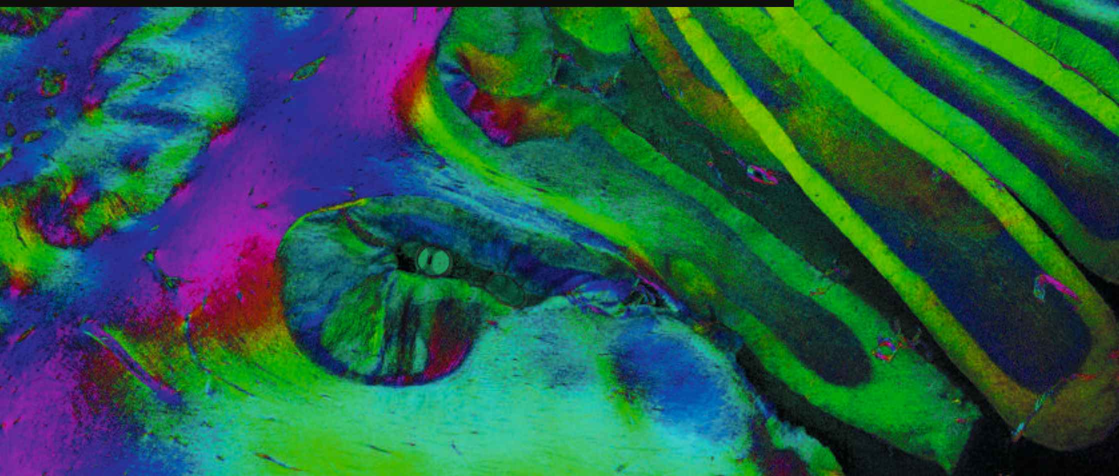
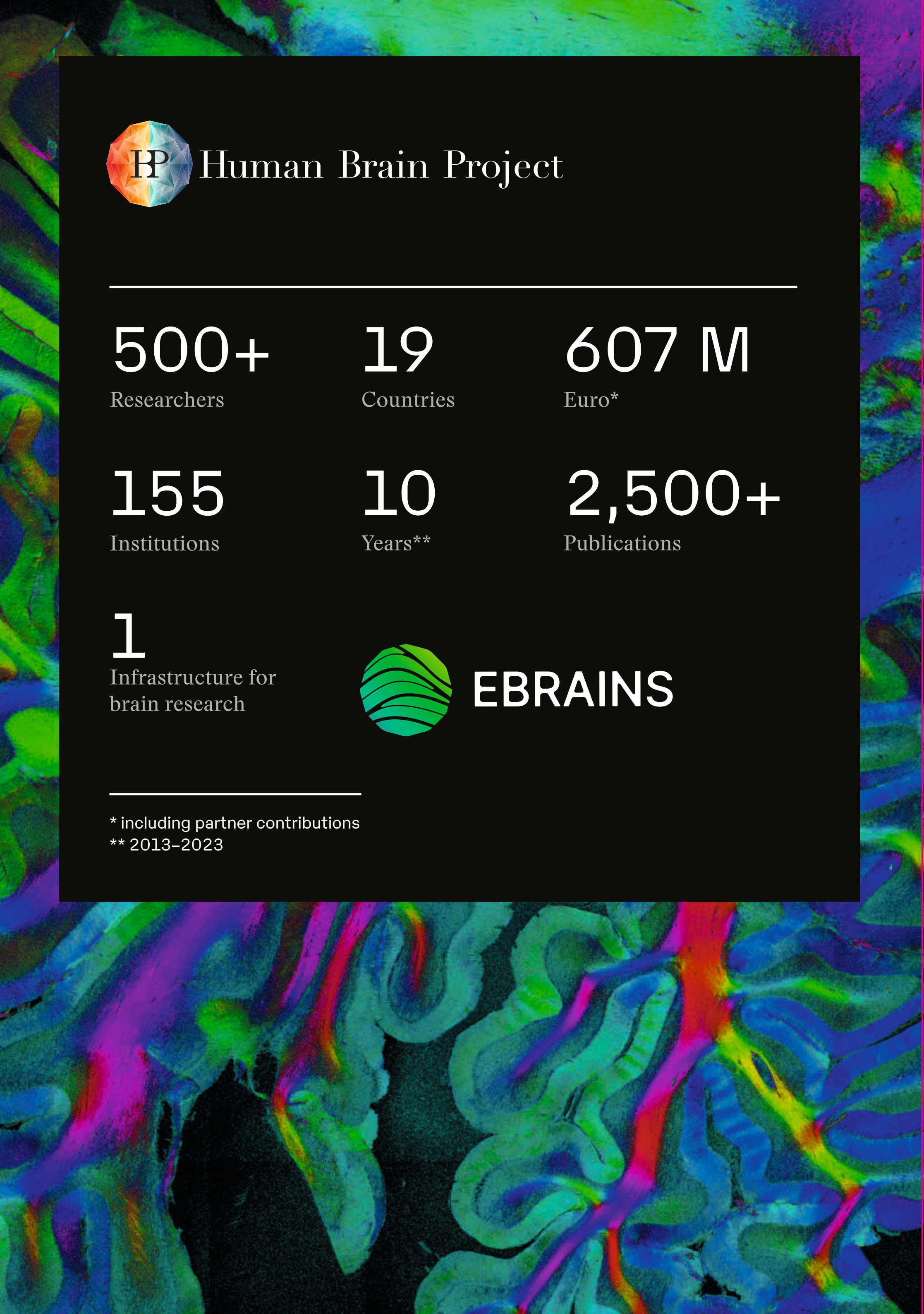
Human Brain Project

