(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 April 2016 (21.04.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/061487 A1

(51) International Patent Classification:
C12N 15/113 (2010.01) *A61K 31/713* (2006.01)
A61K 31/712 (2006.01) *A61P 43/00* (2006.01)

(21) International Application Number:
PCT/US2015/055989

(22) International Filing Date:
16 October 2015 (16.10.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/065,293 17 October 2014 (17.10.2014) US

(71) Applicant: **ALNYLAM PHARMACEUTICALS, INC.** [US/US]; 300 Third Street, 3rd Floor, Cambridge, MA 02142 (US).

(72) Inventor: **HINKLE, Gregory**; 300 Third Street, 3rd Floor, Cambridge, MA 02142 (US).

(74) Agents: **ZACHARAKIS, Maria Laccotripe** et al.; Mccarter & English, LLP, 265 Franklin Street, Boston, MA 02110 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

— *with sequence listing part of description (Rule 5.2(a))*

WO 2016/061487 A1

(54) Title: POLYNUCLEOTIDE AGENTS TARGETING AMINOLEVULINIC ACID SYNTHASE-1 (ALAS1) AND USES THEREOF

(57) Abstract: The invention relates to polynucleotide agents, e.g., antisense polunucleotide agents, targeting the ALAS 1 gene, and methods of using such agents to alter (e.g., inhibit) expression of ALAS 1 and to treat ALAS 1 associated diseases, e.g., porphyria.

POLYNUCLEOTIDE AGENTS TARGETING AMINOLEVULINIC ACID SYNTHASE-1 (ALAS1) AND USES THEREOF

Related Applications

This application claims the benefit of priority to U.S. Provisional Patent Application No. 62/065,293, filed October 17, 2014. The entire contents of the aforementioned priority application are incorporated herein by reference.

Sequence Listing

This application contains a Sequence Listing which has been submitted electronically in ASCII format and is hereby incorporated by reference in its entirety. Said ASCII copy, created on October 16, 2015, is named 121301-02620_SL.txt and is 348,475 bytes in size.

Background of the Invention

The inherited porphyrias are a family of disorders resulting from the deficient activity of specific enzymes in the heme biosynthetic pathway, also referred to herein as the porphyrin pathway. Deficiency in the enzymes of the porphyrin pathway leads to insufficient heme production and to an accumulation of porphyrin precursors and porphyrins, which are toxic to tissue in high concentrations.

Of the inherited porphyrias, acute intermittent porphyria (AIP, *e.g.*, autosomal dominant AIP), variegate porphyria (VP, *e.g.*, autosomal dominant VP), hereditary coproporphyria (copropophyria or HCP, *e.g.*, autosomal dominant HCP), and 5' aminolevulinic acid (also known as δ- aminolevulinic acid or ALA) dehydratase deficiency porphyria (ADP, *e.g.*, autosomal recessive ADP) are classified as acute hepatic porphyrias and are manifested by acute neurological attacks that can be life threatening. The acute attacks are characterized by autonomic, peripheral, and central nervous system symptoms, including severe abdominal pain, hypertension, tachycardias, constipation, motor weakness, paralysis, and seizures. If not treated properly, quadriplegia, respiratory impairment, and death may ensue. Various factors, including cytrochrome P450-inducing drugs, dieting, and hormonal changes can precipitate acute attacks by increasing the activity of hepatic 5'-aminolevulinic acid synthase 1 (ALAS1), the first and rate-limiting enzyme of the heme biosynthetic pathway. In the acute porphyrias, *e.g.*, AIP, VP, HCP and ADP, the respective enzyme deficiencies result in hepatic production and accumulation of one or more substances (*e.g.*, porphyrins and/or porphyrin precursors, *e.g.*, ALA and/or PBG (porphobilinogen)) that can be neurotoxic and can result in the occurrence of acute neurologic attacks. See, *e.g.*, Balwani, M and Desnick, R.J., *Blood*, 120:4496-4504, 2012.

The current therapy for acute neurologic attacks is the intravenous administration of hemin (Panhematin®, Lundbeck or Normosang®, Orphan Europe), which provides

exogenous heme for the negative feedback inhibition of ALAS1 and, thereby, decreases production of ALA and PBG. Hemin is used for treatment during an acute attack and for prevention of attacks, particularly in women with acute porphyrias who experience frequent attacks with hormonal changes during their menstrual cycles. While patients generally respond well, its effect is slow, typically taking two to four days or longer to normalize urinary ALA and PBG concentrations towards normal levels. As the intravenous hemin is rapidly metabolized, three to four infusions are usually necessary to effectively treat or prevent an acute attack. In addition, repeated infusions may cause iron overload and phlebitis, which may compromise peripheral venous access. Although orthotrophic liver transplantation is curative, this procedure is associated with significant morbidity and mortality and the availability of liver donors is limited. Therefore, an alternative therapeutic approach that is more effective, fast-acting, and safe is needed. It would be particularly advantageous if such treatment could be delivered by subcutaneous administration, as this would preclude the need for infusions and prolonged hospitalization.

Summary of the Invention

The present invention provides polynucleotide agents and compositions comprising such agents which target nucleic acids encoding 5'-aminolevulinic acid synthase 1 (ALAS1) and interfere with the normal function of the targeted nucleic acid. The ALAS1 nucleic acid may be within a cell, *e.g.,* a cell within a subject, such as a human. The present invention also provides methods and combination therapies for treating a subject having a disorder that would benefit from inhibiting or reducing the expression of an ALAS1 mRNA, *e.g.,* an ALAS1-associated disease, *e.g.,* a porphyria, *e.g.,* acute intermittent porphyria (AIP) porphyria and ALA dehydratase deficiency porphyria (ADP), using the polynucleotide agents and compositions of the invention.

Accordingly, in one aspect, the present invention provides an antisense polynucleotide agent for inhibiting expression of an aminolevulinic acid synthase-1 (ALAS1) gene, wherein the agent comprises about 4 to about 50 contiguous nucleotides, wherein at least one of the contiguous nucleotides is a modified nucleotide, and wherein the nucleotide sequence of the agent is about 80% complementary over its entire length to the equivalent region of the nucleotide sequence of any one of SEQ ID NOs:1-2.

In one embodiment, the equivalent region is any one of the target regions of SEQ ID NO:1 provided in Tables 3 and 4.

In one aspect, the invention provides an antisense polynucleotide agent for inhibiting expression of an aminolevulinic acid synthase-1 (ALAS1) gene, wherein the agent comprises at least 8 contiguous nucleotides differing by no more than 3 nucleotides from any one of the nucleotide sequences listed in Tables 3 and 4.

In one embodiment, substantially all of the nucleotides of the antisense polynucleotide agent are modified nucleotides.

In another embodiment, all of the nucleotides of the antisense polynucleotide agent are modified nucleotides.

The agent may be 10 to 40 nucleotides in length, 10 to 30 nucleotides in length, 18 to 30 nucleotides in length, 10 to 24 nucleotides in length, 18 to 24 nucleotides in length, 21 nucleotides in length, or 20 nucleotides in length.

In some embodiments, the modified nucleotide comprises a modified sugar moiety selected from the group consisting of: a 2′-O-methoxyethyl modified sugar moiety, a 2′-methoxy modified sugar moiety, a 2′-O-alkyl modified sugar moiety, and a bicyclic sugar moiety.

sugar moiety, a 2′-O-alkyl modified sugar moiety, and a bicyclic sugar moiety.

In one embodiment, the bicyclic sugar moiety has a (—CRH—)n group forming a bridge between the 2′ oxygen and the 4′ carbon atoms of the sugar ring, wherein n is 1 or 2 and wherein R is H, CH_3 or CH_3OCH_3.

In a further embodiment, n is 1 and R is CH_3.

In another embodiment, the modified nucleotide is a 5-methylcytosine.

In another embodiment, the modified nucleotide includes a modified internucleoside linkage, auch as a phosphorothioate internucleoside linkage.

In one embodiment, an agent of the invention comprises one 2′-deoxynucleotide. In another embodiment, an agent of the invention comprises one 2′-deoxynucleotide flanked on each side by at least one nucleotide having a modified sugar moiety.

In one embodiment, an agent of the invention comprises a plurality, *e.g.,* more than 1, *e.g.,* 2, 3, 4, 5, 6, or 7, 2′-deoxynucleotides. In one embodiment, an agent of the invention comprises a plurality, *e.g.,* more than 1, 2′-deoxynucleotides flanked on each side by at least one nucleotide having a modified sugar moiety.

In one embodiment, the agent is a gapmer comprising a gap segment comprised of linked 2′-deoxynucleotides positioned between a 5′ and a 3′ wing segment.

In one embodiment, the modified sugar moiety is selected from the group consisting of a 2′-O-methoxyethyl modified sugar moiety, a 2′-methoxy modified sugar moiety, a 2′-O-alkyl modified sugar moiety, and a bicyclic sugar moiety.

In one embodiment, the agent including about 4 to about 50 contiguous nucleotides includes a plurality of 2′-deoxynucleotides flanked on each side by at least one nucleotide having a modified sugar moiety.

In one embodiment, the 5’-wing segment is 1 to 6 nucleotides in length.

In one embodiment, the 3’-wing segment is 1 to 6 nucleotides in length.

In one embodiment, the gap segment is 5 to 14 nucleotides in length.

In one embodiment, the 5’-wing segment is 6 nucleotides in length.

In one embodiment, the 3'-wing segment is 6 nucleotides in length.

In one embodiment, the 5'-wing segment is 5 nucleotides in length.

In one embodiment, the 3'-wing segment is 5 nucleotides in length.

In one embodiment, the 5'-wing segment is 4 nucleotides in length.

In one embodiment, the 3'-wing segment is 4 nucleotides in length.

In one embodiment, the 5'-wing segment is 3 nucleotides in length.

In one embodiment,the 3'-wing segment is 3 nucleotides in length.

In one embodiment, gap segment is 10 nucleotides in length.

In one embodiment, gap segment is 11 nucleotides in length.

In another aspect, the invention provides an antisense polynucleotide agent for inhibiting aminolevulinic acid synthase-1 (ALAS1) expression, including a gap segment consisting of linked deoxynucleotides; a 5'-wing segment consisting of linked nucleotides; a 3'-wing segment consisting of linked nucleotides; such that the gap segment is positioned between the 5'-wing segment and the 3'-wing segment and wherein each nucleotide of each wing segment comprises a modified sugar.

In one embodiment, the gap segment is ten 2′-deoxynucleotides in length and each of the wing segments is 5 nucleotides in length.

In another embodiment, the gap segment is eleven 2′-deoxynucleotides in length and each of the wing segments is 5 nucleotides in length.

In yet another embodiment, the gap segment is ten 2′-deoxynucleotides in length and each of the wing segments is 4 nucleotides in length.

In some embodiments, the gap segment is eleven 2′-deoxynucleotides in length and each of the wing segments is 4 nucleotides in length.

In one embodiment, the gap segment is ten 2′-deoxynucleotides in length and each of the wing segments is 3 nucleotides in length.

In one embodiment, the gap segment is eleven 2′-deoxynucleotides in length and each of the wing segments is 3 nucleotides in length.

In one embodiment, the gap segment is ten 2′-deoxynucleotides in length and each of the wing segments is 2 nucleotides in length.

In one embodiment, the gap segment is eleven 2′-deoxynucleotides in length and each of the wing segments is 2 nucleotides in length.

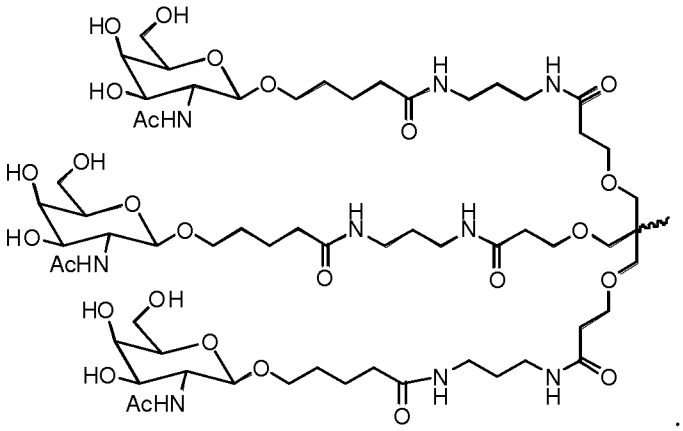
In one embodiment, the modified sugar moiety of the agent for inhibiting aminolevulinic acid synthase-1 (ALAS1) expression is selected from the group consisting of a 2′-O-methoxyethyl modified sugar moiety, a 2′-methoxy modified sugar moiety, a 2′-O-alkyl modified sugar moiety, and a bicyclic sugar moiety.

In yet another aspect of the invention, the polynucleotide agent for inhibiting expression of aminolevulinic acid synthase-1 (ALAS1) further includes a ligand.

In one embodiment, the antisense polynucleotide agent is conjugated to the ligand at the 3'-terminus.

In one embodiment the ligand is an N-acetylgalactosamine (GalNAc) derivative.

For example, the ligand is:



Further, in another aspect, the invention provides a pharmaceutical composition for inhibiting expression of a aminolevulinic acid synthase-1 (ALAS1) gene including an antisense polynucleotide for inhibiting ALAS1 expression as described herein.

In one embodiment, the agent is present in an unbuffered solution.

In one embodiment, the unbuffered solution is saline or water.

In another embodiment, the agent is present in a buffer solution.

In one embodiment, the buffer solution includes acetate, citrate, prolamine, carbonate, or phosphate or any combination thereof.

In one embodiment, the buffer solution is phosphate buffered saline (PBS).

In one embodiment, the pharmaceutical composition includes a lipid formulation.

In one embodiment, the lipid formulation includes a LNP.

In another embodiment, the lipid formulation includes a MC3.

In another aspect, the invention provides a method of inhibiting aminolevulinic acid synthase-1 (ALAS1) expression in a cell, the method including contacting the cell with any one of the agents or pharmaceutical compositions described herein; and maintaining the cell produced in step (a) for a time sufficient to obtain antisense inhibition of an ALAS1 gene, thereby inhibiting expression of the ALAS gene in the cell.

In one embodiment, the cell is within a subject.

In one embodiment, the subject is a human.

In one embodiment, the ALAS1 expression is inhibited by at least about 30%, about 40%, about 50%, about 60%, about 70%, about 80%, about 90%, about 95%, about 98% or about 100%.

In yet another aspect, the invention provides a method of treating a subject having a disease or disorder that would benefit from reduction in aminolevulinic acid synthase-1 (ALAS1) expression, the method including administering to the subject a therapeutically effective amount of any one of the agents or the pharmaceutical compositions described above, thereby treating the subject.

In another aspect, the invention provides a method of preventing at least one symptom in a subject having a disease or disorder that would benefit from reduction in aminolevulinic acid synthase-1 (ALAS1) expression, the method including administering to the subject a prophylactically effective amount of any one of the agents or the pharmaceutical compositions described above, thereby preventing at least one symptom in the subject having a disorder that would benefit from reduction in ALAS1 expression.

In one embodiment, the administration of the antisense polynucleotide agent to the subject causes a decrease in ALAS1 protein levels.

In one embodiment, the disorder is an ALAS1-associated disease.

For example, the ALAS1-associated disease is porphyria, *e.g.*, the porphyria is one of: X-linked sideroblastic anemia (XLSA), ALA deyhdratase deficiency porphyria (Doss porphyria), acute intermittent porphyria (AIP), congenital erythropoietic porphyria (CEP), prophyria cutanea tarda (PCT), hereditary coproporphyria (coproporphyria, or HCP), variegate porphyria (VP), erythropoietic protoporphyria (EPP), or transient erythroporphyria of infancy, acute hepatic porphyria, hepatoerythropoietic porphyria, or dual porphyria.

In one embodiment, an ALAS1-associated disease, is a hepatic porphyria, *e.g.,* a hepatic porphyria characterized by a deficiency in the enzyme porphobilinogen deaminase (PBGD), such as acute intermittent porphyria (AIP) porphyria. In another embodiment, an ALAS1-associated disease, is a hepatic porphyria, *e.g.,* a hepatic porphyria characterized by overexpression of δ-aminolevulinic acid synthase 1 (ALAS1) in the liver, such as ALA dehydratase deficiency porphyria (ADP).

In one embodiment, the agent or the composition is administered after an acute attack of porphyria.

In another embodiment, the agent or the composition is administered during an acute attack of porphyria.

In one embodiment, the agent or composition is administered prophylactically to prevent an acute attack of porphyria.

In one embodiment, the subject is human.

In one embodiment, the agent is administered at a dose of about 0.01 mg/kg to about 10 mg/kg or about 0.5 mg/kg to about 50 mg/kg.

In one embodiment, the agent is administered at a dose of about 10 mg/kg to about 30 mg/kg.

In one embodiment, the agent is administered to the subject once a week.

In one embodiment, the agent is administered to the subject twice a week.

In one embodiment, the agent is administered to the subject twice a month.

In one embodiment, the agent is administered to the subject subcutaneously.

Brief Description of the Drawings

Figure 1 depicts the heme biosynthetic pathway.

Figure 2 summarizes certain porphyrias associated with genetic errors in heme metabolism.

Figure 3 depicts a human ALAS1 mRNA sequence transcript variant 1 (Ref. Seq. NM_000688.4 (GI:40316942, record dated November 19, 2011), SEQ ID NO: 1).

Figure 4 depicts a human ALAS1 mRNA sequence transcript variant 2 (Ref. Seq. NM_000688.5 (GI: 362999011, record dated April 1, 2012), SEQ ID NO: 2).

Detailed Description of the Invention

The present invention provides polynucleotide agents and compositions comprising such agents which target nucleic acids encoding ALAS1(*e.g.,* mRNA encoding ALAS1 as provided in, for example, any one of SEQ ID NO:1 (NM_000688.4) or SEQ ID NO:2 (NM_000688.5)). The polynucleotide agents bind to nucleic acids encoding SEQ ID NO:1 *via*, *e.g.,*Watson-Crick base pairing, and interfere with the normal function of the targeted nucleic acid.

The polynucleotide agents of the invention include a nucleotide sequence which is about 4 to about 50 nucleotides or less in length and which is about 80% complementary to at least part of an mRNA transcript of an ALAS1 gene. The use of these polynucleotide agents enables the targeted inhibition of RNA expression and/or activity of an ALAS1 gene in mammals.

The present inventors have demonstrated that polynucleotide agents targeting ALAS1 can mediate antisense inhibition *in vitro* resulting in significant inhibition of expression of an ALAS1 gene. Thus, methods and compositions including these polynucleotide agents are useful for treating a subject who would benefit by a reduction in the levels and/or activity of an ALAS1 protein, such as a subject having an ALAS1-associated disease, *e.g.,* a porphyria.

The present invention also provides methods and combination therapies for treating a subject having a disorder that would benefit from inhibiting or reducing the expression of an ALAS1 gene, such as an ALAS1-associated disease, *e.g.,* a porphyria, using the polynucleotide agents and compositions of the invention.

The present invention also provides methods for preventing at least one symptom, *e.g.,* severe abdominal pain, in a subject having a disorder that would benefit from inhibiting or reducing the expression of an ALAS1 gene, *e.g.,* an ALAS1-associated disease, *e.g.,* a

porphyria. The present invention further provides compositions comprising polynucleotide agents which effect antisense inhibition of an ALAS1 gene. The ALAS1 gene may be within a cell, *e.g.,* a cell within a subject, such as a human.

The combination therapies of the present invention include administering to a subject having an ALAS1-associated disease, a polynucleotide agent of the invention and an additional therapeutic, such as glucose and/or a heme product such as hemin. The combination therapies of the invention reduce ALAS1 levels in the subject (*e.g.,* by about 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, or about 99%) by targeting ALAS1 mRNA with a polynucleotide agent of the invention and, accordingly, allow the therapeutically (or prophylactically) effective amount of the additional therapeutic required to treat the subject to be reduced, thereby decreasing the costs of treatment and permitting easier and more convenient ways of administering the additional therapeutic, such as subcutaneous administration.

The following detailed description discloses how to make and use polynucleotide agents to inhibit the mRNA and/or protein expression of an ALAS1 gene, as well as compositions, uses, and methods for treating subjects having diseases and disorders that would benefit from inhibition and/or reduction of the expression of this gene.

I. Definitions

In order that the present invention may be more readily understood, certain terms are first defined. In addition, it should be noted that whenever a value or range of values of a parameter are recited, it is intended that values and ranges intermediate to the recited values are also intended to be part of this invention.

The articles “a” and “an” are used herein to refer to one or to more than one (*i.e.*, to at least one) of the grammatical object of the article. By way of example, “an element” means one element or more than one element, *e.g.*, a plurality of elements.

The term "including" is used herein to mean, and is used interchangeably with, the phrase "including but not limited to".

The term "or" is used herein to mean, and is used interchangeably with, the term "and/or," unless context clearly indicates otherwise.

As used herein, “ALAS1” (also known as ALAS1; δ-aminolevulinate synthase 1; δ-ALA synthase 1; 5’-aminolevulinic acid synthase 1; ALAS-H; ALASH; ALAS-N; ALAS3; EC2.3.1.37; 5-aminolevulinate synthase, nonspecific, mitochondrial; ALAS; MIG4; OTTHUMP00000212619; OTTHUMP00000212620; OTTHUMP00000212621; OTTHUMP00000212622; migration-inducing protein 4; EC 2.3.1) refers to a nuclear-encoded mitochondrial enzyme that is the first and rate-limiting enzyme in the mammalian

heme biosynthetic pathway. ALAS1 catalyzes the condensation of glycine with succinyl-CoA to form δ-aminolevulinic acid (ALA). The level of the mature encoded ALAS1 protein is regulated by heme: high levels of heme down-regulate the mature enzyme in mitochondria while low heme levels up-regulate. Multiple alternatively spliced variants, encoding the same protein, have been identified.

The human ALAS1 gene is expressed ubiquitously, is found on chromosome 3p21.1 and typically encodes a sequence of 640 amino acids. In contrast, the ALAS-2 gene, which encodes an isozyme, is expressed only in erythrocytes, is found on chromoxome Xp11.21, and typically encodes a sequence of 550 amino acids.

As used herein an "ALAS1 protein" means any protein variant of ALAS1 from any species (*e.g.*, human, mouse, non-human primate), as well as any mutants and fragments thereof that retain an ALAS1 activity. Similarly, an "ALAS1 transcript" refers to any transcript variant of ALAS1, from any species (*e.g.*, human, mouse, non-human primate). A sequence of a human ALAS1 variant 1 mRNA transcript can be found at NM_000688.4 (FIG. 3; SEQ ID NO:1). Another version, a human ALAS1 variant 2 mRNA transcript, can be found at NM_000688.5 (FIG. 4; SEQ ID NO:382).

Additional examples of ALAS1 mRNA sequences are readily available using publicly available databases, *e.g.*, GenBank, Prosite, OMIM.

The term"ALAS1," as used herein, also refers to naturally occurring DNA sequence variations of the ALAS1 gene, such as a single nucleotide polymorphism in the ALAS1 gene (see, *e.g.*, ncbi.nlm.nih.gov/snp).

The terms "antisense polynucleotide agent" "antisense compound", and "agent" as used interchangeably herein, refer to an agent comprising a single-stranded oligonucleotide that contains RNA as that term is defined herein, and which targets nucleic acid molecules encoding ALAS1 (*e.g.,* mRNA encoding ALAS1 as provided in, for example, any one of SEQ ID NOs:1-2). The antisense polynucleotide agents specifically bind to the target nucleic acid molecules *via* hydrogen bonding (*e.g.*, Watson-Crick, Hoogsteen or reversed Hoogsteen hydrogen bonding) and interfere with the normal function of the targeted nucleic acid (*e.g.*, by an antisense mechanism of action). This interference with or modulation of the function of a target nucleic acid by the polynucleotide agents of the present invention is referred to as "antisense inhibition."

The functions of the target nucleic acid molecule to be interfered with may include functions such as, for example, translocation of the RNA to the site of protein translation, translation of protein from the RNA, splicing of the RNA to yield one or more mRNA species, and catalytic activity which may be engaged in or facilitated by the RNA.

In some embodiments, antisense inhibition refers to "inhibiting the expression" of target nucleic acid levels and/or target protein levels in a cell, *e.g.,* a cell within a subject, such as a mammalian subject, in the presence of the antisense polynucleotide agent

complementary to a target nucleic acid as compared to target nucleic acid levels and/or target protein levels in the absence of the antisense polynucleotide agent. For example, the antisense polynucleotide agents of the invention can inhibit translation in a stoichiometric manner by base pairing to the mRNA and physically obstructing the translation machinery, see Dias, N. *et al.*, (2002) *Mol Cancer Ther* 1:347-355.

As used herein, "target sequence" refers to a contiguous portion of the nucleotide sequence of an mRNA molecule formed during the transcription of an ALAS1 gene, including mRNA that is a product of RNA processing of a primary transcription product.

As used herein, "target nucleic acid" refers to a nucleic acid molecule to which an antisense polynucleotide agent specifically hybridizes.

As used herein, the term "specifically hybridizes" refers to an antisense polynucleotide agent having a sufficient degree of complementarity between the antisense polynucleotide agent and a target nucleic acid to induce a desired effect, while exhibiting minimal or no effects on non-target nucleic acids under conditions in which specific binding is desired, *e.g.,* under physiological conditions in the case of *in vivo* assays and therapeutic treatments.

A target sequence may be from about 4-50 nucleotides in length, *e.g.*, 8-45, 10-45, 10-40, 10-35, 10-30, 10-20, 11-45, 11-40, 11-35, 11-30, 11-20, 12-45, 12-40, 12-35, 12-30, 12-25, 12-20, 13-45, 13-40, 13-35, 13-30, 13-25, 13-20, 14-45, 14-40, 14-35, 14-30, 14-25, 14-20, 15-45, 15-40, 15-35, 15-30, 15-25, 15-20, 16-45, 16-40, 16-35, 16-30, 16-25, 16-20, 17-45, 17-40, 17-35, 17-30, 17-25, 17-20, 18-45, 18-40, 18-35, 18-30, 18-25, 18-20, 19-45, 19-40, 19-35, 19-30, 19-25, 19-20, *e.g.,* 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, or 50 contiguous nucleotides of the nucleotide sequence of an mRNA molecule formed during the transcription of an ALAS1 gene. Ranges and lengths intermediate to the above recited ranges and lengths are also contemplated to be part of the invention.

The terms "complementary," "fully complementary" and "substantially complementary" are used herein with respect to the base matching between an antisense polynucleotide agent and a target sequence. The term"complementarity" refers to the capacity for pairing between nucleobases of a first nucleic acid and a second nucleic acid.

As used herein, an antisense polynucleotide agent that is "substantially complementary to at least part of" a messenger RNA (mRNA) refers to an antisense polynucleotide agent that is substantially complementary to a contiguous portion of the mRNA of interest (*e.g.*, an mRNA encoding ALAS1). For example, a polynucleotide is complementary to at least a part of an ALAS1 mRNA if the sequence is substantially complementary to a non-interrupted portion of an mRNA encoding ALAS1.

As used herein, the term "region of complementarity" refers to the region of the antisense polynucletiode agent that is substantially complementary to a sequence, for example a target sequence, *e.g.,* an ALAS1 nucleotide sequence, as defined herein. Where the region of complementarity is not fully complementary to the target sequence, the mismatches can be in the internal or terminal regions of the molecule. Generally, the most tolerated mismatches are in the terminal regions, *e.g.*, within 5, 4, 3, or 2 nucleotides of the 5'- and/or 3'-terminus of the antisense polynucleotide.

As used herein, and unless otherwise indicated, the term "complementary," when used to describe a first nucleotide sequence in relation to a second nucleotide sequence, refers to the ability of a polynucleotide comprising the first nucleotide sequence to hybridize and form a duplex structure under certain conditions with the second nucleotide sequence, as will be understood by the skilled person. Such conditions can, for example, be stringent conditions, where stringent conditions can include: 400 mM NaCl, 40 mM PIPES pH 6.4, 1 mM EDTA, 50°C or 70°C for 12-16 hours followed by washing (see, *e.g.,* "Molecular Cloning: A Laboratory Manual, Sambrook, *et al.* (1989) Cold Spring Harbor Laboratory Press). Other conditions, such as physiologically relevant conditions as can be encountered inside an organism, can apply. The skilled person will be able to determine the set of conditions most appropriate for a test of complementarity of two sequences in accordance with the ultimate application of the nucleotides.

Complementary sequences include those nucleotide sequences of an antisense polynucleotide agent of the invention that base-pair to a second nucleotide sequence over the entire length of one or both nucleotide sequences. Such sequences can be referred to as "fully complementary" with respect to each other herein. However, where a first sequence is referred to as "substantially complementary" with respect to a second sequence herein, the two sequences can be fully complementary, or they can form one or more, but generally not more than 5, 4, 3 or 2 mismatched base pairs upon hybridization for a duplex up to 30 base pairs, while retaining the ability to hybridize under the conditions most relevant to their ultimate application, *e.g.*, antisense inhibition of target gene expression.

"Complementary" sequences, as used herein, can also include, or be formed entirely from, non-Watson-Crick base pairs and/or base pairs formed from non-natural and modified nucleotides, in so far as the above requirements with respect to their ability to hybridize are fulfilled. Such non-Watson-Crick base pairs include, but are not limited to, G:U Wobble or Hoogstein base pairing.

As used herein, the term "strand comprising a sequence" refers to an oligonucleotide comprising a chain of nucleotides that is described by the sequence referred to using the standard nucleotide nomenclature.

"G," "C," "A," "T" and "U" each generally stand for a nucleotide that contains guanine, cytosine, adenine, thymidine and uracil as a base, respectively. However, it will be

understood that the terms "deoxyribonucleotide", "ribonucleotide" and "nucleotide" can also refer to a modified nucleotide, as further detailed below, or a surrogate replacement moiety (see, *e.g.,* Table 2). The skilled person is well aware that guanine, cytosine, adenine, and uracil can be replaced by other moieties without substantially altering the base pairing properties of an oligonucleotide comprising a nucleotide bearing such replacement moiety. For example, without limitation, a nucleotide comprising inosine as its base can base pair with nucleotides containing adenine, cytosine, or uracil. Hence, nucleotides containing uracil, guanine, or adenine can be replaced in the nucleotide sequences of the agents featured in the invention by a nucleotide containing, for example, inosine. In another example, adenine and cytosine anywhere in the oligonucleotide can be replaced with guanine and uracil, respectively to form G-U Wobble base pairing with the target mRNA. Sequences containing such replacement moieties are suitable for the compositions and methods featured in the invention.

A "nucleoside" is a base-sugar combination. The "nucleobase" (also known as "base") portion of the nucleoside is normally a heterocyclic base moiety. "Nucleotides" are nucleosides that further include a phosphate group covalently linked to the sugar portion of the nucleoside. For those nucleosides that include a pentofuranosyl sugar, the phosphate group can be linked to the 2′, 3′ or 5′ hydroxyl moiety of the sugar.

"Polynucleotides," also referred to as "oligonucleotides," are formed through the covalent linkage of adjacent nucleosides to one another, to form a linear polymeric oligonucleotide. Within the polynucleotide structure, the phosphate groups are commonly referred to as forming the internucleoside linkages of the polynucleotide.

In general, the majority of nucleotides of the antisense polynucleotide agents are ribonucleotides, but as described in detail herein, the agents may also include one or more non-ribonucleotides, *e.g.*, a deoxyribonucleotide. In addition, as used in this specification, an "antisense polynucleotide agent" may include nucleotides (*e.g.,* ribonucleotides or deoxyribonucleotides) with chemical modifications; an antisense polynucleotide agent may include substantial modifications at multiple nucleotides.

As used herein, the term "modified nucleotide" refers to a nucleotide having, independently, a modified sugar moiety, a modified internucleotide linkage, and/or modified nucleobase. Thus, the term modified nucleotide encompasses substitutions, additions or removal of, *e.g.,* a functional group or atom, to internucleoside linkages, sugar moieties, or nucleobases. The modifications suitable for use in the antisense polynucleiotde agents of the invention include all types of modifications disclosed herein or known in the art. Any such modifications, as used in nucleotides, are encompassed by "antisense polynucleotide agent" for the purposes of this specification and claims.

As used herein, a "subject" is an animal, such as a mammal, including a primate (such as a human, a non-human primate, *e.g.*, a monkey, and a chimpanzee), a non-primate (such as

a cow, a pig, a camel, a llama, a horse, a goat, a rabbit, a sheep, a hamster, a guinea pig, a cat, a dog, a rat, a mouse, a horse, and a whale), or a bird (*e.g.*, a duck or a goose). In an embodiment, the subject is a human, such as a human being treated or assessed for a disease, disorder or condition that would benefit from reduction in ALAS1 expression; a human at risk for a disease, disorder or condition that would benefit from reduction in ALAS1 expression; a human having a disease, disorder or condition that would benefit from reduction in ALAS1 expression; and/or human being treated for a disease, disorder or condition that would benefit from reduction in ALAS1 expression as described herein.

As used herein in the context of ALAS1 expression, the terms "treat," "treating," "treatment," and the like, refer to relief from or alleviation of pathological processes related to ALAS1 expression (*e.g.*, pathological processes involving porphyrins or defects in the porphyrin pathway, such as, for example, porphyrias). In the context of the present invention insofar as it relates to any of the other conditions recited herein below (other than pathological processes related to ALAS1 expression), the terms "treat," "treatment," and the like mean to prevent, relieve or alleviate at least one symptom associated with such condition, or to slow or reverse the progression or anticipated progression of such condition. For example, the methods featured herein, when employed to treat porphyria, may serve to reduce or prevent one or more symptoms associated with porphyria (*e.g.*, pain, vomiting, constipation, diarrhea, loss or impairment of movement, respiratory paralysis, behavioral changes, including agitation, confusion, hallucinations, and depression, convulsions, as a result of excessive vomiting and/or diarrhea, and/or increased heart rate), to reduce the severity or frequency of attacks associated with porphyria, to reduce the likelihood that an attack of one or more symptoms associated with porphyria will occur upon exposure to a precipitating condition, to shorten an attack associated with porphyria, and/or to reduce the risk of developing conditions associated with porphyria (*e.g.*, kidney damage, hepatocellular cancer or neuropathy (*e.g.*, progressive neuropathy). Thus, unless the context clearly indicates otherwise, the terms "treat," "treatment," and the like are intended to encompass prophylaxis, *e.g.*, prevention of disorders and/or symptoms of disorders related to ALAS1 expression. "Treatment" can also mean prolonging survival as compared to expected survival in the absence of treatment.

The term "lower" in the context of the level of an ALAS1 in a subject or a disease marker or symptom refers to a statistically significant decrease in such level. The decrease can be, for example, at least 10%, at least 15%, at least 20%, at least 25%, at least 30%, at least 35%, at least 40%, at least 45%, at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, or more and is preferably down to a level accepted as within the range of normal for an individual without such disorder.

As used herein, "prevention" or "preventing," when used in reference to a disease, disorder or condition thereof, that would benefit from a reduction in expression of an ALAS1 gene, refers to a reduction in the likelihood that a subject will develop a symptom associated with such a disease, disorder, or condition, *e.g.,* vomiting, constipation, diarrhea, loss or impairment of movement, respiratory paralysis, behavioral changes, including agitation, confusion, hallucinations, and depression, convulsions, as a result of excessive vomiting and/or diarrhea, increased heart rate, and/or pain (*e.g.*, neuropathic pain and/or neuropathy, *e.g.*, progressive neuropathy). The failure to develop a disease, disorder or condition, or the reduction in the development of a symptom associated with such a disease, disorder or condition (*e.g.*, by at least about 10% on a clinically accepted scale for that disease or disorder), or the exhibition of delayed symptoms delayed (*e.g.*, by days, weeks, months or years) is considered effective prevention.

II. Polynucleotide Agents of the Invention

The present invention provides polynucleotide agents, *e.g.,* antisense polynucleotide agents, and compositions comprising such agents, which target an ALAS1 gene and inhibit the expression of the ALAS1 gene. In one embodiment, the antisense polynucleotide agents inhibit the expression of an ALAS1 gene in a cell, such as a cell within a subject, *e.g.,* a mammal, such as a human having an ALAS1-associated disease, *e.g.,* a porphyria, *e.g.,* AIP or ADP.

The antisense polynucleotde agents of the invention include a region of complementarity which is complementary to at least a part of an mRNA formed in the expression of an ALAS1 gene. The region of complementarity may be about 50 nucleotides or less in length (*e.g.,* about 50, 49, 48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, or 4 nucleotides or less in length). Upon contact with a cell expressing the ALAS1 gene, the antisense polynucleotide agent inhibits the expression of the ALAS1 gene (*e.g.,* a human, a primate, a non-primate, or a bird ALAS1 gene) by at least about 10% as assayed by, for example, a PCR or branched DNA (bDNA)-based method, or by a protein-based method, such as by immunofluorescence analysis, using, for example, Western Blotting or flow cytometric techniques.

The region of complementarity between an antisense polynucleotide agent and a target sequence may be substantially complementary (*e.g.,* there is a sufficient degree of complementarity between the antisense polynucleotide agent and a target nucleic acid to so that they specifically hybridize and induce a desired effect), but is generally fully complementary to the target sequence. The target sequence can be derived from the sequence of an mRNA formed during the expression of an ALAS1 gene.

Accordingly, in one aspect, an antisense polynucleotide agent of the invention specifically hybridizes to a target nucleic acid molecule, such as the mRNA encoding ALAS1, and comprises a contiguous nucleotide sequence which corresponds to the reverse complement of a nucleotide sequence of any one of SEQ ID NO:1-2, or a fragment of any one of SEQ ID NOs:1-2.

In some embodiments, the antisense polynucleotide agents of the invention may be substantially complementary to the target sequence. For example, an antisense polynucleotide agent that is substantially complementary to the target sequence may include a contiguous nucleotide sequence comprising no more than 5 mismatches (*e.g.*, no more than 1, no more than 2, no more than 3, no more than 4, or no more than 5 mismatches) when hybridizing to a target sequence, such as to the corresponding region of a nucleic acid which encodes a mammalian ALAS1 mRNA. In some embodiments, the contiguous nucleotide sequence comprises no more than a single mismatch when hybridizing to the target sequence, such as the corresponding region of a nucleic acid which encodes a mammalian ALAS1 mRNA.

In some embodiments, the antisense polynucleotide agents of the invention that are substantially complementary to the target sequence comprise a contiguous nucleotide sequence which is at least about 80% complementary over its entire length to the equivalent region of the nucleotide sequence of any one of SEQ ID NOs:1-2, or a fragment of any one of SEQ ID NOs:1-2, such as about 85%, about 86%, about 87%, about 88%, about 89%, about 90%, about % 91%, about 92%, about 93%, about 94%, about 95%, about 96%, about 97%, about 98%, or about 99% complementary.

In some embodiments, an antisense polynucleotide agent comprises a contiguous nucleotide sequence which is fully complementary over its entire length to the equivalent region of the nucleotide sequence of any one of SEQ ID NOs:1-2 (or a fragment of any one of SEQ ID NOs:1-2).

An antisense polynucleotide agent may comprise a contiguous nucleotide sequence of about 4 to about 50 nucleotides in length, *e.g.*, 8-49, 8-48, 8-47, 8-46, 8-45, 8-44, 8-43, 8-42, 8-41, 8-40, 8-39, 8-38, 8-37, 8-36, 8-35, 8-34, 8-33, 8-32, 8-31, 8-30, 8-29, 8-28, 8-27, 8-26, 8-25, 8-24, 8-23, 8-22, 8-21, 8-20, 8-19, 8-18, 8-17, 8-16, 8-15, 8-14, 8-13, 8-12, 8-11, 8-10, 8-9, 10-49, 10-48, 10-47, 10-46, 10-45, 10-44, 10-43, 10-42, 10-41, 10-40, 10-39, 10-38, 10-37, 10-36, 10-35, 10-34, 10-33, 10-32, 10-31, 10-30, 10-29, 10-28, 10-27, 10-26, 10-25, 10-24, 10-23, 10-22, 10-21, 10-20, 10-19, 10-18, 10-17, 10-16, 10-15, 10-14, 10-13, 10-12, 10-11,11-49, 11-48, 11-47, 11-46, 11-45, 11-44, 11-43, 11-42, 11-41, 11-40, 11-39, 11-38, 11-37, 11-36, 11-35, 11-34, 11-33, 11-32, 11-31, 11-30, 11-29, 11-28, 11-27, 11-26, 11-25, 11-24, 11-23, 11-22, 11-21, 11-20, 11-19, 11-18, 11-17, 11-16, 11-15, 11-14, 11-13, 11-12, 12-49, 12-48, 12-47, 12-46, 12-45, 12-44, 12-43, 12-42, 12-41, 12-40, 12-39, 12-38, 12-37, 12-36, 12-35, 12-34, 12-33, 12-32, 12-31, 12-30, 12-29, 12-28, 12-27, 12-26, 12-25, 12-24, 12-

23, 12-22, 12-21, 12-20, 12-19, 12-18, 12-17, 12-16, 12-15, 12-14, 12-13, 13-49, 13-48, 13-47, 13-46, 13-45, 13-44, 13-43, 13-42, 13-41, 13-40, 13-39, 13-38, 13-37, 13-36, 13-35, 13-34, 13-33, 13-32, 13-31, 13-30, 13-29, 13-28, 13-27, 13-26, 13-25, 13-24, 13-23, 13-22, 13-21, 13-20, 13-19, 13-18, 13-17, 13-16, 13-15, 13-14, 14-49, 14-48, 14-47, 14-46, 14-45, 14-44, 14-43, 14-42, 14-41, 14-40, 14-39, 14-38, 14-37, 14-36, 14-35, 14-34, 14-33, 14-32, 14-31, 14-30, 14-29, 14-28, 14-27, 14-26, 14-25, 14-24, 14-23, 14-22, 14-21, 14-20, 14-19, 14-18, 14-17, 14-16, 14-15, 15-49, 15-48, 15-47, 15-46, 15-45, 15-44, 15-43, 15-42, 15-41, 15-40, 15-39, 15-38, 15-37, 15-36, 15-35, 15-34, 15-33, 15-32, 15-31, 15-30, 15-29, 15-28, 15-27, 15-26, 15-25, 15-24, 15-23, 15-22, 15-21, 15-20, 15-19, 15-18, 15-17, 15-16,16-49, 16-48, 16-47, 16-46, 16-45, 16-44, 16-43, 16-42, 16-41, 16-40, 16-39, 16-38, 16-37, 16-36, 16-35, 16-34, 16-33, 16-32, 16-31, 16-30, 16-29, 16-28, 16-27, 16-26, 16-25, 16-24, 16-23, 16-22, 16-21, 16-20, 16-19, 16-18, 16-17, 17-49, 17-48, 17-47, 17-46, 17-45, 17-44, 17-43, 17-42, 17-41, 17-40, 17-39, 17-38, 17-37, 17-36, 17-35, 17-34, 17-33, 17-32, 17-31, 17-30, 17-29, 17-28, 17-27, 17-26, 17-25, 17-24, 17-23, 17-22, 17-21, 17-20, 17-19, 17-18, 18-49, 18-48, 18-47, 18-46, 18-45, 18-44, 18-43, 18-42, 18-41, 18-40, 18-39, 18-38, 18-37, 18-36, 18-35, 18-34, 18-33, 18-32, 18-31, 18-30, 18-29, 18-28, 18-27, 18-26, 18-25, 18-24, 18-23, 18-22, 18-21, 18-20, 19-49, 19-48, 19-47, 19-46, 19-45, 19-44, 19-43, 19-42, 19-41, 19-40, 19-39, 19-38, 19-37, 19-36, 19-35, 19-34, 19-33, 19-32, 19-31, 19-30, 19-29, 19-28, 19-27, 19-26, 19-25, 19-24, 19-23, 19-22, 19-21, 19-20, 20-49, 20-48, 20-47, 20-46, 20-45, 20-44, 20-43, 20-42, 20-41, 20-40, 20-39, 20-38, 20-37, 20-36, 20-35, 20-34, 20-33, 20-32, 20-31, 20-30, 20-29, 20-28, 20-27, 20-26, 20-25, 20-24,20-23, 20-22, 20-21, 21-49, 21-48, 21-47, 21-46, 21-45, 21-44, 21-43, 21-42, 21-41, 21-40, 21-39, 21-38, 21-37, 21-36, 21-35, 21-34, 21-33, 21-32, 21-31, 21-30, 21-29, 21-28, 21-27, 21-26, 21-25, 21-24, 21-23, 21-22, 22-49, 22-48, 22-47, 22-46, 22-45, 22-44, 22-43, 22-42, 22-41, 22-40, 22-39, 22-38, 22-37, 22-36, 22-35, 22-34, 22-33, 22-32, 22-31, 22-30, 22-29, 22-28, 22-27, 22-26, 22-25, 22-24, 22-23, 23-49, 23-48, 23-47, 23-46, 23-45, 23-44, 23-43, 23-42, 23-41, 23-40, 23-39, 23-38, 23-37, 23-36, 23-35, 23-34, 23-33, 23-32, 23-31, 23-30, 23-29, 23-28, 23-27, 23-26, 23-25, 23-24, 24-49, 24-48, 24-47, 24-46, 24-45, 24-44, 24-43, 24-42, 24-41, 24-40, 24-39, 24-38, 24-37, 24-36, 24-35, 24-34, 24-33, 24-32, 24-31, 24-30, 24-29, 24-28, 24-27, 24-26, 24-25, 25-49, 25-48, 25-47, 25-46, 25-45, 25-44, 25-43, 25-42, 25-41, 25-40, 25-39, 25-38, 25-37, 25-36, 25-35, 25-34, 25-33, 25-32, 25-31, 25-30, 25-29, 25-28, 25-27, 25-26,26-49, 26-48, 26-47, 26-46, 26-45, 26-44, 26-43, 26-42, 26-41, 26-40, 26-39, 26-38, 26-37, 26-36, 26-35, 26-34, 26-33, 26-32, 26-31, 26-30, 26-29, 26-28, 26-27, 27-49, 27-48, 27-47, 27-46, 27-45, 27-44, 27-43, 27-42, 27-41, 27-40, 27-39, 27-38, 27-37, 27-36, 27-35, 27-34, 27-33, 27-32, 27-31, 27-30, 27-29, 27-28, 28-49, 28-48, 28-47, 28-46, 28-45, 28-44, 28-43, 28-42, 28-41, 28-40, 28-39, 28-38, 28-37, 28-36, 28-35, 28-34, 28-33, 28-32, 28-31, 28-30, 28-29, 29-49, 29-48, 29-47, 29-46, 29-45, 29-44, 29-43, 29-42, 29-41, 29-40, 29-39, 29-38, 29-37, 29-36, 29-35, 29-34, 29-33, 29-32, 29-31, 29-30, 30-49, 30-48, 30-47, 30-46, 30-45, 30-44, 30-43, 30-42, 30-

41, 30-40, 30-39, 30-38, 30-37, 30-36, 30-35, 30-34, 30-33, 30-32, or 30-31 nucleotides in length, *e.g.,* 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, or 50 nucleotides in length.

In some embodiments, an antisense polynucleotide agent may comprise a contiguous nucleotide sequence of no more than 22 nucleotides, such as no more than 21 nucleotides, 20 nucleotides, 19 nucleotides, or no more than 18 nucleotides. In some embodiments the antisense polynucleotide agenst of the invention comprises less than 20 nucleotides. In other emabodiments, the antisense polynucleotide agents of the invention comprise 20 nucleotides.

In one aspect, an antisense polynucleotide agent of the invention includes a sequence selected from the group of sequences provided in Tables 3 and 4. It will be understood that, although some of the sequences in Tables 3 and 4 are described as modified and/or conjugated sequences, an antisense polynucleotide agent of the invention, may also comprise any one of the sequences set forth in Tables 3 and 4 that is un-modified, un-conjugated, and/or modified and/or conjugated differently than described therein.

By virtue of the nature of the nucleotide sequences provided in Tables 3 and 4, antisense polynucleotide agents of the invention may include one of the sequences of Tables 3 minus only a few nucleotides on one or both ends and yet remain similarly effective as compared to the antisense polynucleotide agents described above. Hence, antisense polynucleotide agents having a sequence of at least 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14,15, 16, 17, 18, 19, 20, or more contiguous nucleotides derived from one of the sequences of Tables 3 and 4 and differing in their ability to inhibit the expression of an ALAS1 gene by not more than about 5, 10, 15, 20, 25, or 30% inhibition from an antisense polynucleotide agent comprising the full sequence, are contemplated to be within the scope of the present invention.

In addition, the antisense polynucleotide agents provided in Tables 3 and 4 identify a region(s) in an ALAS1 transcript that is susceptible to antisense inhibition (*e.g.,* the regions encompassed by the start and end positions relative to NM_000688.4 in Table 3 and NM_000688.5 in Table 4). As such, the present invention further features antisense polynucleotide agents that target within one of these sites. As used herein, an antisense polynucleotide agent is said to target within a particular site of an RNA transcript if the antisense polynucleotide agent promotes antisense inhibition of the target at that site. Such an antisense polynucleotide agent will generally include at least about 15 contiguous nucleotides from one of the sequences provided in Tables 3 and 4 coupled to additional nucleotide sequences taken from the region contiguous to the selected sequence in an ALAS1 gene.

