler options. You can use it to configure the compiler in the composeCompiler {} block of the build.gradle.kts file for the module you're applying the plugin to.

There are two kinds of options you can specify:

- General compiler settings, which can be disabled or enabled as needed in any given project.
- Feature flags that enable or disable new and experimental features, which should eventually become part of the baseline.

You can find the list of available general settings and the list of supported feature flags in the Compose compiler Gradle plugin API reference.

Here's an example configuration:

```
composeCompiler {
    includeSourceInformation = true

    featureFlags = setOf(
        ComposeFeatureFlag.StrongSkipping.disabled(),
        ComposeFeatureFlag.OptimizeNonSkippingGroups
    )
}
```

The Gradle plugin provides defaults for several Compose compiler options that were only specified manually before Kotlin 2.0. If you have any of them set up with freeCompilerArgs, for example, Gradle reports a duplicate options error.

Purpose and use of feature flags

Feature flags are organized into a separate set of options to minimize changes to top-level properties as new flags are continuously rolled out and deprecated.

To enable a feature flag that is disabled by default, specify it in the set, for example:

```
featureFlags = setOf(ComposeFeatureFlag.OptimizeNonSkippingGroups)
```

To disable a feature flag that is enabled by default, call the disabled() function on it, for example:

```
featureFlags = setOf(ComposeFeatureFlag.StrongSkipping.disabled())
```

If you are configuring the Compose compiler directly, use the following syntax to pass feature flags to it:

```
-P plugin:androidx.compose.compiler.plugins.kotlin:featureFlag=<flag name>
```

See the list of supported feature flags in the Compose compiler Gradle plugin API reference.

Kotlin Symbol Processing API

Kotlin Symbol Processing (KSP) is an API that you can use to develop lightweight compiler plugins. KSP provides a simplified compiler plugin API that leverages the power of Kotlin while keeping the learning curve at a minimum. Compared to kapt, annotation processors that use KSP can run up to two times faster.

- To learn more about how KSP compares to kapt, check out why KSP.
- To get started writing a KSP processor, take a look at the KSP quickstart.

Overview

The KSP API processes Kotlin programs idiomatically. KSP understands Kotlin-specific features, such as extension functions, declaration-site variance, and local functions. It also models types explicitly and provides basic type checking, such as equivalence and assign-compatibility.

The API models Kotlin program structures at the symbol level according to Kotlin grammar. When KSP-based plugins process source programs, constructs like classes, class members, functions, and associated parameters are accessible for the processors, while things like if blocks and for loops are not.

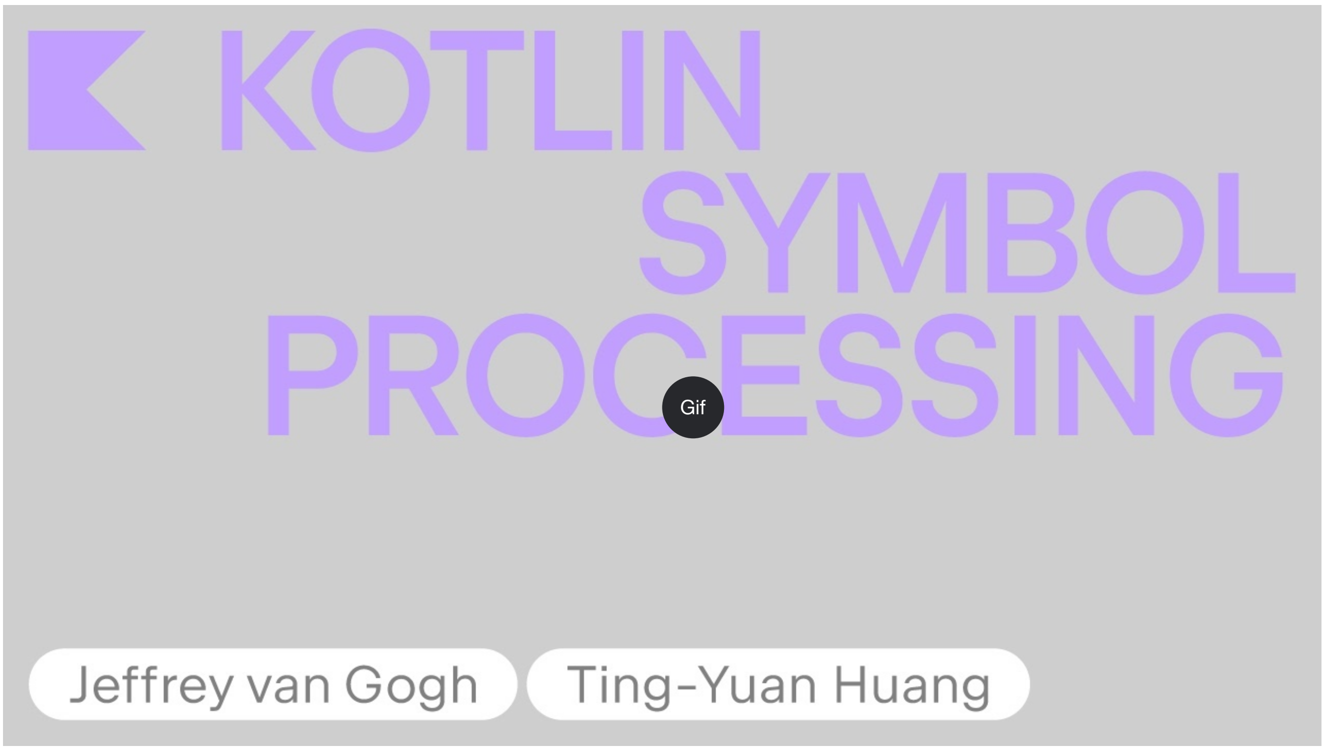
Conceptually, KSP is similar to KType in Kotlin reflection. The API allows processors to navigate from class declarations to corresponding types with specific type arguments and vice-versa. You can also substitute type arguments, specify variances, apply star projections, and mark nullabilities of types.

Another way to think of KSP is as a preprocessor framework of Kotlin programs. By considering KSP-based plugins as symbol processors, or simply processors, the data flow in a compilation can be described in the following steps:

1. Processors read and analyze source programs and resources.
2. Processors generate code or other forms of output.
3. The Kotlin compiler compiles the source programs together with the generated code.

Unlike a full-fledged compiler plugin, processors cannot modify the code. A compiler plugin that changes language semantics can sometimes be very confusing. KSP avoids that by treating the source programs as read-only.

You can also get an overview of KSP in this video:



Watch video online.

How KSP looks at source files

Most processors navigate through the various program structures of the input source code. Before diving into usage of the API, let's see at how a file might look from KSP's point of view:

```
KSFile
  packageName: KSName
  fileName: String
  annotations: List<KSAnnotation>  (File annotations)
  declarations: List<KSDeclaration>
    KSClassDeclaration // class, interface, object
      simpleName: KSName
      qualifiedName: KSName
      containingFile: String
      typeParameters: KSTypeParameter
      parentDeclaration: KSDeclaration
      classKind: ClassKind
      primaryConstructor: KSFunctionDeclaration
      superTypes: List<KSTypeReference>
      // contains inner classes, member functions, properties, etc.
      declarations: List<KSDeclaration>
    KSFunctionDeclaration // top level function
      simpleName: KSName
      qualifiedName: KSName
      containingFile: String
      typeParameters: KSTypeParameter
      parentDeclaration: KSDeclaration
      functionKind: FunctionKind
      extensionReceiver: KSTypeReference?
      returnType: KSTypeReference
      parameters: List<KSValueParameter>
      // contains local classes, local functions, local variables, etc.
      declarations: List<KSDeclaration>
    KSPropertyDeclaration // global variable
      simpleName: KSName
      qualifiedName: KSName
      containingFile: String
      typeParameters: KSTypeParameter
      parentDeclaration: KSDeclaration
      extensionReceiver: KSTypeReference?
      type: KSTypeReference
      getter: KSPropertyGetter
        returnType: KSTypeReference
      setter: KSPropertySetter
        parameter: KSValueParameter
```

This view lists common things that are declared in the file: classes, functions, properties, and so on.

SymbolProcessorProvider: the entry point

KSP expects an implementation of the SymbolProcessorProvider interface to instantiate SymbolProcessor:

```kotlin
interface SymbolProcessorProvider {
    fun create(environment: SymbolProcessorEnvironment): SymbolProcessor
}
```

While SymbolProcessor is defined as:

```kotlin
interface SymbolProcessor {
    fun process(resolver: Resolver): List<KSAnnotated> // Let's focus on this
    fun finish() {}
    fun onError() {}
}
```

A Resolver provides SymbolProcessor with access to compiler details such as symbols. A processor that finds all top-level functions and non-local functions in top-level classes might look something like the following:

```kotlin
class HelloFunctionFinderProcessor : SymbolProcessor() {
    // ...
    val functions = mutableListOf<KSClassDeclaration>()
    val visitor = FindFunctionsVisitor()
    override fun process(resolver: Resolver) {
        resolver.getAllFiles().forEach { it.accept(visitor, Unit) }
    }

    inner class FindFunctionsVisitor : KSVisitorVoid() {
        override fun visitClassDeclaration(classDeclaration: KSClassDeclaration, data: Unit) {
            classDeclaration.getDeclaredFunctions().forEach { it.accept(this, Unit) }
        }

        override fun visitFunctionDeclaration(function: KSFunctionDeclaration, data: Unit) {
            functions.add(function)
        }

        override fun visitFile(file: KSFile, data: Unit) {
            file.declarations.forEach { it.accept(this, Unit) }
        }
    }
    // ...

    class Provider : SymbolProcessorProvider {
        override fun create(environment: SymbolProcessorEnvironment): SymbolProcessor = TODO()
    }
}
```

Resources

- Quickstart
- Why use KSP?
- Examples
- How KSP models Kotlin code
- Reference for Java annotation processor authors
- Incremental processing notes
- Multiple round processing notes
- KSP on multiplatform projects
- Running KSP from command line
- FAQ

Supported libraries

The table includes a list of popular libraries on Android and their various stages of support for KSP:

Library	Status
Room	Officially supported
Moshi	Officially supported
RxHttp	Officially supported
Kotshi	Officially supported
Lyricist	Officially supported

Library	Status
Lich SavedState	Officially supported
gRPC Dekorator	Officially supported
EasyAdapter	Officially supported
Koin Annotations	Officially supported
Glide	Officially supported
Micronaut	Officially supported
Epoxy	Officially supported
Paris	Officially supported
Auto Dagger	Officially supported
SealedX	Officially supported
Ktorfit	Officially supported
Mockative	Officially supported
DeeplinkDispatch	Supported via airbnb/DeepLinkDispatch#323
Dagger	Alpha
Motif	Alpha
Hilt	In progress
Auto Factory	Not yet supported

KSP quickstart

For a quick start, you can create your own processor or get a sample one.

Add a processor

To add a processor, you need to include the KSP Gradle Plugin and add a dependency on the processor:

1. Add the KSP Gradle Plugin com.google.devtools.ksp to your build.gradle(.kts) file:

   Kotlin

   ```kotlin
   plugins {
       id("com.google.devtools.ksp") version "2.1.21-2.0.1"
   }
   ```

   Groovy

   ```groovy
   plugins {
       id 'com.google.devtools.ksp' version '2.1.21-2.0.1'
   }
   ```

2. Add a dependency on the processor. This example uses Dagger. Replace it with the processor you want to add.

   Kotlin

   ```kotlin
   dependencies {
       implementation("com.google.dagger:dagger-compiler:2.51.1")
       ksp("com.google.dagger:dagger-compiler:2.51.1")
   }
   ```

   Groovy

   ```groovy
   dependencies {
       implementation 'com.google.dagger:dagger-compiler:2.51.1'
       ksp 'com.google.dagger:dagger-compiler:2.51.1'
   }
   ```

3. Run ./gradlew build. You can find the generated code in the build/generated/ksp directory.

Here is a full example:

Kotlin

```kotlin
plugins {
    id("com.google.devtools.ksp") version "2.1.21-2.0.1"
    kotlin("jvm")
}

repositories {
    mavenCentral()
}

dependencies {
    implementation(kotlin("stdlib-jdk8"))
    implementation("com.google.dagger:dagger-compiler:2.51.1")
    ksp("com.google.dagger:dagger-compiler:2.51.1")
}
```

Groovy

```groovy
plugins {
    id 'com.google.devtools.ksp' version '2.1.21-2.0.1'
    id 'org.jetbrains.kotlin.jvm' version '2.2.0'
}

repositories {
    mavenCentral()
```

```
}

dependencies {
    implementation 'org.jetbrains.kotlin:kotlin-stdlib:2.2.0'
    implementation 'com.google.dagger:dagger-compiler:2.51.1'
    ksp 'com.google.dagger:dagger-compiler:2.51.1'
}
```

Create a processor of your own

1. Create an empty gradle project.
2. Specify version 2.1.21 of the Kotlin plugin in the root project for use in other project modules:

Kotlin

```
plugins {
    kotlin("jvm") version "2.1.21" apply false
}

buildscript {
    dependencies {
        classpath(kotlin("gradle-plugin", version = "2.1.21"))
    }
}
```

Groovy

```
plugins {
    id 'org.jetbrains.kotlin.jvm' version '2.1.21' apply false
}

buildscript {
    dependencies {
        classpath 'org.jetbrains.kotlin:kotlin-gradle-plugin:2.1.21'
    }
}
```

3. Add a module for hosting the processor.
4. In the module's build script, apply Kotlin plugin and add the KSP API to the dependencies block.

Kotlin

```
plugins {
    kotlin("jvm")
}

repositories {
    mavenCentral()
}

dependencies {
    implementation("com.google.devtools.ksp:symbol-processing-api:2.1.21-2.0.1")
}
```

Groovy

```
plugins {
    id 'org.jetbrains.kotlin.jvm' version '2.2.0'
}

repositories {
    mavenCentral()
}

dependencies {
    implementation 'com.google.devtools.ksp:symbol-processing-api:2.1.21-2.0.1'
}
```

5. You'll need to implement com.google.devtools.ksp.processing.SymbolProcessor and com.google.devtools.ksp.processing.SymbolProcessorProvider. Your implementation of SymbolProcessorProvider will be loaded as a service to instantiate the SymbolProcessor you implement. Note the following:

   - Implement SymbolProcessorProvider.create() to create a SymbolProcessor. Pass dependencies that your processor needs (such as CodeGenerator, processor options) through the parameters of SymbolProcessorProvider.create().
   - Your main logic should be in the SymbolProcessor.process() method.
   - Use resolver.getSymbolsWithAnnotation() to get the symbols you want to process, given the fully-qualified name of an annotation.
   - A common use case for KSP is to implement a customized visitor (interface com.google.devtools.ksp.symbol.KSVisitor) for operating on symbols. A simple template visitor is com.google.devtools.ksp.symbol.KSDefaultVisitor.
   - For sample implementations of the SymbolProcessorProvider and SymbolProcessor interfaces, see the following files in the sample project.
     - src/main/kotlin/BuilderProcessor.kt
     - src/main/kotlin/TestProcessor.kt
   - After writing your own processor, register your processor provider to the package by including its fully-qualified name in src/main/resources/META-INF/services/com.google.devtools.ksp.processing.SymbolProcessorProvider.

Use your own processor in a project

1. Create another module that contains a workload where you want to try out your processor.

Kotlin

```
pluginManagement {
    repositories {
        gradlePluginPortal()
    }
}
```

Groovy

```
pluginManagement {
    repositories {
        gradlePluginPortal()
    }
}
```

2. In the module's build script, apply the com.google.devtools.ksp plugin with the specified version and add your processor to the list of dependencies.

Kotlin

```
plugins {
    id("com.google.devtools.ksp") version "2.1.21-2.0.1"
}

dependencies {
    implementation(kotlin("stdlib-jdk8"))
    implementation(project(":test-processor"))
    ksp(project(":test-processor"))
}
```

Groovy

```
plugins {
    id 'com.google.devtools.ksp' version '2.1.21-2.0.1'
}
```

```
dependencies {
    implementation 'org.jetbrains.kotlin:kotlin-stdlib:2.2.0'
    implementation project(':test-processor')
    ksp project(':test-processor')
}
```

3. Run ./gradlew build. You can find the generated code under build/generated/ksp.

Here's a sample build script to apply the KSP plugin to a workload:

Kotlin

```kotlin
plugins {
    id("com.google.devtools.ksp") version "2.1.21-2.0.1"
    kotlin("jvm")
}

repositories {
    mavenCentral()
}

dependencies {
    implementation(kotlin("stdlib-jdk8"))
    implementation(project(":test-processor"))
    ksp(project(":test-processor"))
}
```

Groovy

```groovy
plugins {
    id 'com.google.devtools.ksp' version '2.1.21-2.0.1'
    id 'org.jetbrains.kotlin.jvm' version '2.2.0'
}

repositories {
    mavenCentral()
}

dependencies {
    implementation 'org.jetbrains.kotlin:kotlin-stdlib:2.2.0'
    implementation project(':test-processor')
    ksp project(':test-processor')
}
```

Pass options to processors

Processor options in SymbolProcessorEnvironment.options are specified in gradle build scripts:

```
ksp {
    arg("option1", "value1")
    arg("option2", "value2")
    ...
}
```

Make IDE aware of generated code

Generated source files are registered automatically since KSP 1.8.0-1.0.9. If you're using KSP 1.0.9 or newer and don't need to make the IDE aware of generated resources, feel free to skip this section.

By default, IntelliJ IDEA or other IDEs don't know about the generated code. So it will mark references to generated symbols unresolvable. To make an IDE be able to reason about the generated symbols, mark the following paths as generated source roots:

```
build/generated/ksp/main/kotlin/
```

```
build/generated/ksp/main/java/
```

If your IDE supports resource directories, also mark the following one:

```
build/generated/ksp/main/resources/
```

It may also be necessary to configure these directories in your KSP consumer module's build script:

Kotlin

```kotlin
kotlin {
    sourceSets.main {
        kotlin.srcDir("build/generated/ksp/main/kotlin")
    }
    sourceSets.test {
        kotlin.srcDir("build/generated/ksp/test/kotlin")
    }
}
```

Groovy

```groovy
kotlin {
    sourceSets {
        main.kotlin.srcDirs += 'build/generated/ksp/main/kotlin'
        test.kotlin.srcDirs += 'build/generated/ksp/test/kotlin'
    }
}
```

If you are using IntelliJ IDEA and KSP in a Gradle plugin then the above snippet will give the following warning:

```
Execution optimizations have been disabled for task ':publishPluginJar' to ensure correctness due to the following reasons:
Gradle detected a problem with the following location: '../build/generated/ksp/main/kotlin'.
Reason: Task ':publishPluginJar' uses this output of task ':kspKotlin' without declaring an explicit or implicit dependency.
```

In this case, use the following script instead:

Kotlin

```kotlin
plugins {
    // ...
    idea
}

idea {
    module {
        // Not using += due to https://github.com/gradle/gradle/issues/8749
        sourceDirs = sourceDirs + file("build/generated/ksp/main/kotlin") // or tasks["kspKotlin"].destination
        testSourceDirs = testSourceDirs + file("build/generated/ksp/test/kotlin")
        generatedSourceDirs = generatedSourceDirs + file("build/generated/ksp/main/kotlin") +
file("build/generated/ksp/test/kotlin")
    }
}
```

Groovy

```groovy
plugins {
    // ...
    id 'idea'
}

idea {
    module {
        // Not using += due to https://github.com/gradle/gradle/issues/8749
        sourceDirs = sourceDirs + file('build/generated/ksp/main/kotlin') // or tasks["kspKotlin"].destination
        testSourceDirs = testSourceDirs + file('build/generated/ksp/test/kotlin')
        generatedSourceDirs = generatedSourceDirs + file('build/generated/ksp/main/kotlin') +
file('build/generated/ksp/test/kotlin')
    }
}
```

Why KSP

Compiler plugins are powerful metaprogramming tools that can greatly enhance how you write code. Compiler plugins call compilers directly as libraries to analyze and edit input programs. These plugins can also generate output for various uses. For example, they can generate boilerplate code, and they can even generate full implementations for specially-marked program elements, such as Parcelable. Plugins have a variety of other uses and can even be used to implement and fine-tune features that are not provided directly in a language.

While compiler plugins are powerful, this power comes at a price. To write even the simplest plugin, you need to have some compiler background knowledge, as well as a certain level of familiarity with the implementation details of your specific compiler. Another practical issue is that plugins are often closely tied to specific compiler versions, meaning you might need to update your plugin each time you want to support a newer version of the compiler.

KSP makes creating lightweight compiler plugins easier

KSP is designed to hide compiler changes, minimizing maintenance efforts for processors that use it. KSP is designed not to be tied to the JVM so that it can be adapted to other platforms more easily in the future. KSP is also designed to minimize build times. For some processors, such as Glide, KSP reduces full compilation times by up to 25% when compared to kapt.

KSP is itself implemented as a compiler plugin. There are prebuilt packages on Google's Maven repository that you can download and use without having to build the project yourself.

Comparison to kotlinc compiler plugins

kotlinc compiler plugins have access to almost everything from the compiler and therefore have maximum power and flexibility. On the other hand, because these plugins can potentially depend on anything in the compiler, they are sensitive to compiler changes and need to be maintained frequently. These plugins also require a deep understanding of kotlinc's implementation, so the learning curve can be steep.

KSP aims to hide most compiler changes through a well-defined API, though major changes in compiler or even the Kotlin language might still require to be exposed to API users.

KSP tries to fulfill common use cases by providing an API that trades power for simplicity. Its capability is a strict subset of a general kotlinc plugin. For example, while kotlinc can examine expressions and statements and can even modify code, KSP cannot.

While writing a kotlinc plugin can be a lot of fun, it can also take a lot of time. If you aren't in a position to learn kotlinc's implementation and do not need to modify source code or read expressions, KSP might be a good fit.

Comparison to reflection

KSP's API looks similar to kotlin.reflect. The major difference between them is that type references in KSP need to be resolved explicitly. This is one of the reasons why the interfaces are not shared.

Comparison to kapt

kapt is a remarkable solution which makes a large amount of Java annotation processors work for Kotlin programs out-of-box. The major advantages of KSP over kapt are improved build performance, not tied to JVM, a more idiomatic Kotlin API, and the ability to understand Kotlin-only symbols.

To run Java annotation processors unmodified, kapt compiles Kotlin code into Java stubs that retain information that Java annotation processors care about. To create these stubs, kapt needs to resolve all symbols in the Kotlin program. The stub generation costs roughly 1/3 of a full kotlinc analysis and the same order of kotlinc code-generation. For many annotation processors, this is much longer than the time spent in the processors themselves. For example, Glide looks at a very limited number of classes with a predefined annotation, and its code generation is fairly quick. Almost all of the build overhead resides in the stub generation phase. Switching to KSP would immediately reduce the time spent in the compiler by 25%.

For performance evaluation, we implemented a simplified version of Glide in KSP to make it generate code for the Tachiyomi project. While the total Kotlin compilation time of the project is 21.55 seconds on our test device, it took 8.67 seconds for kapt to generate the code, and it took 1.15 seconds for our KSP implementation to generate the code.

Unlike kapt, processors in KSP do not see input programs from Java's point of view. The API is more natural to Kotlin, especially for Kotlin-specific features such as top-level functions. Because KSP doesn't delegate to javac like kapt, it doesn't assume JVM-specific behaviors and can be used with other platforms potentially.

Limitations

While KSP tries to be a simple solution for most common use cases, it has made several trade-offs compared to other plugin solutions. The following are not goals of KSP:

- Examining expression-level information of source code.
- Modifying source code.
- 100% compatibility with the Java Annotation Processing API.

KSP examples

Get all member functions

```kotlin
fun KSClassDeclaration.getDeclaredFunctions(): Sequence<KSFunctionDeclaration> =
    declarations.filterIsInstance<KSFunctionDeclaration>()
```

Check whether a class or function is local

```kotlin
fun KSDeclaration.isLocal(): Boolean =
    parentDeclaration != null && parentDeclaration !is KSClassDeclaration
```

Find the actual class or interface declaration that the type alias points to

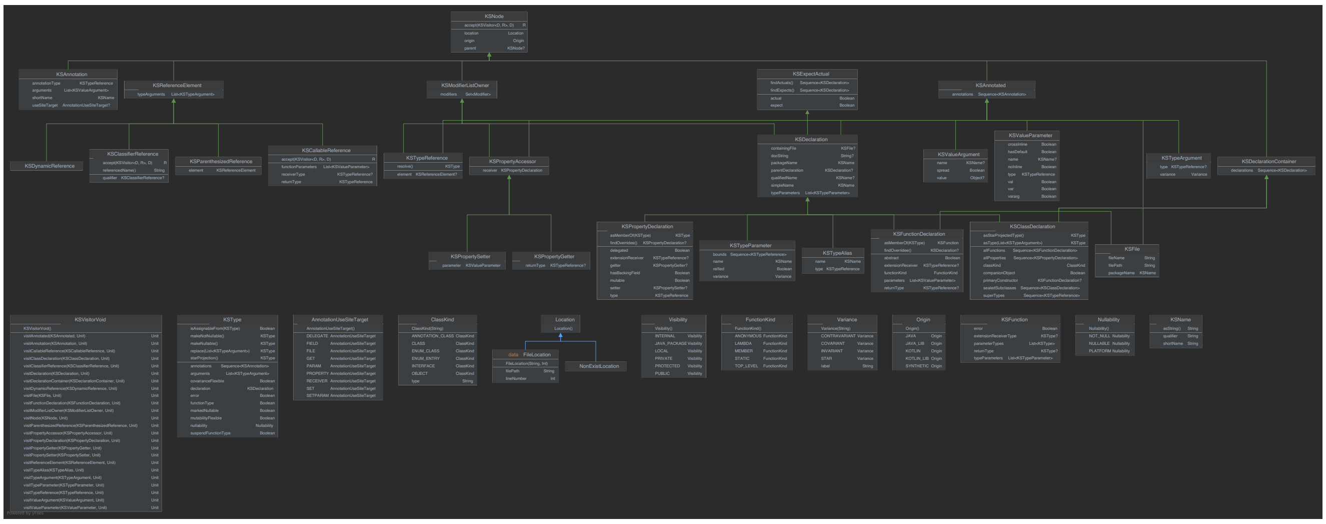
```kotlin
fun KSTypeAlias.findActualType(): KSClassDeclaration {
    val resolvedType = this.type.resolve().declaration
    return if (resolvedType is KSTypeAlias) {
        resolvedType.findActualType()
    } else {
        resolvedType as KSClassDeclaration
    }
}
```

Collect suppressed names in a file annotation

```kotlin
// @file:kotlin.Suppress("Example1", "Example2")
fun KSFile.suppressedNames(): Sequence<String> = annotations
    .filter {
        it.shortName.asString() == "Suppress" &&
        it.annotationType.resolve().declaration.qualifiedName?.asString() == "kotlin.Suppress"
    }.flatMap {
        it.arguments.flatMap {
            (it.value as Array<String>).toList()
        }
    }
```

How KSP models Kotlin code

You can find the API definition in the KSP GitHub repository. The diagram shows an overview of how Kotlin is modeled in KSP:


class diagram

See the full-sized diagram.

Type and resolution

The resolution takes most of the cost of the underlying API implementation. So type references are designed to be resolved by processors explicitly (with a few exceptions). When a type (such as KSFunctionDeclaration.returnType or KSAnnotation.annotationType) is referenced, it is always a KSTypeReference, which is a KSReferenceElement with annotations and modifiers.

```
interface KSFunctionDeclaration : ... {
  val returnType: KSTypeReference?
  // ...
}

interface KSTypeReference : KSAnnotated, KSModifierListOwner {
  val type: KSReferenceElement
}
```

A KSTypeReference can be resolved to a KSType, which refers to a type in Kotlin's type system.

A KSTypeReference has a KSReferenceElement, which models Kotlin's program structure: namely, how the reference is written. It corresponds to the type element in Kotlin's grammar.

A KSReferenceElement can be a KSClassifierReference or KSCallableReference, which contains a lot of useful information without the need for resolution. For example, KSClassifierReference has referencedName, while KSCallableReference has receiverType, functionArguments, and returnType.

If the original declaration referenced by a KSTypeReference is needed, it can usually be found by resolving to KSType and accessing through KSType.declaration. Moving from where a type is mentioned to where its class is defined looks like this:

```
val ksType: KSType = ksTypeReference.resolve()
val ksDeclaration: KSDeclaration = ksType.declaration
```

Type resolution is costly and therefore has explicit form. Some of the information obtained from resolution is already available in KSReferenceElement. For example, KSClassifierReference.referencedName can filter out a lot of elements that are not interesting. You should resolve type only if you need specific information from KSDeclaration or KSType.

KSTypeReference pointing to a function type has most of its information in its element. Although it can be resolved to the family of Function0, Function1, and so on, these resolutions don't bring any more information than KSCallableReference. One use case for resolving function type references is dealing with the identity of the function's prototype.

Java annotation processing to KSP reference

Program elements

Java	Closest facility in KSP	Notes
AnnotationMirror	KSAnnotation	
AnnotationValue	KSValueArguments	
Element	KSDeclaration/KSDeclarationContainer	
ExecutableElement	KSFunctionDeclaration	
PackageElement	KSFile	KSP doesn't model packages as program elements
Parameterizable	KSDeclaration	
QualifiedNameable	KSDeclaration	
TypeElement	KSClassDeclaration	
TypeParameterElement	KSTypeParameter	
VariableElement	KSValueParameter/KSPropertyDeclaration	

Types

KSP requires explicit type resolution, so some functionalities in Java can only be carried out by KSType and the corresponding elements before resolution.

Java	Closest facility in KSP	Notes
ArrayType	KSBuiltIns.arrayType	
DeclaredType	KSType/KSClassifierReference	
ErrorType	KSType.isError	
ExecutableType	KSType/KSCallableReference	
IntersectionType	KSType/KSTypeParameter	

Java	Closest facility in KSP	Notes
NoType	KSType.isError	N/A in KSP
NullType		N/A in KSP
PrimitiveType	KSBuiltIns	Not exactly same as primitive type in Java
ReferenceType	KSTypeReference	
TypeMirror	KSType	
TypeVariable	KSTypeParameter	
UnionType	N/A	Kotlin has only one type per catch block. UnionType is also not observable by even Java annotation processors
WildcardType	KSType/KSTypeArgument	

Misc

Java	Closest facility in KSP	Notes
Name	KSName	
ElementKind	ClassKind/FunctionKind	
Modifier	Modifier	
NestingKind	ClassKind/FunctionKind	
AnnotationValueVisitor		
ElementVisitor	KSVisitor	
AnnotatedConstruct	KSAnnotated	
TypeVisitor		
TypeKind	KSBuiltIns	Some can be found in builtins, otherwise check KSClassDeclaration for DeclaredType

Java	Closest facility in KSP	Notes
ElementFilter	Collection.filterIsInstance	
ElementKindVisitor	KSVisitor	
ElementScanner	KSTopDownVisitor	
SimpleAnnotationValueVisitor		Not needed in KSP
SimpleElementVisitor	KSVisitor	
SimpleTypeVisitor		
TypeKindVisitor		
Types	Resolver/utils	Some of the utils are also integrated into symbol interfaces
Elements	Resolver/utils	

Details

See how functionalities of Java annotation processing API can be carried out by KSP.

AnnotationMirror

Java	KSP equivalent
getAnnotationType	ksAnnotation.annotationType
getElementValues	ksAnnotation.arguments

AnnotationValue

Java	KSP equivalent
getValue	ksValueArgument.value

Element

Java	KSP equivalent
asType	ksClassDeclaration.asType(...) is available for KSClassDeclaration only. Type arguments need to be supplied.
getAnnotation	To be implemented
getAnnotationMirrors	ksDeclaration.annotations
getEnclosedElements	ksDeclarationContainer.declarations
getEnclosingElements	ksDeclaration.parentDeclaration
getKind	Type check and cast following ClassKind or FunctionKind
getModifiers	ksDeclaration.modifiers
getSimpleName	ksDeclaration.simpleName

ExecutableElement

Java	KSP equivalent
getDefaultValue	To be implemented
getParameters	ksFunctionDeclaration.parameters
getReceiverType	ksFunctionDeclaration.parentDeclaration
getReturnType	ksFunctionDeclaration.returnType
getSimpleName	ksFunctionDeclaration.simpleName
getThrownTypes	Not needed in Kotlin
getTypeParameters	ksFunctionDeclaration.typeParameters
isDefault	Check whether parent declaration is an interface or not
isVarArgs	ksFunctionDeclaration.parameters.any { it.isVarArg }

Parameterizable

Java	KSP equivalent
getTypeParameters	ksFunctionDeclaration.typeParameters

QualifiedNameable

Java	KSP equivalent
getQualifiedName	ksDeclaration.qualifiedName

TypeElement

Java	KSP equivalent
getEnclosedElements	ksClassDeclaration.declarations
getEnclosingElement	ksClassDeclaration.parentDeclaration

getInterfaces	
	```
	// Should be able to do without resolution
	ksClassDeclaration.superTypes
	    .map { it.resolve() }
	    .filter { (it?.declaration as? KSClassDeclaration)?.classKind == ClassKind.INTERFACE
	}
	```

getNestingKind	Check KSClassDeclaration.parentDeclaration and inner modifier
getQualifiedName	ksClassDeclaration.qualifiedName
getSimpleName	ksClassDeclaration.simpleName

getSuperclass	
	```
	// Should be able to do without resolution
	ksClassDeclaration.superTypes
	    .map { it.resolve() }
	    .filter { (it?.declaration as? KSClassDeclaration)?.classKind == ClassKind.CLASS }
	```

getTypeParameters	ksClassDeclaration.typeParameters

TypeParameterElement

Java	KSP equivalent

Java	KSP equivalent
getBounds	ksTypeParameter.bounds
getEnclosingElement	ksTypeParameter.parentDeclaration
getGenericElement	ksTypeParameter.parentDeclaration

VariableElement

Java	KSP equivalent
getConstantValue	To be implemented
getEnclosingElement	ksValueParameter.parentDeclaration
getSimpleName	ksValueParameter.simpleName

ArrayType

Java	KSP equivalent
getComponentType	ksType.arguments.first()

DeclaredType

Java	KSP equivalent
asElement	ksType.declaration
getEnclosingType	ksType.declaration.parentDeclaration
getTypeArguments	ksType.arguments

ExecutableType

A KSType for a function is just a signature represented by the FunctionN<R, T1, T2, ..., TN> family.

Java	KSP equivalent
getParameterTypes	ksType.declaration.typeParameters, ksFunctionDeclaration.parameters.map { it.type }
getReceiverType	ksFunctionDeclaration.parentDeclaration.asType(...)
getReturnType	ksType.declaration.typeParameters.last()
getThrownTypes	Not needed in Kotlin
getTypeVariables	ksFunctionDeclaration.typeParameters

IntersectionType

Java	KSP equivalent
getBounds	ksTypeParameter.bounds

TypeMirror

Java	KSP equivalent
getKind	Compare with types in KSBuiltIns for primitive types, Unit type, otherwise declared types

TypeVariable

Java	KSP equivalent
asElement	ksType.declaration
getLowerBound	To be decided. Only needed if capture is provided and explicit bound checking is needed.
getUpperBound	ksTypeParameter.bounds

WildcardType

Java	KSP equivalent

Java	KSP equivalent
getExtendsBound	`if (ksTypeArgument.variance == Variance.COVARIANT) ksTypeArgument.type else null`
getSuperBound	`if (ksTypeArgument.variance == Variance.CONTRAVARIANT) ksTypeArgument.type else null`

Elements

Java	KSP equivalent
getAllAnnotationMirrors	KSDeclarations.annotations
getAllMembers	getAllFunctions, getAllProperties is to be implemented
getBinaryName	To be decided, see Java Specification
getConstantExpression	There is constant value, not expression
getDocComment	To be implemented
getElementValuesWithDefaults	To be implemented
getName	resolver.getKSNameFromString
getPackageElement	Package not supported, while package information can be retrieved. Operation on package is not possible for KSP
getPackageOf	Package not supported
getTypeElement	Resolver.getClassDeclarationByName
hides	To be implemented
isDeprecated	`KsDeclaration.annotations.any { it.annotationType.resolve()!!.declaration.qualifiedName!!.asString() == Deprecated::class.qualifiedName }`
overrides	KSFunctionDeclaration.overrides/KSPropertyDeclaration.overrides (member function of respective class)

Java	KSP equivalent
printElements	KSP has basic toString() implementation on most classes

Types

Java	KSP equivalent
asElement	ksType.declaration
asMemberOf	resolver.asMemberOf
boxedClass	Not needed
capture	To be decided
contains	KSType.isAssignableFrom
directSuperTypes	(ksType.declaration as KSClassDeclaration).superTypes
erasure	ksType.starProjection()
getArrayType	ksBuiltIns.arrayType.replace(...)
getDeclaredType	ksClassDeclaration.asType
getNoType	ksBuiltIns.nothingType/null
getNullType	Depending on the context, KSType.markNullable could be useful
getPrimitiveType	Not needed, check for KSBuiltins
getWildcardType	Use Variance in places expecting KSTypeArgument
isAssignable	ksType.isAssignableFrom
isSameType	ksType.equals
isSubsignature	functionTypeA == functionTypeB/functionTypeA == functionTypeB.starProjection()

Java	KSP equivalent
isSubtype	ksType.isAssignableFrom
unboxedType	Not needed

Incremental processing

Incremental processing is a processing technique that avoids re-processing of sources as much as possible. The primary goal of incremental processing is to reduce the turn-around time of a typical change-compile-test cycle. For general information, see Wikipedia's article on incremental computing.

To determine which sources are dirty (those that need to be reprocessed), KSP needs processors' help to identify which input sources correspond to which generated outputs. To help with this often cumbersome and error-prone process, KSP is designed to require only a minimal set of root sources that processors use as starting points to navigate the code structure. In other words, a processor needs to associate an output with the sources of the corresponding KSNode if the KSNode is obtained from any of the following:

- Resolver.getAllFiles
- Resolver.getSymbolsWithAnnotation
- Resolver.getClassDeclarationByName
- Resolver.getDeclarationsFromPackage

Incremental processing is currently enabled by default. To disable it, set the Gradle property ksp.incremental=false. To enable logs that dump the dirty set according to dependencies and outputs, use ksp.incremental.log=true. You can find these log files in the build output directory with a .log file extension.

On the JVM, classpath changes, as well as Kotlin and Java source changes, are tracked by default. To track only Kotlin and Java source changes, disable classpath tracking by setting the ksp.incremental.intermodule=false Gradle property.

Aggregating vs Isolating

Similar to the concepts in Gradle annotation processing, KSP supports both aggregating and isolating modes. Note that unlike Gradle annotation processing, KSP categorizes each output as either aggregating or isolating, rather than the entire processor.

An aggregating output can potentially be affected by any input changes, except removing files that don't affect other files. This means that any input change results in a rebuild of all aggregating outputs, which in turn means reprocessing of all corresponding registered, new, and modified source files.

As an example, an output that collects all symbols with a particular annotation is considered an aggregating output.

An isolating output depends only on its specified sources. Changes to other sources do not affect an isolating output. Note that unlike Gradle annotation processing, you can define multiple source files for a given output.

As an example, a generated class that is dedicated to an interface it implements is considered isolating.

To summarize, if an output might depend on new or any changed sources, it is considered aggregating. Otherwise, the output is isolating.

Here's a summary for readers familiar with Java annotation processing:

- In an isolating Java annotation processor, all the outputs are isolating in KSP.
- In an aggregating Java annotation processor, some outputs can be isolating and some can be aggregating in KSP.

How it is implemented

The dependencies are calculated by the association of input and output files, instead of annotations. This is a many-to-many relation.

The dirtiness propagation rules due to input-output associations are:

1. If an input file is changed, it will always be reprocessed.

2. If an input file is changed, and it is associated with an output, then all other input files associated with the same output will also be reprocessed. This is transitive, namely, invalidation happens repeatedly until there is no new dirty file.
3. All input files that are associated with one or more aggregating outputs will be reprocessed. In other words, if an input file isn't associated with any aggregating outputs, it won't be reprocessed (unless it meets 1. or 2. in the above).

Reasons are:

1. If an input is changed, new information can be introduced and therefore processors need to run again with the input.
2. An output is made out of a set of inputs. Processors may need all the inputs to regenerate the output.
3. aggregating=true means that an output may potentially depend on new information, which can come from either new files, or changed, existing files. aggregating=false means that processor is sure that the information only comes from certain input files and never from other or new files.

Example 1

A processor generates outputForA after reading class A in A.kt and class B in B.kt, where A extends B. The processor got A by Resolver.getSymbolsWithAnnotation and then got B by KSClassDeclaration.superTypes from A. Because the inclusion of B is due to A, B.kt doesn't need to be specified in dependencies for outputForA. You can still specify B.kt in this case, but it is unnecessary.

```
// A.kt
@Interesting
class A : B()

// B.kt
open class B

// Example1Processor.kt
class Example1Processor : SymbolProcessor {
    override fun process(resolver: Resolver) {
        val declA = resolver.getSymbolsWithAnnotation("Interesting").first() as KSClassDeclaration
        val declB = declA.superTypes.first().resolve().declaration
        // B.kt isn't required, because it can be deduced as a dependency by KSP
        val dependencies = Dependencies(aggregating = true, declA.containingFile!!)
        // outputForA.kt
        val outputName = "outputFor${declA.simpleName.asString()}"
        // outputForA depends on A.kt and B.kt
        val output = codeGenerator.createNewFile(dependencies, "com.example", outputName, "kt")
        output.write("// $declA : $declB\n".toByteArray())
        output.close()
    }
    // ...
}
```

Example 2

Consider that a processor generates outputA after reading sourceA and outputB after reading sourceB.

When sourceA is changed:

- If outputB is aggregating, both sourceA and sourceB are reprocessed.
- If outputB is isolating, only sourceA is reprocessed.

When sourceC is added:

- If outputB is aggregating, both sourceC and sourceB are reprocessed.
- If outputB is isolating, only sourceC is reprocessed.

When sourceA is removed, nothing needs to be reprocessed.

When sourceB is removed, nothing needs to be reprocessed.

How file dirtiness is determined

A dirty file is either directly changed by users or indirectly affected by other dirty files. KSP propagates dirtiness in two steps:

- Propagation by resolution tracing: Resolving a type reference (implicitly or explicitly) is the only way to navigate from one file to another. When a type reference is resolved by a processor, a changed or affected file that contains a change that may potentially affect the resolution result will affect the file containing that reference.
- Propagation by input-output correspondence: If a source file is changed or affected, all other source files having some output in common with that file are affected.

Note that both of them are transitive and the second forms equivalence classes.

Reporting bugs

To report a bug, please set Gradle properties ksp.incremental=true and ksp.incremental.log=true, and perform a clean build. This build produces two log files:

- build/kspCaches/<source set>/logs/kspDirtySet.log
- build/kspCaches/<source set>/logs/kspSourceToOutputs.log

You can then run successive incremental builds, which will generate two additional log files:

- build/kspCaches/<source set>/logs/kspDirtySetByDeps.log
- build/kspCaches/<source set>/logs/kspDirtySetByOutputs.log

These logs contain file names of sources and outputs, plus the timestamps of the builds.

Multiple round processing

KSP supports multiple round processing, or processing files over multiple rounds. It means that subsequent rounds use an output from previous rounds as additional input.

Changes to your processor

To use multiple round processing, the SymbolProcessor.process() function needs to return a list of deferred symbols (List<KSAnnotated>) for invalid symbols. Use KSAnnotated.validate() to filter invalid symbols to be deferred to the next round.

The following sample code shows how to defer invalid symbols by using a validation check:

```kotlin
override fun process(resolver: Resolver): List<KSAnnotated> {
    val symbols = resolver.getSymbolsWithAnnotation("com.example.annotation.Builder")
    val result = symbols.filter { !it.validate() }
    symbols
        .filter { it is KSClassDeclaration && it.validate() }
        .map { it.accept(BuilderVisitor(), Unit) }
    return result
}
```

Multiple round behavior

Deferring symbols to the next round

Processors can defer the processing of certain symbols to the next round. When a symbol is deferred, processor is waiting for other processors to provide additional information. It can continue deferring the symbol as many rounds as needed. Once the other processors provide the required information, the processor can then process the deferred symbol. Processor should only defer invalid symbols which are lacking necessary information. Therefore, processors should not defer symbols from classpath, KSP will also filter out any deferred symbols that are not from source code.

As an example, a processor that creates a builder for an annotated class might require all parameter types of its constructors to be valid (resolved to a concrete type). In the first round, one of the parameter type is not resolvable. Then in the second round, it becomes resolvable because of the generated files from the first round.

Validating symbols

A convenient way to decide if a symbol should be deferred is through validation. A processor should know which information is necessary to properly process the symbol. Note that validation usually requires resolution which can be expensive, so we recommend checking only what is required. Continuing with the previous example, an ideal validation for the builder processor checks only whether all resolved parameter types of the constructors of annotated symbols contain isError == false.

KSP provides a default validation utility. For more information, see the Advanced section.

Termination condition

Multiple round processing terminates when a full round of processing generates no new files. If unprocessed deferred symbols still exist when the termination condition is met, KSP logs an error message for each processor with unprocessed deferred symbols.

Files accessible at each round

Both newly generated files and existing files are accessible through a Resolver. KSP provides two APIs for accessing files: Resolver.getAllFiles() and Resolver.getNewFiles(). getAllFiles() returns a combined list of both existing files and newly generated files, while getNewFiles() returns only newly generated files.