Spotlights on major achievements





Human Brain Project

500+
Researchers

19
Countries

607 M
Euro*

155
Institutions

10
Years**

2,500+
Publications

1
Infrastructure for brain research

EBRAINS

* including partner contributions
** 2013–2023

Pioneering digital brain research

The Human Brain Project (HBP) has been one of the largest research projects funded by the European Union. As a European Future and Emerging Technologies (FET) Flagship – a long-term and large-scale research initiative – the HBP has ambitiously pioneered digital brain research. It has contributed to a deeper understanding of the complex structure and function of the human brain with a unique interdisciplinary approach at the interface of neuroscience and technology.

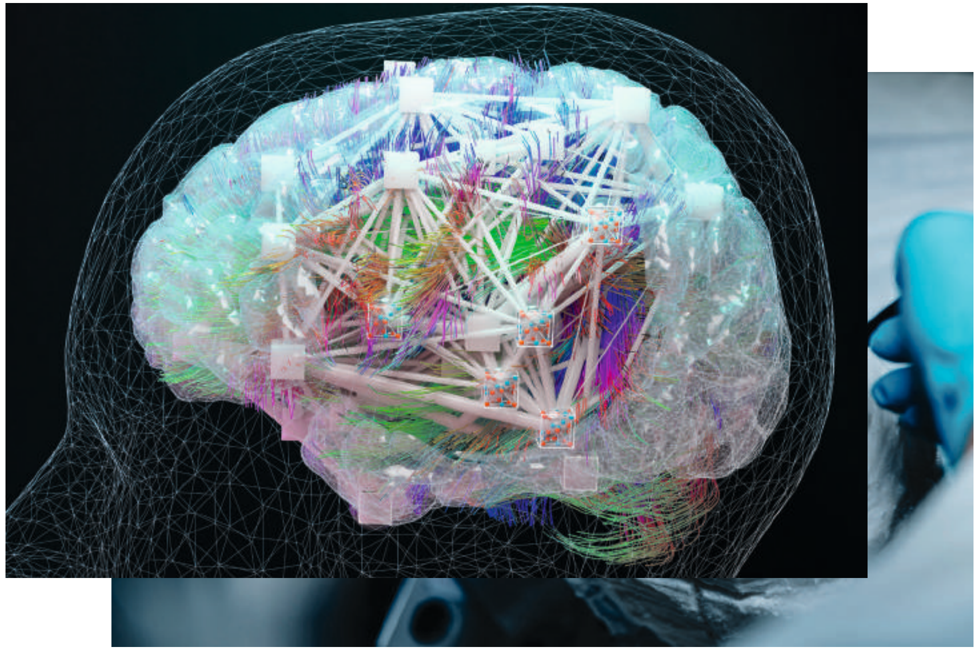
HBP scientists have employed highly advanced methods from computing, neuroinformatics and artificial intelligence to carry out cutting-edge brain research. The acquired knowledge is being translated into novel applications in medicine and technological advances. HBP researchers have also addressed the social and ethical implications arising.

To facilitate the integration of brain science across disciplines and national borders, the HBP has built a digital research infrastructure: EBRAINS is an open platform that provides access to a plethora of digital tools, models, data and services, enabling collaboration on a very large scale.

Katrin Amunts, Scientific Director of the HBP, Heinrich-Heine-Universität Düsseldorf and Forschungszentrum Jülich, Germany

Spotlights on major achievements

The HBP has driven outstanding advances in the fields of brain research and the development of brain-derived applications in medicine and technology. These spotlights highlight some major achievements of the HBP. Many of these innovations, discoveries and developments were the direct result of the HBP's ambitious efforts; for others, the HBP has acted as a catalyst, providing the enabling environment for exceptional breakthroughs.