While a target sequence is generally about 4-50 nucleotides in length, there is wide variation in the suitability of particular sequences in this range for directing antisense inhibition of any given target RNA. Various software packages and the guidelines set out herein provide guidance for the identification of optimal target sequences for any given gene target, but an empirical approach can also be taken in which a "window" or "mask" of a given size (as a non-limiting example, 20 nucleotides) is literally or figuratively (including, *e.g.*, *in silico*) placed on the target RNA sequence to identify sequences in the size range that can serve as target sequences. By moving the sequence "window" progressively one nucleotide upstream or downstream of an initial target sequence location, the next potential target sequence can be identified, until the complete set of possible sequences is identified for any given target size selected. This process, coupled with systematic synthesis and testing of the identified sequences (using assays as described herein or as known in the art) to identify those sequences that perform optimally can identify those RNA sequences that, when targeted with an antisense polynucleotide agent, mediate the best inhibition of target gene expression. Thus, while the sequences identified, for example, in Tables 3 and 4 represent effective target sequences, it is contemplated that further optimization of antisense inhibition efficiency can be achieved by progressively "walking the window" one nucleotide upstream or downstream of the given sequences to identify sequences with equal or better inhibition characteristics.

Further, it is contemplated that for any sequence identified, *e.g.*, in Tables 3 and 4, further optimization could be achieved by systematically either adding or removing nucleotides to generate longer or shorter sequences and testing those sequences generated by walking a window of the longer or shorter size up or down the target RNA from that point. Again, coupling this approach to generating new candidate targets with testing for effectiveness of antisense polynucleotide agents based on those target sequences in an inhibition assay as known in the art and/or as described herein can lead to further improvements in the efficiency of inhibition. Further still, such optimized sequences can be adjusted by, *e.g.*, the introduction of modified nucleotides as described herein or as known in the art, addition or changes in length, or other modifications as known in the art and/or discussed herein to further optimize the molecule (*e.g.*, increasing serum stability or circulating half-life, increasing thermal stability, enhancing transmembrane delivery, targeting to a particular location or cell type, increasing interaction with silencing pathway enzymes, increasing release from endosomes) as an expression inhibitor.

III. Modified Polynucleotide Agents of the Invention

In one embodiment, the nucleotides of a polynucleotide agent of the invention, *e.g.,* an antisense polynucleotide agent of the invention, are un-modified, and do not comprise, *e.g.,* chemical modifications and/or conjugations known in the art and described herein. In

another embodiment, at least one of the nucleotides of a polynucleotide agent of the invention, *e.g.,* an antisense polynucleotide agent of the invention, is chemically modified to enhance stability or other beneficial characteristics. In certain embodiments of the invention, substantially all of the nucleotides of a polynucleotide agent of the invention, *e.g.,* an antisense polynucleotide agent of the invention, are modified. In other embodiments of the invention, all of the nucleotides of a polynucleotide agent of the invention, *e.g.,* an antisense polynucleotide agent of the invention, are modified. Antisense polynucleotide agents of the invention in which "substantially all of the nucleotides are modified" are largely but not wholly modified and can include not more than 5, 4, 3, 2, or 1 unmodified nucleotides.

The nucleic acids featured in the invention can be synthesized and/or modified by standard methods known in the art as further discussed below, *e.g.*, solution-phase or solid-phase organic synthesis or both, *e.g.,* by use of an automated DNA synthesizer, such as are commercially available from, for example, Biosearch, Applied Biosystems, Inc. Well-established methods for the synthesis and/or modification of the nucleic acids featured in the invention are described in, for example, "Current protocols in nucleic acid chemistry," Beaucage, S.L. *et al.* (Edrs.), John Wiley & Sons, Inc., New York, NY, USA, which is hereby incorporated herein by reference. Modifications include, for example, end modifications, *e.g.*, 5'-end modifications (phosphorylation, conjugation, inverted linkages) or 3'-end modifications (conjugation, DNA nucleotides, inverted linkages, *etc.*); base modifications, *e.g.*, replacement with stabilizing bases, destabilizing bases, or bases that base pair with an expanded repertoire of partners, removal of bases (abasic nucleotides), or conjugated bases; sugar modifications (*e.g.*, at the 2'-position or 4'-position) or replacement of the sugar; and/or backbone modifications, including modification or replacement of the phosphodiester linkages.

Specific examples of modified nucleotides useful in the embodiments described herein include, but are not limited to nucleotides containing modified backbones or no natural internucleoside linkages. Nucleotides having modified backbones include, among others, those that do not have a phosphorus atom in the backbone. For the purposes of this specification, and as sometimes referenced in the art, modified nucleotides that do not have a phosphorus atom in their internucleoside backbone can also be considered to be oligonucleosides. In some embodiments, a modified antisense polynucleotide agent will have a phosphorus atom in its internucleoside backbone.

Modified nucleotide backbones include, for example, phosphorothioates, chiral phosphorothioates, phosphorodithioates, phosphotriesters, aminoalkylphosphotriesters, methyl and other alkyl phosphonates including 3'-alkylene phosphonates and chiral phosphonates, phosphinates, phosphoramidates including 3'-amino phosphoramidate and aminoalkylphosphoramidates, thionophosphoramidates, thionoalkylphosphonates, thionoalkylphosphotriesters, and boranophosphates having normal 3'-5' linkages, 2'-5'-linked

analogs of these, and those having inverted polarity wherein the adjacent pairs of nucleoside units are linked 3'-5' to 5'-3' or 2'-5' to 5'-2'. Various salts, mixed salts and free acid forms are also included.

Representative U.S. patents that teach the preparation of the above phosphorus-containing linkages include, but are not limited to, U.S. Patent Nos. 3,687,808; 4,469,863; 4,476,301; 5,023,243; 5,177,195; 5,188,897; 5,264,423; 5,276,019; 5,278,302; 5,286,717; 5,321,131; 5,399,676; 5,405,939; 5,453,496; 5,455,233; 5,466,677; 5,476,925; 5,519,126; 5,536,821; 5,541,316; 5,550,111; 5,563,253; 5,571,799; 5,587,361; 5,625,050; 6,028,188; 6,124,445; 6,160,109; 6,169,170; 6,172,209; 6, 239,265; 6,277,603; 6,326,199; 6,346,614; 6,444,423; 6,531,590; 6,534,639; 6,608,035; 6,683,167; 6,858,715; 6,867,294; 6,878,805; 7,015,315; 7,041,816; 7,273,933; 7,321,029; and US Pat RE39464, the entire contents of each of which are hereby incorporated herein by reference.

Modified nucleotide backbones that do not include a phosphorus atom therein have backbones that are formed by short chain alkyl or cycloalkyl internucleoside linkages, mixed heteroatoms and alkyl or cycloalkyl internucleoside linkages, or one or more short chain heteroatomic or heterocyclic internucleoside linkages. These include those having morpholino linkages (formed in part from the sugar portion of a nucleoside); siloxane backbones; sulfide, sulfoxide and sulfone backbones; formacetyl and thioformacetyl backbones; methylene formacetyl and thioformacetyl backbones; alkene containing backbones; sulfamate backbones; methyleneimino and methylenehydrazino backbones; sulfonate and sulfonamide backbones; amide backbones; and others having mixed N, O, S and CH_2 component parts.

Representative U.S. patents that teach the preparation of the above oligonucleosides include, but are not limited to, U.S. Patent Nos. 5,034,506; 5,166,315; 5,185,444; 5,214,134; 5,216,141; 5,235,033; 5,64,562; 5,264,564; 5,405,938; 5,434,257; 5,466,677; 5,470,967; 5,489,677; 5,541,307; 5,561,225; 5,596,086; 5,602,240; 5,608,046; 5,610,289; 5,618,704; 5,623,070; 5,663,312; 5,633,360; 5,677,437; and, 5,677,439, the entire contents of each of which are hereby incorporated herein by reference.

In other embodiments, suitable nucleotide mimetics are contemplated for use in antisense polynucleotide agents, in which both the sugar and the internucleoside linkage, *i.e.*, the backbone, of the nucleotide units are replaced with novel groups. The base units are maintained for hybridization with an appropriate nucleic acid target compound. One such oligomeric compound, an RNA mimetic that has been shown to have excellent hybridization properties, is referred to as a peptide nucleic acid (PNA). In PNA compounds, the sugar backbone of an RNA is replaced with an amide containing backbone, in particular an aminoethylglycine backbone. The nucleobases are retained and are bound directly or indirectly to aza nitrogen atoms of the amide portion of the backbone. Representative U.S. patents that teach the preparation of PNA compounds include, but are not limited to, U.S.

Patent Nos. 5,539,082; 5,714,331; and 5,719,262, the entire contents of each of which are hereby incorporated herein by reference. Additional PNA compounds suitable for use in the antisense polynucleotide agents of the invention are described in, for example, in Nielsen *et al.*, *Science*, 1991, 254, 1497-1500.

Some embodiments featured in the invention include polynucleotides with phosphorothioate backbones and oligonucleosides with heteroatom backbones, and in particular --CH_2--NH--CH_2-, --CH_2--N(CH_3)--O--CH_2--[known as a methylene (methylimino) or MMI backbone], --CH_2--O--N(CH_3)--CH_2--, --CH_2--N(CH_3)--N(CH_3)--CH_2-- and --N(CH_3)--CH_2--CH_2--[wherein the native phosphodiester backbone is represented as --O--P--O--CH_2--] of the above-referenced U.S. Patent No. 5,489,677, and the amide backbones of the above-referenced U.S. Patent No. 5,602,240. In some embodiments, the antisense polynucleotide agents featured herein have morpholino backbone structures of the above-referenced U.S. Patent No. 5,034,506.

Modified nucleotides can also contain one or more modified or substituted sugar moieties. The antisense polynucleotide agents featured herein can include one of the following at the 2'-position: OH; F; O-, S-, or N-alkyl; O-, S-, or N-alkenyl; O-, S- or N-alkynyl; or O-alkyl-O-alkyl, wherein the alkyl, alkenyl and alkynyl can be substituted or unsubstituted C_1 to C_{10} alkyl or C_2 to C_{10} alkenyl and alkynyl. Exemplary suitable modifications include O[$(CH_2)_n$O] $_m$$CH_3$, O$(CH_2)._nOCH_3$, O$(CH_2)_n$$NH_2$, O$(CH_2)$ $_n$$CH_3$, O$(CH_2)_nONH_2$, and O$(CH_2)_n$ON[$(CH_2)_n$$CH_3$)]$_2$, where n and m are from 1 to about 10.

In other embodiments, antisense polynucleotide agents include one of the following at the 2' position: C_1 to C_{10} lower alkyl, substituted lower alkyl, alkaryl, aralkyl, O-alkaryl or O-aralkyl, SH, SCH_3, OCN, Cl, Br, CN, CF_3, OCF_3, $SOCH_3$, SO_2CH_3, ONO_2, NO_2, N_3, NH_2, heterocycloalkyl, heterocycloalkaryl, aminoalkylamino, polyalkylamino, substituted silyl, an RNA cleaving group, a reporter group, an intercalator, a group for improving the pharmacokinetic properties of an antisense polynucleotide, or a group for improving the pharmacodynamic properties of an antisense polynucleotide agent, and other substituents having similar properties. In some embodiments, the modification includes a 2'-methoxyethoxy (2'-O--$CH_2CH_2OCH_3$, also known as 2'-O-(2-methoxyethyl) or 2'-MOE) (Martin *et al.*, *Helv. Chim. Acta*, 1995, 78:486-504) *i.e.*, an alkoxy-alkoxy group. Another exemplary modification is 2'-dimethylaminooxyethoxy, *i.e.*, a O$(CH_2)_2$ON$(CH_3)_2$ group, also known as 2'-DMAOE, as described in examples herein below, and 2'-dimethylaminoethoxyethoxy (also known in the art as 2'-O-dimethylaminoethoxyethyl or 2'-DMAEOE), *i.e.*, 2'-O--CH_2--O--CH_2--N$(CH_2)_2$.

Other modifications include 2'-methoxy (2'-OCH_3), 2'-aminopropoxy (2'-$OCH_2CH_2CH_2NH_2$) and 2'-fluoro (2'-F). Similar modifications can also be made at other positions on a nucleotide of an antisense polynucleotide agent, particularly the 3' position of the sugar on the 3' terminal nucleotide. Antisense polynucleotide agents can also have sugar

mimetics such as cyclobutyl moieties in place of the pentofuranosyl sugar. Representative U.S. patents that teach the preparation of such modified sugar structures include, but are not limited to, U.S. Patent Nos. 4,981,957; 5,118,800; 5,319,080; 5,359,044; 5,393,878; 5,446,137; 5,466,786; 5,514,785; 5,519,134; 5,567,811; 5,576,427; 5,591,722; 5,597,909; 5,610,300; 5,627,053; 5,639,873; 5,646,265; 5,658,873; 5,670,633; and 5,700,920, certain of which are commonly owned with the instant application. The entire contents of each of the foregoing are hereby incorporated herein by reference.

Additional nucleotides having modified or substituted sugar moieties for use in the polynucleotide agents of the invention include nucleotides comprising a bicyclic sugar. A "bicyclic sugar" is a furanosyl ring modified by the bridging of two atoms. A"bicyclic nucleoside" ("BNA") is a nucleoside having a sugar moiety comprising a bridge connecting two carbon atoms of the sugar ring, thereby forming a bicyclic ring system. In certain embodiments, the bridge connects the 4′-carbon and the 2′-carbon of the sugar ring. Thus, in some embodiments an antisense polynucleotide agent may include one or more locked nucleic acids. A "locked nucleic acid" ("LNA") is a nucleotide having a modified ribose moiety in which the ribose moiety comprises an extra bridge connecting the 2' and 4' carbons. In other words, an LNA is a nucleotide comprising a bicyclic sugar moiety comprising a 4'-CH_2-O-2' bridge. This structure effectively "locks" the ribose in the 3'-endo structural conformation. The addition of locked nucleic acids to santisense polynucleotide agents has been shown to increase santisense polynucleotide agent stability in serum, and to reduce off-target effects (Elmen, J. *et al.*, (2005) *Nucleic Acids Research* 33(1):439-447; Mook, OR. *et al.*, (2007) *Mol Canc Ther* 6(3):833-843; Grunweller, A. *et al.*, (2003) *Nucleic Acids Research* 31(12):3185-3193).

Examples of bicyclic nucleosides for use in the polynucleotides of the invention include without limitation nucleosides comprising a bridge between the 4′ and the 2′ ribosyl ring atoms. In certain embodiments, the antisense polynucleotide agents of the invention include one or more bicyclic nucleosides comprising a 4′ to 2′ bridge. Examples of such 4′ to 2′ bridged bicyclic nucleosides, include but are not limited to 4′-(CH2)—O-2′ (LNA); 4′-(CH2)—S-2′; 4′-(CH2)2—O-2′ (ENA); 4′-CH(CH3)—O-2′ (also referred to as "constrained ethyl" or "cEt") and 4′-CH(CH2OCH3)—O-2′ (and analogs thereof; see, *e.g.,* U.S. Pat. No. 7,399,845); 4′-C(CH3)(CH3)—O-2′ (and analogs thereof; see *e.g.,* US Patent No. 8,278,283); 4′-CH2—N(OCH3)-2′ (and analogs thereof; see *e.g.,* US Patent No. 8,278,425); 4′-CH2—O—N(CH3)-2′ (see, *e.g.,*U.S. Patent Publication No. 2004/0171570); 4′-CH2—N(R)—O-2′, wherein R is H, C1-C12 alkyl, or a protecting group (see, *e.g.,* U.S. Pat. No. 7,427,672); 4′-CH2—C(H)(CH3)-2′ (see, *e.g.,* Chattopadhyaya *et al., J. Org. Chem.*, 2009, 74, 118-134); and 4′-CH2—C(=CH2)-2′ (and analogs thereof; see, *e.g.,* US Patent No. 8,278,426). The entire contents of each of the foregoing are hereby incorporated herein by reference.

Additional representative U.S. Patents and US Patent Publications that teach the preparation of locked nucleic acid nucleotides include, but are not limited to, the following: U.S. Patent Nos. 6,268,490; 6,525,191; 6,670,461; 6,770,748; 6,794,499; 6,998,484; 7,053,207; 7,034,133;7,084,125; 7,399,845; 7,427,672; 7,569,686; 7,741,457; 8,022,193; 8,030,467; 8,278,425; 8,278,426; 8,278,283; US 2008/0039618; and US 2009/0012281, the entire contents of each of which are hereby incorporated herein by reference.

Any of the foregoing bicyclic nucleosides can be prepared having one or more stereochemical sugar configurations including for example α-L-ribofuranose and β-D-ribofuranose (see WO 99/14226).

In one particular embodiment of the invention, an antisense polynucleotide agent can include one or more constrained ethyl nucleotides. As used herein, a "constrained ethyl nucleotide" or "cEt" is a locked nucleic acid comprising a bicyclic sugar moiety comprising a 4'-CH(CH_3)-O-2' bridge. In one embodiment, a constrained ethyl nucleotide is in an S conformation and is referred to as an "*S*-constrained ethyl nucleotide" or "*S*-cEt."

Modified nucleotides included in the antisense polynucleotide agents of the invention can also contain one or more sugar mimetics. For example, the antisense polynucleotide agent may include a "modified tetrahydropyran nucleotide" or "modified THP nucleotide." A "modified tetrahydropyran nucleotide" has a six-membered tetrahydropyran "sugar" substituted in for the pentofuranosyl residue in normal nucleotides (a sugar surrogate). Modified THP nucleotides include, but are not limited to, what is referred to in the art as hexitol nucleic acid (HNA), anitol nucleic acid (ANA), manitol nucleic acid (MNA) (see, *e.g.,* Leumann, *Bioorg. Med. Chem.*, 2002, 10, 841-854), or fluoro HNA (F-HNA).

In some embodiments of the invention, sugar surrogates comprise rings having more than 5 atoms and more than one heteroatom. For example nucleotides comprising morpholino sugar moieties and their use in oligomeric compounds has been reported (see for example: Braasch *et al., Biochemistry*, 2002, 41, 4503-4510; and U.S. Patent Nos. 5,698,685; 5,166,315; 5,185,444; and 5,034,506). Morpholinos may be modified, for example by adding or altering various substituent groups from the above morpholino structure. Such sugar surrogates are referred to herein as "modified morpholinos."

Combinations of modifications are also provided without limitation, such as 2′-F-5′-methyl substituted nucleosides (see PCT International Application WO 2008/101157 published on Aug. 21, 2008 for other disclosed 5′, 2′-bis substituted nucleosides) and replacement of the ribosyl ring oxygen atom with S and further substitution at the 2′-position (see published U.S. Patent Application US2005-0130923, published on Jun. 16, 2005) or alternatively 5′-substitution of a bicyclic nucleic acid (see PCT International Application WO 2007/134181, published on 11/22/07 wherein a 4′-CH2-0-2′ bicyclic nucleoside is further substituted at the 5′ position with a 5′-methyl or a 5′-vinyl group). The synthesis and preparation of carbocyclic bicyclic nucleosides along with their oligomerization and

biochemical studies have also been described (see, *e.g.*, Srivastava et al., J. Am. Chem. Soc. 2007, 129(26), 8362-8379).

In certain embodiments, antisense compounds comprise one or more modified cyclohexenyl nucleosides, which is a nucleoside having a six-membered cyclohexenyl in place of the pentofuranosyl residue in naturally occurring nucleosides. Modified cyclohexenyl nucleosides include, but are not limited to those described in the art (see for example commonly owned, published PCT Application WO 2010/036696, published on Apr. 10, 2010, Robeyns et al., J. Am. Chem. Soc., 2008, 130(6), 1979-1984; Horvath et al., Tetrahedron Letters, 2007, 48, 3621-3623; Nauwelaerts et al., J. Am. Chem. Soc., 2007, 129(30), 9340-9348; Gu et al., Nucleosides, Nucleotides & Nucleic Acids, 2005, 24(5-7), 993-998; Nauwelaerts et al., Nucleic Acids Research, 2005, 33(8), 2452-2463; Robeyns et al., Acta Crystallographica, Section F: Structural Biology and Crystallization Communications, 2005, F61(6), 585-586; Gu et al., Tetrahedron, 2004, 60(9), 2111-2123; Gu et al., Oligonucleotides, 2003, 13(6), 479-489; Wang et al., J. Org. Chem., 2003, 68, 4499-4505; Verbeure et al., Nucleic Acids Research, 2001, 29(24), 4941-4947; Wang et al., J. Org. Chem., 2001, 66, 8478-82; Wang et al., Nucleosides, Nucleotides & Nucleic Acids, 2001, 20(4-7), 785-788; Wang et al., J. Am. Chem., 2000, 122, 8595-8602; Published PCT application, WO 06/047842; and Published PCT Application WO 01/049687; the text of each is incorporated by reference herein, in their entirety).

An antisense polynucleotide agent can also include nucleobase modifications or substitutions. As used herein, "unmodified" or "natural" nucleobases include the purine bases adenine (A) and guanine (G), and the pyrimidine bases thymine (T), cytosine (C) and uracil (U). Modified nucleobases include other synthetic and natural nucleobases such as deoxy-thymine (dT), 5-methylcytosine (5-me-C), 5-hydroxymethyl cytosine, xanthine, hypoxanthine, 2-aminoadenine, 6-methyl and other alkyl derivatives of adenine and guanine, 2-propyl and other alkyl derivatives of adenine and guanine, 2-thiouracil, 2-thiothymine and 2-thiocytosine, 5-halouracil and cytosine, 5-propynyl uracil and cytosine, 6-azo uracil, cytosine and thymine, 5-uracil (pseudouracil), 4-thiouracil, 8-halo, 8-amino, 8-thiol, 8-thioalkyl, 8-hydroxyl anal other 8-substituted adenines and guanines, 5-halo, particularly 5-bromo, 5-trifluoromethyl and other 5-substituted uracils and cytosines, 7-methylguanine and 7-methyladenine, 8-azaguanine and 8-azaadenine, 7-deazaguanine and 7-daazaadenine and 3-deazaguanine and 3-deazaadenine. Further nucleobases include those disclosed in U.S. Patent No. 3,687,808, those disclosed in "Modified Nucleosides in Biochemistry," *Biotechnology and Medicine*, Herdewijn, P. ed. Wiley-VCH, 2008; those disclosed in *The Concise Encyclopedia Of Polymer Science And Engineering*, pages 858-859, Kroschwitz, J. L, ed. John Wiley & Sons, 1990, these disclosed by Englisch *et al.*, *Angewandte Chemie, International Edition,* 1991, 30, 613, and those disclosed by Sanghvi, Y S., Chapter 15, *antisense polynucleotide agent Research and Applications*, pages 289-302, Crooke, S. T. and

Lebleu, B., Ed., CRC Press, 1993. Certain of these nucleobases are particularly useful for increasing the binding affinity of the agents featured in the invention. These include 5-substituted pyrimidines, 6-azapyrimidines and N-2, N-6 and 0-6 substituted purines, including 2-aminopropyladenine, 5-propynyluracil and 5-propynylcytosine. 5-methylcytosine substitutions have been shown to increase nucleic acid duplex stability by 0.6-1.2°C (Sanghvi, Y. S., Crooke, S. T. and Lebleu, B., Eds., *antisense polynucleotide agent Research and Applications*, CRC Press, Boca Raton, 1993, pp. 276-278) and are exemplary base substitutions, even more particularly when combined with 2'-O-methoxyethyl sugar modifications.

Representative U.S. patents that teach the preparation of certain of the above noted modified nucleobases as well as other modified nucleobases include, but are not limited to, the above noted U.S. Patent Nos. 3,687,808, 4,845,205; 5,130,30; 5,134,066; 5,175,273; 5,367,066; 5,432,272; 5,457,187; 5,459,255; 5,484,908; 5,502,177; 5,525,711; 5,552,540; 5,587,469; 5,594,121, 5,596,091; 5,614,617; 5,681,941; 5,750,692; 6,015,886; 6,147,200; 6,166,197; 6,222,025; 6,235,887; 6,380,368; 6,528,640; 6,639,062; 6,617,438; 7,045,610; 7,427,672; and 7,495,088, the entire contents of each of which are hereby incorporated herein by reference.

One or more of the nucleotides of an iRNA of the invention may also include a hydroxymethyl substituted nucleotide. A "hydroxymethyl substituted nucleotide" is an acyclic 2'-3'-seco-nucleotide, also referred to as an "unlocked nucleic acid" ("UNA") modification. Representative U.S. publications that teach the preparation of UNA include, but are not limited to, US Patent No. 8,314,227; and US Patent Publication Nos. 2013/0096289; 2013/0011922; and 2011/0313020, the entire contents of each of which are hereby incorporated herein by reference.

Additional modification which may potentially stabilize the ends of antisense polynucleotide agents can include N- (acetylaminocaproyl)-4-hydroxyprolinol (Hyp-C6-NHAc), N-(caproyl-4-hydroxyprolinol (Hyp-C6), N-(acetyl-4-hydroxyprolinol (Hyp-NHAc), thymidine-2'-0-deoxythymidine (ether), N-(aminocaproyl)-4-hydroxyprolinol (Hyp-C6-amino), 2-docosanoyl-uridine-3"- phosphate, inverted base dT(idT) and others. Disclosure of this modification can be found in US Patent Publication No. 2012/0142101.

Any of the antisense polynucleotide agents of the invention may be optionally conjugated with a GalNAc derivative ligand, as described in Section IV, below.

As described in more detail below, an agent that contains conjugations of one or more carbohydrate moieties to an antisense polynucleotide agent can optimize one or more properties of the agent. In many cases, the carbohydrate moiety will be attached to a modified subunit of the antisense polynucleotide agent. For example, the ribose sugar of one or more ribonucleotide subunits of an agent can be replaced with another moiety, *e.g.*, a non-carbohydrate (preferably cyclic) carrier to which is attached a carbohydrate ligand. A

ribonucleotide subunit in which the ribose sugar of the subunit has been so replaced is referred to herein as a ribose replacement modification subunit (RRMS). A cyclic carrier may be a carbocyclic ring system, *i.e.*, all ring atoms are carbon atoms, or a heterocyclic ring system, *i.e.*, one or more ring atoms may be a heteroatom, *e.g.*, nitrogen, oxygen, sulfur. The cyclic carrier may be a monocyclic ring system, or may contain two or more rings, *e.g.* fused rings. The cyclic carrier may be a fully saturated ring system, or it may contain one or more double bonds.

The ligand may be attached to the polynucleotide via a carrier. The carriers include (i) at least one "backbone attachment point," preferably two "backbone attachment points" and (ii) at least one "tethering attachment point." A "backbone attachment point" as used herein refers to a functional group, *e.g.* a hydroxyl group, or generally, a bond available for, and that is suitable for incorporation of the carrier into the backbone, *e.g.*, the phosphate, or modified phosphate, *e.g.*, sulfur containing, backbone, of a ribonucleic acid. A "tethering attachment point" (TAP) in some embodiments refers to a constituent ring atom of the cyclic carrier, *e.g.*, a carbon atom or a heteroatom (distinct from an atom which provides a backbone attachment point), that connects a selected moiety. The moiety can be, *e.g.*, a carbohydrate, *e.g.* monosaccharide, disaccharide, trisaccharide, tetrasaccharide, oligosaccharide and polysaccharide. Optionally, the selected moiety is connected by an intervening tether to the cyclic carrier. Thus, the cyclic carrier will often include a functional group, *e.g.*, an amino group, or generally, provide a bond, that is suitable for incorporation or tethering of another chemical entity, *e.g.*, a ligand to the constituent ring.

The antisense polynucleotide agents may be conjugated to a ligand *via* a carrier, wherein the carrier can be cyclic group or acyclic group; preferably, the cyclic group is selected from pyrrolidinyl, pyrazolinyl, pyrazolidinyl, imidazolinyl, imidazolidinyl, piperidinyl, piperazinyl, [1,3]dioxolane, oxazolidinyl, isoxazolidinyl, morpholinyl, thiazolidinyl, isothiazolidinyl, quinoxalinyl, pyridazinonyl, tetrahydrofuryl and and decalin; preferably, the acyclic group is selected from serinol backbone or diethanolamine backbone.

In certain specific embodiments, the antisense polynucleotide agent for use in the methods of the invention is an agent selected from the group of agents listed in Tables 3 and 4. These agents may further comprise a ligand, as described in Section IV, below.

A. Polynucleotide Agents Comprising Motifs

In certain embodiments of the invention, at least one of the contiguous nucleotides of the polynucleotide agents of the invention, *e.g.,* the antisense polynucleotide agents of the invention, may be a modified nucleotide. In one embodiment, the modified nucleotide comprises one or more modified sugars. In other embodiments, the modified nucleotide comprises one or more modified nucleobases. In yet other embodiments, the modified nucleotide comprises one or more modified internucleoside linkages. In some embodiments,

the modifications (sugar modifications, nucleobase modifications, and/or linkage modifications) define a pattern or motif. In one embodiment, the patterns of modifications of sugar moieties, internucleoside linkages, and nucleobases are each independent of one another.

Antisense polynucleotide agents having modified oligonucleotides arranged in patterns, or motifs may, for example, confer to the agents properties such as enhanced inhibitory activity, increased binding affinity for a target nucleic acid, or resistance to degradation by *in vivo* nucleases. For example, such agents may contain at least one region modified so as to confer increased resistance to nuclease degradation, increased cellular uptake, increased binding affinity for the target nucleic acid, and/or increased inhibitory activity. A second region of such agents may optionally serve as a substrate for the cellular endonuclease RNase H, which cleaves the RNA strand of an RNA:DNA duplex.

An exemplary antisense polynucleotide agent having modified oligonucleotides arranged in patterns, or motifs is a gapmer. In a “gapmer”, an internal region or "gap" having a plurality of linked nucleotides that supports RNaseH cleavage is positioned between two external flanking regions or "wings" having a plurality of linked nucleotides that are chemically distinct from the linked nucleotides of the internal region. The gap segment generally serves as the substrate for endonuclease cleavage, while the wing segments comprise modified nucleotides.

The three regions of a gapmer motif (the 5 '-wing, the gap, and the 3 '-wing) form a contiguous sequence of nucleotides and may be described as “X-Y-Z”, wherein “X” represents the length of the 5-wing, “Y” represents the length of the gap, and “Z” represents the length of the 3’-wing. In one embodiment, a gapmer described as “X-Y-Z” has a configuration such that the gap segment is positioned immediately adjacent to each of the 5′ wing segment and the 3′ wing segment. Thus, no intervening nucleotides exist between the 5′ wing segment and gap segment, or the gap segment and the 3′ wing segment. Any of the antisense compounds described herein can have a gapmer motif. In some embodiments, X and Z are the same, in other embodiments they are different.

In certain embodiments, the regions of a gapmer are differentiated by the types of modified nucleotides in the region. The types of modified nucleotides that may be used to differentiate the regions of a gapmer, in some embodiments, include β-D-ribonucleotides, β-D-deoxyribonucleotides, 2′-modified nucleotides, *e.g.,* 2′-modified nucleotides (*e.g.,* 2′-MOE, and 2′-O—CH3), and bicyclic sugar modified nucleotides (*e.g.,* those having a 4′-(CH2)n-O-2′ bridge, where n=1 or n=2).

In one embodiment, at least some of the modified nucleotides of each of the wings may differ from at least some of the modified nucleotides of the gap. For example, at least some of the modified nucleotides of each wing that are closest to the gap (the 3 '-most nucleotide of the 5'-wing and the 5'-most nucleotide of the 3 -wing) differ from the modified

nucleotides of the neighboring gap nucleotides, thus defining the boundary between the wings and the gap. In certain embodiments, the modified nucleotides within the gap are the same as one another. In certain embodiments, the gap includes one or more modified nucleotides that differ from the modified nucleotides of one or more other nucleotides of the gap.

The length of the 5'- wing (X) of a gapmer may be 1 to 6 nucleotides in length, *e.g.,* 2 to 6, 2 to 5, 3 to 6, 3 to 5, 1 to 5, 1 to 4, 1 to 3, 2 to 4 nucleotides in length, *e.g.,* 1, 2, 3, 4, 5, or 6 nucleotides in length.

The length of the 3'- wing (Z) of a gapmer may be 1 to 6 nucleotides in length, *e.g.,* 2 to 6, 2-5, 3 to 6, 3 to 5, 1 to 5, 1 to 4, 1 to 3, 2 to 4 nucleotides in length, *e.g.,* 1, 2, 3, 4, 5, or 6 nucleotides in length.

The length of the gap (Y) of a gapmer may be 5 to 14 nucleotides in length, *e.g.,* 5 to 13, 5 to 12, 5 to 11, 5 to 10, 5 to 9, 5 to 8, 5 to 7, 5 to 6, 6 to 14, 6 to 13, 6 to 12, 6 to 11, 6 to 10, 6 to 9, 6 to 8, 6 to 7, 7 to 14, 7 to 13, 7 to 12, 7 to 11, 7 to 10, 7 to 9, 7 to 8, 8 to 14, 8 to 13, 8 to 12, 8 to 11, 8 to 10, 8 to 9, 9 to 14, 9 to 13, 9 to 12, 9 to 11, 9 to 10, 10 to 14, 10 to 13, 10 to 12, 10 to 11, 11 to 14, 11 to 13, 11 to 12, 12 to 14, 12 to 13, or 13 to 14 nucleotides in length, *e.g.,* 5, 6, 7, 8, 9, 10, 11, 12, 13, or 14 nucleotides in length.

In some embodiments of the invention X consists of 2, 3, 4, 5 or 6 nucleotides, Y consists of 7, 8, 9, 10, 11, or 12 nucleotides, and Z consists of 2, 3, 4, 5 or 6 nucleotides. Such gapmers include (X-Y-Z) 2-7-2, 2-7-3, 2-7-4, 2-7-5, 2-7-6, 3-7-2, 3-7-3, 3-7-4, 3-7-5, 3-7-6, 4-7-3, 4-7-4, 4-7-5, 4-7-6, 5-7-3, 5-7-4, 5-7-5, 5-7-6, 6-7-3, 6-7-4, 6-7-5, 6-7-6, 3-7-3, 3-7-4, 3-7-5, 3-7-6, 4-7-3, 4-7-4, 4-7-5, 4-7-6, 5-7-3, 5-7-4, 5-7-5, 5-7-6, 6-7-3, 6-7-4, 6-7-5, 6-7-6, 2-8-2, 2-8-3, 2-8-4, 2-8-5, 2-8-6, 3-8-2, 3-8-3, 3-8-4, 3-8-5, 3-8-6, 4-8-3, 4-8-4, 4-8-5, 4-8-6, 5-8-3, 5-8-4, 5-8-5, 5-8-6, 6-8-3, 6-8-4, 6-8-5, 6-8-6, 2-9-2, 2-9-3, 2-9-4, 2-9-5, 2-9-6, 3-9-2, 3-9-3, 3-9-4, 3-9-5, 3-9-6, 4-9-3, 4-9-4, 4-9-5, 4-9-6, 5-9-3, 5-9-4, 5-9-5, 5-9-6, 6-9-3, 6-9-4, 6-9-5, 6-9-6, 2-10-2, 2-10-3, 2-10-4, 2-10-5, 2-10-6, 3-10-2, 3-10-3, 3-10-4, 3-10-5, 3-10-6, 4-10-3, 4-10-4, 4-10-5, 4-10-6, 5-10-3, 5-10-4, 5-10-5, 5-10-6, 6-10-3, 6-10-4, 6-10-5, 6-10-6, 2-11-2, 2-11-3, 2-11-4, 2-11-5, 2-11-6, 3-11-2, 3-11-3, 3-11-4, 3-11-5, 3-11-6, 4-11-3, 4-11-4, 4-11-5, 4-11-6, 5-11-3, 5-11-4, 5-11-5, 5-11-6, 6-11-3, 6-11-4, 6-11-5, 6-11-6, 2-12-2, 2-12-3, 2-12-4, 2-12-5, 2-12-6, 3-12-2, 3-12-3, 3-12-4, 3-12-5, 3-12-6, 4-12-3, 4-12-4, 4-12-5, 4-12-6, 5-12-3, 5-12-4, 5-12-5, 5-12-6, 6-12-3, 6-12-4, 6-12-5, or 6-12-6.

In some embodiments of the invention, antisense polynucleotide agents targeting ALAS1 include a 5-10-5 gapmer motif. In some embodiments of the invention, antisense polynucleotide agents targeting ALAS1 include a 5-11-5 gapmer motif. In other embodiments of the invention, antisense polynucleotide agents targeting ALAS1 include a 4-10-4 gapmer motif. In other embodiments of the invention, antisense polynucleotide agents targeting ALAS1 include a 4-11-4 gapmer motif. In another embodiment of the invention, antisense polynucleotide agents targeting ALAS1 include a 3-10-3 gapmer motif. In other

embodiments of the invention, antisense polynucleotide agents targeting ALAS1 include a 3-11-3 gapmer motif. In yet other embodiments of the invention, antisense polynucleotide agents targeting ALAS1 include a 2-10-2 gapmer motif. In other embodiments of the invention, antisense polynucleotide agents targeting ALAS1 include a 2-11-2 gapmer motif.

The 5'- wing and/or 3'-wing of a gapmer may independently include 1-6 modified nucleotides, *e.g.,* 1, 2, 3, 4, 5, or 6 modified nucleotides.

In some embodiment, the 5'-wing of a gapmer includes at least one modified nucleotide. In one embodiment, the 5'- wing of a gapmer comprises at least two modified nucleotides. In another embodiment, the 5'- wing of a gapmer comprises at least three modified nucleotides. In yet another embodiment, the 5'- wing of a gapmer comprises at least four modified nucleotides. In another embodiment, the 5'- wing of a gapmer comprises at least five modified nucleotides. In certain embodiments, each nucleotide of the 5'-wing of a gapmer is a modified nucleotide.

In some embodiments, the 3'-wing of a gapmer includes at least one modified nucleotide. In one embodiment, the 3'- wing of a gapmer comprises at least two modified nucleotides. In another embodiment, the 3'- wing of a gapmer comprises at least three modified nucleotides. In yet another embodiment, the 3'- wing of a gapmer comprises at least four modified nucleotides. In another embodiment, the 3'- wing of a gapmer comprises at least five modified nucleotides. In certain embodiments, each nucleotide of the 3'-wing of a gapmer is a modified nucleotide.

In certain embodiments, the regions of a gapmer are differentiated by the types of sugar moieties of the nucleotides. In one embodiment, the nucleotides of each distinct region comprise uniform sugar moieties. In other embodiments, the nucleotides of each distinct region comprise different sugar moieties. In certain embodiments, the sugar nucleotide modification motifs of the two wings are the same as one another. In certain embodiments, the sugar nucleotide modification motifs of the 5'-wing differs from the sugar nucleotide modification motif of the 3'-wing.

The 5'-wing of a gapmer may include 1-6 modified nucleotides, *e.g.,* 1, 2, 3, 4, 5, or 6 modified nucleotides.

In one embodiment, at least one modified nucleotide of the 5'-wing of a gapmer is a bicyclic nucleotide, such as a constrained ethyl nucleotide, or an LNA. In another embodiment, the 5'-wing of a gapmer includes 2, 3, 4, or 5 bicyclic nucleotides. In some embodiments, each nucleotide of the 5'- wing of a gapmer is a bicyclic nucleotide.

In one embodiment, the 5'-wing of a gapmer includes at least 1, 2, 3, 4, or 5 constrained ethyl nucleotides. In some embodiments, each nucleotide of the 5'- wing of a gapmer is a constrained ethyl nucleotide.

In one embodiment, the 5'-wing of a gapmer comprises at least one LNA nucleotide. In another embodiment, the 5'-wing of a gapmer includes 2, 3, 4, or 5 LNA nucleotides. In other embodiments, each nucleotide of the 5'- wing of a gapmer is an LNA nucleotide.

In certain embodiments, at least one modified nucleotide of the 5'- wing of a gapmer is a non-bicyclic modified nucleotide, *e.g.,* a 2 '-substituted nucleotide. A "2 '-substituted nucleotide" is a nucleotide comprising a modification at the 2'-position which is other than H or OH, such as a 2'-OMe nucleotide, or a 2'-MOE nucleotide. In one embodiment, the 5'-wing of a gapmer comprises 2, 3, 4, or 5 2 '-substituted nucleotides. In one embodiment, each nucleotide of the 5'-wing of a gapmer is a 2 '-substituted nucleotide.

In one embodiment, the 5'- wing of a gapmer comprises at least one 2'-OMe nucleotide. In one embodiment, the 5'- wing of a gapmer comprises at least 2, 3, 4, or 5 2'-OMe nucleotides. In one embodiment, each of the nucleotides of the 5'- wing of a gapmer comprises a 2'-OMe nucleotide.

In one embodiment, the 5'- wing of a gapmer comprises at least one 2'- MOE nucleotide. In one embodiment, the 5'- wing of a gapmer comprises at least 2, 3, 4, or 5 2'-MOE nucleotides. In one embodiment, each of the nucleotides of the 5'- wing of a gapmer comprises a 2'- MOE nucleotide.

In certain embodiments, the 5'- wing of a gapmer comprises at least one 2'-deoxynucleotide. In certain embodiments, each nucleotide of the 5'- wing of a gapmer is a 2'-deoxynucleotide. In a certain embodiments, the 5'- wing of a gapmer comprises at least one ribonucleotide. In certain embodiments, each nucleotide of the 5'- wing of a gapmer is a ribonucleotide.

The 3'-wing of a gapmer may include 1-6 modified nucleotides, *e.g.,* 1, 2, 3, 4, 5, or 6 modified nucleotides.

In one embodiment, at least one modified nucleotide of the 3'-wing of a gapmer is a bicyclic nucleotide, such as a constrained ethyl nucleotide, or an LNA. In another embodiment, the 3'-wing of a gapmer includes 2, 3, 4, or 5 bicyclic nucleotides. In some embodiments, each nucleotide of the 3'-wing of a gapmer is a bicyclic nucleotide.

In one embodiment, the 3'-wing of a gapmer includes at least one constrained ethyl nucleotide. In another embodiment, the 3'-wing of a gapmer includes 2, 3, 4, or 5 constrained ethyl nucleotides. In some embodiments, each nucleotide of the 3'-wing of a gapmer is a constrained ethyl nucleotide.

In one embodiment, the 3'-wing of a gapmer comprises at least one LNA nucleotide. In another embodiment, the 3'-wing of a gapmer includes 2, 3, 4, or 5 LNA nucleotides. In other embodiments, each nucleotide of the 3'-wing of a gapmer is an LNA nucleotide.

In certain embodiments, at least one modified nucleotide of the 3'-wing of a gapmer is a non-bicyclic modified nucleotide, *e.g.,* a 2 '-substituted nucleotide. In one embodiment, the 3'-wing of a gapmer comprises 2, 3, 4, or 5 2 '-substituted nucleotides. In one embodiment, each nucleotide of the 3'-wing of a gapmer is a 2 '-substituted nucleotide.

In one embodiment, the 3'-wing of a gapmer comprises at least one 2'-OMe nucleotide. In one embodiment, the 3'-wing of a gapmer comprises at least 2, 3, 4, or 5 2'-OMe nucleotides. In one embodiment, each of the nucleotides of the 3'-wing of a gapmer comprises a 2'-OMe nucleotide.

In one embodiment, the 3'-wing of a gapmer comprises at least one 2'- MOE nucleotide. In one embodiment, the 3'-wing of a gapmer comprises at least 2, 3, 4, or 5 2'-MOE nucleotides. In one embodiment, each of the nucleotides of the 3'-wing of a gapmer comprises a 2'- MOE nucleotide.

In certain embodiments, the 3'-wing of a gapmer comprises at least one 2'-deoxynucleotide. In certain embodiments, each nucleotide of the 3'-wing of a gapmer is a 2'-deoxynucleotide. In a certain embodiments, the 3'-wing of a gapmer comprises at least one ribonucleotide. In certain embodiments, each nucleotide of the 3'-wing of a gapmer is a ribonucleotide.

The gap of a gapmer may include 5-14 modified nucleotides, *e.g.,* 5, 6, 7, 8, 9, 10, 11, 12, 13, or 14 modified nucleotides.

In one embodiment, the gap of a gapmer comprises at least one 5-methylcytosine. In one embodiment, the gap of a gapmer comprises at least 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, or 13 5-methylcytosines. In one embodiment, all of the nucleotides of the the gap of a gapmer are 5-methylcytosines.

In one embodiment, the gap of a gapmer comprises at least one 2'-deoxynucleotide. In one embodiment, the gap of a gapmer comprises at least 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, or 13 2'-deoxynucleotides. In one embodiment, all of the nucleotides of the the gap of a gapmer are 2'-deoxynucleotides.

A gapmer may include one or more modified internucleotide linkages. In some embodiments, a gapmer includes one or more phosphodiester internucleotide linkages. In other embodiments, a gapmer includes one or more phosphorothioate internucleotide linkages.

In one embodiment, each nucleotide of a 5'-wing of a gapmer are linked *via* a phosphorothioate internucleotide linkage. In another embodiment, each nucleotide of a 3'-wing of a gapmer are linked *via* a phosphorothioate internucleotide linkage. In yet another embodiment, each nucleotide of a gap segment of a gapmer is linked *via* a phosphorothioate internucleotide linkage. In one embodiment, all of the nucleotides in a gapmer are linked *via* phosphorothioate internucleotide linkages.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising five nucleotides and a 3’-wing segment comprising 5 nucleotides.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising five nucleotides and a 3’-wing segment comprising 5 nucleotides.

In another embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising four nucleotides and a 3’-wing segment comprising four nucleotides.

In another embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising four nucleotides and a 3’-wing segment comprising four nucleotides.

In another embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising three nucleotides and a 3’-wing segment comprising three nucleotides.

In another embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising three nucleotides and a 3’-wing segment comprising three nucleotides.

In another embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising two nucleotides and a 3’-wing segment comprising two nucleotides.

In another embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising two nucleotides and a 3’-wing segment comprising two nucleotides.

In one embodiment, each nucleotide of a 5-wing flanking a gap segment of 10 2′-deoxyribonucleotides comprises a modified nucleotide. In another embodiment, each nucleotide of a 3-wing flanking a gap segment of 10 2′-deoxyribonucleotides comprises a modified nucleotide. In another embodiment, each nucleotide of a 3-wing flanking a gap segment of 11 2′-deoxyribonucleotides comprises a modified nucleotide. In one embodiment, each of the modified 5’-wing nucleotides and each of the modified 3’-wing nucleotides

comprise a 2′-sugar modification. In one embodiment, the 2′-sugar modification is a 2'-OMe modification. In another embodiment, the 2′-sugar modification is a 2'-MOE modification. In one embodiment, each of the modified 5'-wing nucleotides and each of the modified 3'-wing nucleotides comprise a bicyclic nucleotide. In one embodiment, the bicyclic nucleotide is a constrained ethyl nucleotide. In another embodiment, the bicyclic nucleotide is an LNA nucleotide. In one embodiment, each cytosine in an antisense polynucleotide agent targeting an ALAS1 gene is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising five nucleotides comprising a 2'OMe modification and a 3'-wing segment comprising five nucleotides comprising a 2'OMe modification, wherein each internucleotde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine. In one embodiment, the agent further comprises a ligand.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising five nucleotides comprising a 2'OMe modification and a 3'-wing segment comprising five nucleotides comprising a 2'OMe modification, wherein each internucleotde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine. In one embodiment, the agent further comprises a ligand.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising five nucleotides comprising a 2'MOE modification and a 3'-wing segment comprising five nucleotides comprising a 2'MOE modification, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine. In one embodiment, the agent further comprises a ligand.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising five nucleotides comprising a 2'MOE modification and a 3'-wing segment comprising five nucleotides comprising a 2'MOE modification, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine. In one embodiment, the agent further comprises a ligand.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising five constrained ethyl nucleotides and a 3'-wing

segment comprising five constrained ethyl nucleotides, wherein each internucleoitde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising five constrained ethyl nucleotides and a 3'-wing segment comprising five constrained ethyl nucleotides, wherein each internucleoitde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising five LNA nucleotides and a 3'-wing segment comprising five LNA nucleotides, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising five LNA nucleotides and a 3'-wing segment comprising five LNA nucleotides, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising four nucleotides comprising a 2'OMe modification and a 3'-wing segment comprising four nucleotides comprising a 2'OMe modification, wherein each internucleotde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising four nucleotides comprising a 2'OMe modification and a 3'-wing segment comprising four nucleotides comprising a 2'OMe modification, wherein each internucleotde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising four nucleotides comprising a 2'MOE modification and a 3'-wing segment comprising four nucleotides comprising a 2'MOE

modification, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising four nucleotides comprising a 2'MOE modification and a 3'-wing segment comprising four nucleotides comprising a 2'MOE modification, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising four constrained ethyl nucleotides and a 3'-wing segment comprising four constrained ethyl nucleotides, wherein each internucleoitde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising four constrained ethyl nucleotides and a 3'-wing segment comprising four constrained ethyl nucleotides, wherein each internucleoitde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising four LNA nucleotides and a 3'-wing segment comprising four LNA nucleotides, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising four LNA nucleotides and a 3'-wing segment comprising four LNA nucleotides, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising three nucleotides comprising a 2'OMe modification and a 3'-wing segment comprising three nucleotides comprising a 2'OMe modification, wherein each internucleotde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising three nucleotides comprising a 2’OMe modification and a 3’-wing segment comprising three nucleotides comprising a 2’OMe modification, wherein each internucleotde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising three nucleotides comprising a 2’MOE modification and a 3’-wing segment comprising three nucleotides comprising a 2’MOE modification, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising three nucleotides comprising a 2’MOE modification and a 3’-wing segment comprising three nucleotides comprising a 2’MOE modification, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising three constrained ethyl nucleotides and a 3’-wing segment comprising three constrained ethyl nucleotides, wherein each internucleoitde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising three constrained ethyl nucleotides and a 3’-wing segment comprising three constrained ethyl nucleotides, wherein each internucleoitde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting a an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5’-wing segment comprising three LNA nucleotides and a 3’-wing segment comprising three LNA nucleotides, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting a an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising three LNA nucleotides and a 3'-wing segment comprising three LNA nucleotides, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising two nucleotides comprising a 2'OMe modification and a 3'-wing segment comprising two nucleotides comprising a 2'OMe modification, wherein each internucleotde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising two nucleotides comprising a 2'OMe modification and a 3'-wing segment comprising two nucleotides comprising a 2'OMe modification, wherein each internucleotde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising two nucleotides comprising a 2'MOE modification and a 3'-wing segment comprising two nucleotides comprising a 2'MOE modification, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising two nucleotides comprising a 2'MOE modification and a 3'-wing segment comprising two nucleotides comprising a 2'MOE modification, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising two constrained ethyl nucleotides and a 3'-wing segment comprising two constrained ethyl nucleotides, wherein each internucleoitde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising two constrained ethyl nucleotides and a 3'-wing segment comprising two constrained ethyl nucleotides, wherein each internucleoitde linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of ten 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising two LNA nucleotides and a 3'-wing segment comprising two LNA nucleotides, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

In one embodiment, an antisense polynucleotide agent targeting an ALAS1 gene comprises a gap segment of eleven 2′-deoxyribonucleotides positioned immediately adjacent to and between a 5'-wing segment comprising two LNA nucleotides and a 3'-wing segment comprising two LNA nucleotides, wherein each internucleotide linkage of the agent is a phosphorothioate linkage. In one embodiment, each cytosine of the agent is a 5-methylcytosine.