Changes to getSymbolsAnnotatedWith()

To avoid unnecessary reprocessing of symbols, getSymbolsAnnotatedWith() returns only those symbols found in newly generated files, together with the symbols from deferred symbols from the last round.

Processor instantiating

A processor instance is created only once, which means you can store information in the processor object to be used for later rounds.

Information consistent cross rounds

All KSP symbols will not be reusable across multiple rounds, as the resolution result can potentially change based on what was generated in a previous round. However, since KSP does not allow modifying existing code, some information such as the string value for a symbol name should still be reusable. To summarize, processors can store information from previous rounds but need to bear in mind that this information might be invalid in future rounds.

Error and exception handling

When an error (defined by processor calling KSPLogger.error()) or exception occurs, processing stops after the current round completes. All processors will call the onError() method and will not call the finish() method.

Note that even though an error has occurred, other processors continue processing normally for that round. This means that error handling occurs after processing has completed for the round.

Upon exceptions, KSP will try to distinguish the exceptions from KSP and exceptions from processors. Exceptions will result in a termination of processing immediately and be logged as an error in KSPLogger. Exceptions from KSP should be reported to KSP developers for further investigation. At the end of the round where exceptions or errors happened, all processors will invoke onError() function to do their own error handling.

KSP provides a default no-op implementation for onError() as part of the SymbolProcessor interface. You can override this method to provide your own error handling logic.

Advanced

Default behavior for validation

The default validation logic provided by KSP validates all directly reachable symbols inside the enclosing scope of the symbol that is being validated. Default validation checks whether references in the enclosed scope are resolvable to a concrete type but does not recursively dive into the referenced types to perform validation.

Write your own validation logic

Default validation behavior might not be suitable for all cases. You can reference KSValidateVisitor and write your own validation logic by providing a custom predicate lambda, which is then used by KSValidateVisitor to filter out symbols that need to be checked.

KSP with Kotlin Multiplatform

For a quick start, see a sample Kotlin Multiplatform project defining a KSP processor.

Starting from KSP 1.0.1, applying KSP on a multiplatform project is similar to that on a single platform, JVM project. The main difference is that, instead of writing the ksp(...) configuration in dependencies, add(ksp<Target>) or add(ksp<SourceSet>) is used to specify which compilation targets need symbol processing, before compilation.

```
plugins {
    kotlin("multiplatform")
    id("com.google.devtools.ksp")
}

kotlin {
    jvm()
    linuxX64 {
        binaries {
            executable()
        }
    }
}

dependencies {
    add("kspCommonMainMetadata", project(":test-processor"))
    add("kspJvm", project(":test-processor"))
    add("kspJvmTest", project(":test-processor")) // Not doing anything because there's no test source set for JVM
    // There is no processing for the Linux x64 main source set, because kspLinuxX64 isn't specified
    // add("kspLinuxX64Test", project(":test-processor"))
}
```

Compilation and processing

In a multiplatform project, Kotlin compilation may happen multiple times (main, test, or other build flavors) for each platform. So is symbol processing. A symbol processing task is created whenever there is a Kotlin compilation task and a corresponding ksp<Target> or ksp<SourceSet> configuration is specified.

For example, in the above build.gradle.kts, there are 4 compilation tasks: common/metadata, JVM main, Linux x64 main, Linux x64 test, and 3 symbol processing tasks: common/metadata, JVM main, Linux x64 test.

Avoid the ksp(...) configuration on KSP 1.0.1+

Before KSP 1.0.1, there is only one, unified ksp(...) configuration available. Therefore, processors either applies to all compilation targets, or nothing at all. Note that the ksp(...) configuration not only applies to the main source set, but also the test source set if it exists, even on traditional, non-multiplatform projects. This brought unnecessary overheads to build time.

Starting from KSP 1.0.1, per-target configurations are provided as shown in the above example. In the future:

1. For multiplatform projects, the ksp(...) configuration will be deprecated and removed.
2. For single platform projects, the ksp(...) configuration will only apply to the main, default compilation. Other targets like test will need to specify kspTest(...) in order to apply processors.

Starting from KSP 1.0.1, there is an early access flag -DallowAllTargetConfiguration=false to switch to the more efficient behavior. If the current behavior is causing performance issues, please give it a try. The default value of the flag will be flipped from true to false on KSP 2.0.

Running KSP from command line

KSP is a Kotlin compiler plugin and needs to run with Kotlin compiler. Download and extract them.

```
#!/bin/bash
```

```
# Kotlin compiler
wget https://github.com/JetBrains/kotlin/releases/download/v2.1.21/kotlin-compiler-2.1.21.zip
unzip kotlin-compiler-2.1.21.zip

# KSP
wget https://github.com/google/ksp/releases/download/2.1.21-2.0.1/artifacts.zip
unzip artifacts.zip
```

To run KSP with kotlinc, pass the -Xplugin option to kotlinc.

```
-Xplugin=/path/to/symbol-processing-cmdline-2.1.21-2.0.1.jar
```

This is different from the symbol-processing-2.1.21-2.0.1.jar, which is designed to be used with kotlin-compiler-embeddable when running with Gradle. The command line kotlinc needs symbol-processing-cmdline-2.1.21-2.0.1.jar.

You'll also need the API jar.

```
-Xplugin=/path/to/symbol-processing-api-2.1.21-2.0.1.jar
```

See the complete example:

```
#!/bin/bash

KSP_PLUGIN_ID=com.google.devtools.ksp.symbol-processing
KSP_PLUGIN_OPT=plugin:$KSP_PLUGIN_ID

KSP_PLUGIN_JAR=./com/google/devtools/ksp/symbol-processing-cmdline/2.1.21-2.0.1/symbol-processing-cmdline-2.1.21-2.0.1.jar
KSP_API_JAR=./com/google/devtools/ksp/symbol-processing-api/2.1.21-2.0.1/symbol-processing-api-2.1.21-2.0.1.jar
KOTLINC=./kotlinc/bin/kotlinc

AP=/path/to/your-processor.jar

mkdir out
$KOTLINC \
        -Xplugin=$KSP_PLUGIN_JAR \
        -Xplugin=$KSP_API_JAR \
        -Xallow-no-source-files \
        -P $KSP_PLUGIN_OPT:apclasspath=$AP \
        -P $KSP_PLUGIN_OPT:projectBaseDir=. \
        -P $KSP_PLUGIN_OPT:classOutputDir=./out \
        -P $KSP_PLUGIN_OPT:javaOutputDir=./out \
        -P $KSP_PLUGIN_OPT:kotlinOutputDir=./out \
        -P $KSP_PLUGIN_OPT:resourceOutputDir=./out \
        -P $KSP_PLUGIN_OPT:kspOutputDir=./out \
        -P $KSP_PLUGIN_OPT:cachesDir=./out \
        -P $KSP_PLUGIN_OPT:incremental=false \
        -P $KSP_PLUGIN_OPT:apoption=key1=value1 \
        -P $KSP_PLUGIN_OPT:apoption=key2=value2 \
        $*
```

KSP FAQ

Why KSP?

KSP has several advantages over kapt:

- It is faster.
- The API is more fluent for Kotlin users.
- It supports multiple round processing on generated Kotlin sources.
- It is being designed with multiplatform compatibility in mind.

Why is KSP faster than kapt?

kapt has to parse and resolve every type reference in order to generate Java stubs, whereas KSP resolves references on-demand. Delegating to javac also takes time.

Additionally, KSP's incremental processing model has a finer granularity than just isolating and aggregating. It finds more opportunities to avoid reprocessing everything. Also, because KSP traces symbol resolutions dynamically, a change in a file is less likely to pollute other files and therefore the set of files to be reprocessed is smaller. This is not possible for kapt because it delegates processing to javac.

Is KSP Kotlin-specific?

KSP can process Java sources as well. The API is unified, meaning that when you parse a Java class and a Kotlin class you get a unified data structure in KSP.

How to upgrade KSP?

KSP has API and implementation. The API rarely changes and is backward compatible: there can be new interfaces, but old interfaces never change. The implementation is tied to a specific compiler version. With the new release, the supported compiler version can change.

Processors only depend on API and therefore are not tied to compiler versions. However, users of processors need to bump KSP version when bumping the compiler version in their project. Otherwise, the following error will occur:

```
ksp-a.b.c is too old for kotlin-x.y.z. Please upgrade ksp or downgrade kotlin-gradle-plugin
```

> Users of processors don't need to bump processor's version because processors only depend on API.

For example, some processor is released and tested with KSP 1.0.1, which depends strictly on Kotlin 1.6.0. To make it work with Kotlin 1.6.20, the only thing you need to do is bump KSP to a version (for example, KSP 1.1.0) that is built for Kotlin 1.6.20.

Can I use a newer KSP implementation with an older Kotlin compiler?

If the language version is the same, Kotlin compiler is supposed to be backward compatible. Bumping Kotlin compiler should be trivial most of the time. If you need a newer KSP implementation, please upgrade the Kotlin compiler accordingly.

How often do you update KSP?

KSP tries to follow Semantic Versioning as close as possible. With KSP version major.minor.patch,

- major is reserved for incompatible API changes. There is no pre-determined schedule for this.
- minor is reserved for new features. This is going to be updated approximately quarterly.
- patch is reserved for bug fixes and new Kotlin releases. It's updated roughly monthly.

Usually a corresponding KSP release is available within a couple of days after a new Kotlin version is released, including the pre-releases (Beta or RC).

Besides Kotlin, are there other version requirements for libraries?

Here is a list of requirements for libraries/infrastructures:

- Android Gradle Plugin 7.1.3+
- Gradle 6.8.3+

What is KSP's future roadmap?

The following items have been planned:

- Support new Kotlin compiler
- Improve support to multiplatform. For example, running KSP on a subset of targets/sharing computations between targets.

- Improve performance. There are a bunch of optimizations to be done!
- Keep fixing bugs.

Please feel free to reach out to us in the #ksp channel in Kotlin Slack (get an invite) if you would like to discuss any ideas. Filing GitHub issues/feature requests or pull requests are also welcome!

Learning materials overview

You can use the following materials and resources for learning Kotlin:

- Basic syntax – get a quick overview of the Kotlin syntax.
- Idioms – learn how to write idiomatic Kotlin code for popular cases.
  - Java to Kotlin migration guide: Strings – learn how to perform typical tasks with strings in Java and Kotlin.
  - Java to Kotlin migration guide: Collections — learn how to perform typical tasks with collections in Java and Kotlin.
  - Java to Kotlin migration guide: Nullability — learn how to handle nullability in Java and Kotlin.
- Kotlin Koans – complete exercises to learn the Kotlin syntax. Each exercise is created as a failing unit test and your job is to make it pass. Recommended for developers with Java experience.
- Kotlin by example – review a set of small and simple annotated examples for the Kotlin syntax.
- Kotlin Core track by JetBrains Academy – learn all the Kotlin essentials while creating working applications step by step.
- Kotlin books – find books we've reviewed and recommend for learning Kotlin.
- Kotlin tips – watch short videos where the Kotlin team shows you how to use Kotlin in a more efficient and idiomatic way, so you can have more fun when writing code.
- Advent of Code puzzles – learn idiomatic Kotlin and test your language skills by completing short and fun tasks.
- Kotlin hands-on tutorials – complete long-form tutorials to fully grasp a technology. These tutorials guide you through a self-contained project related to a specific topic.
- Kotlin for Java Developers – learn the similarities and differences between Java and Kotlin in this course on Coursera.
- Kotlin documentation in PDF format – read our documentation offline.

Kotlin Koans

Kotlin Koans are a series of exercises designed primarily for Java developers, to help you become familiar with the Kotlin syntax. Each exercise is created as a failing unit test, and your job is to make it pass. You can complete the Kotlin Koans tasks in one of the following ways:

- You can play with Koans online.
- You can perform the tasks right inside IntelliJ IDEA or Android Studio by installing the JetBrains Academy plugin and choosing the Kotlin Koans course.

Whatever way you choose to solve koans, you can see the solution for each task:

- In the online version, click Show answer.
- For the JetBrains Academy plugin, try to complete the task first and then choose Peek solution if your answer is incorrect.

We recommend you check the solution after implementing the task to compare your answer with the proposed one. Make sure you don't cheat!

Kotlin hands-on

A series of hands-on tutorials where you can create applications with Kotlin using a variety of different technologies and targeting multiple platforms. The exercises are divided into a series of steps, walking you through each section.

Building Reactive Spring Boot applications with Kotlin coroutines and RSocket

Build a simple chat application using Spring Boot and Kotlin, and learn about the benefits of using Kotlin for server-side development from a syntax perspective.

Start

Building web applications with React and Kotlin/JS

Create a React Application using Kotlin/JS, and see how you can leverage Kotlin's type system, library ecosystem, and interoperability features.

Start

Building web applications with Spring Boot and Kotlin

Build a simple blog application by combining the power of Spring Boot and Kotlin.

Start

Creating HTTP APIs with Ktor

Create a backend API for your application that responds to HTTP requests.

Start

Creating a WebSocket chat with Ktor

Create a simple Chat application using Ktor including both a JVM server and a JVM client.

Start

Creating an interactive website with Ktor

Learn how to serve files, use templating engines such as Freemarker and the kotlinx.html DSL, and work with form input from Ktor.

Start

Introduction to Kotlin coroutines and channels

Learn about coroutines in Kotlin and how you can communicate between them using channels.

Start

Introduction to Kotlin/Native

Create a simple HTTP client that can run natively on multiple platforms using Kotlin/Native and libcurl.

Start

Kotlin Multiplatform: networking and data storage

Learn how to create a mobile application for Android and iOS using Kotlin Multiplatform with Ktor and SQLDelight.

Start

Targeting iOS and Android with Kotlin Multiplatform

Learn how to create a mobile application that can target both iOS and Android using Kotlin Multiplatform.

Start

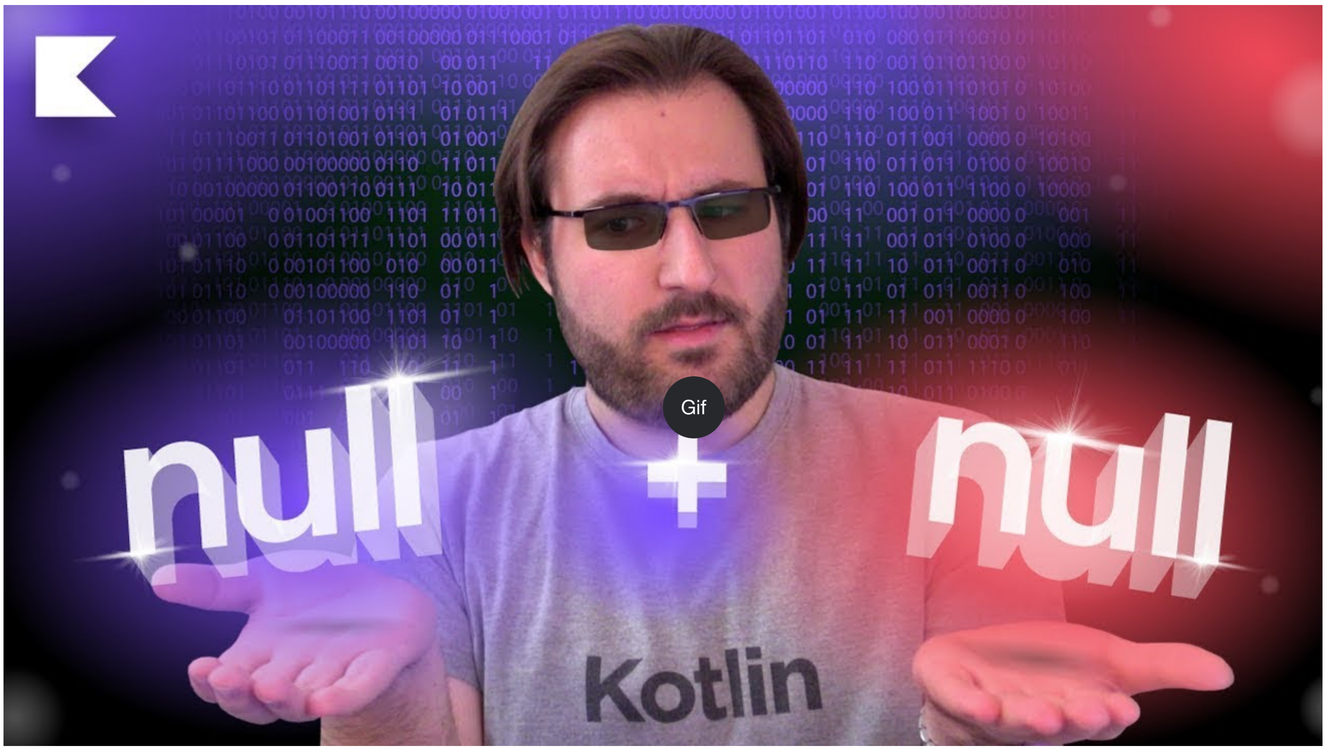
Kotlin tips

Kotlin Tips is a series of short videos where members of the Kotlin team show how to use Kotlin in a more efficient and idiomatic way to have more fun when writing code.

Subscribe to our YouTube channel to not miss new Kotlin Tips videos.

null + null in Kotlin

What happens when you add null + null in Kotlin, and what does it return? Sebastian Aigner addresses this mystery in our latest quick tip. Along the way, he also shows why there's no reason to be scared of nullables:



Watch video online.

Deduplicating collection items

Got a Kotlin collection that contains duplicates? Need a collection with only unique items? Let Sebastian Aigner show you how to remove duplicates from your lists, or turn them into sets in this Kotlin tip:

Watch video online.

The suspend and inline mystery

How come functions like repeat(), map() and filter() accept suspending functions in their lambdas, even though their signatures aren't coroutines-aware? In this episode of Kotlin Tips Sebastian Aigner solves the riddle: it has something to do with the inline modifier:

Watch video online.

Unshadowing declarations with their fully qualified name

Shadowing means having two declarations in a scope have the same name. So, how do you pick? In this episode of Kotlin Tips Sebastian Aigner shows you a simple Kotlin trick to call exactly the function that you need, using the power of fully qualified names:

Watch video online.

Return and throw with the Elvis operator

Elvis has entered the building once more! Sebastian Aigner explains why the operator is named after the famous singer, and how you can use ?: in Kotlin to return or throw. The magic behind the scenes? The Nothing type.

Watch video online.

Destructuring declarations

With destructuring declarations in Kotlin, you can create multiple variables from a single object, all at once. In this video Sebastian Aigner shows you a selection of things that can be destructured – pairs, lists, maps, and more. And what about your own objects? Kotlin's component functions provide an answer for those as well:

Watch video online.

Operator functions with nullable values

In Kotlin, you can override operators like addition and subtraction for your classes and supply your own logic. But what if you want to allow null values, both on their left and right sides? In this video, Sebastian Aigner answers this question:

Watch video online.

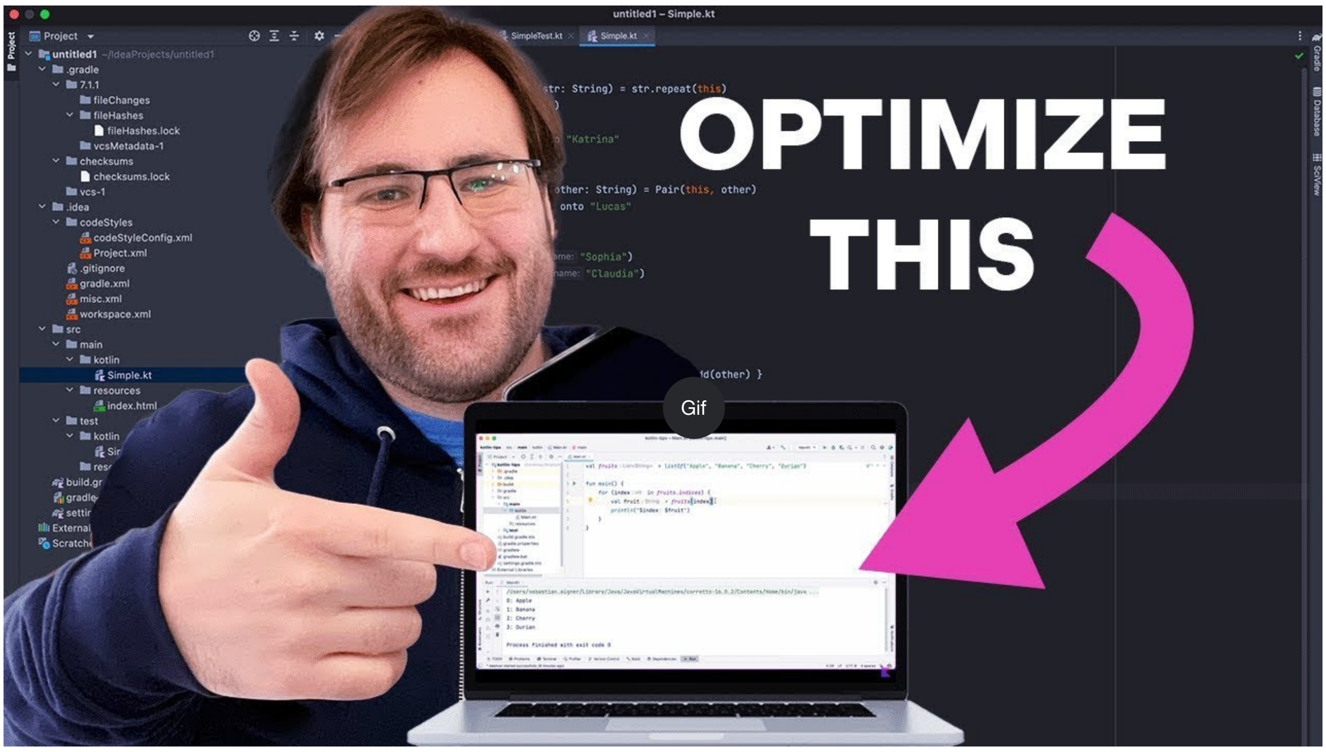
Timing code

Watch Sebastian Aigner give a quick overview of the measureTimedValue() function, and learn how you can time your code:

Watch video online.

Improving loops

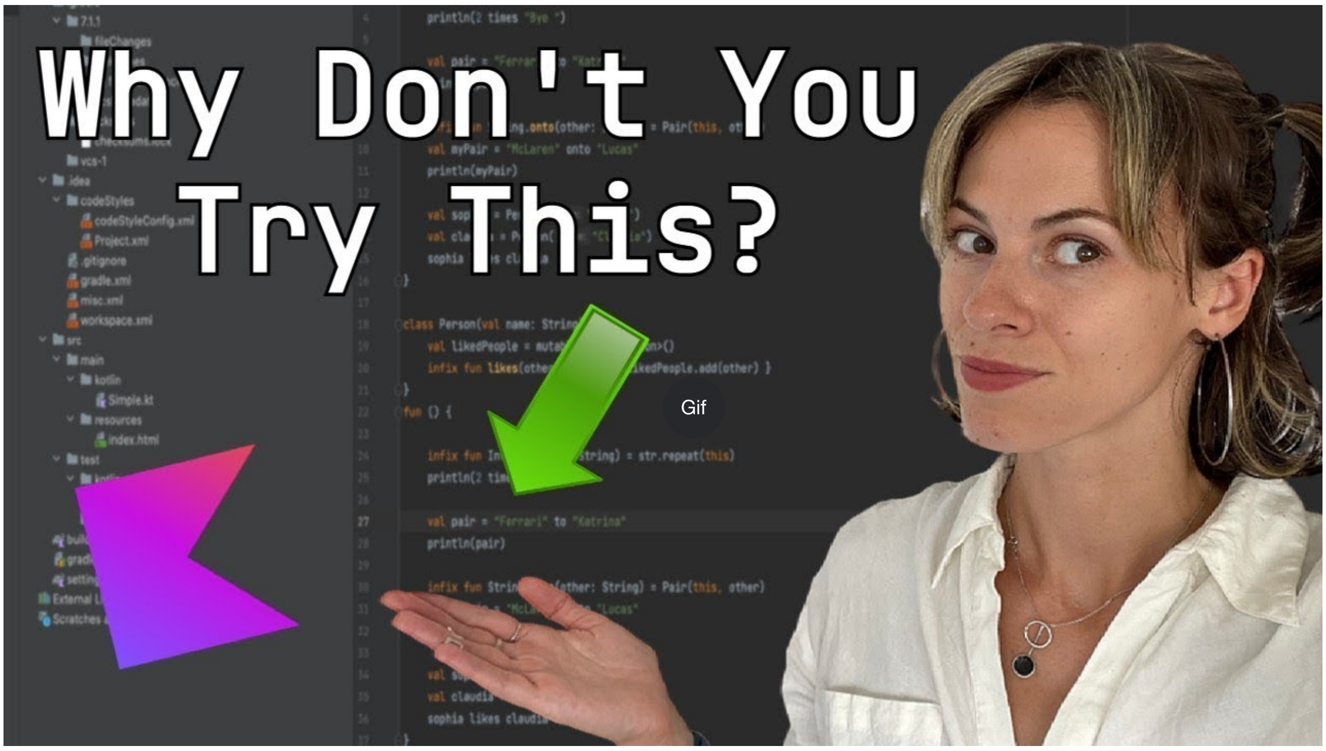
In this video, Sebastian Aigner will demonstrate how to improve loops to make your code more readable, understandable, and concise:



Watch video online.

Strings

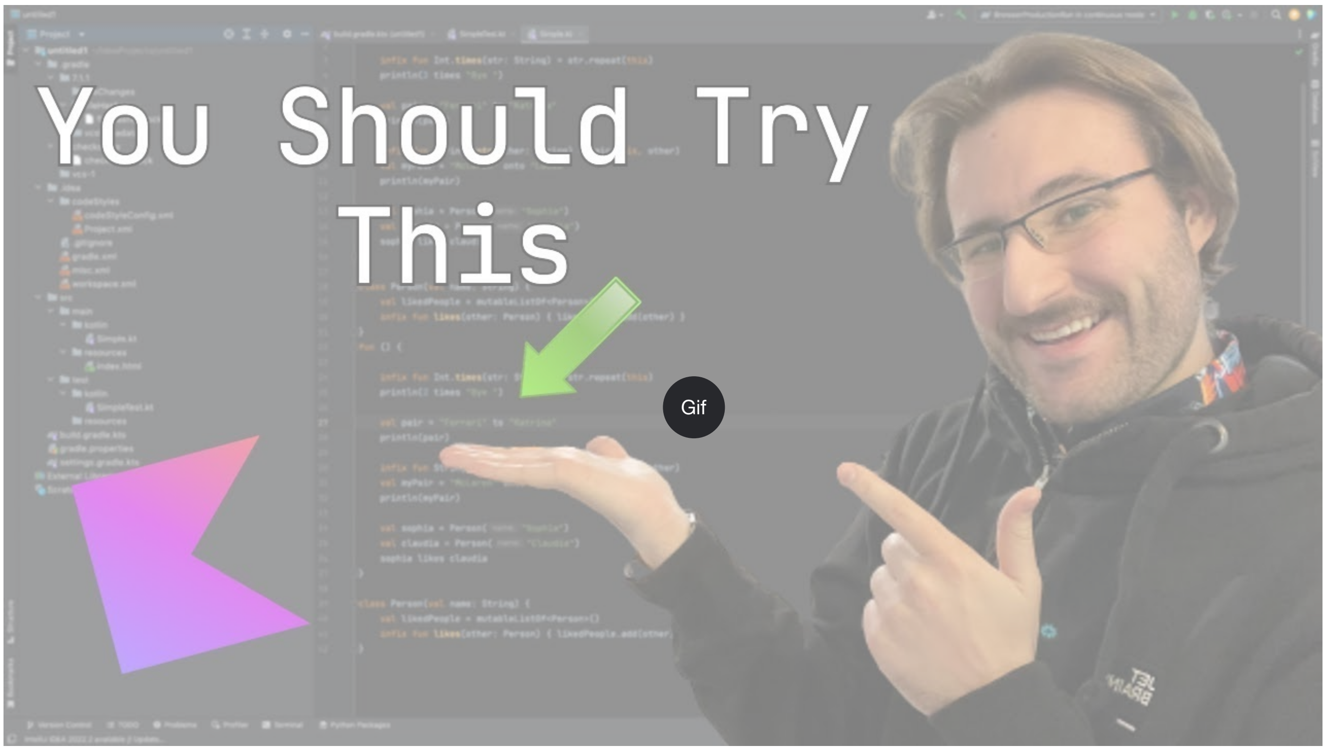
In this episode, Kate Petrova shows three tips to help you work with Strings in Kotlin:



Watch video online.

Doing more with the Elvis operator

In this video, Sebastian Aigner will show how to add more logic to the Elvis operator, such as logging to the right part of the operator:



Watch video online.

Kotlin collections

In this episode, Kate Petrova shows three tips to help you work with Kotlin Collections:

Watch video online.

What's next?

- See the complete list of Kotlin Tips in our YouTube playlist
- Learn how to write idiomatic Kotlin code for popular cases

Kotlin books

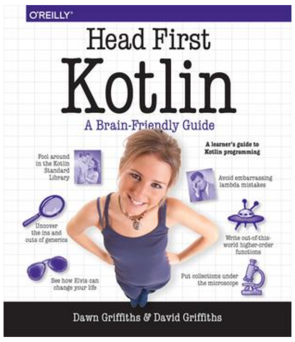
More and more authors write books for learning Kotlin in different languages. We are very thankful to all of them and appreciate all their efforts in helping us increase a number of professional Kotlin developers.

Here are just a few books we've reviewed and recommend you for learning Kotlin. You can find more books on our community website.

Atomic Kotlin

Atomic Kotlin is for both beginning and experienced programmers!

From Bruce Eckel, author of the multi-award-winning Thinking in C++ and Thinking in Java, and Svetlana Isakova, Kotlin Developer Advocate at JetBrains, comes a book that breaks the language concepts into small, easy-to-digest "atoms", along with a free course consisting of exercises supported by hints and solutions directly inside IntelliJ IDEA!

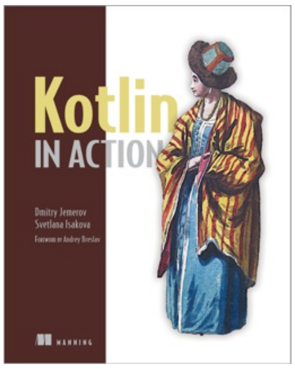


Head First Kotlin

Head First Kotlin is a complete introduction to coding in Kotlin. This hands-on book helps you learn the Kotlin language with a unique method that goes beyond syntax and how-to manuals and teaches you how to think like a great Kotlin developer.

You'll learn everything from language fundamentals to collections, generics, lambdas, and higher-order functions. Along the way, you'll get to play with both object-oriented and functional programming.

If you want to really understand Kotlin, this is the book for you.

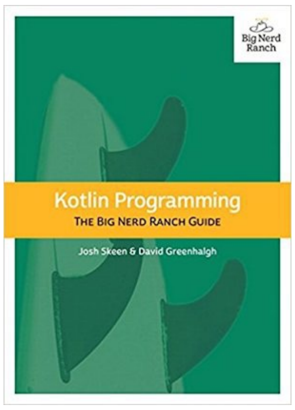


Kotlin in Action

Kotlin in Action teaches you to use the Kotlin language for production-quality applications. Written for experienced Java developers, this example-rich book goes further than most language books, covering interesting topics like building DSLs with natural language syntax.

The book is written by Dmitry Jemerov and Svetlana Isakova, developers on the Kotlin team.

Chapter 6, covering the Kotlin type system, and chapter 11, covering DSLs, are available as a free preview on the publisher web site.



Kotlin Programming: The Big Nerd Ranch Guide

Kotlin Programming: The Big Nerd Ranch Guide

In this book you will learn to work effectively with the Kotlin language through carefully considered examples designed to teach you Kotlin's elegant style and features.

Starting from first principles, you will work your way to advanced usage of Kotlin, empowering you to create programs that are more reliable with less code.

Programming Kotlin

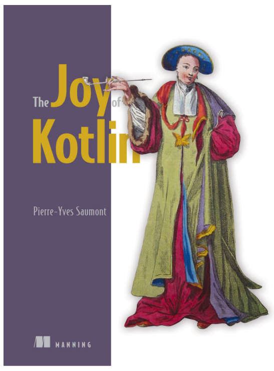
Programming Kotlin is written by Venkat Subramaniam.

Programmers don't just use Kotlin, they love it. Even Google has adopted it as a first-class language for Android development.

With Kotlin, you can intermix imperative, functional, and object-oriented styles of programming and benefit from the approach that's most suitable for the problem at hand.

Learn to use the many features of this highly concise, fluent, elegant, and expressive statically typed language with easy-to-understand examples.

Learn to write maintainable, high-performing JVM and Android applications, create DSLs, program asynchronously, and much more.


The Joy of Kotlin

The Joy of Kotlin teaches you the right way to code in Kotlin.

In this insight-rich book, you'll master the Kotlin language while exploring coding techniques that will make you a better developer no matter what language you use. Kotlin natively supports a functional style of programming, so seasoned author Pierre-Yves Saumont begins by reviewing the FP principles of immutability, referential transparency, and the separation between functions and effects.

Then, you'll move deeper into using Kotlin in the real world, as you learn to handle errors and data properly, encapsulate shared state mutations, and work with laziness.

This book will change the way you code — and give you back some of the joy you had when you first started.

Advent of Code puzzles in idiomatic Kotlin

Advent of Code is an annual December event, where holiday-themed puzzles are published every day from December 1 to December 25. With the permission of Eric Wastl, creator of Advent of Code, we'll show how to solve these puzzles using the idiomatic Kotlin style:

- Advent of Code 2024
- Advent of Code 2023
- Advent of Code 2022
- Advent of Code 2021

- Advent of Code 2020

Get ready for Advent of Code

We'll take you through the basic tips on how to get up and running with solving Advent of Code challenges with Kotlin:

- Use this GitHub template to create projects
- Check out the welcome video by Kotlin Developer Advocate, Sebastian Aigner:

Watch video online.

Advent of Code 2022

Day 1: Calorie counting

Learn about the Kotlin Advent of Code template and convenience functions for working with strings and collections in Kotlin, such as maxOf() and sumOf(). See how extension functions can help you structure your solution in a nice manner.

- Read the puzzle description on Advent of Code
- Check out the solution in the video:

▶ Advent of Code 2022 Day 1 | Kotlin

Day 2: Rock paper scissors

Understand operations on the Char type in Kotlin, see how the Pair type and the to constructor work well with pattern matching. Understand how to order your own objects using the compareTo() function.

- Read the puzzle description on Advent of Code
- Check out the solution in the video:

▶ Advent of Code 2022 Day 2 | Kotlin

Day 3: Rucksack reorganization

Learn how the kotlinx.benchmark library helps you understand the performance characteristics of your code. See how set operations like intersect can help you select overlapping data, and see performance comparisons between different implementations of the same solution.

- Read the puzzle description on Advent of Code
- Check out the solution in the video:

▶ Advent of Code 2022 Day 3 | Kotlin

Day 4: Camp cleanup

See how infix and operator functions can make your code more expressive, and how extension functions for the String and IntRange types make it easy to parse input.

- Read the puzzle description on Advent of Code
- Check out the solution in the video:

▶ Advent of Code 2022 Day 4 | Kotlin

Day 5: Supply stacks

Learn about constructing more complex objects with factory functions, how to use regular expressions, and the double-ended ArrayDeque type.

- Read the puzzle description on Advent of Code
- Check out the solution in the video:

▶ Advent of Code 2022 Day 5 | Kotlin

Day 6: Tuning trouble

See more in-depth performance investigations with the kotlinx.benchmark library, comparing the characteristics of 16 different variations of the same solution.

- Read the puzzle description on Advent of Code
- Check out the solution in the video:

▶ Advent of Code 2022 Day 6 | Kotlin

Day 7: No space left on device

Learn how to model tree structures, and see a demo of generating Kotlin code programmatically.

- Read the puzzle description on Advent of Code
- Check out the solution in the video:

▶ Advent of Code 2022 Day 7 | Kotlin

Day 8: Treetop tree house

See the sequence builder in action, and how far a first draft of a program and an idiomatic Kotlin solution can differ (with special guest Roman Elizarov!).

- Read the puzzle description on Advent of Code
- Check out the solution in the video:

▶ Advent of Code 2022 Day 8 | Kotlin

Day 9: Rope bridge

See the run function, labeled returns, and convenient standard library functions like coerceIn, or zipWithNext. See how you can construct lists of given sizes using the List and MutableList constructors, and get a peek at a Kotlin-based visualization of the problem statement.

* Read the puzzle description on Advent of Code
* Check out the solution in the video:

▶ Advent of Code 2022 Day 9 | Kotlin

Day 10: Cathode-ray tube

Learn how ranges and the in operator make checking ranges natural, how function parameters can be turned into receivers, and a brief exploration of the tailrec modifier.

* Read the puzzle description on Advent of Code
* Check out the solution in the video:

▶ Advent of Code 2022 Day 10 | Kotlin

Day 11: Monkey in the middle

See how you can move from mutable, imperative code to a more functional approach that makes use of immutable and read-only data structures. Learn about context receivers and how our guest built his own visualization library just for Advent of Code.

* Read the puzzle description on Advent of Code
* Check out the solution in the video:

▶ Advent of Code 2022 Day 11 | Kotlin

Day 12: Hill Climbing algorithm

Use queues, ArrayDeque, function references, and the tailrec modifier to solve path finding problems with Kotlin.

* Read the puzzle description on Advent of Code
* Check out the solution in the video:

▶ Advent of Code 2022 Day 12 | Kotlin

Advent of Code 2021

> Read our blog post about Advent of Code 2021

Day 1: Sonar sweep

Apply windowed and count functions to work with pairs and triplets of integers.

* Read the puzzle description on Advent of Code
* Check out the solution from Anton Arhipov on the Kotlin Blog or watch the video:

▶ Advent of Code 2021 in Kotlin, Day 1: Sonar Sweep

Day 2: Dive!

Learn about destructuring declarations and the when expression.

* Read the puzzle description on Advent of Code
* Check out the solution from Pasha Finkelshteyn on GitHub or watch the video:

▶ Advent of Code 2021 in Kotlin, Day 2: Dive!

Day 3: Binary diagnostic

Explore different ways to work with binary numbers.

- Read the puzzle description on Advent of Code
- Check out the solution from Sebastian Aigner on Kotlin Blog or watch the video:

▶ Advent of Code 2021 in Kotlin, Day 3: Binary Diagnostic

Day 4: Giant squid

Learn how to parse the input and introduce some domain classes for more convenient processing.

- Read the puzzle description on Advent of Code
- Check out the solution from Anton Arhipov on the GitHub or watch the video:

▶ Advent of Code 2021 in Kotlin, Day 4: Giant Squid

Advent of Code 2020

> You can find all the solutions for the Advent of Code 2020 puzzles in our GitHub repository.

Day 1: Report repair

Explore input handling, iterating over a list, different ways of building a map, and using the let function to simplify your code.

- Read the puzzle description on Advent of Code
- Check out the solution from Svetlana Isakova on the Kotlin Blog or watch the video:

▶ Learn Kotlin With the Kotlin Team: Advent of Code 2020 #1

Day 2: Password philosophy

Explore string utility functions, regular expressions, operations on collections, and how the let function can be helpful to transform your expressions.

- Read the puzzle description on Advent of Code
- Check out the solution from Svetlana Isakova on the Kotlin Blog or watch the video:

▶ Learn Kotlin with The Kotlin Team: Advent of Code 2020 #2

Day 3: Toboggan trajectory

Compare imperative and more functional code styles, work with pairs and the reduce() function, edit code in the column selection mode, and fix integer overflows.

- Read the puzzle description on Advent of Code
- Check out the solution from Mikhail Dvorkin on GitHub or watch the video:

▶ Learn Kotlin with the Kotlin Team: Advent of Code 2020 #3

Day 4: Passport processing

Apply the when expression and explore different ways of how to validate the input: utility functions, working with ranges, checking set membership, and matching a particular regular expression.

- Read the puzzle description on Advent of Code
- Check out the solution from Sebastian Aigner on the Kotlin Blog or watch the video:

▶ Learn Kotlin with the Kotlin Team: Advent of Code 2020 #4

Day 5: Binary boarding

Use the Kotlin standard library functions (replace(), toInt(), find()) to work with the binary representation of numbers, explore powerful local functions, and learn how to use the max() function in Kotlin 1.5.

- Read the puzzle description on Advent of Code
- Check out the solution from Svetlana Isakova on the Kotlin Blog or watch the video:

▶ Learn Kotlin with the Kotlin Team: Advent of Code 2020 #5

Day 6: Custom customs

Learn how to group and count characters in strings and collections using the standard library functions: map(), reduce(), sumOf(), intersect(), and union().

- Read the puzzle description on Advent of Code
- Check out the solution from Anton Arhipov on the Kotlin Blog or watch the video:

▶ Learn Kotlin with the Kotlin Team: Advent of Code 2020 #6

Day 7: Handy haversacks

Learn how to use regular expressions, use Java's compute() method for HashMaps from Kotlin for dynamic calculations of the value in the map, use the forEachLine() function to read files, and compare two types of search algorithms: depth-first and breadth-first.

- Read the puzzle description on Advent of Code
- Check out the solution from Pasha Finkelshteyn on the Kotlin Blog or watch the video:

▶ Learn Kotlin with the Kotlin Team: Advent of Code 2020 #7

Day 8: Handheld halting

Apply sealed classes and lambdas to represent instructions, apply Kotlin sets to discover loops in the program execution, use sequences and the sequence { } builder function to construct a lazy collection, and try the experimental measureTimedValue() function to check performance metrics.

- Read the puzzle description on Advent of Code
- Check out the solution from Sebastian Aigner on the Kotlin Blog or watch the video:

▶ Learn Kotlin with the Kotlin Team: Advent of Code 2020 #8

Day 9: Encoding error

Explore different ways to manipulate lists in Kotlin using the any(), firstOrNull(), firstNotNullOfOrNull(), windowed(), takeIf(), and scan() functions, which exemplify an idiomatic Kotlin style.

- Read the puzzle description on Advent of Code
- Check out the solution from Svetlana Isakova on the Kotlin Blog or watch the video:

▶ Learn Kotlin with the Kotlin Team: Advent of Code 2020 #9

What's next?

- Complete more tasks with Kotlin Koans
- Create working applications with the free Kotlin Core track by JetBrains Academy

Learning Kotlin with JetBrains Academy plugin

With the JetBrains Academy plugin, available both in Android Studio and IntelliJ IDEA, you can learn Kotlin through code practicing tasks.

Take a look at the Learner Start Guide, which will get you started with the Kotlin Koans course inside IntelliJ IDEA. Solve interactive coding challenges and get instant feedback right inside the IDE.

If you want to use the JetBrains Academy plugin for teaching, read Teaching Kotlin with JetBrains Academy plugin.

Teaching Kotlin with JetBrains Academy plugin

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Introduction to library authors' guidelines

This guide contains a summary of best practices and ideas to consider when designing libraries.

To be effective, a library must achieve certain fundamental objectives. Specifically, it should:

- Define its problem domain and implement a set of related functional requirements that solve the problems it defined. For example, an HTTP client may aim to support all HTTP request types and understand the various headers, content types, and status codes.
- Meet the non-functional criteria appropriate to the problem domain. These typically involve performance, reliability, security, and usability. The relative importance of these criteria varies widely. For example, a library designed for batch processing may not require the same level of performance as one intended for day trading.

> The process of identifying and defining functional and non-functional requirements is a complex topic that has been extensively studied in software engineering. This guide does not cover these topics in depth, as they are beyond its scope.

The main focus of this guide is to explore the characteristics that a library must have to stay relevant and popular with its users. These characteristics include:

- Minimize mental complexity: All developers must consider the readability and maintainability of their code. It's crucial to reduce the mental effort required for others to read, understand, and use your APIs. Achieving this involves creating libraries that are clear, consistent, predictable, and easy to debug.
- Backward compatibility: When releasing a new version of an API, ensure the existing API remains operational. Clearly communicate and document any breaking changes well in advance. Provide a straightforward, clear, and gradual pathway for users to adopt the new API or design changes.
- Informative documentation: The documentation that accompanies the library needs to do more than repeat function and type declarations. It should be comprehensive and specifically tailored to the library's audience. It should accurately reflect the needs and scenarios of various user roles, ensuring it provides essential information without being overly simplistic or complex. Always include clear examples, balancing explanatory text with practical code samples.

Additionally, building your Kotlin library with multiplatform support can broaden its applicability across projects targeting various environments. Designing APIs to work reliably in both shared and platform-specific code can improve the library's versatility and usability across all supported targets.

The following sections dig deeper into these characteristics, with practical advice on how you can provide the best possible experience to users of your libraries.

What's next

- Explore strategies for minimizing mental complexity in Minimizing mental complexity.
- Learn about maintaining backward compatibility in Backward compatibility.
- For an extensive overview on effective documentation practices, see Informative documentation.
- Discover best practices for building multiplatform libraries in Building Kotlin library for multiplatform.

Minimizing mental complexity overview

Users need to quickly and accurately build a mental model of your library's functions and abstractions before using it. The best way to achieve this is by minimizing the amount of complexity they encounter.