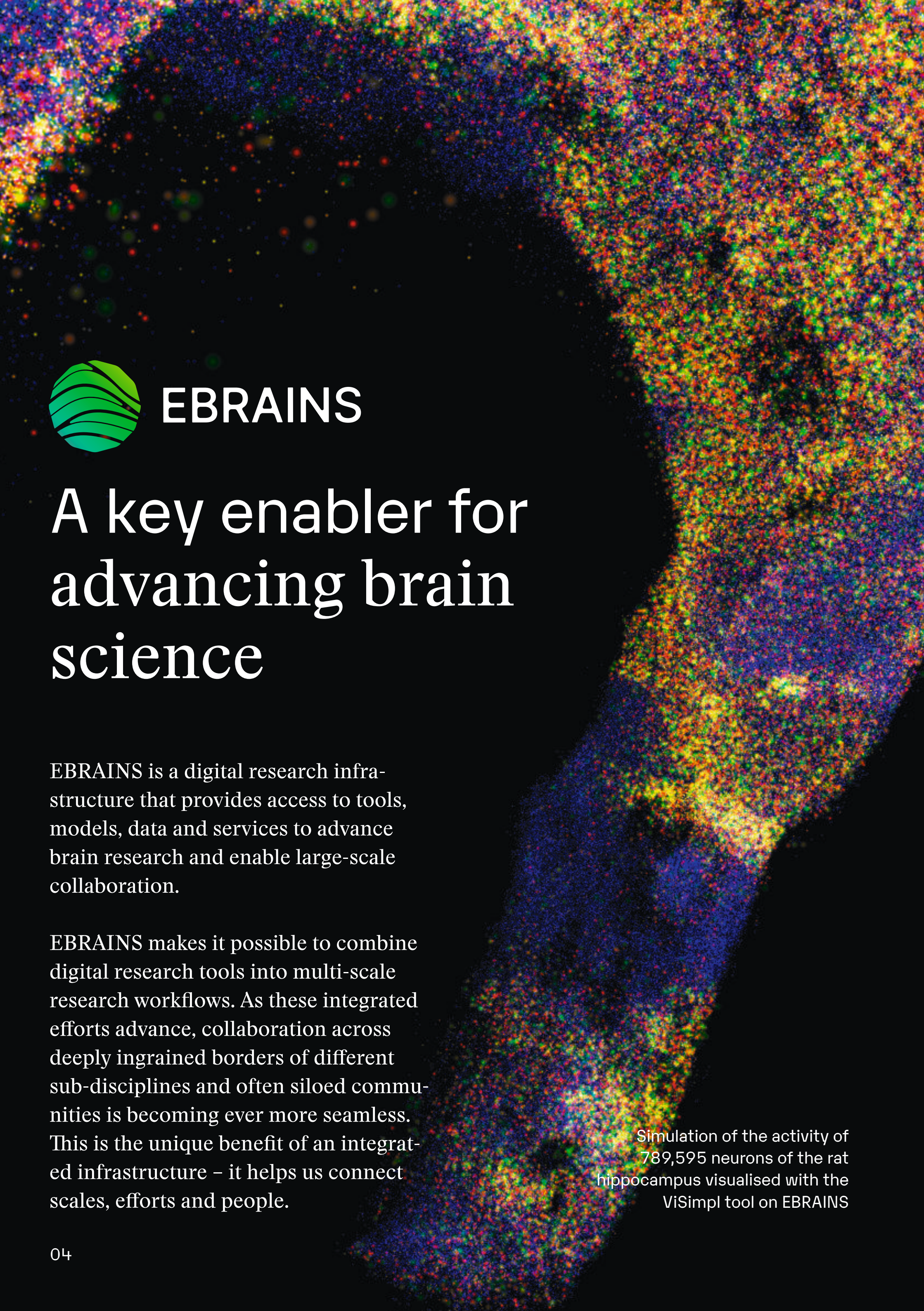


Different layers of a personalised brain network model

New technologies for a multi-scale approach

The HBP has developed more than 160 digital tools that enable brain research at multiple spatial scales and facilitate collaboration between different research teams. These tools include software and services, middleware and hardware platforms. They span a range of different research methods, from data management to simulation to core infrastructure tools that facilitate integration and collaboration. Via the EBRAINS infrastructure, different tools can be connected in common workflows for the multi-scale study of the brain. EBRAINS provides free access to HBP-developed tools for the entire scientific community.

→ A comprehensive overview of HBP-developed tools can be found in the booklet "An extensive guide to the tools developed", published in September 2023.



EBRAINS

A key enabler for advancing brain science

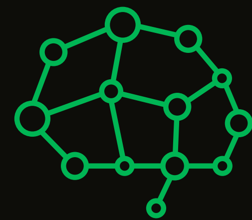
EBRAINS is a digital research infrastructure that provides access to tools, models, data and services to advance brain research and enable large-scale collaboration.

EBRAINS makes it possible to combine digital research tools into multi-scale research workflows. As these integrated efforts advance, collaboration across deeply ingrained borders of different sub-disciplines and often siloed communities is becoming ever more seamless. This is the unique benefit of an integrated infrastructure – it helps us connect scales, efforts and people.

Simulation of the activity of 789,595 neurons of the rat hippocampus visualised with the ViSimpl tool on EBRAINS

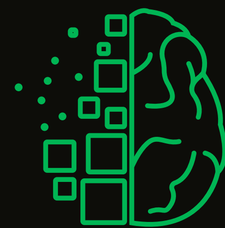
Service Categories

Services on the EBRAINS Research Infrastructure are highly interconnected.