Further gapmer designs suitable for use in the agents, compositions, and methods of the invention are disclosed in, for example, U.S. Patent Nos. 7,687,617 and 8,580,756; U.S. Patent Publication Nos. 20060128646, 20090209748, 20140128586, 20140128591, 20100210712, and 20080015162A1; and International Publication No. WO 2013/159108, the entire content of each of which are incorporated herein by reference.

IV. Polynucleotide Agents Conjugated to Ligands

Another modification of the polynucleotide agents of the invention involves chemically linking to the agent one or more ligands, moieties or conjugates that enhance the activity, cellular distribution or cellular uptake of the antisense polynucleotide agent. Such moieties include but are not limited to lipid moieties such as a cholesterol moiety (Letsinger *et al.*, *Proc. Natl. Acid. Sci. USA*, 1989, 86: 6553-6556), cholic acid (Manoharan *et al.*, *Biorg. Med. Chem. Let.*, 1994, 4:1053-1060), a thioether, *e.g.*, beryl-S-tritylthiol (Manoharan *et al.*, *Ann. N.Y. Acad. Sci.*, 1992, 660:306-309; Manoharan *et al.*, *Biorg. Med. Chem. Let.*, 1993, 3:2765-2770), a thiocholesterol (Oberhauser *et al.*, *Nucl. Acids Res.*, 1992, 20:533-538), an aliphatic chain, *e.g.*, dodecandiol or undecyl residues (Saison-Behmoaras *et al.*, *EMBO J*, 1991, 10:1111-1118; Kabanov *et al.*, *FEBS Lett.*, 1990, 259:327-330; Svinarchuk *et al.*, *Biochimie*, 1993, 75:49-54), a phospholipid, *e.g.*, di-hexadecyl-rac-glycerol or triethyl-ammonium 1,2-di-O-hexadecyl-rac-glycero-3-phosphonate (Manoharan *et al.*, *Tetrahedron Lett.*, 1995, 36:3651-3654; Shea *et al.*, *Nucl. Acids Res.*, 1990, 18:3777-3783), a polyamine

or a polyethylene glycol chain (Manoharan *et al.*, *Nucleosides & Nucleotides*, 1995, 14:969-973), or adamantane acetic acid (Manoharan *et al.*, *Tetrahedron Lett.*, 1995, 36:3651-3654), a palmityl moiety (Mishra *et al.*, *Biochim. Biophys. Acta*, 1995, 1264:229-237), or an octadecylamine or hexylamino-carbonyloxycholesterol moiety (Crooke *et al.*, J. *Pharmacol. Exp. Ther.*, 1996, 277:923-937).

In one embodiment, a ligand alters the distribution, targeting or lifetime of an antisense polynucleotide agent into which it is incorporated. In preferred embodiments a ligand provides an enhanced affinity for a selected target, *e.g.*, molecule, cell or cell type, compartment, *e.g.*, a cellular or organ compartment, tissue, organ or region of the body, as, *e.g.*, compared to a species absent such a ligand. Preferred ligands will not take part in hybridization of an antisense polynucleotide agent to the targeted mRNA.

Ligands can include a naturally occurring substance, such as a protein (*e.g.*, human serum albumin (HSA), low-density lipoprotein (LDL), or globulin); carbohydrate (*e.g.*, a dextran, pullulan, chitin, chitosan, inulin, cyclodextrin, N-acetylgalactosamine, or hyaluronic acid); or a lipid. The ligand can also be a recombinant or synthetic molecule, such as a synthetic polymer, *e.g.*, a synthetic polyamino acid. Examples of polyamino acids include polyamino acid is a polylysine (PLL), poly L-aspartic acid, poly L-glutamic acid, styrene-maleic acid anhydride copolymer, poly(L-lactide-co-glycolied) copolymer, divinyl ether-maleic anhydride copolymer, N-(2-hydroxypropyl)methacrylamide copolymer (HMPA), polyethylene glycol (PEG), polyvinyl alcohol (PVA), polyurethane, poly(2-ethylacryllic acid), N-isopropylacrylamide polymers, or polyphosphazine. Example of polyamines include: polyethylenimine, polylysine (PLL), spermine, spermidine, polyamine, pseudopeptide-polyamine, peptidomimetic polyamine, dendrimer polyamine, arginine, amidine, protamine, cationic lipid, cationic porphyrin, quaternary salt of a polyamine, or an alpha helical peptide.

Ligands can also include targeting groups, *e.g.*, a cell or tissue targeting agent, *e.g.*, a lectin, glycoprotein, lipid or protein, *e.g.*, an antibody, that binds to a specified cell type such as a kidney cell. A targeting group can be a thyrotropin, melanotropin, lectin, glycoprotein, surfactant protein A, Mucin carbohydrate, multivalent lactose, multivalent galactose, N-acetyl-galactosamine, N-acetyl-gulucoseamine multivalent mannose, multivalent fucose, glycosylated polyaminoacids, multivalent galactose, transferrin, bisphosphonate, polyglutamate, polyaspartate, a lipid, cholesterol, a steroid, bile acid, folate, vitamin B12, vitamin A, biotin, or an RGD peptide or RGD peptide mimetic.

Other examples of ligands include dyes, intercalating agents (*e.g.* acridines), cross-linkers (*e.g.* psoralene, mitomycin C), porphyrins (TPPC4, texaphyrin, Sapphyrin), polycyclic aromatic hydrocarbons (*e.g.*, phenazine, dihydrophenazine), artificial endonucleases (*e.g.* EDTA), lipophilic molecules, *e.g.*, cholesterol, cholic acid, adamantane acetic acid, 1-pyrene butyric acid, dihydrotestosterone, 1,3-Bis-O(hexadecyl)glycerol, geranyloxyhexyl group,

hexadecylglycerol, borneol, menthol, 1,3-propanediol, heptadecyl group, palmitic acid, myristic acid,O3-(oleoyl)lithocholic acid, O3-(oleoyl)cholenic acid, dimethoxytrityl, or phenoxazine)and peptide conjugates (*e.g.*, antennapedia peptide, Tat peptide), alkylating agents, phosphate, amino, mercapto, PEG (*e.g.*, PEG-40K), MPEG, $[MPEG]_2$, polyamino, alkyl, substituted alkyl, radiolabeled markers, enzymes, haptens (*e.g.* biotin), transport/absorption facilitators (*e.g.*, aspirin, vitamin E, folic acid), synthetic ribonucleases (*e.g.*, imidazole, bisimidazole, histamine, imidazole clusters, acridine-imidazole conjugates, Eu3+ complexes of tetraazamacrocycles), dinitrophenyl, HRP, or AP.

Ligands can be proteins, *e.g.*, glycoproteins, or peptides, *e.g.*, molecules having a specific affinity for a co-ligand, or antibodies *e.g.*, an antibody, that binds to a specified cell type such as a hepatic cell. Ligands can also include hormones and hormone receptors. They can also include non-peptidic species, such as lipids, lectins, carbohydrates, vitamins, cofactors, multivalent lactose, multivalent galactose, N-acetyl-galactosamine, N-acetyl-gulucosamine multivalent mannose, or multivalent fucose. The ligand can be, for example, a lipopolysaccharide, an activator of p38 MAP kinase, or an activator of NF-κB.

The ligand can be a substance, *e.g.*, a drug, which can increase the uptake of the antisense polynucleotide agent into the cell, for example, by disrupting the cell's cytoskeleton, *e.g.*, by disrupting the cell's microtubules, microfilaments, and/or intermediate filaments. The drug can be, for example, taxon, vincristine, vinblastine, cytochalasin, nocodazole, japlakinolide, latrunculin A, phalloidin, swinholide A, indanocine, or myoservin.

In some embodiments, a ligand attached to an antisense polynucleotide agent as described herein acts as a pharmacokinetic modulator (PK modulator). PK modulators include lipophiles, bile acids, steroids, phospholipid analogues, peptides, protein binding agents, PEG, vitamins *etc*. Exemplary PK modulators include, but are not limited to, cholesterol, fatty acids, cholic acid, lithocholic acid, dialkylglycerides, diacylglyceride, phospholipids, sphingolipids, naproxen, ibuprofen, vitamin E, biotin *etc*. Oligonucleotides that comprise a number of phosphorothioate linkages are also known to bind to serum protein, thus short oligonucleotides, *e.g.*, oligonucleotides of about 5 bases, 10 bases, 15 bases or 20 bases, comprising multiple of phosphorothioate linkages in the backbone are also amenable to the present invention as ligands (*e.g.* as PK modulating ligands). In addition, aptamers that bind serum components (*e.g.* serum proteins) are also suitable for use as PK modulating ligands in the embodiments described herein.

Ligand-conjugated polynucleotides of the invention may be synthesized by the use of a polynucleotide that bears a pendant reactive functionality, such as that derived from the attachment of a linking molecule onto the oligonucleotide (described below). This reactive polynucleotide may be reacted directly with commercially-available ligands, ligands that are synthesized bearing any of a variety of protecting groups, or ligands that have a linking moiety attached thereto.

The polynucleotides used in the conjugates of the present invention may be conveniently and routinely made through the well-known technique of solid-phase synthesis. Equipment for such synthesis is sold by several vendors including, for example, Applied Biosystems (Foster City, Calif.). Any other means for such synthesis known in the art may additionally or alternatively be employed. It is also known to use similar techniques to prepare other polynucleotides, such as the phosphorothioates and alkylated derivatives.

In the ligand-conjugated polynucleotides and ligand-molecule bearing sequence-specific linked nucleosides of the present invention, the polynucleotides and polynucleosides may be assembled on a suitable DNA synthesizer utilizing standard nucleotide or nucleoside precursors, or nucleotide or nucleoside conjugate precursors that already bear the linking moiety, ligand-nucleotide or nucleoside-conjugate precursors that already bear the ligand molecule, or non-nucleoside ligand-bearing building blocks.

When using nucleotide-conjugate precursors that already bear a linking moiety, the synthesis of the sequence-specific linked nucleosides is typically completed, and the ligand molecule is then reacted with the linking moiety to form the ligand-conjugated oligonucleotide. In some embodiments, the polynucleotides or linked nucleosides of the present invention are synthesized by an automated synthesizer using phosphoramidites derived from ligand-nucleoside conjugates in addition to the standard phosphoramidites and non-standard phosphoramidites that are commercially available and routinely used in oligonucleotide synthesis.

A. Lipid Conjugates

In one embodiment, the ligand or conjugate is a lipid or lipid-based molecule. Such a lipid or lipid-based molecule preferably binds a serum protein, *e.g.*, human serum albumin (HSA). An HSA binding ligand allows for distribution of the conjugate to a target tissue, *e.g.*, a non-kidney target tissue of the body. For example, the target tissue can be the liver, including parenchymal cells of the liver. Other molecules that can bind HSA can also be used as ligands. For example, naproxen or aspirin can be used. A lipid or lipid-based ligand can (a) increase resistance to degradation of the conjugate, (b) increase targeting or transport into a target cell or cell membrane, and/or (c) can be used to adjust binding to a serum protein, *e.g.*, HSA.

A lipid based ligand can be used to inhibit, *e.g.*, control the binding of the conjugate to a target tissue. For example, a lipid or lipid-based ligand that binds to HSA more strongly will be less likely to be targeted to the kidney and therefore less likely to be cleared from the body. A lipid or lipid-based ligand that binds to HSA less strongly can be used to target the conjugate to the kidney.

In a preferred embodiment, the lipid based ligand binds HSA. Preferably, it binds HSA with a sufficient affinity such that the conjugate will be preferably distributed to a non-

kidney tissue. However, it is preferred that the affinity not be so strong that the HSA-ligand binding cannot be reversed.

In another preferred embodiment, the lipid based ligand binds HSA weakly or not at all, such that the conjugate will be preferably distributed to the kidney. Other moieties that target to kidney cells can also be used in place of or in addition to the lipid based ligand.

In another aspect, the ligand is a moiety, *e.g.*, a vitamin, which is taken up by a target cell, *e.g.*, a proliferating cell. These are particularly useful for treating disorders characterized by unwanted cell proliferation, *e.g.*, of the malignant or non-malignant type, *e.g.*, cancer cells. Exemplary vitamins include vitamin A, E, and K. Other exemplary vitamins include are B vitamin, *e.g.*, folic acid, B12, riboflavin, biotin, pyridoxal or other vitamins or nutrients taken up by target cells such as liver cells. Also included are HSA and low density lipoprotein (LDL).

B. Cell Permeation Agents

In another aspect, the ligand is a cell-permeation agent, preferably a helical cell-permeation agent. Preferably, the agent is amphipathic. An exemplary agent is a peptide such as tat or antennopedia. If the agent is a peptide, it can be modified, including a peptidylmimetic, invertomers, non-peptide or pseudo-peptide linkages, and use of D-amino acids. The helical agent is preferably an alpha-helical agent, which preferably has a lipophilic and a lipophobic phase.

The ligand can be a peptide or peptidomimetic. A peptidomimetic (also referred to herein as an oligopeptidomimetic) is a molecule capable of folding into a defined three-dimensional structure similar to a natural peptide. The attachment of peptide and peptidomimetics to antisense polynucleotide agents can affect pharmacokinetic distribution of the agent, such as by enhancing cellular recognition and absorption. The peptide or peptidomimetic moiety can be about 5-50 amino acids long, *e.g.*, about 5, 10, 15, 20, 25, 30, 35, 40, 45, or 50 amino acids long.

A peptide or peptidomimetic can be, for example, a cell permeation peptide, cationic peptide, amphipathic peptide, or hydrophobic peptide (*e.g.*, consisting primarily of Tyr, Trp or Phe). The peptide moiety can be a dendrimer peptide, constrained peptide or crosslinked peptide. In another alternative, the peptide moiety can include a hydrophobic membrane translocation sequence (MTS). An exemplary hydrophobic MTS-containing peptide is RFGF having the amino acid sequence AAVALLPAVLLALLAP (SEQ ID NO: 3). An RFGF analogue (*e.g.*, amino acid sequence AALLPVLLAAP (SEQ ID NO: 4) containing a hydrophobic MTS can also be a targeting moiety. The peptide moiety can be a "delivery" peptide, which can carry large polar molecules including peptides, oligonucleotides, and protein across cell membranes. For example, sequences from the HIV Tat protein (GRKKRRQRRRPPQ (SEQ ID NO: 5) and the Drosophila Antennapedia protein (RQIKIWFQNRRMKWKK (SEQ ID NO: 6) have been found to be capable of functioning

as delivery peptides. A peptide or peptidomimetic can be encoded by a random sequence of DNA, such as a peptide identified from a phage-display library, or one-bead-one-compound (OBOC) combinatorial library (Lam *et al.*, Nature, 354:82-84, 1991). Examples of a peptide or peptidomimetic tethered to an antisens epolynucleotide agent *via* an incorporated monomer unit for cell targeting purposes is an arginine-glycine-aspartic acid (RGD)-peptide, or RGD mimic. A peptide moiety can range in length from about 5 amino acids to about 40 amino acids. The peptide moieties can have a structural modification, such as to increase stability or direct conformational properties. Any of the structural modifications described below can be utilized.

An RGD peptide for use in the compositions and methods of the invention may be linear or cyclic, and may be modified, *e.g.,* glycosylated or methylated, to facilitate targeting to a specific tissue(s). RGD-containing peptides and peptidiomimemtics may include D-amino acids, as well as synthetic RGD mimics. In addition to RGD, one can use other moieties that target the integrin ligand. Preferred conjugates of this ligand target PECAM-1 or VEGF.

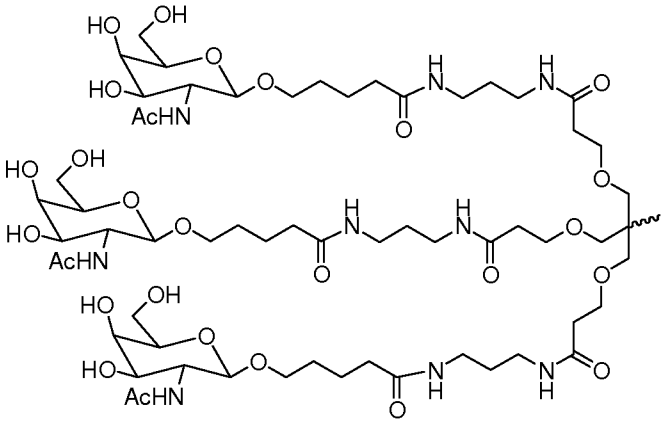
A "cell permeation peptide" is capable of permeating a cell, *e.g.,* a microbial cell, such as a bacterial or fungal cell, or a mammalian cell, such as a human cell. A microbial cell-permeating peptide can be, for example, an α-helical linear peptide (*e.g.*, LL-37 or Ceropin P1), a disulfide bond-containing peptide (*e.g.*, α -defensin, β-defensin or bactenecin), or a peptide containing only one or two dominating amino acids (*e.g.*, PR-39 or indolicidin). A cell permeation peptide can also include a nuclear localization signal (NLS). For example, a cell permeation peptide can be a bipartite amphipathic peptide, such as MPG, which is derived from the fusion peptide domain of HIV-1 gp41 and the NLS of SV40 large T antigen (Simeoni *et al.*, Nucl. Acids Res. 31:2717-2724, 2003).

C. Carbohydrate Conjugates

In some embodiments of the compositions and methods of the invention, an antisense polynucleotide agent further comprises a carbohydrate. The carbohydrate conjugated agents are advantageous for the *in vivo* delivery of nucleic acids, as well as compositions suitable for *in vivo* therapeutic use, as described herein (see, *e.g.,* Prakash, *et al.* (2014) *Nuc Acid Res* doi 10.1093/nar/gku531). As used herein, "carbohydrate" refers to a compound which is either a carbohydrate *per se* made up of one or more monosaccharide units having at least 6 carbon atoms (which can be linear, branched or cyclic) with an oxygen, nitrogen or sulfur atom bonded to each carbon atom; or a compound having as a part thereof a carbohydrate moiety made up of one or more monosaccharide units each having at least six carbon atoms (which can be linear, branched or cyclic), with an oxygen, nitrogen or sulfur atom bonded to each carbon atom. Representative carbohydrates include the sugars (mono-, di-, tri- and oligosaccharides containing from about 4, 5, 6, 7, 8, or 9 monosaccharide units), and polysaccharides such as starches, glycogen, cellulose and polysaccharide gums. Specific

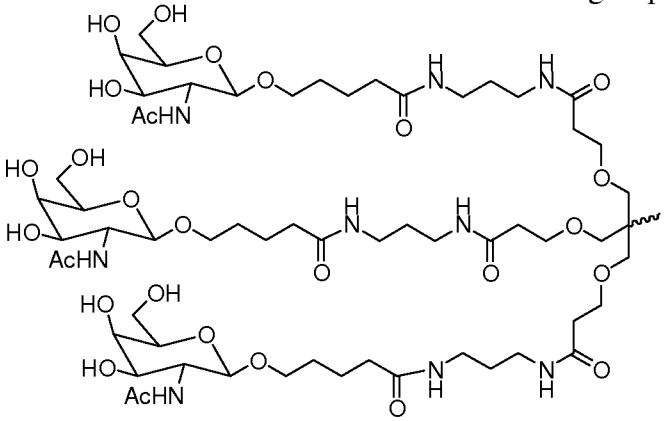
monosaccharides include C5 and above (*e.g.,* C5, C6, C7, or C8) sugars; di- and trisaccharides include sugars having two or three monosaccharide units (*e.g.,* C5, C6, C7, or C8).

In one embodiment, a carbohydrate conjugate for use in the compositions and methods of the invention is a monosaccharide. In one embodiment, the monosaccharide is an N-acetylgalactosamine, such as

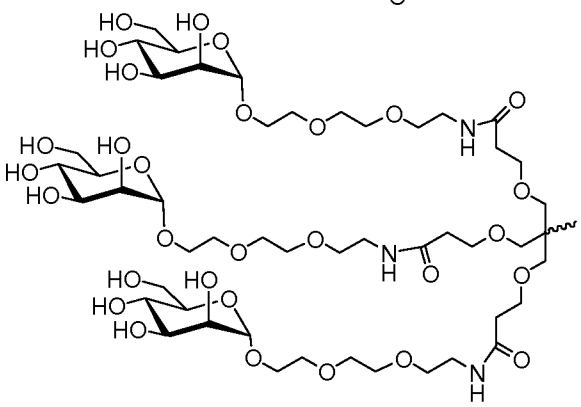


Formula II.

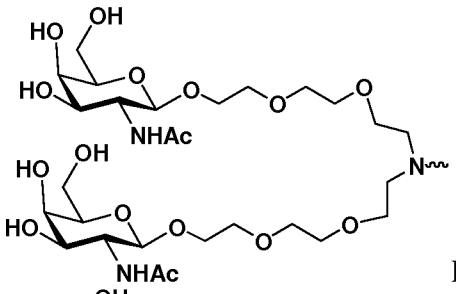
In another embodiment, a carbohydrate conjugate for use in the compositions and methods of the invention is selected from the group consisting of:



Formula II,



Formula III,



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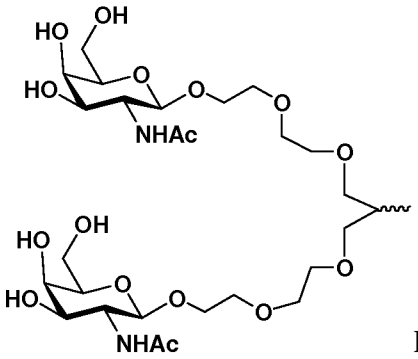
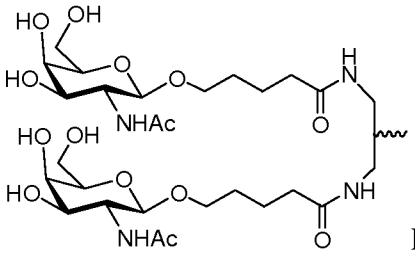


Formula V,



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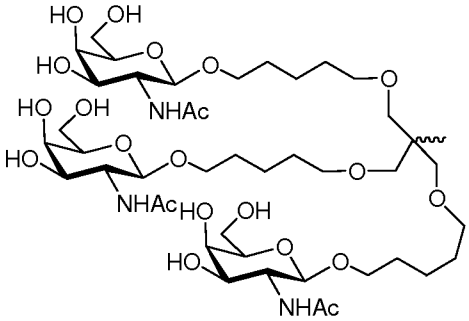

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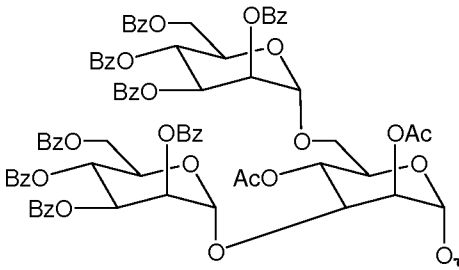

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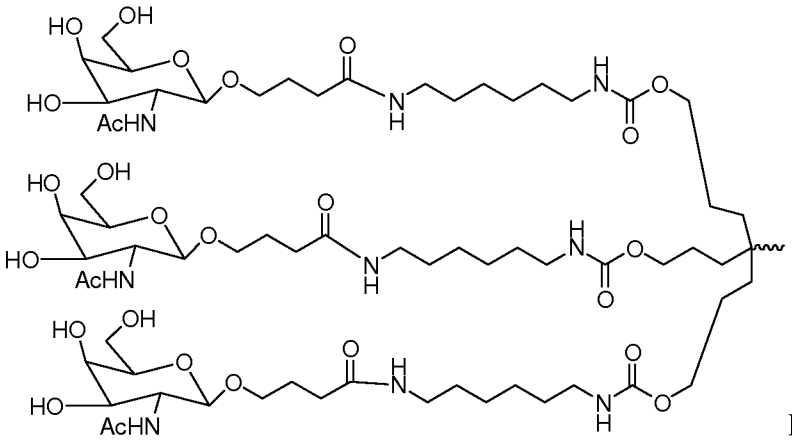

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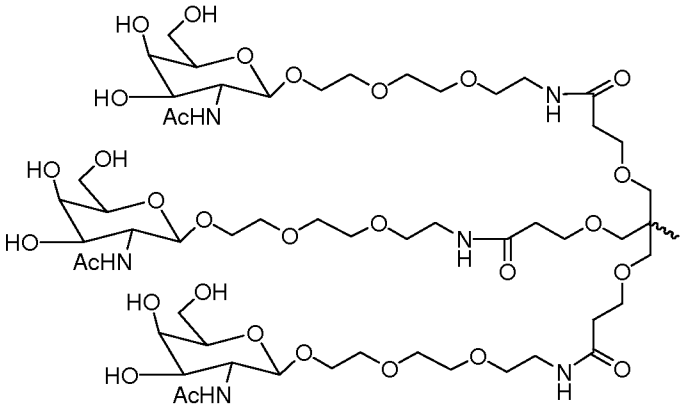
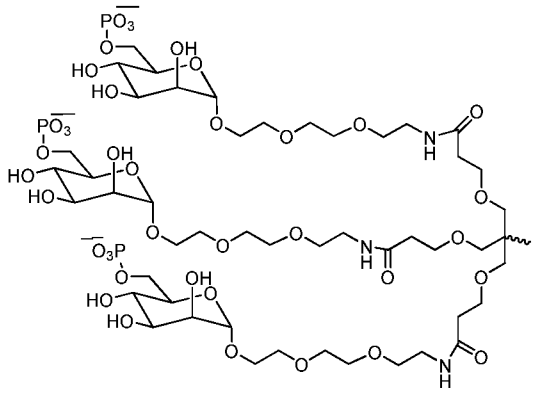


Formula X,



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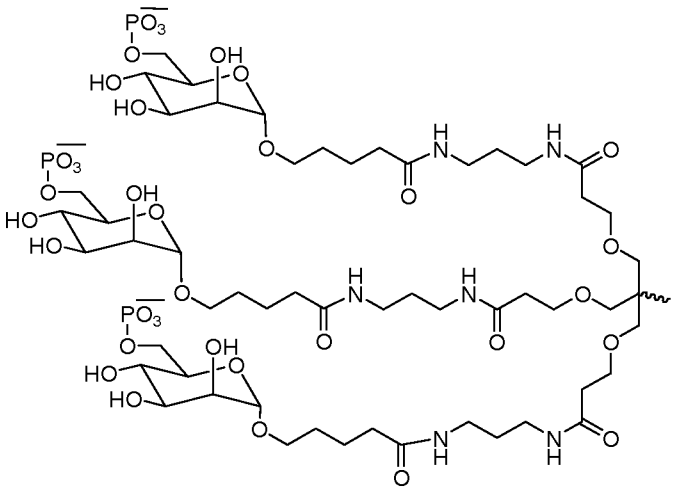

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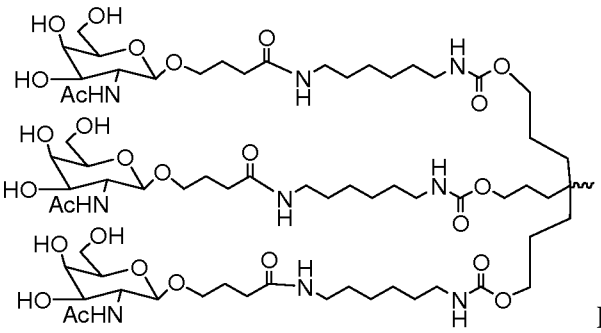

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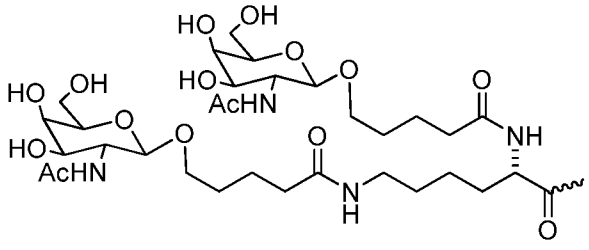

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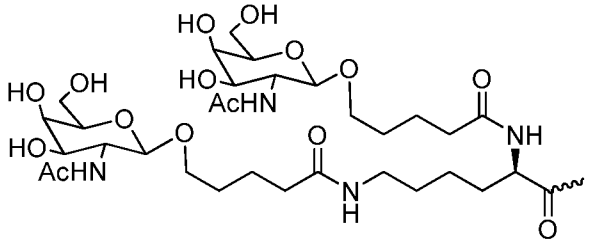

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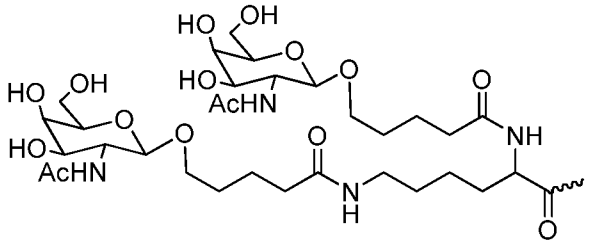
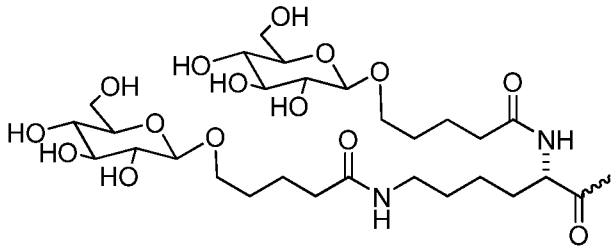
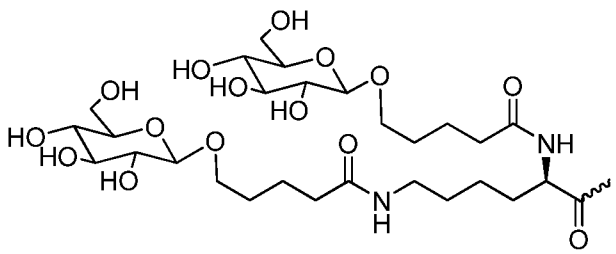


Formula XVI,



Formula XVII,



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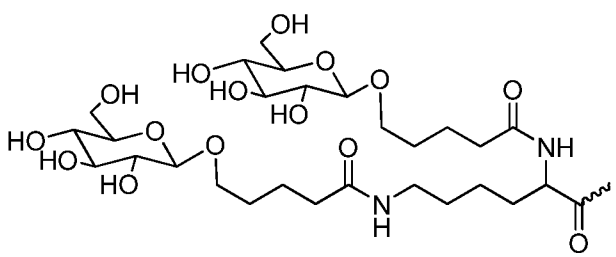
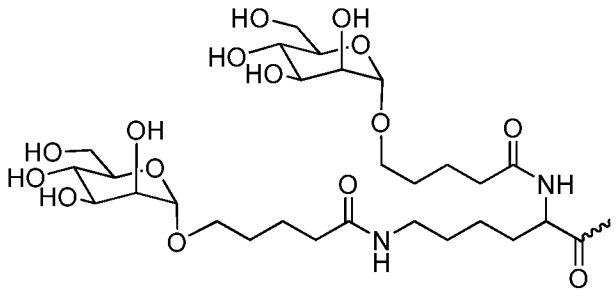
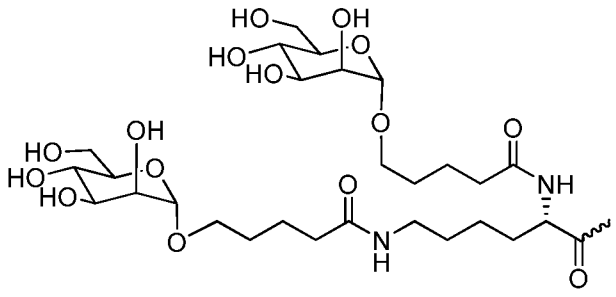


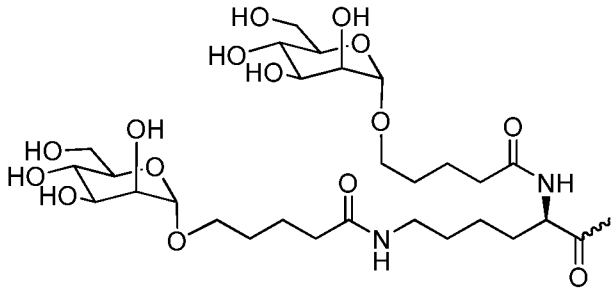
Formula XIX,



Formula XX,

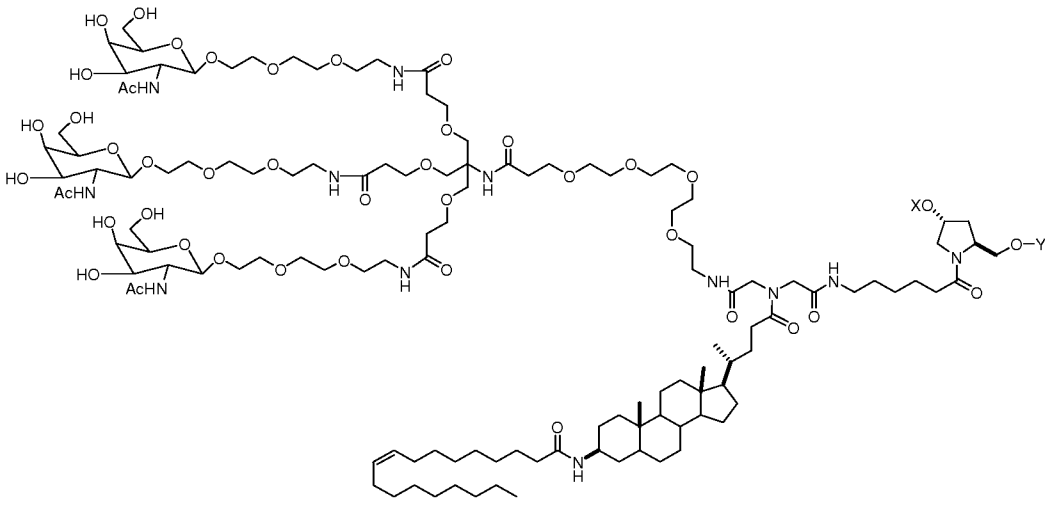


Formula XXI,



Formula XXII.

Another representative carbohydrate conjugate for use in the embodiments described herein includes, but is not limited to



(Formula XXIII),

when one of X or Y is an oligonucleotide, the other is a hydrogen.

In some embodiments, the carbohydrate conjugate further comprises one or more additional ligands as described above, such as, but not limited to, a PK modulator and/or a cell permeation peptide.

D. Linkers

In some embodiments, the conjugate or ligand described herein can be attached to an antisense polynucleotide agent with various linkers that can be cleavable or non-cleavable.

The term "linker" or “linking group” means an organic moiety that connects two parts of a compound, *e.g.,* covalently attaches two parts of a compound. Linkers typically comprise a direct bond or an atom such as oxygen or sulfur, a unit such as NR8, C(O), C(O)NH, SO, SO_2, SO_2NH or a chain of atoms, such as, but not limited to, substituted or unsubstituted alkyl, substituted or unsubstituted alkenyl, substituted or unsubstituted alkynyl, arylalkyl, arylalkenyl, arylalkynyl, heteroarylalkyl, heteroarylalkenyl, heteroarylalkynyl, heterocyclylalkyl, heterocyclylalkenyl, heterocyclylalkynyl, aryl, heteroaryl, heterocyclyl, cycloalkyl, cycloalkenyl, alkylarylalkyl, alkylarylalkenyl, alkylarylalkynyl, alkenylarylalkyl, alkenylarylalkenyl, alkenylarylalkynyl, alkynylarylalkyl, alkynylarylalkenyl, alkynylarylalkynyl, alkylheteroarylalkyl, alkylheteroarylalkenyl, alkylheteroarylalkynyl, alkenylheteroarylalkyl, alkenylheteroarylalkenyl, alkenylheteroarylalkynyl, alkynylheteroarylalkyl, alkynylheteroarylalkenyl, alkynylheteroarylalkynyl, alkylheterocyclylalkyl, alkylheterocyclylalkenyl, alkylhererocyclylalkynyl, alkenylheterocyclylalkyl, alkenylheterocyclylalkenyl, alkenylheterocyclylalkynyl, alkynylheterocyclylalkyl, alkynylheterocyclylalkenyl, alkynylheterocyclylalkynyl, alkylaryl, alkenylaryl, alkynylaryl, alkylheteroaryl, alkenylheteroaryl, alkynylhereroaryl, which one or more methylenes can be interrupted or terminated by O, S, S(O), SO_2, N(R8), C(O), substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl, substituted or unsubstituted heterocyclic; where R8 is hydrogen, acyl, aliphatic or substituted aliphatic. In one embodiment, the linker is between about 1-24 atoms, 2-24, 3-24, 4-24, 5-24, 6-24, 6-18, 7-18, 8-18 atoms, 7-17, 8-17, 6-16, 7-16, or 8-16 atoms.

A cleavable linking group is one which is sufficiently stable outside the cell, but which upon entry into a target cell is cleaved to release the two parts the linker is holding together. In a preferred embodiment, the cleavable linking group is cleaved at least about 10 times, 20, times, 30 times, 40 times, 50 times, 60 times, 70 times, 80 times, 90 times or more, or at least about 100 times faster in a target cell or under a first reference condition (which can, *e.g.*, be selected to mimic or represent intracellular conditions) than in the blood of a subject, or under a second reference condition (which can, *e.g.*, be selected to mimic or represent conditions found in the blood or serum).

Cleavable linking groups are susceptible to cleavage agents, *e.g.*, pH, redox potential or the presence of degradative molecules. Generally, cleavage agents are more prevalent or found at higher levels or activities inside cells than in serum or blood. Examples of such degradative agents include: redox agents which are selected for particular substrates or which have no substrate specificity, including, *e.g.*, oxidative or reductive enzymes or reductive agents such as mercaptans, present in cells, that can degrade a redox cleavable linking group

by reduction; esterases; endosomes or agents that can create an acidic environment, *e.g.*, those that result in a pH of five or lower; enzymes that can hydrolyze or degrade an acid cleavable linking group by acting as a general acid, peptidases (which can be substrate specific), and phosphatases.

A cleavable linkage group, such as a disulfide bond can be susceptible to pH. The pH of human serum is 7.4, while the average intracellular pH is slightly lower, ranging from about 7.1-7.3. Endosomes have a more acidic pH, in the range of 5.5-6.0, and lysosomes have an even more acidic pH at around 5.0. Some linkers will have a cleavable linking group that is cleaved at a preferred pH, thereby releasing a cationic lipid from the ligand inside the cell, or into the desired compartment of the cell.

A linker can include a cleavable linking group that is cleavable by a particular enzyme. The type of cleavable linking group incorporated into a linker can depend on the cell to be targeted. For example, a liver-targeting ligand can be linked to a cationic lipid through a linker that includes an ester group. Liver cells are rich in esterases, and therefore the linker will be cleaved more efficiently in liver cells than in cell types that are not esterase-rich. Other cell-types rich in esterases include cells of the lung, renal cortex, and testis.

Linkers that contain peptide bonds can be used when targeting cell types rich in peptidases, such as liver cells and synoviocytes.

In general, the suitability of a candidate cleavable linking group can be evaluated by testing the ability of a degradative agent (or condition) to cleave the candidate linking group. It will also be desirable to also test the candidate cleavable linking group for the ability to resist cleavage in the blood or when in contact with other non-target tissue. Thus, one can determine the relative susceptibility to cleavage between a first and a second condition, where the first is selected to be indicative of cleavage in a target cell and the second is selected to be indicative of cleavage in other tissues or biological fluids, *e.g.*, blood or serum. The evaluations can be carried out in cell free systems, in cells, in cell culture, in organ or tissue culture, or in whole animals. It can be useful to make initial evaluations in cell-free or culture conditions and to confirm by further evaluations in whole animals. In preferred embodiments, useful candidate compounds are cleaved at least about 2, 4, 10, 20, 30, 40, 50, 60, 70, 80, 90, or about 100 times faster in the cell (or under *in vitro* conditions selected to mimic intracellular conditions) as compared to blood or serum (or under *in vitro* conditions selected to mimic extracellular conditions).

i. Redox cleavable linking groups

In one embodiment, a cleavable linking group is a redox cleavable linking group that is cleaved upon reduction or oxidation. An example of reductively cleavable linking group is a disulphide linking group (-S-S-). To determine if a candidate cleavable linking group is a suitable "reductively cleavable linking group," or for example is suitable for use with a particular antisense polynucleotide agent moiety and particular targeting agent one can look

to methods described herein. For example, a candidate can be evaluated by incubation with dithiothreitol (DTT), or other reducing agent using reagents know in the art, which mimic the rate of cleavage which would be observed in a cell, *e.g.*, a target cell. The candidates can also be evaluated under conditions which are selected to mimic blood or serum conditions. In one, candidate compounds are cleaved by at most about 10% in the blood. In other embodiments, useful candidate compounds are degraded at least about 2, 4, 10, 20, 30, 40, 50, 60, 70, 80, 90, or about 100 times faster in the cell (or under *in vitro* conditions selected to mimic intracellular conditions) as compared to blood (or under *in vitro* conditions selected to mimic extracellular conditions). The rate of cleavage of candidate compounds can be determined using standard enzyme kinetics assays under conditions chosen to mimic intracellular media and compared to conditions chosen to mimic extracellular media.

ii. Phosphate-based cleavable linking groups

In another embodiment, a cleavable linker comprises a phosphate-based cleavable linking group. A phosphate-based cleavable linking group is cleaved by agents that degrade or hydrolyze the phosphate group. An example of an agent that cleaves phosphate groups in cells are enzymes such as phosphatases in cells. Examples of phosphate-based linking groups are -O-P(O)(ORk)-O-, -O-P(S)(ORk)-O-, -O-P(S)(SRk)-O-, -S-P(O)(ORk)-O-, -O-P(O)(ORk)-S-, -S-P(O)(ORk)-S-, -O-P(S)(ORk)-S-, -S-P(S)(ORk)-O-, -O-P(O)(Rk)-O-, -O-P(S)(Rk)-O-, -S-P(O)(Rk)-O-, -S-P(S)(Rk)-O-, -S-P(O)(Rk)-S-, -O-P(S)(Rk)-S-. Preferred embodiments are -O-P(O)(OH)-O-, -O-P(S)(OH)-O-, -O-P(S)(SH)-O-, -S-P(O)(OH)-O-, -O-P(O)(OH)-S-, -S-P(O)(OH)-S-, -O-P(S)(OH)-S-, -S-P(S)(OH)-O-, -O-P(O)(H)-O-, -O-P(S)(H)-O-, -S-P(O)(H)-O, -S-P(S)(H)-O-, -S-P(O)(H)-S-, -O-P(S)(H)-S-. A preferred embodiment is -O-P(O)(OH)-O-. These candidates can be evaluated using methods analogous to those described above.

iii. Acid cleavable linking groups

In another embodiment, a cleavable linker comprises an acid cleavable linking group. An *a*cid cleavable linking group is a linking group that is cleaved under acidic conditions. In preferred embodiments acid cleavable linking groups are cleaved in an acidic environment with a pH of about 6.5 or lower (*e.g.*, about 6.0, 5.75, 5.5, 5.25, 5.0, or lower), or by agents such as enzymes that can act as a general acid. In a cell, specific low pH organelles, such as endosomes and lysosomes can provide a cleaving environment for acid cleavable linking groups. Examples of acid cleavable linking groups include but are not limited to hydrazones, esters, and esters of amino acids. Acid cleavable groups can have the general formula -C=NN-, C(O)O, or -OC(O). A preferred embodiment is when the carbon attached to the oxygen of the ester (the alkoxy group) is an aryl group, substituted alkyl group, or tertiary alkyl group such as dimethyl pentyl or t-butyl. These candidates can be evaluated using methods analogous to those described above.

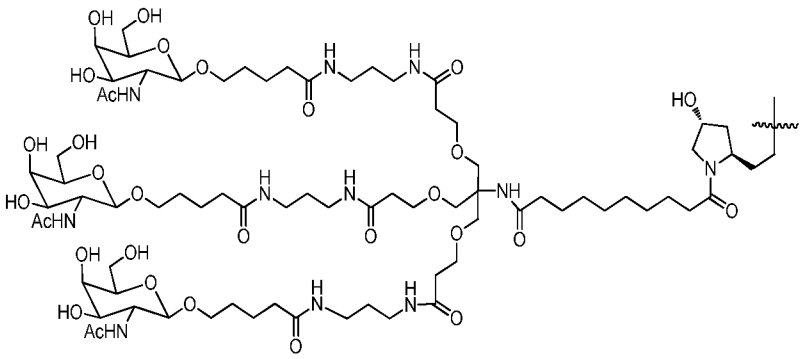
iv. Ester-based linking groups

In another embodiment, a cleavable linker comprises an ester-based cleavable linking group. An ester-based cleavable linking group is cleaved by enzymes such as esterases and amidases in cells. Examples of ester-based cleavable linking groups include but are not limited to esters of alkylene, alkenylene and alkynylene groups. Ester cleavable linking groups have the general formula -C(O)O-, or -OC(O)-. These candidates can be evaluated using methods analogous to those described above.

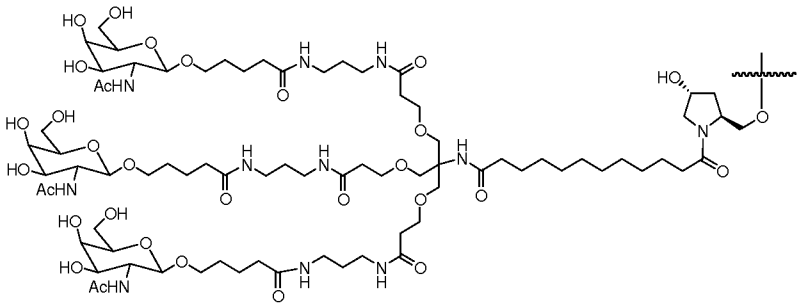
v. Peptide-based cleaving groups

In yet another embodiment, a cleavable linker comprises a peptide-based cleavable linking group. A peptide-based cleavable linking group is cleaved by enzymes such as peptidases and proteases in cells. Peptide-based cleavable linking groups are peptide bonds formed between amino acids to yield oligopeptides (*e.g.*, dipeptides, tripeptides *etc*.) and polypeptides. Peptide-based cleavable groups do not include the amide group (-C(O)NH-). The amide group can be formed between any alkylene, alkenylene or alkynelene. A peptide bond is a special type of amide bond formed between amino acids to yield peptides and proteins. The peptide based cleavage group is generally limited to the peptide bond (*i.e.*, the amide bond) formed between amino acids yielding peptides and proteins and does not include the entire amide functional group. Peptide-based cleavable linking groups have the general formula – NHCHRAC(O)NHCHRBC(O)-, where RA and RB are the R groups of the two adjacent amino acids. These candidates can be evaluated using methods analogous to those described above.