Strategies for minimizing mental complexity include:

- Simplicity: Strive for an API that provides the most functionality with the fewest components, reusing existing Kotlin types and structures to avoid redundancy. Where possible, create a small set of core abstractions and build additional functionality on top of them.
- Readability: Write the API in a declarative style to make the code's intent clear. Choose names for abstractions directly from the problem domain, unless it's absolutely necessary to invent new ones. Use basic data types for their intended purposes. Clearly distinguish between core and optional functionality.
- Consistency: Maintain a single, clear approach for every design aspect of your API. Use uniform naming conventions, error handling strategies, and patterns, whether they are object-oriented or functional.
- Predictability: Design your library to adhere to the 'principle of least surprise'. Ensure the default settings match the most common use cases, allowing users to accomplish their tasks with the simplest and shortest code. Allow extensions to your library only in clearly specified ways to maintain consistency and predictability.
- Debuggability: Ensure your library aids users in troubleshooting by facilitating the extraction of information and navigation through nested function calls. When exceptions are thrown, both the type and content of the exception should match the underlying issue, providing all necessary details to effectively diagnose and resolve problems. It should be possible to capture and output the state of domain objects, and to view any intermediate representations.
- Testability: Ensure that your library, as well as the code that uses it, can be easily tested.

The following sections give more detailed information on implementing these strategies in Kotlin.

Next step

To begin exploring these strategies in depth, you can start with learning about simplicity in the next section.

Proceed to the next part

Simplicity

The fewer concepts your users need to understand and the more explicitly these are communicated, the simpler their mental model is likely to be. This can be achieved by limiting the number of operations and abstractions in the API.

Ensure that the visibility of declarations in your library is set appropriately to keep internal implementation details out of the public API. Only APIs that are explicitly designed and documented for public use should be accessible to users.

In the next part of the guide, we'll discuss some guidelines for promoting simplicity.

Use explicit API mode

We recommend using the explicit API mode feature of the Kotlin compiler, which forces you to explicitly state your intentions when you're designing the API for your library.

With explicit API mode, you must:

- Add visibility modifiers to your declarations to make them public, instead of relying on the default public visibility. This ensures that you've considered what you're exposing as part of the public API.
- Define the types for all your public functions and properties to prevent unintended changes to your API from inferred types.

Reuse existing concepts

One way to limit the size of your API is to reuse existing types. For example, instead of creating a new type for durations, you can use kotlin.time.Duration. This approach not only streamlines development but also improves interoperability with other libraries.

Be careful when relying on types from third-party libraries or platform-specific types, as they can tie your library to these elements. In such cases, the costs may outweigh the benefits.

Reusing common types such as String, Long, Pair, and Triple can be effective, but this should not stop you from developing abstract data types if they better encapsulate domain-specific logic.

Define and build on top of core API

Another route to simplicity is to define a small conceptual model based around a limited set of core operations. Once the behavior of these operations is clearly documented, you can expand the API by developing new operations that build directly on or combine these core functions.

For example:

- In the Kotlin Flows API, common operations like filter and map are built on top of the transform operation.
- In the Kotlin Time API the measureTime function utilizes TimeSource.Monotonic.

While it's often beneficial to base additional operations on these core components, it's not always necessary. You may find opportunities to introduce optimized or platform-specific variations that expand the functionality or adapt more broadly to different inputs.

As long as users are able to solve non-trivial problems with the core operations and can refactor their solutions with additional operations without altering any behavior, the simplicity of the conceptual model is preserved.

Next step

In the next part of the guide, you'll learn about readability.

Proceed to the next part

Readability

Creating a readable API involves more than just writing clean code. It requires thoughtful design that simplifies integration and usage. This section explores how you can enhance API readability by structuring your library with composability in mind, utilizing domain-specific languages (DSLs) for concise and expressive setup, and using extension functions and properties for clear and maintainable code.

Prefer Explicit Composability

Libraries often provide advanced operators that allow for customization. For example, an operation might permit users to supply their own data structures, networking channels, timers, or lifecycle observers. However, introducing these customization options through additional function parameters can significantly increase the complexity of the API.

Instead of adding more parameters for customization, it's more effective to design an API where different behaviors can be composed together. For example, in the coroutine Flows API both buffering and conflation are implemented as separate functions. These can be chained together with more basic operations like filter and map, instead of each basic operation accepting parameters to control buffering and conflation.

Another example involves the Modifiers API in Jetpack Compose. This allows Composable components to accept a single Modifier parameter that handles common customization options, such as padding, sizing, and background color. This approach avoids the need for each Composable to accept separate parameters for these customizations, streamlining the API and reducing complexity.

```
Box(
    modifier = Modifier
        .padding(10.dp)
        .onClick { println("Box clicked!") }
        .fillMaxWidth()
        .fillMaxHeight()
        .verticalScroll(rememberScrollState())
        .horizontalScroll(rememberScrollState())
) {
    // Box content goes here
}
```

Use DSLs

A Kotlin library can significantly improve readability by providing a builder DSL. Using a DSL allows you to concisely repeat domain-specific data declarations. For example, consider the following sample from a Ktor-based server application:

```
fun Application.module() {
    install(ContentNegotiation) {
        json(Json {
            prettyPrint = true
            isLenient = true
        })
    }
    routing {
        post("/article") {
            call.respond<String>(HttpStatusCode.Created, ...)
        }
        get("/article/list") {
            call.respond<List<CreateArticle>>(...)
        }
        get("/article/{id}") {
            call.respond<Article>(...)
        }
    }
}
```

This sets up an application, installing the ContentNegotiation plugin configured to use Json serialization, and sets up routing so that the application responds to requests on various /article endpoints.

For a detailed description of creating DSLs, see Type-safe builders. The following points are worth noting in the context of creating libraries:

- The functions used in the DSL are builder functions, which take a lambda with receiver as the final parameter. This design allows these functions to be called without parentheses, making the syntax clearer. The lambda being passed can be used to configure the entity being created. In the example above the lambda passed to the routing function is used to configure the details of the routing.
- Factory functions that create instances of classes should have the same name as the return type and start with a capital letter. You can see this in the sample above with the creation of the Json instance. These functions may still take lambda parameters for configuration. For more information, see Coding conventions.
- As it's not possible to ensure that required properties have been set within the lambda supplied to a builder function at compile time, we recommend passing required values as function parameters.

Using DSLs to build objects not only improves readability but also improves backward compatibility, and simplifies the documentation process. For example, take the following function:

```
fun Json(prettyPrint: Boolean, isLenient: Boolean): Json
```

This function could replace the Json{} DSL builder. However, the DSL approach has noticeable benefits:

- Backward compatibility is easier to maintain with the DSL builder than with this function, as adding new configuration options simply means adding new properties (or in other examples, new functions), which is a backward-compatible change, unlike changing the parameter list of an existing function.
- It also makes creating and maintaining documentation easier. You can document each property separately at its point of declaration, instead of having to document many parameters of a function, all in one place.

Use extension functions and properties

We recommend using extension functions and properties to improve readability.

Classes and interfaces should define the core concept of a type. Additional functionality and information should be written as extension functions and properties. This makes it clear to the reader that the additional functionality can be implemented on top of the core concept, and additional information can be calculated from the data in the type.

For example, the CharSequence type (which String also implements) only contains the most basic information and operators to access its contents:

```
interface CharSequence {
    val length: Int
    operator fun get(index: Int): Char
    fun subSequence(startIndex: Int, endIndex: Int): CharSequence
}
```

Functionality commonly associated with strings is mostly defined as extension functions, which can all be implemented on top of the core concepts and basic APIs of the type:

```
inline fun CharSequence.isEmpty(): Boolean = length == 0
inline fun CharSequence.isNotEmpty(): Boolean = length > 0

inline fun CharSequence.trimStart(predicate: (Char) -> Boolean): CharSequence {
    for (index in this.indices)
        if (!predicate(this[index]))
           return subSequence(index, length)
    return ""
}
```

Consider declaring computed properties and normal methods as extensions. Only regular properties, overrides, and overloaded operators should be declared as members by default.

Avoid using the boolean type as an argument

Consider the following function:

```
fun doWork(optimizeForSpeed: Boolean) { ... }
```

If you were to provide this function in your API it could be invoked as:

```
doWork(true)
doWork(optimizeForSpeed=true)
```

In the first call it is impossible to infer what the boolean argument is for, unless you are reading the code in an IDE with Parameter Name Hints enabled. Using named arguments does clarify the intention, but there is no way to force your users to adopt this style. Consequently, to improve readability, your code should not use boolean types as arguments.

Alternatively, the API could create a separate function specifically for the task controlled by the boolean argument. This function should have a descriptive name that indicates what it does.

For example, the following extensions are available on the Iterable interface:

```
fun <T, R> Iterable<T>.map(transform: (T) -> R): List<R>
fun <T, R : Any> Iterable<T>.mapNotNull(
    transform: (T) -> R?
): List<R>
```

Instead of the single method:

```
fun <T, R> Iterable<T>.map(
    includeNullResults: Boolean = true,
    transform: (T) -> R
): List<R>
```

Another good approach could be to use an enum class to define different operation modes. This approach is useful if there are several modes of operation, or if you expect these modes to change over time.

Use numeric types appropriately

Kotlin defines a set of numeric types that you may use as part of your API. Here's how to use them appropriately:

- Use the Int, Long and Double types as arithmetic types. They represent values with which calculations are performed.
- Avoid using arithmetic types for non-arithmetic entities. For example, if you represent an ID as a Long, your users might be tempted to compare IDs, on the assumption they are assigned in order. This could lead to unreliable or meaningless results, or create dependencies on implementations that could change without warning. A better strategy is to define a specialized class for the ID abstraction. You could use Inline value classes to build such abstractions without affecting performance. See the Duration class for an example.
- The Byte, Float and Short types are memory layout types. They are used to restrict the amount of memory available for storing a value, such as in caches or when transmitting data over a network. These types should only be used when the underlying data reliably fits within that type, and calculations are not required.

- The unsigned integer types UByte, UShort, UInt and ULong should be used to utilize the full range of positive values available in a given format. They are suitable for scenarios requiring values beyond the range of signed types or for interoperability with native libraries. However, avoid using them in situations where the domain only requires non-negative integers.

Next step

In the next part of the guide, you'll learn about consistency.

Proceed to the next part

Consistency

Consistency is crucial in API design to ensure ease of use. By maintaining consistent parameter order, naming conventions, and error handling mechanisms, your library will be more intuitive and reliable for users. Following these best practices helps avoid confusion and misuse, leading to a better developer experience and more robust applications.

Preserve parameter order, naming and usage

When designing a library, maintain consistency in the ordering of arguments, the naming scheme, and the use of overloading. For example, if one of your existing methods has offset and length parameters, you should not switch to alternatives like startIndex and endIndex for a new method unless there is a compelling reason.

Overloaded functions provided by the library should behave identically. Users expect the behavior to remain consistent when they change the type of a value they pass into your library. For example, these calls all create identical instances, as the input is semantically the same:

```
BigDecimal(200)
BigDecimal(200L)
BigDecimal("200")
```

Avoid mixing parameter names like startIndex and stopIndex with synonyms like beginIndex and endIndex. Similarly, choose one term for values in collections, such as element, item, entry, or entity, and stick with it.

Name related methods consistently and predictably. As an example, the Kotlin standard library contains pairs like first and firstOrNull, single or singleOrNull. These pairs clearly indicate that some might return null while others might throw an exception. Parameters should be declared from the general to the specific, so essential inputs appear first and optional inputs last. For example, in CharSequence.findAnyOf the strings collection goes first, followed by the startIndex, and finally the ignoreCase flag.

Consider a library managing employee records, and provides the following API to search for employees:

```
fun findStaffBySeniority(
    startIndex: Int,
    minYearsServiceExclusive: Int
): List<Employee>

fun findStaffByAge(
    minAgeInclusive: Int,
    startIndex: Int
): List<Employee>
```

This API would be extremely hard to use correctly. There are multiple parameters of the same type presented in an inconsistent order, and used in an inconsistent way. Users of your library will likely make incorrect assumptions about new functions based on their experience with existing ones.

Use Object-Oriented design for data and state

Kotlin supports both the Object-Oriented and Functional programming styles. Use classes to represent data and state in your API. When the data and state is hierarchical, consider using inheritance.

If all the state required can be passed as parameters, prefer using top-level functions. When calls to these functions will be chained, consider writing them as extension functions to improve readability.

Choose the appropriate error handling mechanism

Kotlin provides several mechanisms for error handling. Your API can throw an exception, return a null value, use a custom result type, or use the built-in Result type. Ensure that your library uses these options consistently and appropriately.

When data cannot be fetched or calculated, use a nullable return type and return null to indicate missing data. In other cases, throw an exception or return a Result type.

Consider providing overloads of functions, where one throws an exception, while the other wraps it in a result type instead. In these cases, use the Catching suffix to indicate that exceptions are caught in the function. For example, the standard library has the run and runCatching functions using this convention, and the coroutines library has receive and receiveCatching methods for channels.

Avoid using exceptions for normal control flow. Design your API to allow for condition checks before attempting operations, thus preventing unnecessary error handling. Command / Query Separation is a useful pattern that can be applied here.

Maintain conventions and quality

The final aspect of consistency relates, not to the design of the library itself, but to maintaining a high level of quality.

You should use automated tools (linters) for static analysis to ensure your code follows both general Kotlin conventions and project-specific conventions.

A Kotlin library should also provide a suite of unit and integration tests covering all documented behaviors of all the API entry points. Tests should include a wide range of inputs, especially known boundary and edge cases. Any untested behavior should be assumed to be (at best) unreliable.

Use this suite of tests during development to verify that changes do not break existing behavior. Run these tests on every release as part of a standardized build and release pipeline. Tools like Kover can be integrated into your build process to measure coverage and generate reports.

Next step

In the next part of the guide, you'll learn about predictability.

Proceed to the next part

Predictability

To design a robust and user-friendly Kotlin library, it's essential to anticipate common use cases, allow for extensibility, and enforce proper usage. Following best practices for default settings, error handling, and state management ensures a seamless experience for users while maintaining the integrity and quality of the library.

Do the right thing by default

Your library should anticipate the "happy path" for each use case, and provide default settings accordingly. Users should not need to supply default values for the library to function correctly.

For example, when using the Ktor HttpClient the most common use case is sending a GET request to the server. This can be accomplished using the code below, where only essential information needs to be specified:

```kotlin
val client = HttpClient(CIO)
val response: HttpResponse = client.get("https://ktor.io/")
```

It's not necessary to provide values for mandatory HTTP headers or custom event handlers for possible status codes in the response.

If there is no obvious "happy path" for a use case or if a parameter should have a default value but there is no non-contentious option, it likely indicates a flaw in the requirement analysis.

Allow opportunities for extension

When the correct choice cannot be anticipated, allow users to specify their preferred approach. Your library should also let the user supply their own approach or use a third-party extension.

For example, with the Ktor HttpClient, users are encouraged to install support for content negotiation when configuring the client, and to specify their preferred serialization formats:

```
val client = HttpClient(CIO) {
    install(ContentNegotiation) {
        json(Json {
            prettyPrint = true
            isLenient = true
        })
    }
}
```

Users can choose which plugins to install or create their own using the separate API for defining client plugins.

Additionally, users can define extension functions and properties for types in the library. As a library author, you can make this easier by designing with extensions in mind, and ensuring your library's types have clear core concepts.

Prevent unwanted and invalid extensions

Users should not be able to extend your library in ways that violate its original design or are impossible within the rules of the problem domain.

For example, when marshaling data to and from JSON, only six types are supported in the output format: object, array, number, string, boolean, and null.

If you create an open class or interface called JsonElement, users could create invalid derived types, like JsonDate. Instead, you can make the JsonElement interface sealed and provide an implementation for each type:

```
sealed interface JsonElement

class JsonNumber(val value: Number) : JsonElement
class JsonObject(val values: Map<String, JsonElement>) : JsonElement
class JsonArray(val values: List<JsonElement>) : JsonElement
class JsonBoolean(val value: Boolean) : JsonElement
class JsonString(val value: String) : JsonElement
object JsonNull : JsonElement
```

Sealed types also enable the compiler to ensure your when expressions are exhaustive, without requiring an else statement, improving readability and consistency.

Avoid exposing mutable state

When managing multiple values, your API should, whenever possible, accept and/or return read-only collections. Mutable collections are not thread-safe and introduce complexity and unpredictability into your library.

For example, if a user modifies a mutable collection returned from an API entry point, it will be unclear whether they are modifying the implementation's structure or a copy. Similarly, if users can modify the values within a collection after passing it to a library, it will be unclear whether this affects the implementation.

Since arrays are mutable collections, avoid using them in your API. If arrays must be used, make defensive copies before sharing data with users. This ensures your data structures remain unmodified.

This policy of making defensive copies is automatically performed by the compiler for vararg arguments. When using the spread operator to pass an existing array where a vararg argument is expected, a copy of your array is automatically created.

This behavior is demonstrated in the following example:

```
fun main() {
    fun demo(vararg input: String): Array<out String> = input

    val originalArray = arrayOf("one", "two", "three", "four")
    val newArray = demo(*originalArray)

    originalArray[1] = "ten"

    //prints "one, ten, three, four"
    println(originalArray.joinToString())

    //prints "one, two, three, four"
    println(newArray.joinToString())
}
```

Validate inputs and state

Ensure that your library is used correctly by validating inputs and existing state before implementation proceeds. Use the require function to verify inputs and the check function to validate existing state.

The require function throws an IllegalArgumentException if its condition is false, causing the function to fail immediately with an appropriate error message:

```kotlin
fun saveUser(username: String, password: String) {
    require(username.isNotBlank()) { "Username should not be blank" }
    require(username.all { it.isLetterOrDigit() }) {
        "Username can only contain letters and digits, was: $username"
    }
    require(password.isNotBlank()) { "Password should not be blank" }
    require(password.length >= 7) {
        "Password must contain at least 7 characters"
    }

    /* Implementation can proceed */
}
```

Error messages should include relevant inputs to help users determine the cause of the failure, as shown above by the error message for usernames that contain invalid characters, which includes the incorrect username. An exception to this practice is when including a value in the error message could reveal information that might be used maliciously as part of a security exploit, which is why the error message for the password's length does not include the password input.

Similarly, the check function throws an IllegalStateException if its condition is false. Use this function to verify the state of an instance, as shown in the example below:

```kotlin
class ShoppingCart {
    private val contents = mutableListOf<Item>()

    fun addItem(item: Item) {
       contents.add(item)
    }

    fun purchase(): Amount {
       check(contents.isNotEmpty()) {
           "Cannot purchase an empty cart"
       }
       // Calculate and return amount
    }
}
```

Next step

In the next part of the guide, you'll learn about debuggability.

Proceed to the next part

Debuggability

Users of your library will build on its functionality, and the features they build will contain errors that need to be identified and resolved. This error resolution process might be conducted within a debugger during development or using logging and observability tools in production. Your library can follow these best practices to make debugging it easier.

Provide a toString method for stateful types

For every type that contains state, provide a meaningful toString implementation. This implementation should return an intelligible representation of the instance's current content, even for internal types.

Since toString representations of types are often written to logs, consider security when implementing this method and avoid returning sensitive user data.

Ensure the format used to describe the state is as consistent as possible across the different types in your library. This format should be explicitly described and thoroughly documented when it is part of a contract implemented by your API. The output from your toString methods may support parsing, for example in automated test suites.

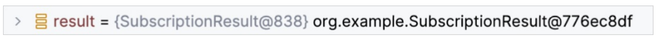
For example, consider the following types from a library supporting service subscriptions:

```
enum class SubscriptionResultReason {
    Success, InsufficientFunds, IncompatibleAccount
}

class SubscriptionResult(
    val result: Boolean,
    val reason: SubscriptionResultReason,
    val description: String
)
```

Without a toString method, printing a SubscriptionResult instance is not very useful:

```
fun main() {
    val result = SubscriptionResult(
       false,
       IncompatibleAccount,
       "Users account does not support this type of subscription"
    )

    //prints 'org.example.SubscriptionResult@13221655'
    println(result)
}
```

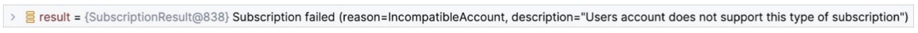
Nor is the information readily displayed in the debugger:



```
result = {SubscriptionResult@838} org.example.SubscriptionResult@776ec8df
```

Adding a simple toString implementation improves the output significantly in both cases:

```
//prints 'Subscription failed (reason=IncompatibleAccount, description="Users
// account does not support this type of subscription")'
override fun toString(): String {
    val resultText = if(result) "succeeded" else "failed"
    return "Subscription $resultText (reason=$reason, description=\"$description\")"
}
```



```
result = {SubscriptionResult@838} Subscription failed (reason=IncompatibleAccount, description="Users account does not support this type of subscription")
```

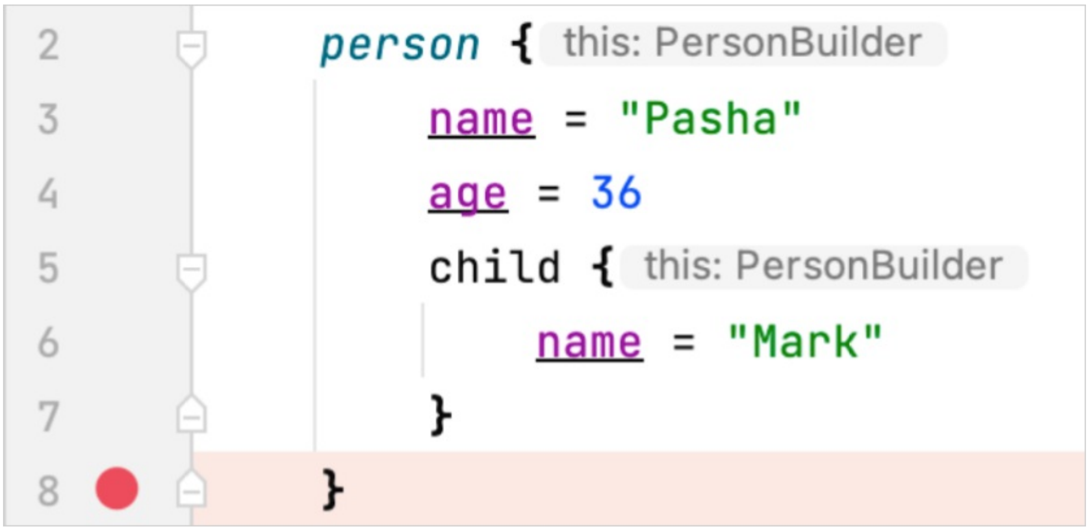
While it might be tempting to use data classes to gain a toString method automatically, it's not recommended for backward compatibility reasons. Data classes are discussed in more detail in the Avoid using data classes in your API section.

Note that the state described in the toString method does not need to be information from the problem domain. It can relate to the status of ongoing requests (as in the example above), the health of connections to external services, or intermediate state within an ongoing operation.

For example, consider the following builder type:

```
class Person(
    val name: String?,
    val age: Int?,
    val children: List<Person>
) {
    override fun toString(): String =
        "Person(name=$name, age=$age, children=$children)"
}

class PersonBuilder {
    var name: String? = null
    var age: Int? = null
    val children = arrayListOf<Person>()


    fun child(personBuilder: PersonBuilder.() -> Unit = {}) {
       children.add(person(personBuilder))
    }
    fun build(): Person = Person(name, age, children)
}

fun person(personBuilder: PersonBuilder.() -> Unit = {}): Person =
    PersonBuilder().apply(personBuilder).build()
```

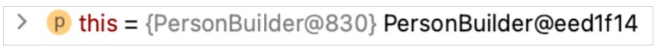
This is how you would use this type:



```
person { this: PersonBuilder
    name = "Pasha"
    age = 36
    child { this: PersonBuilder
        name = "Mark"
    }
}
```

Using the builder type example

If you halt the code at the breakpoint displayed on the image above, the information displayed will not be helpful:

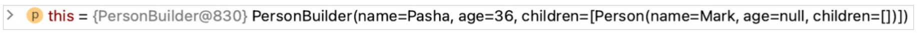


```
> p this = {PersonBuilder@830} PersonBuilder@eed1f14
```

Adding a simple toString implementation results in a much more helpful output:

```
override fun toString(): String =
    "PersonBuilder(name=$name, age=$age, children=$children)"
```

With this addition, the debugger shows:



```
> p this = {PersonBuilder@830} PersonBuilder(name=Pasha, age=36, children=[Person(name=Mark, age=null, children=[])])
```

This way, you can immediately see which fields are set and which are not.

Adopt and document a policy for handling exceptions

As discussed in the Choose appropriate error handling mechanism section, there are occasions when it's appropriate for your library to throw an exception to signal an error. You may create your own exception types for this purpose.

Libraries that abstract and simplify low-level APIs will also need to handle exceptions thrown by their dependencies. A library might choose to suppress the exception, pass it on as it is, convert it to a different type of an exception, or signal the error to users in a different way.

Any of these options could be valid, depending on the context. For example:

- If a user adopts library A purely for the convenience of simplifying library B, it may be appropriate for library A to rethrow any exceptions generated by library B without modification.
- If library A adopts library B purely as an internal implementation detail, then library-specific exceptions thrown by library B should never be exposed to users of library A.

You must adopt and document a consistent approach to exception handling so users can make productive use of your library. This is especially important for debugging. Users of your library should be able to recognise, in the debugger and in logs, when an exception has originated from your library.

The type of the exception should indicate the type of the error, and the data in the exception should help the user locate the root cause of the issue. A common pattern is to wrap a low-level exception in a library-specific one, with the original exception accessible as the cause.

Next step

In the next part of the guide, you'll learn about testability.

Proceed to the next part

Testability

In addition to testing your library, ensure that code using your library is also testable.

Avoid global state and stateful top-level functions

Your library should not rely on state in global variables or provide stateful top-level functions as part of its public API. Such variables and functions make testing code that uses the library difficult, as tests need to find ways to control these global values.

For example, a library might define a globally accessible function that provides access to the current time:

```
val instant: Instant = Clock.now()
println(instant)
```

Any code using this API will be difficult to test, as the call to the now() function will always return the real current time, while in tests it's often desirable to return fake values instead.

To enable testability, the kotlinx-datetime library has an API that lets users get a Clock instance, and then use that to get the current time:

```
val clock: Clock = Clock.System
val instant: Instant = clock.now()
println(instant)
```

This allows users of a library to inject a Clock instance into their own classes, and replace the real implementation with a fake one during tests.

What's next

If you haven't already, consider checking out these pages:

- Learn about maintaining backward compatibility in the Backward compatibility page.
- For an extensive overview on effective documentation practices, see Informative Documentation.

Backward compatibility guidelines for library authors

The most common motivation for creating a library is to expose functionality to a wider community. This community might be a single team, a company, a particular industry, or a technology platform. In every case backward compatibility will be an important consideration. The wider the community the more important backward compatibility becomes, since you will be less aware of who your users are and what constraints they work within.

Backward compatibility is not a single term, but can be defined at the binary, source and behavioral levels. More information about these types is provided in this section.

Note that:

- It is possible to break binary compatibility without breaking source compatibility, as well as the other way around.
- It is desirable but very difficult to guarantee source compatibility. As a library author, you must consider every possible way a function or type could be invoked or instantiated by a user of the library. Source compatibility is typically an aspiration, not a promise.

The rest of this section describes actions you can take, and tools you can use to help ensure the different kinds of compatibility.

Compatibility types

Binary compatibility means that a new version of a library can replace a previously compiled version of the library. Any software that was compiled against the previous version of the library should continue to work correctly.

> Learn more about binary compatibility in the Binary compatibility validator's README or from the Evolving Java-based APIs document.

Source compatibility means that a new version of a library can replace a previous one without modifying any of the source code that uses the library. However, the outputs from compiling this client code may no longer be compatible with the outputs from compiling the library, so the client code must be rebuilt against the new version of the library to guarantee compatibility.

Behavioral compatibility means that a new version of the library does not modify the existing functionality, except to fix bugs. The same features are involved and they have the same semantics.

Use the Binary compatibility validator

JetBrains provides a Binary compatibility validator tool, which can be used to ensure binary compatibility across different versions of your API.

This tool is implemented as a Gradle plugin, and it adds two tasks to your build:

- The apiDump task creates a human-readable .api file that describes your API.
- The apiCheck task compares the saved description of the API to classes compiled in the current build.

The apiCheck task is invoked at build time by the standard Gradle check task. When compatibility is broken, the build fails. At that point, you should run the apiDump task manually and compare the differences between the old and new versions. If you are satisfied with the changes, you can update the existing.api file, which resides within your VCS.

The validator has experimental support for validating KLibs produced by multiplatform libraries.

Specify return types explicitly

As discussed in the Kotlin coding guidelines, you should always explicitly specify function return types and property types within the API. See also the section about Explicit API mode.

Consider the following example, where the library author creates a JsonDeserializer and, for convenience, uses an extension function to associate it with the Int type:

```kotlin
class JsonDeserializer<T>(private val fromJson: (String) -> T) {
    fun deserialize(input: String): T {
        ...
    }
}

fun Int.defaultDeserializer() = JsonDeserializer { ... }
```

Let's say the author replaces this implementation with a JsonOrXmlDeserializer:

```kotlin
class JsonOrXmlDeserializer<T>(
    private val fromJson: (String) -> T,
    private val fromXML: (String) -> T
) {
    fun deserialize(input: String): T {
        ...
    }
}

fun Int.defaultDeserializer() = JsonOrXmlDeserializer({ ... }, { ... })
```

Existing functionality will continue to work, with the added ability to deserialize XML. However, this breaks binary compatibility.

Avoid adding arguments to existing API functions

Adding non-default arguments to a public API breaks both binary and source compatibility, as users are required to provide more information on an invocation than before. However, even adding default arguments can break compatibility.

For example, imagine you have the following function in lib.kt:

```
fun fib() = … // Returns zero
```

And the following function in client.kt:

```
fun main() {
    println(fib()) // Prints zero
}
```

Compiling these two files on the JVM would produce the outputs LibKt.class and ClientKt.class.

Let's say you reimplement and compile the fib function to represent the Fibonacci sequence, such that fib(3) returns 2, fib(4) returns 3, and so on. You add a parameter but give it a default value of zero to preserve the existing behavior:

```
fun fib(input: Int = 0) = … // Returns Fibonacci member
```

You now need to recompile the file lib.kt. You might expect that the client.kt file does not need to be recompiled, and the associated class file can be invoked as follows:

```
$ kotlin ClientKt.class
```

But if you try this, a NoSuchMethodError occurs:

```
Exception in thread "main" java.lang.NoSuchMethodError: 'int LibKt.fib()'
       at LibKt.main(fib.kt:2)
       at LibKt.main(fib.kt)
       …
```

This is because the signature of the method changed in the bytecode generated by the Kotlin/JVM compiler, breaking binary compatibility.

Source compatibility, however, is preserved. If you recompile both files, the program will run as before.

Use overloads to preserve compatibility

When writing Kotlin code for the JVM, you can use the @JvmOverloads annotation on functions with default arguments. This generates overloads of the function, one for each parameter with a default argument that may be omitted from the end of the parameter list. With these individual generated functions, adding a new parameter to the end of the parameter list preserves binary compatibility, as it doesn't change any existing functions in the output, just adds a new one.

For example, the above function might be annotated like this:

```
@JvmOverloads
fun fib(input: Int = 0) = …
```

This would generate two methods in the output bytecode, one with no parameter and one with an Int parameter:

```
public final static fib()I
public final static fib(I)I
```

For all Kotlin targets, you may choose to manually create several overloads of your function instead of a single function that accepts default arguments to preserve binary compatibility. In the example above, this means creating a separate fib function for the case where you wish to take an Int parameter:

```
fun fib() = …
fun fib(input: Int) = …
```

Avoid widening or narrowing return types

When evolving an API, it is common to want to widen or narrow the return type of a function. For example, in an upcoming version of your API, you might want to switch a return type from List to Collection or from Collection to List.

You might want to narrow the type to List to meet user requests for indexing support. Conversely, you might want to widen the type to Collection because you realize the data you are working with has no natural order.

It is easy to see why widening a return type breaks compatibility. For example, converting from List to Collection breaks all the code that uses indexing.

You might think that narrowing a return type, for example from Collection to List would preserve compatibility. Unfortunately, while source compatibility is preserved, binary compatibility is broken.

Let's say you have a demo function in the file Library.kt:

```
public fun demo(): Number = 3
```

And a client for the function in Client.kt:

```
fun main() {
    println(demo()) // Prints 3
}
```

Let's imagine a scenario where you change the return type of demo and only recompile Library.kt:

```
fun demo(): Int = 3
```

When you rerun the client, the following error will occur (on the JVM):

```
Exception in thread "main" java.lang.NoSuchMethodError: 'java.lang.Number Library.demo()'
        at ClientKt.main(call.kt:2)
        at ClientKt.main(call.kt)
        …
```

This happens because of the following instruction in the bytecode generated from the main method:

```
0: invokestatic  #12 // Method Library.demo:()Ljava/lang/Number;
```

The JVM is trying to invoke a static method called demo which returns a Number. However, as this method no longer exists, you have broken binary compatibility.

Avoid using data classes in your API

In regular development, the strength of data classes is the extra functions that are generated for you. In API design, this strength becomes a weakness.

For example, let's say you use the following data class in your API:

```
data class User(
    val name: String,
    val email: String
)
```

Later, you might want to add a property called active:

```
data class User(
    val name: String,
    val email: String,
    val active: Boolean = true
)
```

This would break binary compatibility in two ways. Firstly, the generated constructor will have a different signature. Additionally, the signature of the generated copy method changes.

The original signature (on Kotlin/JVM) would be:

```
public final User copy(java.lang.String, java.lang.String)
```

After adding the active property, the signature becomes:

```
public final User copy(java.lang.String, java.lang.String, boolean)
```

As with the constructor, this breaks binary compatibility.

It's possible to work around these issues by manually writing a secondary constructor and overriding the copy method. However, the effort involved negates the convenience of using a data class.

Another issue with data classes is that changing the order of constructor arguments affects the generated componentX methods, which are used for destructuring. Even if it does not break binary compatibility, changing the order will definitely break behavioral compatibility.

Considerations for using the PublishedApi annotation

Kotlin allows inline functions to be a part of your library's API. Calls to these functions will be inlined into the client code written by your users. This can introduce compatibility issues, so these functions are not allowed to call non-public-API declarations.

If you need to call an internal API of your library from an inlined public function, you can do so by annotating it with @PublishedApi. This makes the internal declaration effectively public, as references to it will end up in compiled client code. Therefore, it must be treated the same as public declarations when making changes to it, as these changes might affect binary compatibility.

Evolve APIs pragmatically

There are cases where you need to make breaking changes to your library's API over time by removing or changing an existing declaration. In this section, we'll discuss how to handle such cases pragmatically.

When users upgrade to a newer version of your library, they should not end up with unresolved references to your library's APIs in their project's source code. Instead of immediately removing something from your library's public API, you should follow a deprecation cycle. This way, you give your users time to migrate to an alternative.

Use the @Deprecated annotation on the old declaration to indicate that it's being replaced. The parameters of this annotation provide important details about the deprecation:

- The message should explain what's being changed and why.
- The replaceWith parameter should be used where possible to provide automatic migration to a new API.
- The deprecation's level should be used to deprecate the API gradually. For more information, see the Deprecated page of the Kotlin documentation.

Generally, a deprecation should first produce a warning, then an error, and then hide the declaration. This process should occur across several minor releases, giving users time to make any required changes in their projects. Breaking changes, such as removing an API, should happen only in major releases. A library may adopt different versioning and deprecation strategies, but this must be communicated to its users to set the correct expectations.

You can learn more in the Kotlin Evolution principles document or in the Evolving your Kotlin API painlessly for clients talk by Leonid Startsev from KotlinConf 2023.

Use the RequiresOptIn mechanism

The Kotlin standard library provides the opt-in mechanism to require explicit consent from users before they use a part of your API. This is based on creating marker annotations, which are themselves annotated with @RequiresOptIn. You should use this mechanism to manage expectations concerning source and behavioral compatibility, especially when introducing new APIs to your library.

If you choose to use this mechanism, we recommend following these best practices:

- Use the opt-in mechanism to provide different guarantees to different parts of the API. For example, you could mark features as Preview, Experimental, and Delicate. Each category should be clearly explained in your documentation and in KDoc comments, with appropriate warning messages.
- If your library uses an experimental API, propagate the annotation to your own users. This ensures your users are aware that you have dependencies which are still evolving.
- Avoid using the opt-in mechanism to deprecate already existing declarations in your library. Use @Deprecated instead, as described in the Evolve APIs pragmatically section.

What's next

If you haven't already, consider checking out these pages:

- Explore strategies for minimizing mental complexity in the Minimizing mental complexity page.
- For an extensive overview on effective documentation practices, see Informative documentation.

Best practices for library authors to create informative documentation

The documentation you provide for your library is crucial. It can determine whether users investigate your library, adopt it within their projects, and persevere when they encounter difficulties. Developers today have unprecedented choice between languages, libraries, frameworks and platforms. Therefore, it is essential to engage and inform your users; otherwise they may pursue other options.

In the earliest versions of your library, feedback from users will be scarce. Fortunately, creating and refining documentation can serve as a feedback loop to greatly increase the quality of your project. As such, creating documentation should never be seen as a burden, and should not be pushed down the list of priorities when creating a library.

Effective documentation not only informs users but also drives the development and refinement of your library. Here are several key ways documentation can guide your development process:

- You should be able to explain, in a couple of paragraphs, what your library does, who will benefit from using it, and what the advantages are over alternative approaches. If you cannot do this, reconsider the scope and objectives of your project.
- You should be able to create a "Getting Started" guide that can get a potential user up and running as quickly as possible. What counts as quickly will depend on the problem domain, but you can compare against similar libraries on other platforms. The guide should hook the user into a feedback loop that keeps getting easier and faster while always producing reliable results. Creating this guide will help you identify sudden increases in complexity (cliff edges) that could hinder the user's progress.
- The act of documenting a function forces you to consider all the edge cases, such as valid ranges of inputs, exceptions that might be thrown, and how performance degrades as the work increases. This can often lead to improvements in the function signatures and the underlying implementation.
- If the code required to initialize your library always eclipses the code required to accomplish a task, rethink your configuration options.
- If you cannot create clear examples of performing basic tasks with standard options, consider optimizing your API for day-to-day use.
- If you cannot demonstrate how to test your library without using real data sources and online services, consider providing test doubles for components that access the network (and the outside world in general).

The sooner you provide documentation for your library, the sooner it can be tested by real-world users. Feedback from these tests can then be used to improve the design.

Provide comprehensive documentation

Your library must provide sufficient documentation to let users adopt it with minimum effort. This documentation should include:

- A Getting Started guide
- An in-depth description of the API
- Longer examples for common use cases (also known as recipes)
- Links to resources such as blogs, articles, webinars, and conference talks

The Getting Started guide should cover how your library integrates with the supported build systems. It should include a brief description of the most commonly used entities, with small examples of how they are used. At each point where the library interacts with the outside world, specify the necessary steps to configure the environment and how to verify that these steps have been completed successfully. State explicitly if no steps are necessary.

If possible, provide separate versions of the documentation for each version of the library you support. This prevents users from viewing information that is either outdated or too recent. When this is not possible, clearly mark sections of the documentation that relate to parts of the API that have been redesigned.

Create personas for your users

Creating and evaluating documentation without a clear understanding of the intended audience is challenging. Defining multiple personas for the types of users who will read your documentation can be helpful.

Consider the user's constraints, such as the pre-existing software stack within which they need to operate. Reviewers of the documentation can adopt these personas to make their conclusions more meaningful.

When you lack specific information about your users, it's best to be pessimistic. For example, do not assume expertise in the latest or most advanced features of Kotlin. Keep your code examples as simple as possible.

Personas are especially useful when real-world users cannot be consulted due to time, budgetary constraints, or confidentiality agreements. Over time, as you gain a better understanding of your users, refine the personas to match their needs more accurately.

Document by example whenever possible

Documentation by example is one of the most cost-effective ways to explain basic concepts to users. Whenever possible, provide simple and clear code examples that help to explain or demonstrate the current topic or concept being discussed.

The KDoc documentation format lets you use inline markup using Markdown in your documentation comments. Use inline code snippets in comments to showcase the usage of an API. For an example, see the source code and rendered documentation of the test dispatchers of the coroutines library.

Providing examples like this can avoid the need to write lengthy descriptions of expected inputs, possible outputs, and failure modes. However, the context for each example needs to be clear, as do the circumstances in which it is relevant. Simply providing a folder of uncommented sample programs does not qualify as documentation.

Thoroughly document your API

Every supported API entry point should be documented using KDoc.

Kotlin's documentation engine, Dokka, includes only public declarations in its outputs by default. As discussed in the Simplicity section, you should minimize your public API and remove public entry points that you don't want users to access. If there are APIs you cannot hide from users by controlling their visibility, omit them from the documentation using the suppress directive.

Begin the description of entry points with a clear, high-level description of what the function does. Avoid simply restating the signature in natural language.

For example, don't say “takes a String and returns a Connection” but instead perhaps “Attempts to connect to the database specified by the input string, returning a Connection if successful, and throwing a ConnectionTimeoutException otherwise”.

Specify each input's expected values and behavior with different inputs. Explain the range of valid values and what happens when invalid values are provided. For example, if a string input is supposed to be a URL, describe what happens when the string is empty, invalid, uses an unsupported protocol, or refers to a location that does not exist.

Document every exception an API entry point may throw. Discuss failure conditions in the general description and reserve the exception section for detailed information. This enhances readability and helps the reader focus. Instead, include this information organically into the general description. Providing usage examples whenever possible also helps users understand how to use the API correctly.

> We recommend learning about technical writing to improve the clarity and effectiveness of your documentation. Consider exploring resources, such as this course from Google (part one and part two).

Document lambda parameters

When an API entry point takes a lambda, the user is providing some functionality that your library will execute on their behalf. This requires extra documentation in at least two areas.

First, document what happens if the lambda throws an exception. Consider addressing the following questions:

- Will this cause an immediate failure, will the lambda be invoked repeatedly, or is there a fallback behavior?
- If the calling function needs to exit, will it rethrow the exception thrown from the lambda or a different one?
- If the exception is different, will it include the original?

Additionally, unless the function is declared as inline,document any special behavior relating to concurrency. Ensure the following are covered:

- Will the lambda be invoked in the same thread as the caller?
- If the lambda is not invoked in the same thread as the caller, which thread (or thread pool) will it be invoked in?
- Could multiple copies of the lambda be run in parallel?
- Which other jobs of work may be using that thread?
- Can the user specify a thread for the library to use?
- Where multiple lambdas are being invoked, what guarantees are provided regarding sequencing?

Use explicit links in documentation

It is very rare for an API entry point to be completely independent of other functionality in your library. Typically, calls must be made in a specific sequence, there are multiple options for performing a particular task, and entry points that perform related tasks are used in similar ways. For example, functions like format and parse mirror each other.

Use the @see tag or internal links to make these relationships explicit in your documentation. This helps the reader by enabling them to chunk the information together, building a better-integrated mental map of the library.

Be self-contained where possible

When describing what makes an input valid, it is tempting to simply refer to the relevant standard, such as those produced by the W3C, IEEE, or Unicode Consortium. While providing these links can be helpful, the reader should not be forced to refer to an external specification to discover basic information, like the set of whitespace characters.

Wherever possible, the documentation should be self-contained. It should provide enough information for the user to understand the typical use of each API entry point. You can refer the user to external documents for edge cases that will not happen in common use.

Use simple English

It's important to use simple and clear English when creating documentation. This ensures that your content is accessible to a global audience, including those whose first language is not English. Avoid using complex words, jargon, Latin phrases, or idiomatic expressions that might confuse readers. Instead, use straightforward language and concise sentences.

Simple English also makes the documentation easier to translate if needed. Clear, unambiguous text reduces the risk of misinterpretation and improves the overall readability.

What's next

If you haven't already, consider checking out these pages:

- Explore strategies for minimizing mental complexity in the Minimizing mental complexity page.
- Learn about maintaining backward compatibility in the Backward compatibility page.

Building a Kotlin library for multiplatform

When creating a Kotlin library, consider building and publishing it with support for Kotlin Multiplatform. This broadens the target audience of your library, making it compatible with projects targeting multiple platforms.

The following sections provide guidelines to help you build a Kotlin Multiplatform library effectively.

Maximize your reach

To make your library available to the largest number of projects as a dependency, aim to support as many target platforms of Kotlin Multiplatform as possible.

If your library doesn't support the platforms used by a multiplatform project, whether it's a library or an application, it becomes difficult for that project to depend on your library. In that case, projects can use your library for some platforms and need to implement separate solutions for others, or they will choose an alternative library altogether that supports all their platforms.

To streamline artifact production, you can try Experimental cross-compilation to publish Kotlin Multiplatform libraries from any host. This allows you to generate .klib artifacts for Apple targets without an Apple machine. We plan to stabilize this feature and further improve library publication in the future. Please leave your feedback about this feature in our issue tracker YouTrack.

For Kotlin/Native targets, consider using a tiered approach to support all possible targets.

Design APIs for use from common code

When creating a library, design the APIs to be usable from common Kotlin code, instead of writing platform-specific implementations.

Provide reasonable default configurations when possible and include platform-specific configuration options. Good defaults allow users to use the library's APIs from common Kotlin code, without the need to write platform-specific implementations to configure the library.

Place APIs in the broadest relevant source set using the following priority:

- The commonMain source set: APIs in the commonMain source set are available to all platforms the library supports. Aim to place most of your library's API here.
- Intermediate source sets: If some platforms don't support certain APIs, use intermediate source sets to target specific platforms. For example, you can create a concurrent source set for targets that support multi-threading or a nonJvm source set for all non-JVM targets.
- Platform-specific source sets: For platform-specific APIs, use source sets like androidMain.