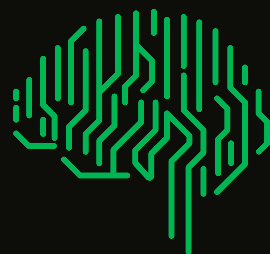


Data and Knowledge

Atlases

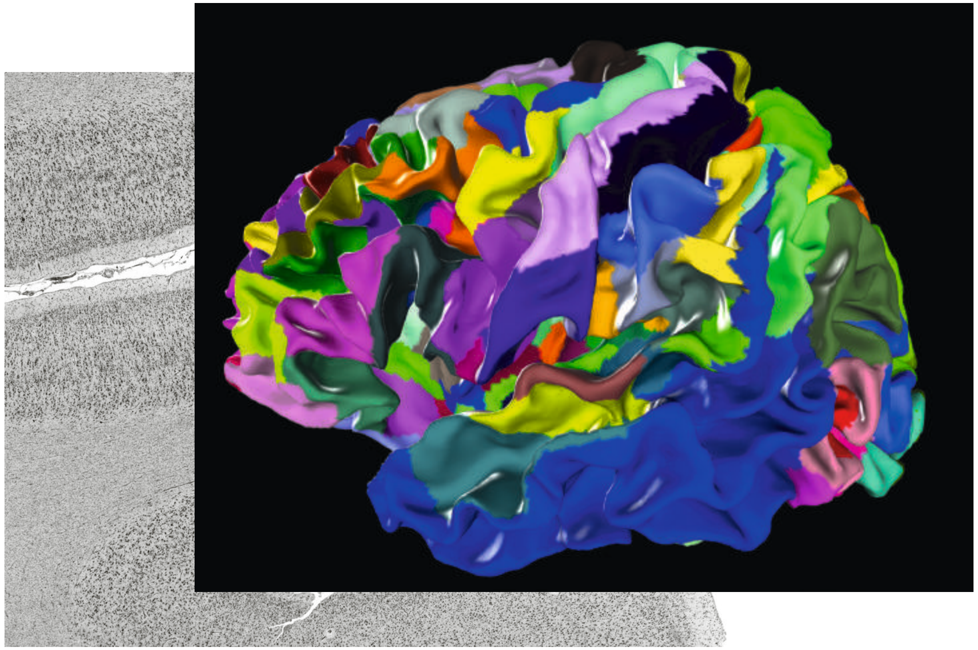


Simulation



Brain-Inspired Technologies

Medical Data Analytics



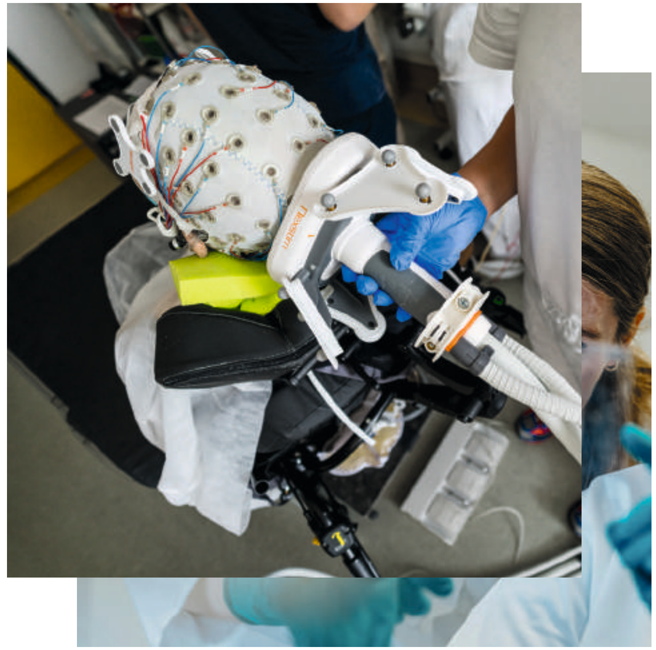
The Multilevel Human Brain Atlas contains more brain areas than ever mapped before.

The most detailed atlas of the human brain

HBP researchers from Germany have generated an atlas of the human brain that contains more brain areas than ever mapped before. The atlas shows the brain's cellular architecture in a three-dimensional space and captures variability between individual brains. The massive amounts of data require supercomputers and AI. The atlas is freely available online on the EBRAINS platform, where new data is constantly integrated. The atlas displays microstructure, connectivity and function, enabling researchers to collaboratively decode the brain and clinicians to improve treatments of patients suffering from neurological disease.

→ Zachlod et al. (2023). Biol. Psychiatry 93(5):471-479.
→ Amunts et al. (2020). Science 369:988–992.

Measuring consciousness



Simultaneous EEG recording and magnetic stimulation

After severe brain injury, unresponsive patients are commonly declared unconscious, but this diagnosis is not always correct, as some patients may be conscious but unable to show it. HBP scientists from Italy and Belgium have established a new method with unprecedented sensitivity to assess the level of consciousness. It involves non-invasive magnetic stimulation of the brain and measuring the complexity of the brain's response with an electroencephalogram (EEG). A large, multi-centric validation study is currently underway.

→ Comanducci et al. (2023). Eur. J. Neurosci. 10.1111/ejn.15994.
→ Goldmann et al. (2023). Front. Comput. Neurosci. 16:1058957.
→ Lee et al. (2022). Nat. Commun. 13(1):1064.
→ Lutkenhoff et al. (2020). Brain Stimul. 13:1426–1435.