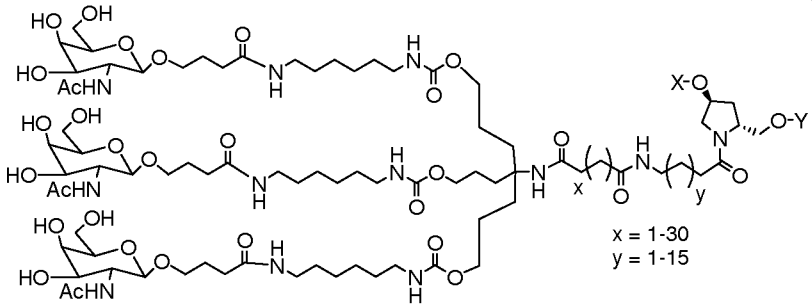
In one embodiment, an antisense polynucleotide agent of the invention is conjugated to a carbohydrate through a linker. Non-limiting examples of antisense polynucleotide agent carbohydrate conjugates with linkers of the compositions and methods of the invention include, but are not limited to,



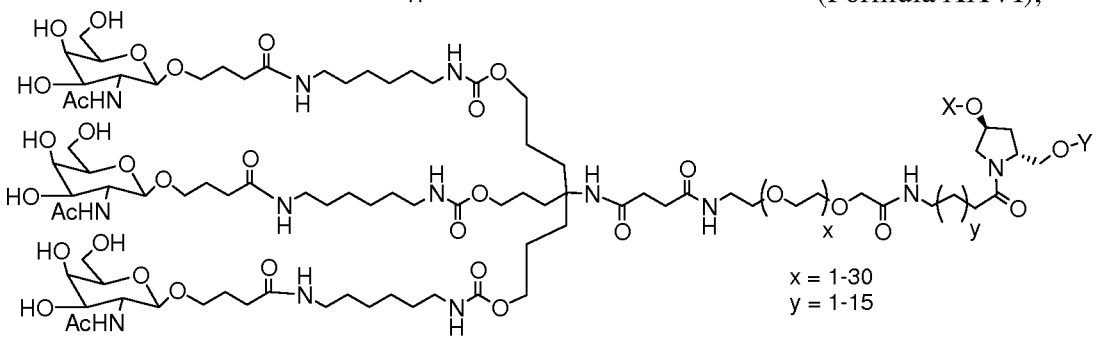
(Formula XXIV),



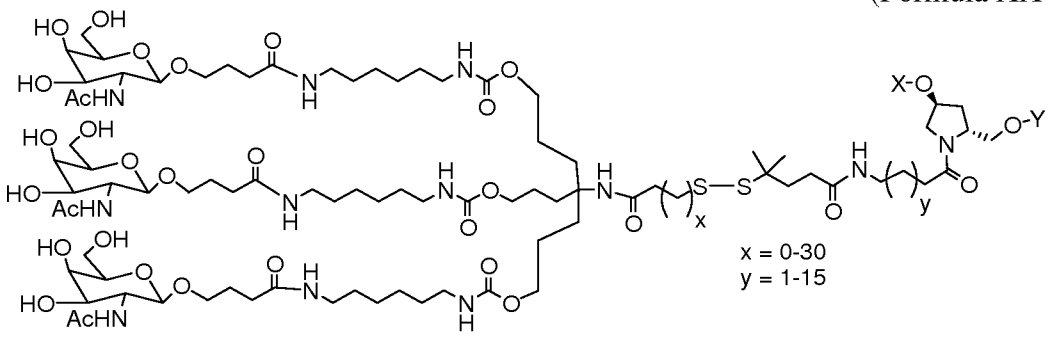
(Formula XXV),



(Formula XXVI),



(Formula XXVII),



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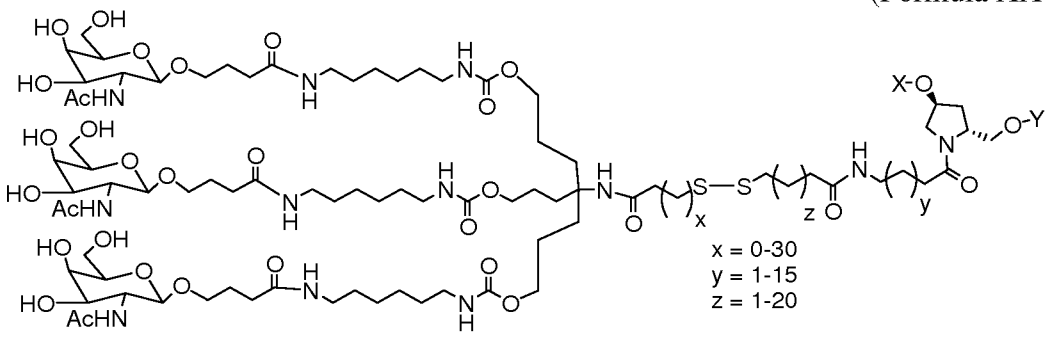
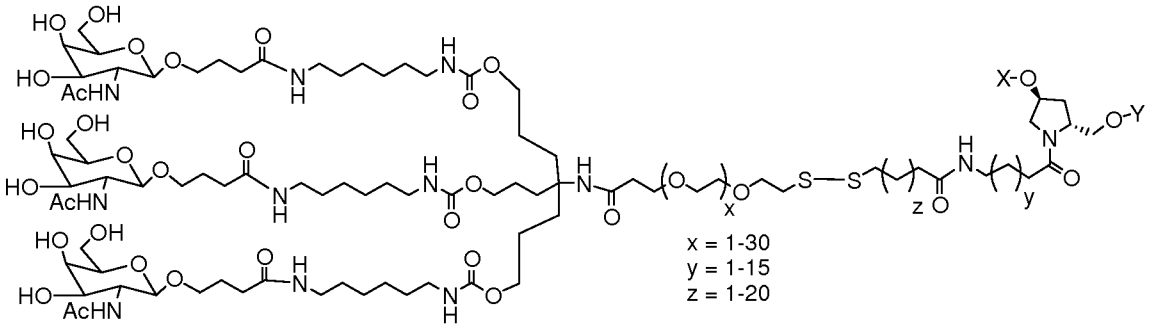
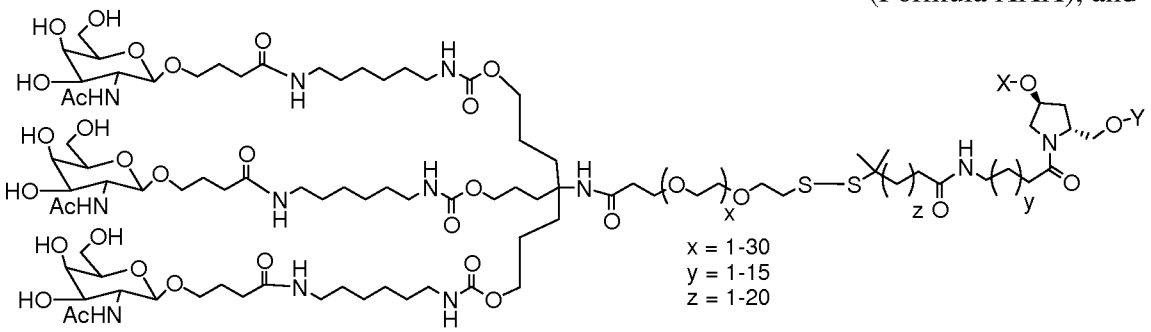


(Formula XXIX),



(Formula XXX), and



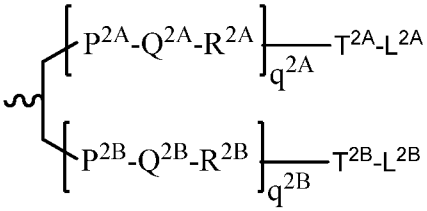
(Formula XXXI),

when one of X or Y is an oligonucleotide, the other is a hydrogen.

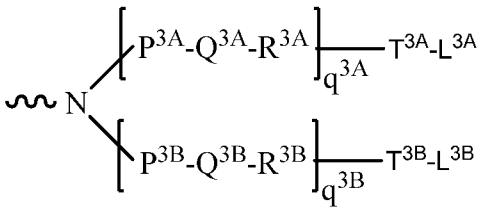
In certain embodiments of the compositions and methods of the invention, a ligand is one or more "GalNAc" (N-acetylgalactosamine) derivatives attached through a bivalent or trivalent branched linker.

In one embodiment, a antisense polynucleotide agent of the invention is conjugated to a bivalent or trivalent branched linker selected from the group of structures shown in any of formula (XXXII) – (XXXV):

Formula XXXII



Formula XXXIII



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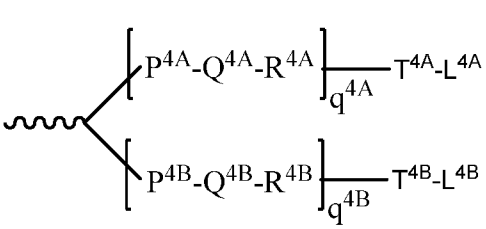

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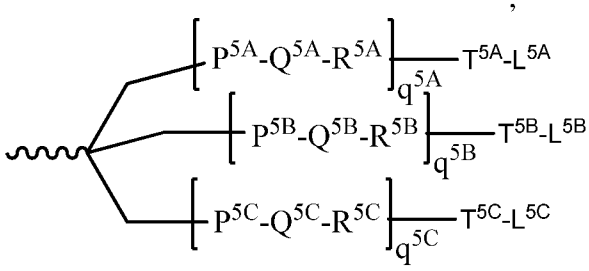


, or ;

Formula XXXIV

Formula XXXV

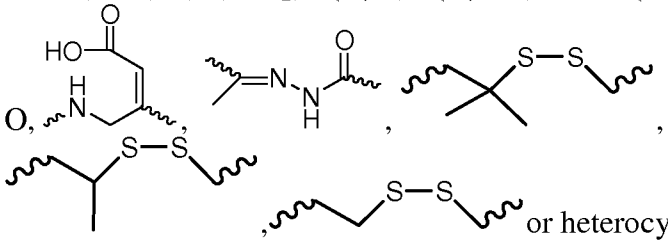
wherein:

q2A, q2B, q3A, q3B, q4A, q4B, q5A, q5B and q5C represent independently for each occurrence 0-20 and wherein the repeating unit can be the same or different;

P^{2A}, P^{2B}, P^{3A}, P^{3B}, P^{4A}, P^{4B}, P^{5A}, P^{5B}, P^{5C}, T^{2A}, T^{2B}, T^{3A}, T^{3B}, T^{4A}, T^{4B}, T^{4A}, T^{5B}, T^{5C} are each independently for each occurrence absent, CO, NH, O, S, OC(O), NHC(O), CH_2, CH_2NH or CH_2O;

Q^{2A}, Q^{2B}, Q^{3A}, Q^{3B}, Q^{4A}, Q^{4B}, Q^{5A}, Q^{5B}, Q^{5C} are independently for each occurrence absent, alkylene, substituted alkylene wherin one or more methylenes can be interrupted or terminated by one or more of O, S, S(O), SO_2, $N(R^N)$, C(R')=C(R''), C≡C or C(O);

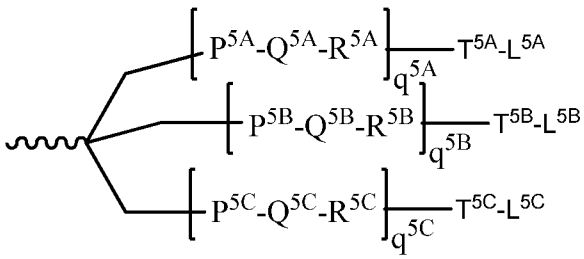
R^{2A}, R^{2B}, R^{3A}, R^{3B}, R^{4A}, R^{4B}, R^{5A}, R^{5B}, R^{5C} are each independently for each occurrence absent, NH, O, S, CH_2, C(O)O, C(O)NH, $NHCH(R^a)C(O)$, $-C(O)-CH(R^a)-NH-$, CO, CH=N-



or heterocyclyl;

L^{2A}, L^{2B}, L^{3A}, L^{3B}, L^{4A}, L^{4B}, L^{5A}, L^{5B} and L^{5C} represent the ligand; *i.e.* each independently for each occurrence a monosaccharide (such as GalNAc), disaccharide, trisaccharide, tetrasaccharide, oligosaccharide, or polysaccharide; andR^a is H or amino acid side chain.Trivalent conjugating GalNAc derivatives are particularly useful for use with antisense polynucleotide agents for inhibiting the expression of a target gene, such as those of formula (XXXVI):

Formula XXXVI



,

wherein L^{5A}, L^{5B} and L^{5C} represent a monosaccharide, such as GalNAc derivative.

Examples of suitable bivalent and trivalent branched linker groups conjugating GalNAc derivatives include, but are not limited to, the structures recited above as formulas II, VII, XI, X, and XIII.

Representative U.S. patents that teach the preparation of RNA conjugates include, but are not limited to, U.S. Pat. Nos. 4,828,979; 4,948,882; 5,218,105; 5,525,465; 5,541,313; 5,545,730; 5,552,538; 5,578,717, 5,580,731; 5,591,584; 5,109,124; 5,118,802; 5,138,045; 5,414,077; 5,486,603; 5,512,439; 5,578,718; 5,608,046; 4,587,044; 4,605,735; 4,667,025; 4,762,779; 4,789,737; 4,824,941; 4,835,263; 4,876,335; 4,904,582; 4,958,013; 5,082,830; 5,112,963; 5,214,136; 5,082,830; 5,112,963; 5,214,136; 5,245,022; 5,254,469; 5,258,506; 5,262,536; 5,272,250; 5,292,873; 5,317,098; 5,371,241, 5,391,723; 5,416,203, 5,451,463; 5,510,475; 5,512,667; 5,514,785; 5,565,552; 5,567,810; 5,574,142; 5,585,481; 5,587,371; 5,595,726; 5,597,696; 5,599,923; 5,599,928 and 5,688,941; 6,294,664; 6,320,017; 6,576,752; 6,783,931; 6,900,297; 7,037,646; 8,106,022, the entire contents of each of which are hereby incorporated herein by reference.

It is not necessary for all positions in a given compound to be uniformly modified, and in fact more than one of the aforementioned modifications can be incorporated in a single compound or even at a single nucleoside within an antisense polynucleotide agent. The present invention also includes antisense polynucleotide agents that are chimeric compounds.

"Chimeric" antisense polynucleotide agents or "chimeras," in the context of this invention, are antisense polynucleotide agent compounds, which contain two or more chemically distinct regions, each made up of at least one monomer unit, *i.e.*, a nucleotide in the case of an antisense polynucleotide agent. These antisense polynucleotide agents typically contain at least one region wherein the RNA is modified so as to confer upon the antisense polynucleotide agent increased resistance to nuclease degradation, increased cellular uptake, and/or increased binding affinity for the target nucleic acid. An additional region of the antisense polynucleotide agent can serve as a substrate for enzymes capable of cleaving RNA:DNA or RNA:RNA hybrids. By way of example, RNase H is a cellular endonuclease which cleaves the RNA strand of an RNA:DNA duplex. Activation of RNase H, therefore, results in cleavage of the RNA target, thereby greatly enhancing the efficiency of antisense polynucleotide agent inhibition of gene expression. Consequently, comparable results can often be obtained with shorter antisense polynucleotide agents when chimeric antisense polynucleotide agents are used, compared to phosphorothioate deoxy antisense polynucleotide agents hybridizing to the same target region. Cleavage of the RNA target can be routinely detected by gel electrophoresis and, if necessary, associated nucleic acid hybridization techniques known in the art.

In certain instances, the nucleotide of an antisense polynucleotide agent can be modified by a non-ligand group. A number of non-ligand molecules have been conjugated to antisense polynucleotide agents in order to enhance the activity, cellular distribution or cellular uptake of the antisense polynucleotide agent, and procedures for performing such conjugations are available in the scientific literature. Such non-ligand moieties have included lipid moieties, such as cholesterol (Kubo, T. *et al., Biochem. Biophys. Res. Comm.*, 2007,

365(1):54-61; Letsinger *et al.*, *Proc. Natl. Acad. Sci. USA*, 1989, 86:6553), cholic acid (Manoharan *et al.*, *Bioorg. Med. Chem. Lett.*, 1994, 4:1053), a thioether, *e.g.*, hexyl-S-tritylthiol (Manoharan *et al.*, *Ann. N.Y. Acad. Sci.*, 1992, 660:306; Manoharan *et al.*, *Bioorg. Med. Chem. Let.*, 1993, 3:2765), a thiocholesterol (Oberhauser *et al.*, *Nucl. Acids Res.*, 1992, 20:533), an aliphatic chain, *e.g.*, dodecandiol or undecyl residues (Saison-Behmoaras *et al.*, *EMBO J.*, 1991, 10:111; Kabanov *et al.*, *FEBS Lett.*, 1990, 259:327; Svinarchuk *et al.*, *Biochimie*, 1993, 75:49), a phospholipid, *e.g.*, di-hexadecyl-rac-glycerol or triethylammonium 1,2-di-O-hexadecyl-rac-glycero-3-H-phosphonate (Manoharan *et al.*, *Tetrahedron Lett.*, 1995, 36:3651; Shea *et al.*, *Nucl. Acids Res.*, 1990, 18:3777), a polyamine or a polyethylene glycol chain (Manoharan *et al.*, *Nucleosides & Nucleotides*, 1995, 14:969), or adamantane acetic acid (Manoharan *et al.*, *Tetrahedron Lett.*, 1995, 36:3651), a palmityl moiety (Mishra *et al.*, *Biochim. Biophys. Acta*, 1995, 1264:229), or an octadecylamine or hexylamino-carbonyl-oxycholesterol moiety (Crooke *et al.*, *J. Pharmacol. Exp. Ther.*, 1996, 277:923). Representative United States patents that teach the preparation of such RNA conjugates have been listed above. Typical conjugation protocols involve the synthesis of an RNAs bearing an aminolinker at one or more positions of the sequence. The amino group is then reacted with the molecule being conjugated using appropriate coupling or activating reagents. The conjugation reaction can be performed either with the RNA still bound to the solid support or following cleavage of the RNA, in solution phase. Purification of the RNA conjugate by HPLC typically affords the pure conjugate.

V. Delivery of a Polynucleotide Agent of the Invention

The delivery of a polynucleotide agent of the invention, *e.g.,* an antisense polynucleotide agent of the invention, to a cell *e.g.,* a cell within a subject, such as a human subject (*e.g.,* a subject in need thereof, such as a subject having an ALAS1-associated disease) can be achieved in a number of different ways. For example, delivery may be performed by contacting a cell with an antisense polynucleotide agent of the invention either *in vitro* or *in vivo*. *In vivo* delivery may also be performed directly by administering a composition comprising an antisense polynucleotide agent to a subject.

In general, any method of delivering a nucleic acid molecule (*in vitro* or *in vivo*) can be adapted for use with an antisense polynucleotide agent of the invention (see *e.g.*, Akhtar S. and Julian RL. (1992) *Trends Cell. Biol.* 2(5):139-144 and WO94/02595, which are incorporated herein by reference in their entireties). For *in vivo* delivery, factors to consider in order to deliver an antisense polynucleotide agent include, for example, biological stability of the delivered molecule, prevention of non-specific effects, and accumulation of the delivered molecule in the target tissue. The non-specific effects of an antisense polynucleotide agent can be minimized by local administration, for example, by direct injection or implantation into a tissue or topically administering the preparation. Local

administration to a treatment site maximizes local concentration of the agent, limits the exposure of the agent to systemic tissues that can otherwise be harmed by the agent or that can degrade the agent, and permits a lower total dose of the antisense polynucleotide agent to be administered. Several studies have shown successful knockdown of gene products when an antisense polynucleotide agent is administered locally. For example, intraocular delivery of a VEGF antisense polynucleotide agent by intravitreal injection in cynomolgus monkeys (Tolentino, MJ., *et al* (2004) *Retina* 24:132-138) and subretinal injections in mice (Reich, SJ., *et al* (2003) *Mol. Vis.* 9:210-216) were both shown to prevent neovascularization in an experimental model of age-related macular degeneration. In addition, direct intratumoral injection of a antisense polynucleotide agent in mice reduces tumor volume (Pille, J., *et al* (2005) *Mol. Ther.*11:267-274) and can prolong survival of tumor-bearing mice (Kim, WJ., *et al* (2006) *Mol. Ther.* 14:343-350; Li, S., *et al* (2007) *Mol. Ther.* 15:515-523). RNA interference has also shown success with local delivery to the CNS by direct injection (Dorn, G., *et al.* (2004) *Nucleic Acids* 32:e49; Tan, PH., *et al* (2005) *Gene Ther.* 12:59-66; Makimura, H., *et al* (2002) *BMC Neurosci.* 3:18; Shishkina, GT., *et al* (2004) *Neuroscience* 129:521-528; Thakker, ER., *et al* (2004) *Proc. Natl. Acad. Sci. U.S.A.* 101:17270-17275; Akaneya,Y., *et al* (2005) *J. Neurophysiol.* 93:594-602) and to the lungs by intranasal administration (Howard, KA., *et al* (2006) *Mol. Ther.* 14:476-484; Zhang, X., *et al* (2004) *J. Biol. Chem.* 279:10677-10684; Bitko, V., *et al* (2005) *Nat. Med.* 11:50-55). For administering an antisense polynucleotide agent systemically for the treatment of a disease, the agent can be modified or alternatively delivered using a drug delivery system; both methods act to prevent the rapid degradation of the antisense polynucleotide agent by endo- and exo-nucleases *in vivo*. Modification of the agent or the pharmaceutical carrier can also permit targeting of the antisense polynucleotide agent composition to the target tissue and avoid undesirable off-target effects. Antisense polynucleotide agent can be modified by chemical conjugation to lipophilic groups such as cholesterol to enhance cellular uptake and prevent degradation. In an alternative embodiment, the antisense polynucleotide agent can be delivered using drug delivery systems such as a nanoparticle, a dendrimer, a polymer, liposomes, or a cationic delivery system. Positively charged cationic delivery systems facilitate binding of an antisense polynucleotide agent molecule (negatively charged) and also enhance interactions at the negatively charged cell membrane to permit efficient uptake of an antisense polynucleotide agent by the cell. Cationic lipids, dendrimers, or polymers can either be bound to an antisense polynucleotide agent, or induced to form a vesicle or micelle (see *e.g.*, Kim SH., *et al* (2008) *Journal of Controlled Release* 129(2):107-116) that encases an antisense polynucleotide agent. The formation of vesicles or micelles further prevents degradation of the antisense polynucleotide agent when administered systemically. Methods for making and administering cationic- antisense polynucleotide agent complexes are well within the abilities of one skilled in the art (see *e.g.*, Sorensen, DR., *et al* (2003) *J. Mol. Biol* 327:761-766;

Verma, UN, *et al* (2003) Clin. *Cancer Res.* 9:1291-1300; Arnold, AS *et al* (2007) *J. Hypertens.* 25:197-205, which are incorporated herein by reference in their entirety). Some non-limiting examples of drug delivery systems useful for systemic delivery of antisense polynucleotide agents include DOTAP (Sorensen, DR., *et al* (2003), supra; Verma, UN., *et al* (2003), *supra*), Oligofectamine, "solid nucleic acid lipid particles" (Zimmermann, TS., *et al* (2006) *Nature* 441:111-114), cardiolipin (Chien, PY., *et al* (2005) *Cancer Gene Ther.* 12:321-328; Pal, A., *et al* (2005) *Int J. Oncol.* 26:1087-1091), polyethyleneimine (Bonnet ME., *et al* (2008) *Pharm. Res.* Aug 16 Epub ahead of print; Aigner, A. (2006) *J. Biomed. Biotechnol.* 71659), Arg-Gly-Asp (RGD) peptides (Liu, S. (2006) *Mol. Pharm.* 3:472-487), and polyamidoamines (Tomalia, DA., *et al* (2007) *Biochem. Soc. Trans.* 35:61-67; Yoo, H., *et al* (1999) *Pharm. Res.* 16:1799-1804). In some embodiments, an antisense polynucleotide agent forms a complex with cyclodextrin for systemic administration. Methods for administration and pharmaceutical compositions of antisense polynucleotide agents and cyclodextrins can be found in U.S. Patent No. 7,427,605, which is herein incorporated by reference in its entirety.

VI. Pharmaceutical Compositions of the Invention

The present invention also includes pharmaceutical compositions and formulations which include the polynucleotide agents of the invention. In one embodiment, provided herein are pharmaceutical compositions containing an antisense polynucleotide agent, as described herein, and a pharmaceutically acceptable carrier.

The phrase "pharmaceutically acceptable" is employed herein to refer to those compounds, materials, compositions, and/or dosage forms which are, within the scope of sound medical judgment, suitable for use in contact with the tissues of human subjects and animal subjects without excessive toxicity, irritation, allergic response, or other problem or complication, commensurate with a reasonable benefit/risk ratio.

The phrase "pharmaceutically-acceptable carrier" as used herein means a pharmaceutically-acceptable material, composition or vehicle, such as a liquid or solid filler, diluent, excipient, manufacturing aid (*e.g.*, lubricant, talc magnesium, calcium or zinc stearate, or steric acid), or solvent encapsulating material, involved in carrying or transporting the subject compound from one organ, or portion of the body, to another organ, or portion of the body. Each carrier must be "acceptable" in the sense of being compatible with the other ingredients of the formulation and not injurious to the subject being treated. Some examples of materials which can serve as pharmaceutically-acceptable carriers include: (1) sugars, such as lactose, glucose and sucrose; (2) starches, such as corn starch and potato starch; (3) cellulose, and its derivatives, such as sodium carboxymethyl cellulose, ethyl cellulose and cellulose acetate; (4) powdered tragacanth; (5) malt; (6) gelatin; (7) lubricating agents, such as magnesium state, sodium lauryl sulfate and talc; (8) excipients, such as cocoa butter and

suppository waxes; (9) oils, such as peanut oil, cottonseed oil, safflower oil, sesame oil, olive oil, corn oil and soybean oil; (10) glycols, such as propylene glycol; (11) polyols, such as glycerin, sorbitol, mannitol and polyethylene glycol; (12) esters, such as ethyl oleate and ethyl laurate; (13) agar; (14) buffering agents, such as magnesium hydroxide and aluminum hydroxide; (15) alginic acid; (16) pyrogen-free water; (17) isotonic saline; (18) Ringer's solution; (19) ethyl alcohol; (20) pH buffered solutions; (21) polyesters, polycarbonates and/or polyanhydrides; (22) bulking agents, such as polypeptides and amino acids (23) serum components, such as serum albumin, HDL and LDL; and (22) other non-toxic compatible substances employed in pharmaceutical formulations.

The pharmaceutical compositions containing the antisense polynucleotide agents are useful for treating a disease or disorder associated with the expression or activity of an ALAS1 gene, *e.g.* an ALAS1-associated disease. Such pharmaceutical compositions are formulated based on the mode of delivery. One example is compositions that are formulated for systemic administration *via* parenteral delivery, *e.g.*, by subcutaneous (SC) or intravenous (IV) delivery. Another example is compositions that are formulated for direct delivery into the brain parenchyma, *e.g.*, by infusion into the brain, such as by continuous pump infusion. The pharmaceutical compositions of the invention may be administered in dosages sufficient to inhibit expression of an ALAS1 gene. In general, a suitable dose of an antisense polynucleotide agent of the invention will be in the range of about 0.001 to about 200.0 milligrams per kilogram body weight of the recipient per day, generally in the range of about 1 to 50 mg per kilogram body weight per day. For example, the antisense polynucleotide agent can be administered at about 0.01 mg/kg, about 0.05 mg/kg, about 0.5 mg/kg, about 1 mg/kg, about 1.5 mg/kg, about 2 mg/kg, about 3 mg/kg, about 10 mg/kg, about 20 mg/kg, about 30 mg/kg, about 40 mg/kg, or about 50 mg/kg per single dose.

For example, the antisense polynucleotide agent may be administered at a dose of about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 8, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 9, 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 2, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, or about 50 mg/kg. Values and ranges intermediate to the recited values are also intended to be part of this invention.

In another embodiment, the antisense polynucleotide agent is administered at a dose of about 0.1 to about 50 mg/kg, about 0.25 to about 50 mg/kg, about 0.5 to about 50 mg/kg, about 0.75 to about 50 mg/kg, about 1 to about 50 mg/mg, about 1.5 to about 50 mg/kb, about 2 to about 50 mg/kg, about 2.5 to about 50 mg/kg, about 3 to about 50 mg/kg, about 3.5 to about 50 mg/kg, about 4 to about 50 mg/kg, about 4.5 to about 50 mg/kg, about 5 to about 50

mg/kg, about 7.5 to about 50 mg/kg, about 10 to about 50 mg/kg, about 15 to about 50 mg/kg, about 20 to about 50 mg/kg, about 20 to about 50 mg/kg, about 25 to about 50 mg/kg, about 25 to about 50 mg/kg, about 30 to about 50 mg/kg, about 35 to about 50 mg/kg, about 40 to about 50 mg/kg, about 45 to about 50 mg/kg, about 0.1 to about 45 mg/kg, about 0.25 to about 45 mg/kg, about 0.5 to about 45 mg/kg, about 0.75 to about 45 mg/kg, about 1 to about 45 mg/mg, about 1.5 to about 45 mg/kb, about 2 to about 45 mg/kg, about 2.5 to about 45 mg/kg, about 3 to about 45 mg/kg, about 3.5 to about 45 mg/kg, about 4 to about 45 mg/kg, about 4.5 to about 45 mg/kg, about 5 to about 45 mg/kg, about 7.5 to about 45 mg/kg, about 10 to about 45 mg/kg, about 15 to about 45 mg/kg, about 20 to about 45 mg/kg, about 20 to about 45 mg/kg, about 25 to about 45 mg/kg, about 25 to about 45 mg/kg, about 30 to about 45 mg/kg, about 35 to about 45 mg/kg, about 40 to about 45 mg/kg, about 0.1 to about 40 mg/kg, about 0.25 to about 40 mg/kg, about 0.5 to about 40 mg/kg, about 0.75 to about 40 mg/kg, about 1 to about 40 mg/mg, about 1.5 to about 40 mg/kb, about 2 to about 40 mg/kg, about 2.5 to about 40 mg/kg, about 3 to about 40 mg/kg, about 3.5 to about 40 mg/kg, about 4 to about 40 mg/kg, about 4.5 to about 40 mg/kg, about 5 to about 40 mg/kg, about 7.5 to about 40 mg/kg, about 10 to about 40 mg/kg, about 15 to about 40 mg/kg, about 20 to about 40 mg/kg, about 25 to about 40 mg/kg, about 30 to about 40 mg/kg, about 35 to about 40 mg/kg, about 0.1 to about 30 mg/kg, about 0.25 to about 30 mg/kg, about 0.5 to about 30 mg/kg, about 0.75 to about 30 mg/kg, about 1 to about 30 mg/mg, about 1.5 to about 30 mg/kb, about 2 to about 30 mg/kg, about 2.5 to about 30 mg/kg, about 3 to about 30 mg/kg, about 3.5 to about 30 mg/kg, about 4 to about 30 mg/kg, about 4.5 to about 30 mg/kg, about 5 to about 30 mg/kg, about 7.5 to about 30 mg/kg, about 10 to about 30 mg/kg, about 15 to about 30 mg/kg, about 20 to about 30 mg/kg, about 20 to about 30 mg/kg, about 25 to about 30 mg/kg, about 0.1 to about 20 mg/kg, about 0.25 to about 20 mg/kg, about 0.5 to about 20 mg/kg, about 0.75 to about 20 mg/kg, about 1 to about 20 mg/mg, about 1.5 to about 20 mg/kb, about 2 to about 20 mg/kg, about 2.5 to about 20 mg/kg, about 3 to about 20 mg/kg, about 3.5 to about 20 mg/kg, about 4 to about 20 mg/kg, about 4.5 to about 20 mg/kg, about 5 to about 20 mg/kg, about 7.5 to about 20 mg/kg, about 10 to about 20 mg/kg, or about 15 to about 20 mg/kg. Values and ranges intermediate to the recited values are also intended to be part of this invention.

For example, the antisense polynucleotide agent may be administered at a dose of about 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 8, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 9, 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 2, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, or about 50 mg/kg.

Values and ranges intermediate to the recited values are also intended to be part of this invention.

In another embodiment, the antisense polynucleotide agent is administered at a dose of about 0.5 to about 50 mg/kg, about 0.75 to about 50 mg/kg, about 1 to about 50 mg/mg, about 1.5 to about 50 mg/kgb, about 2 to about 50 mg/kg, about 2.5 to about 50 mg/kg, about 3 to about 50 mg/kg, about 3.5 to about 50 mg/kg, about 4 to about 50 mg/kg, about 4.5 to about 50 mg/kg, about 5 to about 50 mg/kg, about 7.5 to about 50 mg/kg, about 10 to about 50 mg/kg, about 15 to about 50 mg/kg, about 20 to about 50 mg/kg, about 20 to about 50 mg/kg, about 25 to about 50 mg/kg, about 25 to about 50 mg/kg, about 30 to about 50 mg/kg, about 35 to about 50 mg/kg, about 40 to about 50 mg/kg, about 45 to about 50 mg/kg, about 0.5 to about 45 mg/kg, about 0.75 to about 45 mg/kg, about 1 to about 45 mg/mg, about 1.5 to about 45 mg/kb, about 2 to about 45 mg/kg, about 2.5 to about 45 mg/kg, about 3 to about 45 mg/kg, about 3.5 to about 45 mg/kg, about 4 to about 45 mg/kg, about 4.5 to about 45 mg/kg, about 5 to about 45 mg/kg, about 7.5 to about 45 mg/kg, about 10 to about 45 mg/kg, about 15 to about 45 mg/kg, about 20 to about 45 mg/kg, about 20 to about 45 mg/kg, about 25 to about 45 mg/kg, about 25 to about 45 mg/kg, about 30 to about 45 mg/kg, about 35 to about 45 mg/kg, about 40 to about 45 mg/kg, about 0.5 to about 40 mg/kg, about 0.75 to about 40 mg/kg, about 1 to about 40 mg/mg, about 1.5 to about 40 mg/kb, about 2 to about 40 mg/kg, about 2.5 to about 40 mg/kg, about 3 to about 40 mg/kg, about 3.5 to about 40 mg/kg, about 4 to about 40 mg/kg, about 4.5 to about 40 mg/kg, about 5 to about 40 mg/kg, about 7.5 to about 40 mg/kg, about 10 to about 40 mg/kg, about 15 to about 40 mg/kg, about 20 to about 40 mg/kg, about 25 to about 40 mg/kg, about 30 to about 40 mg/kg, about 35 to about 40 mg/kg, about 0.5 to about 30 mg/kg, about 0.75 to about 30 mg/kg, about 1 to about 30 mg/mg, about 1.5 to about 30 mg/kb, about 2 to about 30 mg/kg, about 2.5 to about 30 mg/kg, about 3 to about 30 mg/kg, about 3.5 to about 30 mg/kg, about 4 to about 30 mg/kg, about 4.5 to about 30 mg/kg, about 5 to about 30 mg/kg, about 7.5 to about 30 mg/kg, about 10 to about 30 mg/kg, about 15 to about 30 mg/kg, about 20 to about 30 mg/kg, about 20 to about 30 mg/kg, about 25 to about 30 mg/kg, about 0.5 to about 20 mg/kg, about 0.75 to about 20 mg/kg, about 1 to about 20 mg/mg, about 1.5 to about 20 mg/kb, about 2 to about 20 mg/kg, about 2.5 to about 20 mg/kg, about 3 to about 20 mg/kg, about 3.5 to about 20 mg/kg, about 4 to about 20 mg/kg, about 4.5 to about 20 mg/kg, about 5 to about 20 mg/kg, about 7.5 to about 20 mg/kg, about 10 to about 20 mg/kg, or about 15 to about 20 mg/kg. In one embodiment, the antisense polynucleotide agent is administered at a dose of about 10mg/kg to about 30 mg/kg. Values and ranges intermediate to the recited values are also intended to be part of this invention.

For example, subjects can be administered, *e.g.,* subcutaneously or intravenously, a single therapeutic amount of antisense polynucleotide agent, such as about 0.1, 0.125, 0.15, 0.175, 0.2, 0.225, 0.25, 0.275, 0.3, 0.325, 0.35, 0.375, 0.4, 0.425, 0.45, 0.475, 0.5, 0.525,

0.55, 0.575, 0.6, 0.625, 0.65, 0.675, 0.7, 0.725, 0.75, 0.775, 0.8, 0.825, 0.85, 0.875, 0.9, 0.925, 0.95, 0.975, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 8, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 9, 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, 10, 10.5, 11, 11.5, 12, 12.5, 13, 13.5, 14, 14.5, 15, 15.5, 16, 16.5, 17, 17.5, 18, 18.5, 19, 19.5, 20, 20.5, 21, 21.5, 22, 22.5, 23, 23.5, 24, 24.5, 25, 25.5, 26, 26.5, 27, 27.5, 28, 28.5, 29, 29.5, 30, 31, 32, 33, 34, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, or about 50 mg/kg. Values and ranges intermediate to the recited values are also intended to be part of this invention.

In some embodiments, subjects are administered, *e.g.,* subcutaneously or intravenously, multiple doses of a therapeutic amount of antisense polynucleotide agent, such as a dose about 0.1, 0.125, 0.15, 0.175, 0.2, 0.225, 0.25, 0.275, 0.3, 0.325, 0.35, 0.375, 0.4, 0.425, 0.45, 0.475, 0.5, 0.525, 0.55, 0.575, 0.6, 0.625, 0.65, 0.675, 0.7, 0.725, 0.75, 0.775, 0.8, 0.825, 0.85, 0.875, 0.9, 0.925, 0.95, 0.975, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 8, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 9, 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, 10, 10.5, 11, 11.5, 12, 12.5, 13, 13.5, 14, 14.5, 15, 15.5, 16, 16.5, 17, 17.5, 18, 18.5, 19, 19.5, 20, 20.5, 21, 21.5, 22, 22.5, 23, 23.5, 24, 24.5, 25, 25.5, 26, 26.5, 27, 27.5, 28, 28.5, 29, 29.5, 30, 31, 32, 33, 34, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, or about 50 mg/kg. A multi-dose regimine may include administration of a therapeutic amount of antisense polynucleotide agent daily, such as for two days, three days, four days, five days, six days, seven days, or longer.

In other embodiments, subjects are administered, *e.g.,* subcutaneously or intravenously, a repeat dose of a therapeutic amount of antisense polynucleotide agent, such as a dose about 0.1, 0.125, 0.15, 0.175, 0.2, 0.225, 0.25, 0.275, 0.3, 0.325, 0.35, 0.375, 0.4, 0.425, 0.45, 0.475, 0.5, 0.525, 0.55, 0.575, 0.6, 0.625, 0.65, 0.675, 0.7, 0.725, 0.75, 0.775, 0.8, 0.825, 0.85, 0.875, 0.9, 0.925, 0.95, 0.975, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 8, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 9, 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, 10, 10.5, 11, 11.5, 12, 12.5, 13, 13.5, 14, 14.5, 15, 15.5, 16, 16.5, 17, 17.5, 18, 18.5, 19, 19.5, 20, 20.5, 21, 21.5, 22, 22.5, 23, 23.5, 24, 24.5, 25, 25.5, 26, 26.5, 27, 27.5, 28, 28.5, 29, 29.5, 30, 31, 32, 33, 34, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, or about 50 mg/kg. A repeat-dose regimine may include administration of a therapeutic amount of antisense polynucleotide agent on a regular

basis, such as every other day, every third day, every fourth day, twice a week, once a week, every other week, or once a month.

The pharmaceutical composition can be administered by intravenous infusion over a period of time, such as over a 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, and 21, 22, 23, 24, or about a 25 minute period. The administration may be repeated, for example, on a regular basis, such as weekly, biweekly (*i.e.*, every two weeks) for one month, two months, three months, four months or longer. After an initial treatment regimen, the treatments can be administered on a less frequent basis. For example, after administration weekly or biweekly for three months, administration can be repeated once per month, for six months or a year or longer.

The pharmaceutical composition can be administered once daily, or the antisense polynucleotide agent can be administered as two, three, or more sub-doses at appropriate intervals throughout the day or even using continuous infusion or delivery through a controlled release formulation. In that case, the antisense polynucleotide agent contained in each sub-dose must be correspondingly smaller in order to achieve the total daily dosage. The dosage unit can also be compounded for delivery over several days, *e.g.*, using a conventional sustained release formulation which provides sustained release of the antisense polynucleotide agent over a several day period. Sustained release formulations are well known in the art and are particularly useful for delivery of agents at a particular site, such as could be used with the agents of the present invention. In this embodiment, the dosage unit contains a corresponding multiple of the daily dose.

In other embodiments, a single dose of the pharmaceutical compositions can be long lasting, such that subsequent doses are administered at not more than 3, 4, or 5 day intervals, or at not more than 1, 2, 3, or 4 week intervals. In some embodiments of the invention, a single dose of the pharmaceutical compositions of the invention is administered once per week. In other embodiments of the invention, a single dose of the pharmaceutical compositions of the invention is administered bi-monthly.

The skilled artisan will appreciate that certain factors can influence the dosage and timing required to effectively treat a subject, including but not limited to the severity of the disease or disorder, previous treatments, the general health and/or age of the subject, and other diseases present. Moreover, treatment of a subject with a therapeutically effective amount of a composition can include a single treatment or a series of treatments. Estimates of effective dosages and *in vivo* half-lives for the individual antisense polynucleotide agents encompassed by the invention can be made using conventional methodologies or on the basis of *in vivo* testing using an appropriate animal model, as described elsewhere herein.

The pharmaceutical compositions of the present invention can be administered in a number of ways depending upon whether local or systemic treatment is desired and upon the area to be treated. Administration can be topical (*e.g.*, by a transdermal patch), pulmonary,

e.g., by inhalation or insufflation of powders or aerosols, including by nebulizer; intratracheal, intranasal, epidermal and transdermal, oral or parenteral. Parenteral administration includes intravenous, intraarterial, subcutaneous, intraperitoneal or intramuscular injection or infusion; subdermal, *e.g.*, via an implanted device; or intracranial, *e.g.*, by intraparenchymal, intrathecal or intraventricular, administration.

The antisense polynucleotide agent can be delivered in a manner to target a particular tissue, such as the liver (*e.g.*, the hepatocytes of the liver).

Pharmaceutical compositions and formulations for topical administration can include transdermal patches, ointments, lotions, creams, gels, drops, suppositories, sprays, liquids and powders. Conventional pharmaceutical carriers, aqueous, powder or oily bases, thickeners and the like can be necessary or desirable. Coated condoms, gloves and the like can also be useful. Suitable topical formulations include those in which the antisense polynucleotide agents featured in the invention are in admixture with a topical delivery agent such as lipids, liposomes, fatty acids, fatty acid esters, steroids, chelating agents and surfactants. Suitable lipids and liposomes include neutral (*e.g.,* dioleoylphosphatidyl DOPE ethanolamine, dimyristoylphosphatidyl choline DMPC, distearolyphosphatidyl choline) negative (*e.g.,* dimyristoylphosphatidyl glycerol DMPG) and cationic (*e.g.,* dioleoyltetramethylaminopropyl DOTAP and dioleoylphosphatidyl ethanolamine DOTMA). Antisense polynucleotide agents featured in the invention can be encapsulated within liposomes or can form complexes thereto, in particular to cationic liposomes. Alternatively, antisense polynucleotide agents can be complexed to lipids, in particular to cationic lipids. Suitable fatty acids and esters include but are not limited to arachidonic acid, oleic acid, eicosanoic acid, lauric acid, caprylic acid, capric acid, myristic acid, palmitic acid, stearic acid, linoleic acid, linolenic acid, dicaprate, tricaprate, monoolein, dilaurin, glyceryl 1-monocaprate, 1-dodecylazacycloheptan-2-one, an acylcarnitine, an acylcholine, or a C_{1-20} alkyl ester (*e.g.,* isopropylmyristate IPM), monoglyceride, diglyceride or pharmaceutically acceptable salt thereof). Topical formulations are described in detail in U.S. Patent No. 6,747,014, which is incorporated herein by reference.

A. Antisense Polynucleotide Agent Formulations Comprising Membranous Molecular Assemblies

An antisense polynucleotide agent for use in the compositions and methods of the invention can be formulated for delivery in a membranous molecular assembly, *e.g.*, a liposome or a micelle. As used herein, the term "liposome" refers to a vesicle composed of amphiphilic lipids arranged in at least one bilayer, *e.g.*, one bilayer or a plurality of bilayers. Liposomes include unilamellar and multilamellar vesicles that have a membrane formed from a lipophilic material and an aqueous interior. The aqueous portion contains the antisense polynucleotide agent composition. The lipophilic material isolates the aqueous interior from an aqueous exterior, which typically does not include the antisense polynucleotide agent

composition, although in some examples, it may. Liposomes are useful for the transfer and delivery of active ingredients to the site of action. Because the liposomal membrane is structurally similar to biological membranes, when liposomes are applied to a tissue, the liposomal bilayer fuses with bilayer of the cellular membranes. As the merging of the liposome and cell progresses, the internal aqueous contents that include the antisense polynucleotide agent are delivered into the cell where the antisense polynucleotide agent can specifically bind to a target RNA and can mediate antisense inhibition. In some cases the liposomes are also specifically targeted, *e.g.*, to direct the antisense polynucleotide agent to particular cell types.

A liposome containing an antisense polynucleotide agent can be prepared by a variety of methods. In one example, the lipid component of a liposome is dissolved in a detergent so that micelles are formed with the lipid component. For example, the lipid component can be an amphipathic cationic lipid or lipid conjugate. The detergent can have a high critical micelle concentration and may be nonionic. Exemplary detergents include cholate, CHAPS, octylglucoside, deoxycholate, and lauroyl sarcosine. The antisense polynucleotide agent preparation is then added to the micelles that include the lipid component. The cationic groups on the lipid interact with the antisense polynucleotide agent and condense around the antisense polynucleotide agent to form a liposome. After condensation, the detergent is removed, *e.g.*, by dialysis, to yield a liposomal preparation of antisense polynucleotide agent.

If necessary a carrier compound that assists in condensation can be added during the condensation reaction, *e.g.*, by controlled addition. For example, the carrier compound can be a polymer other than a nucleic acid (*e.g.*, spermine or spermidine). pH can also be adjusted to favor condensation.

Methods for producing stable polynucleotide delivery vehicles, which incorporate a polynucleotide/cationic lipid complex as structural components of the delivery vehicle, are further described in, *e.g.*, WO 96/37194, the entire contents of which are incorporated herein by reference. Liposome formation can also include one or more aspects of exemplary methods described in Felgner, P. L. *et al., Proc. Natl. Acad. Sci., USA* 8:7413-7417, 1987; U.S. Pat. No. 4,897,355; U.S. Pat. No. 5,171,678; Bangham, *et al. M. Mol. Biol.* 23:238, 1965; Olson, *et al. Biochim. Biophys. Acta* 557:9, 1979; Szoka, *et al. Proc. Natl. Acad. Sci.* 75: 4194, 1978; Mayhew, e*t al. Biochim. Biophys. Acta* 775:169, 1984; Kim, *et al. Biochim. Biophys. Acta* 728:339, 1983; and Fukunaga, *et al. Endocrinol.* 115:757, 1984. Commonly used techniques for preparing lipid aggregates of appropriate size for use as delivery vehicles include sonication and freeze-thaw plus extrusion (see, *e.g.,* Mayer, *et al. Biochim. Biophys. Acta* 858:161, 1986). Microfluidization can be used when consistently small (50 to 200 nm) and relatively uniform aggregates are desired (Mayhew, *et al. Biochim. Biophys. Acta* 775:169, 1984). These methods are readily adapted to packaging antisense polynucleotide agent preparations into liposomes.

Liposomes fall into two broad classes. Cationic liposomes are positively charged liposomes which interact with the negatively charged nucleic acid molecules to form a stable complex. The positively charged nucleic acid/liposome complex binds to the negatively charged cell surface and is internalized in an endosome. Due to the acidic pH within the endosome, the liposomes are ruptured, releasing their contents into the cell cytoplasm (Wang *et al.*, *Biochem. Biophys. Res. Commun.*, 1987, 147, 980-985).

Liposomes which are pH-sensitive or negatively-charged, entrap nucleic acids rather than complex with it. Since both the nucleic acid and the lipid are similarly charged, repulsion rather than complex formation occurs. Nevertheless, some nucleic acid is entrapped within the aqueous interior of these liposomes. pH-sensitive liposomes have been used to deliver nucleic acids encoding the thymidine kinase gene to cell monolayers in culture. Expression of the exogenous gene was detected in the target cells (Zhou *et al.*, *Journal of Controlled Release*, 1992, 19, 269-274).

One major type of liposomal composition includes phospholipids other than naturally-derived phosphatidylcholine. Neutral liposome compositions, for example, can be formed from dimyristoyl phosphatidylcholine (DMPC) or dipalmitoyl phosphatidylcholine (DPPC). Anionic liposome compositions generally are formed from dimyristoyl phosphatidylglycerol, while anionic fusogenic liposomes are formed primarily from dioleoyl phosphatidylethanolamine (DOPE). Another type of liposomal composition is formed from phosphatidylcholine (PC) such as, for example, soybean PC, and egg PC. Another type is formed from mixtures of phospholipid and/or phosphatidylcholine and/or cholesterol.

Examples of other methods to introduce liposomes into cells *in vitro* and *in vivo* include U.S. Pat. No. 5,283,185; U.S. Pat. No. 5,171,678; WO 94/00569; WO 93/24640; WO 91/16024; Felgner, *J. Biol. Chem.* 269:2550, 1994; Nabel, *Proc. Natl. Acad. Sci.* 90:11307, 1993; Nabel, *Human Gene Ther.* 3:649, 1992; Gershon, *Biochem.* 32:7143, 1993; and Strauss *EMBO J.* 11:417, 1992.

Non-ionic liposomal systems have also been examined to determine their utility in the delivery of drugs to the skin, in particular systems comprising non-ionic surfactant and cholesterol. Non-ionic liposomal formulations comprising Novasome™ I (glyceryl dilaurate/cholesterol/polyoxyethylene-10-stearyl ether) and Novasome™ II (glyceryl distearate/cholesterol/polyoxyethylene-10-stearyl ether) were used to deliver cyclosporin-A into the dermis of mouse skin. Results indicated that such non-ionic liposomal systems were effective in facilitating the deposition of cyclosporine A into different layers of the skin (Hu *et al. S.T.P.Pharma. Sci.*, 1994, 4(6) 466).