To learn more about the source sets of Kotlin Multiplatform projects, see Hierarchical project structure.

Ensure consistent behavior across platforms

To ensure your library behaves consistently on all supported platforms, APIs in a multiplatform library should accept the same range of valid inputs, perform the same actions, and return the same results across all platforms. Similarly, the library should treat invalid inputs uniformly and report errors or throw exceptions consistently on all platforms.

Inconsistent behavior makes the library difficult to use and forces users to add conditional logic in common code to manage platform-specific differences.

You can use expect and actual declarations to declare functions in common code with platform-specific implementations that have full access to the native APIs of each platform. These implementations must also have the same behavior to ensure that they can be used reliably from common code.

When APIs behave consistently across platforms, they only need to be documented once in the commonMain source set.

If platform differences are unavoidable, such as when one platform supports a broader set of inputs, minimize them where possible. For example, you might not want to limit one platform's functionality to match the others. In such cases, clearly document the specific differences.

Test on all platforms

Multiplatform libraries can have multiplatform tests written in common code that runs on all platforms. Executing this common test suite regularly on your supported platforms can ensure that the library behaves correctly and consistently.

Regularly testing Kotlin/Native targets across all published platforms can be challenging. However, to ensure broader compatibility, consider publishing the library for all the targets it can support, using a tiered method when testing compatibility.

Use the kotlin-test library to write tests in common code and execute them with platform-specific test runners.

Consider non-Kotlin users

Kotlin Multiplatform offers interoperability with native APIs and languages across its supported target platforms. When creating a Kotlin Multiplatform library, consider whether users might need to use your library's types and declarations from languages other than Kotlin.

For example, if some types from your library will be exposed to Swift code through interoperability, design those types to be easily accessible from Swift. The Kotlin-Swift interopedia provides useful insights into how Kotlin APIs appear when called from Swift.

Promote your library

Your library can be featured on the JetBrains' search platform. It's designed to make it easy to look for Kotlin Multiplatform libraries based on their target platforms.

Libraries that meet the criteria are added automatically. For more information on how to add your library, see FAQ.

Participate in the Kotlin Early Access Preview

You can participate in the Kotlin Early Access Preview (EAP) to try out the latest Kotlin features before they are released.

We ship a few Beta (Beta) and Release Candidate (RC) builds before every language (2.x.0) and tooling (2.x.20) release.

We'll be very thankful if you find and report bugs to our issue tracker YouTrack. It is very likely that we'll be able to fix them before the final release, which means you won't need to wait until the next Kotlin release for your issues to be addressed.

By participating in the Early Access Preview and reporting bugs, you contribute to Kotlin and help us make it better for everyone in the growing Kotlin community. We appreciate your help a lot!

If you have any questions and want to participate in discussions, you are welcome to join the #eap channel in Kotlin Slack. In this channel, you can also get notifications about new EAP builds.

Configure your project for the Kotlin EAP version

> By participating in the EAP, you expressly acknowledge that the EAP version may not be reliable, may not work as intended, and may contain errors.
>
> Please note that we don't provide any guarantees of compatibility between EAP and final versions of the same release.

How the EAP can help you be more productive with Kotlin

- Prepare for the Stable release. If you work on a complex multimodule project, participating in the EAP may streamline your experience when you adopt the Stable release version. The sooner you update to the Stable version, the sooner you can take advantage of its performance improvements and new language features.

  The migration of huge and complex projects might take a while, not only because of their size, but also because some specific use cases may not have been covered by the Kotlin team yet. By participating in the EAP and continuously testing new versions of Kotlin, you can provide us with early feedback about your specific use cases. This will help us address as many issues as possible and ensure you can safely update to the Stable version when it's released. Check out how Slack benefits from testing Android, Kotlin, and Gradle pre-release versions.

- Keep your library up-to-date. If you're a library author, updating to the new Kotlin version is extremely important. Using older versions could block your users from updating Kotlin in their projects. Working with EAP versions allows you to support the latest Kotlin versions in your library almost immediately with the Stable release, which makes your users happier and your library more popular.

- Share the experience. If you're a Kotlin enthusiast and enjoy contributing to the Kotlin ecosystem by creating educational content, trying new features in the Kotlin EAP allows you to be among the first to share the experience of using the new cool features with the community.

Build details

No preview versions are currently available.

Configure your build for EAP

To configure your build to use the EAP version of Kotlin, you need to:

- Specify the EAP version of Kotlin. Available EAP versions are listed here.
- Change the versions of dependencies to EAP ones. The EAP version of Kotlin may not work with the libraries of the previously released version.

The following procedures describe how to configure your build in Gradle and Maven:

- Configure in Gradle
- Configure in Maven

Configure in Gradle

This section describes how you can:

- Adjust the Kotlin version
- Adjust versions in dependencies

Adjust the Kotlin version

In the plugins block within build.gradle(.kts), change the KOTLIN-EAP-VERSION to the actual EAP version, such as 2.2.0-RC3. Available EAP versions are listed here.

Alternatively, you can specify the EAP version in the pluginManagement block in settings.gradle(.kts) – see Gradle documentation for details.

Here is an example for the Multiplatform project.

Kotlin

```kotlin
plugins {
    java
    kotlin("multiplatform") version "KOTLIN-EAP-VERSION"
}

repositories {
    mavenCentral()
}
```

Groovy

```groovy
plugins {
    id 'java'
    id 'org.jetbrains.kotlin.multiplatform' version 'KOTLIN-EAP-VERSION'
}

repositories {
    mavenCentral()
}
```

Adjust versions in dependencies

If you use kotlinx libraries in your project, your versions of the libraries may not be compatible with the EAP version of Kotlin.

To resolve this issue, you need to specify the version of a compatible library in dependencies. For a list of compatible libraries, see EAP build details.

> In most cases we create libraries only for the first EAP version of a specific release and these libraries work with the subsequent EAP versions for this release.
>
> If there are incompatible changes in next EAP versions, we release a new version of the library.

Here is an example.

For the kotlinx.coroutines library, add the version number – 1.10.2 – that is compatible with 2.2.0-RC3.

Kotlin

```
dependencies {
    implementation("org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2")
}
```

Groovy

```
dependencies {
    implementation "org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.2"
}
```

Configure in Maven

In the sample Maven project definition, replace KOTLIN-EAP-VERSION with the actual version, such as 2.2.0-RC3. Available EAP versions are listed here.

```
<project ...>
    <properties>
        <kotlin.version>KOTLIN-EAP-VERSION</kotlin.version>
    </properties>

    <repositories>
        <repository>
           <id>mavenCentral</id>
           <url>https://repo1.maven.org/maven2/</url>
        </repository>
    </repositories>

    <pluginRepositories>
       <pluginRepository>
          <id>mavenCentral</id>
          <url>https://repo1.maven.org/maven2/</url>
       </pluginRepository>
    </pluginRepositories>

    <dependencies>
        <dependency>
            <groupId>org.jetbrains.kotlin</groupId>
            <artifactId>kotlin-stdlib</artifactId>
            <version>${kotlin.version}</version>
        </dependency>
    </dependencies>

    <build>
        <plugins>
            <plugin>
                <groupId>org.jetbrains.kotlin</groupId>
                <artifactId>kotlin-maven-plugin</artifactId>
                <version>${kotlin.version}</version>
                ...
            </plugin>
        </plugins>
    </build>
</project>
```

If you run into any problems

- Report an issue to our issue tracker, YouTrack.
- Find help in the #eap channel in Kotlin Slack (get an invite).
- Roll back to the latest stable version: change it in your build script file.

FAQ

What is Kotlin?

Kotlin is an open-source statically typed programming language that targets the JVM, Android, JavaScript, Wasm, and Native. It's developed by JetBrains. The project started in 2010 and was open source from very early on. The first official 1.0 release was in February 2016.

What is the current version of Kotlin?

The currently released version is 2.2.0, published on June 23, 2025.
You can find more information on GitHub.

Is Kotlin free?

Yes. Kotlin is free, has been free and will remain free. It is developed under the Apache 2.0 license, and the source code is available on GitHub.

Is Kotlin an object-oriented language or a functional one?

Kotlin has both object-oriented and functional constructs. You can use it in both OO and FP styles, or mix elements of the two. With first-class support for features such as higher-order functions, function types, and lambdas, Kotlin is a great choice if you're doing or exploring functional programming.

What advantages does Kotlin give me over the Java programming language?

Kotlin is more concise. Rough estimates indicate approximately a 40% cut in the number of lines of code. It's also more type-safe – for example, support for non-nullable types makes applications less prone to NPE's. Other features including smart casting, higher-order functions, extension functions, and lambdas with receivers provide the ability to write expressive code as well as facilitating creation of DSL.

Is Kotlin compatible with the Java programming language?

Yes. Kotlin is 100% interoperable with the Java programming language, and major emphasis has been placed on making sure that your existing codebase can interact properly with Kotlin. You can easily call Kotlin code from Java and Java code from Kotlin. This makes adoption much easier and lower-risk. There's also an automated Java-to-Kotlin converter built into the IDE that simplifies migration of existing code.

What can I use Kotlin for?

Kotlin can be used for any kind of development, be it server-side, client-side web, Android, or multiplatform library. With Kotlin/Native currently in the works, support for other platforms such as embedded systems, macOS, and iOS. People are using Kotlin for mobile and server-side applications, client-side with JavaScript or JavaFX, and data science, just to name a few possibilities.

Can I use Kotlin for Android development?

Yes. Kotlin is supported as a first-class language on Android. There are hundreds of applications already using Kotlin for Android, such as Basecamp, Pinterest and more. For more information, check out the resource on Android development.

Can I use Kotlin for server-side development?

Yes. Kotlin is 100% compatible with the JVM, and as such you can use any existing frameworks such as Spring Boot, vert.x or JSF. In addition, there are specific frameworks written in Kotlin, such as Ktor. For more information, check out the resource on server-side development.

Can I use Kotlin for web development?

Yes. For backend web development, Kotlin works well with frameworks such as Ktor and Spring, enabling you to build server-side applications efficiently. Additionally, you can use Kotlin/Wasm for client-side web development. Learn how to get started with Kotlin/Wasm.

Can I use Kotlin for desktop development?

Yes. You can use any Java UI framework such as JavaFx, Swing or other. In addition, there are Kotlin-specific frameworks such as TornadoFX.

Can I use Kotlin for native development?

Yes. Kotlin/Native is available as a part of Kotlin. It compiles Kotlin to native code that can run without a VM. You can try it on popular desktop and mobile platforms and even some IoT devices. For more information, check out the Kotlin/Native documentation.

What IDEs support Kotlin?

Kotlin has full out-of-the-box support in IntelliJ IDEA and Android Studio with an official Kotlin plugin developed by JetBrains.

Other IDEs and code editors only have Kotlin community-supported plugins.

You can also try Kotlin Playground for writing, running, and sharing Kotlin code in your browser.

In addition, a command line compiler is available, which provides straightforward support for compiling and running applications.

What build tools support Kotlin?

On the JVM side, the main build tools include Gradle and Maven. There are also some build tools available that target client-side JavaScript.

What does Kotlin compile down to?

When targeting the JVM, Kotlin produces Java-compatible bytecode.

When targeting JavaScript, Kotlin transpiles to ES5.1 and generates code which is compatible with module systems including AMD and CommonJS.

When targeting native, Kotlin will produce platform-specific code (via LLVM).

Which versions of JVM does Kotlin target?

Kotlin lets you choose the version of JVM for execution. By default, the Kotlin/JVM compiler produces Java 8 compatible bytecode. If you want to make use of optimizations available in newer versions of Java, you can explicitly specify the target Java version from 9 to 24. Note that in this case the resulting bytecode might not run on lower versions. Starting with Kotlin 1.5, the compiler does not support producing bytecode compatible with Java versions below 8.

Is Kotlin hard?

Kotlin is inspired by existing languages such as Java, C#, JavaScript, Scala and Groovy. We've tried to ensure that Kotlin is easy to learn, so that people can easily jump on board, reading and writing Kotlin in a matter of days. Learning idiomatic Kotlin and using some more of its advanced features can take a little longer, but overall it is not a complicated language.
For more information, check out our learning materials.

What companies are using Kotlin?

There are too many companies using Kotlin to list, but some more visible companies that have publicly declared usage of Kotlin, be this via blog posts, GitHub repositories or talks include Square, Pinterest, Basecamp, and Corda.

Who develops Kotlin?

Kotlin is developed by a team of engineers at JetBrains (current team size is 100+). The lead language designer is Michail Zarečenskij. In addition to the core team, there are also over 250 external contributors on GitHub.

Where can I learn more about Kotlin?

The best place to start is our website. To start with Kotlin, you can install one of the official IDEs or try it online.

Are there any books on Kotlin?

There are a number of books available for Kotlin. Some of them we have reviewed and can recommend to start with. They are listed on the Books page. For more books, see the community-maintained list at kotlin.link.

Are any online courses available for Kotlin?

You can learn all the Kotlin essentials while creating working applications with the Kotlin Core track by JetBrains Academy.

A few other courses you can take:

- Pluralsight Course: Getting Started with Kotlin by Kevin Jones
- O'Reilly Course: Introduction to Kotlin Programming by Hadi Hariri
- Udemy Course: 10 Kotlin Tutorials for Beginners by Peter Sommerhoff

You can also check out the other tutorials and content on our YouTube channel.

Does Kotlin have a community?

Yes! Kotlin has a very vibrant community. Kotlin developers hang out on the Kotlin forums, StackOverflow and more actively on the Kotlin Slack (with close to 30000 members as of April 2020).

Are there Kotlin events?

Yes! There are many User Groups and Meetups now focused exclusively around Kotlin. You can find a list on the website. In addition, there are community-organized Kotlin Nights events around the world.

Is there a Kotlin conference?

Yes! KotlinConf is an annual conference hosted by JetBrains, which brings together developers, enthusiasts, and experts from around the world to share their knowledge and experience with Kotlin.

In addition to technical talks and workshops, KotlinConf also offers networking opportunities, community interactions, and social events where attendees can connect with fellow Kotliners and exchange ideas. It serves as a platform for fostering collaboration and community building within the Kotlin ecosystem.

Kotlin is also being covered in different conferences worldwide. You can find a list of upcoming talks on the website.

Is Kotlin on social media?

Yes. Subscribe to the Kotlin YouTube channel and follow Kotlin on Twitter or on Bluesky.

Any other online Kotlin resources?

The website has a bunch of online resources, including Kotlin Digests by community members, a newsletter, a podcast and more.

Where can I get an HD Kotlin logo?

Logos can be downloaded here. When using the logos, please follow simple rules in the guidelines.pdf inside the archive and Kotlin brand usage guidelines.

For more information, check out the page about Kotlin brand assets.

Compatibility guide for Kotlin 2.2

Keeping the Language Modern and Comfortable Updates are among the fundamental principles in Kotlin Language Design. The former says that constructs which obstruct language evolution should be removed, and the latter says that this removal should be well-communicated beforehand to make code migration as smooth as possible.

While most of the language changes were already announced through other channels, like update changelogs or compiler warnings, this document summarizes them all, providing a complete reference for migration from Kotlin 2.1 to Kotlin 2.2.

Basic terms

In this document, we introduce several kinds of compatibility:

- source: source-incompatible change stops code that used to compile fine (without errors or warnings) from compiling anymore
- binary: two binary artifacts are said to be binary-compatible if interchanging them doesn't lead to loading or linkage errors
- behavioral: a change is said to be behavioral-incompatible if the same program demonstrates different behavior before and after applying the change

Remember that those definitions are given only for pure Kotlin. Compatibility of Kotlin code from the other languages perspective (for example, from Java) is out of the scope of this document.

Language

Enable invokedynamic for annotated lambdas by default

Issue: KTLC-278

Component: Core language

Incompatible change type: behavioral

Short summary: Lambdas with annotations now use invokedynamic through LambdaMetafactory by default, aligning their behavior with Java lambdas. This affects reflection-based code that relied on retrieving annotations from generated lambda classes. To revert to the old behavior, use the -Xindy-allow-annotated-lambdas=false compiler option.

Deprecation cycle:

- 2.2.0: enable invokedynamic for annotated lambdas by default

Prohibit constructor call and inheritance on type aliases with variance in expanded types in K2

Issue: KTLC-4

Component: Core language

Incompatible change type: source

Short summary: Constructor calls and inheritance using type aliases that expand to types that use variance modifiers such as out are no longer supported by the K2 compiler. This resolves inconsistencies where using the original type wasn't allowed, but the same usage through a type alias was permitted. To migrate, use the original type explicitly where needed.

Deprecation cycle:

- 2.0.0: report a warning for constructor calls or supertype usage on type aliases that expand to types with variance modifiers
- 2.2.0: raise the warning to an error

Prohibit synthetic properties from Kotlin getters

Issue: KTLC-272

Component: Core language

Incompatible change type: source

Short summary: Synthetic properties are no longer allowed for getters defined in Kotlin. This affects cases where Java classes extend Kotlin ones and when working with mapped types like java.util.LinkedHashSet. To migrate, replace property access with direct calls to the corresponding getter functions.

Deprecation cycle:

- 2.0.0: report a warning for accessing synthetic properties created from Kotlin getters
- 2.2.0: raise the warning to an error

Change default method generation for interface functions on JVM

Issue: KTLC-269

Component: Core language

Incompatible change type: binary

Short summary: Functions declared in interfaces are now compiled to JVM default methods unless configured otherwise. This may result in compilation errors in Java code when unrelated supertypes define conflicting implementations. The behavior is controlled by the stable -jvm-default compiler option, which replaces the now deprecated -Xjvm-default option. To restore the previous behavior, where default implementations are generated only in DefaultImpls classes and subclasses, use -jvm-default=disable.

Deprecation cycle:

- 2.2.0: -jvm-default compiler option is set to enable by default

Forbid field-targeted annotations on annotation properties

Issue: KTLC-7

Component: Core language

Incompatible change type: source

Short summary: Field-targeted annotations are no longer allowed on annotation properties. Although these annotations had no observable effect, this change may affect custom IR plugins that relied on them. To migrate, remove the field-targeted annotation from the property.

Deprecation cycle:

- 2.1.0: @JvmField annotation is deprecated with a warning on annotation properties
- 2.1.20: report a warning for all field-targeted annotations on annotation properties
- 2.2.0: raise the warning to an error

Forbid reified type parameters in type aliases

Issue: KTLC-5

Component: Core language

Incompatible change type: source

Short summary: The reified modifier is no longer allowed on type parameters in type aliases. Reified type parameters are only valid in inline functions, so using them in type aliases had no effect. To migrate, remove the reified modifier from typealias declarations.

Deprecation cycle:

- 2.1.0: report a warning for reified type parameters in type aliases
- 2.2.0: raise the warning to an error

Correct type checks on inline value classes for Number and Comparable

Issue: KTLC-21

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Inline value classes are no longer treated as implementors of java.lang.Number or java.lang.Comparable in is and as checks. These checks previously returned incorrect results when applied to boxed inline classes. The optimization now applies only to primitive types and their wrappers.

Deprecation cycle:

- 2.2.0: enable the new behavior

Prohibit inaccessible generic types from indirect dependencies

Issue: KTLC-3

Component: Core language

Incompatible change type: source

Short summary: The K2 compiler now reports errors when using types from indirect dependencies that are not visible to the compiler. This affects cases such as lambda parameters or generic type arguments, where the referenced type is not available due to a missing dependency.

Deprecation cycle:

- 2.0.0: report errors for inaccessible generic types in lambdas and selected usages of inaccessible generic type arguments; report warnings for inaccessible non-generic types in lambdas and inaccessible type arguments in expression and super types
- 2.1.0: raise the warning on inaccessible non-generic types in lambdas to an error
- 2.2.0: raise the warning on inaccessible type arguments in expression types to an error

Enforce visibility checks on type parameter bounds

Issue: KTLC-274

Component: Core language

Incompatible change type: source

Short summary: Functions and properties can no longer use a type parameter bound that has more restrictive visibility than the declaration itself. This prevents exposing inaccessible types indirectly, which previously compiled without errors but led to runtime failures or IR validation errors in some cases.

Deprecation cycle:

- 2.1.0: report a warning when a type parameter has a bound that is not visible from the declaration's visibility scope
- 2.2.0: raise the warning to an error

Report errors when exposing private types in non-private inline functions

Issue: KT-70916

Component: Core language

Incompatible change type: source

Short summary: Accessing private types, functions, or properties from non-private inline functions is no longer allowed. To migrate, either avoid referencing private entities, make the function private, or remove the inline modifier. Note that removing inline breaks binary compatibility.

Deprecation cycle:

- 2.2.0: report an error when accessing private types or members from non-private inline functions

Forbid non-local returns in default argument lambdas

Issue: KTLC-286

Component: Core language

Incompatible change type: source

Short summary: Non-local return statements are no longer allowed in lambdas used as default arguments. This pattern previously compiled but led to runtime crashes. To migrate, rewrite the lambda to avoid non-local returns or move the logic outside the default argument.

Deprecation cycle:

- 2.2.0: report an error for non-local returns in lambdas used as default argument values

Standard library

Deprecate kotlin.native.Throws

Issue: KT-72137

Component: Kotlin/Native

Incompatible change type: source

Short summary: kotlin.native.Throws is deprecated; use the common kotlin.Throws annotation instead.

Deprecation cycle:

- 1.9.0: report a warning when using kotlin.native.Throws
- 2.2.0: raise the warning to an error

Deprecate AbstractDoubleTimeSource

Issue: KT-72137

Component: kotlin-stdlib

Incompatible change type: source

Short summary: AbstractDoubleTimeSource is deprecated; use AbstractLongTimeSource instead.

Deprecation cycle:

- 1.8.20: report a warning when using AbstractDoubleTimeSource
- 2.2.0: raise the warning to an error

Tools

Correct setSource() function in KotlinCompileTool to replace sources

Issue: KT-59632

Component: Gradle

Incompatible change type: behavioral

Short summary: The setSource() function in the KotlinCompileTool interface now replaces configured sources instead of adding to them. If you want to add sources without replacing existing ones, use the source() function.

Deprecation cycle:

- 2.2.0: enable the new behavior

Deprecate KotlinCompilationOutput#resourcesDirProvider property

Issue: KT-70620

Component: Gradle

Incompatible change type: source

Short summary: The KotlinCompilationOutput#resourcesDirProvider property is deprecated. Use KotlinSourceSet.resources in your Gradle build script instead to add additional resource directories.

Deprecation cycle:

- 2.1.0: KotlinCompilationOutput#resourcesDirProvider is deprecated with a warning
- 2.2.0: raise the warning to an error

Deprecate BaseKapt.annotationProcessorOptionProviders property

Issue: KT-58009

Component: Gradle

Incompatible change type: source

Short summary: The BaseKapt.annotationProcessorOptionProviders property is deprecated in favor of BaseKapt.annotationProcessorOptionsProviders, which accepts a ListProperty<CommandLineArgumentProvider> instead of a MutableList<Any>. This clearly defines the expected element type and prevents runtime failures caused by adding incorrect elements, such as nested lists. If your current code adds a list as a single element, replace the add() function with the addAll() function.

Deprecation cycle:

- 2.2.0: enforce the new type in the API

Deprecate kotlin-android-extensions plugin

Issue: KT-72341

Component: Gradle

Incompatible change type: source

Short summary: The kotlin-android-extensions plugin is deprecated. Use a separate plugin, kotlin-parcelize, for the Parcelable implementation generator and the Android Jetpack's view bindings for synthetic views instead.

Deprecation cycle:

- 1.4.20: the plugin is deprecated
- 2.1.20: a configuration error is introduced, and no plugin code is executed
- 2.2.0: the plugin code is removed

Deprecate kotlinOptions DSL

Issue: KT-54110

Component: Gradle

Incompatible change type: source

Short summary: The ability to configure compiler options through the kotlinOptions DSL and the related KotlinCompile<KotlinOptions> task interface is deprecated in favor of the new compilerOptions DSL. As part of this deprecation, all properties in the kotlinOptions interface are now also individually marked as deprecated. To migrate, use the compilerOptions DSL to configure compiler options. For guidance on the migration, see Migrate from kotlinOptions {} to compilerOptions {}.

Deprecation cycle:

- 2.0.0: report a warning for kotlinOptions DSL
- 2.2.0: raise the warning to an error and deprecate all properties in kotlinOptions

Remove kotlin.incremental.useClasspathSnapshot property

Issue: KT-62963

Component: Gradle

Incompatible change type: source

Short summary: The kotlin.incremental.useClasspathSnapshot Gradle property is removed. This property controlled the deprecated JVM history-based incremental compilation mode, which has been replaced by the classpath-based approach enabled by default since Kotlin 1.8.20.

Deprecation cycle:

- 2.0.20: deprecate the kotlin.incremental.useClasspathSnapshot property with a warning
- 2.2.0: remove the property

Deprecations to Kotlin scripting

Issues: KT-71685, KT-75632, KT-76196.

Component: Scripting

Incompatible change type: source

Short summary: Kotlin 2.2.0 deprecates support for:

- REPL: To continue to use REPL via kotlinc, opt in with the -Xrepl compiler option.
- JSR-223: Since the JSR is in Withdrawn state. The JSR-223 implementation continues to work with language version 1.9 but there are no plans to migrate to the K2 compiler in the future.
- The KotlinScriptMojo Maven plugin. You will see compiler warnings if you continue to use it.

For more information, see our blog post.

Deprecation cycle:

- 2.1.0: deprecate the use of REPL in kotlinc with a warning
- 2.2.0: to use REPL via kotlinc, opt in with the -Xrepl compiler option; deprecate JSR-223, support can be restored by switching to language version 1.9; deprecate the KotlinScriptMojo Maven plugin

Deprecate disambiguation classifier properties

Issue: KT-58231

Component: Gradle

Incompatible change type: source

Short summary: Options that were used to control how the Kotlin Gradle plugin disambiguates source set names and IDE imports became obsolete. Therefore, the following properties are now deprecated in the KotlinTarget interface:

- useDisambiguationClassifierAsSourceSetNamePrefix
- overrideDisambiguationClassifierOnIdeImport

Deprecation cycle:

- 2.0.0: report a warning when the Gradle properties are used
- 2.1.0: raise this warning to an error
- 2.2.0: remove Gradle properties

Deprecate commonization parameters

Issue: KT-75161

Component: Gradle

Incompatible change type: source

Short summary: The parameters for experimental commonization modes are deprecated in the Kotlin Gradle plugin. These parameters may produce invalid compilation artifacts that are then cached. To delete affected artifacts:

1. Remove the following options from your gradle.properties file:

   ```
   kotlin.mpp.enableOptimisticNumberCommonization
   kotlin.mpp.enablePlatformIntegerCommonization
   ```

2. Clear the commonization cache in the ~/.konan/*/klib/commonized directory or run the following command:

   ```
   ./gradlew cleanNativeDistributionCommonization
   ```

Deprecation cycle:

- 2.2.0: deprecate commonization parameters with an error
- 2.2.20: remove commonization parameters

Deprecate support for legacy metadata compilation

Issue: KT-61817

Component: Gradle

Incompatible change type: source

Short summary: Options that were used to set up hierarchical structure and create intermediate source sets between the common and intermediate source sets became obsolete. The following compiler options are removed:

- isCompatibilityMetadataVariantEnabled
- withGranularMetadata
- isKotlinGranularMetadataEnabled

Deprecation cycle:

- 2.2.0: remove compiler options from the Kotlin Gradle plugin

Deprecate KotlinCompilation.source API

Issue: KT-64991

Component: Gradle

Incompatible change type: source

Short summary: The access to KotlinCompilation.source API that allowed adding Kotlin source sets directly to the Kotlin compilation has been deprecated.

Deprecation cycle:

- 1.9.0: report a warning when KotlinCompilation.source is used
- 1.9.20: raise this warning to an error
- 2.2.0: remove KotlinCompilation.source from the Kotlin Gradle plugin; attempts to use it lead to "unresolved reference" errors during the buildscript compilation

Deprecate target presets APIs

Issue: KT-71698

Component: Gradle

Incompatible change type: source

Short summary: Target presets for Kotlin Multiplatform targets became obsolete; target DSL functions like jvm() or iosSimulatorArm64() now cover the same use cases. All presets-related APIs are deprecated:

- The presets property in org.jetbrains.kotlin.gradle.dsl.KotlinMultiplatformExtension
- The org.jetbrains.kotlin.gradle.plugin.KotlinTargetPreset interface and all its inheritors
- The fromPreset overloads

Deprecation cycle:

- 1.9.20: report a warning on any usages of the presets-related API
- 2.0.0: raise this warning to an error
- 2.2.0: remove the presets-related API from the public API of the Kotlin Gradle plugin; sources that still use it fail with "unresolved reference" errors, and binaries (for example, Gradle plugins) might fail with linkage errors unless recompiled against the latest versions of the Kotlin Gradle plugin

Deprecate Apple target shortcuts

Issue: KT-70615

Component: Gradle

Incompatible change type: source

Short summary: The ios(), watchos(), and tvos() target shortcuts are deprecated in Kotlin Multiplatform DSL. The shortcuts were designed to partially create a source set hierarchy for Apple targets. The Kotlin Multiplatform Gradle plugin now provides a built-in hierarchy template. Instead of shortcuts, specify the list of targets, and then the plugin automatically sets up intermediate source sets for them.

Deprecation cycle:

- 1.9.20: report a warning when target shortcuts are used; the default hierarchy template is enabled by default instead
- 2.1.0: report an error when target shortcuts are used
- 2.2.0: remove target shortcut DSL from the Kotlin Multiplatform Gradle plugin

Deprecate publishAllLibraryVariants() function

Issue: KT-60623

Component: Gradle

Incompatible change type: source

Short summary: The publishAllLibraryVariants() function is deprecated. It was designed to publish all build variants for Android targets. This approach is not recommended now, as it can cause problems with variant resolution, especially when multiple flavors and build types are used. Use the publishLibraryVariants() function, which specifies build variants, instead.

Deprecation cycle:

- 2.2.0: publishAllLibraryVariants() is deprecated

Deprecate android target

Issue: KT-71608

Component: Gradle

Incompatible change type: source

Short summary: The android target name is deprecated in the current Kotlin DSL. Use androidTarget instead.

Deprecation cycle:

- 1.9.0: introduce a deprecation warning when the android name is used in Kotlin Multiplatform projects
- 2.1.0: raise this warning to an error
- 2.2.0: remove the android target DSL from the Kotlin Multiplatform Gradle plugin

Deprecate konanVersion in CInteropProcess

Issue: KT-71069

Component: Gradle

Incompatible change type: source

Short summary: The konanVersion property in the CInteropProcess task is deprecated. Use CInteropProcess.kotlinNativeVersion instead.

Deprecation cycle:

- 2.1.0: report a warning when the konanVersion property is used
- 2.2.0: raise this warning to an error
- 2.3.0: remove the konanVersion property from the Kotlin Gradle plugin

Deprecate destinationDir in CInteropProcess

Issue: KT-71068

Component: Gradle

Incompatible change type: source

Short summary: The destinationDir property in the CInteropProcess task is deprecated. Use the CInteropProcess.destinationDirectory.set() function instead.

Deprecation cycle:

- 2.1.0: report a warning when the destinationDir property is used
- 2.2.0: raise this warning to an error
- 2.3.0: remove the destinationDir property from the Kotlin Gradle plugin

Deprecate kotlinArtifacts API

Issue: KT-74953

Component: Gradle

Incompatible change type: source

Short summary: The experimental kotlinArtifacts API is deprecated. Use the current DSL available in the Kotlin Gradle plugin to build final native binaries. If it's not sufficient for migration, leave a comment in this YT issue.

Deprecation cycle:

- 2.2.0: report a warning when the kotlinArtifacts API is used
- 2.3.0: raise this warning to an error

Compatibility guide for Kotlin 2.1

Keeping the Language Modern and Comfortable Updates are among the fundamental principles in Kotlin Language Design. The former says that constructs which obstruct language evolution should be removed, and the latter says that this removal should be well-communicated beforehand to make code migration as smooth as possible.

While most of the language changes were already announced through other channels, like update changelogs or compiler warnings, this document summarizes them all, providing a complete reference for migration from Kotlin 2.0 to Kotlin 2.1.

Basic terms

In this document we introduce several kinds of compatibility:

- source: source-incompatible change stops code that used to compile fine (without errors or warnings) from compiling anymore
- binary: two binary artifacts are said to be binary-compatible if interchanging them doesn't lead to loading or linkage errors
- behavioral: a change is said to be behavioral-incompatible if the same program demonstrates different behavior before and after applying the change

Remember that those definitions are given only for pure Kotlin. Compatibility of Kotlin code from the other languages perspective (for example, from Java) is out of the scope of this document.

Language

Remove language versions 1.4 and 1.5

Issue: KT-60521

Component: Core language

Incompatible change type: source

Short summary: Kotlin 2.1 introduces language version 2.1 and removes support for language versions 1.4 and 1.5. Language versions 1.6 and 1.7 are deprecated.

Deprecation cycle:

- 1.6.0: report a warning for language version 1.4
- 1.9.0: report a warning for language version 1.5
- 2.1.0: report a warning for language versions 1.6 and 1.7; raise the warning to an error for language versions 1.4 and 1.5

Change the typeOf() function behavior on Kotlin/Native

Issue: KT-70754

Component: Core language

Incompatible change type: behavioral

Short summary: The behavior of the typeOf() function on Kotlin/Native is aligned with Kotlin/JVM to ensure consistency across platforms.

Deprecation cycle:

- 2.1.0: align the typeOf() function behavior on Kotlin/Native

Prohibit exposing types through type parameters' bounds

Issue: KT-69653

Component: Core language

Incompatible change type: source

Short summary: Exposing types with lower visibility through type parameter bounds is now prohibited, addressing inconsistencies in type visibility rules. This change ensures that bounds on type parameters follow the same visibility rules as classes, preventing issues like IR validation errors in the JVM.

Deprecation cycle:

- 2.1.0: report a warning for exposing types via type parameter bounds with lower visibility
- 2.2.0: raise the warning to an error

Prohibit inheriting an abstract var property and a val property with the same name

Issue: KT-58659

Component: Core language

Incompatible change type: source

Short summary: If a class inherits an abstract var property from an interface and a val property with the same name from a superclass, it now triggers a compilation error. This resolves runtime crashes caused by missing setters in such cases.

Deprecation cycle:

- 2.1.0: report a warning (or an error in progressive mode) when a class inherits an abstract var property from an interface and a val property with the same name from a superclass
- 2.2.0: raise the warning to an error

Report error when accessing uninitialized enum entries

Issue: KT-68451

Component: Core language

Incompatible change type: source

Short summary: The compiler now reports an error when uninitialized enum entries are accessed during enum class or entry initialization. This aligns the behavior with member property initialization rules, preventing runtime exceptions and ensuring consistent logic.

Deprecation cycle:

- 2.1.0: report an error when accessing uninitialized enum entries

Changes in K2 smart cast propagation

Issue: KTLC-34

Component: Core language

Incompatible change type: behavioral

Short summary: The K2 compiler changes its behavior for smart cast propagation by introducing bidirectional propagation of type information for inferred variables, like val x = y. Explicitly typed variables, such as val x: T = y, no longer propagate type information, ensuring stricter adherence to declared types.

Deprecation cycle:

- 2.1.0: enable the new behavior

Correct the handling of member-extension property overrides in Java subclasses

Issue: KTLC-35

Component: Core language

Incompatible change type: behavioral

Short summary: The getter for member-extension properties overridden by Java subclasses is now hidden in the subclass's scope, aligning its behavior with that of regular Kotlin properties.

Deprecation cycle:

- 2.1.0: enable the new behavior

Correct visibility alignment for getters and setters of var properties overriding a protected val

Issue: KTLC-36

Component: Core language

Incompatible change type: binary

Short summary: The visibility of getters and setters for var properties overriding a protected val property is now consistent, with both inheriting the visibility of the overridden val property.

Deprecation cycle:

- 2.1.0: enforce consistent visibility for both getters and setters in K2; K1 remains unaffected

Raise severity of JSpecify nullability mismatch diagnostics to errors

Issue: KTLC-11

Component: Core language

Incompatible change type: source

Short summary: Nullability mismatches from org.jspecify.annotations, such as @NonNull, @Nullable, and @NullMarked are now treated as errors instead of warnings, enforcing stricter type safety for Java interoperability. To adjust the severity of these diagnostics, use the -Xnullability-annotations compiler option.

Deprecation cycle:

- 1.6.0: report warnings for potential nullability mismatches
- 1.8.20: expand warnings to specific JSpecify annotations, including: @Nullable, @NullnessUnspecified, @NullMarked, and legacy annotations in org.jspecify.nullness (JSpecify 0.2 and earlier)
- 2.0.0: add support for the @NonNull annotation
- 2.1.0: change default mode to strict for JSpecify annotations, converting warnings into errors; use -Xnullability-annotations=@org.jspecify.annotations:warning or -Xnullability-annotations=@org.jspecify.annotations:ignore to override the default behavior

Change overload resolution to prioritize extension functions over invoke calls in ambiguous cases

Issue: KTLC-37

Component: Core language

Incompatible change type: behavioral

Short summary: Overload resolution now consistently prioritizes extension functions over invoke calls in ambiguous cases. This resolves inconsistencies in the resolution logic for local functions and properties. The change applies only after recompilation, without affecting precompiled binaries.

Deprecation cycle:

- 2.1.0: change overload resolution to consistently prioritize extension functions over invoke calls for extension functions with matching signatures; this change applies only after recompilation and does not affect precompiled binaries

Prohibit returning nullable values from lambdas in SAM constructors of JDK function interfaces

Issue: KTLC-42

Component: Core language

Incompatible change type: source

Short summary: Returning nullable values from lambdas in SAM constructors of JDK function interfaces now triggers a compilation error if the specified type argument is non-nullable. This resolves issues where nullability mismatches could lead to runtime exceptions, ensuring stricter type safety.

Deprecation cycle:

- 2.0.0: report a deprecation warning for nullable return values in SAM constructors of JDK function interfaces
- 2.1.0: enable the new behavior by default

Correct handling of private members conflicting with public members in Kotlin/Native

Issue: KTLC-43

Component: Core language

Incompatible change type: behavioral

Short summary: In Kotlin/Native, private members no longer override or conflict with public members in a superclass, aligning behavior with Kotlin/JVM. This resolves inconsistencies in override resolution and eliminates unexpected behavior caused by separate compilation.

Deprecation cycle:

- 2.1.0: private functions and properties in Kotlin/Native no longer override or affect public members in a superclass, aligning with JVM behavior

Forbid access to private operator functions in public inline functions

Issue: KTLC-71

Component: Core language

Incompatible change type: source

Short summary: Private operator functions such as getValue(), setValue(), provideDelegate(), hasNext(), and next() can no longer be accessed in public inline functions.

Deprecation cycle:

- 2.0.0: report a deprecation warning for accessing private operator functions in public inline functions
- 2.1.0: raise the warning to an error

Prohibit passing invalid arguments to invariant parameters annotated with @UnsafeVariance

Issue: KTLC-72

Component: Core language

Incompatible change type: source

Short summary: The compiler now ignores @UnsafeVariance annotations during type checks, enforcing stricter type safety for invariant type parameters. This prevents invalid calls that rely on @UnsafeVariance to bypass expected type checks.

Deprecation cycle:

- 2.1.0: activate the new behavior

Report nullability errors for error-level nullable arguments of warning-level Java types

Issue: KTLC-100

Component: Core language

Incompatible change type: source

Short summary: The compiler now detects nullability mismatches in Java methods where a warning-level nullable type contains type arguments with stricter, error-level nullability. This ensures that previously ignored errors in type arguments are reported correctly.

Deprecation cycle:

- 2.0.0: report a deprecation warning for nullability mismatches in Java methods with stricter type arguments
- 2.1.0: raise the warning to an error

Report implicit usages of inaccessible types

Issue: KTLC-3

Component: Core language

Incompatible change type: source

Short summary: The compiler now reports usages of inaccessible types in function literals and type arguments, preventing compilation and runtime failures caused by incomplete type information.

Deprecation cycle:

- 2.0.0: report warnings for function literals with parameters or receivers of inaccessible non-generic types and for types with inaccessible type argument; report errors for function literals with parameters or receivers of inaccessible generic types and for types with inaccessible generic type arguments in specific scenarios
- 2.1.0: raise warnings to errors for function literals with parameters and receivers of inaccessible non-generic types
- 2.2.0: raise warnings to errors for types with inaccessible type arguments

Standard library

Deprecate locale-sensitive case conversion functions for Char and String

Issue: KT-43023

Component: kotlin-stdlib

Incompatible change type: source

Short summary: Among other Kotlin standard library APIs, locale-sensitive case conversion functions for Char and String, such as Char.toUpperCase() and String.toLowerCase(), are deprecated. Replace them with locale-agnostic alternatives like String.lowercase() or explicitly specify the locale for locale-sensitive behavior, such as String.lowercase(Locale.getDefault()).

For a comprehensive list of deprecated Kotlin standard library APIs in Kotlin 2.1.0, see KT-71628.

Deprecation cycle:

- 1.4.30: introduce locale-agnostic alternatives as experimental API
- 1.5.0: deprecate locale-sensitive case conversion functions with a warning
- 2.1.0: raise the warning to an error

Remove kotlin-stdlib-common JAR artifact

Issue: KT-62159

Component: kotlin-stdlib

Incompatible change type: binary

Short summary: The kotlin-stdlib-common.jar artifact, previously used for legacy multiplatform declarations metadata, is deprecated and replaced by .klib files as the standard format for common multiplatform declarations metadata. This change does not affect the main kotlin-stdlib.jar or kotlin-stdlib-all.jar artifacts.

Deprecation cycle:

- 2.1.0: deprecate and remove kotlin-stdlib-common.jar artifact

Deprecate appendln() in favor of appendLine()

Issue: KTLC-27

Component: kotlin-stdlib

Incompatible change type: source

Short summary: StringBuilder.appendln() is deprecated in favor of StringBuilder.appendLine().

Deprecation cycle:

- 1.4.0: the appendln() function is deprecated; report a warning on use
- 2.1.0: raise the warning to an error

Deprecate freezing-related APIs in Kotlin/Native

Issue: KT-69545

Component: kotlin-stdlib

Incompatible change type: source

Short summary: Freezing-related APIs in Kotlin/Native, previously marked with the @FreezingIsDeprecated annotation, are now deprecated. This aligns with the introduction of the new memory manager that removes the need for freezing objects for thread sharing. For migration details, see the Kotlin/Native migration guide.

Deprecation cycle:

- 1.7.20: deprecate freezing-related APIs with a warning
- 2.1.0: raise the warning to an error

Change Map.Entry behavior to fail-fast on structural modification

Issue: KTLC-23

Component: kotlin-stdlib

Incompatible change type: behavioral

Short summary: Accessing a Map.Entry key-value pair after its associated map has been structurally modified now throws a ConcurrentModificationException.

Deprecation cycle:

- 2.1.0: throw an exception when a map structural modification is detected

Tools

Deprecate KotlinCompilationOutput#resourcesDirProvider

Issue: KT-69255

Component: Gradle

Incompatible change type: source

Short summary: The KotlinCompilationOutput#resourcesDirProvider field is deprecated. Use KotlinSourceSet.resources in your Gradle build script instead to add additional resource directories.

Deprecation cycle:

- 2.1.0: KotlinCompilationOutput#resourcesDirProvider is deprecated

Deprecate registerKotlinJvmCompileTask(taskName, moduleName) function

Issue: KT-69927

Component: Gradle

Incompatible change type: source

Short summary: The registerKotlinJvmCompileTask(taskName, moduleName) function is deprecated in favor of the new registerKotlinJvmCompileTask(taskName, compilerOptions, explicitApiMode) function, which now accepts KotlinJvmCompilerOptions. This allows you to pass a compilerOptions instance, typically from an extension or target, with values used as conventions for the task's options.

Deprecation cycle:

- 2.1.0: the registerKotlinJvmCompileTask(taskName, moduleName) function is deprecated

Deprecate registerKaptGenerateStubsTask(taskName) function

Issue: KT-70383

Component: Gradle

Incompatible change type: source

Short summary: The registerKaptGenerateStubsTask(taskName) function is deprecated. Use the new registerKaptGenerateStubsTask(compileTask, kaptExtension, explicitApiMode) function instead. This new version allows you to link values as conventions from the relevant KotlinJvmCompile task, ensuring both tasks are using the same set of options.

Deprecation cycle:

- 2.1.0: the registerKaptGenerateStubsTask(taskName) function is deprecated

Deprecate KotlinTopLevelExtension and KotlinTopLevelExtensionConfig interfaces

Issue: KT-71602

Component: Gradle

Incompatible change type: behavioral

Short summary: KotlinTopLevelExtension and KotlinTopLevelExtensionConfig interfaces are deprecated in favor of a new KotlinTopLevelExtension interface. This interface merges KotlinTopLevelExtensionConfig, KotlinTopLevelExtension, and KotlinProjectExtension to streamline API hierarchy, and provide official access to the JVM toolchain and compiler properties.

Deprecation cycle:

- 2.1.0: the KotlinTopLevelExtension and KotlinTopLevelExtensionConfig interfaces are deprecated

Remove kotlin-compiler-embeddable from build runtime dependencies

Issue: KT-61706

Component: Gradle

Incompatible change type: source

Short summary: The kotlin-compiler-embeddable dependency is removed from the runtime in Kotlin Gradle Plugin (KGP). Required modules are now included directly in KGP artifacts, with the Kotlin language version limited to 2.0 to support compatibility with Gradle Kotlin runtime in versions below 8.2.