Improving health care with digital brain models

The Virtual Brain

HBP scientists from France have developed personalised brain models of epilepsy patients who do not respond to medication. Such virtual brain models help to identify the brain areas where seizures emerge. A 400-patient clinical trial is ongoing with the aim of providing surgeons with a precise tool to help individual surgery decisions and improve outcomes. The HBP's brain atlas serves to further enhance accuracy. Such models have potential also for the treatment of other brain disorders including Parkinson's disease and depression. A future vision is the continuous update of brain models whenever new measurements are made – in a "digital twin" approach.

→ Amunts et al. (2023). Zenodo 10.5281/zenodo.7764003.
→ Jirsa et al. (2023). Lancet Neurol. 22(5):443-454.
→ Wang et al. (2023). Sci. Transl. Med. 15(680):eabp8982.

"The tools for personalisation of our epilepsy models could have only emerged from the HBP. Without the HBP, we would not be in clinical trial today."

Viktor Jirsa, Leader of the HBP's multiscale connectome focus area, Institut de Neurosciences des Systèmes Aix- Marseille University, France.

HBP research has contributed to targeted spinal cord stimulation that has helped patients with paralysis walk again.

Neural implants to overcome blindness and paralysis

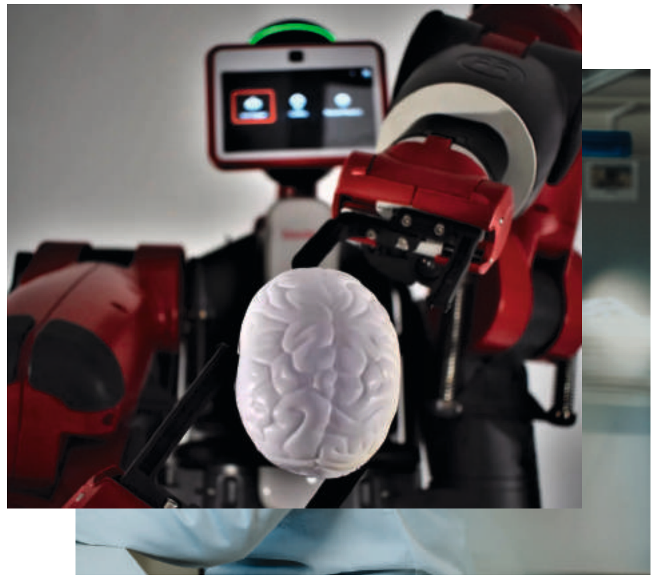
HBP researchers have developed implants that stimulate neurons to overcome blindness and paralysis. Dutch HBP researchers have built a brain implant that electrically stimulates the brain's visual cortex with high precision. On a small scale, the technology has already been transferred into human medicine. In Switzerland, HBP researchers used neural implants stimulating the spinal cord to enable paraplegic patients to stand and walk again. The team had simulated the spinal cord of each patient in order to design and place the implants.

→ Rowald et al. (2022). Nat. Med. 28(2):260-271.
→ Squair et al. (2021). Nature 590:308–314.
→ Chen et al. (2020). Science 370:1191–1196.

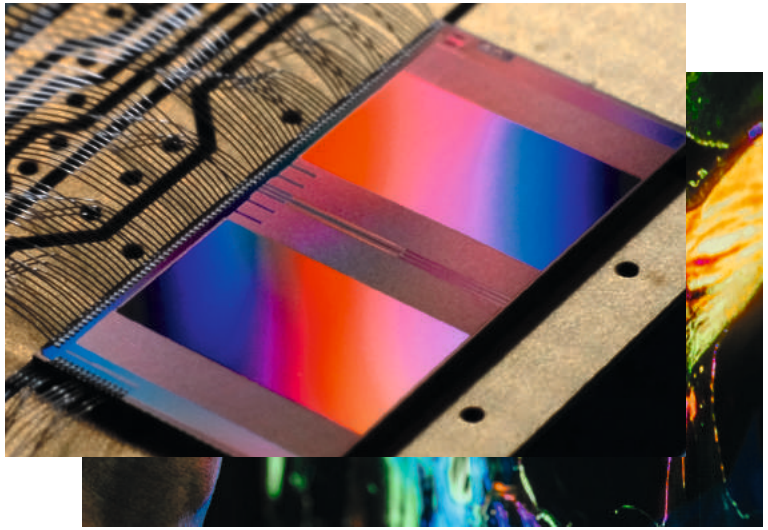
Building robots with brain-inspired movement and cognition

Researchers are connecting brain-inspired deep learning to biomimetic robots to teach them more human-like capabilities. Teams from Spain and Italy have equipped robots with detailed simulation of the cerebellum and hippocampus, parts of the brain that are involved in motor control and spatial navigation. Researchers from the Netherlands and the UK have used the EBRAINS Neurorobotics Platform to teach robots how to remember places and improve autonomous navigation. The work improves our understanding of embodied cognition in the brain and opens new paths to overcome current limits in AI and robotics.

Robot controlled by artificial cerebellum



→ Coppolino & Migliore (2023). Neural Netw. 163:97-107.
→ Prescott & Wilson (2023). Sci. Robot. 8:eadg6014.
→ Abadía, Naveros et al. (2021). Sci. Robot. 6:eabf2756.
→ Pearson et al. (2021). Front. Robot. AI 8:732023.