Liposomes also include "sterically stabilized" liposomes, a term which, as used herein, refers to liposomes comprising one or more specialized lipids that, when incorporated into liposomes, result in enhanced circulation lifetimes relative to liposomes lacking such specialized lipids. Examples of sterically stabilized liposomes are those in which part of the

vesicle-forming lipid portion of the liposome (A) comprises one or more glycolipids, such as monosialoganglioside G_{M1}, or (B) is derivatized with one or more hydrophilic polymers, such as a polyethylene glycol (PEG) moiety. While not wishing to be bound by any particular theory, it is thought in the art that, at least for sterically stabilized liposomes containing gangliosides, sphingomyelin, or PEG-derivatized lipids, the enhanced circulation half-life of these sterically stabilized liposomes derives from a reduced uptake into cells of the reticuloendothelial system (RES) (Allen *et al.*, *FEBS Letters*, 1987, 223, 42; Wu *et al.*, *Cancer Research*, 1993, 53, 3765).

Various liposomes comprising one or more glycolipids are known in the art. Papahadjopoulos *et al.* (*Ann. N.Y. Acad. Sci.*, 1987, 507, 64) reported the ability of monosialoganglioside G_{M1}, galactocerebroside sulfate and phosphatidylinositol to improve blood half-lives of liposomes. These findings were expounded upon by Gabizon *et al.* (*Proc. Natl. Acad. Sci. U.S.A.*, 1988, 85, 6949). U.S. Pat. No. 4,837,028 and WO 88/04924, both to Allen *et al.*, disclose liposomes comprising (1) sphingomyelin and (2) the ganglioside G_{M1} or a galactocerebroside sulfate ester. U.S. Pat. No. 5,543,152 (Webb *et al.*) discloses liposomes comprising sphingomyelin. Liposomes comprising 1,2-sn-dimyristoylphosphatidylcholine are disclosed in WO 97/13499 (Lim *et al*).

In one embodiment, cationic liposomes are used. Cationic liposomes possess the advantage of being able to fuse to the cell membrane. Non-cationic liposomes, although not able to fuse as efficiently with the plasma membrane, are taken up by macrophages in vivo and can be used to deliver antisense polynucleotide agents to macrophages.

Further advantages of liposomes include: liposomes obtained from natural phospholipids are biocompatible and biodegradable; liposomes can incorporate a wide range of water and lipid soluble drugs; liposomes can protect encapsulated antisense polynucleotide agents in their internal compartments from metabolism and degradation (Rosoff, in "Pharmaceutical Dosage Forms," Lieberman, Rieger and Banker (Eds.), 1988, volume 1, p. 245). Important considerations in the preparation of liposome formulations are the lipid surface charge, vesicle size and the aqueous volume of the liposomes.

A positively charged synthetic cationic lipid, N-[1-(2,3-dioleyloxy)propyl]-N,N,N-trimethylammonium chloride (DOTMA) can be used to form small liposomes that interact spontaneously with nucleic acid to form lipid-nucleic acid complexes which are capable of fusing with the negatively charged lipids of the cell membranes of tissue culture cells, resulting in delivery of Antisense polynucleotide agent (see, *e.g.*, Felgner, P. L. *et al., Proc. Natl. Acad. Sci., USA* 8:7413-7417, 1987 and U.S. Pat. No. 4,897,355 for a description of DOTMA and its use with DNA).

A DOTMA analogue, 1,2-bis(oleoyloxy)-3-(trimethylammonia)propane (DOTAP) can be used in combination with a phospholipid to form DNA-complexing vesicles. Lipofectin™ Bethesda Research Laboratories, Gaithersburg, Md.) is an effective agent for

the delivery of highly anionic nucleic acids into living tissue culture cells that comprise positively charged DOTMA liposomes which interact spontaneously with negatively charged polynucleotides to form complexes. When enough positively charged liposomes are used, the net charge on the resulting complexes is also positive. Positively charged complexes prepared in this way spontaneously attach to negatively charged cell surfaces, fuse with the plasma membrane, and efficiently deliver functional nucleic acids into, for example, tissue culture cells. Another commercially available cationic lipid, 1,2-bis(oleoyloxy)-3,3-(trimethylammonia)propane ("DOTAP") (Boehringer Mannheim, Indianapolis, Indiana) differs from DOTMA in that the oleoyl moieties are linked by ester, rather than ether linkages.

Other reported cationic lipid compounds include those that have been conjugated to a variety of moieties including, for example, carboxyspermine which has been conjugated to one of two types of lipids and includes compounds such as 5-carboxyspermylglycine dioctaoleoylamide ("DOGS") (Transfectam™, Promega, Madison, Wisconsin) and dipalmitoylphosphatidylethanolamine 5-carboxyspermyl-amide ("DPPES") (see, *e.g.*, U.S. Pat. No. 5,171,678).

Another cationic lipid conjugate includes derivatization of the lipid with cholesterol ("DC-Chol") which has been formulated into liposomes in combination with DOPE (See, Gao, X. and Huang, L., *Biochim. Biophys. Res. Commun.* 179:280, 1991). Lipopolylysine, made by conjugating polylysine to DOPE, has been reported to be effective for transfection in the presence of serum (Zhou, X. et al., *Biochim. Biophys. Acta* 1065:8, 1991). For certain cell lines, these liposomes containing conjugated cationic lipids, are said to exhibit lower toxicity and provide more efficient transfection than the DOTMA-containing compositions. Other commercially available cationic lipid products include DMRIE and DMRIE-HP (Vical, La Jolla, California) and Lipofectamine (DOSPA) (Life Technology, Inc., Gaithersburg, Maryland). Other cationic lipids suitable for the delivery of oligonucleotides are described in WO 98/39359 and WO 96/37194.

Liposomal formulations are particularly suited for topical administration; liposomes present several advantages over other formulations. Such advantages include reduced side effects related to high systemic absorption of the administered drug, increased accumulation of the administered drug at the desired target, and the ability to administer an antisense polynucleotide agent into the skin. In some implementations, liposomes are used for delivering antisense polynucleotide agenst to epidermal cells and also to enhance the penetration of antisense polynucleotide agenst into dermal tissues, *e.g.*, into skin. For example, the liposomes can be applied topically. Topical delivery of drugs formulated as liposomes to the skin has been documented (see, *e.g.*, Weiner *et al., Journal of Drug Targeting,* 1992, vol. 2,405-410 and du Plessis *et al., Antiviral Research*, 18, 1992, 259-265; Mannino, R. J. and Fould-Fogerite, S., *Biotechniques* 6:682-690, 1988; Itani, T. *et al. Gene*

56:267-276. 1987; Nicolau, C. *et al. Meth. Enz.* 149:157-176, 1987; Straubinger, R. M. and Papahadjopoulos, D. *Meth. Enz.* 101:512-527, 1983; Wang, C. Y. and Huang, L., P*roc. Natl. Acad. Sci. USA* 84:7851-7855, 1987).

Non-ionic liposomal systems have also been examined to determine their utility in the delivery of drugs to the skin, in particular systems comprising non-ionic surfactant and cholesterol. Non-ionic liposomal formulations comprising Novasome I (glyceryl dilaurate/cholesterol/polyoxyethylene-10-stearyl ether) and Novasome II (glyceryl distearate/ cholesterol/polyoxyethylene-10-stearyl ether) were used to deliver a drug into the dermis of mouse skin. Such formulations with antisense polynucleotide agents are useful for treating a dermatological disorder.

Liposomes that include antisense polynucleotide agent can be made highly deformable. Such deformability can enable the liposomes to penetrate through pore that are smaller than the average radius of the liposome. For example, transfersomes are a type of deformable liposomes. Transferosomes can be made by adding surface edge activators, usually surfactants, to a standard liposomal composition. Transfersomes that include antisense polynucleotide agents can be delivered, for example, subcutaneously by infection in order to deliver antisense polynucleotide agents to keratinocytes in the skin. In order to cross intact mammalian skin, lipid vesicles must pass through a series of fine pores, each with a diameter less than 50 nm, under the influence of a suitable transdermal gradient. In addition, due to the lipid properties, these transferosomes can be self-optimizing (adaptive to the shape of pores, *e.g.*, in the skin), self-repairing, and can frequently reach their targets without fragmenting, and often self-loading.

Other formulations amenable to the present invention are described in United States provisional application serial Nos. 61/018,616, filed January 2, 2008; 61/018,611, filed January 2, 2008; 61/039,748, filed March 26, 2008; 61/047,087, filed April 22, 2008 and 61/051,528, filed May 8, 2008. PCT application no PCT/US2007/080331, filed October 3, 2007 also describes formulations that are amenable to the present invention.

Transfersomes are yet another type of liposomes, and are highly deformable lipid aggregates which are attractive candidates for drug delivery vehicles. Transfersomes can be described as lipid droplets which are so highly deformable that they are easily able to penetrate through pores which are smaller than the droplet. Transfersomes are adaptable to the environment in which they are used, *e.g.,* they are self-optimizing (adaptive to the shape of pores in the skin), self-repairing, frequently reach their targets without fragmenting, and often self-loading. To make transfersomes it is possible to add surface edge-activators, usually surfactants, to a standard liposomal composition. Transfersomes have been used to deliver serum albumin to the skin. The transfersome-mediated delivery of serum albumin has been shown to be as effective as subcutaneous injection of a solution containing serum albumin.

Surfactants find wide application in formulations such as emulsions (including microemulsions) and liposomes. The most common way of classifying and ranking the properties of the many different types of surfactants, both natural and synthetic, is by the use of the hydrophile/lipophile balance (HLB). The nature of the hydrophilic group (also known as the "head") provides the most useful means for categorizing the different surfactants used in formulations (Rieger, in “Pharmaceutical Dosage Forms”, Marcel Dekker, Inc., New York, N.Y., 1988, p. 285).

If the surfactant molecule is not ionized, it is classified as a nonionic surfactant. Nonionic surfactants find wide application in pharmaceutical and cosmetic products and are usable over a wide range of pH values. In general their HLB values range from 2 to about 18 depending on their structure. Nonionic surfactants include nonionic esters such as ethylene glycol esters, propylene glycol esters, glyceryl esters, polyglyceryl esters, sorbitan esters, sucrose esters, and ethoxylated esters. Nonionic alkanolamides and ethers such as fatty alcohol ethoxylates, propoxylated alcohols, and ethoxylated/propoxylated block polymers are also included in this class. The polyoxyethylene surfactants are the most popular members of the nonionic surfactant class.

If the surfactant molecule carries a negative charge when it is dissolved or dispersed in water, the surfactant is classified as anionic. Anionic surfactants include carboxylates such as soaps, acyl lactylates, acyl amides of amino acids, esters of sulfuric acid such as alkyl sulfates and ethoxylated alkyl sulfates, sulfonates such as alkyl benzene sulfonates, acyl isethionates, acyl taurates and sulfosuccinates, and phosphates. The most important members of the anionic surfactant class are the alkyl sulfates and the soaps.

If the surfactant molecule carries a positive charge when it is dissolved or dispersed in water, the surfactant is classified as cationic. Cationic surfactants include quaternary ammonium salts and ethoxylated amines. The quaternary ammonium salts are the most used members of this class.

If the surfactant molecule has the ability to carry either a positive or negative charge, the surfactant is classified as amphoteric. Amphoteric surfactants include acrylic acid derivatives, substituted alkylamides, N-alkylbetaines and phosphatides.

The use of surfactants in drug products, formulations and in emulsions has been reviewed (Rieger, in “Pharmaceutical Dosage Forms”, Marcel Dekker, Inc., New York, N.Y., 1988, p. 285).

The antisense polynucleotide agent for use in the compositions and methods of the invention can also be provided as micellar formulations. “Micelles” are defined herein as a particular type of molecular assembly in which amphipathic molecules are arranged in a spherical structure such that all the hydrophobic portions of the molecules are directed inward, leaving the hydrophilic portions in contact with the surrounding aqueous phase. The converse arrangement exists if the environment is hydrophobic.

A mixed micellar formulation suitable for delivery through transdermal membranes may be prepared by mixing an aqueous solution of the antisense polynucleotide agent composition, an alkali metal C_8 to C_{22} alkyl sulphate, and a micelle forming compounds. Exemplary micelle forming compounds include lecithin, hyaluronic acid, pharmaceutically acceptable salts of hyaluronic acid, glycolic acid, lactic acid, chamomile extract, cucumber extract, oleic acid, linoleic acid, linolenic acid, monoolein, monooleates, monolaurates, borage oil, evening of primrose oil, menthol, trihydroxy oxo cholanyl glycine and pharmaceutically acceptable salts thereof, glycerin, polyglycerin, lysine, polylysine, triolein, polyoxyethylene ethers and analogues thereof, polidocanol alkyl ethers and analogues thereof, chenodeoxycholate, deoxycholate, and mixtures thereof. The micelle forming compounds may be added at the same time or after addition of the alkali metal alkyl sulphate. Mixed micelles will form with substantially any kind of mixing of the ingredients but vigorous mixing in order to provide smaller size micelles.

In one method a first micellar composition is prepared which contains the antisense polynucleotide agent composition and at least the alkali metal alkyl sulphate. The first micellar composition is then mixed with at least three micelle forming compounds to form a mixed micellar composition. In another method, the micellar composition is prepared by mixing the antisense polynucleotide agent composition, the alkali metal alkyl sulphate and at least one of the micelle forming compounds, followed by addition of the remaining micelle forming compounds, with vigorous mixing.

Phenol and/or m-cresol may be added to the mixed micellar composition to stabilize the formulation and protect against bacterial growth. Alternatively, phenol and/or m-cresol may be added with the micelle forming ingredients. An isotonic agent such as glycerin may also be added after formation of the mixed micellar composition.

For delivery of the micellar formulation as a spray, the formulation can be put into an aerosol dispenser and the dispenser is charged with a propellant. The propellant, which is under pressure, is in liquid form in the dispenser. The ratios of the ingredients are adjusted so that the aqueous and propellant phases become one, *i.e.,* there is one phase. If there are two phases, it is necessary to shake the dispenser prior to dispensing a portion of the contents, *e.g.,* through a metered valve. The dispensed dose of pharmaceutical agent is propelled from the metered valve in a fine spray.

Propellants may include hydrogen-containing chlorofluorocarbons, hydrogen-containing fluorocarbons, dimethyl ether and diethyl ether. In certain embodiments, HFA 134a (1,1,1,2 tetrafluoroethane) may be used.

The specific concentrations of the essential ingredients can be determined by relatively straightforward experimentation. For absorption through the oral cavities, it is often desirable to increase, *e.g.,* at least double or triple, the dosage for through injection or administration through the gastrointestinal tract.

B. *Lipid particles*

Antisense polynucleotide agents of in the invention may be fully encapsulated in a lipid formulation, *e.g.,* a LNP, or other nucleic acid-lipid particle.

As used herein, the term "LNP" refers to a stable nucleic acid-lipid particle comprising a lipid layer encapsulating a pharmaceutically active molecule. LNPs typically contain a cationic lipid, a non-cationic lipid, and a lipid that prevents aggregation of the particle (*e.g.*, a PEG-lipid conjugate). LNPs are extremely useful for systemic applications, as they exhibit extended circulation lifetimes following intravenous (i.v.) injection and accumulate at distal sites (*e.g.*, sites physically separated from the administration site). LNPs include "pSPLP," which include an encapsulated condensing agent-nucleic acid complex as set forth in PCT Publication No. WO 00/03683. The particles of the present invention typically have a mean diameter of about 50 nm to about 150 nm, more typically about 60 nm to about 130 nm, more typically about 70 nm to about 110 nm, most typically about 70 nm to about 90 nm, and are substantially nontoxic. In addition, the nucleic acids when present in the nucleic acid- lipid particles of the present invention are resistant in aqueous solution to degradation with a nuclease. Nucleic acid-lipid particles and their method of preparation are disclosed in, *e.g.*, U.S. Patent Nos. 5,976,567; 5,981,501; 6,534,484; 6,586,410; 6,815,432; 6,858,225; 8,158,601; and 8,058,069; U.S. Publication No. 2010/0324120 and PCT Publication No. WO 96/40964.

In one embodiment, the lipid to drug ratio (mass/mass ratio) (*e.g.*, lipid to antisense polynucleotide agent ratio) will be in the range of from about 1:1 to about 50:1, from about 1:1 to about 25:1, from about 3:1 to about 15:1, from about 4:1 to about 10:1, from about 5:1 to about 9:1, or about 6:1 to about 9:1. Ranges intermediate to the above recited ranges are also contemplated to be part of the invention.

The cationic lipid can be, for example, N,N-dioleyl-N,N-dimethylammonium chloride (DODAC), N,N-distearyl-N,N-dimethylammonium bromide (DDAB), N-(I -(2,3-dioleoyloxy)propyl)-N,N,N-trimethylammonium chloride (DOTAP), N-(I -(2,3-dioleyloxy)propyl)-N,N,N-trimethylammonium chloride (DOTMA), N,N-dimethyl-2,3-dioleyloxy)propylamine (DODMA), 1,2-DiLinoleyloxy-N,N-dimethylaminopropane (DLinDMA), l,2-Dilinolenyloxy-N,N-dimethylaminopropane (DLenDMA), 1,2-Dilinoleylcarbamoyloxy-3-dimethylaminopropane (DLin-C-DAP), 1,2-Dilinoleyoxy-3-(dimethylamino)acetoxypropane (DLin-DAC), 1,2-Dilinoleyoxy-3-morpholinopropane (DLin-MA), 1,2-Dilinoleoyl-3-dimethylaminopropane (DLinDAP), 1,2-Dilinoleylthio-3-dimethylaminopropane (DLin-S-DMA), 1-Linoleoyl-2-linoleyloxy-3-dimethylaminopropane (DLin-2-DMAP), 1,2-Dilinoleyloxy-3-trimethylaminopropane chloride salt (DLin-TMA.Cl), 1,2-Dilinoleoyl-3-trimethylaminopropane chloride salt (DLin-TAP.Cl), 1,2-Dilinoleyloxy-3-(N-methylpiperazino)propane (DLin-MPZ), or 3-(N,N-Dilinoleylamino)-1,2-propanediol (DLinAP), 3-(N,N-Dioleylamino)-1,2-propanedio (DOAP), 1,2-Dilinoleyloxo-3-(2-N,N-

dimethylamino)ethoxypropane (DLin-EG-DMA), l,2-Dilinolenyloxy-N,N-dimethylaminopropane (DLinDMA), 2,2-Dilinoleyl-4-dimethylaminomethyl-[1,3]-dioxolane (DLin-K-DMA) or analogs thereof, (3aR,5s,6aS)-N,N-dimethyl-2,2-di((9Z,12Z)-octadeca-9,12-dienyl)tetrahydro-3aH-cyclopenta[d][1,3]dioxol-5-amine (ALN100), (6Z,9Z,28Z,31Z)-heptatriaconta-6,9,28,31-tetraen-19-yl 4-(dimethylamino)butanoate (MC3), 1,1'-(2-(4-(2-((2-(bis(2-hydroxydodecyl)amino)ethyl)(2-hydroxydodecyl)amino)ethyl)piperazin-1-yl)ethylazanediyl)didodecan-2-ol (Tech G1), or a mixture thereof. The cationic lipid can comprise from about 20 mol % to about 50 mol % or about 40 mol % of the total lipid present in the particle.

In another embodiment, the compound 2,2-Dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane can be used to prepare lipid-santisense polynucleotide agent nanoparticles. Synthesis of 2,2-Dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane is described in United States provisional patent application number 61/107,998 filed on October 23, 2008, which is herein incorporated by reference.

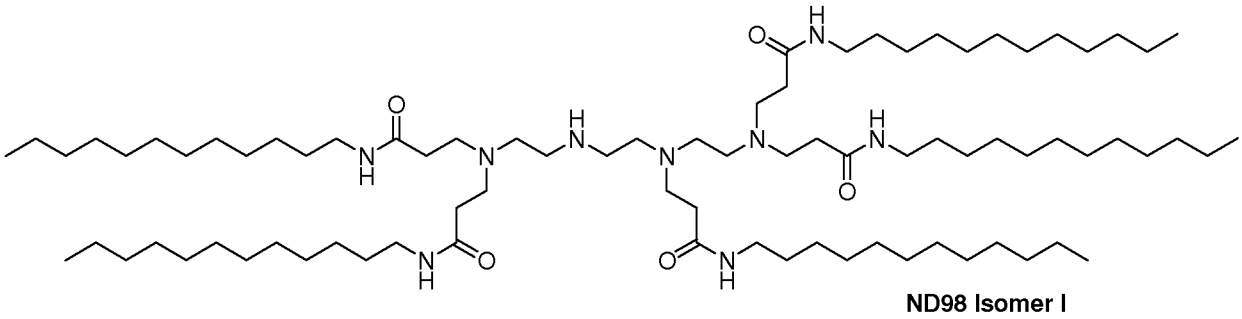
In one embodiment, the lipid-antisense polynucleotide agent particle includes 40% 2, 2-Dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane: 10% DSPC: 40% Cholesterol: 10% PEG-C-DOMG (mole percent) with a particle size of 63.0 ± 20 nm and a 0.027 antisense polynucleotide agent/Lipid Ratio.

The ionizable/non-cationic lipid can be an anionic lipid or a neutral lipid including, but not limited to, distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG), dioleoyl-phosphatidylethanolamine (DOPE), palmitoyloleoylphosphatidylcholine (POPC), palmitoyloleoylphosphatidylethanolamine (POPE), dioleoyl- phosphatidylethanolamine 4-(N-maleimidomethyl)-cyclohexane-l-carboxylate (DOPE-mal), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidyl-ethanolamine (DSPE), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1 -trans PE, 1 -stearoyl-2-oleoyl-phosphatidyethanolamine (SOPE), cholesterol, or a mixture thereof. The non-cationic lipid can be from about 5 mol % to about 90 mol %, about 10 mol %, or about 58 mol % if cholesterol is included, of the total lipid present in the particle.

The conjugated lipid that inhibits aggregation of particles can be, for example, a polyethyleneglycol (PEG)-lipid including, without limitation, a PEG-diacylglycerol (DAG), a PEG-dialkyloxypropyl (DAA), a PEG-phospholipid, a PEG-ceramide (Cer), or a mixture thereof. The PEG-DAA conjugate can be, for example, a PEG-dilauryloxypropyl (Ci_2), a PEG-dimyristyloxypropyl (Ci_4), a PEG-dipalmityloxypropyl (Ci_6), or a PEG-distearyloxypropyl ($C]_8$). The conjugated lipid that prevents aggregation of particles can be from 0 mol % to about 20 mol % or about 2 mol % of the total lipid present in the particle.

In some embodiments, the nucleic acid-lipid particle further includes cholesterol at, *e.g.*, about 10 mol % to about 60 mol % or about 48 mol % of the total lipid present in the particle.

In one embodiment, the lipidoid ND98·4HCl (MW 1487) (see U.S. Patent Application No. 12/056,230, filed 3/26/2008, which is incorporated herein by reference), Cholesterol (Sigma-Aldrich), and PEG-Ceramide C16 (Avanti Polar Lipids) can be used to prepare lipid-antisense polynucleotide agent nanoparticles (*i.e.,* LNP01 particles). Stock solutions of each in ethanol can be prepared as follows: ND98, 133 mg/ml; Cholesterol, 25 mg/ml, PEG-Ceramide C16, 100 mg/ml. The ND98, Cholesterol, and PEG-Ceramide C16 stock solutions can then be combined in a, *e.g.*, 42:48:10 molar ratio. The combined lipid solution can be mixed with aqueous antisense polynucleotide agent (*e.g.*, in sodium acetate pH 5) such that the final ethanol concentration is about 35-45% and the final sodium acetate concentration is about 100-300 mM. Lipid-antisense polynucleotide agent nanoparticles typically form spontaneously upon mixing. Depending on the desired particle size distribution, the resultant nanoparticle mixture can be extruded through a polycarbonate membrane (*e.g.*, 100 nm cut-off) using, for example, a thermobarrel extruder, such as Lipex Extruder (Northern Lipids, Inc). In some cases, the extrusion step can be omitted. Ethanol removal and simultaneous buffer exchange can be accomplished by, for example, dialysis or tangential flow filtration. Buffer can be exchanged with, for example, phosphate buffered saline (PBS) at about pH 7, *e.g.*, about pH 6.9, about pH 7.0, about pH 7.1, about pH 7.2, about pH 7.3, or about pH 7.4.



Formula 1

LNP01 formulations are described, *e.g.*, in International Application Publication No. WO 2008/042973, which is hereby incorporated by reference.

Additional exemplary lipid-antisense polynucleotide agent formulations are described in Table 1.

Table 1

	Ionizable/Cationic Lipid	cationic lipid/non-cationic lipid/cholesterol/PEG-lipid conjugate Lipid:santisense polynucleotide agent ratio

SNALP-1	l,2-Dilinolenyloxy-N,N-dimethylaminopropane (DLinDMA)	DLinDMA/DPPC/Cholesterol/PEG-cDMA (57.1/7.1/34.4/1.4) lipid:santisense polynucleotide agent ~ 7:1
2-XTC	2,2-Dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (XTC)	XTC/DPPC/Cholesterol/PEG-cDMA 57.1/7.1/34.4/1.4 lipid:santisense polynucleotide agent ~ 7:1
LNP05	2,2-Dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (XTC)	XTC/DSPC/Cholesterol/PEG-DMG 57.5/7.5/31.5/3.5 lipid:santisense polynucleotide agent ~ 6:1
LNP06	2,2-Dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (XTC)	XTC/DSPC/Cholesterol/PEG-DMG 57.5/7.5/31.5/3.5 lipid:santisense polynucleotide agent ~ 11:1
LNP07	2,2-Dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (XTC)	XTC/DSPC/Cholesterol/PEG-DMG 60/7.5/31/1.5, lipid:santisense polynucleotide agent ~ 6:1
LNP08	2,2-Dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (XTC)	XTC/DSPC/Cholesterol/PEG-DMG 60/7.5/31/1.5, lipid:santisense polynucleotide agent ~ 11:1
LNP09	2,2-Dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (XTC)	XTC/DSPC/Cholesterol/PEG-DMG 50/10/38.5/1.5 Lipid:santisense polynucleotide agent 10:1
LNP10	(3aR,5s,6aS)-N,N-dimethyl-2,2-di((9Z,12Z)-octadeca-9,12-dienyl)tetrahydro-3aH-cyclopenta[d][1,3]dioxol-5-amine (ALN100)	ALN100/DSPC/Cholesterol/PEG-DMG 50/10/38.5/1.5 Lipid:santisense polynucleotide agent 10:1
LNP11	(6Z,9Z,28Z,31Z)-heptatriaconta-6,9,28,31-tetraen-19-yl 4-(dimethylamino)butanoate (MC3)	MC-3/DSPC/Cholesterol/PEG-DMG 50/10/38.5/1.5 Lipid:santisense polynucleotide agent 10:1
LNP12	1,1'-(2-(4-(2-((2-(bis(2-hydroxydodecyl)amino)ethyl)(2-hydroxydodecyl)amino)ethyl)piperazin-1-yl)ethylazanediyl)didodecan-2-ol (Tech G1)	Tech G1/DSPC/Cholesterol/PEG-DMG 50/10/38.5/1.5 Lipid:santisense polynucleotide agent 10:1
LNP13	XTC	XTC/DSPC/Chol/PEG-DMG 50/10/38.5/1.5

		Lipid:santisense polynucleotide agent: 33:1
LNP14	MC3	MC3/DSPC/Chol/PEG-DMG 40/15/40/5 Lipid:santisense polynucleotide agent: 11:1
LNP15	MC3	MC3/DSPC/Chol/PEG-DSG/GalNAc-PEG-DSG 50/10/35/4.5/0.5 Lipid:santisense polynucleotide agent: 11:1
LNP16	MC3	MC3/DSPC/Chol/PEG-DMG 50/10/38.5/1.5 Lipid:santisense polynucleotide agent: 7:1
LNP17	MC3	MC3/DSPC/Chol/PEG-DSG 50/10/38.5/1.5 Lipid:santisense polynucleotide agent: 10:1
LNP18	MC3	MC3/DSPC/Chol/PEG-DMG 50/10/38.5/1.5 Lipid:santisense polynucleotide agent: 12:1
LNP19	MC3	MC3/DSPC/Chol/PEG-DMG 50/10/35/5 Lipid:santisense polynucleotide agent: 8:1
LNP20	MC3	MC3/DSPC/Chol/PEG-DPG 50/10/38.5/1.5 Lipid:santisense polynucleotide agent: 10:1
LNP21	C12-200	C12-200/DSPC/Chol/PEG-DSG 50/10/38.5/1.5 Lipid:santisense polynucleotide agent: 7:1
LNP22	XTC	XTC/DSPC/Chol/PEG-DSG 50/10/38.5/1.5 Lipid:santisense polynucleotide agent: 10:1

DSPC: distearoylphosphatidylcholine

DPPC: dipalmitoylphosphatidylcholine

PEG-DMG: PEG-didimyristoyl glycerol (C14-PEG, or PEG-C14) (PEG with avg mol wt of 2000)

PEG-DSG: PEG-distyryl glycerol (C18-PEG, or PEG-C18) (PEG with avg mol wt of 2000)

PEG-cDMA: PEG-carbamoyl-1,2-dimyristyloxypropylamine (PEG with avg mol wt of 2000)

SNALP (1,2-Dilinolenyloxy-N,N-dimethylaminopropane (DLinDMA)) comprising formulations are described in International Publication No. WO2009/127060, filed April 15, 2009, which is hereby incorporated by reference.

XTC comprising formulations are described, *e.g.*, in U.S. Provisional Serial No. 61/148,366, filed January 29, 2009; U.S. Provisional Serial No. 61/156,851, filed March 2, 2009; U.S. Provisional Serial No. filed June 10, 2009; U.S. Provisional Serial No. 61/228,373, filed July 24, 2009; U.S. Provisional Serial No. 61/239,686, filed September 3, 2009, and International Application No. PCT/US2010/022614, filed January 29, 2010, which are hereby incorporated by reference.

MC3 comprising formulations are described, *e.g.*, in U.S. Publication No. 2010/0324120, filed June 10, 2010, the entire contents of which are hereby incorporated by reference.

ALNY-100 comprising formulations are described, *e.g.*, International patent application number PCT/US09/63933, filed on November 10, 2009, which is hereby incorporated by reference.

C12-200 comprising formulations are described in U.S. Provisional Serial No. 61/175,770, filed May 5, 2009 and International Application No. PCT/US10/33777, filed May 5, 2010, which are hereby incorporated by reference.

Compositions and formulations for oral administration include powders or granules, microparticulates, nanoparticulates, suspensions or solutions in water or non-aqueous media, capsules, gel capsules, sachets, tablets or minitablets. Thickeners, flavoring agents, diluents, emulsifiers, dispersing aids or binders can be desirable. In some embodiments, oral formulations are those in which the antisense polynucleotide agents featured in the invention are administered in conjunction with one or more penetration enhancer surfactants and chelators. Suitable surfactants include fatty acids and/or esters or salts thereof, bile acids and/or salts thereof. Suitable bile acids/salts include chenodeoxycholic acid (CDCA) and ursodeoxychenodeoxycholic acid (UDCA), cholic acid, dehydrocholic acid, deoxycholic acid, glucholic acid, glycholic acid, glycodeoxycholic acid, taurocholic acid, taurodeoxycholic acid, sodium tauro-24,25-dihydro-fusidate and sodium glycodihydrofusidate. Suitable fatty acids include arachidonic acid, undecanoic acid, oleic acid, lauric acid, caprylic acid, capric acid, myristic acid, palmitic acid, stearic acid, linoleic acid, linolenic acid, dicaprate, tricaprate, monoolein, dilaurin, glyceryl 1-monocaprate, 1-dodecylazacycloheptan-2-one, an acylcarnitine, an acylcholine, or a monoglyceride, a diglyceride or a pharmaceutically acceptable salt thereof (*e.g.,* sodium). In some embodiments, combinations of penetration enhancers are used, for example, fatty acids/salts in combination with bile acids/salts. One exemplary combination is the sodium salt of lauric acid, capric acid and UDCA. Further penetration enhancers include polyoxyethylene-9-lauryl ether, polyoxyethylene-20-cetyl ether. Antisense polynucleotide agents featured in the

invention can be delivered orally, in granular form including sprayed dried particles, or complexed to form micro or nanoparticles. Antisense polynucleotide agent complexing agents include poly-amino acids; polyimines; polyacrylates; polyalkylacrylates, polyoxethanes, polyalkylcyanoacrylates; cationized gelatins, albumins, starches, acrylates, polyethyleneglycols (PEG) and starches; polyalkylcyanoacrylates; DEAE-derivatized polyimines, pollulans, celluloses and starches. Suitable complexing agents include chitosan, N-trimethylchitosan, poly-L-lysine, polyhistidine, polyornithine, polyspermines, protamine, polyvinylpyridine, polythiodiethylaminomethylethylene P(TDAE), polyaminostyrene (*e.g.,* p-amino), poly(methylcyanoacrylate), poly(ethylcyanoacrylate), poly(butylcyanoacrylate), poly(isobutylcyanoacrylate), poly(isohexylcynaoacrylate), DEAE-methacrylate, DEAE-hexylacrylate, DEAE-acrylamide, DEAE-albumin and DEAE-dextran, polymethylacrylate, polyhexylacrylate, poly(D,L-lactic acid), poly(DL-lactic-co-glycolic acid (PLGA), alginate, and polyethyleneglycol (PEG). Oral formulations for antisense polynucleotide agents and their preparation are described in detail in U.S. Patent 6,887,906, US Publn. No. 20030027780, and U.S. Patent No. 6,747,014, each of which is incorporated herein by reference.

Compositions and formulations for parenteral, intraparenchymal (into the brain), intrathecal, intraventricular or intrahepatic administration can include sterile aqueous solutions which can also contain buffers, diluents and other suitable additives such as, but not limited to, penetration enhancers, carrier compounds and other pharmaceutically acceptable carriers or excipients.

Pharmaceutical compositions of the present invention include, but are not limited to, solutions, emulsions, and liposome-containing formulations. These compositions can be generated from a variety of components that include, but are not limited to, preformed liquids, self-emulsifying solids and self-emulsifying semisolids. Particularly preferred are formulations that target the liver, *e.g.,* when treating hepatic disorders, *e.g.,* hepatic carcinoma.

The pharmaceutical formulations of the present invention, which can conveniently be presented in unit dosage form, can be prepared according to conventional techniques well known in the pharmaceutical industry. Such techniques include the step of bringing into association the active ingredients with the pharmaceutical carrier(s) or excipient(s). In general, the formulations are prepared by uniformly and intimately bringing into association the active ingredients with liquid carriers or finely divided solid carriers or both, and then, if necessary, shaping the product.

The compositions of the present invention can be formulated into any of many possible dosage forms such as, but not limited to, tablets, capsules, gel capsules, liquid syrups, soft gels, suppositories, and enemas. The compositions of the present invention can also be formulated as suspensions in aqueous, non-aqueous or mixed media. Aqueous

suspensions can further contain substances which increase the viscosity of the suspension including, for example, sodium carboxymethylcellulose, sorbitol and/or dextran. The suspension can also contain stabilizers.

C. Additional Formulations

i. Emulsions

The compositions of the present invention can be prepared and formulated as emulsions. Emulsions are typically heterogeneous systems of one liquid dispersed in another in the form of droplets usually exceeding 0.1μm in diameter (see *e.g.*, Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems, Allen, LV., Popovich NG., and Ansel HC., 2004, Lippincott Williams & Wilkins (8th ed.), New York, NY; Idson, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 1, p. 199; Rosoff, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., Volume 1, p. 245; Block in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 2, p. 335; Higuchi *et al.*, in Remington's Pharmaceutical Sciences, Mack Publishing Co., Easton, Pa., 1985, p. 301). Emulsions are often biphasic systems comprising two immiscible liquid phases intimately mixed and dispersed with each other. In general, emulsions can be of either the water-in-oil (w/o) or the oil-in-water (o/w) variety. When an aqueous phase is finely divided into and dispersed as minute droplets into a bulk oily phase, the resulting composition is called a water-in-oil (w/o) emulsion. Alternatively, when an oily phase is finely divided into and dispersed as minute droplets into a bulk aqueous phase, the resulting composition is called an oil-in-water (o/w) emulsion. Emulsions can contain additional components in addition to the dispersed phases, and the active drug which can be present as a solution in either the aqueous phase, oily phase or itself as a separate phase. Pharmaceutical excipients such as emulsifiers, stabilizers, dyes, and anti-oxidants can also be present in emulsions as needed. Pharmaceutical emulsions can also be multiple emulsions that are comprised of more than two phases such as, for example, in the case of oil-in-water-in-oil (o/w/o) and water-in-oil-in-water (w/o/w) emulsions. Such complex formulations often provide certain advantages that simple binary emulsions do not. Multiple emulsions in which individual oil droplets of an o/w emulsion enclose small water droplets constitute a w/o/w emulsion. Likewise a system of oil droplets enclosed in globules of water stabilized in an oily continuous phase provides an o/w/o emulsion.

Emulsions are characterized by little or no thermodynamic stability. Often, the dispersed or discontinuous phase of the emulsion is well dispersed into the external or continuous phase and maintained in this form through the means of emulsifiers or the viscosity of the formulation. Either of the phases of the emulsion can be a semisolid or a solid, as is the case of emulsion-style ointment bases and creams. Other means of stabilizing emulsions entail the use of emulsifiers that can be incorporated into either phase of the

emulsion. Emulsifiers can broadly be classified into four categories: synthetic surfactants, naturally occurring emulsifiers, absorption bases, and finely dispersed solids (see *e.g.*, Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems, Allen, LV., Popovich NG., and Ansel HC., 2004, Lippincott Williams & Wilkins (8th ed.), New York, NY; Idson, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 1, p. 199).

Synthetic surfactants, also known as surface active agents, have found wide applicability in the formulation of emulsions and have been reviewed in the literature (see *e.g.*, Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems, Allen, LV., Popovich NG., and Ansel HC., 2004, Lippincott Williams & Wilkins (8th ed.), New York, NY; Rieger, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 1, p. 285; Idson, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), Marcel Dekker, Inc., New York, N.Y., 1988, volume 1, p. 199). Surfactants are typically amphiphilic and comprise a hydrophilic and a hydrophobic portion. The ratio of the hydrophilic to the hydrophobic nature of the surfactant has been termed the hydrophile/lipophile balance (HLB) and is a valuable tool in categorizing and selecting surfactants in the preparation of formulations. Surfactants can be classified into different classes based on the nature of the hydrophilic group: nonionic, anionic, cationic and amphoteric (see *e.g.*, Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems, Allen, LV., Popovich NG., and Ansel HC., 2004, Lippincott Williams & Wilkins (8th ed.), New York, NY Rieger, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 1, p. 285).

Naturally occurring emulsifiers used in emulsion formulations include lanolin, beeswax, phosphatides, lecithin and acacia. Absorption bases possess hydrophilic properties such that they can soak up water to form w/o emulsions yet retain their semisolid consistencies, such as anhydrous lanolin and hydrophilic petrolatum. Finely divided solids have also been used as good emulsifiers especially in combination with surfactants and in viscous preparations. These include polar inorganic solids, such as heavy metal hydroxides, nonswelling clays such as bentonite, attapulgite, hectorite, kaolin, montmorillonite, colloidal aluminum silicate and colloidal magnesium aluminum silicate, pigments and nonpolar solids such as carbon or glyceryl tristearate.

A large variety of non-emulsifying materials are also included in emulsion formulations and contribute to the properties of emulsions. These include fats, oils, waxes, fatty acids, fatty alcohols, fatty esters, humectants, hydrophilic colloids, preservatives and antioxidants (Block, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 1, p. 335; Idson, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 1, p. 199).

Hydrophilic colloids or hydrocolloids include naturally occurring gums and synthetic polymers such as polysaccharides (for example, acacia, agar, alginic acid, carrageenan, guar gum, karaya gum, and tragacanth), cellulose derivatives (for example, carboxymethylcellulose and carboxypropylcellulose), and synthetic polymers (for example, carbomers, cellulose ethers, and carboxyvinyl polymers). These disperse or swell in water to form colloidal solutions that stabilize emulsions by forming strong interfacial films around the dispersed-phase droplets and by increasing the viscosity of the external phase.

Since emulsions often contain a number of ingredients such as carbohydrates, proteins, sterols and phosphatides that can readily support the growth of microbes, these formulations often incorporate preservatives. Commonly used preservatives included in emulsion formulations include methyl paraben, propyl paraben, quaternary ammonium salts, benzalkonium chloride, esters of p-hydroxybenzoic acid, and boric acid. Antioxidants are also commonly added to emulsion formulations to prevent deterioration of the formulation. Antioxidants used can be free radical scavengers such as tocopherols, alkyl gallates, butylated hydroxyanisole, butylated hydroxytoluene, or reducing agents such as ascorbic acid and sodium metabisulfite, and antioxidant synergists such as citric acid, tartaric acid, and lecithin.

The application of emulsion formulations via dermatological, oral and parenteral routes and methods for their manufacture have been reviewed in the literature (see *e.g.*, Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems, Allen, LV., Popovich NG., and Ansel HC., 2004, Lippincott Williams & Wilkins (8th ed.), New York, NY; Idson, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 1, p. 199). Emulsion formulations for oral delivery have been very widely used because of ease of formulation, as well as efficacy from an absorption and bioavailability standpoint (see *e.g.*, Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems, Allen, LV., Popovich NG., and Ansel HC., 2004, Lippincott Williams & Wilkins (8th ed.), New York, NY; Rosoff, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 1, p. 245; Idson, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 1, p. 199). Mineral-oil base laxatives, oil-soluble vitamins and high fat nutritive preparations are among the materials that have commonly been administered orally as o/w emulsions.

ii. Microemulsions

In one embodiment of the present invention, the compositions of antisense polynucleotide agents are formulated as microemulsions. A microemulsion can be defined as a system of water, oil and amphiphile which is a single optically isotropic and thermodynamically stable liquid solution (see *e.g.*, Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems, Allen, LV., Popovich NG., and Ansel HC., 2004, Lippincott Williams & Wilkins (8th ed.), New York, NY; Rosoff, in Pharmaceutical Dosage Forms,

Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 1, p. 245). Typically microemulsions are systems that are prepared by first dispersing an oil in an aqueous surfactant solution and then adding a sufficient amount of a fourth component, generally an intermediate chain-length alcohol to form a transparent system. Therefore, microemulsions have also been described as thermodynamically stable, isotropically clear dispersions of two immiscible liquids that are stabilized by interfacial films of surface-active molecules (Leung and Shah, in: Controlled Release of Drugs: Polymers and Aggregate Systems, Rosoff, M., Ed., 1989, VCH Publishers, New York, pages 185-215). Microemulsions commonly are prepared *via* a combination of three to five components that include oil, water, surfactant, cosurfactant and electrolyte. Whether the microemulsion is of the water-in-oil (w/o) or an oil-in-water (o/w) type is dependent on the properties of the oil and surfactant used and on the structure and geometric packing of the polar heads and hydrocarbon tails of the surfactant molecules (Schott, in Remington's Pharmaceutical Sciences, Mack Publishing Co., Easton, Pa., 1985, p. 271).

The phenomenological approach utilizing phase diagrams has been extensively studied and has yielded a comprehensive knowledge, to one skilled in the art, of how to formulate microemulsions (see *e.g.*, Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems, Allen, LV., Popovich NG., and Ansel HC., 2004, Lippincott Williams & Wilkins (8th ed.), New York, NY; Rosoff, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 1, p. 245; Block, in Pharmaceutical Dosage Forms, Lieberman, Rieger and Banker (Eds.), 1988, Marcel Dekker, Inc., New York, N.Y., volume 1, p. 335). Compared to conventional emulsions, microemulsions offer the advantage of solubilizing water-insoluble drugs in a formulation of thermodynamically stable droplets that are formed spontaneously.

Surfactants used in the preparation of microemulsions include, but are not limited to, ionic surfactants, non-ionic surfactants, Brij 96, polyoxyethylene oleyl ethers, polyglycerol fatty acid esters, tetraglycerol monolaurate (ML310), tetraglycerol monooleate (MO310), hexaglycerol monooleate (PO310), hexaglycerol pentaoleate (PO500), decaglycerol monocaprate (MCA750), decaglycerol monooleate (MO750), decaglycerol sequioleate (SO750), decaglycerol decaoleate (DAO750), alone or in combination with cosurfactants. The cosurfactant, usually a short-chain alcohol such as ethanol, 1-propanol, and 1-butanol, serves to increase the interfacial fluidity by penetrating into the surfactant film and consequently creating a disordered film because of the void space generated among surfactant molecules. Microemulsions can, however, be prepared without the use of cosurfactants and alcohol-free self-emulsifying microemulsion systems are known in the art. The aqueous phase can typically be, but is not limited to, water, an aqueous solution of the drug, glycerol, PEG300, PEG400, polyglycerols, propylene glycols, and derivatives of ethylene glycol. The oil phase can include, but is not limited to, materials such as Captex 300, Captex 355,

Capmul MCM, fatty acid esters, medium chain (C8-C12) mono, di, and tri-glycerides, polyoxyethylated glyceryl fatty acid esters, fatty alcohols, polyglycolized glycerides, saturated polyglycolized C8-C10 glycerides, vegetable oils and silicone oil.

Microemulsions are particularly of interest from the standpoint of drug solubilization and the enhanced absorption of drugs. Lipid based microemulsions (both o/w and w/o) have been proposed to enhance the oral bioavailability of drugs, including peptides (see *e.g.*, U.S. Patent Nos. 6,191,105; 7,063,860; 7,070,802; 7,157,099; Constantinides *et al.*, *Pharmaceutical Research*, 1994, 11, 1385-1390; Ritschel, *Meth. Find. Exp. Clin. Pharmacol.*, 1993, 13, 205). Microemulsions afford advantages of improved drug solubilization, protection of drug from enzymatic hydrolysis, possible enhancement of drug absorption due to surfactant-induced alterations in membrane fluidity and permeability, ease of preparation, ease of oral administration over solid dosage forms, improved clinical potency, and decreased toxicity (see *e.g.*, U.S. Patent Nos. 6,191,105; 7,063,860; 7,070,802; 7,157,099; Constantinides *et al.*, *Pharmaceutical Research*, 1994, 11, 1385; Ho *et al.*, *J. Pharm. Sci.,* 1996, 85, 138-143). Often microemulsions can form spontaneously when their components are brought together at ambient temperature. This can be particularly advantageous when formulating thermolabile drugs, peptides or antisense polynucleotide agents. Microemulsions have also been effective in the transdermal delivery of active components in both cosmetic and pharmaceutical applications. It is expected that the microemulsion compositions and formulations of the present invention will facilitate the increased systemic absorption of antisense polynucleotide agents from the gastrointestinal tract, as well as improve the local cellular uptake of antisense polynucleotide agents and nucleic acids.

Microemulsions of the present invention can also contain additional components and additives such as sorbitan monostearate (Grill 3), Labrasol, and penetration enhancers to improve the properties of the formulation and to enhance the absorption of the antisense polynucleotide agents of the present invention. Penetration enhancers used in the microemulsions of the present invention can be classified as belonging to one of five broad categories--surfactants, fatty acids, bile salts, chelating agents, and non-chelating non-surfactants (Lee *et al.*, *Critical Reviews in Therapeutic Drug Carrier Systems*, 1991, p. 92). Each of these classes has been discussed above.

iii. Microparticles

An antisense polynucleotide agent of the invention may be incorporated into a particle, *e.g.*, a microparticle. Microparticles can be produced by spray-drying, but may also be produced by other methods including lyophilization, evaporation, fluid bed drying, vacuum drying, or a combination of these techniques.

iv. Penetration Enhancers

In one embodiment, the present invention employs various penetration enhancers to effect the efficient delivery of nucleic acids, particularly antisense polynucleotide agents, to the skin of animals. Most drugs are present in solution in both ionized and nonionized forms. However, usually only lipid soluble or lipophilic drugs readily cross cell membranes. It has been discovered that even non-lipophilic drugs can cross cell membranes if the membrane to be crossed is treated with a penetration enhancer. In addition to aiding the diffusion of non-lipophilic drugs across cell membranes, penetration enhancers also enhance the permeability of lipophilic drugs.

Penetration enhancers can be classified as belonging to one of five broad categories, *i.e.*, surfactants, fatty acids, bile salts, chelating agents, and non-chelating non-surfactants (see *e.g.*, Malmsten, M. Surfactants and polymers in drug delivery, Informa Health Care, New York, NY, 2002; Lee *et al.*, Critical Reviews in Therapeutic Drug Carrier Systems, 1991, p.92). Each of the above mentioned classes of penetration enhancers are described below in greater detail.

Surfactants (or "surface-active agents") are chemical entities which, when dissolved in an aqueous solution, reduce the surface tension of the solution or the interfacial tension between the aqueous solution and another liquid, with the result that absorption of antisense polynucleotide agents through the mucosa is enhanced. In addition to bile salts and fatty acids, these penetration enhancers include, for example, sodium lauryl sulfate, polyoxyethylene-9-lauryl ether and polyoxyethylene-20-cetyl ether) (see *e.g.*, Malmsten, M. Surfactants and polymers in drug delivery, Informa Health Care, New York, NY, 2002; Lee *et al.*, Critical Reviews in Therapeutic Drug Carrier Systems, 1991, p.92); and perfluorochemical emulsions, such as FC-43. Takahashi *et al.*, *J. Pharm. Pharmacol.*, 1988, 40, 252).