Deprecation cycle:

- 2.1.0: report a warning on using kotlin-compiler-embeddable
- 2.2.0: raise the warning to an error

Hide compiler symbols from the Kotlin Gradle Plugin API

Issue: KT-70251

Component: Gradle

Incompatible change type: source

Short summary: Compiler module symbols bundled within the Kotlin Gradle Plugin (KGP), such as KotlinCompilerVersion, are hidden from the public API to prevent unintended access in build scripts.

Deprecation cycle:

- 2.1.0: report a warning on accessing these symbols
- 2.2.0: raise the warning to an error

Add support for multiple stability configuration files

Issue: KT-68345

Component: Gradle

Incompatible change type: source

Short summary: The stabilityConfigurationFile property in the Compose extension is deprecated in favor of a new stabilityConfigurationFiles property, which allows specifying multiple configuration files.

Deprecation cycle:

- 2.1.0: stabilityConfigurationFile property is deprecated

Remove deprecated platform plugin IDs

Issue: KT-65565

Component: Gradle

Incompatible change type: source

Short summary: Support for these platform plugin IDs have been removed:

- kotlin-platform-common
- org.jetbrains.kotlin.platform.common

Deprecation cycle:

- 1.3: the platform plugin IDs are deprecated
- 2.1.0: the platform plugin IDs are no longer supported

Compatibility guide for Kotlin 2.0

Keeping the Language Modern and Comfortable Updates are among the fundamental principles in Kotlin Language Design. The former says that constructs which obstruct language evolution should be removed, and the latter says that this removal should be well-communicated beforehand to make code migration as smooth as possible.

While most of the language changes were already announced through other channels, like updated changelogs or compiler warnings, this document provides a complete reference for migration from Kotlin 1.9 to Kotlin 2.0.

The Kotlin K2 compiler is introduced as part of Kotlin 2.0. For information on the benefits of the new compiler, changes you might encounter during migration, and how to roll back to the previous compiler, see K2 compiler migration guide.

Basic terms

In this document we introduce several kinds of compatibility:

- source: source-incompatible change stops code that used to compile fine (without errors or warnings) from compiling anymore
- binary: two binary artifacts are said to be binary-compatible if interchanging them doesn't lead to loading or linkage errors
- behavioral: a change is said to be behavioral-incompatible if the same program demonstrates different behavior before and after applying the change

Remember that those definitions are given only for pure Kotlin. Compatibility of Kotlin code from the other languages perspective (for example, from Java) is out of the scope of this document.

Language

Deprecate use of a synthetic setter on a projected receiver

Issue: KT-54309

Component: Core language

Incompatible change type: source

Short summary: If you use the synthetic setter of a Java class to assign a type that conflicts with the class's projected type, an error is triggered.

Deprecation cycle:

- 1.8.20: report a warning when a synthetic property setter has a projected parameter type in contravariant position making call-site argument types incompatible
- 2.0.0: raise the warning to an error

Correct mangling when calling functions with inline class parameters that are overloaded in a Java subclass

Issue: KT-56545

Component: Core language

Incompatible change type: behavioral

Deprecation cycle:

- 2.0.0: use the correct mangling behavior in function invocations; to revert to the previous behaviour, use the -XXLanguage:-MangleCallsToJavaMethodsWithValueClasses compiler option.

Correct type approximation algorithm for contravariant captured types

Issue: KT-49404

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.8.20: report a warning on problematic calls
- 2.0.0: raise the warning to an error

Prohibit accessing property value before property initialization

Issue: KT-56408

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: report an error when a property is accessed before initialization in the affected contexts

Report error when there's ambiguity in imported classes with the same name

Issue: KT-57750

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: report an error when resolving a class name that is present in several packages imported with a star import

Generate Kotlin lambdas via invokedynamic and LambdaMetafactory by default

Issue: KT-45375

Component: Core language

Incompatible change type: behavioral

Deprecation cycle:

- 2.0.0: implement new behavior; lambdas are generated using invokedynamic and LambdaMetafactory by default

Forbid if condition with one branch when an expression is required

Issue: KT-57871

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: report an error in case the if condition has only one branch

Prohibit violation of self upper bounds by passing a star-projection of a generic type

Issue: KT-61718

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: report an error when self upper bounds are violated by passing a star-projection of a generic type

Approximate anonymous types in private inline functions return type

Issue: KT-54862

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.9.0: report a warning on private inline functions if the inferred return type contains an anonymous type
- 2.0.0: approximate return type of such private inline functions to a supertype

Change overload resolution behavior to prioritize local extension function calls over invoke conventions of local functional type properties

Issue: KT-37592

Component: Core language

Incompatible change type: behavioral

Deprecation cycle:

- 2.0.0: new overload resolution behavior; function calls are consistently prioritized over invoke conventions

Report error when an inherited member conflict occurs due to a change in a supertype from binary dependency

Issue: KT-51194

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.7.0: report a warning CONFLICTING_INHERITED_MEMBERS_WARNING on declarations where inherited member conflict has occurred in the supertype from binary dependency
- 2.0.0: raise the warning to an error: CONFLICTING_INHERITED_MEMBERS

Ignore @UnsafeVariance annotations on parameters in invariant types

Issue: KT-57609

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: implement new behavior; the @UnsafeVariance annotation is ignored when reporting errors about type mismatch in contravariant parameters

Change type for out-of-call references to a companion object's member

Issue: KT-54316

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.8.20: report a warning on a companion object function reference type inferred as an unbound reference
- 2.0.0: change the behavior so that companion object function references are inferred as bound references in all usage contexts

Prohibit exposure of anonymous types from private inline functions

Issue: KT-33917

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.3.0: report a warning on calls to own members of anonymous objects, returned from private inline functions
- 2.0.0: approximate return type of such private inline functions to a supertype and don't resolve calls to anonymous object members

Report error for an unsound smart cast after a while-loop break

Issue: KT-22379

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: implement new behavior; the old behavior can be restored by switching to language version 1.9

Report error when a variable of an intersection type is assigned a value that is not a subtype of that intersection type

Issue: KT-53752

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: report an error when a variable having an intersection type is assigned a value that is not a subtype of that intersection type

Require opt-in when an interface constructed with a SAM constructor contains a method that requires an opt-in

Issue: KT-52628

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.7.20: report a warning for OptIn usages via SAM constructor
- 2.0.0: raise the warning to an error for OptIn usages via SAM constructor (or keep reporting the warning if OptIn marker severity is a warning)

Prohibit upper bound violation in typealias constructors

Issue: KT-54066

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.8.0: introduce a warning for cases when the upper bound is violated in typealias constructors
- 2.0.0: raise the warning to an error in the K2 compiler

Make the real type of a destructuring variable consistent with the explicit type when specified

Issue: KT-57011

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: implement new behavior; the real type of destructuring variable is now consistent with the explicit type when specified

Require opt-in when calling a constructor that has parameter types with default values that require an opt-in

Issue: KT-55111

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.8.20: report a warning on constructor calls that has parameter types which require opt-in
- 2.0.0: raise the warning to an error (or keep reporting a warning if the OptIn marker severity is a warning)

Report ambiguity between a property and an enum entry with the same name at the same scope level

Issue: KT-52802

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.7.20: report a warning when the compiler resolves to a property instead of an enum entry at the same scope level
- 2.0.0: report ambiguity when the compiler encounters both a property and an enum entry with the same name at the same scope level in the K2 compiler (leaving the warning as is in the old compiler)

Change qualifier resolution behavior to prefer companion property over enum entry

Issue: KT-47310

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: implement new resolution behavior; companion property is preferred over enum entry

Resolve invoke call receiver type and the invoke function type as if written in desugared form

Issue: KT-58260

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: resolve invoke call receiver type and the invoke function type independently as if they were written in a desugared form

Prohibit exposing private class members through non-private inline functions

Issue: KT-55179

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.9.0: report the PRIVATE_CLASS_MEMBER_FROM_INLINE_WARNING warning when calling private class companion object member from internal inline functions
- 2.0.0: raise this warning to the PRIVATE_CLASS_MEMBER_FROM_INLINE error

Correct nullability of definitely non-null types in projected generic types

Issue: KT-54663

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: implement new behavior; projected types take into account all in-place not-null types

Change inferred type of prefix increment to match getter's return type instead of inc() operator's return type

Issue: KT-57178

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: implement new behavior; inferred type of prefix increment is changed to match getter's return type instead of the inc() operator's return type

Enforce bound checks when inheriting inner classes from generic inner classes declared in superclasses

Issue: KT-61749

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: report an error when upper bound of the type parameter of a generic inner superclass is violated

Forbid assigning callable references with SAM types when the expected type is a function type with a function type parameter

Issue: KT-64342

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: report a compilation error on callable references with SAM types when the expected type is a function type with a function type parameter

Consider companion object scope for annotation resolution on companion objects

Issue: KT-64299

Component: Core language

Incompatible change type: behavioral

Deprecation cycle:

- 2.0.0: implement new behavior; the companion object scope is now not ignored during annotation resolution on companion objects

Change evaluation semantics for combination of safe calls and convention operators

Issue: KT-41034

Component: Core language

Incompatible change type: behavioral

Deprecation cycle:

- 1.4.0: report warnings on each incorrect call
- 2.0.0: implement new resolution behavior

Require properties with backing field and a custom setter to be immediately initialized

Issue: KT-58589

Component: Core language

Incompatible change type: behavioral

Deprecation cycle:

- 1.9.20: introduce the MUST_BE_INITIALIZED warning for cases where there is no primary constructor
- 2.0.0: raise the warning to an error

Prohibit Unit conversion on arbitrary expressions in invoke operator convention call

Issue: KT-61182

Component: Core language

Incompatible change type: behavioral

Deprecation cycle:

- 2.0.0: report an error when Unit conversion is applied to an arbitrary expression on variable and invoke resolution; use the -XXLanguage:+UnitConversionsOnArbitraryExpressions compiler option to keep the previous behavior with affected expressions.

Forbid nullable assignment to non-null Java field when the field is accessed with a safe call

Issue: KT-62998

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: report to an error in case a nullable is assigned to a non-null Java field

Require star-projected type when overriding a Java method containing a raw-type parameter

Issue: KT-57600

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: implement new behavior; overriding is forbidden for raw type parameters

Change (V)::foo reference resolution when V has a companion

Issue: KT-47313

Component: Core language

Incompatible change type: behavioral

Deprecation cycle:

- 1.6.0: report a warning on callable references currently bound to companion object instances
- 2.0.0: implement new behavior; adding parentheses around a type no longer makes it a reference to the type's companion object instance

Forbid implicit non-public API access in effectively public inline functions

Issue: KT-54997

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.8.20: report a compilation warning when implicit non-public API is accessed in public inline functions
- 2.0.0: raise the warning to an error

Prohibit use-site get annotations on property getters

Issue: KT-57422

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.9.0: report a warning (an error in the progressive mode) on use-site get annotations on getters
- 2.0.0: raise the warning to the INAPPLICABLE_TARGET_ON_PROPERTY error; use -XXLanguage:-ProhibitUseSiteGetTargetAnnotations to revert to a warning

Prevent implicit inference of type parameters into upper bounds in builder inference lambda functions

Issue: KT-47986

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.7.20: report a warning (or an error in the progressive mode) when the type parameter for a type argument cannot be inferred into declared upper bounds
- 2.0.0: raise the warning to an error

Keep nullability when approximating local types in public signatures

Issue: KT-53982

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.8.0: flexible types are approximated by flexible supertypes; report a warning when a declaration is inferred to have a non-nullable type that should be nullable, prompting to specify the type explicitly to avoid NPEs
- 2.0.0: nullable types are approximated by nullable supertypes

Remove special handling for false && ... and false || ... for the purposes of smart-casting

Issue: KT-65776

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 2.0.0: implement new behavior; no special handling for false && ... and false || ...

Forbid inline open functions in enums

Issue: KT-34372

Component: Core language

Incompatible change type: source

Deprecation cycle:

- 1.8.0: report a warning on inline open functions in enums
- 2.0.0: raise the warning to an error

Tools

Visibility changes in Gradle

Issue: KT-64653

Component: Gradle

Incompatible change type: source

Short summary: Previously, certain Kotlin DSL functions and properties intended for a specific DSL context would inadvertently leak into other DSL contexts. We've added the @KotlinGradlePluginDsl annotation, which prevents the exposure of the Kotlin Gradle plugin DSL functions and properties to levels where they are not intended to be available. The following levels are separated from each other:

- Kotlin extension
- Kotlin target
- Kotlin compilation
- Kotlin compilation task

Deprecation cycle:

- 2.0.0: for most popular cases, the compiler reports warnings with suggestions on how to fix them if your build script is configured incorrectly; otherwise, the compiler reports an error

Deprecate kotlinOptions DSL

Issue: KT-63419

Component: Gradle

Incompatible change type: source

Short summary: The ability to configure compiler options through the kotlinOptions DSL and the related KotlinCompile<KotlinOptions> task interface have been deprecated.

Deprecation cycle:

- 2.0.0: report a warning

Deprecate compilerOptions in KotlinCompilation DSL

Issue: KT-65568

Component: Gradle

Incompatible change type: source

Short summary: The ability to configure the compilerOptions property in the KotlinCompilation DSL has been deprecated.

Deprecation cycle:

- 2.0.0: report a warning

Deprecate old ways of CInteropProcess handling

Issue: KT-62795

Component: Gradle

Incompatible change type: source

Short summary: the CInteropProcess task and the CInteropSettings class now use the definitionFile property instead of defFile and defFileProperty.

This eliminates the need to add extra dependsOn relations between the CInteropProcess task and the task that generates defFile when the defFile is dynamically generated.

In Kotlin/Native projects, Gradle now lazily verifies the presence of the definitionFile property after the connected task has run later in the build process.

Deprecation cycle:

- 2.0.0: defFile and defFileProperty parameters are deprecated

Remove kotlin.useK2 Gradle property

Issue: KT-64379

Component: Gradle

Incompatible change type: behavioral

Short summary: The kotlin.useK2 Gradle property has been removed. In Kotlin 1.9.*, it could be used to enable the K2 compiler. In Kotlin 2.0.0 and later, the K2 compiler is enabled by default, so the property has no effect and cannot be used to switch back to the previous compiler.

Deprecation cycle:

- 1.8.20: the kotlin.useK2 Gradle property is deprecated
- 2.0.0: the kotlin.useK2 Gradle property is removed

Remove deprecated platform plugin IDs

Issue: KT-65187

Component: Gradle

Incompatible change type: source

Short summary: support for these platform plugin IDs have been removed:

- kotlin-platform-android
- kotlin-platform-jvm
- kotlin-platform-js
- org.jetbrains.kotlin.platform.android
- org.jetbrains.kotlin.platform.jvm
- org.jetbrains.kotlin.platform.js

Deprecation cycle:

- 1.3: the platform plugin IDs are deprecated
- 2.0.0: the platform plugin IDs are no longer supported

Remove outputFile JavaScript compiler option

Issue: KT-61116

Component: Gradle

Incompatible change type: source

Short summary: The outputFile JavaScript compiler option has been removed. Instead, you can use the destinationDirectory property of the Kotlin2JsCompile task to specify the directory where the compiled JavaScript output files are written.

Deprecation cycle:

- 1.9.25: the outputFile compiler option is deprecated
- 2.0.0: the outputFile compiler option is removed

Compatibility guide for Kotlin 1.9

Keeping the Language Modern and Comfortable Updates are among the fundamental principles in Kotlin Language Design. The former says that constructs which obstruct language evolution should be removed, and the latter says that this removal should be well-communicated beforehand to make code migration as smooth as possible.

While most of the language changes were already announced through other channels, like update changelogs or compiler warnings, this document summarizes them all, providing a complete reference for migration from Kotlin 1.8 to Kotlin 1.9.

Basic terms

In this document we introduce several kinds of compatibility:

- source: source-incompatible change stops code that used to compile fine (without errors or warnings) from compiling anymore
- binary: two binary artifacts are said to be binary-compatible if interchanging them doesn't lead to loading or linkage errors
- behavioral: a change is said to be behavioral-incompatible if the same program demonstrates different behavior before and after applying the change

Remember that those definitions are given only for pure Kotlin. Compatibility of Kotlin code from the other languages perspective (for example, from Java) is out of the scope of this document.

Language

Remove language version 1.3

Issue: KT-61111

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 introduces language version 1.9 and removes support for language version 1.3.

Deprecation cycle:

- 1.6.0: report a warning
- 1.9.0: raise the warning to an error

Prohibit super constructor call when the super interface type is a function literal

Issue: KT-46344

Component: Core language

Incompatible change type: source

Short summary: If an interface inherits from a function literal type, Kotlin 1.9 prohibits super constructor calls because no such constructor exists.

Deprecation cycle:

- 1.7.0: report a warning (or an error in progressive mode)
- 1.9.0: raise the warning to an error

Prohibit cycles in annotation parameter types

Issue: KT-47932

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 prohibits the type of an annotation being used as one of its parameter types, either directly or indirectly. This prevents cycles from being created. However, you are allowed to have parameter types that are an Array or a vararg of the annotation type.

Deprecation cycle:

- 1.7.0: report a warning (or an error in progressive mode) on cycles in types of annotation parameters
- 1.9.0: raise the warning to an error, -XXLanguage:-ProhibitCyclesInAnnotations can be used to temporarily revert to pre-1.9 behavior

Prohibit use of @ExtensionFunctionType annotation on function types with no parameters

Issue: KT-43527

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 prohibits using the @ExtensionFunctionType annotation on function types with no parameters, or on types that aren't function types.

Deprecation cycle:

- 1.7.0: report a warning for annotations on types that aren't function types, report an error for annotations on types that are function types
- 1.9.0: raise the warning for function types to an error

Prohibit Java field type mismatch on assignment

Issue: KT-48994

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.9 reports a compiler error if it detects that the type of a value assigned to a Java field doesn't match the Java field's projected type.

Deprecation cycle:

- 1.6.0: report a warning (or an error in the progressive mode) when a projected Java field type doesn't match the assigned value type
- 1.9.0: raise the warning to an error, -XXLanguage:-RefineTypeCheckingOnAssignmentsToJavaFields can be used to temporarily revert to pre-1.9 behavior

No source code excerpts in platform-type nullability assertion exceptions

Issue: KT-57570

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: In Kotlin 1.9, exception messages for expression null checks do not include source code excerpts. Instead, the name of the method or field is displayed. If the expression is not a method or field, there is no additional information provided in the message.

Deprecation cycle:

- < 1.9.0: exception messages generated by expression null checks contain source code excerpts
- 1.9.0: exception messages generated by expression null checks contain method or field names only, -XXLanguage:-NoSourceCodeInNotNullAssertionExceptions can be used to temporarily revert to pre-1.9 behavior

Prohibit the delegation of super calls to an abstract superclass member

Issues: KT-45508, KT-49017, KT-38078

Component: Core language

Incompatible change type: source

Short summary: Kotlin will report a compile error when an explicit or implicit super call is delegated to an abstract member of the superclass, even if there's a default implementation in a super interface.

Deprecation cycle:

- 1.5.20: introduce a warning when non-abstract classes that do not override all abstract members are used
- 1.7.0: report a warning if a super call, in fact, accesses an abstract member from a superclass
- 1.7.0: report an error in all affected cases if the -Xjvm-default=all or -Xjvm-default=all-compatibility compatibility modes are enabled; report an error in the progressive mode
- 1.8.0: report an error in cases of declaring a concrete class with a non-overridden abstract method from the superclass, and super calls of Any methods are overridden as abstract in the superclass
- 1.9.0: report an error in all affected cases, including explicit super calls to an abstract method from the super class

Deprecate confusing grammar in when-with-subject

Issue: KT-48385

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.6 deprecated several confusing grammar constructs in when condition expressions.

Deprecation cycle:

- 1.6.20: introduce a deprecation warning on the affected expressions
- 1.8.0: raise this warning to an error, -XXLanguage:-ProhibitConfusingSyntaxInWhenBranches can be used to temporarily revert to the pre-1.8 behavior
- >= 2.1: repurpose some deprecated constructs for new language features

Prevent implicit coercions between different numeric types

Issue: KT-48645

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Kotlin will avoid converting numeric values automatically to a primitive numeric type where only a downcast to that type is needed semantically.

Deprecation cycle:

- < 1.5.30: the old behavior in all affected cases
- 1.5.30: fix the downcast behavior in generated property delegate accessors, -Xuse-old-backend can be used to temporarily revert to the pre-1.5.30 fix behavior
- >= 2.0: fix the downcast behavior in other affected cases

Prohibit upper bound violation in a generic type alias usage (a type parameter used in a generic type argument of a type argument of the aliased type)

Issue: KT-54066

Component: Core language

Incompatible change type: source

Short summary: Kotlin will prohibit using a type alias with type arguments that violate the upper bound restrictions of the corresponding type parameters of the aliased type in case when the typealias type parameter is used as a generic type argument of a type argument of the aliased type, for example, typealias Alias<T> = Base<List<T>>.

Deprecation cycle:

- 1.8.0: report a warning when a generic typealias usage has type arguments violating upper bound constraints of the corresponding type parameters of the aliased type
- 2.0.0: raise the warning to an error

Keep nullability when approximating local types in public signatures

Issue: KT-53982

Component: Core language

Incompatible change type: source, binary

Short summary: when a local or anonymous type is returned from an expression-body function without an explicitly specified return type, Kotlin compiler infers (or approximates) the return type using the known supertype of that type. During this, the compiler can infer a non-nullable type where the null value could in fact be returned.

Deprecation cycle:

- 1.8.0: approximate flexible types by flexible supertypes
- 1.8.0: report a warning when a declaration is inferred to have a non-nullable type that should be nullable, prompting users to specify the type explicitly
- 2.0.0: approximate nullable types by nullable supertypes, -XXLanguage:-KeepNullabilityWhenApproximatingLocalType can be used to temporarily revert to the pre-2.0 behavior

Do not propagate deprecation through overrides

Issue: KT-47902

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will no longer propagate deprecation from a deprecated member in the superclass to its overriding member in the subclass, thus providing an explicit mechanism for deprecating a member of the superclass while leaving it non-deprecated in the subclass.

Deprecation cycle:

- 1.6.20: reporting a warning with the message of the future behavior change and a prompt to either suppress this warning or explicitly write a @Deprecated annotation on an override of a deprecated member
- 1.9.0: stop propagating deprecation status to the overridden members. This change also takes effect immediately in the progressive mode

Prohibit using collection literals in annotation classes anywhere except their parameters declaration

Issue: KT-39041

Component: Core language

Incompatible change type: source

Short summary: Kotlin allows using collection literals in a restricted way - for passing arrays to parameters of annotation classes or specifying default values for these parameters. However besides that, Kotlin allowed using collections literals anywhere else inside an annotation class, for example, in its nested object. Kotlin 1.9 will prohibit using collection literals in annotation classes anywhere except their parameters' default values.

Deprecation cycle:

- 1.7.0: report a warning (or an error in the progressive mode) on array literals in nested objects in annotation classes
- 1.9.0: raise the warning to an error

Prohibit forward referencing of parameters in default value expressions

Issue: KT-25694

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will prohibit forward referencing of parameters in default value expressions of other parameters. This ensures that by the time the parameter is accessed in a default value expression, it would already have a value either passed to the function or initialized by its own default value expression.

Deprecation cycle:

- 1.7.0: report a warning (or an error in the progressive mode) when a parameter with default value is references in default value of another parameter that comes before it
- 1.9.0: raise the warning to an error, -XXLanguage:-ProhibitIllegalValueParameterUsageInDefaultArguments can be used to temporarily revert to the pre-1.9 behavior

Prohibit extension calls on inline functional parameters

Issue: KT-52502

Component: Core language

Incompatible change type: source

Short summary: while Kotlin allowed passing an inline functional parameter to another inline function as a receiver, it always resulted in compiler exceptions when compiling such code. Kotlin 1.9 will prohibit this, thus reporting an error instead of crashing the compiler.

Deprecation cycle:

- 1.7.20: report a warning (or an error in the progressive mode) for inline extension calls on inline functional parameters
- 1.9.0: raise the warning to an error

Prohibit calls to infix functions named suspend with an anonymous function argument

Issue: KT-49264

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will no longer allow calling infix functions named suspend that have a single argument of a functional type passed as an anonymous function literal.

Deprecation cycle:

- 1.7.20: report a warning on suspend infix calls with an anonymous function literal
- 1.9.0: raise the warning to an error, -XXLanguage:-ModifierNonBuiltinSuspendFunError can be used to temporarily revert to the pre-1.9 behavior
- TODO: Change how the suspend fun token sequence is interpreted by the parser

Prohibit using captured type parameters in inner classes against their variance

Issue: KT-50947

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will prohibit using type parameters of an outer class having in or out variance in an inner class of that class in positions violating that type parameters' declared variance.

Deprecation cycle:

- 1.7.0: report a warning (or an error in the progressive mode) when an outer class' type parameter usage position violates the variance rules of that parameter
- 1.9.0: raise the warning to an error, -XXLanguage:-ReportTypeVarianceConflictOnQualifierArguments can be used to temporarily revert to the pre-1.9 behavior

Prohibit recursive call of a function without explicit return type in compound assignment operators

Issue: KT-48546

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will prohibit calling a function without explicitly specified return type in an argument of a compound assignment operator inside that function's body, as it currently does in other expressions inside the body of that function.

Deprecation cycle:

- 1.7.0: report a warning (or an error in the progressive mode) when a function without explicitly specified return type is called recursively in that function's body in a compound assignment operator argument
- 1.9.0: raise the warning to an error

Prohibit unsound calls with expected @NotNull T and given Kotlin generic parameter with nullable bound

Issue: KT-36770

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.9 will prohibit method calls where a value of a potentially nullable generic type is passed for a @NotNull-annotated parameter of a Java method.

Deprecation cycle:

- 1.5.20: report a warning when an unconstrained generic type parameter is passed where a non-nullable type is expected
- 1.9.0: report a type mismatch error instead of the warning above,

  -XXLanguage:-ProhibitUsingNullableTypeParameterAgainstNotNullAnnotated can be used to temporarily revert to the pre-1.8 behavior

Prohibit access to members of a companion of an enum class from entry initializers of this enum

Issue: KT-49110

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will prohibit all kinds of access to the companion object of an enum from an enum entry initializer.

Deprecation cycle:

- 1.6.20: report a warning (or an error in the progressive mode) on such companion member access
- 1.9.0: raise the warning to an error, -XXLanguage:-ProhibitAccessToEnumCompanionMembersInEnumConstructorCall can be used to temporarily revert to the pre-1.8 behavior

Deprecate and remove Enum.declaringClass synthetic property

Issue: KT-49653

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin allowed using the synthetic property declaringClass on Enum values produced from the method getDeclaringClass() of the underlying Java class java.lang.Enum even though this method is not available for Kotlin Enum type. Kotlin 1.9 will prohibit using this property, proposing to migrate to the extension property declaringJavaClass instead.

Deprecation cycle:

- 1.7.0: report a warning (or an error in the progressive mode) on declaringClass property usages, propose the migration to declaringJavaClass extension
- 1.9.0: raise the warning to an error, -XXLanguage:-ProhibitEnumDeclaringClass can be used to temporarily revert to the pre-1.9 behavior
- 2.0.0: remove declaringClass synthetic property

Deprecate enable and compatibility modes of the compiler option -Xjvm-default

Issues: KT-46329, KT-54746

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.9 prohibits using the enable and compatibility modes of the -Xjvm-default compiler option.

Deprecation cycle:

- 1.6.20: introduce a warning on the enable and compatibility modes of the -Xjvm-default compiler option
- 1.9.0: raise this warning to an error

Prohibit implicit inferring a type variable into an upper bound in the builder inference context

Issue: KT-47986

Component: Core language

Incompatible change type: source

Short summary: Kotlin 2.0 will prohibit inferring a type variable into the corresponding type parameter's upper bound in the absence of any use-site type information in the scope of builder inference lambda functions, the same way as it does currently in other contexts.

Deprecation cycle:

- 1.7.20: report a warning (or an error in the progressive mode) when a type parameter is inferred into declared upper bounds in the absence of use-site type information
- 2.0.0: raise the warning to an error

Standard library

Warn about potential overload resolution change when Range/Progression starts implementing Collection

Issue: KT-49276

Component: Core language / kotlin-stdlib

Incompatible change type: source

Short summary: it is planned to implement the Collection interface in the standard progressions and concrete ranges inherited from them in Kotlin 1.9. This could make a different overload selected in the overload resolution if there are two overloads of some method, one accepting an element and another accepting a collection. Kotlin will make this situation visible by reporting a warning or an error when such overloaded method is called with a range or progression argument.

Deprecation cycle:

- 1.6.20: report a warning when an overloaded method is called with the standard progression or its range inheritor as an argument if implementing the Collection interface by this progression/range leads to another overload being selected in this call in future
- 1.8.0: raise this warning to an error
- 2.1.0: stop reporting the error, implement Collection interface in progressions thus changing the overload resolution result in the affected cases

Migrate declarations from kotlin.dom and kotlin.browser packages to kotlinx.*

Issue: KT-39330

Component: kotlin-stdlib (JS)

Incompatible change type: source

Short summary: declarations from the kotlin.dom and kotlin.browser packages are moved to the corresponding kotlinx.* packages to prepare for extracting them from stdlib.

Deprecation cycle:

- 1.4.0: introduce the replacement API in kotlinx.dom and kotlinx.browser packages
- 1.4.0: deprecate the API in kotlin.dom and kotlin.browser packages and propose the new API above as a replacement
- 1.6.0: raise the deprecation level to an error
- 1.8.20: remove the deprecated functions from stdlib for JS-IR target
- >= 2.0: move the API in kotlinx.* packages to a separate library

Deprecate some JS-only API

Issue: KT-48587

Component: kotlin-stdlib (JS)

Incompatible change type: source

Short summary: a number of JS-only functions in stdlib are deprecated for removal. They include: String.concat(String), String.match(regex: String), String.matches(regex: String), and the sort functions on arrays taking a comparison function, for example, Array<out T>.sort(comparison: (a: T, b: T) -> Int).

Deprecation cycle:

- 1.6.0: deprecate the affected functions with a warning
- 1.9.0: raise the deprecation level to an error
- >=2.0: remove the deprecated functions from the public API

Tools

Remove enableEndorsedLibs flag from Gradle setup

Issue: KT-54098

Component: Gradle

Incompatible change type: source

Short summary: the enableEndorsedLibs flag is no longer supported in Gradle setup.

Deprecation cycle:

- < 1.9.0: enableEndorsedLibs flag is supported in Gradle setup
- 1.9.0: enableEndorsedLibs flag is not supported in Gradle setup

Remove Gradle conventions

> Issue: KT-52976
>
> Component: Gradle
>
> Incompatible change type: source
>
> Short summary: Gradle conventions were deprecated in Gradle 7.1 and have been removed in Gradle 8.
>
> Deprecation cycle:
>
> - 1.7.20: Gradle conventions deprecated
> - 1.9.0: Gradle conventions removed

Remove classpath property of KotlinCompile task

> Issue: KT-53748
>
> Component: Gradle
>
> Incompatible change type: source
>
> Short summary: the classpath property of the KotlinCompile task is removed.
>
> Deprecation cycle:
>
> - 1.7.0: the classpath property is deprecated
> - 1.8.0: raise the deprecation level to an error
> - 1.9.0: remove the deprecated functions from the public API

Deprecate kotlin.internal.single.build.metrics.file property

> Issue: KT-53357
>
> Component: Gradle
>
> Incompatible change type: source
>
> Short summary: deprecate the kotlin.internal.single.build.metrics.file property used to define a single file for build reports. Use the property kotlin.build.report.single_file instead with kotlin.build.report.output=single_file.
>
> Deprecation cycle:
>
> - 1.8.0: raise the deprecation level to a warning
> - >= 1.9: delete the property

Compatibility guide for Kotlin 1.8

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While most of the language changes were already announced through other channels, like update changelogs or compiler warnings, this document summarizes them all, providing a complete reference for migration from Kotlin 1.7 to Kotlin 1.8.

Basic terms

In this document we introduce several kinds of compatibility:

- source: source-incompatible change stops code that used to compile fine (without errors or warnings) from compiling anymore
- binary: two binary artifacts are said to be binary-compatible if interchanging them doesn't lead to loading or linkage errors
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Remember that those definitions are given only for pure Kotlin. Compatibility of Kotlin code from the other languages perspective (for example, from Java) is out of the scope of this document.

Language

Prohibit the delegation of super calls to an abstract superclass member

> Issues: KT-45508, KT-49017, KT-38078
>
> Component: Core language
>
> Incompatible change type: source
>
> Short summary: Kotlin will report a compile error when an explicit or implicit super call is delegated to an abstract member of the superclass, even if there's a default implementation in a super interface
>
> Deprecation cycle:
>
> - 1.5.20: introduce a warning when non-abstract classes that do not override all abstract members are used
> - 1.7.0: report a warning if a super call, in fact, accesses an abstract member from a superclass
> - 1.7.0: report an error in all affected cases if the -Xjvm-default=all or -Xjvm-default=all-compatibility compatibility modes are enabled; report an error in the progressive mode
> - 1.8.0: report an error in cases of declaring a concrete class with a non-overridden abstract method from the superclass, and super calls of Any methods are overridden as abstract in the superclass
> - 1.9.0: report an error in all affected cases, including explicit super calls to an abstract method from the super class

Deprecate confusing grammar in when-with-subject

> Issue: KT-48385
>
> Component: Core language
>
> Incompatible change type: source
>
> Short summary: Kotlin 1.6 deprecated several confusing grammar constructs in when condition expressions
>
> Deprecation cycle:
>
> - 1.6.20: introduce a deprecation warning on the affected expressions
> - 1.8.0: raise this warning to an error, -XXLanguage:-ProhibitConfusingSyntaxInWhenBranches can be used to temporarily revert to the pre-1.8 behavior
> - >= 1.9: repurpose some deprecated constructs for new language features

Prevent implicit coercions between different numeric types

Issue: KT-48645

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Kotlin will avoid converting numeric values automatically to a primitive numeric type where only a downcast to that type is needed semantically

Deprecation cycle:

- < 1.5.30: the old behavior in all affected cases
- 1.5.30: fix the downcast behavior in generated property delegate accessors, -Xuse-old-backend can be used to temporarily revert to the pre-1.5.30 fix behavior
- >= 1.9: fix the downcast behavior in other affected cases

Make private constructors of sealed classes really private

Issue: KT-44866

Component: Core language

Incompatible change type: source

Short summary: after relaxing restrictions on where the inheritors of sealed classes could be declared in the project structure, the default visibility of sealed class constructors became protected. However, until 1.8, Kotlin still allowed calling explicitly declared private constructors of sealed classes outside those classes' scopes

Deprecation cycle:

- 1.6.20: report a warning (or an error in the progressive mode) when a private constructor of a sealed class is called outside that class
- 1.8.0: use default visibility rules for private constructors (a call to a private constructor can be resolved only if this call is inside the corresponding class), the old behavior can be brought back temporarily by specifying the -XXLanguage:-UseConsistentRulesForPrivateConstructorsOfSealedClasses compiler argument

Prohibit using operator == on incompatible numeric types in builder inference context

Issue: KT-45508

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.8 will prohibit using the operator == on incompatible numeric types, for example, Int and Long, in scopes of builder inference lambda functions, the same way as it currently does in other contexts

Deprecation cycle:

- 1.6.20: report a warning (or an error in the progressive mode) when the operator == is used on incompatible numeric types
- 1.8.0: raise the warning to an error, -XXLanguage:-ProperEqualityChecksInBuilderInferenceCalls can be used to temporarily revert to the pre-1.8 behavior

Prohibit if without else and non-exhaustive when in right hand side of elvis operator

Issue: KT-44705

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.8 will prohibit using a non-exhaustive when or the if expression without an else branch on the right hand side of the Elvis operator (?:). Previously, it was allowed if the Elvis operator's result was not used as an expression

Deprecation cycle:

- 1.6.20: report a warning (or an error in the progressive mode) on such non-exhaustive if and when expressions
- 1.8.0: raise this warning to an error,

  -XXLanguage:-ProhibitNonExhaustiveIfInRhsOfElvis can be used to temporarily revert to the pre-1.8 behavior

Prohibit upper bound violation in a generic type alias usage (one type parameter used in several type arguments of the aliased type)

Issues: KT-29168

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.8 will prohibit using a type alias with type arguments that violate the upper bound restrictions of the corresponding type parameters of the aliased type in case when one typealias type parameter is used in several type arguments of the aliased type, for example, typealias Alias<T> = Base<T, T>

Deprecation cycle:

- 1.7.0: report a warning (or an error in the progressive mode) on usages of a type alias with type arguments violating upper bound constraints of the corresponding type parameters of the aliased type
- 1.8.0: raise this warning to an error, -XXLanguage:-ReportMissingUpperBoundsViolatedErrorOnAbbreviationAtSupertypes can be used to temporarily revert to the pre-1.8 behavior

Prohibit upper bound violation in a generic type alias usage (a type parameter used in a generic type argument of a type argument of the aliased type)

Issue: KT-54066

Component: Core language

Incompatible change type: source

Short summary: Kotlin will prohibit using a type alias with type arguments that violate the upper bound restrictions of the corresponding type parameters of the aliased type in case when the typealias type parameter is used as a generic type argument of a type argument of the aliased type, for example, typealias Alias<T> = Base<List<T>>

Deprecation cycle:

- 1.8.0: report a warning when a generic typealias usage has type arguments violating upper bound constraints of the corresponding type parameters of the aliased type
- >=1.10: raise the warning to an error

Prohibit using a type parameter declared for an extension property inside delegate

Issue: KT-24643

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.8 will prohibit delegating extension properties on a generic type to generic types that use the type parameter of the receiver in an unsafe way

Deprecation cycle:

- 1.6.0: report a warning (or an error in the progressive mode) when delegating an extension property to a type that uses type parameters inferred from the delegated property's type arguments in a particular way
- 1.8.0: raise the warning to an error, -XXLanguage:-ForbidUsingExtensionPropertyTypeParameterInDelegate can be used to temporarily revert to the pre-1.8 behavior

Forbid @Synchronized annotation on suspend functions

Issue: KT-48516

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.8 will prohibit placing the @Synchronized annotation on suspend functions because a suspending call should not be allowed to happen inside a synchronized block

Deprecation cycle:

- 1.6.0: report a warning on suspend functions annotated with the @Synchronized annotation, the warning is reported as an error in the progressive mode
- 1.8.0: raise the warning to an error, -XXLanguage:-SynchronizedSuspendError can be used to temporarily revert to the pre-1.8 behavior

Prohibit using spread operator for passing arguments to non-vararg parameters

Issue: KT-48162

Component: Core language

Incompatible change type: source

Short summary: Kotlin allowed passing arrays with the spread operator (*) to non-vararg array parameters in certain conditions. Since Kotlin 1.8, this will be prohibited

Deprecation cycle:

- 1.6.0: report a warning (or an error in the progressive mode) on using the spread operator where a non-vararg array parameter is expected
- 1.8.0: raise the warning to an error, -XXLanguage:-ReportNonVarargSpreadOnGenericCalls can be used to temporarily revert to the pre-1.8 behavior

Prohibit null-safety violation in lambdas passed to functions overloaded by lambda return type

Issue: KT-49658

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.8 will prohibit returning null from lambdas passed to functions overloaded by those lambdas' return types when overloads don't allow a nullable return type. Previously, it was allowed when null was returned from one of the branches of the when operator

Deprecation cycle:

- 1.6.20: report a type mismatch warning (or an error in the progressive mode)
- 1.8.0: raise the warning to an error, -XXLanguage:-DontLoseDiagnosticsDuringOverloadResolutionByReturnType can be used to temporarily revert to the pre-1.8 behavior

Keep nullability when approximating local types in public signatures

Issue: KT-53982

Component: Core language

Incompatible change type: source, binary

Short summary: when a local or anonymous type is returned from an expression-body function without an explicitly specified return type, Kotlin compiler infers (or approximates) the return type using the known supertype of that type. During this, the compiler can infer a non-nullable type where the null value could in fact be returned

Deprecation cycle:

- 1.8.0: approximate flexible types by flexible supertypes
- 1.8.0: report a warning when a declaration is inferred to have a non-nullable type that should be nullable, prompting users to specify the type explicitly
- 1.9.0: approximate nullable types by nullable supertypes, -XXLanguage:-KeepNullabilityWhenApproximatingLocalType can be used to temporarily revert to the pre-1.9 behavior

Do not propagate deprecation through overrides

Issue: KT-47902

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will no longer propagate deprecation from a deprecated member in the superclass to its overriding member in the subclass, thus providing an explicit mechanism for deprecating a member of the superclass while leaving it non-deprecated in the subclass

Deprecation cycle:

- 1.6.20: reporting a warning with the message of the future behavior change and a prompt to either suppress this warning or explicitly write a @Deprecated annotation on an override of a deprecated member
- 1.9.0: stop propagating deprecation status to the overridden members. This change also takes effect immediately in the progressive mode

Prohibit implicit inferring a type variable into an upper bound in the builder inference context

Issue: KT-47986

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will prohibit inferring a type variable into the corresponding type parameter's upper bound in the absence of any use-site type information in the scope of builder inference lambda functions, the same way as it does currently in other contexts

Deprecation cycle:

- 1.7.20: report a warning (or an error in the progressive mode) when a type parameter is inferred into declared upper bounds in the absence of use-site type information
- 1.9.0: raise the warning to an error, -XXLanguage:-ForbidInferringPostponedTypeVariableIntoDeclaredUpperBound can be used to temporarily revert to the pre-1.9 behavior

Prohibit using collection literals in annotation classes anywhere except their parameters declaration

Issue: KT-39041

Component: Core language

Incompatible change type: source

Short summary: Kotlin allows using collection literals in a restricted way - for passing arrays to parameters of annotation classes or specifying default values for these parameters. However besides that, Kotlin allowed using collections literals anywhere else inside an annotation class, for example, in its nested object. Kotlin 1.9 will prohibit using collection literals in annotation classes anywhere except their parameters' default values.