Close-up of a BrainScaleS-2 chip

Mimicking the brain to make AI more energy-efficient

HBP scientists from the Netherlands, Austria, Germany and Switzerland have taken inspiration from the human brain to improve the energy efficiency of artificial intelligence. The teams have developed and optimised a number of powerful brain-inspired algorithms that have advantages over traditional deep-learning approaches. The resulting spiking neural networks can be implemented in large-scale neuromorphic systems. Two of the largest such computers have been developed within the HBP and are accessible to any researcher via EBRAINS: SpiNNaker and BrainScaleS-2.

→ Yin et al. (2023). Nat. Mach. Intell. 5:518–527.
→ Rao et al. (2022). Nat. Mach. Intell. 4:467–479.
→ Göltz, Kriener et al. (2021). Nat. Mach. Intell. 3:823–835.
→ Stöckl & Maass. (2021). Nat. Mach. Intell. 3:230–238.

“Brain-ScaleS is a versatile system, especially, when you have dedicated experts running it for you in close collaboration. This is one of the crucial and much needed links that the HBP has made possible.”

Viola Priesemann, Leader of a HBP Voucher Project, Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany

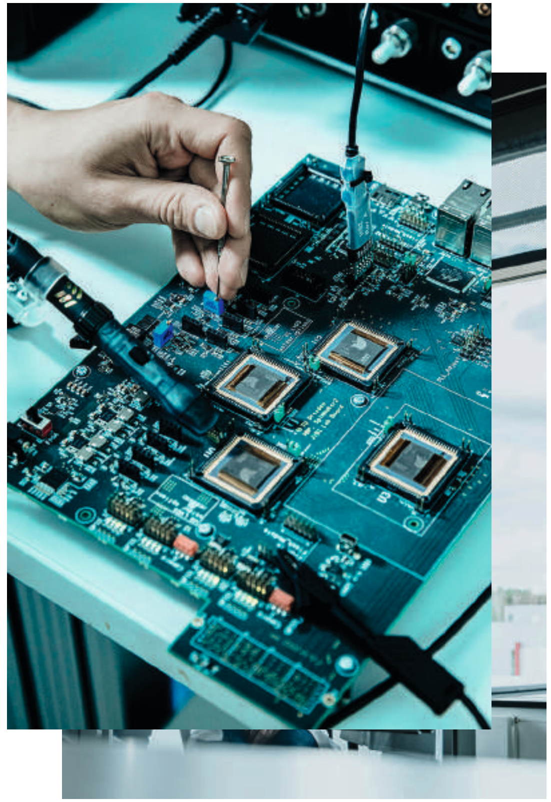
Powerful supercomputing for the community at large

Understanding the complex system of the human brain requires handling massive amounts of data and places high demands on computing. This motivated the implementation of the Fenix infrastructure via the EU-funded project Interactive Computing E-Infrastructure for the Human Brain Project (ICEI). Fenix is a federated infrastructure formed by six of Europe's leading supercomputing centres and provides computing, cloud and storage resources to the entire scientific community. Fenix serves as a base infrastructure offering computing services upon which different EBRAINS platform services are built. The setup of Fenix allows not only the neuroscience community but also other research communities to leverage Fenix infrastructure services for their research.

→ Alam et al. (2022). Commun. ACM 65(4):46-47.
→ Amunts & Lippert (2021). Science 374:1054–1055.

The TGCC computing centre of the French Alternative Energies and Atomic Energy Commission (CEA) is part of the Fenix infrastructure.

SpiNNaker2 circuit board



Neuroscience research translated into clinical and tech innovations

Human Brain Project research has enabled a number of innovations in the realms of neurology, artificial intelligence and computing technology. Successful spin-offs founded by HBP members have brought science-based innovations closer to the market. Examples include SpiNNcloud Systems in Germany, VBtech in France, Intrinsic Powers in Italy, Onward Medical in Switzerland and the Netherlands and Phosphoenix in the Netherlands.

A new culture of collaboration

The HBP has brought together interdisciplinary research teams.

Integrating knowledge from multiple scales of the brain requires advanced digital technologies co-designed by developers and neuroscientists. It also requires close collaboration between interdisciplinary research teams bringing together insights acquired by multiple methods and approaches. The HBP has pioneered the digitalisation of neuroscience and made strides in overcoming fragmentation of the research community. In a large community effort going beyond the HBP, more than 100 researchers have written a position paper outlining their shared vision for the coming decade of digital brain research.

→ Amunts et al. (2023). Zenodo 10.5281/zenodo.7764003.

Successful conclusion of Europe's largest brain research initiative

After ten years, the EU-funded FET Flagship Human Brain Project is now concluding in September 2023. HBP researchers have made significant contributions to our understanding of the complexity of the human brain with important implications not only for neuroscience but also for brain medicine and the development of neuro-derived technologies.