Various fatty acids and their derivatives which act as penetration enhancers include, for example, oleic acid, lauric acid, capric acid (n-decanoic acid), myristic acid, palmitic acid, stearic acid, linoleic acid, linolenic acid, dicaprate, tricaprate, monoolein (1-monooleoyl-rac-glycerol), dilaurin, caprylic acid, arachidonic acid, glycerol 1-monocaprate, 1-dodecylazacycloheptan-2-one, acylcarnitines, acylcholines, C_{1-20} alkyl esters thereof (*e.g.*, methyl, isopropyl and t-butyl), and mono- and di-glycerides thereof (*i.e.*, oleate, laurate, caprate, myristate, palmitate, stearate, linoleate, *etc.*) (see *e.g.*, Touitou, E., *et al.* Enhancement in Drug Delivery, CRC Press, Danvers, MA, 2006; Lee *et al.*, Critical Reviews in Therapeutic Drug Carrier Systems, 1991, p.92; Muranishi, Critical Reviews in Therapeutic Drug Carrier Systems, 1990, 7, 1-33; El Hariri *et al.*, *J. Pharm. Pharmacol.*, 1992, 44, 651-654).

The physiological role of bile includes the facilitation of dispersion and absorption of lipids and fat-soluble vitamins (see *e.g.*, Malmsten, M. Surfactants and polymers in drug

delivery, Informa Health Care, New York, NY, 2002; Brunton, Chapter 38 in: Goodman & Gilman's The Pharmacological Basis of Therapeutics, 9th Ed., Hardman *et al.* Eds., McGraw-Hill, New York, 1996, pp. 934-935). Various natural bile salts, and their synthetic derivatives, act as penetration enhancers. Thus the term "bile salts" includes any of the naturally occurring components of bile as well as any of their synthetic derivatives. Suitable bile salts include, for example, cholic acid (or its pharmaceutically acceptable sodium salt, sodium cholate), dehydrocholic acid (sodium dehydrocholate), deoxycholic acid (sodium deoxycholate), glucholic acid (sodium glucholate), glycholic acid (sodium glycocholate), glycodeoxycholic acid (sodium glycodeoxycholate), taurocholic acid (sodium taurocholate), taurodeoxycholic acid (sodium taurodeoxycholate), chenodeoxycholic acid (sodium chenodeoxycholate), ursodeoxycholic acid (UDCA), sodium tauro-24,25-dihydro-fusidate (STDHF), sodium glycodihydrofusidate and polyoxyethylene-9-lauryl ether (POE) (see *e.g.*, Malmsten, M. Surfactants and polymers in drug delivery, Informa Health Care, New York, NY, 2002; Lee *et al.*, Critical Reviews in Therapeutic Drug Carrier Systems, 1991, page 92; Swinyard, Chapter 39 In: Remington's Pharmaceutical Sciences, 18th Ed., Gennaro, ed., Mack Publishing Co., Easton, Pa., 1990, pages 782-783; Muranishi, Critical Reviews in Therapeutic Drug Carrier Systems, 1990, 7, 1-33; Yamamoto *et al.*, *J. Pharm. Exp. Ther.*, 1992, 263, 25; Yamashita *et al.*, *J. Pharm. Sci.*, 1990, 79, 579-583).

Chelating agents, as used in connection with the present invention, can be defined as compounds that remove metallic ions from solution by forming complexes therewith, with the result that absorption of antisense polynucleotide agents through the mucosa is enhanced. With regards to their use as penetration enhancers in the present invention, chelating agents have the added advantage of also serving as DNase inhibitors, as most characterized DNA nucleases require a divalent metal ion for catalysis and are thus inhibited by chelating agents (Jarrett, *J. Chromatogr.*, 1993, 618, 315-339). Suitable chelating agents include but are not limited to disodium ethylenediaminetetraacetate (EDTA), citric acid, salicylates (*e.g.*, sodium salicylate, 5-methoxysalicylate and homovanilate), N-acyl derivatives of collagen, laureth-9 and N-amino acyl derivatives of beta-diketones (enamines)(see *e.g.*, Katdare, A. *et al.*, Excipient development for pharmaceutical, biotechnology, and drug delivery, CRC Press, Danvers, MA, 2006; Lee *et al.*, Critical Reviews in Therapeutic Drug Carrier Systems, 1991, page 92; Muranishi, Critical Reviews in Therapeutic Drug Carrier Systems, 1990, 7, 1-33; Buur *et al.*, *J. Control Rel.*, 1990, 14, 43-51).

As used herein, non-chelating non-surfactant penetration enhancing compounds can be defined as compounds that demonstrate insignificant activity as chelating agents or as surfactants but that nonetheless enhance absorption of antisense polynucleotide agents through the alimentary mucosa (see *e.g.*, Muranishi, Critical Reviews in Therapeutic Drug Carrier Systems, 1990, 7, 1-33). This class of penetration enhancers includes, for example, unsaturated cyclic ureas, 1-alkyl- and 1-alkenylazacyclo-alkanone derivatives (Lee *et al.*,

Critical Reviews in Therapeutic Drug Carrier Systems, 1991, page 92); and non-steroidal anti-inflammatory agents such as diclofenac sodium, indomethacin and phenylbutazone (Yamashita *et al.*, *J. Pharm. Pharmacol.*, 1987, 39, 621-626).

Agents that enhance uptake of antisense polynucleotide agents at the cellular level can also be added to the pharmaceutical and other compositions of the present invention. For example, cationic lipids, such as lipofectin (Junichi *et al*, U.S. Pat. No. 5,705,188), cationic glycerol derivatives, and polycationic molecules, such as polylysine (Lollo *et al.*, PCT Application WO 97/30731), are also known to enhance the cellular uptake of antisense polynucleotide agents. Examples of commercially available transfection reagents include, for example Lipofectamine™ (Invitrogen; Carlsbad, CA), Lipofectamine 2000™ (Invitrogen; Carlsbad, CA), 293fectin™ (Invitrogen; Carlsbad, CA), Cellfectin™ (Invitrogen; Carlsbad, CA), DMRIE-C™ (Invitrogen; Carlsbad, CA), FreeStyle™ MAX (Invitrogen; Carlsbad, CA), Lipofectamine™ 2000 CD (Invitrogen; Carlsbad, CA), Lipofectamine™ (Invitrogen; Carlsbad, CA), RNAiMAX (Invitrogen; Carlsbad, CA), Oligofectamine™ (Invitrogen; Carlsbad, CA), Optifect™ (Invitrogen; Carlsbad, CA), X-tremeGENE Q2 Transfection Reagent (Roche; Grenzacherstrasse, Switzerland), DOTAP Liposomal Transfection Reagent (Grenzacherstrasse, Switzerland), DOSPER Liposomal Transfection Reagent (Grenzacherstrasse, Switzerland), or Fugene (Grenzacherstrasse, Switzerland), Transfectam® Reagent (Promega; Madison, WI), TransFast™ Transfection Reagent (Promega; Madison, WI), Tfx™-20 Reagent (Promega; Madison, WI), Tfx™-50 Reagent (Promega; Madison, WI), DreamFect™ (OZ Biosciences; Marseille, France), EcoTransfect (OZ Biosciences; Marseille, France), TransPass[a] D1 Transfection Reagent (New England Biolabs; Ipswich, MA, USA), LyoVec™/LipoGen™ (Invitrogen; San Diego, CA, USA), PerFectin Transfection Reagent (Genlantis; San Diego, CA, USA), NeuroPORTER Transfection Reagent (Genlantis; San Diego, CA, USA), GenePORTER Transfection reagent (Genlantis; San Diego, CA, USA), GenePORTER 2 Transfection reagent (Genlantis; San Diego, CA, USA), Cytofectin Transfection Reagent (Genlantis; San Diego, CA, USA), BaculoPORTER Transfection Reagent (Genlantis; San Diego, CA, USA), TroganPORTER™ transfection Reagent (Genlantis; San Diego, CA, USA), RiboFect (Bioline; Taunton, MA, USA), PlasFect (Bioline; Taunton, MA, USA), UniFECTOR (B-Bridge International; Mountain View, CA, USA), SureFECTOR (B-Bridge International; Mountain View, CA, USA), or HiFect™ (B-Bridge International, Mountain View, CA, USA), among others.

Other agents can be utilized to enhance the penetration of the administered nucleic acids, including glycols such as ethylene glycol and propylene glycol, pyrrols such as 2-pyrrol, azones, and terpenes such as limonene and menthone.

v. Carriers

Certain compositions of the present invention also incorporate carrier compounds in the formulation. As used herein, "carrier compound" or "carrier" can refer to a nucleic acid, or analog thereof, which is inert (*i.e.*, does not possess biological activity *per se*) but is recognized as a nucleic acid by *in vivo* processes that reduce the bioavailability of a nucleic acid having biological activity by, for example, degrading the biologically active nucleic acid or promoting its removal from circulation. The coadministration of a nucleic acid and a carrier compound, typically with an excess of the latter substance, can result in a substantial reduction of the amount of nucleic acid recovered in the liver, kidney or other extracirculatory reservoirs, presumably due to competition between the carrier compound and the nucleic acid for a common receptor. For example, the recovery of a partially phosphorothioated antisense polynucleotide agent in hepatic tissue can be reduced when it is coadministered with polyinosinic acid, dextran sulfate, polycytidic acid or 4-acetamido-4'isothiocyano-stilbene-2,2'-disulfonic acid (Miyao *et al.*, Antisense polynucleotide agent Res. Dev., 1995, 5, 115-121; Takakura *et al.*, Antisense polynucleotide agent & Nucl. Acid Drug Dev., 1996, 6, 177-183.

vi. Excipients

In contrast to a carrier compound, a "pharmaceutical carrier" or "excipient" is a pharmaceutically acceptable solvent, suspending agent or any other pharmacologically inert vehicle for delivering one or more nucleic acids to an animal. The excipient can be liquid or solid and is selected, with the planned manner of administration in mind, so as to provide for the desired bulk, consistency, *etc.*, when combined with a nucleic acid and the other components of a given pharmaceutical composition. Typical pharmaceutical carriers include, but are not limited to, binding agents (*e.g.*, pregelatinized maize starch, polyvinylpyrrolidone or hydroxypropyl methylcellulose, *etc.*); fillers (*e.g.*, lactose and other sugars, microcrystalline cellulose, pectin, gelatin, calcium sulfate, ethyl cellulose, polyacrylates or calcium hydrogen phosphate, *etc.*); lubricants (*e.g.*, magnesium stearate, talc, silica, colloidal silicon dioxide, stearic acid, metallic stearates, hydrogenated vegetable oils, corn starch, polyethylene glycols, sodium benzoate, sodium acetate, *etc.*); disintegrants (*e.g.*, starch, sodium starch glycolate, *etc.*); and wetting agents (*e.g.*, sodium lauryl sulphate, *etc*).

Pharmaceutically acceptable organic or inorganic excipients suitable for non-parenteral administration which do not deleteriously react with nucleic acids can also be used to formulate the compositions of the present invention. Suitable pharmaceutically acceptable carriers include, but are not limited to, water, salt solutions, alcohols, polyethylene glycols, gelatin, lactose, amylose, magnesium stearate, talc, silicic acid, viscous paraffin, hydroxymethylcellulose, polyvinylpyrrolidone and the like.

Formulations for topical administration of nucleic acids can include sterile and non-sterile aqueous solutions, non-aqueous solutions in common solvents such as alcohols, or

solutions of the nucleic acids in liquid or solid oil bases. The solutions can also contain buffers, diluents and other suitable additives. Pharmaceutically acceptable organic or inorganic excipients suitable for non-parenteral administration which do not deleteriously react with nucleic acids can be used.

Suitable pharmaceutically acceptable excipients include, but are not limited to, water, salt solutions, alcohol, polyethylene glycols, gelatin, lactose, amylose, magnesium stearate, talc, silicic acid, viscous paraffin, hydroxymethylcellulose, polyvinylpyrrolidone and the like.

vii. Other Components

The compositions of the present invention can additionally contain other adjunct components conventionally found in pharmaceutical compositions, at their art-established usage levels. Thus, for example, the compositions can contain additional, compatible, pharmaceutically-active materials such as, for example, antipruritics, astringents, local anesthetics or anti-inflammatory agents, or can contain additional materials useful in physically formulating various dosage forms of the compositions of the present invention, such as dyes, flavoring agents, preservatives, antioxidants, opacifiers, thickening agents and stabilizers. However, such materials, when added, should not unduly interfere with the biological activities of the components of the compositions of the present invention. The formulations can be sterilized and, if desired, mixed with auxiliary agents, *e.g.*, lubricants, preservatives, stabilizers, wetting agents, emulsifiers, salts for influencing osmotic pressure, buffers, colorings, flavorings and/or aromatic substances and the like which do not deleteriously interact with the nucleic acid(s) of the formulation.

Aqueous suspensions can contain substances which increase the viscosity of the suspension including, for example, sodium carboxymethylcellulose, sorbitol and/or dextran. The suspension can also contain stabilizers.

In some embodiments, pharmaceutical compositions featured in the invention include (a) one or more antisense polynucleotide agents and (b) one or more agents which function by a non-antisense inhibition mechanism and which are useful in treating a hemolytic disorder. Examples of such agents include, but are not lmited to an anti-inflammatory agent, anti-steatosis agent, anti-viral, and/or anti-fibrosis agent. In addition, other substances commonly used to protect the liver, such as silymarin, can also be used in conjunction with the antisense polynucleotide agents described herein. Other agents useful for treating liver diseases include telbivudine, entecavir, and protease inhibitors such as telaprevir and other disclosed, for example, in Tung *et al.*, U.S. Application Publication Nos. 2005/0148548, 2004/0167116, and 2003/0144217; and in Hale *et al.*, U.S. Application Publication No. 2004/0127488.

Toxicity and therapeutic efficacy of such compounds can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, *e.g.*, for determining the LD_{50} (the dose lethal to 50% of the population) and the ED_{50} (the dose therapeutically

effective in 50% of the population). The dose ratio between toxic and therapeutic effects is the therapeutic index and it can be expressed as the ratio LD_{50}/ED_{50}. Compounds that exhibit high therapeutic indices are preferred.

The data obtained from cell culture assays and animal studies can be used in formulating a range of dosage for use in humans. The dosage of compositions featured herein in the invention lies generally within a range of circulating concentrations that include the ED_{50} with little or no toxicity. The dosage can vary within this range depending upon the dosage form employed and the route of administration utilized. For any compound used in the methods featured in the invention, the therapeutically effective dose can be estimated initially from cell culture assays. A dose can be formulated in animal models to achieve a circulating plasma concentration range of the compound or, when appropriate, of the polypeptide product of a target sequence (*e.g.*, achieving a decreased concentration of the polypeptide) that includes the IC_{50} (*i.e.*, the concentration of the test compound which achieves a half-maximal inhibition of symptoms) as determined in cell culture. Such information can be used to more accurately determine useful doses in humans. Levels in plasma can be measured, for example, by high performance liquid chromatography.

In addition to their administration, as discussed above, the antisense polynucleotide agents featured in the invention can be administered in combination with other known agents effective in treatment of pathological processes mediated by ALAS1 expression. In any event, the administering physician can adjust the amount and timing of antisense polynucleotide agent administration on the basis of results observed using standard measures of efficacy known in the art or described herein.

VII. Methods For Inhibiting ALAS1 Expression

The present invention provides methods of inhibiting expression of ALAS1 in a cell. The methods include contacting a cell with a polynucleotide agent of the invention, *e.g.,* an antisense polynucleotide agent of the invention, in an amount effective to inhibit expression of the ALAS1 in the cell, thereby inhibiting expression of the ALAS1 in the cell.

Contacting of a cell with an antisense polynucleotide agent may be done *in vitro* or *in vivo*. Contacting a cell *in vivo* with the antisense polynucleotide agent includes contacting a cell or group of cells within a subject, *e.g.*, a human subject, with the antisense polynucleotide agent. Combinations of *in vitro* and *in vivo* methods of contacting are also possible. Contacting may be direct or indirect, as discussed above. Furthermore, contacting a cell may be accomplished *via* a targeting ligand, including any ligand described herein or known in the art. In preferred embodiments, the targeting ligand is a carbohydrate moiety, *e.g.*, a $GalNAc_3$ ligand, or any other ligand that directs the antisense polynucleotide agent to a site of interest, *e.g.*, the liver of a subject.

The term "inhibiting," as used herein, is used interchangeably with "reducing," "silencing," "downregulating" and other similar terms, and includes any level of inhibition.

The phrase "inhibiting expression of an ALAS1" is intended to refer to inhibition of expression of any ALAS1 gene (such as, *e.g.*, a mouse ALAS1 gene, a rat ALAS1 gene, a monkey ALAS1 gene, or a human ALAS1 gene) as well as variants or mutants of an ALAS1 gene. Thus, the ALAS1 gene may be a wild-type ALAS1 gene, a mutant ALAS1 gene, or a transgenic ALAS1 gene in the context of a genetically manipulated cell, group of cells, or organism.

"Inhibiting expression of an ALAS1 gene" includes any level of inhibition of an ALAS1 gene, *e.g.*, at least partial suppression of the expression of an ALAS1 gene. The expression of the ALAS1 gene may be assessed based on the level, or the change in the level, of any variable associated with ALAS1 gene expression, *e.g.*, ALAS1 mRNA level or ALAS1 protein level. This level may be assessed in an individual cell or in a group of cells, including, for example, a sample derived from a subject.

Inhibition may be assessed by a decrease in an absolute or relative level of one or more variables that are associated with ALAS1 expression compared with a control level. The control level may be any type of control level that is utilized in the art, *e.g.*, a pre-dose baseline level, or a level determined from a similar subject, cell, or sample that is untreated or treated with a control (such as, *e.g.*, buffer only control or inactive agent control).

In some embodiments of the methods of the invention, expression of an ALAS1 gene is inhibited by at least about 5%, at least about 10%, at least about 15%, at least about 20%, at least about 25%, at least about 30%, at least about 35%, at least about 40%, at least about 45%, at least about 50%, at least about 55%, at least about 60%, at least about 65%, at least about 70%, at least about 75%, at least about 80%, at least about 85%, at least about 90%, at least about 91%, at least about 92%, at least about 93%, at least about 94%. at least about 95%, at least about 96%, at least about 97%, at least about 98%, or at least about 99%.

Inhibition of the expression of an ALAS1 gene may be manifested by a reduction of the amount of mRNA expressed by a first cell or group of cells (such cells may be present, for example, in a sample derived from a subject) in which an ALAS1 gene is transcribed and which has or have been treated (*e.g.*, by contacting the cell or cells with an antisense polynucleotide agent of the invention, or by administering an antisense polynucleotide agent of the invention to a subject in which the cells are or were present) such that the expression of an ALAS1 gene is inhibited, as compared to a second cell or group of cells substantially identical to the first cell or group of cells but which has not or have not been so treated (control cell(s)). In preferred embodiments, the inhibition is assessed by expressing the level of mRNA in treated cells as a percentage of the level of mRNA in control cells, using the following formula:

$$\frac{(\text{mRNA in control cells}) - (\text{mRNA in treated cells})}{(\text{mRNA in control cells})} \bullet 100\%$$

Alternatively, inhibition of the expression of an ALAS1 gene may be assessed in terms of a reduction of a parameter that is functionally linked to ALAS1 gene expression, *e.g.*, levels of porphyrins and/or porphyrin precursors, *e.g.*, ALA and/or PBG. ALAS1 gene silencing may be determined in any cell expressing ALAS1, either constitutively or by genomic engineering, and by any assay known in the art. The liver is the major site of ALAS1 expression. Other significant sites of expression include the kidneys and the uterus.

Inhibition of the expression of an ALAS1 protein may be manifested by a reduction in the level of the ALAS1 protein that is expressed by a cell or group of cells (*e.g.*, the level of protein expressed in a sample derived from a subject). As explained above for the assessment of mRNA suppression, the inhibiton of protein expression levels in a treated cell or group of cells may similarly be expressed as a percentage of the level of protein in a control cell or group of cells.

A control cell or group of cells that may be used to assess the inhibition of the expression of an ALAS1 gene includes a cell or group of cells that has not yet been contacted with an antisense polynucleotide agent of the invention. For example, the control cell or group of cells may be derived from an individual subject (*e.g.*, a human or animal subject) prior to treatment of the subject with an antisense polynucleotide agent.

The level of ALAS1 mRNA that is expressed by a cell or group of cells may be determined using any method known in the art for assessing mRNA expression. In one embodiment, the level of expression of ALAS1 in a sample is determined by detecting a transcribed polynucleotide, or portion thereof, *e.g.*, mRNA of the ALAS1 gene. RNA may be extracted from cells using RNA extraction techniques including, for example, using acid phenol/guanidine isothiocyanate extraction (RNAzol B; Biogenesis), RNeasy RNA preparation kits (Qiagen) or PAXgene (PreAnalytix, Switzerland). Typical assay formats utilizing ribonucleic acid hybridization include nuclear run-on assays, RT-PCR, RNase protection assays (Melton *et al.*, *Nuc. Acids Res.* 12:7035), Northern blotting, *in situ* hybridization, and microarray analysis.

In one embodiment, the level of expression of ALAS1 is determined using a nucleic acid probe. The term "probe", as used herein, refers to any molecule that is capable of selectively binding to a specific ALAS1. Probes can be synthesized by one of skill in the art, or derived from appropriate biological preparations. Probes may be specifically designed to be labeled. Examples of molecules that can be utilized as probes include, but are not limited to, RNA, DNA, proteins, antibodies, and organic molecules.

Isolated mRNA can be used in hybridization or amplification assays that include, but are not limited to, Southern or Northern analyses, polymerase chain reaction (PCR) analyses and probe arrays. One method for the determination of mRNA levels involves contacting the

isolated mRNA with a nucleic acid molecule (probe) that can hybridize to ALAS1 mRNA. In one embodiment, the mRNA is immobilized on a solid surface and contacted with a probe, for example by running the isolated mRNA on an agarose gel and transferring the mRNA from the gel to a membrane, such as nitrocellulose. In an alternative embodiment, the probe(s) are immobilized on a solid surface and the mRNA is contacted with the probe(s), for example, in an Affymetrix gene chip array. A skilled artisan can readily adapt known mRNA detection methods for use in determining the level of ALAS1 mRNA.

An alternative method for determining the level of expression of ALAS1 in a sample involves the process of nucleic acid amplification and/or reverse transcriptase (to prepare cDNA) of for example mRNA in the sample, *e.g.*, by RT-PCR (the experimental embodiment set forth in Mullis, 1987, U.S. Pat. No. 4,683,202), ligase chain reaction (Barany (1991) *Proc. Natl. Acad. Sci. USA* 88:189-193), self sustained sequence replication (Guatelli et al. (1990) *Proc. Natl. Acad. Sci. USA* 87:1874-1878), transcriptional amplification system (Kwoh *et al.* (1989) *Proc. Natl. Acad. Sci. USA* 86:1173-1177), Q-Beta Replicase (Lizardi *et al.* (1988) *Bio/Technology* 6:1197), rolling circle replication (Lizardi et al., U.S. Pat. No. 5,854,033) or any other nucleic acid amplification method, followed by the detection of the amplified molecules using techniques well known to those of skill in the art. These detection schemes are especially useful for the detection of nucleic acid molecules if such molecules are present in very low numbers. In particular aspects of the invention, the level of expression of ALAS1 is determined by quantitative fluorogenic RT-PCR (*i.e.*, the TaqMan™ System).

The expression levels of ALAS1 mRNA may be monitored using a membrane blot (such as used in hybridization analysis such as Northern, Southern, dot, and the like), or microwells, sample tubes, gels, beads or fibers (or any solid support comprising bound nucleic acids). See U.S. Pat. Nos. 5,770,722, 5,874,219, 5,744,305, 5,677,195 and 5,445,934, which are incorporated herein by reference. The determination of ALAS1 expression level may also comprise using nucleic acid probes in solution.

In preferred embodiments, the level of mRNA expression is assessed using branched DNA (bDNA) assays or real time PCR (qPCR). The use of these methods is described and exemplified in the Examples presented herein.

The level of ALAS1 protein expression may be determined using any method known in the art for the measurement of protein levels. Such methods include, for example, electrophoresis, capillary electrophoresis, high performance liquid chromatography (HPLC), thin layer chromatography (TLC), hyperdiffusion chromatography, fluid or gel precipitin reactions, absorption spectroscopy, a colorimetric assays, spectrophotometric assays, flow cytometry, immunodiffusion (single or double), immunoelectrophoresis, Western blotting, radioimmunoassay (RIA), enzyme-linked immunosorbent assays (ELISAs), immunofluorescent assays, electrochemiluminescence assays, and the like.

The term "sample" as used herein refers to a collection of similar fluids, cells, or tissues isolated from a subject, as well as fluids, cells, or tissues present within a subject. Examples of biological fluids include blood, serum and serosal fluids, plasma, lymph, urine, cerebrospinal fluid, saliva, ocular fluids, and the like. Tissue samples may include samples from tissues, organs or localized regions. For example, samples may be derived from particular organs, parts of organs, or fluids or cells within those organs. In certain embodiments, samples may be derived from the liver (*e.g.*, whole liver or certain segments of liver or certain types of cells in the liver, such as, *e.g.*, hepatocytes). In preferred embodiments, a "sample derived from a subject" refers to blood or plasma drawn from the subject. In further embodiments, a "sample derived from a subject" refers to liver tissue derived from the subject.

In some embodiments of the methods of the invention, the antisense polynucleotide agent is administered to a subject such that the antisense polynucleotide agent is delivered to a specific site within the subject. The inhibition of expression of ALAS1 may be assessed using measurements of the level or change in the level of ALAS1 mRNA or ALAS1 protein in a sample derived from fluid or tissue from the specific site within the subject. In preferred embodiments, the site is the liver. The site may also be a subsection or subgroup of cells from any one of the aforementioned sites. The site may also include cells that express a particular type of receptor.

The phrase "contacting a cell with an antisense polynucleotide agent," as used herein, includes contacting a cell by any possible means. Contacting a cell with an antisense polynucleotide agent includes contacting a cell *in vitro* with the antisense polynucleotide agent or contacting a cell *in vivo* with the antisense polynucleotide agent. The contacting may be done directly or indirectly. Thus, for example, the antisense polynucleotide agent may be put into physical contact with the cell by the individual performing the method, or alternatively, the antisense polynucleotide agent may be put into a situation that will permit or cause it to subsequently come into contact with the cell.

Contacting a cell *in vitro* may be done, for example, by incubating the cell with the antisense polynucleotide agent. Contacting a cell *in vivo* may be done, for example, by injecting the antisense polynucleotide agent into or near the tissue where the cell is located, or by injecting the antisense polynucleotide agent into another area, *e.g.*, the bloodstream or the subcutaneous space, such that the agent will subsequently reach the tissue where the cell to be contacted is located. For example, the antisense polynucleotide agent may contain and/or be coupled to a ligand, *e.g.*, GalNAc3, that directs the antisense polynucleotide agent to a site of interest, *e.g.*, the liver. Combinations of *in vitro* and *in vivo* methods of contacting are also possible. For example, a cell may also be contacted *in vitro* with an antisense polynucleotide agent and subsequently transplanted into a subject.

In one embodiment, contacting a cell with an antisense polynucleotide agent includes "introducing" or "delivering the antisense polynucleotide agent into the cell" by facilitating or effecting uptake or absorption into the cell. Absorption or uptake of an antisense polynucleotide agent can occur through unaided diffusive or active cellular processes, or by auxiliary agents or devices. Introducing an antisense polynucleotide agent into a cell may be *in vitro* and/or *in vivo*. For example, for *in vivo* introduction, antisense polynucleotide agent can be injected into a tissue site or administered systemically. *In vivo* delivery can also be done by a beta-glucan delivery system, such as those described in U.S. Patent Nos. 5,032,401 and 5,607,677, and U.S. Publication No. 2005/0281781, the entire contents of which are hereby incorporated herein by reference. *In vitro* introduction into a cell includes methods known in the art such as electroporation and lipofection. Further approaches are described herein below and/or are known in the art.

VIII. Methods for Treating or Preventing an ALAS1-Associated Disorder

The present invention also provides therapeutic and prophylactic methods which include administering to a subject having an ALAS1-associated disease, *e.g.,* porphyria, an antisense polynucleotide agent or pharmaceutical compositions comprising an antisense polynucleotide agent of the invention. In some aspects of the invention, the methods further include administering to the subject an additional therapeutic agent, such as glucose and/or a heme product such as hemin.

In one aspect, the present invention provides methods of treating a subject having a disorder that would benefit from reduction in ALAS1 expression, *e.g.,* an ALAS1-associated disease, *e.g.,* porphyria. The treatment methods (and uses) of the invention include administering to the subject, *e.g.,* a human, a therapeutically effective amount of an antisense polynucleotide agent targeting an ALAS1 gene or a pharmaceutical composition comprising an antisense polynucleotide agent targeting an ALAS1 gene, thereby treating the subject having a disorder that would benefit from reduction in ALAS1 expression.

In another aspect, the present invention provides methods of treating a subject having a disorder that would benefit from reduction in an ALAS1 expression, *e.g.,* an ALAS1-associated disease, *e.g.,* porphyria, which include administering to the subject, *e.g.,* a human, a therapeutically effective amount of an antisense polynucleotide agent targeting an ALAS1 gene or a pharmaceutical composition comprising an antisense polynucleotide agent targeting an ALAS1 gene, and an additional therapeutic agent, such as glucose and/or a heme product such as hemin, thereby treating the subject having a disorder that would benefit from reduction in ALAS1 expression.

In one aspect, the invention provides methods of preventing at least one symptom in a subject having a disorder that would benefit from reduction in ALAS1 expression, *e.g.,* an ALAS1-associated disease, *e.g.,* porphyria. The methods include administering to the subject

a prohpylactically effective amount of an antisense polynucleotide agent targeting an ALAS1 gene or a pharmaceutical composition comprising an antisense polynucleotide agent targeting an ALAS1 gene, thereby preventing at least one symptom in the subject having a disorder that would benefit from reduction in ALAS1 expression.

In another aspect, the invention provides methods of preventing at least one symptom in a subject having a disorder that would benefit from reduction in ALAS1 expression, *e.g.,* an ALAS1-associated disease, *e.g.,* porphyria. The methods include administering to the subject a prophylactically effective amount of an antisense polynucleotide agent targeting an ALAS1 gene or a pharmaceutical composition comprising an antisense polynucleotide agent targeting an ALAS1 gene, and an additional therapeutic agent, such as glucose and/or a heme product such as hemin, thereby preventing at least one symptom in the subject having a disorder that would benefit from reduction in ALAS1 expression.

As used herein, "an ALAS1 associated disease", "a disorder related to ALAS1 expression," a "disease related to ALAS1 expression, a "pathological process related to ALAS1 expression," or the like includes any condition, disorder, or disease in which ALAS1 expression is altered (*e.g.*, elevated), the level of one or more porphyrins is altered (*e.g.*, elevated), the level or activity of one or more enzymes in the heme biosynthetic pathway (porphyrin pathway) is altered, or other mechisms that lead to pathological changes in the heme biosynthetic pathway. For example, an antisense polynucleotide agent targeting an ALAS1 gene, or a combination thereof, may be used for treatment of conditions in which levels of a porphyrin or a porphyrin precursor (*e.g.*, ALA or PBG) are elevated (*e.g.*, certain porphyrias), or conditions in which there are defects in the enzymes of the heme biosynthetic pathway (*e.g.*, certain porphyrias). Disorders related to ALAS1 expression include, for example, X-linked sideroblastic anemia (XLSA), ALA deyhdratase deficiency porphyria (Doss porphyria), acute intermittent porphyria (AIP), congenital erythropoietic porphyria, prophyria cutanea tarda, hereditary coproporphyria (coproporphyria), variegate porphyria, erythropoietic protoporphyria (EPP), and transient erythroporphyria of infancy.

As used herein, a "subject" to be treated according to the methods described herein, includes a human or non-human animal, *e.g.*, a mammal. The mammal may be, for example, a rodent (*e.g.*, a rat or mouse) or a primate (*e.g.*, a monkey). In some embodiments, the subject is a human.

In some embodiments, the subject is suffering from a disorder related to ALAS1 expression (*e.g.*, has been diagnosed with a porphyria or has suffered from one or more symptoms of porphyria and is a carrier of a mutation associated with porphyria) or is at risk of developing a disorder related to ALAS1 expression (*e.g.*, a subject with a family history of porphyria, or a subject who is a carrier of a genetic mutation associated with porphyria).

Classifications of porphyrias, including acute hepatic porphyrias, are described, *e.g.*, in Balwani, M. & Desnick, R.J., *Blood*, 120(23), published online as Blood First Edition

paper, July 12, 102; DOI 10.1182/blood-2012-05-423186. As described in Balwain & Desnick, acute intermittent porphyria (AIP) hereditary coproporphyria (HCP), variegate porphyria (VP) are autosomal dominant porphyrias and ALA deyhdratase deficiency porphyria (ADP) is autosomal recessive. In rare cases, AIP, HCP, and VP occur as homozygous dominant forms. In addition, there is a rare homozygous recessive form of porphyria cutanea tarda (PCT), which is the single hepatic cutaneous porphyria, and is also known as hepatoerythropoietic porphyria. The clinical and laboratory features of these porphyrias are described in the Table below.

Human hepatic porphyrias: clinical and laboratory features

Porphyria	Deficient enzyme	Inheritance	Principal symptoms, NV or CP	Enzyme activity, % of normal	Increased porphyrin precursors and/or porphyrins*		
					Erythrocytes	Urine	Stool
Acute hepatic porphyrias							
ADP	ALA-dehydratase	AR	NV	~5	Zn-protoporphyrin	ALA, coproporphyrin III	_
AIP	HMB-synthase	AD	NV	~50	_	ALA, PBG, uroporphyrin	_
HCP	COPRO-oxidase	AD	NV and CP	~50	_	ALA, PBG, coproporphyrin III	coproporphyrin III
VP	PROTO-oxidase	AD	NV and CP	~50	_	ALA, PBG coproporphyrin III	coproporphyrin III, protoporphyrin
Hepatic cutaneous porphyrias							
PCT	URO-decarboxylase	Sporadic or AD	CP	<20	_	uroporphyrin, 7-carboxylate porphyrin	uroporphyrin, 7-carboxylate porphyrin

AR indicates autosomal recessive; AD, autosomal dominant; NV, neurovisceral; CP, cutaneous photosensitivity; and -, not applicable.

*Increases that may be important for diagnosis.

In some embodiments, the subject has or is at risk for developing a porphyria, *e.g.*, a hepatic porphyria, *e.g.*, AIP, HCP, VP, ADP, or hepatoerythropoietic porphyria.

In some embodiments, the porphyria is an acute hepatic porphyria, *e.g.*, an acute hepatic porphyria iselected from acute intermittent porphyria (AIP), hereditary coproporphyria (HCP), variegate porphyria (VP), and ALA deyhdratase deficiency porphyria (ADP).

In some embodiments, the porphyria is a dual porphyria, *e.g.*, at least two porphyrias. In some embodiments, the dual porphyria comprises two or more porphyrias selected from acute intermittent porphyria (AIP) hereditary coproporphyria (HCP), variegate porphyria (VP), and ALA deyhdratase deficiency porphyria (ADP).

In some embodiments, the porphyria is a homozygous dominant hepatic porphyria (*e.g.*, homozygous dominant AIP, HCP, or VP) or hepatoerythropoietic porphyria. In some embodiments, the porphyria is AIP, HCP, VP, or hepatoerythropoietic porphyria, or a combination thereof (*e.g.*, a dual porphyria). In embodiments, the AIP, HCP, or VP is either heterozygous dominant or homozygous dominant.

In embodiments, the subject has or is at risk for developing a porphyria, *e.g.*, ADP, and shows an elevated level (*e.g.*, an elevated urine level) of ALA and/or coproporphyrin III. In embodiments, the subject has or is at risk for developing a porphyria, *e.g.*, ADP, and shows an elevated level of erythrocyte Zn-protoporphyrin.

In embodiments, the subject has or is at risk for developing a porphyria, *e.g.*, AIP, and shows an elevated level (*e.g.*, an elevated urine level) of ALA, PBG, and/or uroporphyrin.

In embodiments, the subject has or is at risk for developing a porphyria, *e.g.*, HCP, and shows an elevated level (*e.g.*, an elevated urine level) of ALA, PBG, and/or coproporphyrin III. In embodiments, the subject has or is at risk for developing a porphyria, *e.g.*, HCP, and shows an elevated level (*e.g.*, an elevated stool level) of coproporphyrin III.

In embodiments, the subject has or is at risk for developing a porphyria, *e.g.*, VP, and shows an elevated level (*e.g.*, an elevated urine level) of ALA, PBG, and/or coproporphyrin III.

In embodiments, the subject has or is at risk for developing a porphyria, *e.g.*, HCP, and shows an elevated level (*e.g.*, an elevated stool level) of coproporphyrin III and/or protoporphyrin.

In embodiments, the subject has or is at risk for developing a porphyria, *e.g.*, PCT, (*e.g.*,hepatoerythropoietic porphyria) and shows an elevated level (*e.g.*, an elevated urine level) of uroporphyrin and/or 7-carboxylate porphyrin. In embodiments, the subject has or is at risk for developing a porphyria, *e.g.*, PCT, (*e.g.*,hepatoerythropoietic porphyria) and shows an elevated level (*e.g.*, an elevated stool level) of uroporphyrin and/or 7-carboxylate porphyrin.

A mutation associated with porphyria includes any mutation in a gene encoding an enzyme in the heme biosynthetic pathway (porphyrin pathway) or a gene which alters the expression of a gene in the heme biosynthetic pathway. In many embodiments, the subject carries one or more mutations in an enzyme of the porphyrin pathway (*e.g.*, a mutation in ALA deydratase or PBG deaminase). In some embodiments, the subject is suffereing from an acute porphyria (*e.g.*, AIP, ALA deydratase deficiency porphyria).

In some cases, patients with an acute hepatic porphyria (*e.g.*, AIP), or patients who carry mutations associated with an acute hepatic porphyria (*e.g.*, AIP) but who are asymptomatic, have elevated ALA and/or PBG levels compared with healthy individuals. See, *e.g.*, Floderus, Y. et al, Clinical Chemistry, 52(4): 701-707, 2006; Sardh et al., Clinical Pharmacokinetics, 46(4): 335-349, 2007. In such cases, the level of ALA and/or PBG can be

elevated even when the patient is not having, or has never had, an attack. In some such cases, the patient is otherwise completely asymptomatic. In some such cases, the patient suffers from pain, *e.g.*, neuropathic pain, which can be chronic pain (*e.g.*, chronic neuropathic pain). In some cases, the patient has a neuropathy. In some cases, the patient has a progressive neuropathy.

In some embodiments, the subject to be treated according to the methods described herein has an elevated level of a porphyrin or a porphyrin precursor, *e.g.*, ALA and/or PBG. Levels of a porphyrin or a porphyrin precursor can be assessed using methods known in the art or methods described herein. For example, methods of assessing urine and plasma ALA and PBG levels, as well as urine and plasma porphyrin levels, are disclosed in Floderus, Y. et al, Clinical Chemistry, 52(4): 701-707, 2006; and Sardh et al., Clinical Pharmacokinetics, 46(4): 335-349, 2007, the entire contents of which are hereby incorporated in their entirety.

"Therapeutically effective amount," as used herein, is intended to include the amount of an antisense polynucleotide agent that, when administered to a subject having an ALAS1-associated disease, is sufficient to effect treatment of the disease (*e.g.*, by diminishing, ameliorating or maintaining the existing disease or one or more symptoms of disease). The "therapeutically effective amount" may vary depending on the antisense polynucleotide agent, how the agent is administered, the disease and its severity and the history, age, weight, family history, genetic makeup, the types of preceding or concomitant treatments, if any, and other individual characteristics of the subject to be treated.

"Prophylactically effective amount," as used herein, is intended to include the amount of an antisense polynucleotide agent that, when administered to a subject having an ALAS1-associate disease but not yet (or currently) experiencing or displaying symptoms of the disease, and/or a subject at risk of developing an ALAS1-associated disease, *e.g.,* porphyria, is sufficient to prevent or ameliorate the disease or one or more symptoms of the disease. Ameliorating the disease includes slowing the course of the disease or reducing the severity of later-developing disease. The "prophylactically effective amount" may vary depending on the antisense polynucleotide agent, how the agent is administered, the degree of risk of disease, and the history, age, weight, family history, genetic makeup, the types of preceding or concomitant treatments, if any, and other individual characteristics of the patient to be treated.

A "therapeutically effective amount" or "prophylactically effective amount" also includes an amount of an antisense polynucleotide agent that produces some desired local or systemic effect at a reasonable benefit/risk ratio applicable to any treatment. Antisense polynucleotide agents employed in the methods of the present invention may be administered in a sufficient amount to produce a reasonable benefit/risk ratio applicable to such treatment.

In another aspect, the present invention provides uses of a therapeutically effective amount of an antisense polynucleotide agent of the invention for treating a subject, *e.g.*, a subject that would benefit from a reduction and/or inhibition of ALAS1 expression.

In another aspect, the present invention provides uses of a therapeutically effective amount of an antisense polynucleotide agent of the invention and an additional therapeutic agent, such as glucose and/or a heme product such as hemin, for treating a subject, *e.g.*, a subject that would benefit from a reduction and/or inhibition of ALAS1 expression.

In yet another aspect, the present invention provides use of an antisense polynucleotide agent of the invention targeting an ALAS1 gene or a pharmaceutical composition comprising an antisense polynucleotide agent targeting an ALAS1 gene in the manufacture of a medicament for treating a subject, *e.g.*, a subject that would benefit from a reduction and/or inhibition of ALAS1 expression, such as a subject having a disorder that would benefit from reduction in ALAS1 expression, *e.g.,* porphyria.

In another aspect, the present invention provides uses of an antisense polynucleotide agent of the invention targeting an ALAS1 gene or a pharmaceutical composition comprising an antisense polynucleotide agent targeting an ALAS1 gene in the manufacture of a medicament for use in combination with an additional therapeutic agent, such as glucose and/or a heme product such as hemin, for treating a subject, *e.g.*, a subject that would benefit from a reduction and/or inhibition of ALAS1 expression, *e.g.,* an ALAS1-associated disease, *e.g.,* porphyria.

In another aspect, the invention provides uses of an antisense polynucleotide agent of the invention for preventing at least one symptom in a subject suffering from a disorder that would benefit from a reduction and/or inhibition of ALAS1 expression, such as an ALAS1-associated disease, *e.g.,* porphyria.

In yet another aspect, the invention provides uses of an antisense polynucleotide agent of the invention, and an additional therapeutic agent, such as glucose and/or a heme product such as hemin, for preventing at least one symptom in a subject suffering from a disorder that would benefit from a reduction and/or inhibition of ALAS1 expression, such as an ALAS1-associated disease, *e.g.,* porphyria.

In a further aspect, the present invention provides uses of an antisense polynucleotide agent of the invention in the manufacture of a medicament for preventing at least one symptom in a subject suffering from a disorder that would benefit from a reduction and/or inhibition of ALAS1 expression, such as an ALAS1-associated disease, *e.g.,* porphyria.

In a further aspect, the present invention provides uses of an antisense polynucleotide agent of the invention in the manufacture of a medicament for use in combination with an additional therapeutic agent, such as glucose and/or a heme product such as hemin, for preventing at least one symptom in a subject suffering from a disorder that would benefit

from a reduction and/or inhibition of ALAS1 expression, such as an ALAS1-associated disease, *e.g.,* porphyria.

In one embodiment, an antisense polynucleotide agent targeting ALAS1 is administered to a subject having an ALAS1-associated disease such that ALAS1 levels, *e.g.*, in a cell, tissue, blood, urine or other tissue or fluid of the subject are reduced by at least about 10%, 11%, 12%, 13%, 14%, 15%, 16%, 17%, 18%, 19%, 20%, 21%, 22%, 23%, 24%, 25%, 26%, 27%, 28%, 29%, 30%, 31%, 32%, 33%, 34%, 35%, 36%, 37%, 38%, 39%, 40%, 41%, 42%, 43%, 44%, 45%, 46%, 47%, 48%, 49%, 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 62%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or at least about 99% or more and, subsequently, an additional therapeutic (as described below) is administered to the subject.

The additional therapeutic may be glucose and/or a heme product such as hemin. The additional therapeutic may be administered to the subject at the same time as the antisense polynucleotide agent targeting ALAS1 or at a different time.

Moreover, the additional therapeutic may be administered to the subject in the same formulation as the antisense polynucleotide agent targeting ALAS1 or in a different formulation as the antisense polynucleotide agent targeting ALAS1.

The methods and uses of the invention include administering a composition described herein such that expression of the target ALAS1 gene is decreased, such as for about 1, 2, 3, 4, 5, 6, 7, 8, 12, 16, 18, 24, 28, 32, 36, 40, 44, 48, 52, 56, 60, 64, 68, 72, 76, or about 80 hours. In one embodiment, expression of the target ALAS1 gene is decreased for an extended duration, *e.g.*, at least about two, three, four, five, six, seven days or more, *e.g.*, about one week, two weeks, three weeks, or about four weeks or longer.

Administration of the antisense polynucleotide agent according to the methods and uses of the invention may result in a reduction of the severity, signs, symptoms, and/or markers of such diseases or disorders in a patient with an ALAS1-associated disease. By "reduction" in this context is meant a statistically significant decrease in such level. The reduction can be, for example, at least about 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, or about 100%.

Efficacy of treatment or prevention of disease can be assessed, for example by measuring disease progression, disease remission, symptom severity, reduction in pain, quality of life, dose of a medication required to sustain a treatment effect, level of a disease marker or any other measurable parameter appropriate for a given disease being treated or targeted for prevention. It is well within the ability of one skilled in the art to monitor efficacy of treatment or prevention by measuring any one of such parameters, or any combination of parameters, *e.g.*, a plasma or urine level of ALA and/or PBG. Comparisons of the later readings with the initial readings provide a physician an indication of whether the

treatment is effective. It is well within the ability of one skilled in the art to monitor efficacy of treatment or prevention by measuring any one of such parameters, or any combination of parameters. In connection with the administration of an antisense polynucleotide agent targeting ALAS1 or pharmaceutical composition thereof, "effective against" an ALAS1-associated disease indicates that administration in a clinically appropriate manner results in a beneficial effect for at least a statistically significant fraction of patients, such as improvement of symptoms, a cure, a reduction in disease, extension of life, improvement in quality of life, or other effect generally recognized as positive by medical doctors familiar with treating an ALAS1-associated disease and the related causes.

A treatment or preventive effect is evident when there is a statistically significant improvement in one or more parameters of disease status, or by a failure to worsen or to develop symptoms where they would otherwise be anticipated. As an example, a favorable change of at least 10% in a measurable parameter of disease, and preferably at least 20%, 30%, 40%, 50% or more can be indicative of effective treatment. Efficacy for a given antisense polynucleotide agent drug or formulation of that drug can also be judged using an experimental animal model for the given disease as known in the art. When using an experimental animal model, efficacy of treatment is evidenced when a statistically significant reduction in a marker or symptom is observed.

Alternatively, the efficacy can be measured by a reduction in the severity of disease as determined by one skilled in the art of diagnosis based on a clinically accepted disease severity grading scale. Any positive change resulting in *e.g.*, lessening of severity of disease measured using the appropriate scale, represents adequate treatment using an antisense polynucleotide agent or antisense polynucleotide agent formulation as described herein.

Subjects can be administered a therapeutic amount of antisense polynucleotide agent, such as about 0.01 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.1 mg/kg, 0.15 mg/kg, 0.2 mg/kg, 0.25 mg/kg, 0.3 mg/kg, 0.35 mg/kg, 0.4 mg/kg, 0.45 mg/kg, 0.5 mg/kg, 0.55 mg/kg, 0.6 mg/kg, 0.65 mg/kg, 0.7 mg/kg, 0.75 mg/kg, 0.8 mg/kg, 0.85 mg/kg, 0.9 mg/kg, 0.95 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, 2.0 mg/kg, 2.1mg/kg, 2.2mg/kg, 2.3 mg/kg, 2.4 mg/kg, 2.5 mg/kg, 2.6 mg/kg, 2.7 mg/kg, 2.8 mg/kg, 2.9 mg/kg, 3.0 mg/kg, 3.1 mg/kg, 3.2 mg/kg, 3.3 mg/kg, 3.4 mg/kg, 3.5 mg/kg, 3.6 mg/kg, 3.7 mg/kg, 3.8 mg/kg, 3.9 mg/kg, 4.0 mg/kg, 4.1 mg/kg, 4.2 mg/kg, 4.3 mg/kg, 4.4 mg/kg, 4.5 mg/kg, 4.6 mg/kg, 4.7 mg/kg, 4.8 mg/kg, 4.9 mg/kg, 5.0 mg/kg, 5.1 mg/kg, 5.2 mg/kg, 5.3 mg/kg, 5.4 mg/kg, 5.5 mg/kg, 5.6 mg/kg, 5.7 mg/kg, 5.8 mg/kg, 5.9 mg/kg, 6.0 mg/kg, 6.1 mg/kg, 6.2 mg/kg, 6.3 mg/kg, 6.4 mg/kg, 6.5 mg/kg, 6.6 mg/kg, 6.7 mg/kg, 6.8 mg/kg, 6.9 mg/kg, 7.0 mg/kg, 7.1 mg/kg, 7.2 mg/kg, 7.3 mg/kg, 7.4 mg/kg, 7.5 mg/kg, 7.6 mg/kg, 7.7 mg/kg, 7.8 mg/kg, 7.9 mg/kg, 8.0 mg/kg, 8.1 mg/kg, 8.2 mg/kg, 8.3 mg/kg, 8.4 mg/kg, 8.5 mg/kg, 8.6 mg/kg, 8.7 mg/kg, 8.8 mg/kg, 8.9 mg/kg, 9.0 mg/kg, 9.1 mg/kg, 9.2 mg/kg, 9.3 mg/kg, 9.4 mg/kg, 9.5 mg/kg, 9.6

mg/kg, 9.7 mg/kg, 9.8 mg/kg, 9.9 mg/kg, 9.0 mg/kg, 10 mg/kg, 15 mg/kg, 20 mg/kg, 25 mg/kg, 30 mg/kg, 35 mg/kg, 40 mg/kg, 45 mg/kg, or about 50 mg/kg. Values and ranges intermediate to the recited values are also intended to be part of this invention.