Deprecation cycle:

- 1.7.0: report a warning (or an error in the progressive mode) on array literals in nested objects in annotation classes
- 1.9.0: raise the warning to an error

Prohibit forward referencing of parameters with default values in default value expressions

Issue: KT-25694

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will prohibit forward referencing of parameters with default values in default value expressions of other parameters. This ensures that by the time the parameter is accessed in a default value expression, it would already have a value either passed to the function or initialized by its own default value expression

Deprecation cycle:

- 1.7.0: report a warning (or an error in the progressive mode) when a parameter with default value is references in default value of another parameter that comes before it
- 1.9.0: raise the warning to an error, -XXLanguage:-ProhibitIllegalValueParameterUsageInDefaultArguments can be used to temporarily revert to the pre-1.9 behavior

Prohibit extension calls on inline functional parameters

Issue: KT-52502

Component: Core language

Incompatible change type: source

Short summary: while Kotlin allowed passing an inline functional parameter to another inline function as a receiver, it always resulted in compiler exceptions when compiling such code. Kotlin 1.9 will prohibit this, thus reporting an error instead of crashing the compiler

Deprecation cycle:

- 1.7.20: report a warning (or an error in the progressive mode) for inline extension calls on inline functional parameters
- 1.9.0: raise the warning to an error

Prohibit calls to infix functions named suspend with an anonymous function argument

Issue: KT-49264

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will no longer allow calling infix functions named suspend that have a single argument of a functional type passed as an anonymous function literal

Deprecation cycle:

- 1.7.20: report a warning on suspend infix calls with an anonymous function literal
- 1.9.0: raise the warning to an error, -XXLanguage:-ModifierNonBuiltinSuspendFunError can be used to temporarily revert to the pre-1.9 behavior
- >=1.10: Change how the suspend fun token sequence is interpreted by the parser

Prohibit using captured type parameters in inner classes against their variance

Issue: KT-50947

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will prohibit using type parameters of an outer class having in or out variance in an inner class of that class in positions violating that type parameters' declared variance

Deprecation cycle:

- 1.7.0: report a warning (or an error in the progressive mode) when an outer class' type parameter usage position violates the variance rules of that parameter
- 1.9.0: raise the warning to an error, -XXLanguage:-ReportTypeVarianceConflictOnQualifierArguments can be used to temporarily revert to the pre-1.9 behavior

Prohibit recursive call of a function without explicit return type in compound assignment operators

Issue: KT-48546

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will prohibit calling a function without explicitly specified return type in an argument of a compound assignment operator inside that function's body, as it currently does in other expressions inside the body of that function

Deprecation cycle:

- 1.7.0: report a warning (or an error in the progressive mode) when a function without explicitly specified return type is called recursively in that function's body in a compound assignment operator argument
- 1.9.0: raise the warning to an error

Prohibit unsound calls with expected @NotNull T and given Kotlin generic parameter with nullable bound

Issue: KT-36770

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.9 will prohibit method calls where a value of a potentially nullable generic type is passed for a @NotNull-annotated parameter of a Java method

Deprecation cycle:

- 1.5.20: report a warning when an unconstrained generic type parameter is passed where a non-nullable type is expected
- 1.9.0: report a type mismatch error instead of the warning above,

  -XXLanguage:-ProhibitUsingNullableTypeParameterAgainstNotNullAnnotated can be used to temporarily revert to the pre-1.8 behavior

Prohibit access to members of a companion of an enum class from entry initializers of this enum

Issue: KT-49110

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.9 will prohibit all kinds of access to the companion object of an enum from an enum entry initializer

Deprecation cycle:

- 1.6.20: report a warning (or an error in the progressive mode) on such companion member access
- 1.9.0: raise the warning to an error, -XXLanguage:-ProhibitAccessToEnumCompanionMembersInEnumConstructorCall can be used to temporarily revert to the pre-1.8 behavior

Deprecate and remove Enum.declaringClass synthetic property

Issue: KT-49653

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin allowed using the synthetic property declaringClass on Enum values produced from the method getDeclaringClass() of the underlying Java class java.lang.Enum even though this method is not available for Kotlin Enum type. Kotlin 1.9 will prohibit using this property, proposing to migrate to the extension property declaringJavaClass instead

Deprecation cycle:

- 1.7.0: report a warning (or an error in the progressive mode) on declaringClass property usages, propose the migration to declaringJavaClass extension
- 1.9.0: raise the warning to an error, -XXLanguage:-ProhibitEnumDeclaringClass can be used to temporarily revert to the pre-1.9 behavior
- >=1.10: remove declaringClass synthetic property

Deprecate the enable and the compatibility modes of the compiler option -Xjvm-default

Issue: KT-46329

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.6.20 warns about the usage of the enable and compatibility modes of the -Xjvm-default compiler option

Deprecation cycle:

- 1.6.20: introduce a warning on the enable and compatibility modes of the -Xjvm-default compiler option
- >= 1.9: raise this warning to an error

Standard library

Warn about potential overload resolution change when Range/Progression starts implementing Collection

Issue: KT-49276

Component: Core language / kotlin-stdlib

Incompatible change type: source

Short summary: it is planned to implement the Collection interface in the standard progressions and concrete ranges inherited from them in Kotlin 1.9. This could make a different overload selected in the overload resolution if there are two overloads of some method, one accepting an element and another accepting a collection. Kotlin will make this situation visible by reporting a warning or an error when such overloaded method is called with a range or progression argument

Deprecation cycle:

- 1.6.20: report a warning when an overloaded method is called with the standard progression or its range inheritor as an argument if implementing the Collection interface by this progression/range leads to another overload being selected in this call in future
- 1.8.0: raise this warning to an error
- 1.9.0: stop reporting the error, implement Collection interface in progressions thus changing the overload resolution result in the affected cases

Migrate declarations from kotlin.dom and kotlin.browser packages to kotlinx.*

Issue: KT-39330

Component: kotlin-stdlib (JS)

Incompatible change type: source

Short summary: declarations from the kotlin.dom and kotlin.browser packages are moved to the corresponding kotlinx.* packages to prepare for extracting them from stdlib

Deprecation cycle:

- 1.4.0: introduce the replacement API in kotlinx.dom and kotlinx.browser packages
- 1.4.0: deprecate the API in kotlin.dom and kotlin.browser packages and propose the new API above as a replacement
- 1.6.0: raise the deprecation level to an error
- 1.8.20: remove the deprecated functions from stdlib for JS-IR target
- >= 1.9: move the API in kotlinx.* packages to a separate library

Deprecate some JS-only API

Issue: KT-48587

Component: kotlin-stdlib (JS)

Incompatible change type: source

Short summary: a number of JS-only functions in stdlib are deprecated for removal. They include: String.concat(String), String.match(regex: String), String.matches(regex: String), and the sort functions on arrays taking a comparison function, for example, Array<out T>.sort(comparison: (a: T, b: T) -> Int)

Deprecation cycle:

- 1.6.0: deprecate the affected functions with a warning
- 1.9.0: raise the deprecation level to an error
- >=1.10.0: remove the deprecated functions from the public API

Tools

Raise deprecation level of classpath property of KotlinCompile task

Issue: KT-51679

Component: Gradle

Incompatible change type: source

Short summary: the classpath property of the KotlinCompile task is deprecated

Deprecation cycle:

- 1.7.0: the classpath property is deprecated
- 1.8.0: raise the deprecation level to an error
- >=1.9.0: remove the deprecated functions from the public API

Remove kapt.use.worker.api Gradle property

Issue: KT-48827

Component: Gradle

Incompatible change type: behavioral

Short summary: remove the kapt.use.worker.api property that allowed to run kapt via Gradle Workers API (default: true)

Deprecation cycle:

- 1.6.20: raise the deprecation level to a warning
- 1.8.0: remove this property

Remove kotlin.compiler.execution.strategy system property

Issue: KT-51831

Component: Gradle

Incompatible change type: behavioral

Short summary: remove the kotlin.compiler.execution.strategy system property used to choose a compiler execution strategy. Use the Gradle property kotlin.compiler.execution.strategy or the compile task property compilerExecutionStrategy instead

Deprecation cycle:

- 1.7.0: raise the deprecation level to a warning
- 1.8.0: remove the property

Changes in compiler options

Issues: KT-27301, KT-48532

Component: Gradle

Incompatible change type: source, binary

Short summary: this change might affect Gradle plugins authors. In kotlin-gradle-plugin, there are additional generic parameters to some internal types (you should add generic types or *). KotlinNativeLink task does not inherit the AbstractKotlinNativeCompile task anymore. KotlinJsCompilerOptions.outputFile and the related KotlinJsOptions.outputFile options are deprecated. Use the Kotlin2JsCompile.outputFileProperty task input instead. The kotlinOptions task input and the kotlinOptions{...} task DSL are in a support mode and will be deprecated in upcoming releases. compilerOptions and kotlinOptions can not be changed on a task execution phase (see one exception in What's new in Kotlin 1.8). freeCompilerArgs returns an immutable List<String> – kotlinOptions.freeCompilerArgs.remove("something") will fail. The useOldBackend property that allowed to use the old JVM backend is removed

Deprecation cycle:

- 1.8.0: KotlinNativeLink task does not inherit the AbstractKotlinNativeCompile. KotlinJsCompilerOptions.outputFile and the related KotlinJsOptions.outputFile options are deprecated. The useOldBackend property that allowed to use the old JVM backend is removed.

Deprecate kotlin.internal.single.build.metrics.file property

Issue: KT-53357

Component: Gradle

Incompatible change type: source

Short summary: deprecate the kotlin.internal.single.build.metrics.file property used to define a single file for build reports. Use the property kotlin.build.report.single_file instead with kotlin.build.report.output=single_file

Deprecation cycle:

- 1.8.0: raise the deprecation level to a warning >= 1.9: delete the property

Compatibility guide for Kotlin 1.7.20

Keeping the Language Modern and Comfortable Updates are among the fundamental principles in Kotlin Language Design. The former says that constructs which obstruct language evolution should be removed, and the latter says that this removal should be well-communicated beforehand to make code migration as smooth as possible.

Usually incompatible changes happen only in feature releases, but this time we have to introduce two such changes in an incremental release to limit spread of the problems introduced by changes in Kotlin 1.7.

This document summarizes them, providing a reference for migration from Kotlin 1.7.0 and 1.7.10 to Kotlin 1.7.20.

Basic terms

In this document we introduce several kinds of compatibility:

- source: source-incompatible change stops code that used to compile fine (without errors or warnings) from compiling anymore
- binary: two binary artifacts are said to be binary-compatible if interchanging them doesn't lead to loading or linkage errors
- behavioral: a change is said to be behavioral-incompatible if the same program demonstrates different behavior before and after applying the change

Remember that those definitions are given only for pure Kotlin. Compatibility of Kotlin code from the other languages perspective (for example, from Java) is out of the scope of this document.

Language

Rollback attempt to fix proper constraints processing

Issue: KT-53813

Component: Core language

Incompatible change type: source

Short summary: Rollback an attempt of fixing issues in type inference constraints processing appeared in 1.7.0 after implementing the change described in KT-52668. The attempt was made in 1.7.10, but it in turn introduced new problems.

Deprecation cycle:

- 1.7.20: Rollback to 1.7.0 behavior

Forbid some builder inference cases to avoid problematic interaction with multiple lambdas and resolution

Issue: KT-53797

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.7 introduced a feature called unrestricted builder inference, so that even the lambdas passed to parameters not annotated with @BuilderInference could benefit from the builder inference. However, that could cause several problems if more than one such lambda occurred in a function invocation.

Kotlin 1.7.20 will report an error if more than one lambda function having the corresponding parameter not annotated with @BuilderInference requires using builder inference to complete inferring the types in the lambda.

Deprecation cycle:

- 1.7.20: report an error on such lambda functions,

  -XXLanguage:+NoBuilderInferenceWithoutAnnotationRestriction can be used to temporarily revert to the pre-1.7.20 behavior

Compatibility guide for Kotlin 1.7

Keeping the Language Modern and Comfortable Updates are among the fundamental principles in Kotlin Language Design. The former says that constructs which obstruct language evolution should be removed, and the latter says that this removal should be well-communicated beforehand to make code migration as smooth as possible.

While most of the language changes were already announced through other channels, like update changelogs or compiler warnings, this document summarizes them all, providing a complete reference for migration from Kotlin 1.6 to Kotlin 1.7.

Basic terms

In this document we introduce several kinds of compatibility:

- source: source-incompatible change stops code that used to compile fine (without errors or warnings) from compiling anymore
- binary: two binary artifacts are said to be binary-compatible if interchanging them doesn't lead to loading or linkage errors
- behavioral: a change is said to be behavioral-incompatible if the same program demonstrates different behavior before and after applying the change

Remember that those definitions are given only for pure Kotlin. Compatibility of Kotlin code from the other languages perspective (for example, from Java) is out of the scope of this document.

Language

Make safe call result always nullable

Issue: KT-46860

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.7 will consider the type of safe call result always nullable, even when the receiver of the safe call is non-nullable

Deprecation cycle:

- <1.3: report a warning on an unnecessary safe call on non-nullable receivers
- 1.6.20: warn additionally that the result of an unnecessary safe call will change its type in the next version
- 1.7.0: change the type of safe call result to nullable,

  -XXLanguage:-SafeCallsAreAlwaysNullable can be used to temporarily revert to the pre-1.7 behavior

Prohibit the delegation of super calls to an abstract superclass member

Issues: KT-45508, KT-49017, KT-38078

Component: Core language

Incompatible change type: source

Short summary: Kotlin will report a compile error when an explicit or implicit super call is delegated to an abstract member of the superclass, even if there's a default implementation in a super interface

Deprecation cycle:

- 1.5.20: introduce a warning when non-abstract classes that do not override all abstract members are used
- 1.7.0: report an error if a super call, in fact, accesses an abstract member from a superclass
- 1.7.0: report an error if the -Xjvm-default=all or -Xjvm-default=all-compatibility compatibility modes are enabled; report an error in the progressive mode
- >=1.8.0: report an error in all cases

Prohibit exposing non-public types through public properties declared in a non-public primary constructor

Issue: KT-28078

Component: Core language

Incompatible change type: source

Short summary: Kotlin will prevent declaring public properties having non-public types in a private primary constructor. Accessing such properties from another package could lead to an IllegalAccessError

Deprecation cycle:

- 1.3.20: report a warning on a public property that has a non-public type and is declared in a non-public constructor
- 1.6.20: raise this warning to an error in the progressive mode
- 1.7.0: raise this warning to an error

Prohibit access to uninitialized enum entries qualified with the enum name

Issue: KT-41124

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.7 will prohibit access to uninitialized enum entries from the enum static initializer block when these entries are qualified with the enum name

Deprecation cycle:

- 1.7.0: report an error when uninitialized enum entries are accessed from the enum static initializer block

Prohibit computing constant values of complex boolean expressions in when condition branches and conditions of loops

Issue: KT-39883

Component: Core language

Incompatible change type: source

Short summary: Kotlin will no longer make exhaustiveness and control flow assumptions based on constant boolean expressions other than literal true and false

Deprecation cycle:

- 1.5.30: report a warning when exhaustiveness of when or control flow reachability is determined based on a complex constant boolean expression in when branch or loop condition
- 1.7.0: raise this warning to an error

Make when statements with enum, sealed, and Boolean subjects exhaustive by default

Issue: KT-47709

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.7 will report an error about the when statement with an enum, sealed, or Boolean subject being non-exhaustive

Deprecation cycle:

- 1.6.0: introduce a warning when the when statement with an enum, sealed, or Boolean subject is non-exhaustive (error in the progressive mode)
- 1.7.0: raise this warning to an error

Deprecate confusing grammar in when-with-subject

Issue: KT-48385

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.6 deprecated several confusing grammar constructs in when condition expressions

Deprecation cycle:

- 1.6.20: introduce a deprecation warning on the affected expressions
- 1.8.0: raise this warning to an error
- >= 1.8: repurpose some deprecated constructs for new language features

Type nullability enhancement improvements

Issue: KT-48623

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.7 will change how it loads and interprets type nullability annotations in Java code

Deprecation cycle:

- 1.4.30: introduce warnings for cases where more precise type nullability could lead to an error
- 1.7.0: infer more precise nullability of Java types, -XXLanguage:-TypeEnhancementImprovementsInStrictMode can be used to temporarily revert to the pre-1.7 behavior

Prevent implicit coercions between different numeric types

Issue: KT-48645

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Kotlin will avoid converting numeric values automatically to a primitive numeric type where only a downcast to that type was needed semantically

Deprecation cycle:

- < 1.5.30: the old behavior in all affected cases
- 1.5.30: fix the downcast behavior in generated property delegate accessors, -Xuse-old-backend can be used to temporarily revert to the pre-1.5.30 fix behavior
- >= 1.7.20: fix the downcast behavior in other affected cases

Deprecate the enable and the compatibility modes of the compiler option -Xjvm-default

Issue: KT-46329

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.6.20 warns about the usage of enable and compatibility modes of the -Xjvm-default compiler option

Deprecation cycle:

- 1.6.20: introduce a warning on the enable and compatibility modes of the -Xjvm-default compiler option
- >= 1.8.0: raise this warning to an error

Prohibit calls to functions named suspend with a trailing lambda

Issue: KT-22562

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.6 no longer allows calling user functions named suspend that have the single argument of a functional type passed as a trailing lambda

Deprecation cycle:

- 1.3.0: introduce a warning on such function calls
- 1.6.0: raise this warning to an error
- 1.7.0: introduce changes to the language grammar so that suspend before { is parsed as a keyword

Prohibit smart cast on a base class property if the base class is from another module

Issue: KT-52629

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.7 will no longer allow smart casts on properties of a superclass if that class is located in another module

Deprecation cycle:

- 1.6.0: report a warning on a smart cast on a property declared in the superclass located in another module
- 1.7.0: raise this warning to an error,

  -XXLanguage:-ProhibitSmartcastsOnPropertyFromAlienBaseClass can be used to temporarily revert to the pre-1.7 behavior

Do not neglect meaningful constraints during type inference

Issue: KT-52668

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.4–1.6 neglected some type constraints during type inference due to an incorrect optimization. It could allow writing unsound code, causing ClassCastException at runtime. Kotlin 1.7 takes these constraints into account, thus prohibiting the unsound code

Deprecation cycle:

- 1.5.20: report a warning on expressions where a type mismatch would happen if all the type inference constraints were taken into account
- 1.7.0: take all the constraints into account, thus raising this warning to an error,

  -XXLanguage:-ProperTypeInferenceConstraintsProcessing can be used to temporarily revert to the pre-1.7 behavior

Standard library

Gradually change the return type of collection min and max functions to non-nullable

Issue: KT-38854

Component: kotlin-stdlib

Incompatible change type: source

Short summary: the return type of collection min and max functions will be changed to non-nullable in Kotlin 1.7

Deprecation cycle:

- 1.4.0: introduce ...OrNull functions as synonyms and deprecate the affected API (see details in the issue)
- 1.5.0: raise the deprecation level of the affected API to an error
- 1.6.0: hide the deprecated functions from the public API
- 1.7.0: reintroduce the affected API but with non-nullable return type

Deprecate floating-point array functions: contains, indexOf, lastIndexOf

Issue: KT-28753

Component: kotlin-stdlib

Incompatible change type: source

Short summary: Kotlin deprecates floating-point array functions contains, indexOf, lastIndexOf that compare values using the IEEE-754 order instead of the total order

Deprecation cycle:

- 1.4.0: deprecate the affected functions with a warning
- 1.6.0: raise the deprecation level to an error
- 1.7.0: hide the deprecated functions from the public API

Migrate declarations from kotlin.dom and kotlin.browser packages to kotlinx.*

Issue: KT-39330

Component: kotlin-stdlib (JS)

Incompatible change type: source

Short summary: declarations from the kotlin.dom and kotlin.browser packages are moved to the corresponding kotlinx.* packages to prepare for extracting them from stdlib

Deprecation cycle:

- 1.4.0: introduce the replacement API in kotlinx.dom and kotlinx.browser packages
- 1.4.0: deprecate the API in kotlin.dom and kotlin.browser packages and propose the new API above as a replacement
- 1.6.0: raise the deprecation level to an error
- >= 1.8: remove the deprecated functions from stdlib
- >= 1.8: move the API in kotlinx.* packages to a separate library

Deprecate some JS-only API

Issue: KT-48587

Component: kotlin-stdlib (JS)

Incompatible change type: source

Short summary: a number of JS-only functions in stdlib are deprecated for removal. They include: String.concat(String), String.match(regex: String), String.matches(regex: String), and the sort functions on arrays taking a comparison function, for example, Array<out T>.sort(comparison: (a: T, b: T) -> Int)

Deprecation cycle:

- 1.6.0: deprecate the affected functions with a warning
- 1.8.0: raise the deprecation level to an error
- 1.9.0: remove the deprecated functions from the public API

Tools

Remove KotlinGradleSubplugin class

Issue: KT-48831

Component: Gradle

Incompatible change type: source

Short summary: remove the KotlinGradleSubplugin class. Use the KotlinCompilerPluginSupportPlugin class instead

Deprecation cycle:

- 1.6.0: raise the deprecation level to an error
- 1.7.0: remove the deprecated class

Remove useIR compiler option

Issue: KT-48847

Component: Gradle

Incompatible change type: source

Short summary: remove the deprecated and hidden useIR compiler option

Deprecation cycle:

- 1.5.0: raise the deprecation level to a warning
- 1.6.0: hide the option
- 1.7.0: remove the deprecated option

Deprecate kapt.use.worker.api Gradle property

Issue: KT-48826

Component: Gradle

Incompatible change type: source

Short summary: deprecate the kapt.use.worker.api property that allowed to run kapt via Gradle Workers API (default: true)

Deprecation cycle:

- 1.6.20: raise the deprecation level to a warning
- >= 1.8.0: remove this property

Remove kotlin.experimental.coroutines Gradle DSL option and kotlin.coroutines Gradle property

Issue: KT-50494

Component: Gradle

Incompatible change type: source

Short summary: remove the kotlin.experimental.coroutines Gradle DSL option and the kotlin.coroutines property

Deprecation cycle:

- 1.6.20: raise the deprecation level to a warning
- 1.7.0: remove the DSL option, its enclosing experimental block, and the property

Deprecate useExperimentalAnnotation compiler option

Issue: KT-47763

Component: Gradle

Incompatible change type: source

Short summary: remove the hidden useExperimentalAnnotation() Gradle function used to opt in to using an API in a module. optIn() function can be used instead

Deprecation cycle:

- 1.6.0: hide the deprecation option
- 1.7.0: remove the deprecated option

Deprecate kotlin.compiler.execution.strategy system property

Issue: KT-51830

Component: Gradle

Incompatible change type: source

Short summary: deprecate the kotlin.compiler.execution.strategy system property used to choose a compiler execution strategy. Use the Gradle property kotlin.compiler.execution.strategy or the compile task property compilerExecutionStrategy instead

Deprecation cycle:

- 1.7.0: raise the deprecation level to a warning
- > 1.7.0: remove the property

Remove kotlinOptions.jdkHome compiler option

Issue: KT-46541

Component: Gradle

Incompatible change type: source

Short summary: remove the kotlinOptions.jdkHome compiler option used to include a custom JDK from the specified location into the classpath instead of the default JAVA_HOME. Use Java toolchains instead

Deprecation cycle:

- 1.5.30: raise the deprecation level to a warning
- > 1.7.0: remove the option

Remove noStdlib compiler option

Issue: KT-49011

Component: Gradle

Incompatible change type: source

Short summary: remove the noStdlib compiler option. The Gradle plugin uses the kotlin.stdlib.default.dependency=true property to control whether the Kotlin standard library is present

Deprecation cycle:

- 1.5.0: raise the deprecation level to a warning
- 1.7.0: remove the option

Remove kotlin2js and kotlin-dce-plugin plugins

Issue: KT-48276

Component: Gradle

Incompatible change type: source

Short summary: remove the kotlin2js and kotlin-dce-plugin plugins. Instead of kotlin2js, use the new org.jetbrains.kotlin.js plugin. Dead code elimination (DCE) works when the Kotlin/JS Gradle plugin is properly configured

Deprecation cycle:

- 1.4.0: raise the deprecation level to a warning
- 1.7.0: remove the plugins

Changes in compile tasks

Issue: KT-32805

Component: Gradle

Incompatible change type: source

Short summary: Kotlin compile tasks no longer inherit the Gradle AbstractCompile task and that's why the sourceCompatibility and targetCompatibility inputs are no longer available in Kotlin users' scripts. The SourceTask.stableSources input is no longer available. The sourceFilesExtensions input was removed. The deprecated Gradle destinationDir: File output was replaced with the destinationDirectory: DirectoryProperty output. The classpath property of the KotlinCompile task is deprecated

Deprecation cycle:

- 1.7.0: inputs are not available, the output is replaced, the classpath property is deprecated

Compatibility guide for Kotlin 1.6

Keeping the Language Modern and Comfortable Updates are among the fundamental principles in Kotlin Language Design. The former says that constructs which obstruct language evolution should be removed, and the latter says that this removal should be well-communicated beforehand to make code migration as smooth as possible.

While most of the language changes were already announced through other channels, like update changelogs or compiler warnings, this document summarizes them all, providing a complete reference for migration from Kotlin 1.5 to Kotlin 1.6.

Basic terms

In this document we introduce several kinds of compatibility:

- source: source-incompatible change stops code that used to compile fine (without errors or warnings) from compiling anymore
- binary: two binary artifacts are said to be binary-compatible if interchanging them doesn't lead to loading or linkage errors
- behavioral: a change is said to be behavioral-incompatible if the same program demonstrates different behavior before and after applying the change

Remember that those definitions are given only for pure Kotlin. Compatibility of Kotlin code from the other languages perspective (for example, from Java) is out of the scope of this document.

Language

Make when statements with enum, sealed, and Boolean subjects exhaustive by default

Issue: KT-47709

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.6 will warn about the when statement with an enum, sealed, or Boolean subject being non-exhaustive

Deprecation cycle:

- 1.6.0: introduce a warning when the when statement with an enum, sealed, or Boolean subject is non-exhaustive (error in the progressive mode)
- 1.7.0: raise this warning to an error

Deprecate confusing grammar in when-with-subject

Issue: KT-48385

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.6 will deprecate several confusing grammar constructs in when condition expressions

Deprecation cycle:

- 1.6.20: introduce a deprecation warning on the affected expressions
- 1.8.0: raise this warning to an error
- >= 1.8: repurpose some deprecated constructs for new language features

Prohibit access to class members in the super constructor call of its companion and nested objects

Issue: KT-25289

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.6 will report an error for arguments of super constructor call of companion and regular objects if the receiver of such arguments refers to the containing declaration

Deprecation cycle:

- 1.5.20: introduce a warning on the problematic arguments
- 1.6.0: raise this warning to an error, -XXLanguage:-ProhibitSelfCallsInNestedObjects can be used to temporarily revert to the pre-1.6 behavior

Type nullability enhancement improvements

Issue: KT-48623

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.7 will change how it loads and interprets type nullability annotations in Java code

Deprecation cycle:

- 1.4.30: introduce warnings for cases where more precise type nullability could lead to an error
- 1.7.0: infer more precise nullability of Java types, -XXLanguage:-TypeEnhancementImprovementsInStrictMode can be used to temporarily revert to the pre-1.7 behavior

Prevent implicit coercions between different numeric types

Issue: KT-48645

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Kotlin will avoid converting numeric values automatically to a primitive numeric type where only a downcast to that type was needed semantically

Deprecation cycle:

- < 1.5.30: the old behavior in all affected cases
- 1.5.30: fix the downcast behavior in generated property delegate accessors, -Xuse-old-backend can be used to temporarily revert to the pre-1.5.30 fix behavior
- >= 1.6.20: fix the downcast behavior in other affected cases

Prohibit declarations of repeatable annotation classes whose container annotation violates JLS

Issue: KT-47928

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.6 will check that the container annotation of a repeatable annotation satisfies the same requirements as in JLS 9.6.3: array-typed value method, retention, and target

Deprecation cycle:

- 1.5.30: introduce a warning on repeatable container annotation declarations violating JLS requirements (error in the progressive mode)
- 1.6.0: raise this warning to an error, -XXLanguage:-RepeatableAnnotationContainerConstraints can be used to temporarily disable the error reporting

Prohibit declaring a nested class named Container in a repeatable annotation class

Issue: KT-47971

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.6 will check that a repeatable annotation declared in Kotlin doesn't have a nested class with the predefined name Container

Deprecation cycle:

- 1.5.30: introduce a warning on nested classes with the name Container in a Kotlin-repeatable annotation class (error in the progressive mode)
- 1.6.0: raise this warning to an error, -XXLanguage:-RepeatableAnnotationContainerConstraints can be used to temporarily disable the error reporting

Prohibit @JvmField on a property in the primary constructor that overrides an interface property

Issue: KT-32753

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.6 will outlaw annotating a property declared in the primary constructor that overrides an interface property with the @JvmField annotation

Deprecation cycle:

- 1.5.20: introduce a warning on the @JvmField annotation on such properties in the primary constructor
- 1.6.0: raise this warning to an error, -XXLanguage:-ProhibitJvmFieldOnOverrideFromInterfaceInPrimaryConstructor can be used to temporarily disable the error reporting

Deprecate the enable and the compatibility modes of the compiler option -Xjvm-default

Issue: KT-46329

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.6.20 will warn about the usage of enable and compatibility modes of the -Xjvm-default compiler option

Deprecation cycle:

- 1.6.20: introduce a warning on the enable and compatibility modes of the -Xjvm-default compiler option
- >= 1.8.0: raise this warning to an error

Prohibit super calls from public-abi inline functions

Issue: KT-45379

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.6 will outlaw calling functions with a super qualifier from public or protected inline functions and properties

Deprecation cycle:

- 1.5.0: introduce a warning on super calls from public or protected inline functions or property accessors
- 1.6.0: raise this warning to an error, -XXLanguage:-ProhibitSuperCallsFromPublicInline can be used to temporarily disable the error reporting

Prohibit protected constructor calls from public inline functions

Issue: KT-48860

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.6 will outlaw calling protected constructors from public or protected inline functions and properties

Deprecation cycle:

- 1.4.30: introduce a warning on protected constructor calls from public or protected inline functions or property accessors
- 1.6.0: raise this warning to an error, -XXLanguage:-ProhibitProtectedConstructorCallFromPublicInline can be used to temporarily disable the error reporting

Prohibit exposing private nested types from private-in-file types

Issue: KT-20094

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.6 will outlaw exposing private nested types and inner classes from private-in-file types

Deprecation cycle:

- 1.5.0: introduce a warning on private types exposed from private-in-file types
- 1.6.0: raise this warning to an error, -XXLanguage:-PrivateInFileEffectiveVisibility can be used to temporarily disable the error reporting

Annotation target is not analyzed in several cases for annotations on a type

Issue: KT-28449

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.6 will no longer allow annotations on types that should not be applicable to types

Deprecation cycle:

- 1.5.20: introduce an error in the progressive mode
- 1.6.0: introduce an error, -XXLanguage:-ProperCheckAnnotationsTargetInTypeUsePositions can be used to temporarily disable the error reporting

Prohibit calls to functions named suspend with a trailing lambda

Issue: KT-22562

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.6 will no longer allow calling functions named suspend that have the single argument of a functional type passed as a trailing lambda

Deprecation cycle:

- 1.3.0: introduce a warning on such function calls
- 1.6.0: raise this warning to an error
- >= 1.7.0: introduce changes to the language grammar, so that suspend before { is parsed as a keyword

Standard library

Remove brittle contains optimization in minus/removeAll/retainAll

Issue: KT-45438

Component: kotlin-stdlib

Incompatible change type: behavioral

Short summary: Kotlin 1.6 will no longer perform conversion to set for the argument of functions and operators that remove several elements from collection/iterable/array/sequence.

Deprecation cycle:

- < 1.6: the old behavior: the argument is converted to set in some cases
- 1.6.0: if the function argument is a collection, it's no longer converted to Set. If it's not a collection, it can be converted to List instead.

  The old behavior can be temporarily turned back on JVM by setting the system property kotlin.collections.convert_arg_to_set_in_removeAll=true
- >= 1.7: the system property above will no longer have an effect

Change value generation algorithm in Random.nextLong

Issue: KT-47304

Component: kotlin-stdlib

Incompatible change type: behavioral

Short summary: Kotlin 1.6 changes the value generation algorithm in the Random.nextLong function to avoid producing values out of the specified range.

Deprecation cycle:

- 1.6.0: the behavior is fixed immediately

Gradually change the return type of collection min and max functions to non-nullable

Issue: KT-38854

Component: kotlin-stdlib

Incompatible change type: source

Short summary: the return type of collection min and max functions will be changed to non-nullable in Kotlin 1.7

Deprecation cycle:

- 1.4.0: introduce ...OrNull functions as synonyms and deprecate the affected API (see details in the issue)
- 1.5.0: raise the deprecation level of the affected API to an error
- 1.6.0: hide the deprecated functions from the public API
- >= 1.7: reintroduce the affected API but with non-nullable return type

Deprecate floating-point array functions: contains, indexOf, lastIndexOf

Issue: KT-28753

Component: kotlin-stdlib

Incompatible change type: source

Short summary: Kotlin deprecates floating-point array functions contains, indexOf, lastIndexOf that compare values using the IEEE-754 order instead of the total order

Deprecation cycle:

- 1.4.0: deprecate the affected functions with a warning
- 1.6.0: raise the deprecation level to an error
- >= 1.7: hide the deprecated functions from the public API

Migrate declarations from kotlin.dom and kotlin.browser packages to kotlinx.*

Issue: KT-39330

Component: kotlin-stdlib (JS)

Incompatible change type: source

Short summary: declarations from the kotlin.dom and kotlin.browser packages are moved to the corresponding kotlinx.* packages to prepare for extracting them from stdlib

Deprecation cycle:

- 1.4.0: introduce the replacement API in kotlinx.dom and kotlinx.browser packages
- 1.4.0: deprecate the API in kotlin.dom and kotlin.browser packages and propose the new API above as a replacement
- 1.6.0: raise the deprecation level to an error
- >= 1.7: remove the deprecated functions from stdlib
- >= 1.7: move the API in kotlinx.* packages to a separate library

Make Regex.replace function not inline in Kotlin/JS

Issue: KT-27738

Component: kotlin-stdlib (JS)

Incompatible change type: source

Short summary: the Regex.replace function with the functional transform parameter will no longer be inline in Kotlin/JS

Deprecation cycle:

- 1.6.0: remove the inline modifier from the affected function

Different behavior of the Regex.replace function in JVM and JS when replacement string contains group reference

Issue: KT-28378

Component: kotlin-stdlib (JS)

Incompatible change type: behavioral

Short summary: the function Regex.replace in Kotlin/JS with the replacement pattern string will follow the same syntax of that pattern as in Kotlin/JVM

Deprecation cycle:

- 1.6.0: change the replacement pattern handling in Regex.replace of the Kotlin/JS stdlib

Use the Unicode case folding in JS Regex

Issue: KT-45928

Component: kotlin-stdlib (JS)

Incompatible change type: behavioral

Short summary: the Regex class in Kotlin/JS will use unicode flag when calling the underlying JS Regular expressions engine to search and compare characters according to the Unicode rules. This brings certain version requirements of the JS environment and causes more strict validation of unnecessary escaping in the regex pattern string.

Deprecation cycle:

- 1.5.0: enable the Unicode case folding in most functions of the JS Regex class
- 1.6.0: enable the Unicode case folding in the Regex.replaceFirst function

Deprecate some JS-only API

Issue: KT-48587

Component: kotlin-stdlib (JS)

Incompatible change type: source

Short summary: a number of JS-only functions in stdlib are deprecated for removal. They include: String.concat(String), String.match(regex: String), String.matches(regex: String), and the sort functions on arrays taking a comparison function, for example, Array<out T>.sort(comparison: (a: T, b: T) -> Int)

Deprecation cycle:

- 1.6.0: deprecate the affected functions with a warning
- 1.7.0: raise the deprecation level to an error
- 1.8.0: remove the deprecated functions from the public API

Hide implementation- and interop-specific functions from the public API of classes in Kotlin/JS

Issue: KT-48587

Component: kotlin-stdlib (JS)

Incompatible change type: source, binary

Short summary: the functions HashMap.createEntrySet and AbstactMutableCollection.toJSON change their visibility to internal

Deprecation cycle:

- 1.6.0: make the functions internal, thus removing them from the public API

Tools

Deprecate KotlinGradleSubplugin class

Issue: KT-48830

Component: Gradle

Incompatible change type: source

Short summary: the class KotlinGradleSubplugin will be deprecated in favor of KotlinCompilerPluginSupportPlugin

Deprecation cycle:

- 1.6.0: raise the deprecation level to an error
- >= 1.7.0: remove the deprecated class

Remove kotlin.useFallbackCompilerSearch build option

Issue: KT-46719

Component: Gradle

Incompatible change type: source

Short summary: remove the deprecated 'kotlin.useFallbackCompilerSearch' build option

Deprecation cycle:

- 1.5.0: raise the deprecation level to a warning
- 1.6.0: remove the deprecated option

Remove several compiler options

Issue: KT-48847

Component: Gradle

Incompatible change type: source

Short summary: remove the deprecated noReflect and includeRuntime compiler options

Deprecation cycle:

- 1.5.0: raise the deprecation level to an error
- 1.6.0: remove the deprecated options

Deprecate useIR compiler option

Issue: KT-48847

Component: Gradle

Incompatible change type: source

Short summary: hide the deprecated useIR compiler option

Deprecation cycle:

- 1.5.0: raise the deprecation level to a warning
- 1.6.0: hide the option
- >= 1.7.0: remove the deprecated option

Deprecate kapt.use.worker.api Gradle property

Issue: KT-48826

Component: Gradle

Incompatible change type: source

Short summary: deprecate the kapt.use.worker.api property that allowed to run kapt via Gradle Workers API (default: true)

Deprecation cycle:

- 1.6.20: raise the deprecation level to a warning
- >= 1.8.0: remove this property

Remove kotlin.parallel.tasks.in.project Gradle property

Issue: KT-46406

Component: Gradle

Incompatible change type: source

Short summary: remove the kotlin.parallel.tasks.in.project property

Deprecation cycle:

- 1.5.20: raise the deprecation level to a warning
- 1.6.20: remove this property

Deprecate kotlin.experimental.coroutines Gradle DSL option and kotlin.coroutines Gradle property

Issue: KT-50369

Component: Gradle

Incompatible change type: source

Short summary: deprecate the kotlin.experimental.coroutines Gradle DSL option and the kotlin.coroutines property

Deprecation cycle:

- 1.6.20: raise the deprecation level to a warning
- >= 1.7.0: remove the DSL option and the property

Compatibility guide for Kotlin 1.5

Keeping the Language Modern and Comfortable Updates are among the fundamental principles in Kotlin Language Design. The former says that constructs which obstruct language evolution should be removed, and the latter says that this removal should be well-communicated beforehand to make code migration as smooth as possible.

While most of the language changes were already announced through other channels, like update changelogs or compiler warnings, this document summarizes them all, providing a complete reference for migration from Kotlin 1.4 to Kotlin 1.5.

Basic terms

In this document we introduce several kinds of compatibility:

- source: source-incompatible change stops code that used to compile fine (without errors or warnings) from compiling anymore
- binary: two binary artifacts are said to be binary-compatible if interchanging them doesn't lead to loading or linkage errors
- behavioral: a change is said to be behavioral-incompatible if the same program demonstrates different behavior before and after applying the change

Remember that those definitions are given only for pure Kotlin. Compatibility of Kotlin code from the other languages perspective (for example, from Java) is out of the scope of this document.

Language and stdlib

Forbid spread operator in signature-polymorphic calls

> Issue: KT-35226
>
> Component: Core language
>
> Incompatible change type: source
>
> Short summary: Kotlin 1.5 will outlaw the use of spread operator (*) on signature-polymorphic calls
>
> Deprecation cycle:
>
> - < 1.5: introduce warning for the problematic operator at call-site
> - >= 1.5: raise this warning to an error, -XXLanguage:-ProhibitSpreadOnSignaturePolymorphicCall can be used to temporarily revert to pre-1.5 behavior

Forbid non-abstract classes containing abstract members invisible from that classes (internal/package-private)

> Issue: KT-27825
>
> Component: Core language
>
> Incompatible change type: source
>
> Short summary: Kotlin 1.5 will outlaw non-abstract classes containing abstract members invisible from that classes (internal/package-private)
>
> Deprecation cycle:
>
> - < 1.5: introduce warning for the problematic classes
> - >= 1.5: raise this warning to an error, -XXLanguage:-ProhibitInvisibleAbstractMethodsInSuperclasses can be used to temporarily revert to pre-1.5 behavior

Forbid using array based on non-reified type parameters as reified type arguments on JVM

Issue: KT-31227

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.5 will outlaw using array based on non-reified type parameters as reified type arguments on JVM

Deprecation cycle:

- < 1.5: introduce warning for the problematic calls
- >= 1.5: raise this warning to an error, -XXLanguage:-ProhibitNonReifiedArraysAsReifiedTypeArguments can be used to temporarily revert to pre-1.5 behavior

Forbid secondary enum class constructors which do not delegate to the primary constructor

Issue: KT-35870

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.5 will outlaw secondary enum class constructors which do not delegate to the primary constructor

Deprecation cycle:

- < 1.5: introduce warning for the problematic constructors
- >= 1.5: raise this warning to an error, -XXLanguage:-RequiredPrimaryConstructorDelegationCallInEnums can be used to temporarily revert to pre-1.5 behavior

Forbid exposing anonymous types from private inline functions

Issue: KT-33917

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.5 will outlaw exposing anonymous types from private inline functions

Deprecation cycle:

- < 1.5: introduce warning for the problematic constructors
- >= 1.5: raise this warning to an error, -XXLanguage:-ApproximateAnonymousReturnTypesInPrivateInlineFunctions can be used to temporarily revert to pre-1.5 behavior

Forbid passing non-spread arrays after arguments with SAM-conversion

Issue: KT-35224

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.5 will outlaw passing non-spread arrays after arguments with SAM-conversion

Deprecation cycle:

- 1.3.70: introduce warning for the problematic calls
- >= 1.5: raise this warning to an error, -XXLanguage:-ProhibitVarargAsArrayAfterSamArgument can be used to temporarily revert to pre-1.5 behavior

Support special semantics for underscore-named catch block parameters

Issue: KT-31567

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.5 will outlaw references to the underscore symbol (_) that is used to omit parameter name of an exception in the catch block

Deprecation cycle:

- 1.4.20: introduce warning for the problematic references
- >= 1.5: raise this warning to an error, -XXLanguage:-ForbidReferencingToUnderscoreNamedParameterOfCatchBlock can be used to temporarily revert to pre-1.5 behavior

Change implementation strategy of SAM conversion from anonymous class-based to invokedynamic

Issue: KT-44912

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Since Kotlin 1.5, implementation strategy of SAM (single abstract method) conversion will be changed from generating an anonymous class to using the invokedynamic JVM instruction

Deprecation cycle:

- 1.5: change implementation strategy of SAM conversion, -Xsam-conversions=class can be used to revert implementation scheme to the one that used before

Performance issues with the JVM IR-based backend

Issue: KT-48233

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Kotlin 1.5 uses the IR-based backend for the Kotlin/JVM compiler by default. The old backend is still used by default for earlier language versions.

You might encounter some performance degradation issues using the new compiler in Kotlin 1.5. We are working on fixing such cases.

Deprecation cycle:

- < 1.5: by default, the old JVM backend is used
- >= 1.5: by default, the IR-based backend is used. If you need to use the old backend in Kotlin 1.5, add the following lines to the project's configuration file to temporarily revert to pre-1.5 behavior:

In Gradle:

Kotlin

```
tasks.withType<org.jetbrains.kotlin.gradle.dsl.KotlinJvmCompile> {
  kotlinOptions.useOldBackend = true
}
```

Groovy

```
tasks.withType(org.jetbrains.kotlin.gradle.dsl.KotlinJvmCompile) {
  kotlinOptions.useOldBackend = true
}
```

In Maven:

```
<configuration>
    <args>
        <arg>-Xuse-old-backend</arg>
    </args>
</configuration>
```

Support for this flag will be removed in one of the future releases.

New field sorting in the JVM IR-based backend

Issue: KT-46378

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Since version 1.5, Kotlin uses the IR-based backend that sorts JVM bytecode differently: it generates fields declared in the constructor before fields declared in the body, while it's vice versa for the old backend. The new sorting may change the behavior of programs that use serialization frameworks that depend on the field order, such as Java serialization.

Deprecation cycle:

- < 1.5: by default, the old JVM backend is used. It has fields declared in the body before fields declared in the constructor.
- >= 1.5: by default, the new IR-based backend is used. Fields declared in the constructor are generated before fields declared in the body. As a workaround, you can temporarily switch to the old backend in Kotlin 1.5. To do that, add the following lines to the project's configuration file:

In Gradle:

Kotlin

```
tasks.withType<org.jetbrains.kotlin.gradle.dsl.KotlinJvmCompile> {
  kotlinOptions.useOldBackend = true
}
```

Groovy

```
tasks.withType(org.jetbrains.kotlin.gradle.dsl.KotlinJvmCompile) {
  kotlinOptions.useOldBackend = true
}
```

In Maven:

```
<configuration>
    <args>
        <arg>-Xuse-old-backend</arg>
    </args>
</configuration>
```

Support for this flag will be removed in one of the future releases.

Generate nullability assertion for delegated properties with a generic call in the delegate expression

Issue: KT-44304

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Since Kotlin 1.5, the Kotlin compiler will emit nullability assertions for delegated properties with a generic call in the delegate expression

Deprecation cycle:

- 1.5: emit nullability assertion for delegated properties (see details in the issue), -Xuse-old-backend or -language-version 1.4 can be used to temporarily revert to pre-1.5 behavior

Turn warnings into errors for calls with type parameters annotated by @OnlyInputTypes

Issue: KT-45861

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.5 will outlaw calls like contains, indexOf, and assertEquals with senseless arguments to improve type safety

Deprecation cycle:

- 1.4.0: introduce warning for the problematic constructors
- >= 1.5: raise this warning to an error, -XXLanguage:-StrictOnlyInputTypesChecks can be used to temporarily revert to pre-1.5 behavior

Use the correct order of arguments execution in calls with named vararg

Issue: KT-17691

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Kotlin 1.5 will change the order of arguments execution in calls with named vararg

Deprecation cycle:

- < 1.5: introduce warning for the problematic constructors
- >= 1.5: raise this warning to an error, -XXLanguage:-UseCorrectExecutionOrderForVarargArguments can be used to temporarily revert to pre-1.5 behavior

Use default value of the parameter in operator functional calls

Issue: KT-42064

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Kotlin 1.5 will use default value of the parameter in operator calls

Deprecation cycle:

- < 1.5: old behavior (see details in the issue)
- >= 1.5: behavior changed, -XXLanguage:-JvmIrEnabledByDefault can be used to temporarily revert to pre-1.5 behavior

Produce empty reversed progressions in for loops if regular progression is also empty

Issue: KT-42533

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Kotlin 1.5 will produce empty reversed progressions in for loops if regular progression is also empty

Deprecation cycle:

- < 1.5: old behavior (see details in the issue)
- >= 1.5: behavior changed, -XXLanguage:-JvmIrEnabledByDefault can be used to temporarily revert to pre-1.5 behavior

Straighten Char-to-code and Char-to-digit conversions out

Issue: KT-23451

Component: kotlin-stdlib

Incompatible change type: source

Short summary: Since Kotlin 1.5, conversions of Char to number types will be deprecated

Deprecation cycle:

- 1.5: deprecate Char.toInt()/toShort()/toLong()/toByte()/toDouble()/toFloat() and the reverse functions like Long.toChar(), and propose replacement

Inconsistent case-insensitive comparison of characters in kotlin.text functions

Issue: KT-45496

Component: kotlin-stdlib

Incompatible change type: behavioral

Short summary: Since Kotlin 1.5, Char.equals will be improved in case-insensitive case by first comparing whether the uppercase variants of characters are equal, then whether the lowercase variants of those uppercase variants (as opposed to the characters themselves) are equal

Deprecation cycle:

- < 1.5: old behavior (see details in the issue)
- 1.5: change behavior for Char.equals function

Remove default locale-sensitive case conversion API

Issue: KT-43023

Component: kotlin-stdlib

Incompatible change type: source

Short summary: Since Kotlin 1.5, default locale-sensitive case conversion functions like String.toUpperCase() will be deprecated

Deprecation cycle:

- 1.5: deprecate case conversions functions with the default locale (see details in the issue), and propose replacement

Gradually change the return type of collection min and max functions to non-nullable

Issue: KT-38854

Component: kotlin-stdlib (JVM)

Incompatible change type: source

Short summary: return type of collection min and max functions will be changed to non-nullable in 1.6

Deprecation cycle:

- 1.4: introduce ...OrNull functions as synonyms and deprecate the affected API (see details in the issue)
- 1.5.0: raise the deprecation level of the affected API to error
- >=1.6: reintroduce the affected API but with non-nullable return type

Raise the deprecation level of conversions of floating-point types to Short and Byte

Issue: KT-30360

Component: kotlin-stdlib (JVM)

Incompatible change type: source

Short summary: conversions of floating-point types to Short and Byte deprecated in Kotlin 1.4 with WARNING level will cause errors since Kotlin 1.5.0.