The HBP has permanently changed the way brain research is carried out. It has brought communities from different disciplines together to work collaboratively on common goals. With the open infrastructure EBRAINS, the HBP facilitates cross-border collaboration not only within Europe but also between large-scale initiatives from different continents. EBRAINS offers access to state-of-the-art tools and services that have been developed within the HBP. All researchers are welcome to join the community.

In 2021, EBRAINS was added to the influential ESFRI Roadmap for Research Infrastructures – a strong demonstration that it is on track to becoming a fixture in the European research landscape. EBRAINS is now transitioning into a sustainable infrastructure that will remain available to the scientific community as a lasting contribution of the HBP to global scientific progress.

More in-depth highlights of HBP scientific achievements can be found in the booklet "A closer look at scientific advances", published in March 2023.

A comprehensive overview of HBP-developed tools can be found in the booklet "An extensive guide to the tools developed", published in September 2023.

What others say about the HBP

"Research in neurosciences allows us to improve the diagnostics and treatment of diseases of the brain and nervous system, which represent a huge challenge to take up due to their human consequences. In that context, the Human Brain Project has been extremely useful to accompany the shift of neuroscience in the era of data science."

Sylvie Retailleau,
French Minister of Research,
Higher Education and Innovation

"The investment in neuroscience, in particular forming a critical mass of talent and forming explanatory theories of experimental data, key elements of HBP, are very likely to be crucial ingredients in bridging the gap between current state-of-the-art in AI and human-level intelligence."

Yoshua Bengio, Leading AI expert,
A.M. Turing Award recipient, Full
Professor at Université de Montréal
and Founder and Scientific Director of
Mila – Quebec AI Institute

Angela Friederici, Leading expert in
neuropsychology and linguistics,
Director at the Max Planck Institute
for Human Cognitive and Brain
Sciences in Leipzig, Vice President of
the Max Planck Society 2014-2020

"The HBP is a thriving neuroscientific enterprise providing a powerful basis for advances in brain science and their clinical and industrial implications. It demonstrates impressively that insight into the fundamental mechanisms of brain function precedes and leads to effective applications. This project is a first successful step which must be followed by further continuous steps."

"Integrated interdisciplinary collaboration across many countries is highly challenging. The HBP has shown how this can be done on an unprecedented scale."

Linda J. Richards, Australian Brain Alliance,
Edison Professor and Chair, Department of
Neuroscience; Director, McDonnell Center for
Cellular & Molecular Neurobiology,
Washington University School of Medicine

HUMAN BRAIN PROJECT
Spotlights on major achievements

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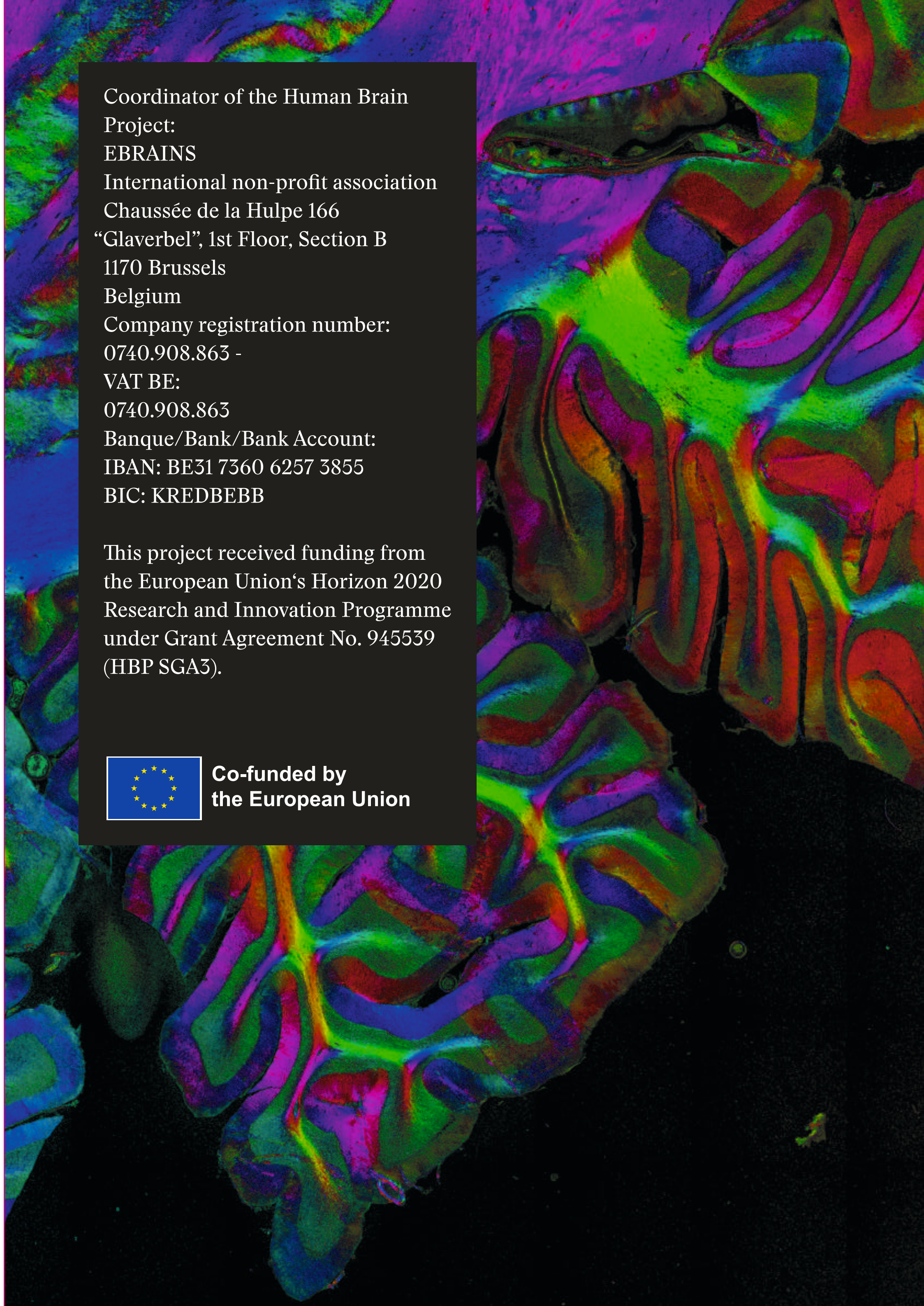