In certain embodiments, for example, when a composition of the invention comprises a antisense polynucleotide agent as described herein and a lipid, subjects can be administered a therapeutic amount of antisense polynucleotide agent, such as about 0.01 mg/kg to about 5 mg/kg, about 0.01 mg/kg to about 10 mg/kg, about 0.05 mg/kg to about 5 mg/kg, about 0.05 mg/kg to about 10 mg/kg, about 0.1 mg/kg to about 5 mg/kg, about 0.1 mg/kg to about 10 mg/kg, about 0.2 mg/kg to about 5 mg/kg, about 0.2 mg/kg to about 10 mg/kg, about 0.3 mg/kg to about 5 mg/kg, about 0.3 mg/kg to about 10 mg/kg, about 0.4 mg/kg to about 5 mg/kg, about 0.4 mg/kg to about 10 mg/kg, about 0.5 mg/kg to about 5 mg/kg, about 0.5 mg/kg to about 10 mg/kg, about 1 mg/kg to about 5 mg/kg, about 1 mg/kg to about 10 mg/kg, about 1.5 mg/kg to about 5 mg/kg, about 1.5 mg/kg to about 10 mg/kg, about 2 mg/kg to about about 2.5 mg/kg, about 2 mg/kg to about 10 mg/kg, about 3 mg/kg to about 5 mg/kg, about 3 mg/kg to about 10 mg/kg, about 3.5 mg/kg to about 5 mg/kg, about 4 mg/kg to about 5 mg/kg, about 4.5 mg/kg to about 5 mg/kg, about 4 mg/kg to about 10 mg/kg, about 4.5 mg/kg to about 10 mg/kg, about 5 mg/kg to about 10 mg/kg, about 5.5 mg/kg to about 10 mg/kg, about 6 mg/kg to about 10 mg/kg, about 6.5 mg/kg to about 10 mg/kg, about 7 mg/kg to about 10 mg/kg, about 7.5 mg/kg to about 10 mg/kg, about 8 mg/kg to about 10 mg/kg, about 8.5 mg/kg to about 10 mg/kg, about 9 mg/kg to about 10 mg/kg, or about 9.5 mg/kg to about 10 mg/kg. Values and ranges intermediate to the recited values are also intended to be part of this invention.

For example, the antisense polynucleotide agent may be administered at a dose of about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 8, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 9, 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, or about 10 mg/kg. Values and ranges intermediate to the recited values are also intended to be part of this invention.

In other embodiments, for example, when a composition of the invention comprises a antisense polynucleotide agent as described herein and an N-acetylgalactosamine, subjects can be administered a therapeutic amount of antisense polynucleotide agent, such as a dose of about 0.1 to about 50 mg/kg, about 0.25 to about 50 mg/kg, about 0.5 to about 50 mg/kg, about 0.75 to about 50 mg/kg, about 1 to about 50 mg/mg, about 1.5 to about 50 mg/kb, about 2 to about 50 mg/kg, about 2.5 to about 50 mg/kg, about 3 to about 50 mg/kg, about 3.5 to about 50 mg/kg, about 4 to about 50 mg/kg, about 4.5 to about 50 mg/kg, about 5 to about 50 mg/kg, about 7.5 to about 50 mg/kg, about 10 to about 50 mg/kg, about 15 to about 50 mg/kg, about 20 to about 50 mg/kg, about 20 to about 50 mg/kg, about 25 to about 50 mg/kg,

about 25 to about 50 mg/kg, about 30 to about 50 mg/kg, about 35 to about 50 mg/kg, about 40 to about 50 mg/kg, about 45 to about 50 mg/kg, about 0.1 to about 45 mg/kg, about 0.25 to about 45 mg/kg, about 0.5 to about 45 mg/kg, about 0.75 to about 45 mg/kg, about 1 to about 45 mg/mg, about 1.5 to about 45 mg/kb, about 2 to about 45 mg/kg, about 2.5 to about 45 mg/kg, about 3 to about 45 mg/kg, about 3.5 to about 45 mg/kg, about 4 to about 45 mg/kg, about 4.5 to about 45 mg/kg, about 5 to about 45 mg/kg, about 7.5 to about 45 mg/kg, about 10 to about 45 mg/kg, about 15 to about 45 mg/kg, about 20 to about 45 mg/kg, about 20 to about 45 mg/kg, about 25 to about 45 mg/kg, about 25 to about 45 mg/kg, about 30 to about 45 mg/kg, about 35 to about 45 mg/kg, about 40 to about 45 mg/kg, about 0.1 to about 40 mg/kg, about 0.25 to about 40 mg/kg, about 0.5 to about 40 mg/kg, about 0.75 to about 40 mg/kg, about 1 to about 40 mg/mg, about 1.5 to about 40 mg/kb, about 2 to about 40 mg/kg, about 2.5 to about 40 mg/kg, about 3 to about 40 mg/kg, about 3.5 to about 40 mg/kg, about 4 to about 40 mg/kg, about 4.5 to about 40 mg/kg, about 5 to about 40 mg/kg, about 7.5 to about 40 mg/kg, about 10 to about 40 mg/kg, about 15 to about 40 mg/kg, about 20 to about 40 mg/kg, about 20 to about 40 mg/kg, about 25 to about 40 mg/kg, about 25 to about 40 mg/kg, about 30 to about 40 mg/kg, about 35 to about 40 mg/kg, about 0.1 to about 30 mg/kg, about 0.25 to about 30 mg/kg, about 0.5 to about 30 mg/kg, about 0.75 to about 30 mg/kg, about 1 to about 30 mg/mg, about 1.5 to about 30 mg/kb, about 2 to about 30 mg/kg, about 2.5 to about 30 mg/kg, about 3 to about 30 mg/kg, about 3.5 to about 30 mg/kg, about 4 to about 30 mg/kg, about 4.5 to about 30 mg/kg, about 5 to about 30 mg/kg, about 7.5 to about 30 mg/kg, about 10 to about 30 mg/kg, about 15 to about 30 mg/kg, about 20 to about 30 mg/kg, about 20 to about 30 mg/kg, about 25 to about 30 mg/kg, about 0.1 to about 20 mg/kg, about 0.25 to about 20 mg/kg, about 0.5 to about 20 mg/kg, about 0.75 to about 20 mg/kg, about 1 to about 20 mg/mg, about 1.5 to about 20 mg/kb, about 2 to about 20 mg/kg, about 2.5 to about 20 mg/kg, about 3 to about 20 mg/kg, about 3.5 to about 20 mg/kg, about 4 to about 20 mg/kg, about 4.5 to about 20 mg/kg, about 5 to about 20 mg/kg, about 7.5 to about 20 mg/kg, about 10 to about 20 mg/kg, or about 15 to about 20 mg/kg. In one embodiment, when a composition of the invention comprises a antisense polynucleotide agent as described herein and an N-acetylgalactosamine, subjects can be administered a therapeutic amount of about 10 to about 30 mg/kg of antisense polynucleotide agent. Values and ranges intermediate to the recited values are also intended to be part of this invention.

For example, subjects can be administered a therapeutic amount of antisense polynucleotide agent, such as about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 4, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 8, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 9, 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, 10, 10.5, 11, 11.5, 12, 12.5, 13, 13.5, 14, 14.5, 15, 15.5, 16, 16.5, 17, 17.5, 18, 18.5, 19, 19.5, 20, 20.5,

21, 21.5, 22, 22.5, 23, 23.5, 24, 24.5, 25, 25.5, 26, 26.5, 27, 27.5, 28, 28.5, 29, 29.5, 30, 31, 32, 33, 34, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, or about 50 mg/kg. Values and ranges intermediate to the recited values are also intended to be part of this invention.

The antisense polynucleotide agent can be administered by intravenous infusion over a period of time, such as over a 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, or about a 25 minute period. The administration may be repeated, for example, on a regular basis, such as weekly, biweekly (*i.e.*, every two weeks) for one month, two months, three months, four months or longer. After an initial treatment regimen, the treatments can be administered on a less frequent basis. For example, after administration weekly or biweekly for three months, administration can be repeated once per month, for six months or a year or longer.

Administration of the antisense polynucleotide agent can reduce ALAS1 levels, *e.g.*, in a cell, tissue, blood, urine or other compartment of the patient by at least about 5%, 6%, 7%, 8%, 9%, 10%, 11%, 12%, 13%, 14%, 15%, 16%, 17%, 18%, 19%, 20%, 21%, 22%, 23%, 24%, 25%, 26%, 27%, 28%, 29%, 30%, 31%, 32%, 33%, 34%, 35%, 36%, 37%, 38%, 39%, 40%, 41%, 42%, 43%, 44%, 45%, 46%, 47%, 48%, 49%, 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or at least about 99% or more.

Before administration of a full dose of the antisense polynucleotide agent, patients can be administered a smaller dose, such as a 5% infusion, and monitored for adverse effects, such as an allergic reaction. In another example, the patient can be monitored for unwanted immunostimulatory effects, such as increased cytokine (*e.g.*, TNF-alpha or INF-alpha) levels.

Owing to the inhibitory effects on ALAS1 expression, a composition according to the invention or a pharmaceutical composition prepared therefrom can enhance the quality of life.

An antisense polynucleotide agent of the invention may be administered in "naked" form, or as a "free antisense polynucleotide agent." A naked antisense polynucleotide agent is administered in the absence of a pharmaceutical composition. The naked antisense polynucleotide agent may be in a suitable buffer solution. The buffer solution may comprise acetate, citrate, prolamine, carbonate, or phosphate, or any combination thereof. In one embodiment, the buffer solution is phosphate buffered saline (PBS). The pH and osmolarity of the buffer solution containing the antisense polynucleotide agent can be adjusted such that it is suitable for administering to a subject.

Alternatively, an antisense polynucleotide agent of the invention may be administered as a pharmaceutical composition, such as an antisense polynucleotide agent liposomal formulation.

Subjects that would benefit from a reduction and/or inhibition of an ALAS1 gene expression are those having an ALAS1-associated disease or disorder as described herein. In one embodiment, a subject having an ALAS1-associated disease has X-linked sideroblastic anemia (XLSA). In another embodiment, a subject having an ALAS1-associated disease has ALA deyhdratase deficiency porphyria (Doss porphyria or ADP). In another embodiment, a subject having an ALAS1-associated disease has acute intermittent porphyria (AIP). In yet another embodiment, a subject having an ALAS1-associated disease has congenital erythropoietic porphyria (CEP). In one embodiment, a subject having an ALAS1-associated disease has prophyria cutanea tarda (PCT). In another embodiment, a subject having an ALAS1-associated disease has hereditary coproporphyria (coproporphyria, or HCP). In yet another embodiment, a subject having an ALAS1-associated disease has variegate porphyria (VP). In one embodiment, a subject having an ALAS1-associated disease has erythropoietic protoporphyria (EPP). In another embodiment, a subject having an ALAS -associated disease has transient erythroporphyria of infancy. In anothre embodiment, a subject having an ALAS1-associated disease has hepatic porphyria, *e.g.*, ALA deyhdratase deficiency porphyria (ADP), AIP, HCP, or VP. In yet another embodiment, a subject having an ALAS1-associated disease has homozygous dominant hepatic porphyria (*e.g.*, homozygous dominant AIP, HCP, or VP. In one embodiment, a subject having an ALAS1-associated disease has hepatoerythropoietic porphyria. In one embodiment, a subject having an ALAS1-associated disease has dual porphyria.

Treatment of a subject that would benefit from a reduction and/or inhibition of an ALAS1 gene expression includes therapeutic and prophylactic (*e.g.,* the subject is to undergo sensitized (or allogenic) transplant surgery) treatment.

The invention further provides methods and uses of an antisense polynucleotide agent or a pharmaceutical composition thereof for treating a subject that would benefit from reduction and/or inhibition of ALAS1 expression, *e.g.,* a subject having an ALAS1-associated disease, in combination with other pharmaceuticals and/or other therapeutic methods, *e.g.*, with known pharmaceuticals and/or known therapeutic methods, such as, for example, those which are currently employed for treating these disorders. For example, in certain embodiments, an antisense polynucleotide agent targeting ALAS1 is administered in combination with, *e.g.*, an agent useful in treating an ALAS1-associated disease as described elsewhere herein.

The antisense polynucleotide agent and an additional therapeutic agent and/or treatment may be administered at the same time and/or in the same combination, *e.g.*, parenterally, or the additional therapeutic agent can be administered as part of a separate

composition or at separate times and/or by another method known in the art or described herein.

The present invention also provides methods of using an antisense polynucleotide agent of the invention and/or a composition containing an antisense polynucleotide agent of the invention to reduce and/or inhibit ALAS1 expression in a cell. In other aspects, the present invention provides an antisense polynucleotide agent of the invention and/or a composition comprising an antisense polynucleotide agent of the invention for use in reducing and/or inhibiting ALAS1 expression in a cell. In yet other aspects, use of an antisense polynucleotide agent of the invention and/or a composition comprising an antisense polynucleotide agent of the invention for the manufactuire of a medicament for reducing and/or inhibiting ALAS1 expression in a cell are provided.

The methods and uses include contacting the cell with an antisense polynucleotide agent, *e.g.,* a antisense polynucleotide agent, of the invention and maintaining the cell for a time sufficient to obtain antisense inhibition of an ALAS1 gene, thereby inhibiting expression of the ALAS1 gene in the cell.

Reduction in gene expression can be assessed by any methods known in the art. For example, a reduction in the expression of ALAS1 may be determined by determining the mRNA expression level of ALAS1 using methods routine to one of ordinary skill in the art, *e.g.,* Northern blotting, qRT-PCR, by determining the protein level of ALAS1 using methods routine to one of ordinary skill in the art, such as Western blotting, immunological techniques, flow cytometry methods, ELISA, and/or by determining a biological activity of ALAS1.

In the methods and uses of the invention the cell may be contacted *in vitro* or *in vivo, i.e.,* the cell may be within a subject. In embodiments of the invention in which the cell is within a subject, the methods may include further contacting the cell with glucose and/or a heme product such as hemin.

A cell suitable for treatment using the methods of the invention may be any cell that expresses an ALAS1 gene. A cell suitable for use in the methods and uses of the invention may be a mammalian cell, *e.g.,* a primate cell (such as a human cell or a non-human primate cell, *e.g.*, a monkey cell or a chimpanzee cell), a non-primate cell (such as a cow cell, a pig cell, a camel cell, a llama cell, a horse cell, a goat cell, a rabbit cell, a sheep cell, a hamster, a guinea pig cell, a cat cell, a dog cell, a rat cell, a mouse cell, a lion cell, a tiger cell, a bear cell, or a buffalo cell), a bird cell (*e.g.*, a duck cell or a goose cell), or a whale cell. In one embodiment, the cell is a human cell, *e.g.,* a human liver cell.

ALAS1 expression may be inhibited in the cell by at least about 5%, 6%, 7%, 8%, 9%, 10%, 11%, 12%, 13%, 14%, 15%, 16%, 17%, 18%, 19%, 20%, 21%, 22%, 23%, 24%, 25%, 26%, 27%, 28%, 29%, 30%, 31%, 32%, 33%, 34%, 35%, 36%, 37%, 38%, 39%, 40%, 41%, 42%, 43%, 44%, 45%, 46%, 47%, 48%, 49%, 50%, 51%, 52%, 53%, 54%, 55%, 56%,

57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or about 100%.

The *in vivo* methods and uses of the invention may include administering to a subject a composition containing an antisense polynucleotide agent, where the antisense polynucleotide agent includes a nucleotide sequence that is complementary to at least a part of an RNA transcript of the ALAS1 gene of the mammal to be treated. When the organism to be treated is a mammal such as a human, the composition can be administered by any means known in the art including, but not limited to subcutaneous, intravenous, oral, intraperitoneal, or parenteral routes, including intracranial (*e.g.*, intraventricular, intraparenchymal and intrathecal), intramuscular, transdermal, airway (aerosol), nasal, rectal, and topical (including buccal and sublingual) administration. In certain embodiments, the compositions are administered by subcutaneous or intravenous infusion or injection.

In some embodiments, the administration is *via* a depot injection. A depot injection may release the antisense polynucleotide agent in a consistent way over a prolonged time period. Thus, a depot injection may reduce the frequency of dosing needed to obtain a desired effect, *e.g.*, a desired inhibition of ALAS1, or a therapeutic or prophylactic effect. A depot injection may also provide more consistent serum concentrations. Depot injections may include subcutaneous injections or intramuscular injections. In preferred embodiments, the depot injection is a subcutaneous injection.

In some embodiments, the administration is *via* a pump. The pump may be an external pump or a surgically implanted pump. In certain embodiments, the pump is a subcutaneously implanted osmotic pump. In other embodiments, the pump is an infusion pump. An infusion pump may be used for intravenous, subcutaneous, arterial, or epidural infusions. In preferred embodiments, the infusion pump is a subcutaneous infusion pump. In other embodiments, the pump is a surgically implanted pump that delivers the antisense polynucleotide agent to the liver.

The mode of administration may be chosen based upon whether local or systemic treatment is desired and based upon the area to be treated. The route and site of administration may be chosen to enhance targeting.

In one aspect, the present invention also provides methods for inhibiting the expression of an ALAS1 gene in a mammal, *e.g.*, a human. The present invention also provides a composition comprising an antisense polynucleotide agen that targets an ALAS1 gene in a cell of a mammal for use in inhibiting expression of the ALAS1 gene in the mammal. In another aspect, the present invention provides use of an antisense polynucleotide agen that targets an ALAS1 gene in a cell of a mammal in the manufacture of a medicament for inhibiting expression of the ALAS1 gene in the mammal.

The methods and uses include administering to the mammal, *e.g.,* a human, a composition comprising an antisense polynucleotide agent that targets an ALAS1 gene in a cell of the mammal and maintaining the mammal for a time sufficient to obtain antisense inhibition of the mRNA transcript of the ALAS1 gene, thereby inhibiting expression of the ALAS1 gene in the mammal. In some embodiment, the methods further comprise administering glucose and/or a heme product such as hemin to the subject.

Reduction in gene expression can be assessed by any methods known it the art and by methods, *e.g.* qRT-PCR, described herein. Reduction in protein production can be assessed by any methods known it the art and by methods, *e.g.*, ELISA or Western blotting, described herein. In one embodiment, a puncture liver biopsy sample serves as the tissue material for monitoring the reduction in ALAS1 gene and/or protein expression. In another embodiment, a blood sample serves as the tissue material for monitoring the reduction in ALAS1 gene and/or protein expression. In other embodiments, inhibition of the expression of an ALAS1 gene is monitored indirectly by, for example, determining the expression and/or activity of a gene in an ALAS1 pathway. Suitable assays are further described in the Examples section below.

This invention is further illustrated by the following examples which should not be construed as limiting. The entire contents of all references, patents and published patent applications cited throughout this application, as well as the Figures and the Sequence Listing, are hereby incorporated herein by reference.

EXAMPLES

Example 1. Antisense Synthesis

The antisense polynucleotides targeting ALAS1 were synthesized using standard synthesis methods well known in the art.

A detailed list of antisense molecules targeting ALAS1 is shown in Tables 3 and 4 below.

Table 2: Abbreviations of nucleotide monomers used in nucleic acid sequence representation. It will be understood that these monomers, when present in an oligonucleotide, are mutually linked by 5'-3'-phosphodiester bonds.

Abbreviation	Nucleotide(s)
A	Adenosine-3'-phosphate
Af	2'-fluoroadenosine-3'-phosphate
Afs	2'-fluoroadenosine-3'-phosphorothioate
As	adenosine-3'-phosphorothioate

Abbreviation	Nucleotide(s)
a	2'-O-methyladenosine-3'-phosphate
as	2'-O-methyladenosine-3'- phosphorothioate
C	cytidine-3'-phosphate
dA	2`-deoxyadenosine-3`-phosphate
dAs	2`-deoxyadenosine-3`-phosphorothioate
Cf	2'-fluorocytidine-3'-phosphate
Cfs	2'-fluorocytidine-3'-phosphorothioate
Cs	cytidine-3'-phosphorothioate
c	2'-O-methylcytidine-3'-phosphate
cs	2'-O-methylcytidine-3'- phosphorothioate
dC	2`-deoxycytidine-3`-phosphate
dCs	2`-deoxycytidine-3`-phosphorothioate
G	guanosine-3'-phosphate
Gf	2'-fluoroguanosine-3'-phosphate
Gfs	2'-fluoroguanosine-3'-phosphorothioate
Gs	guanosine-3'-phosphorothioate
g	2'-O-methylguanosine-3'-phosphate
gs	2'-O-methylguanosine-3'- phosphorothioate
dG	2`-deoxyguanosine-3`-phosphate
dGs	2`-deoxyguanosine-3`-phosphorothioate
T	5'-methyluridine-3'-phosphate
Tf	2'-fluoro-5-methyluridine-3'-phosphate
Tfs	2'-fluoro-5-methyluridine-3'-phosphorothioate
Ts	5-methyluridine-3'-phosphorothioate
t	2'-O-methyl-5-methyluridine-3'-phosphate
ts	2'-O-methyl-5-methyluridine-3'-phosphorothioate
dT	2`-deoxythymidine-3`-phosphate
dTs	2`-deoxythymidine-3`-phosphorothioate
U	Uridine-3'-phosphate
Uf	2'-fluorouridine-3'-phosphate
Ufs	2'-fluorouridine -3'-phosphorothioate
Us	uridine -3'-phosphorothioate
u	2'-O-methyluridine-3'-phosphate
us	2'-O-methyluridine-3'-phosphorothioate
dU	2`-deoxyuridine-3'-phosphate
dUs	2`-deoxyuridine-3`-phosphorothioate

Abbreviation	Nucleotide(s)
s	phosphorothioate linkage
N	any nucleotide (G, A, C, T or U)
L96	N-[tris(GalNAc-alkyl)-amidodecanoyl)]-4-hydroxyprolinol Hyp-(GalNAc-alkyl)3
(dt)	deoxy-thymine
(5MdC) or (m5dC)	5'-methyl-deoxycytidine-3`-phosphate
(5MdC)s or (m5dCs)	5'-methyl-deoxycytidine-3`-phosphorothioate

Table 3. Antisense polynucleotides targeting aminolevulinic acid synthase-1 (ALAS1)

Sequence ID	Alternative Sequence ID	Modified Sequence (5'-3')	SEQ ID NO:
A-130452.1	X10361	gsusgsascs(5MdC)sdGs(5MdC)sdTsdGs(5MdC)sdGs(5MdC)sdAsdTsdGsgscsgscsc	7
A-130453.1	X10362	usascsasgs(5MdC)sdGsdGsdGsdAsdGsdTsdGsdAs(5MdC)s(5MdC)scsgscsusg	8
A-130454.1	X10363	csgscscsusdTsdAsdAsdTsdAsdTsdAs(5MdC)sdAsdGs(5MdC)scsgsgsgsa	9
A-130455.1	X10364	csgsasuscsdGs(5MdC)s(5MdC)sdGsdGs(5MdC)sdGs(5MdC)s(5MdC)sdTsdTsusasasusa	10
A-130456.1	X10365	cscsuscsasdGsdGs(5MdC)s(5MdC)sdGs(5MdC)sdGsdAsdTs(5MdC)sdGsgscscsgsg	11
A-130457.1	X10366	cscsgsgsgsdAsdGs(5MdC)sdAsdGs(5MdC)s(5MdC)sdTs(5MdC)sdAsdGsgsgscscsg	12
A-130458.1	X10367	ususgscscs(5MdC)sdTsdTsdGsdTs(5MdC)s(5MdC)sdGsdGsdGsdAsasgscsasg	13
A-130459.1	X10368	gsasasascsdGs(5MdC)sdTs(5MdC)sdGsdTsdTsdGs(5MdC)s(5MdC)s(5MdC)scsususgsu	14
A-130460.1	X10369	asasgsuscs(5MdC)sdAsdAsdAs(5MdC)sdGsdAsdAsdAs(5MdC)sdGsgscsuscsg	15
A-130461.1	X10370	uscsasasgsdTs(5MdC)sdGsdAsdGsdAsdAsdGsdTs(5MdC)s(5MdC)scsasasasc	16
A-130462.1	X10371	asgsgscsgsdGsdGs(5MdC)sdAs(5MdC)sdTs(5MdC)sdAsdAsdGsdTsuscsgsasg	17
A-130463.1	X10372	gscsgsgscsdGsdAsdAsdGsdGsdAsdGsdGs(5MdC)sdGsdGsgsgscsasc	18
A-130464.1	X10373	usgscsasgsdAsdGsdGs(5MdC)sdGsdGs(5MdC)sdGsdGs(5MdC)sdGsgsasasgsg	19
A-130465.1	X10374	csgscsusgsdAsdGsdGsdAs(5MdC)sdTsdGs(5MdC)sdAsdGsdAsasgsgscsg	20
A-130466.1	X10375	gsgscsasusdAsdAs(5MdC)sdTsdGs(5MdC)sdGs(5MdC)sdTsdGsdAsasgsgsasc	21
A-130467.1	X10376	gsgsasasgsdAsdAs(5MdC)sdTsdGsdGsdGs(5MdC)sdAsdTsdAsasascsusg	22
A-130468.1	X10377	cscscscsas(5MdC)sdAsdGs(5MdC)sdGsdGsdGsdAsdAsdGsdAsasascsusg	23
A-130469.1	X10378	gsusgsgsus(5MdC)sdGsdTsdGsdTs(5MdC)s(5MdC)s(5MdC)s(5MdC)sdAs(5MdC)scsasgscsg	24
A-130470.1	X10379	gsgsasusus(5MdC)s(5MdC)sdTs(5MdC)s(5MdC)sdGsdTsdGsdGsdTs(5MdC)scsgsusgsu	25
A-130471.1	X10380	cscsusgsasdAsdGs(5MdC)sdAsdAsdGsdGsdAsdTsdTs(5MdC)scscsuscsc	26
A-130472.1	X10381	gsuscscscsdGsdAsdGsdTs(5MdC)s(5MdC)s(5MdC)sdTsdGsdAsdAsasgscsasa	27
A-130473.1	X10382	gsuscscsasdGs(5MdC)sdAsdGsdGsdGsdTs(5MdC)s(5MdC)s(5MdC)sdGsgsasgsusc	28
A-130474.1	X10383	csgsasgsgsdAsdAsdGsdGsdGsdGsdTs(5MdC)s(5MdC)sdAsdGsgscsasgsg	29
A-130475.1	X10384	cscscscsusdAsdAsdAs(5MdC)s(5MdC)s(5MdC)sdGsdAsdGsdGsdAsasasgsgsg	30

A-130476.1	X10385	gsuscscscs(5MdC)sdAs(5MdC)sdAsdTs(5MdC)s(5MdC)s(5MdC)s(5MdC)sdTsdAsasasascsc	31
A-130477.1	X10386	csusususcsdTs(5MdC)s(5MdC)sdTsdGsdGsdTs(5MdC)s(5MdC)s(5MdC)s(5MdC)scsascsasu	32
A-130478.1	X10387	gsgsgsasus(5MdC)s(5MdC)sdTsdGsdAs(5MdC)sdTsdTsdTs(5MdC)sdTsuscscsusg	33
A-130479.1	X10388	asasgsascsdTs(5MdC)sdTsdTsdAsdGsdGsdGsdAsdTs(5MdC)scscsusgsa	34
A-130480.1	X10389	cscsasgsgs(5MdC)sdAsdGsdGsdGsdAsdAsdGsdAs(5MdC)sdTsuscsususa	35
A-130481.1	X10390	ascsuscsasdTs(5MdC)s(5MdC)sdAsdTs(5MdC)s(5MdC)sdAsdGsdGs(5MdC)scsasgsgsg	36
A-130482.1	X10391	asgsasasgsdAsdAsdGs(5MdC)s(5MdC)sdAs(5MdC)sdTs(5MdC)sdAsdTsuscscsasu	37
A-130483.1	X10392	asuscsusasdGsdGsdTsdGsdGsdAsdGsdAsdAsdGsdAsasasgscsc	38
A-130484.1	X10393	usgsusgsgsdAsdAsdAsdGsdAsdAsdTs(5MdC)sdTsdAsdGsgsgsusgsg	39
A-130485.1	X10394	usgscsusgsdGs(5MdC)sdTs(5MdC)s(5MdC)sdTsdGsdTsdGsdGsdAsasasasgsa	40
A-130486.1	X10395	uscsasgsgsdAsdAsdGsdTsdAsdTsdGs(5MdC)sdTsdGsdGsgscsuscsc	41
A-130487.1	X10396	csuscsuscs(5MdC)sdAsdTsdGsdTsdTs(5MdC)sdAsdGsdGsdAsasasgsusa	42
A-130488.1	X10397	gscsgsasas(5MdC)sdAsdAs(5MdC)sdAs(5MdC)sdTs(5MdC)sdTs(5MdC)s(5MdC)scsasusgsu	43
A-130489.1	X10398	asusgsgsgs(5MdC)sdAsdGs(5MdC)sdGsdGs(5MdC)sdGsdAsdAs(5MdC)scsasascsa	44
A-130490.1	X10399	csgsgsgsasdTsdAsdAsdGsdAsdAsdTsdGsdGsdGs(5MdC)scsasgscsg	45
A-130491.1	X10400	csusgsgsgsdGsdGsdAs(5MdC)sdTs(5MdC)sdGsdGsdGsdAsdTsusasasgsa	46
A-130492.1	X10401	gscsasgsasdAsdAsdGsdGs(5MdC)s(5MdC)sdTsdGsdGsdGsdGsgsgsascsu	47
A-130493.1	X10402	cscsusgscsdTsdTsdTs(5MdC)sdTsdGs(5MdC)sdAsdGsdAsdAsasasgsgsc	48
A-130494.1	X10403	csasgsasgsdAsdTsdTsdTsdGs(5MdC)s(5MdC)sdTsdGs(5MdC)sdTsusususcsu	49
A-130495.1	X10404	csasusasgsdAsdAs(5MdC)sdAsdAs(5MdC)sdAsdGsdAsdGsdAsasusususg	50
A-130496.1	X10405	csasgsususdTsdTsdGsdGsdGs(5MdC)sdAsdTsdAsdGsdAsasascsasa	51
A-130497.1	X10406	csasuscsusdTsdGsdGsdGsdGs(5MdC)sdAsdGsdTsdTsdTsususgsgsg	52
A-130498.1	X10407	csasascsusdTs(5MdC)s(5MdC)sdAsdTs(5MdC)sdAsdTs(5MdC)sdTsdTsusgsgsgsg	53
A-130499.1	X10408	gsgscsususdGsdGs(5MdC)s(5MdC)s(5MdC)s(5MdC)sdAsdAs(5MdC)sdTsdTsuscscsasu	54
A-130500.1	X10409	cscsgsasgsdGsdGsdGs(5MdC)sdTsdGsdGs(5MdC)sdTsdTsdGsgsgscscsc	55
A-130501.1	X10410	usgsgsascsdAsdAsdTsdGs(5MdC)s(5MdC)s(5MdC)sdGsdAsdGsdGsgsgsgscsu	56
A-130502.1	X10411	ascsusgscsdTsdGs(5MdC)sdAsdGsdTsdGsdGsdAs(5MdC)sdAsasasusgsc	57
A-130503.1	X10412	ususgsgsusdAsdGsdTsdGsdTsdAs(5MdC)sdTsdGs(5MdC)sdTsusgscsasg	58

A-130504.1	X10413	csususugsdAsdTs(5MdC)sdTsdGsdTsdTsdGsdGsdTsdAsasgsusgsu	59
A-130505.1	X10414	ggsgasgsgsdGsdGsdTsdTsdTs(5MdC)sdTsdTsdTsdGsdAsasuscsusg	60
A-130506.1	X10415	csuscsascsdTsdGsdGs(5MdC)s(5MdC)sdGsdGsdAsdGsdGsdGsgsgsususu	61
A-130507.1	X10416	ususususgsdTs(5MdC)sdTsdTsdTs(5MdC)sdTs(5MdC)sdAs(5MdC)sdTsusgsgscsc	62
A-130508.1	X10417	gscscsususdAsdGs(5MdC)sdAsdGsdTsdTsdTsdGsdTsuscsususu	63
A-130509.1	X10418	ususgsgsas(5MdC)s(5MdC)sdTsdTsdGsdGs(5MdC)s(5MdC)sdTsdTsdAsasgscsasg	64
A-130510.1	X10419	csasggsgsasdGsdTs(5MdC)sdTsdTsdGsdGsdAs(5MdC)scscsususg	65
A-130511.1	X10420	usgsgsgsgasdTs(5MdC)s(5MdC)sdAsdTs(5MdC)sdAsdGsdGsdAsdGsgsuscsusg	66
A-130512.1	X10421	usgsgsascsdTs(5MdC)sdTsdGs(5MdC)sdTsdGsdGsdGsdAsdTsuscscsasu	67
A-130513.1	X10422	gsusgsusgs(5MdC)s(5MdC)sdAsdTs(5MdC)sdTsdGsdGsdAs(5MdC)sdTsuscsusgsc	68
A-130514.1	X10423	gsascsgsgsdAsdAsdGs(5MdC)sdTsdGsdTsdGsdTsdGs(5MdC)scscsasusc	69
A-130515.1	X10424	gsgsgsgsusdGsdTs(5MdC)s(5MdC)sdAsdGsdAs(5MdC)sdGsdGsdGsdAsasasgscsu	70
A-130516.1	X10425	usgsgscsasdGsdGs(5MdC)sdAsdAsdGsdGsdGsdGsdTsdGsgsuscscsa	71
A-130517.1	X10426	cscscsusgsdGs(5MdC)sdTsdTsdGsdTsdGsdGs(5MdC)sdAsdGsgsgscsasa	72
A-130518.1	X10427	gscsususgs(5MdC)sdAsdGsdTsdGs(5MdC)s(5MdC)s(5MdC)sdTsdGsdGsgscsususg	73
A-130519.1	X10428	asasgsgsgs(5MdC)sdAsdTsdTsdTsdGs(5MdC)sdTsdTsdGs(5MdC)scsasgsusg	74
A-130520.1	X10429	gscsusgscs(5MdC)sdAsdGsdGsdAsdAsdGsdGsdGs(5MdC)scsasususu	75
A-130521.1	X10430	asususcsasdTs(5MdC)sdTsdGsdTsdGs(5MdC)sdTsdGs(5MdC)s(5MdC)scsasggsa	76
A-130522.1	X10431	usgscscsus(5MdC)sdTs(5MdC)sdTsdGsdAsdTsdTs(5MdC)sdAsdTsuscsusgsu	77
A-130523.1	X10432	asasgsascsdAs(5MdC)sdTsdGs(5MdC)sdTsdGs(5MdC)s(5MdC)sdTs(5MdC)scsuscsusg	78
A-130524.1	X10433	ggsgscsususdTsdGs(5MdC)sdAsdGsdAsdAsdGsdAs(5MdC)sdAsascsusgsc	79
A-130525.1	X10434	gscsuscsasdAsdGsdAs(5MdC)sdTsdGsdGs(5MdC)sdTsdTsdTsusgscsasg	80
A-130526.1	X10435	uscscsuscs(5MdC)sdTsdGsdAsdAsdGs(5MdC)sdTs(5MdC)sdAsdAsasgsascsu	81
A-130527.1	X10436	ususcscsusdGs(5MdC)sdAs(5MdC)sdAsdTs(5MdC)s(5MdC)sdTs(5MdC)s(5MdC)scsusgsasa	82
A-130528.1	X10437	csgsgscsasdTsdTs(5MdC)sdAsdTsdTsdTs(5MdC)s(5MdC)sdTsdGsgscsascsa	83
A-130529.1	X10438	uscsususus(5MdC)s(5MdC)sdTs(5MdC)sdAs(5MdC)sdGsdGs(5MdC)sdAsdTsususcsasu	84
A-130530.1	X10439	ususcsasgs(5MdC)sdAsdAs(5MdC)s(5MdC)sdTs(5MdC)sdTsdTsdTs(5MdC)scscsuscsa	85
A-130531.1	X10440	csusgscsusdGsdAsdGsdGsdTsdTs(5MdC)sdAsdGs(5MdC)scsasascsc	86

A-130532.1	X10441	ascsascsusdGsdGsdGsdGs(5MdC)s(5MdC)sdTsdGs(5MdC)sdTsdGsgsasgsgsu	87
A-130533.1	X10442	csascsascsdTsdAsdAs(5MdC)s(5MdC)sdAs(5MdC)sdAs(5MdC)sdTsdGsgsgsgsgsc	88
A-130534.1	X10443	csasuscsgsdGsdTsdTsdTsdTs(5MdC)sdAs(5MdC)sdAs(5MdC)sdTsusasascsc	89
A-130535.1	X10444	gsgsasuscs(5MdC)s(5MdC)s(5MdC)sdTs(5MdC)s(5MdC)sdAsdTs(5MdC)sdGsdGsgsusususu	90
A-130536.1	X10445	csasgsuscs(5MdC)sdAs(5MdC)sdTsdGsdGsdGsdAsdTs(5MdC)s(5MdC)scscscsusc	91
A-130537.1	X10446	asgsususcsdTsdTs(5MdC)sdAsdGs(5MdC)sdAsdGsdTs(5MdC)s(5MdC)scsascsusg	92
A-130538.1	X10447	asusgsuscs(5MdC)sdTsdGsdGsdAsdAsdGsdTsdTs(5MdC)sdTsususcsasg	93
A-130539.1	X10448	csususususdGs(5MdC)sdAsdTsdGsdAsdTsdGsdTs(5MdC)s(5MdC)scsusgsgsa	94
A-130540.1	X10449	csusgsgsus(5MdC)sdTsdTsdTsdGs(5MdC)sdTsdTsdTsdTsdGsgscsasusg	95
A-130541.1	X10450	uscsusgsgsdTs(5MdC)sdTsdTsdTsdGs(5MdC)sdTsdTsdTsdTsusgscsasu	96
A-130542.1	X10451	ususcsusgsdGsdTs(5MdC)sdTsdTsdTsdGs(5MdC)sdTsdTsdTsususgscsa	97
A-130543.1	X10452	usususcsusdGsdGsdTs(5MdC)sdTsdTsdTsdGs(5MdC)sdTsdTsususususgsc	98
A-130544.1	X10453	csusususcsdTsdGsdGsdTs(5MdC)sdTsdTsdTsdGs(5MdC)sdTsususususg	99
A-130545.1	X10454	uscsususus(5MdC)sdTsdGsdGsdTs(5MdC)sdTsdTsdTsdGs(5MdC)scsususususu	100
A-130546.1	X10455	csuscsususdTs(5MdC)sdTsdGsdGsdTs(5MdC)sdTsdTsdTsdGsgscsususu	101
A-130547.1	X10456	ascsuscsusdTsdTs(5MdC)sdTsdGsdGsdTs(5MdC)sdTsdTsdTsusgscsusu	102
A-130548.1	X10457	csascsuscsdTsdTsdTs(5MdC)sdTsdGsdGsdTs(5MdC)sdTsdTsususgscsu	103
A-130549.1	X10458	ascsascsus(5MdC)sdTsdTsdTs(5MdC)sdTsdGsdGsdTs(5MdC)sdTsususususgsc	104
A-130550.1	X10459	gsascsascsdTs(5MdC)sdTsdTsdTs(5MdC)sdTsdGsdGsdTs(5MdC)scsususususg	105
A-130551.1	X10460	asgsascsas(5MdC)sdTs(5MdC)sdTsdTsdTs(5MdC)sdTsdGsdGsdTsuscsususu	106
A-130552.1	X10461	gsasgsascsdAs(5MdC)sdTs(5MdC)sdTsdTsdTs(5MdC)sdTsdGsdGsgsuscsusu	107
A-130553.1	X10462	usgsasgsas(5MdC)sdAs(5MdC)sdTs(5MdC)sdTsdTsdTs(5MdC)sdTsdGsgsgsuscsu	108
A-130554.1	X10463	asusgsasgsdAs(5MdC)sdAs(5MdC)sdTs(5MdC)sdTsdTsdTs(5MdC)sdTsusgsgsusc	109
A-130555.1	X10464	gsasusgsasdGsdAs(5MdC)sdAs(5MdC)sdTs(5MdC)sdTsdTsdTs(5MdC)scsusgsgsu	110
A-130556.1	X10465	asgsasusgsdAsdGsdAs(5MdC)sdAs(5MdC)sdTs(5MdC)sdTsdTsdTsuscsusgsg	111
A-130557.1	X10466	asasgsasusdGsdAsdGsdAs(5MdC)sdAs(5MdC)sdTs(5MdC)sdTsdTsususcsusg	112
A-130558.1	X10467	gsasasgsasdTsdGsdAsdGsdAs(5MdC)sdAs(5MdC)sdTs(5MdC)sdTsusususcsu	113
A-130559.1	X10468	asgsasasgsdAsdTsdGsdAsdGsdAs(5MdC)sdAs(5MdC)sdTs(5MdC)scsusususc	114

A-130560.1	X10469	asasgsasasdGsdAsdTsdGsdAsdGsdAs(5MdC)sdAs(5MdC)sdTsuscsususu	115
A-130561.1	X10470	gsasasgsasdAsdGsdAsdTsdGsdAsdGsdAs(5MdC)sdAs(5MdC)scsuscsusu	116
A-130562.1	X10471	usgsasasgsdAsdAsdGsdAsdTsdGsdAsdGsdAs(5MdC)sdAsascsuscsu	117
A-130563.1	X10472	ususgsasasdGsdAsdAsdGsdAsdTsdGsdAsdGsdAs(5MdC)scsascsusc	118
A-130564.1	X10473	csususgsasdAsdGsdAsdAsdGsdAsdTsdGsdAsdGsdAsascsascsu	119
A-130565.1	X10474	uscsususgsdAsdAsdGsdAsdAsdGsdAsdTsdGsdAsdGsgsascsasc	120
A-130566.1	X10475	asuscsususdGsdAsdAsdGsdAsdAsdGsdAsdTsdGsdAsasgsascsa	121
A-130567.1	X10476	usasuscsusdTsdGsdAsdAsdGsdAsdAsdGsdAsdTsdGsgsasgsasc	122
A-130568.1	X10477	ususasuscsdTsdTsdGsdAsdAsdGsdAsdAsdGsdAsdTsusgsasgsa	123
A-130569.1	X10478	gsususasus(5MdC)sdTsdTsdGsdAsdAsdGsdAsdAsdGsdAsasusgsasg	124
A-130570.1	X10479	asgsususasdTs(5MdC)sdTsdTsdGsdAsdAsdGsdAsdAsdGsgsasusgsa	125
A-130571.1	X10480	asasgsususdAsdTs(5MdC)sdTsdTsdGsdAsdAsdGsdAsdAsasgsasusg	126
A-130572.1	X10481	gsasusususdTsdGsdGs(5MdC)sdAsdAsdGsdTsdTsdAsdTsuscsususg	127
A-130573.1	X10482	asgsusgsgsdAsdAsdAs(5MdC)sdAsdGsdAsdTsdTsdTsdTsusgsgscsa	128
A-130574.1	X10483	csasusascsdTsdGsdAsdAsdAsdAsdGsdTsdGsdGsdAsasasascsa	129
A-130575.1	X10484	asasgsasasdAs(5MdC)sdGsdAsdTs(5MdC)sdAsdTsdAs(5MdC)sdTsusgsasasa	130
A-130576.1	X10485	ususususususdTs(5MdC)sdTs(5MdC)sdAsdAsdAsdGsdAsdAsdAsascsgsasu	131
A-130577.1	X10486	uscsuscsasdTs(5MdC)sdAsdAsdTsdTsdTsdTsdTsdTsuscsuscsa	132
A-130578.1	X10487	uscsasusus(5MdC)sdTsdTsdTsdTsdTs(5MdC)sdTs(5MdC)sdAsdTsuscsasasu	133
A-130579.1	X10488	asusasgsgsdTsdGsdTsdGsdGsdTs(5MdC)sdAsdTsdTs(5MdC)scsususususu	134
A-130580.1	X10489	usasasasasdAs(5MdC)sdTs(5MdC)sdGsdAsdTsdAsdGsdGsdTsusgsusgsg	135
A-130581.1	X10490	ususcsascsdAsdGsdTsdTsdTsdTsdAsdAsdAsdAsdAsascsuscsg	136
A-130582.1	X10491	usgscsuscsdGs(5MdC)s(5MdC)sdGsdGsdTsdTs(5MdC)sdAs(5MdC)sdAsasgsususu	137
A-130583.1	X10492	gsgsasasgsdAsdTsdGsdTsdGsdTsdGs(5MdC)sdTs(5MdC)sdGsgscscsgsg	138
A-130584.1	X10493	uscsusgscs(5MdC)sdAsdTsdGsdGsdGsdGsdAsdAsdGsdAsasusgsusg	139
A-130585.1	X10494	usgsasasusdAsdGsdTs(5MdC)sdAsdTs(5MdC)sdTsdGs(5MdC)s(5MdC)scsasusgsg	140
A-130586.1	X10495	usgsasgsgsdGsdAsdGsdTs(5MdC)sdTsdGsdAsdAsdTsdAsasgsuscsa	141
A-130587.1	X10496	ususususususdGsdGsdTsdGsdAsdTsdGsdAsdGsdGsdGsgsasgsusc	142

A-130588.1	X10497	usgsascsas(5MdC)sdTsdTsdGs(5MdC)sdTsdTsdTsdTsdTsdGsgsgsusgsa	143
A-130589.1	X10498	usgscsascs(5MdC)sdAsdGsdAs(5MdC)sdTsdGsdAs(5MdC)sdAs(5MdC)scsususgsc	144
A-130590.1	X10499	usasgsuscsdAsdTsdTsdAs(5MdC)sdTsdGs(5MdC)sdAs(5MdC)s(5MdC)scsasgsasc	145
A-130591.1	X10500	csasususcs(5MdC)sdTsdAsdGsdGsdTsdAsdGsdTs(5MdC)sdAsasususasc	146
A-130592.1	X10501	gsgsusgsgs(5MdC)sdGsdAs(5MdC)sdTs(5MdC)sdAsdTsdTs(5MdC)s(5MdC)scsusasgsg	147
A-130593.1	X10502	csascsascs(5MdC)s(5MdC)sdGsdTsdGsdGsdGsdTsdGsdGs(5MdC)scsgsascsu	148
A-130594.1	X10503	asascsusgs(5MdC)s(5MdC)s(5MdC)s(5MdC)sdAs(5MdC)sdAs(5MdC)sdAs(5MdC)s(5MdC)scscsgsusg	149
A-130595.1	X10504	asasgsusgsdTs(5MdC)s(5MdC)sdAsdTsdAsdAs(5MdC)sdTsdGs(5MdC)scscscscsa	150
A-130596.1	X10505	usgsususgsdTsdTsdTs(5MdC)sdAsdAsdAsdGsdTsdGsdTsuscscsasu	151
A-130597.1	X10506	cscscsasgs(5MdC)sdAs(5MdC)s(5MdC)sdAsdTsdGsdTsdTsdGsdTsusususcsa	152
A-130598.1	X10507	usascscsas(5MdC)s(5MdC)sdTsdGs(5MdC)s(5MdC)s(5MdC)s(5MdC)sdAsdGs(5MdC)scsascscsa	153
A-130599.1	X10508	asusasususdTs(5MdC)sdTsdAsdGsdTsdAs(5MdC)s(5MdC)sdAs(5MdC)scscsusgsc	154
A-130600.1	X10509	asgsususcs(5MdC)sdAsdGsdAsdAsdAsdTsdAsdTsdTsdTsuscsusasg	155
A-130601.1	X10510	gsgsasasusdTsdTsdAs(5MdC)sdTsdAsdGsdTsdTs(5MdC)s(5MdC)scsasgsasa	156
A-130602.1	X10511	asasgsuscs(5MdC)sdAs(5MdC)sdAsdTsdGsdGsdAsdAsdTsdTsususascsu	157
A-130603.1	X10512	csuscscscsdGs(5MdC)sdTs(5MdC)sdTsdAsdAsdGsdTs(5MdC)s(5MdC)scsascsasu	158
A-130604.1	X10513	gsgsuscsusdGs(5MdC)s(5MdC)sdAsdGs(5MdC)sdTs(5MdC)s(5MdC)s(5MdC)sdGsgscsuscsu	159
A-130605.1	X10514	ususcscscsdAsdTsdGsdGsdAsdGsdGsdTs(5MdC)sdTsdGsgscscsasg	160
A-130606.1	X10515	usgscsgsgs(5MdC)sdAsdTs(5MdC)sdTsdTsdTs(5MdC)s(5MdC)s(5MdC)sdAsasusgsgsa	161
A-130607.1	X10516	asasasascsdAsdAsdGsdAsdGsdTsdGs(5MdC)sdGsdGs(5MdC)scsasuscsu	162
A-130608.1	X10517	asasgscsas(5MdC)sdGsdAsdGsdGsdAsdAsdAsdAs(5MdC)sdAsasasgsasg	163
A-130609.1	X10518	asususgsgs(5MdC)s(5MdC)sdAs(5MdC)sdAsdAsdAsdGs(5MdC)sdAs(5MdC)scsgsasgsg	164
A-130610.1	X10519	gsgsgsususdGsdAsdGsdTs(5MdC)sdAsdTsdTsdGsdGs(5MdC)scscsascsa	165
A-130611.1	X10520	asgsgsgsusdGsdAsdAsdGsdAsdGsdGsdGsdTsdTsdGsgsasgsusc	166
A-130612.1	X10521	csasuscsusdTsdAsdGs(5MdC)s(5MdC)sdAsdGsdGsdGsdTsdGsgsasasgsa	167
A-130613.1	X10522	asgscscsusdGsdGs(5MdC)sdAsdTs(5MdC)sdAsdTs(5MdC)sdTsdTsusasgscsc	168
A-130614.1	X10523	usasasasus(5MdC)sdTs(5MdC)sdAs(5MdC)sdAsdGs(5MdC)s(5MdC)sdTsdGsgsgscsasu	169
A-130615.1	X10524	asgsasasus(5MdC)sdAsdGsdAsdGsdTsdAsdAsdAsdTs(5MdC)scsuscsasc	170