Deprecation cycle:

- 1.4: deprecate Double.toShort()/toByte() and Float.toShort()/toByte() and propose replacement
- 1.5.0: raise the deprecation level to error

Tools

Do not mix several JVM variants of kotlin-test in a single project

Issue: KT-40225

Component: Gradle

Incompatible change type: behavioral

Short summary: several mutually exclusive kotlin-test variants for different testing frameworks could have been in a project if one of them is brought by a transitive dependency. From 1.5.0, Gradle won't allow having mutually exclusive kotlin-test variants for different testing frameworks.

Deprecation cycle:

- < 1.5: having several mutually exclusive kotlin-test variants for different testing frameworks is allowed
- >= 1.5: behavior changed,

  Gradle throws an exception like "Cannot select module with conflict on capability...". Possible solutions:

  - use the same kotlin-test variant and the corresponding testing framework as the transitive dependency brings.
  - find another variant of the dependency that doesn't bring the kotlin-test variant transitively, so you can use the testing framework you would like to use.
  - find another variant of the dependency that brings another kotlin-test variant transitively, which uses the same testing framework you would like to use.
  - exclude the testing framework that is brought transitively. The following example is for excluding JUnit 4:

    ```
    configurations {
        testImplementation.get().exclude("org.jetbrains.kotlin", "kotlin-test-junit")
    }
    ```

    After excluding the testing framework, test your application. If it stopped working, rollback excluding changes, use the same testing framework as the library does, and exclude your testing framework.

Compatibility guide for Kotlin 1.4

Keeping the Language Modern and Comfortable Updates are among the fundamental principles in Kotlin Language Design. The former says that constructs which obstruct language evolution should be removed, and the latter says that this removal should be well-communicated beforehand to make code migration as smooth as possible.

While most of the language changes were already announced through other channels, like update changelogs or compiler warnings, this document summarizes them all, providing a complete reference for migration from Kotlin 1.3 to Kotlin 1.4.

Basic terms

In this document we introduce several kinds of compatibility:

- source: source-incompatible change stops code that used to compile fine (without errors or warnings) from compiling anymore
- binary: two binary artifacts are said to be binary-compatible if interchanging them doesn't lead to loading or linkage errors
- behavioral: a change is said to be behavioral-incompatible if the same program demonstrates different behavior before and after applying the change

Remember that those definitions are given only for pure Kotlin. Compatibility of Kotlin code from the other languages perspective (for example, from Java) is out of the scope of this document.

Language and stdlib

Unexpected behavior with in infix operator and ConcurrentHashMap

Issue: KT-18053

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.4 will outlaw auto operator contains coming from the implementors of java.util.Map written in Java

Deprecation cycle:

- < 1.4: introduce warning for problematic operators at call-site
- >= 1.4: raise this warning to an error, -XXLanguage:-ProhibitConcurrentHashMapContains can be used to temporarily revert to pre-1.4 behavior

Prohibit access to protected members inside public inline members

Issue: KT-21178

Component: Core language

Incompatible change type: source

Short summary: Kotlin 1.4 will prohibit access to protected members from public inline members.

Deprecation cycle:

- < 1.4: introduce warning at call-site for problematic cases
- 1.4: raise this warning to an error, -XXLanguage:-ProhibitProtectedCallFromInline can be used to temporarily revert to pre-1.4 behavior

Contracts on calls with implicit receivers

Issue: KT-28672

Component: Core Language

Incompatible change type: behavioral

Short summary: smart casts from contracts will be available on calls with implicit receivers in 1.4

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-ContractsOnCallsWithImplicitReceiver can be used to temporarily revert to pre-1.4 behavior

Inconsistent behavior of floating-point number comparisons

Issues: KT-22723

Component: Core language

Incompatible change type: behavioral

Short summary: since Kotlin 1.4, Kotlin compiler will use IEEE 754 standard to compare floating-point numbers

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-ProperIeee754Comparisons can be used to temporarily revert to pre-1.4 behavior

No smart cast on the last expression in a generic lambda

Issue: KT-15020

Component: Core Language

Incompatible change type: behavioral

Short summary: smart casts for last expressions in lambdas will be correctly applied since 1.4

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Do not depend on the order of lambda arguments to coerce result to Unit

Issue: KT-36045

Component: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, lambda arguments will be resolved independently without implicit coercion to Unit

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Wrong common supertype between raw and integer literal type leads to unsound code

Issue: KT-35681

Components: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, common supertype between raw Comparable type and integer literal type will be more specific

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Type safety problem because several equal type variables are instantiated with a different types

Issue: KT-35679

Component: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, Kotlin compiler will prohibit instantiating equal type variables with different types

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Type safety problem because of incorrect subtyping for intersection types

Issues: KT-22474

Component: Core language

Incompatible change type: source

Short summary: in Kotlin 1.4, subtyping for intersection types will be refined to work more correctly

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

No type mismatch with an empty when expression inside lambda

Issue: KT-17995

Component: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, there will be a type mismatch for empty when expression if it's used as the last expression in a lambda

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Return type Any inferred for lambda with early return with integer literal in one of possible return values

Issue: KT-20226

Component: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, integer type returning from a lambda will be more specific for cases when there is early return

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Proper capturing of star projections with recursive types

Issue: KT-33012

Component: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, more candidates will become applicable because capturing for recursive types will work more correctly

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Common supertype calculation with non-proper type and flexible one leads to incorrect results

Issue: KT-37054

Component: Core language

Incompatible change type: behavioral

Short summary: since Kotlin 1.4, common supertype between flexible types will be more specific protecting from runtime errors

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Type safety problem because of lack of captured conversion against nullable type argument

Issue: KT-35487

Component: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, subtyping between captured and nullable types will be more correct protecting from runtime errors

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Preserve intersection type for covariant types after unchecked cast

Issue: KT-37280

Component: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, uchecked casts of covariant types produce the intersection type for smart casts, not the type of the unchecked cast.

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Type variable leaks from builder inference because of using this expression

Issue: KT-32126

Component: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, using this inside builder functions like sequence {} is prohibited if there are no other proper constraints

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Wrong overload resolution for contravariant types with nullable type arguments

Issue: KT-31670

Component: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, if two overloads of a function that takes contravariant type arguments differ only by the nullability of the type (such as In<T> and In<T?>), the nullable type is considered more specific.

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Builder inference with non-nested recursive constraints

Issue: KT-34975

Component: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, builder functions such as sequence {} with type that depends on a recursive constraint inside the passed lambda cause a compiler error.

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Eager type variable fixation leads to a contradictory constraint system

Issue: KT-25175

Component: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, the type inference in certain cases works less eagerly allowing to find the constraint system that is not contradictory.

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-NewInference can be used to temporarily revert to pre-1.4 behavior. Note that this flag will also disable several new language features.

Prohibit tailrec modifier on open functions

Issue: KT-18541

Component: Core language

Incompatible change type: source

Short summary: since Kotlin 1.4, functions can't have open and tailrec modifiers at the same time.

Deprecation cycle:

- < 1.4: report a warning on functions that have open and tailrec modifiers together (error in the progressive mode).
- >= 1.4: raise this warning to an error.

The INSTANCE field of a companion object more visible than the companion object class itself

Issue: KT-11567

Component: Kotlin/JVM

Incompatible change type: source

Short summary: since Kotlin 1.4, if a companion object is private, then its field INSTANCE will be also private

Deprecation cycle:

- < 1.4: the compiler generates object INSTANCE with a deprecated flag
- >= 1.4: companion object INSTANCE field has proper visibility

Outer finally block inserted before return is not excluded from the catch interval of the inner try block without finally

Issue: KT-31923

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: since Kotlin 1.4, the catch interval will be computed properly for nested try/catch blocks

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-ProperFinally can be used to temporarily revert to pre-1.4 behavior

Use the boxed version of an inline class in return type position for covariant and generic-specialized overrides

Issues: KT-30419

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: since Kotlin 1.4, functions using covariant and generic-specialized overrides will return boxed values of inline classes

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed

Do not declare checked exceptions in JVM bytecode when using delegation to Kotlin interfaces

Issue: KT-35834

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.4 will not generate checked exceptions during interface delegation to Kotlin interfaces

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-DoNotGenerateThrowsForDelegatedKotlinMembers can be used to temporarily revert to pre-1.4 behavior

Changed behavior of signature-polymorphic calls to methods with a single vararg parameter to avoid wrapping the argument into another array

Issue: KT-35469

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.4 will not wrap the argument into another array on a signature-polymorphic call

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed

Incorrect generic signature in annotations when KClass is used as a generic parameter

Issue: KT-35207

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.4 will fix incorrect type mapping in annotations when KClass is used as a generic parameter

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed

Forbid spread operator in signature-polymorphic calls

Issue: KT-35226

Component: Kotlin/JVM

Incompatible change type: source

Short summary: Kotlin 1.4 will prohibit the use of spread operator (*) on signature-polymorphic calls

Deprecation cycle:

- < 1.4: report a warning on the use of a spread operator in signature-polymorphic calls
- >= 1.5: raise this warning to an error, -XXLanguage:-ProhibitSpreadOnSignaturePolymorphicCall can be used to temporarily revert to pre-1.4 behavior

Change initialization order of default values for tail-recursive optimized functions

Issue: KT-31540

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Since Kotlin 1.4, the initialization order for tail-recursive functions will be the same as for regular functions

Deprecation cycle:

- < 1.4: report a warning at declaration-site for problematic functions
- >= 1.4: behavior changed, -XXLanguage:-ProperComputationOrderOfTailrecDefaultParameters can be used to temporarily revert to pre-1.4 behavior

Do not generate ConstantValue attribute for non-const vals

Issue: KT-16615

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: Since Kotlin 1.4, the compiler will not generate the ConstantValue attribute for non-const vals

Deprecation cycle:

- < 1.4: report a warning through an IntelliJ IDEA inspection
- >= 1.4: behavior changed, -XXLanguage:-NoConstantValueAttributeForNonConstVals can be used to temporarily revert to pre-1.4 behavior

Generated overloads for @JvmOverloads on open methods should be final

Issue: KT-33240

Components: Kotlin/JVM

Incompatible change type: source

Short summary: overloads for functions with @JvmOverloads will be generated as final

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed, -XXLanguage:-GenerateJvmOverloadsAsFinal can be used to temporarily revert to pre-1.4 behavior

Lambdas returning kotlin.Result now return boxed value instead of unboxed

Issue: KT-39198

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: since Kotlin 1.4, lambdas returning values of kotlin.Result type will return boxed value instead of unboxed

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed

Unify exceptions from null checks

Issue: KT-22275

Component: Kotlin/JVM

Incompatible change type: behavior

Short summary: Starting from Kotlin 1.4, all runtime null checks will throw a java.lang.NullPointerException

Deprecation cycle:

- < 1.4: runtime null checks throw different exceptions, such as KotlinNullPointerException, IllegalStateException, IllegalArgumentException, and TypeCastException
- >= 1.4: all runtime null checks throw a java.lang.NullPointerException. -Xno-unified-null-checks can be used to temporarily revert to pre-1.4 behavior

Comparing floating-point values in array/list operations contains, indexOf, lastIndexOf: IEEE 754 or total order

Issue: KT-28753

Component: kotlin-stdlib (JVM)

Incompatible change type: behavioral

Short summary: the List implementation returned from Double/FloatArray.asList() will implement contains, indexOf, and lastIndexOf, so that they use total order equality

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed

Gradually change the return type of collection min and max functions to non-nullable

Issue: KT-38854

Component: kotlin-stdlib (JVM)

Incompatible change type: source

Short summary: return type of collection min and max functions will be changed to non-nullable in 1.6

Deprecation cycle:

- 1.4: introduce ...OrNull functions as synonyms and deprecate the affected API (see details in the issue)
- 1.5.x: raise the deprecation level of the affected API to error
- >=1.6: reintroduce the affected API but with non-nullable return type

Deprecate appendln in favor of appendLine

Issue: KT-38754

Component: kotlin-stdlib (JVM)

Incompatible change type: source

Short summary: StringBuilder.appendln() will be deprecated in favor of StringBuilder.appendLine()

Deprecation cycle:

- 1.4: introduce appendLine function as a replacement for appendln and deprecate appendln
- >=1.5: raise the deprecation level to error

Deprecate conversions of floating-point types to Short and Byte

Issue: KT-30360

Component: kotlin-stdlib (JVM)

Incompatible change type: source

Short summary: since Kotlin 1.4, conversions of floating-point types to Short and Byte will be deprecated

Deprecation cycle:

- 1.4: deprecate Double.toShort()/toByte() and Float.toShort()/toByte() and propose replacement
- >=1.5: raise the deprecation level to error

Fail fast in Regex.findAll on an invalid startIndex

Issue: KT-28356

Component: kotlin-stdlib

Incompatible change type: behavioral

Short summary: since Kotlin 1.4, findAll will be improved to check that startIndex is in the range of the valid position indices of the input char sequence at the moment of entering findAll, and throw IndexOutOfBoundsException if it's not

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed

Remove deprecated kotlin.coroutines.experimental

Issue: KT-36083

Component: kotlin-stdlib

Incompatible change type: source

Short summary: since Kotlin 1.4, the deprecated kotlin.coroutines.experimental API is removed from stdlib

Deprecation cycle:

- < 1.4: kotlin.coroutines.experimental is deprecated with the ERROR level
- >= 1.4: kotlin.coroutines.experimental is removed from stdlib. On the JVM, a separate compatibility artifact is provided (see details in the issue).

Remove deprecated mod operator

Issue: KT-26654

Component: kotlin-stdlib

Incompatible change type: source

Short summary: since Kotlin 1.4, mod operator on numeric types is removed from stdlib

Deprecation cycle:

- < 1.4: mod is deprecated with the ERROR level
- >= 1.4: mod is removed from stdlib

Hide Throwable.addSuppressed member and prefer extension instead

Issue: KT-38777

Component: kotlin-stdlib

Incompatible change type: behavioral

Short summary: Throwable.addSuppressed() extension function is now preferred over the Throwable.addSuppressed() member function

Deprecation cycle:

- < 1.4: old behavior (see details in the issue)
- >= 1.4: behavior changed

capitalize should convert digraphs to title case

Issue: KT-38817

Component: kotlin-stdlib

Incompatible change type: behavioral

Short summary: String.capitalize() function now capitalizes digraphs from the Serbo-Croatian Gaj's Latin alphabet in the title case (ǅ instead of Ǆ)

Deprecation cycle:

- < 1.4: digraphs are capitalized in the upper case (Ǆ)
- >= 1.4: digraphs are capitalized in the title case (ǅ)

Tools

Compiler arguments with delimiter characters must be passed in double quotes on Windows

Issue: KT-41309

Component: CLI

Incompatible change type: behavioral

Short summary: on Windows, kotlinc.bat arguments that contain delimiter characters (whitespace, =, ;, ,) now require double quotes (")

Deprecation cycle:

- < 1.4: all compiler arguments are passed without quotes
- >= 1.4: compiler arguments that contain delimiter characters (whitespace, =, ;, ,) require double quotes (")

KAPT: Names of synthetic $annotations() methods for properties have changed

Issue: KT-36926

Component: KAPT

Incompatible change type: behavioral

Short summary: names of synthetic $annotations() methods generated by KAPT for properties have changed in 1.4

Deprecation cycle:

- < 1.4: names of synthetic $annotations() methods for properties follow the template <propertyName>@annotations()
- >= 1.4: names of synthetic $annotations() methods for properties include the get prefix: get<PropertyName>@annotations()

Compatibility guide for Kotlin 1.3

Keeping the Language Modern and Comfortable Updates are among the fundamental principles in Kotlin Language Design. The former says that constructs which obstruct language evolution should be removed, and the latter says that this removal should be well-communicated beforehand to make code migration as smooth as possible.

While most of the language changes were already announced through other channels, like update changelogs or compiler warnings, this document summarizes them all, providing a complete reference for migration from Kotlin 1.2 to Kotlin 1.3.

Basic terms

In this document we introduce several kinds of compatibility:

- Source: source-incompatible change stops code that used to compile fine (without errors or warnings) from compiling anymore
- Binary: two binary artifacts are said to be binary-compatible if interchanging them doesn't lead to loading or linkage errors
- Behavioral: a change is said to be behavioral-incompatible if one and the same program demonstrates different behavior before and after applying the change

Remember that those definitions are given only for pure Kotlin. Compatibility of Kotlin code from the other languages perspective (e.g. from Java) is out of the scope of this document.

Incompatible changes

Evaluation order of constructor arguments regarding <clinit> call

Issue: KT-19532

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: evaluation order with respect to class initialization is changed in 1.3

Deprecation cycle:

- <1.3: old behavior (see details in the Issue)
- >= 1.3: behavior changed, -Xnormalize-constructor-calls=disable can be used to temporarily revert to pre-1.3 behavior. Support for this flag is going to be removed in the next major release.

Missing getter-targeted annotations on annotation constructor parameters

Issue: KT-25287

Component: Kotlin/JVM

Incompatible change type: behavioral

Short summary: getter-target annotations on annotations constructor parameters will be properly written to classfiles in 1.3

Deprecation cycle:

- <1.3: getter-target annotations on annotation constructor parameters are not applied
- >=1.3: getter-target annotations on annotation constructor parameters are properly applied and written to the generated code

Missing errors in class constructor's @get: annotations

Issue: KT-19628

Component: Core language

Incompatible change type: Source

Short summary: errors in getter-target annotations will be reported properly in 1.3

Deprecation cycle:

- <1.2: compilation errors in getter-target annotations were not reported, causing incorrect code to be compiled fine.
- 1.2.x: errors reported only by tooling, the compiler still compiles such code without any warnings
- >=1.3: errors reported by the compiler too, causing erroneous code to be rejected

Nullability assertions on access to Java types annotated with @NotNull

Issue: KT-20830

Component: Kotlin/JVM

Incompatible change type: Behavioral

Short summary: nullability assertions for Java-types annotated with not-null annotations will be generated more aggressively, causing code which passes null here to fail faster.

Deprecation cycle:

- <1.3: the compiler could miss such assertions when type inference was involved, allowing potential null propagation during compilation against binaries (see Issue for details).
- >=1.3: the compiler generates missed assertions. This can cause code which was (erroneously) passing nulls here fail faster.

  -XXLanguage:-StrictJavaNullabilityAssertions can be used to temporarily return to the pre-1.3 behavior. Support for this flag will be removed in the next major release.

Unsound smartcasts on enum members

Issue: KT-20772

Component: Core language

Incompatible change type: Source

Short summary: a smartcast on a member of one enum entry will be correctly applied to only this enum entry

Deprecation cycle:

- <1.3: a smartcast on a member of one enum entry could lead to an unsound smartcast on the same member of other enum entries.
- >=1.3: smartcast will be properly applied only to the member of one enum entry.

  -XXLanguage:-SoundSmartcastForEnumEntries will temporarily return old behavior. Support for this flag will be removed in the next major release.

val backing field reassignment in getter

Issue: KT-16681

Components: Core language

Incompatible change type: Source

Short summary: reassignment of the backing field of val-property in its getter is now prohibited

Deprecation cycle:

- <1.2: Kotlin compiler allowed to modify backing field of val in its getter. Not only it violates Kotlin semantic, but also generates ill-behaved JVM bytecode which reassigns final field.
- 1.2.X: deprecation warning is reported on code which reassigns backing field of val
- >=1.3: deprecation warnings are elevated to errors

Array capturing before the for-loop where it is iterated

Issue: KT-21354

Component: Kotlin/JVM

Incompatible change type: Source

Short summary: if an expression in for-loop range is a local variable updated in a loop body, this change affects loop execution. This is inconsistent with iterating over other containers, such as ranges, character sequences, and collections.

Deprecation cycle:

- <1.2: described code patterns are compiled fine, but updates to local variable affect loop execution
- 1.2.X: deprecation warning reported if a range expression in a for-loop is an array-typed local variable which is assigned in a loop body
- 1.3: change behavior in such cases to be consistent with other containers

Nested classifiers in enum entries

Issue: KT-16310

Component: Core language

Incompatible change type: Source

Short summary: since Kotlin 1.3, nested classifiers (classes, object, interfaces, annotation classes, enum classes) in enum entries are prohibited

Deprecation cycle:

- <1.2: nested classifiers in enum entries are compiled fine, but may fail with exception at runtime
- 1.2.X: deprecation warnings reported on the nested classifiers
- >=1.3: deprecation warnings elevated to errors

Data class overriding copy

Issue: KT-19618

Components: Core language

Incompatible change type: Source

Short summary: since Kotlin 1.3, data classes are prohibited to override copy()

Deprecation cycle:

- <1.2: data classes overriding copy() are compiled fine but may fail at runtime/expose strange behavior
- 1.2.X: deprecation warnings reported on data classes overriding copy()
- >=1.3: deprecation warnings elevated to errors

Inner classes inheriting Throwable that capture generic parameters from the outer class

Issue: KT-17981

Component: Core language

Incompatible change type: Source

Short summary: since Kotlin 1.3, inner classes are not allowed to inherit Throwable

Deprecation cycle:

- <1.2: inner classes inheriting Throwable are compiled fine. If such inner classes happen to capture generic parameters, it could lead to strange code patterns which fail at runtime.
- 1.2.X: deprecation warnings reported on inner classes inheriting Throwable
- >=1.3: deprecation warnings elevated to errors

Visibility rules regarding complex class hierarchies with companion objects

Issues: KT-21515, KT-25333

Component: Core language

Incompatible change type: Source

Short summary: since Kotlin 1.3, rules of visibility by short names are stricter for complex class hierarchies involving companion objects and nested classifiers.

Deprecation cycle:

- <1.2: old visibility rules (see Issue for details)
- 1.2.X: deprecation warnings reported on short names which are not going to be accessible anymore. Tooling suggests automated migration by adding full name.
- >=1.3: deprecation warnings elevated to errors. Offending code should add full qualifiers or explicit imports

Non-constant vararg annotation parameters

Issue: KT-23153

Component: Core language

Incompatible change type: Source

Short summary: since Kotlin 1.3, setting non-constant values as vararg annotation parameters is prohibited

Deprecation cycle:

- <1.2: the compiler allows to pass non-constant value for vararg annotation parameter, but actually drops that value during bytecode generation, leading to non-obvious behavior
- 1.2.X: deprecation warnings reported on such code patterns
- >=1.3: deprecation warnings elevated to errors

Local annotation classes

Issue: KT-23277

Component: Core language

Incompatible change type: Source

Short summary: since Kotlin 1.3 local annotation classes are not supported

Deprecation cycle:

- <1.2: the compiler compiled local annotation classes fine
- 1.2.X: deprecation warnings reported on local annotation classes
- >=1.3: deprecation warnings elevated to errors

Smartcasts on local delegated properties

Issue: KT-22517

Component: Core language

Incompatible change type: Source

Short summary: since Kotlin 1.3 smartcasts on local delegated properties are not allowed

Deprecation cycle:

- <1.2: the compiler allowed to smartcast local delegated property, which could lead to unsound smartcast in case of ill-behaved delegates
- 1.2.X: smartcasts on local delegated properries are reported as deprecated (the compiler issues warnings)
- >=1.3: deprecation warnings elevated to errors

mod operator convention

Issues: KT-24197

Component: Core language

Incompatible change type: Source

Short summary: since Kotlin 1.3 declaration of mod operator is prohibited, as well as calls which resolve to such declarations

Deprecation cycle:

- 1.1.X, 1.2.X: report warnings on declarations of operator mod, as well as on calls which resolve to it
- 1.3.X: elevate warnings to error, but still allow to resolve to operator mod declarations
- 1.4.X: do not resolve calls to operator mod anymore

Passing single element to vararg in named form

Issues: KT-20588, KT-20589. See also KT-20171

Component: Core language

Incompatible change type: Source

Short summary: in Kotlin 1.3, assigning single element to vararg is deprecated and should be replaced with consecutive spread and array construction.

Deprecation cycle:

- <1.2: assigning one value element to vararg in named form compiles fine and is treated as assigning single element to array, causing non-obvious behavior when assigning array to vararg
- 1.2.X: deprecation warnings are reported on such assignments, users are suggested to switch to consecutive spread and array construction.
- 1.3.X: warnings are elevated to errors
- >= 1.4: change semantic of assigning single element to vararg, making assignment of array equivalent to the assignment of a spread of an array

Retention of annotations with target EXPRESSION

Issue: KT-13762

Component: Core language

Incompatible change type: Source

Short summary: since Kotlin 1.3, only SOURCE retention is allowed for annotations with target EXPRESSION

Deprecation cycle:

- <1.2: annotations with target EXPRESSION and retention other than SOURCE are allowed, but silently ignored at use-sites
- 1.2.X: deprecation warnings are reported on declarations of such annotations
- >=1.3: warnings are elevated to errors

Annotations with target PARAMETER shouldn't be applicable to parameter's type

Issue: KT-9580

Component: Core language

Incompatible change type: Source

Short summary: since Kotlin 1.3, error about wrong annotation target will be properly reported when annotation with target PARAMETER is applied to parameter's type

Deprecation cycle:

- <1.2: aforementioned code patterns are compiled fine; annotations are silently ignored and not present in the bytecode
- 1.2.X: deprecation warnings are reported on such usages
- >=1.3: warnings are elevated to errors

Array.copyOfRange throws an exception when indices are out of bounds instead of enlarging the returned array

Issue: KT-19489

Component: kotlin-stdlib (JVM)

Incompatible change type: Behavioral

Short summary: since Kotlin 1.3, ensure that the toIndex argument of Array.copyOfRange, which represents the exclusive end of the range being copied, is not greater than the array size and throw IllegalArgumentException if it is.

Deprecation cycle:

- <1.3: in case toIndex in the invocation of Array.copyOfRange is greater than the array size, the missing elements in range fill be filled with nulls, violating soundness of the Kotlin type system.
- >=1.3: check that toIndex is in the array bounds, and throw exception if it isn't

Progressions of ints and longs with a step of Int.MIN_VALUE and Long.MIN_VALUE are outlawed and won't be allowed to be instantiated

Issue: KT-17176

Component: kotlin-stdlib (JVM)

Incompatible change type: Behavioral

Short summary: since Kotlin 1.3, prohibit step value for integer progressions being the minimum negative value of its integer type (Long or Int), so that calling IntProgression.fromClosedRange(0, 1, step = Int.MIN_VALUE) will throw IllegalArgumentException

Deprecation cycle:

- <1.3: it was possible to create an IntProgression with Int.MIN_VALUE step, which yields two values [0, -2147483648], which is non-obvious behavior
- >=1.3: throw IllegalArgumentException if the step is the minimum negative value of its integer type

Check for index overflow in operations on very long sequences

Issue: KT-16097

Component: kotlin-stdlib (JVM)

Incompatible change type: Behavioral

Short summary: since Kotlin 1.3, make sure index, count and similar methods do not overflow for long sequences. See the Issue for the full list of affected methods.

Deprecation cycle:

- <1.3: calling such methods on very long sequences could produce negative results due to integer overflow
- >=1.3: detect overflow in such methods and throw exception immediately

Unify split by an empty match regex result across the platforms

Issue: KT-21049

Component: kotlin-stdlib (JVM)

Incompatible change type: Behavioral

Short summary: since Kotlin 1.3, unify behavior of split method by empty match regex across all platforms

Deprecation cycle:

- <1.3: behavior of described calls is different when comparing JS, JRE 6, JRE 7 versus JRE 8+
- >=1.3: unify behavior across the platforms

Discontinued deprecated artifacts in the compiler distribution

Issue: KT-23799

Component: other

Incompatible change type: Binary

Short summary: Kotlin 1.3 discontinues the following deprecated binary artifacts:

- kotlin-runtime: use kotlin-stdlib instead
- kotlin-stdlib-jre7/8: use kotlin-stdlib-jdk7/8 instead
- kotlin-jslib in the compiler distribution: use kotlin-stdlib-js instead

Deprecation cycle:

- 1.2.X: the artifacts were marked as deprecated, the compiler reported warning on usage of those artifacts
- >=1.3: the artifacts are discontinued

Annotations in stdlib

Issue: KT-21784

Component: kotlin-stdlib (JVM)

Incompatible change type: Binary

Short summary: Kotlin 1.3 removes annotations from the package org.jetbrains.annotations from stdlib and moves them to the separate artifacts shipped with the compiler: annotations-13.0.jar and mutability-annotations-compat.jar

Deprecation cycle:

- <1.3: annotations were shipped with the stdlib artifact
- >=1.3: annotations ship in separate artifacts

Compatibility modes

When a big team is migrating onto a new version, it may appear in an "inconsistent state" at some point, when some developers have already updated but others haven't. To prevent the former from writing and committing code that others may not be able to compile, we provide the following command line switches (also available in the IDE and Gradle/Maven):

- -language-version X.Y - compatibility mode for Kotlin language version X.Y, reports errors for all language features that came out later.
- -api-version X.Y - compatibility mode for Kotlin API version X.Y, reports errors for all code using newer APIs from the Kotlin Standard Library (including the code generated by the compiler).

Currently, we support the development for at least three previous language and API versions in addition to the latest stable one.

Google Summer of Code with Kotlin

The Kotlin Foundation provides mentorship for Google Summer of Code (GSoC), a global online program that introduces new contributors to open-source development.

Learn more about GSoC on the official Google Summer of Code website.

GSoC 2025: project ideas

The Kotlin Foundation has published a list of project ideas for Google Summer of Code 2025. If you're interested in contributing, check out the available projects and guidelines: Google Summer of Code with Kotlin 2025.

Past GSoC projects with Kotlin

You can explore past Google Summer of Code projects and ideas with Kotlin:

- Google Summer of Code with Kotlin 2024
- Google Summer of Code with Kotlin 2023

Google Summer of Code with Kotlin 2025

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   - Read the official documentation to get a better understanding of the language.
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   - Follow the Kotlin X or Kotlin Bluesky accounts to stay up to date on the latest news and developments.
   - Check out the Kotlin YouTube channel for tutorials, tips, and the latest updates.
3. Get to know the Kotlin open source community:
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   - Join the Kotlin Slack channel to connect with other developers and get help with any questions you may have.
   - Join the #gsoc channel to ask questions and get support from the GSoC team.

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2. If you are not familiar with Kotlin, read the introductory info on the Kotlin website.
3. Refer to the GSoC contributor guidelines.
4. Apply via the GSoC website.
   - We suggest that you write a working code sample relevant to the proposed project. You can also show us any code sample that you are particularly proud of.
   - Describe why you are interested in Kotlin and your experience with it.
   - If you participate in open source projects, please reference your contribution history.

- If you have a GitHub, Twitter account, blog, or portfolio of technical or scientific publications, please reference them as well.
- Disclose any conflicts with the GSoC timeline due to other commitments, such as exams and vacations.

Thank you! We look forward to reading your applications!

Project ideas

Build Server Protocol: add Kotlin support [Hard, 350 hrs]

The Kotlin team wants to expand official Kotlin support not only for Gradle and Maven build systems, but any other build system as well and support them natively in JetBrains IDEs with minimal effort. On the other hand, we also want to provide basic Kotlin support in non-JetBrains IDEs – one part of such support is being able to get Kotlin-specific information from any build system supporting Kotlin.

The solution to these requirements could be a Build Server Protocol (BSP) which provides an abstraction layer between the build system and IDE.

The goal of this project would be implementing a prototype which uses the BSP protocol to get all the required information for IntelliJ IDEA from a user project so that it will be possible to work with Kotlin code in the project. To limit the scope of this prototype, the user project will use Gradle to build itself automatically.

Preferred skills

- Knowledge of Kotlin
- Understanding of how to write Gradle plugins
- Bonus: understanding of how to write plugins for IntelliJ IDEA

Possible mentors

Yahor Berdnikau, Bálint Hegyi, and Reinhold Degenfellner

Tasks for applicants

- Task #1. Why are you interested in this project?
- Task #2. Practice assignment: Create a Gradle plugin which exposes a specific task. This task should, in the presence of the Kotlin Gradle Plugin, retrieve all the Kotlin sources' structures and output them. Including tests would be a bonus.

Support Android and iOS targets in Kotlin Multiplatform for Gemini using Vertex AI in Firebase [Medium, 175 hrs]

This project aims to create an open-source Kotlin Multiplatform (KMP) library that supports Gemini using Vertex AI in Firebase on at least Android and iOS. It will showcase best practices in creating KMP libraries for existing services, with a focus on appropriate production implementation (for example, proper API key management, user-managed API keys support, and client throttling).

Expected outcomes

- A new Kotlin Multiplatform library with support for an existing Google service
- Sample code and documentation

Preferred skills

- Kotlin
- Kotlin Multiplatform
- Mobile development (Android and iOS)

Possible mentors

Matt Dyor, and the Google team

Add Kotlin Multiplatform support in Bazel [Hard, 350 hrs]

Bazel's support for Kotlin is evolving, but proper Kotlin Multiplatform (KMP) integration remains a challenge. This project aims to improve Bazel's KMP support by addressing dependency resolution issues, enhancing rules_kotlin and rules_jvm_external compatibility, and enabling cross-platform builds.

Key improvements will focus on handling platform-specific dependencies (expect/actual mechanisms), improving Gradle metadata support, and ensuring a smoother developer experience for KMP in Bazel.

Expected outcomes

- Enhanced dependency resolution for Kotlin Multiplatform in Bazel
- Improved integration with rules_kotlin and rules_jvm_external
- A working KMP build setup in Bazel for seamless multiplatform development

Preferred skills

- Kotlin Multiplatform and Gradle
- Bazel build system
- Dependency resolution strategies

Possible mentors

Shauvik Roy Choudhary, and the Uber team

Kotlin Language Server (LSP) [Hard, 350 hrs]

The Language Server Protocol (LSP) is a widely adopted standard that enables code intelligence features such as autocompletion, go-to definition, and refactoring across different editors and IDEs. While there is currently no official Kotlin LSP server, there is significant demand for one in the community. A publicly maintained, community-driven implementation can support broad use cases, including code migration, AI-powered code assistance, and seamless integration into various development environments.

This project aims to develop a Kotlin LSP implementation, ensuring compatibility with key LSP features and broadening Kotlin's accessibility across development environments.

Expected outcomes

Develop a Kotlin LSP implementation

Preferred skills

- Kotlin
- Language Server Protocol (LSP)
- Plugin or extension development for IDEs

Possible mentors

Shauvik Roy Choudhary, and the Uber team

Maven Central publishing plugin for Gradle with new APIs [Medium, 175 hrs]

Maven Central is one of the most popular Maven repositories for publishing JVM-focused libraries and projects. It is actively used by Apache Maven or Gradle-based open-source projects, and based on Sonatype Nexus v2, pending migration to a newer version. There is ongoing migration of open source projects to a new Maven Central Instance, which has a very different API implementation and needs special support in the build tool plugins. Developing a Gradle plugin that is compatible with the new Maven Central publication APIs would help the library authors building with Gradle to have a smooth experience with the new process.

Currently, there are multiple implementations of Maven Central publishing plugins in Gradle, for example, the Maven Publish Plugin or the New Maven Central Publishing, which already tries to adopt the new APIs. During the application or the community bonding phase, a potential contributor would need to review the implementations and either suggest an existing plugin to update or decide to build a new plugin or fork. The deliverables would include either a new version of an existing plugin for Maven Central publishing or a new plugin for Gradle. We anticipate the implementation to be in Kotlin or Java and to have proper test coverage and documentation. Additional deliverables may include Kotlin DSL extensions to simplify the use of the plugins and Declarative Gradle extensions.

Expected outcomes

- Updated Maven Central publishing plugin or a new plugin

Preferred skills

- Kotlin

- Gradle
- Maven Repositories

Possible mentors

Oleg Nenashev, and the Gradle team

Improving Configuration Cache and lock contention in key Gradle plugins [Easy to Hard, 90 hrs to 350 hrs]

Gradle is working on Isolated Projects – a new feature that greatly extends the configuration cache to further improve performance, particularly the performance of Android Studio and IntelliJ IDEA sync. From the developer experience standpoint, it is one of the most expected features in Gradle.

One of the problems for Isolated projects is the lock contention in the Gradle core, with plugins sometimes getting in the way of parallel execution. We would like to reduce the lock contention, especially in the key Gradle Build Tool plugins for Java, Kotlin, Android, and Kotlin Multiplatform ecosystems. Contributors are welcome to choose the deliverables based on their interests and the desired project size.

Potential deliverables include but are not limited to:

- Embed the Configuration Cache Report tool into the Gradle Profiler (or "implement a GitHub Action for it")
- Profile Gradle and a few popular Gradle plugins in various projects, with automation of the test suite on GHA
- Determine potential areas and plugins where lock contention can be reduced, with or without Configuration Cache
- While around, contribute to other areas of Configuration Cache compatibility in the target plugins
- Implement some of the discovered improvements

Expected outcomes

Implementing extensibility features in the Kotlin DSL for Gradle and improving support for common project integrations

Preferred skills

- Kotlin
- Gradle
- Java
- Performance analysis
- Profiling

Possible mentors

Oleg Nenashev, Laura Kassovic

Gradle convention plugin for developing Jenkins plugins [Easy to Hard, 90 hrs to 350 hrs]

There are more than 50 Jenkins plugins that are implemented with Gradle. There is a Gradle JPI plugin, but it is not fully compliant with Jenkins hosting requirements and needs an update. In this project idea, the aim would be to recover the Gradle developer flow for Jenkins, reach feature parity with the Apache Maven flow (Parent POM, Plugin Compatibility Tester, Jenkins Bill of Materials, and others), and to improve the developer experience for those who develop Jenkins plugins with Gradle.

Contributors are welcome to choose the deliverables based on their interest and the desired project size.

Potential deliverables include but are not limited to:

- Refreshing the Gradle JPI plugin and making it compliant with hosting best practices
- Migrating the Gradle JPI plugin codebase from Groovy to Kotlin
- Implementing a new convention plugin for Jenkins Plugins that would cover the main features of Jenkins plugin Parent POM, with Kotlin and Kotlin DSL. This would include not just building the plugin, but also testing and static analysis according to Jenkins' best practices
- Adopting the refreshed plugin and/or the convention plugin in the most popular Gradle plugin, including the Gradle plugin itself
- Integrating the Gradle plugin into the Plugin Compatibility Tester and Bill of Materials

- Documenting the updated Gradle development flow for Jenkins plugins

Expected outcomes

Updated Gradle JPI plugin and/or new convention plugin for Jenkins, published on Jenkins Update Center and the Gradle Plugin Portal

Preferred skills

- Kotlin DSL
- Kotlin
- Gradle
- Jenkins
- Java

Possible mentors

Oleg Nenashev, Stefan Wolf

Kotlin DSL and Declarative Gradle documentation samples test framework [Easy to Medium, 90 hrs to 175 hrs]

Many projects, including Gradle, have a lot of Kotlin DSL samples and code snippets (see the Gradle Docs for examples). Testing them against multiple versions poses certain challenges because the snippets often represent incomplete code for the sake of brevity. We would like to build a test framework that simplifies the verification of those samples within a unit test framework (Kotest or JUnit 5) on GitHub Actions or TeamCity. Later we would be interested in doing the same for Declarative Gradle samples.

Expected outcomes

Implementing extensibility features in the Kotlin DSL for Gradle and improving support for common project integrations

Preferred skills

- Kotlin
- Gradle
- Java
- Static analysis

Possible mentors

Oleg Nenashev, Laura Kassovic

IntelliJ Platform Gradle Plugin – Gradle Reporting and Parallel Verifications [Medium, 175 hrs]

The IntelliJ Platform Gradle Plugin, a plugin for the Gradle build system, simplifies configuring your environment for building, testing, verifying, and publishing plugins for IntelliJ-based IDEs. The plugin manages the build, test, and verification steps while keeping up with the constant changes introduced in the IntelliJ Platform. The IntelliJ Platform Gradle Plugin is used by JetBrains, third-party developers, and external companies to integrate their workflows with JetBrains tools.

Expected outcomes

- Introduce Gradle Reporting to provide detailed, configurable verification task reports.
- Utilize Gradle Worker API to enable parallel execution of the verifyPlugin task against multiple IntelliJ Platform versions, reducing the task execution time.
- Explore additional Gradle enhancements to further improve plugin development workflows.

Preferred skills

- Kotlin
- Gradle
- IntelliJ Platform

Possible mentors

Jakub Chrzanowski, JetBrains

Add More Kotlin OpenRewrite Recipes [Medium, 175 hrs]

OpenRewrite is a powerful framework for automating code migrations and refactorings in a structured manner. While OpenRewrite has strong support for Java, the Kotlin ecosystem would benefit from a more comprehensive set of OpenRewrite recipes to help developers seamlessly migrate their codebases.

This project aims to expand the Kotlin OpenRewrite recipe collection by adding more automated transformations, such as migrating Java-based AutoValue classes to idiomatic Kotlin data classes, modernizing Kotlin code to follow best practices, and enabling more seamless migrations across Kotlin versions. These recipes will help Kotlin developers maintain clean, up-to-date, and idiomatic codebases with minimal manual effort.

Expected outcomes

- Development of new OpenRewrite recipes for Kotlin code migrations

Preferred skills

- Kotlin
- OpenRewrite framework
- Java-to-Kotlin migration strategies

Possible mentors

Shauvik Roy Choudhary, and the Uber team

Add BOM Support to Bazel rules_jvm_external [Hard, 350 hrs]

Bazel's rules_jvm_external provides a structured way to declare external Java dependencies, but it currently lacks proper support for Bill of Materials (BOM) files. BOM files are widely used in Maven and Gradle to manage dependencies in a consistent manner without requiring developers to specify individual versions. This project aims to enhance rules_jvm_external by adding BOM support, allowing developers to use BOM-based dependency resolution within Bazel. The project may involve contributing to an existing open-source effort or implementing BOM support directly in rules_jvm_external, ensuring compatibility with widely used dependency management approaches.

Expected outcomes

- Implementation of BOM support in Bazel rules_jvm_external
- Improved dependency resolution and usability for Bazel users
- Documentation and examples for using BOM support in Bazel

Preferred skills

- Starlark (Bazel's scripting language)
- Bazel build system
- Dependency resolution strategies

Possible mentors

Shauvik Roy Choudhary, and the Uber team

Clean and actionable reporting for Gradle code quality plugins for Kotlin [Easy to Medium, 90 hrs to 175 hrs]

Gradle recently introduced a new Problems API that allows Gradle and third-party plugins to propagate issues and warnings in a unified way. This API provides clean and actionable error reporting and more insights into the console output, dedicated HTML reports, and connected observability tools. IDEs such as IntelliJ IDEA or Android Studio can also access the details via Gradle's API integration tool, and can show warnings right in the code editor. Several core features and plugins have already adopted the Problems API: Java compilation, dependency resolution errors, deprecation warnings, etc. We want the code quality plugins for Kotlin to adopt this API, too; it would significantly improve the developer experience for 100,000+ Kotlin developers using Gradle.

In this project, we invite contributors to choose a number of Kotlin code quality plugins, such as Ktlint, Detekt, Diktat, ArchUnit, or Checkstyle for Kotlin, and integrate them with Problems API. You can also work on integrating a similar analysis for Gradle builds defined with KotlinDSL.

Expected outcomes

- Implement Problems API integration in the mentioned plugins

Preferred skills

- Kotlin
- Gradle

Possible mentors

Oleg Nenashev, Balint Hegyi, Reinhold Degenfellner

Google Summer of Code with Kotlin 2024

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   - Describe why you are interested in Kotlin and your experience with it.
   - If you participate in open source projects, please reference your contribution history.

- If you have a GitHub, Twitter account, blog, or portfolio of technical or scientific publications, please reference them as well.
- Disclose any conflicts with the GSoC timeline due to other commitments, such as exams and vacations.

Thank you! We look forward to reading your applications!

Project ideas

Incremental compilation for the Kotlin-to-WebAssembly compiler [Hard, 350 hrs]

Incremental compilation is a technique that helps increase compilation speed by recompiling only changed files instead of your whole program (also known as performing a clean build). The Kotlin-to-Wasm compiler currently supports only clean builds, but during this project, we will enhance it to support incremental compilation, too.

Expected outcomes

Implementation of the incremental compilation feature in the Kotlin-to-WebAssembly compiler, contributing to faster development workflows.

Skills required (preferred)

Kotlin

Possible mentor

Artem Kobzar, JetBrains

Compose Multiplatform with Node.js native bindings for Skia [Hard, 350 hrs]

Compose Multiplatform is a declarative framework for sharing UIs built with Kotlin across multiple platforms. The current approach to rendering desktop applications uses the JVM as a platform, but what if we use Compose Multiplatform for Web and try to run an application outside the browser with Skia's native bindings? Will this improve desktop applications performance and memory consumption? Or will it do the opposite? We'll find out in this project!

Expected outcomes

Integration of Skia bindings with Compose Multiplatform and evaluation of performance impact on desktop applications.