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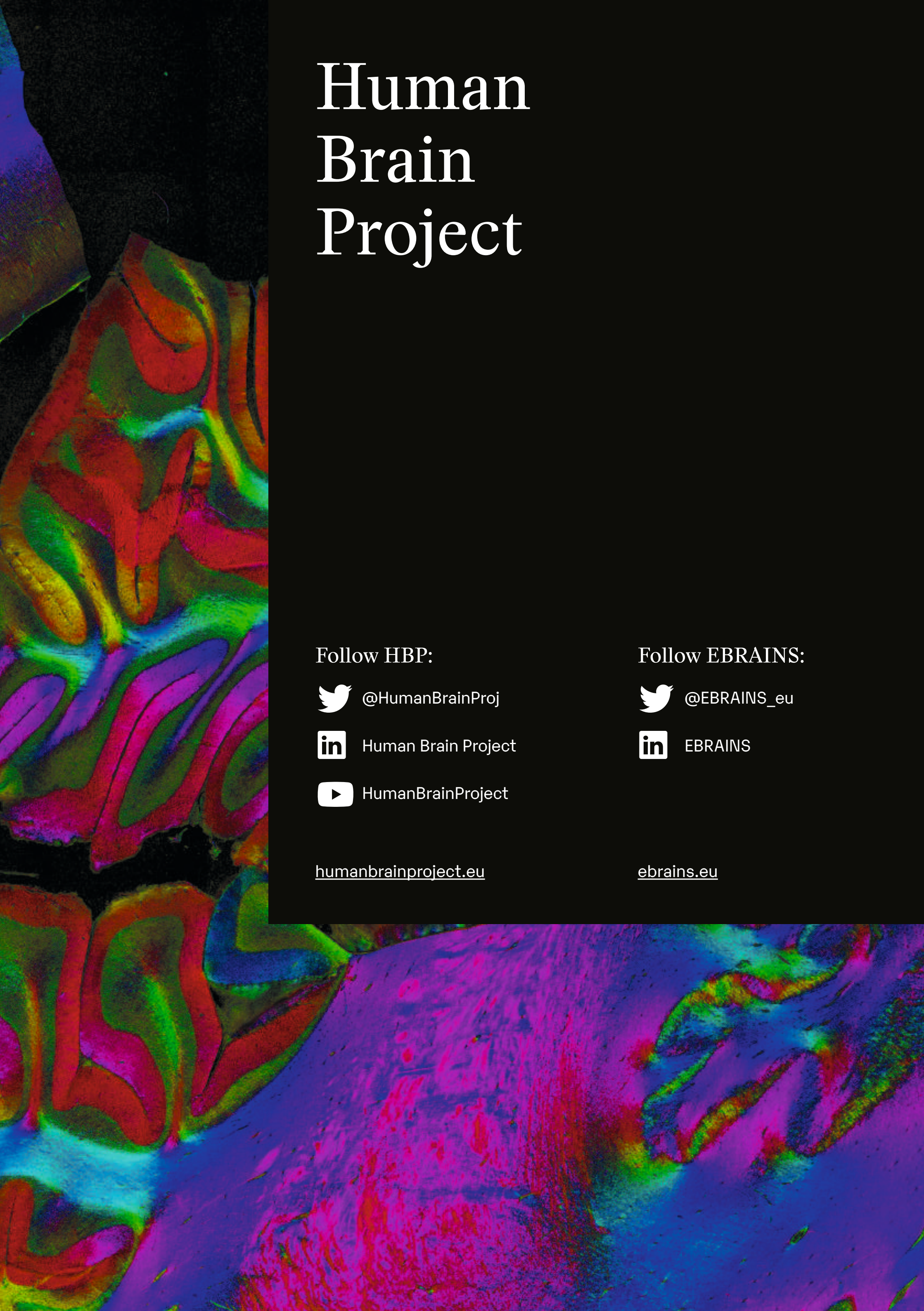

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