Skills required (preferred)

Kotlin, Node.js, C++, or Rust

Possible mentor

Artem Kobzar, JetBrains

Compose Multiplatform component gallery generator [Medium, 350 hrs]

Compose Multiplatform is a declarative framework for sharing UIs built with Kotlin across multiple platforms. At the beginning of the React era of web development, Storybook was created, and Storybook's proposed approach of describing component states and generating the whole UI library gallery is still one of the essential approaches to documentation in web development. Can we do the same with Compose Multiplatform, using it to generate a gallery of web UI elements, as well as galleries for mobile and desktop? Let's give it a try in this project.

Expected outcomes

Creation of a tool to generate UI component galleries for web, mobile, and desktop platforms using Compose Multiplatform.

Skills required (preferred)

Kotlin, Jetpack Compose, UI/UX Design

Possible mentor

Artem Kobzar, JetBrains

Kotlin DSL improvements for declarative Gradle [Medium, 175 hrs]

Last November, the Gradle team announced the new Declarative Gradle project, introducing a higher level Kotlin DSL in the project. We invite GSoC contributors to join us and work on improving the developer experience of the new DSL, in particular by implementing extensibility in Gradle plugins to support the most common Kotlin and Java project integrations: static analysis, test frameworks like Kotest and others.

Expected outcomes

Implementing extensibility features in the Kotlin DSL for Gradle and improving support for common project integrations.

Skills required (preferred)

Kotlin, Gradle, Java, Static Analysis

Possible mentor

Oleg Nenashev, Gradle

Gradle guidelines

Kotlin DSL documentation samples test framework [Easy or Medium, 90 hrs or 175 hrs]

Many projects, including Gradle, have a lot of Kotlin DSL samples and code snippets (see the Gradle Docs for examples). Testing them against multiple versions poses certain challenges because the snippets often represent incomplete code for the sake of brevity. We would like to build a test framework that simplifies the verification of those samples within a unit test framework (Kotest or JUnit 5) on GitHub Actions and Teamcity.

Expected outcomes

Implementation of a basic test framework for Kotlin DSL samples, integrated with GitHub Actions for continuous testing.

Skills required (preferred)

Kotlin, Testing Frameworks, CI/CD

Possible mentor

Oleg Nenashev, Gradle

Gradle guidelines

Gradle build server – support for Android projects [Medium or Hard, 175 hrs or 350 hrs]

Kotlin and Gradle are the default choices for building Android projects. In November 2023, the Microsoft team announced the Gradle Build Server project, which is a Gradle-specific implementation of the Build Server Protocol (BSP). It would be great to introduce full support for Android builds there. For smaller-scope projects, it is possible to implement auto-discovery and cancellation for Gradle tasks in the Gradle Build Server.

Expected outcomes

Implementation of Android project support in the Gradle Build Server, including auto-discovery and task cancellation.

Skills required (preferred)

Kotlin, Gradle, Android Development, Visual Studio Code

Possible mentor

Oleg Nenashev, Gradle

Gradle guidelines

Implement memory usage profiling for Kotlin/Native benchmarks [Medium, 175 hrs]

The kotlinx-benchmark library, an open-source toolkit, facilitates the benchmarking of Kotlin code across various platforms. It currently features GC profiling for the JVM, detailing each benchmark method's allocation rate. This project aims to extend similar profiling capabilities to Kotlin/Native, advancing toward uniform benchmarking capabilities across platforms.

The contributor will collaborate closely with the Kotlin/Native team to create an API for accessing allocation data from the Kotlin/Native memory manager. The objective is to generate reports that align with the JVM format, ensuring the consistency of data presentation across platforms. Furthermore, the project involves identifying and rectifying any discrepancies in reporting formats for other library features, thereby standardizing the benchmarking output for comprehensive cross-platform analysis.

Expected outcomes

Implementation of memory usage profiling in kotlinx-benchmark for Kotlin/Native and standardized benchmarking output.

Skills required (preferred)

Kotlin, Kotlin/Native, Benchmarking, Memory Profiling

Possible mentor

Abduqodiri Qurbonzoda, JetBrains
Alexander Shabalin, JetBrains

Support Android target in kotlinx-benchmark [Medium, 175 hrs]

The kotlinx-benchmark library is an open-source tool designed for benchmarking Kotlin code across multiple platforms, including the JVM, JS, WasmJs, and Native. Despite its broad compatibility, the library currently does not support benchmarking on Android. This project aims to bridge that gap. The plan is to utilize an existing Android library, such as androidx.benchmark, behind the scenes to integrate this functionality. A key aspect of the project will be ensuring that all features currently available for other platforms are also supported on Android, maintaining the library's multiplatform utility.

Expected outcomes

Integration of benchmarking support for Android platforms in kotlinx-benchmark, ensuring feature parity with other platforms.

Skills required (preferred)

Kotlin, Android Development, Benchmarking

Possible mentor

Abduqodiri Qurbonzoda, JetBrains
Rahul Ravikumar, Google

Enabling click-to-run for kotlinx-benchmark benchmarks in IntelliJ IDEA [Medium, 175 hrs]

kotlinx-benchmark is an open-source library for benchmarking multiplatform code written in Kotlin. It includes a Gradle plugin that, when applied, provides tasks for running benchmarks. However, executing these tasks requires navigating to the IDE's Gradle panel or using the terminal. Additionally, running a specific benchmark necessitates further steps, adding to the complication. To mitigate this inconvenience and streamline the process, this project aims to enable users to run an individual benchmark or an entire suite directly from the IntelliJ IDEA interface, mirroring the convenience offered for unit tests. Achieving this goal may necessitate collaboration with the IntelliJ IDEA team and/or contributions directly to the IntelliJ project.

Expected outcomes

Integration of click-to-run functionality for kotlinx-benchmark benchmarks in IntelliJ IDEA, improving user experience.

Skills required (preferred)

Kotlin, IntelliJ IDEA Plugin Development, Benchmarking

Possible mentor

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Google Summer of Code with Kotlin 2023

This article contains the list of project ideas for Google Summer of Code with Kotlin 2023.

Google Summer of Code 2023 has already ended. If you want to participate in GSoC 2024, check out this list of project ideas.

Project ideas

Kotlin Multiplatform protobufs [Hard, 350 hrs]

Description

Add support for Kotlin/Common protos to protoc with Kotlin/Native (iOS) runtime and Objective-C interop.

Motivation

While protobufs have many platform implementations, there isn't a way to use them in Kotlin Multiplatform projects.

Expected outcomes

Design and build Kotlin Multiplatform Protobuf support, culminating in contributions to:

- GitHub – protocolbuffers/protobuf: Protocol Buffers – Google's data interchange format
- GitHub – google/protobuf-gradle-plugin
- Kotlin Multiplatform Gradle Plugin

Skills required (preferred)

- Kotlin
- Objective-C
- C++

Kotlin Compiler error messages [Hard, 350 hrs]

Description

Add improved compiler error messages to the K2 Kotlin compiler: more actionable and detailed information (like Rust has).

Motivation

Rust compiler error messages are often regarded as being by far the most helpful of any compiler. The Kotlin K2 compiler provides a great foundation for better compiler errors in Kotlin but this potential is somewhat untapped.

Expected outcomes

Using StackOverflow and other data sources, uncover common compiler errors which would have significant value to users. Make contributions back to the compiler to improve those error messages.

Skills required (preferred)

- Kotlin
- Compiler architecture

Kotlin Multiplatform libraries [Easy or Medium, 175 or 350 hrs]

Description

Create and deliver (to Maven Central) Kotlin Multiplatform libraries that are commonly needed. For instance, compression, crypto.

Motivation

Kotlin Multiplatform is still fairly new and could use some additional libraries which are either platform independent (Kotlin/Common) and/or have platform implementations (expect/actual).

Expected outcomes

Design and deliver at least one Kotlin Multiplatform library with a greater priority on JVM/Android and Kotlin/Native (iOS) than other targets (Kotlin/JS).

Skills required (preferred)

- Kotlin
- Objective-C

Groovy to Kotlin Gradle DSL Converter [Medium, 350 hrs]

Description

The project aims to create a Groovy-to-Kotlin converter with a primary focus on Gradle scripts. We will start from basic use cases, such as when a user wants to paste Groovy-style dependency declarations to a Kotlin script and the IDE automatically converts them. Later, we will start supporting more complex code constructs and conversions of complete files.

Motivation

The Kotlin Gradle DSL is gaining popularity, so much so that it will soon become the default choice for building projects with Gradle. However, many documents and resources about Gradle still refer to Groovy, and pasting Groovy samples into build.gradle.kts requires manual editing. Furthermore, many new features around Gradle will be in Kotlin first, and consequently users will migrate from the Groovy DSL to the Kotlin DSL. The automatic code conversion of a build setup will therefore greatly ease this migration, saving a lot of time.

Expected outcomes

A plugin for IntelliJ IDEA that can convert Groovy code to Kotlin with the main focus on the Gradle DSL.

Skills required (preferred)

- Basic knowledge of Gradle
- Basic knowledge of parsers and how compilers work in general
- Basic knowledge of Kotlin

Eclipse Gradle KTS editing [Medium, 350 hrs]

Read the blog post about this project

Description

Improve the experience of editing Gradle Kotlin Scripts (KTS) in Eclipse.

Motivation

IntelliJ IDEA and Android Studio have great support for editing KTS Gradle build scripts, but the Eclipse support is lacking. Ctrl-Click to definition, Code completion, Code error highlighting could all be improved.

Expected outcomes

Make contributions to the Gradle Eclipse plugin that improve the developer experience for editing KTS.

Skills required (preferred)

- Kotlin
- Gradle
- Eclipse platform and plugins

Improve support for parameter forwarding in the Kotlin Plugin for IntelliJ IDEA [Medium, 350 hrs]

Description and motivation

The Kotlin plugin provides Kotlin language support in IntelliJ IDEA and Android Studio. In the scope of this project, you will improve parameter forwarding support for the plugin.

To prefer composition over inheritance is a widely known principle. IntelliJ IDEA provides great support for writing code that uses inheritance (completion and quick-fixes the IDE suggests), but the support for code that uses composition instead of inheritance has yet to be implemented.

The main problem of working with code that heavily uses composition is parameter forwarding. In particular:

- The IDE doesn't suggest completing parameter declarations that can be forwarded as arguments to other functions that currently use default arguments.
- The IDE doesn't rename the chain of forwarded parameters.

- The IDE doesn't provide any quick-fixes that fill in all the required arguments with parameters that can be forwarded.

One notable example where such support would be greatly appreciated is Jetpack Compose. Android's modern tool kit for building UI, Jetpack Compose heavily uses function composition and parameter forwarding. It quickly becomes tedious to work with @Composable functions because they have a lot of parameters. For example, androidx.compose.material.TextField has 19 parameters.

Expected outcomes

- Improved parameter and argument completion suggestions in IntelliJ IDEA.
- Implemented IDE quick-fixes that suggest filling in all the required arguments with parameters with the same names and types.
- The Rename refactoring renames the chain of forwarded parameters.
- All other IDE improvements around parameter forwarding and functions that have a lot of parameters.

Skills required (preferred)

- Knowledge of Kotlin and Java
- Ability to navigate in a large codebase

Enhance the kotlinx-benchmark library API and user experience [Easy, 175 hrs]

Read the blog post about this project

Description

kotlinx-benchmark is an open-source library for benchmarking multiplatform code written in Kotlin. It has a barebones skeleton but lacks quality-of-life features, such as fine-grained benchmark configuration (like time units, modes), feature parity between JVM and Kotlin/Native benchmarking, a command-line API, and modern Gradle support. Its documentation, integration tests, and examples are also lagging.

Motivation

The library has already been implemented, but it is sometimes difficult to use correctly and confuses some users. Improving the library's user experience would greatly help the Kotlin community.

Expected outcomes

- The library has clear documentation with usage examples.
- The library API is simple and easy to use.
- Options for benchmarking Kotlin/JVM code are also available for benchmarking code on other platforms.

Skills required (preferred)

- Kotlin
- Gradle internals

Parallel stacks for Kotlin Coroutines in the debugger [Hard, 350 hrs]

Read the blog post about this project

Description

Implement Parallel Stacks view for Kotlin coroutines to improve the coroutine debugging experience.

Motivation

Currently, support for coroutines debugging is very limited in IntelliJ IDEA. The Kotlin debugger has the Coroutines Panel that allows a user to view all of the coroutines and their states, but it's not very helpful when debugging an application with lots of coroutines in it. The JetBrains Rider has the Parallel Stacks feature that allows a user to inspect threads and their stack traces in a graph view, which could be a great way of inspecting coroutines.

Expected outcomes

Using the Kotlin coroutines debugger API, develop the IntelliJ IDEA plugin which would add the parallel stacks view for coroutines to the debugger. Find ways to improve the graph representation of coroutines.

Skills required (preferred)

- Kotlin
- Kotlin coroutines
- IntelliJ IDEA plugin development

Security

We do our best to make sure our products are free of security vulnerabilities. To reduce the risk of introducing a vulnerability, you can follow these best practices:

- Always use the latest Kotlin release. For security purposes, we sign our releases published on Maven Central with these PGP keys:
  - Key ID: kt-a@jetbrains.com
  - Fingerprint: 2FBA 29D0 8D2E 25EE 84C1 32C3 0729 A0AF F899 9A87
  - Key size: RSA 3072
- Use the latest versions of your application's dependencies. If you need to use a specific version of a dependency, periodically check if any new security vulnerabilities have been discovered. You can follow the guidelines from GitHub or browse known vulnerabilities in the CVE base.

We are very eager and grateful to hear about any security issues you find. To report vulnerabilities that you discover in Kotlin, please post a message directly to our issue tracker or send us an email.

For more information on how our responsible disclosure process works, please check the JetBrains Coordinated Disclosure Policy.

Kotlin documentation as PDF

Here you can download a PDF version of Kotlin documentation that includes everything except tutorials and API reference.

Download Kotlin 2.1.20 documentation (PDF)

View the latest Kotlin documentation (online)

Contribution

Kotlin is an open-source project under the Apache 2.0 License. The source code, tooling, documentation, and even this website are maintained on GitHub. Kotlin is developed by JetBrains, but we are always on the lookout for more people to help us.

Participate in Early Access Preview

You can help us improve Kotlin by participating in Kotlin Early Access Preview (EAP) and providing us with your valuable feedback.

For every release, Kotlin ships a few preview builds where you can try out the latest features before they go to production. You can report any bugs you find to our issue tracker YouTrack and we will try to fix them before a final release. This way, you can get bug fixes earlier than the standard Kotlin release cycle.

Contribute to the compiler and standard library

If you want to contribute to the Kotlin compiler and standard library, go to JetBrains/Kotlin GitHub, check out the latest Kotlin version, and follow the instructions on how to contribute.

You can help us by completing open tasks. Please keep an open line of communication with us because we may have questions and comments on your changes. Otherwise, we won't be able to incorporate your contributions.

Contribute to the Kotlin IDE plugin

Kotlin IDE plugin is a part of the IntelliJ IDEA repository.

To contribute to the Kotlin IDE plugin, clone the IntelliJ IDEA repository and follow the instructions on how to contribute.

Contribute to other Kotlin libraries and tools

Besides the standard library that provides core capabilities, Kotlin has a number of additional (kotlinx) libraries that extend its functionality. Each kotlinx library is developed in a separate repository, has its own versioning and release cycle.

If you want to contribute to a kotlinx library (such as kotlinx.coroutines or kotlinx.serialization) and tools, go to Kotlin GitHub, choose the repository you are interested in and clone it.

Follow the contribution process described for each library and tool, such as kotlinx.serialization, ktor and others.

If you have a library that could be useful to other Kotlin developers, let us know via feedback@kotlinlang.org.

Contribute to the documentation

If you've found an issue in the Kotlin documentation, feel free to check out the documentation source code on GitHub and send us a pull request. Follow these guidelines on style and formatting.

Please keep an open line of communication with us because we may have questions and comments on your changes. Otherwise, we won't be able to incorporate your contributions.

Translate documentation to other languages

You are welcome to translate the Kotlin documentation into your own language and publish the translation on your website. However, we won't be able to host your translation in the main repository and publish it on kotlinlang.org.

This site is the official documentation for the language, and we ensure that all the information here is correct and up to date. Unfortunately, we won't be able to review documentation in other languages.

Hold events and presentations

If you've given or just plan to give presentations or hold events on Kotlin, please fill out the form. We'll feature them on the event list.

KUG guidelines

A Kotlin User Group, or KUG, is a community that is dedicated to Kotlin and that offers you a place to share your Kotlin programming experience with like-minded people.

To become a KUG, your community should have some specific features shared by every KUG. It should:

- Provide Kotlin-related content, with regular meetups as the main form of activity.
- Host regular events (at least once every 3 months) with open registration and without any restriction for attendance.
- Be driven and organized by the community, and it should not use events to earn money or gain any other business benefits from members and attendees.
- Follow and ensure a code of conduct to provide a welcoming environment for attendees of any background and experience (check out our recommended Code of Conduct).

There are no limits regarding the format for KUG meetups. They can take place in whatever fashion works best for the community, whether that includes presentations, hands-on labs, lectures, hackathons, or informal beer-driven get-togethers.

For Kotlin User Group brand assets, see Kotlin brand assets documentation.

How to run a KUG?

- To promote group cohesion and prevent miscommunication, we recommend keeping to a limit of one KUG per city. Check out the list of KUGs to see if there is already a KUG in your area.
- Use the official KUG logo and branding. Check out the branding guidelines.
- Keep your user group active. Run meetups regularly, at least once every 3 months.
- Announce your KUG meetups at least 2 weeks in advance. The announcement should contain a list of talks and the names of the speakers, as well as the location, timing, and any other crucial info about the event.
- KUG events should be free or, if you need to cover organizing expenses, limit prices to a maximum of 10 USD.
- Your group should have a code of conduct available for all members.

If your community has all the necessary features and follows these guidelines, you are ready to Apply to be a new KUG.

Have a question? Contact us

Support for KUGs from JetBrains

Active KUGs that host at least 1 meetup every 3 months can apply for the community support program, which includes:

- Official KUG branding.
- A special entry on the Kotlin website.
- Free licenses for JetBrains products to raffle off at meetups.
- Priority support for Kotlin events and campaigns.
- Help with recruiting Kotlin speakers for your events.

Support from JetBrains for other tech communities

If you organize any other tech communities, you can apply for support as well. By doing so, you may receive:

- Free licenses for JetBrains products to raffle off at meetups.
- Information about Kotlin official events and campaigns.
- Kotlin stickers.
- Help with recruiting Kotlin speakers for your events.

Kotlin Night guidelines

Kotlin Night is a meetup that includes 3-4 talks on Kotlin or related technologies.

For Kotlin Night brand assets, see Kotlin brand assets documentation.

Event guidelines

- Please use the branding materials we've provided. Having all events and materials in the same style will help keep the Kotlin Night experience consistent.
- Kotlin Night should be a free event. A minimal fee can be charged to cover expenses, but it should remain a non-profit event.
- The event should be announced publicly and open for all people to attend without any kind of discrimination.
- If you publish the contents of the talks online after the event, they must be free and accessible to everyone, without any sign-up or registration procedures.

- Recordings are optional but recommended, and they should also be made available. If you decide to record the talks, we suggest having a plan to ensure the quality is good.
- The talks should primarily be about Kotlin and should not focus on marketing or sales.
- The event can serve food and drinks optionally.

Event requirements

JetBrains is excited to support your Kotlin Night event. Because we want all events to provide the same high-quality experience, we need organizers to ensure that some basic requirements are met for the event to receive JetBrains support. As an organizer, you are responsible for the following aspects of the event:

1. The location and everything required to host the event, including booking a comfortable venue. Please make sure that:
   - All the participants are aware of the exact date, place, and starting time of the event, along with the event schedule and program.
   - There is enough space as well as food and beverages, if you provide them, for everyone.
   - You have a plan with your speakers. This includes a schedule, topics, abstracts for the talks, and any necessary equipment for the presentations.
2. Content and speakers
   - Feel free to invite presenters from your local community, from neighboring countries, or even from all over the globe. You don't have to have any JetBrains representatives or speakers at your event. However, we are always happy to hear about more Kotlin Nights, so feel free to notify us.
3. Announcements and promotion
   - Announce your event at least three weeks before the date of a meetup.
   - Include the schedule, topics, abstracts, and speaker bios in the announcement.
   - Spread the word on social media.
4. Providing event material to JetBrains after the event
   - We would be glad to announce your event at kotlinlang.org, and we would appreciate it if you provided slides and video materials for a follow-up posting.

JetBrains support

JetBrains provides support with:

- Access to Kotlin Night Branding, which includes the name and logos
- Merchandise, such as stickers and t-shirts for speakers and small souvenirs for attendees
- A listing for the event on the Kotlin Talks page
- Help to reach out to speakers to take part in the event, if necessary
- Help to find a location if possible (via contacts, etc.), as well as help to identify possible partnerships with local businesses

Code of conduct and guidelines for Kotlin Slack

Kotlin Slack aims to be an inclusive space committed to providing a friendly, safe and welcoming environment for all, regardless of gender, sexual orientation, ability, ethnicity, socioeconomic status, and religion (or lack thereof).

For this to be the case, it is vital that we all follow a basic set of guidelines and most importantly, adhere to the code of conduct. As such, please make sure you read this Code of Conduct and Basic Usage Guidelines in its entirety. This isn't your regular License Agreement that you should scroll through and agree blindly. It's here for a reason and also contains practical information.

- How to behave
- How not to behave
- How to report issues

How to behave

* Participate in an authentic and active way. In doing so, you contribute to the health and longevity of this community.
* Exercise consideration, respect and empathy in your speech and actions. Remember, we have all been through different stages of learning when adopting technologies.
* Refrain from demeaning, discriminatory, or harassing behavior and speech.
* Disagreements on things are fine, argumentative behavior or trolling are not.

How not to behave

* Do not perform threats of violence or use violent language directed against another person.
* Do not make jokes of sexist, racist, homophobic, transphobic, ableist or otherwise discriminatory nature, or use language of this nature.
* Do not post or display sexually explicit or violent material.
* Do not post or threaten to post other people's personally identifying information ("doxing").
* Do not make personal insults, particularly those related to gender, sexual orientation, race, religion, or disability.
* Do not engage in sexual attention. This includes, sexualized comments or jokes and sexual advances.
* Do not advocate for, or encourage, any of the above behavior.

How to report issues

If someone is acting inappropriately or violating this Code of Conduct in any shape or form, and they are not receptive to your feedback, or you prefer not to confront them, please get in touch with one of the Administrators. The main Administrators are Ilya Ryzhenkov (@orangy) and Hadi Hariri (@hhariri).

Basic usage guidelines

There are over 50 000 users on many different timezones using the Kotlin Slack, and the number is growing rapidly. The influx of messages per day and the numerous channels can lead to a lot of noise and little value in the long run. If we all follow a set of guidelines, it can help make things more useful and bearable for everyone.

* Please remember this is a Slack team for Kotlin. If you have generic questions that are about a technology (which may or may not be used with Kotlin), maybe it's better to use another forum, such as StackOverflow.
* This Slack is not an official support channel. It is a place where the community hangs out along with some members of the JetBrains and Kotlin team (suffix [JetBrains]).
* This Slack is not the best place for reporting bugs. For this, please use YouTrack.
* Find the right channel to ask your question. There are channels for pretty much every topic.
* New channels should be focused around a well-known technology or area of interest. Create them sparingly. And before requesting for a new channel, make sure it doesn't exist in any other shape or form. Ask an administrator to create a new channel on the #meta channel. If you do end up creating a channel, make sure you set the topic.
* Please refrain from cross-posting the same message on multiple channels. It is considered spamming.
* When you ask a question, please be patient. Don't repeat it. Or at least not immediately.

- Please do not ping or mention someone directly to get your questions answered, especially project owners, whether the project is Kotlin or other, unless they specifically indicate that you can.
- Don't split messages into multiple ones. Ask it all in a single message.
- Use code blocks. Don't paste code as plain text. Slack supports Kotlin markup. If the code you are pasting is longer than a few lines, use "Code or text snippet" available from + menu next to message input. Only first few lines will be displayed to all users and people interested in the code can expand your code to look into details.
- While it's polite to say "Hi" or "I have a question" before asking something, it doesn't scale and leads to noise. You can say hello in the same message you ask the question if you like.
- Using threads is not required, but do take into account that it does allow people to more easily follow conversations, especially those jumping in late.
- Use reactions to show gratitude as opposed to a message. It reduces the noise and gets the message across.
- Don't use reactions to tell people they're in the wrong place or asking the wrong question. If they're on the wrong channel, point them to the right one. If their question is badly worded, help them correct it. Have empathy.
- Take into account cultural differences. As they say, what the British say isn't what the British mean. Remember this both as the receiver and producer of messages.
- Don't create integrations with Slack. Given this is running on the free tier, the number is limited, and thus it won't be approved.
- @channel, @here and other forms of notifications are disabled, even if you own a channel (unfortunately, Slack doesn't allow fine-grained permissions).
- Use the #meta channel if you're unsure about how to do something.

Moderators

A moderator is a member of the Kotlin Slack community who volunteers to keep the kotlinlang Slack a safe and welcoming place for other members. Moderators are approved by kotlinlang Slack administrators. Their responsibilities and the guidelines they follow are described below.

Responsibilities

- Monitor Slack channels to ensure compliance with the Code of Conduct.
- Help community members follow the rules.
- If a channel has additional rules, ensure these are visible and up to date.
- Monitor the #reports and #meta channels.
- Participate in the private #moderators channel.

Guidelines

- Moderators communicate in a friendly manner and do their best to help other community members.
- Any changes suggested by a moderator should be discussed by all moderators and administrators before coming into effect.

Process

- Each moderator oversees at least one channel, or more if possible.
- When moderators notice inappropriate behavior, they explain the rules and guidelines to the members and help figure out how to correct the unwanted behavior. If the unwanted behavior persists, moderators report the case to administrators for further actions. In the case of obvious and/or particularly blatant violations, offending members can be reported immediately.
- To set up or update a channel's rules, the moderator initiates a change proposal and discusses it with the appropriate community members.
- Communication regarding moderation takes place in the private #moderators channel.
- If community members notice that a moderator is ignoring their responsibilities (or engaging in any unwanted behavior), they can alert administrators.

Moderator status acquisition and revocation process

- Any member is welcome to apply to be a moderator once they have been in the Slack community for longer than 6 months.
- Moderator status is provided based upon the decision of the administrators.
- Moderator status can be revoked if (this list is not exhaustive and can be updated on a case-by-case basis):
  - A moderator ignores their responsibilities, which leads to issues in a channel.
  - A moderator violates these guidelines.

The list of moderators

At the moment we have 17 confirmed moderators, and they will be responsible for observing a total of 64 channels. For all other channels, if any issues arise, members can ping any of the moderators or admins directly, or they can post a message in #meta.

- Alexander Nozik (@altavir) – #mathematics, #science, #datascience, #education
- Anderson Lameck (@andylamax) – #coroutines, #kotlin-native, #webassembly, #serialization, #random, #javascript, #react
- Andrey Mischenko (@gildor) – #coroutines, #android, #gradle, #multiplatform, #getting-started, #kotlin-asia, #singapore
- Eric Ampire (@Eric Ampire) – #events
- Holger Steinhauer (@Holger Steinhauer) – #fosdem, #berlin, #vkug, #german-lang, #server
- Louis CAD (@louiscad) – #coroutines, #android
- Magda Miu (@Magda Miu) – #android, #100daysofkotlin
- Maryam Alhuthayfi (@Maryam Alhuthayfi) – #compose, #books, #ksp, #eap, #dagger, and #kontributors.
- Nicola Corti (@gammax) – #feed, #detekt, #appintro, #chucker, #fosdem, #london, #berlin, #hamburg, #sweden, #ktlint, #kug-leads, #kotlinconf, #koin, #koin-dev, #spek, #vkug
- Paulien van Alst (@Paulien van Alst) – #detekt, #koin, #mockk
- Qian Jin (@qian) – #kotlin-native, #android-studio, #french
- Raul Raja (@raulraja) - #arrow, #arrow-contributors, #arrow-meta
- Sam Sam (@sam) – #kotest, #kotest-contributors
- Simon Vergauwen (@simon.vergauwen) – #arrow, #arrow-contributors, #arrow-meta
- Youssef Shoaib (@Youssef Shoaib) – #getting-started, #feed, #language-evolution, #language-proposals
- Zach Klippenstein (@Zach Klippenstein) – #coroutines, #compose, #compose-desktop, #compose-web, #squarelibraries, #library-development

Copyright

Kotlin brand assets

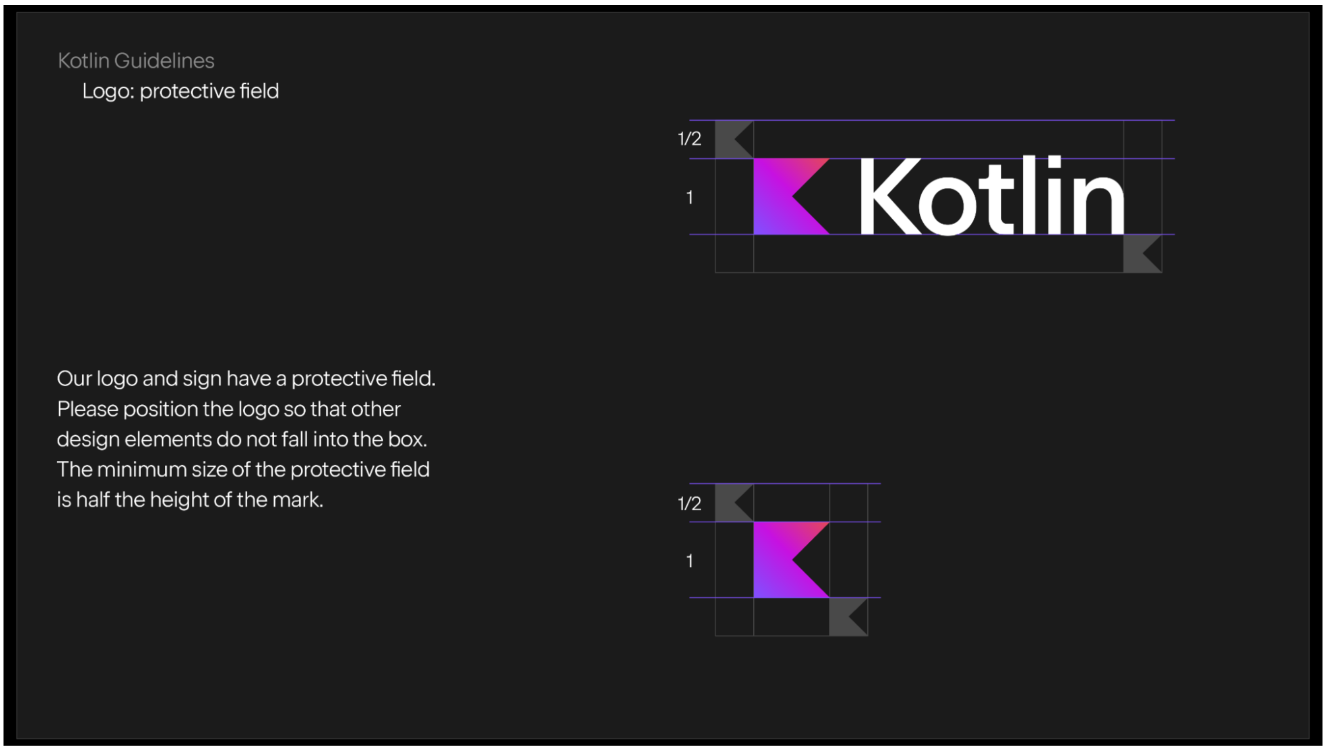
Kotlin Logo

Our logo consists of a mark and a typeface. The full-color version is the main one and should be used in the vast majority of cases.

Download all versions

Kotlin logo

Our logo and mark have a protective field. Please position the logo so that other design elements do not come into the box. The minimum size of the protective field is half the height of the mark.



Kotlin Guidelines

Logo: protective field

Our logo and sign have a protective field. Please position the logo so that other design elements do not fall into the box. The minimum size of the protective field is half the height of the mark.

Kotlin logo proportions

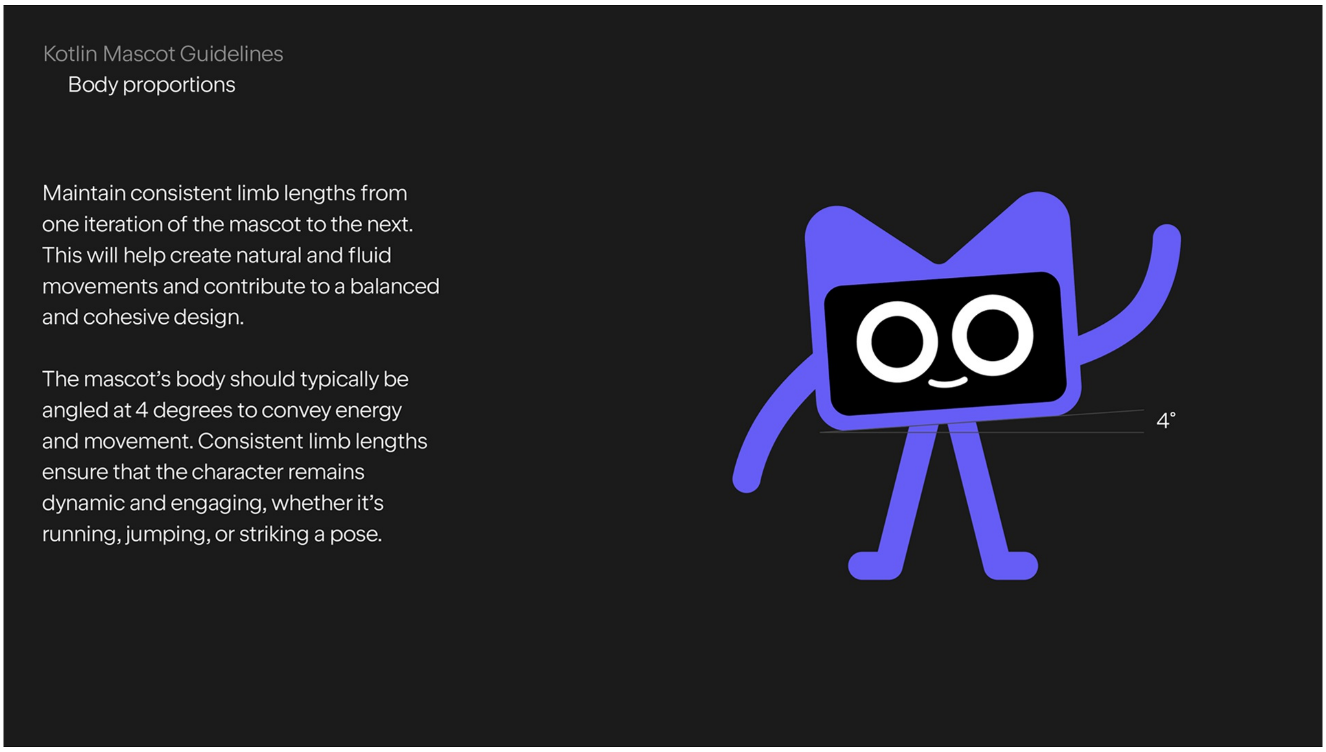
Pay special attention to the following restrictions concerning the use of the logo:

- Do not separate the mark from the text. Do not swap elements.
- Do not change the transparency of the logo.
- Do not outline the logo.
- Do not repaint the logo in third-party colors.
- Do not change the text.
- Do not set the logo against a complex background. Do not place the logo in front of a bright background.

Read the Kotlin brand usage guidelines.

Kotlin mascot

Meet Kodee, the Kotlin mascot and your friendly companion who's always there to encourage and inspire your creativity. When using it, we ask you to follow these simple guidelines.



Kotlin Mascot Guidelines

Body proportions

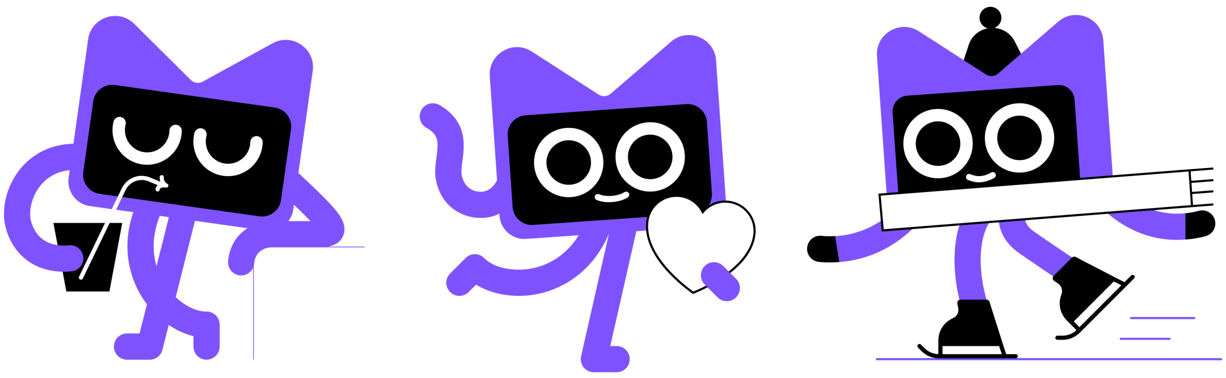
Maintain consistent limb lengths from one iteration of the mascot to the next. This will help create natural and fluid movements and contribute to a balanced and cohesive design.

The mascot's body should typically be angled at 4 degrees to convey energy and movement. Consistent limb lengths ensure that the character remains dynamic and engaging, whether it's running, jumping, or striking a pose.

Kotlin mascot Kodee proportions

You can use Kodee in your digital and print materials. For this purpose, we have prepared a variety of Kotlin mascot assets for you to download and explore.

Download all assets



Kotlin mascot Kodee in action

Kotlin User Group brand assets

We provide Kotlin user groups with a logo that is specifically designed to be recognizable and convey a reference to Kotlin.

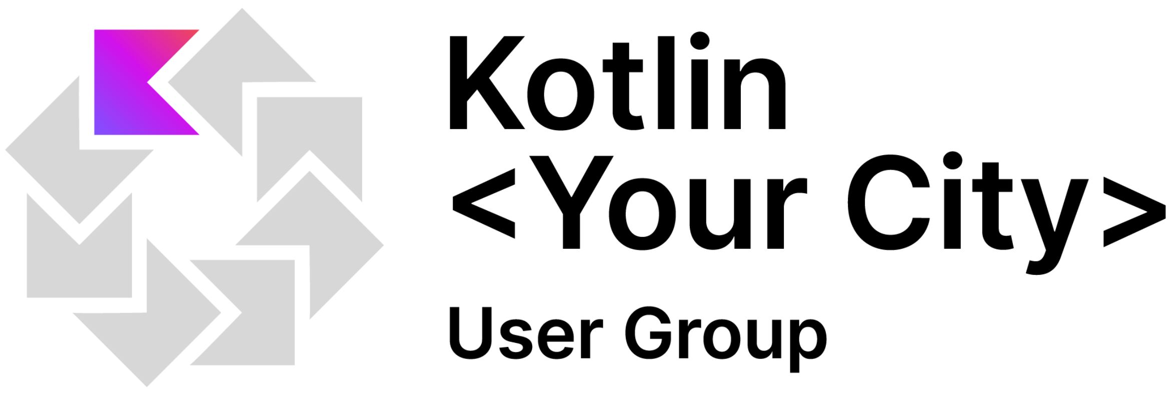
- The official Kotlin logo is associated with the language itself. It should not be used otherwise in different scopes, as this could cause confusion. The same applies to its close derivatives.
- User groups logo also means that the opinions and actions of the community are independent of the Kotlin team.
- Your opinions don't have to agree with ours, and we think this is the most beneficial model for a creative and strong community.

Download all assets

Style for user groups

Since the launch of the Kotlin community support program at the beginning of 2017, the number of user groups has multiplied, with around 2–4 new user groups joining us every month. Please check out the complete list of groups in the Kotlin User Groups section to find one in your area.

We provide new Kotlin user groups with a user group logo and a profile picture.



Branding image

There are two main reasons why we are doing it:

- Firstly, we received many requests from the community asking for special Kotlin style branded materials to help them be recognized as officially dedicated user groups.
- Secondly, we wanted to provide a distinct style for the user group and community content to make it clear which Kotlin-related materials are from the official team and which are created by the community.

Create the logo of your user group

To create a logo of your users group:

1. Copy the Kotlin user group logo file to your Google drive (you have to be signed in to your Google account).
2. Replace the Your City text with the name of your user group.
3. Download the picture and use it for the user group materials.

Belarusian Kotlin User Group sample

Belarusian Kotlin User Group Profile Picture sample

You can download a set of graphics including vector graphics and samples of cover pictures for social networks.

Create your group's profile picture for different platforms

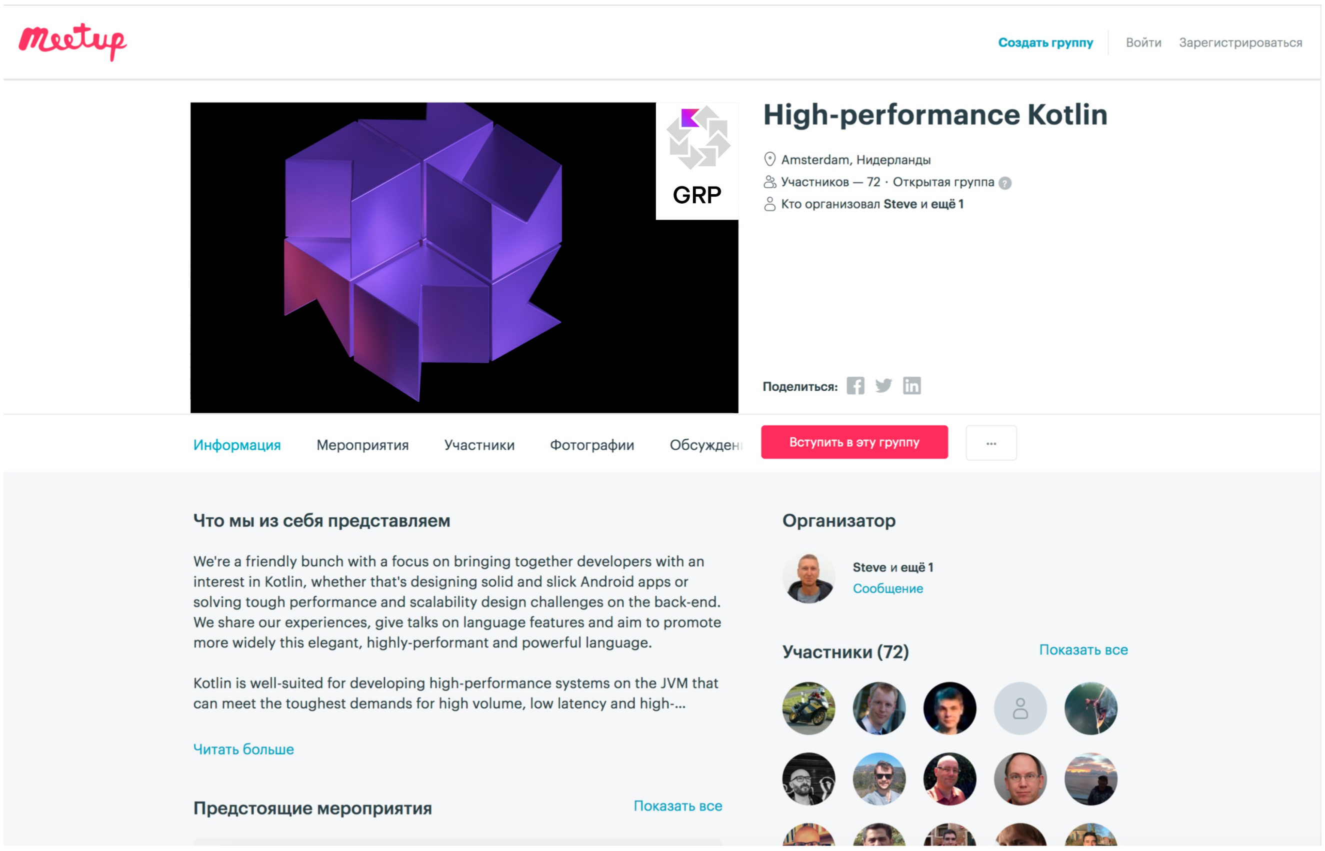
To create your group's profile picture:

1. Make a copy of the Kotlin user group profile picture file to your Google Drive (you have to be signed in to your Google account).
2. Add a shortened name of the user group's location (up to 4 capital symbols according to our default sample).
3. Download the picture and use it for your profiles on Facebook, Twitter, or any other platform.

Create meetup.com cover photo

To create a cover photo with a group's logo for meetup.com:

1. Make a copy of the picture file to your Google Drive (you have to be signed in to your Google account).
2. Add a shortened name of the user group's location to the logo on the right upper corner of the picture. If you want to replace the general pattern with a custom picture, click on the background pattern-picture, choose 'Replace Image', then 'Upload from Computer' or any other source.
3. Download the picture and use it for your profile on meetup.com.



High-performance Kotlin

Amsterdam, Нидерланды
Участников — 72 · Открытая группа
Кто организовал **Steve и ещё 1**

Что мы из себя представляем

We're a friendly bunch with a focus on bringing together developers with an interest in Kotlin, whether that's designing solid and slick Android apps or solving tough performance and scalability design challenges on the back-end. We share our experiences, give talks on language features and aim to promote more widely this elegant, highly-performant and powerful language.

Kotlin is well-suited for developing high-performance systems on the JVM that can meet the toughest demands for high volume, low latency and high-...

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Организатор

Steve и ещё 1
Сообщение

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User Group examples