A-130616.1	X10525	csasusgsgsdTsdTs(5MdC)s(5MdC)s(5MdC)sdAsdGsdAsdAsdTs(5MdC)scsasgsasg	171
A-130617.1	X10526	asuscsasusdGsdGsdAsdGsdGs(5MdC)sdAsdTsdGsdGsdTsususcscsc	172
A-130618.1	X10527	asasuscscs(5MdC)sdTsdTsdGsdGsdAsdTs(5MdC)sdAsdTsdGsgsgsasgsg	173
A-130619.1	X10528	gsgscsusgsdTsdTsdTs(5MdC)sdGsdAsdAsdTs(5MdC)s(5MdC)s(5MdC)scsususgsg	174
A-130620.1	X10529	usususgsgs(5MdC)sdAs(5MdC)sdTs(5MdC)sdGsdGs(5MdC)sdTsdGsdTsusususcsg	175
A-130621.1	X10530	gsasasgsasdTsdGsdTsdAs(5MdC)sdTsdTsdTsdGsdGs(5MdC)scsascsusc	176
A-130622.1	X10531	csasususgsdTsdGsdGs(5MdC)sdGsdGsdAsdAsdGsdAsdTsusgsusasc	177
A-130623.1	X10532	usgsgscsusdGsdAs(5MdC)sdAsdTs(5MdC)sdAsdTsdTsdGsdTsusgsgscsg	178
A-130624.1	X10533	ususcsuscsdTsdGsdAsdGsdGsdTsdGsdGs(5MdC)sdTsdGsgsascsasu	179
A-130625.1	X10534	usususgscsdAsdGs(5MdC)sdAsdGsdTsdTs(5MdC)sdTs(5MdC)sdTsusgsasgsg	180
A-130626.1	X10535	gsgsgsuscsdAsdGsdAsdTs(5MdC)sdTsdTsdTsdGs(5MdC)sdAsasgscsasg	181
A-130627.1	X10536	gsgsgsgsas(5MdC)sdTsdGsdAsdGsdGsdGsdGsdTs(5MdC)sdAsasgsasusc	182
A-130628.1	X10537	cscsascsasdAsdTs(5MdC)sdTsdTsdGsdGsdGsdGsdAs(5MdC)scsusgsasg	183
A-130629.1	X10538	gsusususcsdAsdAsdAsdTsdGs(5MdC)s(5MdC)sdAs(5MdC)sdAsdAsasuscsusu	184
A-130630.1	X10539	usgsasasusdGsdGsdAs(5MdC)sdAsdGsdTsdTsdTs(5MdC)sdAsasasasusg	185
A-130631.1	X10540	cscscscsasdTs(5MdC)s(5MdC)sdAsdTsdTsdGsdAsdAsdTsdGsgsgsascsa	186
A-130632.1	X10541	gsgsgscsas(5MdC)sdAs(5MdC)s(5MdC)sdGs(5MdC)s(5MdC)s(5MdC)s(5MdC)sdAsdTsuscscsasu	187
A-130633.1	X10542	csuscsusus(5MdC)s(5MdC)sdAsdGsdTsdGsdGsdGs(5MdC)sdAs(5MdC)scsascscsg	188
A-130634.1	X10543	csasuscsas(5MdC)sdAs(5MdC)sdAsdGs(5MdC)sdTs(5MdC)sdTsdTs(5MdC)scscsasgsu	189
A-130635.1	X10544	uscsasusgsdGsdGs(5MdC)s(5MdC)sdAs(5MdC)sdAsdTs(5MdC)sdAs(5MdC)scsascsasg	190
A-130636.1	X10545	usgscsuscs(5MdC)sdAsdAsdAs(5MdC)sdTs(5MdC)sdAsdTsdGsdGsgsgscscsa	191
A-130637.1	X10546	csgsasasgsdGsdTsdGsdAsdTsdTsdGs(5MdC)sdTs(5MdC)s(5MdC)scsasasasc	192
A-130638.1	X10547	ascscsuscsdAsdTs(5MdC)s(5MdC)sdAs(5MdC)sdGsdAsdAsdGsdGsgsusgsasu	193
A-130639.1	X10548	csascsusgs(5MdC)sdGsdTsdGsdGsdAs(5MdC)s(5MdC)sdTs(5MdC)sdAsasuscscsa	194
A-130640.1	X10549	csasusasasdAsdGs(5MdC)s(5MdC)s(5MdC)s(5MdC)sdAs(5MdC)sdTsdGs(5MdC)scsgsusgsg	195
A-130641.1	X10550	cscsuscsgsdAsdGs(5MdC)s(5MdC)s(5MdC)s(5MdC)sdAsdTsdAsdAsdAsasgscscsc	196
A-130642.1	X10551	asasuscscs(5MdC)sdTs(5MdC)s(5MdC)sdGs(5MdC)s(5MdC)sdTs(5MdC)sdGsdAsasgscscsc	197
A-130643.1	X10552	cscscsgsasdTs(5MdC)s(5MdC)s(5MdC)s(5MdC)sdAsdAsdTs(5MdC)s(5MdC)s(5MdC)scsuscscsg	198

A-130644.1	X10553	asusgsascsdTs(5MdC)s(5MdC)sdAsdTs(5MdC)s(5MdC)s(5MdC)sdGsdAsdTsuscscscsc	199
A-130645.1	X10554	csasususdTsdTsdGsdGs(5MdC)sdAsdTsdGsdAs(5MdC)sdTsuscscsasu	200
A-130646.1	X10555	asasasusgsdAsdTsdGsdTs(5MdC)s(5MdC)sdAsdTsdTsdTsdTsususgsgsc	201
A-130647.1	X10556	asgsusgsusdTs(5MdC)s(5MdC)sdAsdGsdAsdAsdAsdTsdGsdAsasusgsusc	202
A-130648.1	X10557	gsgscsususdTsdGs(5MdC)s(5MdC)sdAsdAsdGsdTsdGsdTsdTsuscscsasg	203
A-130649.1	X10558	csascsasas(5MdC)s(5MdC)sdAsdAsdAsdGsdGs(5MdC)sdTsdTsdTsusgscscsa	204
A-130650.1	X10559	usascscscsdTs(5MdC)s(5MdC)sdAsdAs(5MdC)sdAs(5MdC)sdAsdAs(5MdC)scscsasasa	205
A-130651.1	X10560	gscsusgsgs(5MdC)sdGsdAsdTsdGsdTsdAs(5MdC)s(5MdC)s(5MdC)sdTsuscscsasa	206
A-130652.1	X10561	gsasgsasas(5MdC)sdTs(5MdC)sdGsdTsdGs(5MdC)sdTsdGsdGs(5MdC)scsgsasusg	207
A-130653.1	X10562	gsusgsuscsdAsdAsdTs(5MdC)sdAsdGsdAsdGsdAsdAs(5MdC)scsuscsgsu	208
A-130654.1	X10563	gsgsascscsdGsdTsdAs(5MdC)sdGsdGsdTsdGsdTs(5MdC)sdAsasasuscsa	209
A-130655.1	X10564	csasgscsasdGs(5MdC)sdAsdTsdAsdGsdGsdAs(5MdC)s(5MdC)sdGsgsusascsg	210
A-130656.1	X10565	asasgsasusdGsdAsdAsdGs(5MdC)s(5MdC)sdAsdGs(5MdC)sdAsdGsgscsasusa	211
A-130657.1	X10566	asgsasgsgsdTsdGsdGsdTsdGsdAsdAsdGsdAsdTsdGsgsasasgsc	212
A-130658.1	X10567	usgsgsgsusdGsdGs(5MdC)sdAsdGsdAsdGsdAsdGsdGsdTsusgsgsusg	213
A-130659.1	X10568	gscscsasgs(5MdC)sdAsdGs(5MdC)sdAsdTsdGsdGsdGsdTsdGsgsgscsasg	214
A-130660.1	X10569	csasgsgsgs(5MdC)sdTs(5MdC)s(5MdC)sdAsdGs(5MdC)s(5MdC)sdAsdGs(5MdC)scsasgscsa	215
A-130661.1	X10570	gscsascsasdGsdAs(5MdC)sdTs(5MdC)s(5MdC)sdAsdGsdGsdGs(5MdC)scsuscscsa	216
A-130662.1	X10571	ususcsasgsdGsdAsdTs(5MdC)s(5MdC)sdGs(5MdC)sdAs(5MdC)sdAsdGsgsascsusc	217
A-130663.1	X10572	csuscsasgs(5MdC)sdGs(5MdC)sdTs(5MdC)sdTsdTs(5MdC)sdAsdGsdGsgsasuscsc	218
A-130664.1	X10573	gscsascscs(5MdC)sdGsdTs(5MdC)s(5MdC)s(5MdC)sdTs(5MdC)sdAsdGs(5MdC)scsgscsusc	219
A-130665.1	X10574	usgsgscsgsdGs(5MdC)sdGsdAsdAsdGs(5MdC)sdAs(5MdC)s(5MdC)s(5MdC)scsgsuscsc	220
A-130666.1	X10575	gscsgscsusdGsdGsdTsdGs(5MdC)sdTsdGsdGs(5MdC)sdGsdGsgscsgsasa	221
A-130667.1	X10576	gsusususgsdAs(5MdC)sdGsdTsdTsdGs(5MdC)sdGs(5MdC)sdTsdGsgsgsusgsc	222
A-130668.1	X10577	usgsuscsus(5MdC)sdAsdTsdGsdAsdGsdTsdTsdTsdGsdAsascsgsusu	223
A-130669.1	X10578	csasususasdGs(5MdC)sdAsdTs(5MdC)sdTsdGsdTs(5MdC)sdTs(5MdC)scsasusgsa	224
A-130670.1	X10579	gsgscscsgsdGs(5MdC)sdAsdTs(5MdC)s(5MdC)sdAsdTsdTsdAsdGsgscsasusc	225
A-130671.1	X10580	ascsasascsdAsdGsdGsdGsdAsdGsdGs(5MdC)s(5MdC)sdGsdGsgscsasusc	226

A-130672.1	X10581	gsggsggscsdAsdGsdTsdGsdGsdAs(5MdC)sdAsdAs(5MdC)sdAsasggsggsa	227
A-130673.1	X10582	usgsasusgsdTsdGsdGs(5MdC)sdTsdGsdGsdGsdGs(5MdC)sdAsasgsusgsg	228
A-130674.1	X10583	csgscsascsdAsdGsdGsdGsdAsdTsdGsdTsusggsgscsu	229
A-130675.1	X10584	asuscsusgs(5MdC)sdAsdAs(5MdC)s(5MdC)sdGs(5MdC)sdAs(5MdC)sdAsasggsggsa	230
A-130676.1	X10585	ususususasdGs(5MdC)sdAsdGs(5MdC)sdAsdTs(5MdC)sdTsdGs(5MdC)scsasascsc	231
A-130677.1	X10586	ascsususcsdTsdGsdTsdGsdTsdTsdTsdAsdGsgscsasgsc	232
A-130678.1	X10587	ususcsasus(5MdC)sdAs(5MdC)sdAsdGsdAs(5MdC)sdTsdTs(5MdC)sdTsusgsusgsu	233
A-130679.1	X10588	usgscsuscsdAsdTsdTsdAsdGsdTsdTs(5MdC)sdAsdTs(5MdC)scsascsasg	234
A-130680.1	X10589	asusgsususdAsdTsdGsdTs(5MdC)sdTsdGs(5MdC)sdTs(5MdC)sdAsasususasg	235
A-130681.1	X10590	ususgscsas(5MdC)sdGsdTsdAsdGsdAsdTsdGsdTsdTsdAsasusgsusc	236
A-130682.1	X10591	asasususgsdAsdTsdTsdGs(5MdC)sdTsdTsdGs(5MdC)sdAs(5MdC)scsgsusasg	237
A-130683.1	X10592	ascscsgsusdAsdGsdGsdGsdTsdAsdAsdTsdTsdGsdAsasususgsc	238
A-130684.1	X10593	uscscscscsdGsdGsdGsdGs(5MdC)sdAs(5MdC)s(5MdC)sdGsdTsdAsasgsgsgsu	239
A-130685.1	X10594	gsgsasgscsdTs(5MdC)sdTsdTs(5MdC)sdTs(5MdC)s(5MdC)s(5MdC)s(5MdC)sdGsgsgsgsgsc	240
A-130686.1	X10595	gscsasasus(5MdC)s(5MdC)sdGsdTsdAsdGsdGsdAsdGs(5MdC)sdTsuscsususc	241
A-130687.1	X10596	asgsgsgsgsdTsdGsdGsdGsdGs(5MdC)sdAsdAsdTs(5MdC)scscsgsusa	242
A-130688.1	X10597	gsusgsusgsdTsdGsdGsdTsdGsdAsdGsdGsdGsdTsusgsgsgsg	243
A-130689.1	X10598	asuscsasus(5MdC)sdTsdGsdGsdGsdGsdTsdGsdTsdGsdTsusgsgsusg	244
A-130690.1	X10599	gsasasgsusdAsdGsdTsdTs(5MdC)sdAsdTs(5MdC)sdAsdTs(5MdC)scsusgsgsg	245
A-130691.1	X10600	gsasususcsdTs(5MdC)sdAsdAsdGsdGsdAsdAsdGsdTsdAsasgsususc	246
A-130692.1	X10601	gsusgsascsdTsdAsdGs(5MdC)sdAsdGsdAsdTsdTs(5MdC)sdTsuscsasasg	247
A-130693.1	X10602	ususgscsusdTs(5MdC)s(5MdC)sdAsdTsdGsdTsdGsdAs(5MdC)sdTsusasgscsa	248
A-130694.1	X10603	cscsasgscs(5MdC)s(5MdC)s(5MdC)sdAs(5MdC)sdTsdTsdGs(5MdC)sdTsdTsuscscsasu	249
A-130695.1	X10604	ggscsusus(5MdC)sdAsdGsdTsdTs(5MdC)s(5MdC)sdAsdGs(5MdC)s(5MdC)scscscsasc	250
A-130696.1	X10605	usgsasggsdAsdAsdTsdGsdAsdGsdGs(5MdC)sdTsdTs(5MdC)scsasgsusu	251
A-130697.1	X10606	usgscsascsdTs(5MdC)sdAsdGs(5MdC)sdTsdGsdAsdGsdGsdAsasasusgsa	252
A-130698.1	X10607	csusgscsasdGsdAsdAsdGsdTsdTsdGs(5MdC)sdAs(5MdC)sdTsuscsasgsc	253
A-130699.1	X10608	csasgsusgsdGs(5MdC)s(5MdC)sdTs(5MdC)s(5MdC)sdTsdGs(5MdC)sdAsdGsgsasasgsu	254

A-130700.1	X10609	csususcsasdAsdAsdAsdTsdGs(5MdC)sdAsdGsdTsdGsdGsgscscsusc	255
A-130701.1	X10610	uscsascsus(5MdC)sdAsdTs(5MdC)sdAs(5MdC)sdTsdTs(5MdC)sdAsdAsasasasusg	256
A-130702.1	X10611	csususcsus(5MdC)sdTs(5MdC)sdTsdTsdTs(5MdC)sdAs(5MdC)sdTs(5MdC)scsasuscsa	257
A-130703.1	X10612	asgsasasasdTsdAsdGsdGsdAs(5MdC)sdTsdTs(5MdC)sdTs(5MdC)scsuscsusu	258
A-130704.1	X10613	csuscsasasdGs(5MdC)s(5MdC)sdTsdGsdAsdGsdAsdAsdTsusasggsgsa	259
A-130705.1	X10614	usascscsasdAs(5MdC)sdTsdTsdGs(5MdC)sdTs(5MdC)sdAsdAsdGsgscscsusg	260
A-130706.1	X10615	cscsusgsasdGs(5MdC)sdAsdGsdAsdTsdAs(5MdC)s(5MdC)sdAsdAsascsususg	261
A-130707.1	X10616	csasusggscsdTs(5MdC)sdAsdGsdGs(5MdC)s(5MdC)sdTsdGsdAsdGsgscsasgsa	262
A-130708.1	X10617	usasasususdGsdAsdGsdGsdTs(5MdC)sdAsdTsdGs(5MdC)sdTsuscsasggsg	263
A-130709.1	X10618	ususasasgsdTsdGsdAsdAsdAsdTsdAsdAsdTsdTsdGsgsasggsgsu	264
A-130710.1	X10619	usggsgscscsdTsdGsdGsdGsdGsdTsdTsdAsdAsdAsdGsdTsusgsasasa	265
A-130711.1	X10620	gsasusasusdGsdAsdTsdAsdAsdAsdTsdGsdGs(5MdC)s(5MdC)sdTsdTsusggsggsg	266
A-130712.1	X10621	asgsascscsdAsdTs(5MdC)sdTsdGsdGsdAsdTsdAsdTsdGsgsasususasa	267
A-130713.1	X10622	ascsasascsdTs(5MdC)sdTsdGsdAsdAsdAsdGsdAs(5MdC)s(5MdC)sdAsasuscsusg	268
A-130714.1	X10623	ascsasususdTsdAsdAsdAsdAsdGsdAs(5MdC)sdAsdAs(5MdC)sdTsdTsuscsusgsa	269
A-130715.1	X10624	asascsususdAsdAsdTsdTs(5MdC)sdAs(5MdC)sdAsdTsdAsdTsdTsusasasasg	270
A-130716.1	X10625	asasususususdAsdAsdTsdAsdTsdAsdAs(5MdC)sdTsdTsdTsdAsasasususc	271
A-130717.1	X10626	usasusasgsdAsdTsdTsdAsdAsdAsdAsdAsdTsdTsdTsdAsasasasusasu	272
A-130718.1	X10627	asusgsususdTsdTsdTsdAs(5MdC)sdTsdAsdTsdAsdGsdAsasususasa	273
A-130719.1	X10628	ususcscsasdGsdGsdAs(5MdC)sdTsdAsdTsdGsdTsdTsdTsususususasc	274
A-130720.1	X10629	asasgsasasdTsdTsdTsdAsdTsdTsdTs(5MdC)s(5MdC)sdAsdGsgsgsascsu	275
A-130721.1	X10630	cscsasususdTsdAsdAsdGs(5MdC)sdAsdAsdGsdAsdAsdTsusususasu	276

Table 4. Antisense polynucleotides targeting aminolevulinic acid synthase-1 (ALAS1)

Sequence ID	Start position relative to NM_000688.5 (SEQ ID NO: 2)	Modified Sequence (5'-3')	SEQ ID NO:	Unmodified Sequence (5'-3')	SEQ ID NO	Reverse Complement of Unmodified Sequence (5'-3')	SEQ ID NO
NM_000688.5_20-39_aso	20	gsusgsascs(m5dCs)dGs(m5dCs)dTsdGs(m5dCs)dGs(m5dCs)dAsdTsgscsgscsc	277	GUGACCGCUGCGCAUGCGCC	547	GGCGCAUGCGCAGCGGUCAC	817
NM_000688.5_30-49_aso	30	usascsasgs(m5dCs)dGsdGsdGsdAsdGsdTsdGsdAs(m5dCs)csgscsusg	278	UACAGCGGGAGUGACCGCUG	548	CAGCGGUCACUCCCGCUGUA	818
NM_000688.5_40-59_aso	40	csgscscsusdTsdAsdAsd TsdAsdTsdAs(m5dCs)d AsdGscsgsgsgsa	279	CGCCUUAAUAUACAGCGGGA	549	UCCCGCUGUAUAUUAAGGCG	819
NM_000688.5_50-69_aso	50	csgsasuscsdGs(m5dCs)(m5dCs)dGsdGs(m5dCs)dGs(m5dCs)(m5dCs)dTsusasasusa	280	CGAUCGCCGGCGCCUUAAUA	550	UAUUAAGGCGCCGGCGAUCG	820
NM_000688.5_60-79_aso	60	cscsuscsasdGsdGs(m5dCs)(m5dCs)dGs(m5dCs)dGsdAsdTs(m5dCs)gscscsgsg	281	CCUCAGGCCGCGAUCGCCGG	551	CCGGCGAUCGCGGCCUGAGG	821
NM_000688.5_70-89_aso	70	cscsgsgsgsdAsdGs(m5dCs)dAsdGs(m5dCs)(m5dCs)dTs(m5dCs)dAsgsgscscsg	282	CCGGGAGCAGCCUCAGGCCG	552	CGGCCUGAGGCUGCUCCCGG	822
NM_000688.5_80-99_aso	80	ususgscscs(m5dCs)dTsdTsdGsdTs(m5dCs)(m5dCs)dGsdGsdGsasgscsasg	283	UUGCCCUUGUCCGGGAGCAG	553	CUGCUCCCGGACAAGGGCAA	823
NM_000688.5_90-109_aso	90	gsasasascsdGs(m5dCs)dTs(m5dCs)dGsdTsdTsdGs(m5dCs)(m5dCs)csususgsu	284	GAAACGCUCGUUGCCCUUGU	554	ACAAGGGCAACGAGCGUUUC	824
NM_000688.5_100-119_aso	100	asasgsuscs(m5dCs)dAsdAsdAs(m5dCs)dGsdAsdAsdAs(m5dCs)gscsuscsg	285	AAGUCCAAACGAAACGCUCG	555	CGAGCGUUUCGUUUGGACUU	825

NM_0006 88.5_110- 129_aso	110	uscsasasgsdTs(m5dCs)dGsdAsdGsdAs dAsdGsdTs(m5dCs)csasasasc	286	UCAAGUCGAGAAGUC CAAAC	556	GUUUGGACUUCUCGAC UUGA	826
NM_0006 88.5_120- 139_aso	120	asgsgscsgsdGsdGs(m5dCs)dAs(m5dC s)dTs(m5dCs)dAsdAsdGsuscsgsasg	287	AGGCGGGCACUCAAG UCGAG	557	CUCGACUUGAGUGCCC GCCU	827
NM_0006 88.5_130- 149_aso	130	gscsgsgscsdGsdAsdAsdGsdGsdAsdGs dGs(m5dCs)dGsgsgscsasc	288	GCGGCGAAGGAGGCG GGCAC	558	GUGCCCGCCUCCUUCG CCGC	828
NM_0006 88.5_140- 159_aso	140	usgscsasgsdAsdGsdGs(m5dCs)dGsdG s(m5dCs)dGsdGs(m5dCs)gsasasgsg	289	UGCAGAGGCGGCGGC GAAGG	559	CCUUCGCCGCCGCCUC UGCA	829
NM_0006 88.5_150- 169_aso	150	csgscsusgsdAsdGsdGsdAs(m5dCs)dTs dGs(m5dCs)dAsdAsdGsasgsgscsg	290	CGCUGAGGACUGCAG AGGCG	560	CGCCUCUGCAGUCCUC AGCG	830
NM_0006 88.5_160- 179_aso	160	gsgscsasusdAsdAs(m5dCs)dTsdGs(m5 dCs)dGs(m5dCs)dTsdGsasgsgsasc	291	GGCAUAACUGCGCUG AGGAC	561	GUCCUCAGCGCAGUUA UGCC	831
NM_0006 88.5_170- 189_aso	170	gsgsasasgsdAsdAs(m5dCs)dTsdGsdGs dGs(m5dCs)dAsdTsasascsusg	292	GGAAGAACUGGGCAU AACUG	562	CAGUUAUGCCCAGUUC UUCC	832
NM_0006 88.5_180- 199_aso	180	cscscscsas(m5dCs)dAsdGs(m5dCs)dG sdGsdGsdAsdAsdGsasascsusg	293	CCCCACAGCGGGAAGA ACUG	563	CAGUUCUUCCCGCUGU GGGG	833
NM_0006 88.5_190- 209_aso	190	gsusgsgsus(m5dCs)dGsdTsdGsdTs(m5 dCs)(m5dCs)(m5dCs)(m5dCs)dAscsas gscsg	294	GUGGUCGUGUCCCCAC AGCG	564	CGCUGUGGGGGACACGA CCAC	834
NM_0006 88.5_200- 219_aso	200	gsgsasusus(m5dCs)(m5dCs)dTs(m5dC s)(m5dCs)dGsdTsdGsdGsdTscsgsusgs u	295	GGAUUCCUCCGUGGUC GUGU	565	ACACGACCACGGAGGA AUCC	835
NM_0006 88.5_210- 229_aso	210	cscsusgsasdAsdGs(m5dCs)dAsdAsdG sdGsdAsdTsdTscscsusc sc	296	CCUGAAGCAAGGAUU CCUCC	566	GGAGGAAUCCUUGCUU CAGG	836
NM_0006 88.5_220- 239_aso	220	gsuscscscsdGsdAsdGsdTs(m5dCs)(m5 dCs)(m5dCs)dTsdGsdAsasgscsasa	297	GUCCCGAGUCCCUGAA GCAA	567	UUGCUUCAGGGACUCG GGAC	837

NM_0006 88.5_230-249_aso	230	gsuscscsasdGs(m5dCs)dAsdGsdGsdG sdTs(m5dCs)(m5dCs)(m5dCs)gsasgsu sc	298	GUCCAGCAGGGUCCCG AGUC	568	GACUCGGGACCCUGCU GGAC	838
NM_0006 88.5_240-259_aso	240	csgsasgsgsdAsdAsdGsdGsdGsdTs (m5dCs)(m5dCs)dAsgscsasgsg	299	CGAGGAAGGGGUCCA GCAGG	569	CCUGCUGGACCCCCUUC CUCG	839
NM_0006 88.5_250-269_aso	250	cscscscsusdAsdAsdAs(m5dCs)(m5dCs)(m5dCs)dGsdAsdGsdGsasasgsgsg	300	CCCCUAAACCCGAGGA AGGG	570	CCCUUCCUCGGGUUUA GGGG	840
NM_0006 88.5_260-279_aso	260	gsuscscscs(m5dCs)dAs(m5dCs)dAsdT s(m5dCs)(m5dCs)(m5dCs)(m5dCs)dT sasasascsc	301	GUCCCCACAUCCCCUA AACC	571	GGUUUAGGGGAUGUGG GGAC	841
NM_0006 88.5_270-289_aso	270	csusususcsdTs(m5dCs)(m5dCs)dTsdG sdGsdTs(m5dCs)(m5dCs)(m5dCs)csas csasu	302	CUUUCUCCUGGUCCCC ACAU	572	AUGUGGGGACCAGGAG AAAG	842
NM_0006 88.5_280-299_aso	280	gsgsgsasus(m5dCs)(m5dCs)dTsdGsdA s(m5dCs)dTsdTsdTs(m5dCs)uscscsus g	303	GGGAUCCUGACUUUC UCCUG	573	CAGGAGAAAGUCAGGA UCCC	843
NM_0006 88.5_290-309_aso	290	asasgsascsdTs(m5dCs)dTsdTsdAsdGs dGsdGsdAsdTscscsusgsa	304	AAGACUCUUAGGGAU CCUGA	574	UCAGGAUCCCUAAGAG UCUU	844
NM_0006 88.5_300-319_aso	300	cscsasgsgs(m5dCs)dAsdGsdGsdGsdA sdAsdGsdAs(m5dCs)uscsususa	305	CCAGGCAGGGAAGAC UCUUA	575	UAAGAGUCUUCCCUGC CUGG	845
NM_0006 88.5_310-329_aso	310	ascsuscsasdTs(m5dCs)(m5dCs)dAsdT s(m5dCs)(m5dCs)dAsdGsdGscsasgsgs g	306	ACUCAUCCAUCCAGGC AGGG	576	CCCUGCCUGGAUGGAU GAGU	846
NM_0006 88.5_320-339_aso	320	asgsasasgsdAsdAsdGs(m5dCs)(m5dCs)dAs(m5dCs)dTs(m5dCs)dAsuscscsas u	307	AGAAGAAGCCACUCA UCCAU	577	AUGGAUGAGUGGCUUC UUCU	847
NM_0006 88.5_330-349_aso	330	asuscsusasdGsdGsdTsdGsdGsdAsdGs dAsdAsdGsasasgscsc	308	AUCUAGGUGGAGAAG AAGCC	578	GGCUUCUUCUCCACCU AGAU	848
NM_0006 88.5_340-359_aso	340	usgsusgsgsdAsdAsdAsdGsdAsdAsdTs (m5dCs)dTsdAsgsgsusgsg	309	UGUGGAAAGAAUCUA GGUGG	579	CCACCUAGAUUCUUUC CACA	849
NM_0006	350	usgscsusgsdGs(m5dCs)dTs(m5dCs)(m	310	UGCUGGCUCCCUGUGG	580	UCUUUCCCACAGGAGCC	850

88.5_350-369_aso		5dCs)dTsdGsdTsdGsdGsasasasgsa		AAAGA		AGCA	
NM_0006 88.5_360-379_aso	360	uscsasgsgsdAsdAsdGsdTsdAsdTsdGs(m5dCs)dTsdGsgscsuscsc	311	UCAGGAAGUAUGCUG GCUCC	581	GGAGCCAGCAUACUUC CUGA	851
NM_0006 88.5_370-389_aso	370	csuscsuscs(m5dCs)dAsdTsdGsdTsdTs(m5dCs)dAsdGsdGsasasgsusa	312	CUCUCCAUGUUCAGGA AGUA	582	UACUUCCUGAACAUGG AGAG	852
NM_0006 88.5_380-399_aso	380	gscsgsasas(m5dCs)dAsdAs(m5dCs)dAs(m5dCs)dTs(m5dCs)dTs(m5dCs)csas usgsu	313	GCGAACAACACUCUCC AUGU	583	ACAUGGAGAGUGUUGU UCGC	853
NM_0006 88.5_390-409_aso	390	asusgsgsgs(m5dCs)dAsdGs(m5dCs)dGsdGs(m5dCs)dGsdAsdAscsasascsa	314	AUGGGCAGCGGCGAA CAACA	584	UGUUGUUCGCCGCUGC CCAU	854
NM_0006 88.5_400-419_aso	400	csgsgsgsasdTsdAsdAsdGsdAsdAsdTsdGsdGsdGscsasgscsg	315	CGGGAUAAGAAUGGG CAGCG	585	CGCUGCCCAUUCUUAU CCCG	855
NM_0006 88.5_410-429_aso	410	csusgsgsgsdGsdGsdAs(m5dCs)dTs(m5dCs)dGsdGsdGsdAsusasasgsa	316	CUGGGGGACUCGGGA UAAGA	586	UCUUAUCCCGAGUCCC CCAG	856
NM_0006 88.5_420-439_aso	420	gscsasgsasdAsdAsdGsdGs(m5dCs)(m5dCs)dTsdGsdGsdGsgsgsascsu	317	GCAGAAAGGCCUGGG GGACU	587	AGUCCCCCAGGCCUUU CUGC	857
NM_0006 88.5_430-449_aso	430	cscsusgscsdTsdTsdTs(m5dCs)dTsdGs(m5dCs)dAsdGsdAsasasgsgsc	318	CCUGCUUUCUGCAGAA AGGC	588	GCCUUUCUGCAGAAAG CAGG	858
NM_0006 88.5_440-459_aso	440	csasgsasgsdAsdTsdTsdTsdGs(m5dCs)(m5dCs)dTsdGs(m5dCs)usususcsu	319	CAGAGAUUUGCCUGC UUUCU	589	AGAAAGCAGGCAAAUC UCUG	859
NM_0006 88.5_450-469_aso	450	csasusasgsdAsdAs(m5dCs)dAsdAs(m5dCs)dAsdGsdAsdGsasususg	320	CAUAGAACAACAGAG AUUUG	590	CAAAUCUCUGUUGUUC UAUG	860
NM_0006 88.5_460-479_aso	460	csasgsususdTsdTsdGsdGsdGs(m5dCs)dAsdTsdAsdGsasascsasa	321	CAGUUUUGGGCAUAG AACAA	591	UUGUUCUAUGCCCAAA ACUG	861
NM_0006 88.5_470-	470	csasuscsusdTsdGsdGsdGsdGs(m5dCs)dAsdGsdTsdTsususggsgg	322	CAUCUUGGGGCAGUU UUGGG	592	CCCAAAACUGCCCCAA GAUG	862

489_aso							
NM_000688.5_480-499_aso	480	csasascsusdTs(m5dCs)(m5dCs)dAsdTs(m5dCs)dAsdTs(m5dCs)dTsusgsgsgsg	323	CAACUUCCAUCAUCUUGGGG	593	CCCCAAGAUGAUGGAAGUUG	863
NM_000688.5_490-509_aso	490	gsgscsususdGsdGs(m5dCs)(m5dCs)(m5dCs)(m5dCs)dAsdAs(m5dCs)dTsuscscsasu	324	GGCUUGGCCCCAACUUCCAU	594	AUGGAAGUUGGGGCCAAGCC	864
NM_000688.5_500-519_aso	500	cscsgsasgsdGsdGsdGs(m5dCs)dTsdGsdGs(m5dCs)dTsdTsgsgscscsc	325	CCGAGGGGCUGGCUUGGCCC	595	GGGCCAAGCCAGCCCCUCGG	865
NM_000688.5_510-529_aso	510	usgsgsascsdAsdAsdTsdGs(m5dCs)(m5dCs)(m5dCs)dGsdAsdGsgsgsgscsu	326	UGGACAAUGCCCGAGGGGCU	596	AGCCCCUCGGGCAUUGUCCA	866
NM_000688.5_520-539_aso	520	ascsusgscsdTsdGs(m5dCs)dAsdGsdTsdGsdGsdAs(m5dCs)asasusgsc	327	ACUGCUGCAGUGGACAAUGC	597	GCAUUGUCCACUGCAGCAGU	867
NM_000688.5_530-549_aso	530	ususgsgsusdAsdGsdTsdGsdTsdAs(m5dCs)dTsdGs(m5dCs)usgscsasg	328	UUGGUAGUGUACUGCUGCAG	598	CUGCAGCAGUACACUACCAA	868
NM_000688.5_540-559_aso	540	csusususgsdAsdTs(m5dCs)dTsdGsdTsdTsdGsdGsdTsasgsusgsu	329	CUUUGAUCUGUUGGUAGUGU	599	ACACUACCAACAGAUCAAAG	869
NM_000688.5_550-569_aso	550	gsgsasgsgsdGsdGsdTsdTsdTs(m5dCs)dTsdTsdTsdGsasuscsusg	330	GGAGGGGUUUCUUUGAUCUG	600	CAGAUCAAAGAAACCCCUCC	870
NM_000688.5_560-579_aso	560	csuscsascsdTsdGsdGs(m5dCs)(m5dCs)dGsdGsdAsdGsdGsgsgsususu	331	CUCACUGGCCGGAGGGGUUU	601	AAACCCCUCCGGCCAGUGAG	871
NM_000688.5_570-589_aso	570	ususususgsdTs(m5dCs)dTsdTsdTs(m5dCs)dTs(m5dCs)dAs(m5dCs)usgsgscsc	332	UUUUGUCUUUCUCACUGGCC	602	GGCCAGUGAGAAAGACAAAA	872
NM_000688.5_580-599_aso	580	gscscsususdAsdGs(m5dCs)dAsdGsdTsdTsdTsdTsdGsuscsususu	333	GCCUUAGCAGUUUUGUCUUU	603	AAAGACAAAACUGCUAAGGC	873
NM_000688.5_590-609_aso	590	ususgsgsas(m5dCs)(m5dCs)dTsdTsdGsdGs(m5dCs)(m5dCs)dTsdTsasgscsasg	334	UUGGACCUUGGCCUUAGCAG	604	CUGCUAAGGCCAAGGUCCAA	874

NM_0006 88.5_600-619_aso	600	csasggsgsasdGsdTs(m5dCs)dTsdGsdTsdTsdGsdGsdAscscsususg	335	CAGGAGUCUGUUGGA CCUUG	605	CAAGGUCCAACAGACU CCUG	875
NM_0006 88.5_610-629_aso	610	usggsgsasdTs(m5dCs)(m5dCs)dAsdTs(m5dCs)dAsdGsdGsdAsgsuscsusg	336	UGGGAUCCAUCAGGA GUCUG	606	CAGACUCCUGAUGGAU CCCA	876
NM_0006 88.5_620-639_aso	620	usggsgsascsdTs(m5dCs)dTsdGs(m5dCs)dTsdGsdGsdGsdAsuscscsasu	337	UGGACUCUGCUGGGA UCCAU	607	AUGGAUCCCAGCAGAG UCCA	877
NM_0006 88.5_630-649_aso	630	gsusgsusgs(m5dCs)(m5dCs)dAsdTs(m5dCs)dTsdGsdGsdAs(m5dCs)uscsusgsc	338	GUGUGCCAUCUGGAC UCUGC	608	GCAGAGUCCAGAUGGC ACAC	878
NM_0006 88.5_640-659_aso	640	gsascsgsgsdAsdAsdGs(m5dCs)dTsdGsdTsdGsdTsdGscscsasusc	339	GACGGAAGCUGUGUG CCAUC	609	GAUGGCACACAGCUUC CGUC	879
NM_0006 88.5_650-669_aso	650	gsgsgsgsusdGsdTs(m5dCs)(m5dCs)dAsdGsdAs(m5dCs)dGsdGsasasgscsu	340	GGGGUGUCCAGACGG AAGCU	610	AGCUUCCGUCUGGACA CCCC	880
NM_0006 88.5_660-679_aso	660	usgsgscsasdGsdGs(m5dCs)dAsdAsdGsdGsdGsdGsdTsgsuscscsa	341	UGGCAGGCAAGGGGU GUCCA	611	UGGACACCCCUUGCCU GCCA	881
NM_0006 88.5_670-689_aso	670	cscscsusgsdGs(m5dCs)dTsdTsdGsdTsdGsdGs(m5dCs)dAsgsgscsasa	342	CCCUGGCUUGUGGCAG GCAA	612	UUGCCUGCCACACAAGCC AGGG	882
NM_0006 88.5_680-699_aso	680	gscsususgs(m5dCs)dAsdGsdTsdGs(m5dCs)(m5dCs)(m5dCs)dTsdGsgscsususg	343	GCUUGCAGUGCCCUGG CUUG	613	CAAGCCAGGGCACUGC AAGC	883
NM_0006 88.5_690-709_aso	690	asasgsgsgs(m5dCs)dAsdTsdTsdTsdGs(m5dCs)dTsdTsdGscsasgsusg	344	AAGGGCAUUUGCUUG CAGUG	614	CACUGCAAGCAAAUGC CCUU	884
NM_0006 88.5_700-719_aso	700	gscsusgscs(m5dCs)dAsdGsdGsdAsdAsdAsdGsdGsdGscsasususu	345	GCUGCCAGGAAAGGG CAUUU	615	AAAUGCCCUUUCCUGG CAGC	885
NM_0006 88.5_710-729_aso	710	asususcsasdTs(m5dCs)dTsdGsdTsdGs(m5dCs)dTsdGs(m5dCs)csasgsgsa	346	AUUCAUCUGUGCUGCC AGGA	616	UCCUGGCAGCACAGAU GAAU	886
NM_0006	720	usgscscsus(m5dCs)dTs(m5dCs)dTsdG	347	UGCCUCUCUGAUUCAU	617	ACAGAUGAAUCAGAGA	887

88.5_720-739_aso		sdAsdTsdTs(m5dCs)dAsuscsusgsu		CUGU		GGCA	
NM_0006 88.5_730-749_aso	730	asasgsascsdAs(m5dCs)dTsdGs(m5dCs)dTsdGs(m5dCs)dTsdGs(m5dCs)(m5dCs)dTscsuscsus g	348	AAGACACUGCUGCCUC UCUG	618	CAGAGAGGCAGCAGUG UCUU	888
NM_0006 88.5_740-759_aso	740	gsgscsususdTsdGs(m5dCs)dAsdGsdA sdAsdGsdAs(m5dCs)ascsusgsc	349	GGCUUUGCAGAAGAC ACUGC	619	GCAGUGUCUUCUGCAA AGCC	889
NM_0006 88.5_750-769_aso	750	gscsuscsasdAsdGsdAs(m5dCs)dTsdGs dGs(m5dCs)dTsdTsusgscsasg	350	GCUCAAGACUGGCUU UGCAG	620	CUGCAAAGCCAGUCUU GAGC	890
NM_0006 88.5_760-779_aso	760	uscscsuscs(m5dCs)dTsdGsdAsdAsdGs (m5dCs)dTs(m5dCs)dAsasgsascsu	351	UCCUCCUGAAGCUCAA GACU	621	AGUCUUGAGCUUCAGG AGGA	891
NM_0006 88.5_770-789_aso	770	ususcscsusdGs(m5dCs)dAs(m5dCs)dA sdTs(m5dCs)(m5dCs)dTs(m5dCs)csus gsasa	352	UUCCUGCACAUCCUCC UGAA	622	UUCAGGAGGAUGUGCA GGAA	892
NM_0006 88.5_780-799_aso	780	csgsgscsasdTsdTs(m5dCs)dAsdTsdTs dTs(m5dCs)(m5dCs)dTsgscsascsa	353	CGGCAUUCAUUUCCUG CACA	623	UGUGCAGGAAAUGAAU GCCG	893
NM_0006 88.5_790-809_aso	790	uscsususus(m5dCs)(m5dCs)dTs(m5dC s)dAs(m5dCs)dGsdGs(m5dCs)dAsusu scsasu	354	UCUUUCCUCACGGCAU UCAU	624	AUGAAUGCCGUGAGGA AAGA	894
NM_0006 88.5_800-819_aso	800	ususcsasgs(m5dCs)dAsdAs(m5dCs)(m 5dCs)dTs(m5dCs)dTsdTsdTscscsuscsa	355	UUCAGCAACCUCUUUC CUCA	625	UGAGGAAAGAGGUUGC UGAA	895
NM_0006 88.5_810-829_aso	810	csusgscsusdGsdAsdGsdGsdTsdTsdTs(m5dCs)dAsdGscsasascsc	356	CUGCUGAGGUUUCAG CAACC	626	GGUUGCUGAAACCUCA GCAG	896
NM_0006 88.5_820-839_aso	820	ascsascsusdGsdGsdGsdGs(m5dCs)(m5 dCs)dTsdGs(m5dCs)dTsgsasgsgsu	357	ACACUGGGGCCUGCUG AGGU	627	ACCUCAGCAGGCCCCA GUGU	897
NM_0006 88.5_830-849_aso	830	csascsascsdTsdAsdAs(m5dCs)(m5dCs)dAs(m5dCs)dAs(m5dCs)dTsgsgsgsgs c	358	CACACUAACCACACUG GGGC	628	GCCCCAGUGUGGUUAG UGUG	898
NM_0006 88.5_840-	840	csasuscsgsdGsdTsdTsdTs(m5dCs) dAs(m5dCs)dAs(m5dCs)usasascsc	359	CAUCGGUUUUCACACU AACC	629	GGUUAGUGUGAAAACC GAUG	899

859_aso							
NM_000688.5_850-869_aso	850	gsgsasuscs(m5dCs)(m5dCs)(m5dCs)dTs(m5dCs)(m5dCs)dAsdTs(m5dCs)dGsgsususu	360	GGAUCCCCUCCAUCGGUUUU	630	AAAACCGAUGGAGGGGAUCC	900
NM_000688.5_860-879_aso	860	csasgsuscs(m5dCs)dAs(m5dCs)dTsdGsdGsdGsdAsdTs(m5dCs)cscscsusc	361	CAGUCCACUGGGAUCCCCUC	631	GAGGGGAUCCCAGUGGACUG	901
NM_000688.5_870-889_aso	870	asgsususcsdTsdTs(m5dCs)dAsdGs(m5dCs)dAsdGsdTs(m5dCs)csascsusg	362	AGUUCUUCAGCAGUCCACUG	632	CAGUGGACUGCUGAAGAACU	902
NM_000688.5_880-899_aso	880	asusgsuscs(m5dCs)dTsdGsdGsdAsdAsdGsdTsdTs(m5dCs)ususcsasg	363	AUGUCCUGGAAGUUCUUCAG	633	CUGAAGAACUUCCAGGACAU	903
NM_000688.5_890-909_aso	890	csususususdGs(m5dCs)dAsdTsdGsdAsdTsdGsdTs(m5dCs)csusgsgsa	364	CUUUUGCAUGAUGUCCUGGA	634	UCCAGGACAUCAUGCAAAAG	904
NM_000688.5_900-919_aso	900	csusgsgsus(m5dCs)dTsdTsdTsdGs(m5dCs)dTsdTsdTsdTsgscsasusg	365	CUGGUCUUUGCUUUUGCAUG	635	CAUGCAAAAGCAAAGACCAG	905
NM_000688.5_901-920_aso	901	uscsusgsgsdTs(m5dCs)dTsdTsdTsdGs(m5dCs)dTsdTsdTsusgscsasu	366	UCUGGUCUUUGCUUUUGCAU	636	AUGCAAAAGCAAAGACCAGA	906
NM_000688.5_902-921_aso	902	ususcsusgsdGsdTs(m5dCs)dTsdTsdTsdGs(m5dCs)dTsdTsususgscsa	367	UUCUGGUCUUUGCUUUUGCA	637	UGCAAAAGCAAAGACCAGAA	907
NM_000688.5_903-922_aso	903	usususcsusdGsdGsdTs(m5dCs)dTsdTsdTsdGs(m5dCs)dTsusususgsc	368	UUUCUGGUCUUUGCUUUUGC	638	GCAAAAGCAAAGACCAGAAA	908
NM_000688.5_904-923_aso	904	csusususcsdTsdGsdGsdTs(m5dCs)dTsdTsdTsdGs(m5dCs)ususususg	369	CUUUCUGGUCUUUGCUUUUG	639	CAAAAGCAAAGACCAGAAAG	909
NM_000688.5_905-924_aso	905	uscsususus(m5dCs)dTsdGsdGsdTs(m5dCs)dTsdTsdTsdGscsususususu	370	UCUUUCUGGUCUUUGCUUUU	640	AAAAGCAAAGACCAGAAAGA	910
NM_000688.5_906-925_aso	906	csuscsususdTs(m5dCs)dTsdGsdGsdTs(m5dCs)dTsdTsdTsgscsususu	371	CUCUUUCUGGUCUUUGCUUU	641	AAAGCAAAGACCAGAAAGAG	911

NM_0006 88.5_907-926_aso	907	ascsuscsusdTsdTs(m5dCs)dTsdGsdGs dTs(m5dCs)dTsdTsusgscsusu	372	ACUCUUUCUGGUCUU UGCUU	642	AAGCAAAGACCAGAAA GAGU	912
NM_0006 88.5_908-927_aso	908	csascsuscsdTsdTsdTs(m5dCs)dTsdGs dGsdTs(m5dCs)dTsususgscsu	373	CACUCUUUCUGGUCUU UGCU	643	AGCAAAGACCAGAAAG AGUG	913
NM_0006 88.5_909-928_aso	909	ascsascsus(m5dCs)dTsdTsdTs(m5dCs) dTsdGsdGsdTs(m5dCs)usususgsc	374	ACACUCUUUCUGGUCU UUGC	644	GCAAAGACCAGAAAGA GUGU	914
NM_0006 88.5_910-929_aso	910	gsascsascsdTs(m5dCs)dTsdTsdTs(m5 dCs)dTsdGsdGsdTscsususg	375	GACACUCUUUCUGGUC UUUG	645	CAAAGACCAGAAAGAG UGUC	915
NM_0006 88.5_911-930_aso	911	asgsascsas(m5dCs)dTs(m5dCs)dTsdTs dTs(m5dCs)dTsdGsdGsuscsususu	376	AGACACUCUUUCUGG UCUUU	646	AAAGACCAGAAAGAGU GUCU	916
NM_0006 88.5_912-931_aso	912	gsasgsascsdAs(m5dCs)dTs(m5dCs)dT sdTsdTs(m5dCs)dTsdGsgsuscsusu	377	GAGACACUCUUUCUG GUCUU	647	AAGACCAGAAAGAGUG UCUC	917
NM_0006 88.5_913-932_aso	913	usgsasgsas(m5dCs)dAs(m5dCs)dTs(m 5dCs)dTsdTsdTs(m5dCs)dTsgsgsuscs u	378	UGAGACACUCUUUCU GGUCU	648	AGACCAGAAAGAGUGU CUCA	918
NM_0006 88.5_914-933_aso	914	asusgsasgsdAs(m5dCs)dAs(m5dCs)dT s(m5dCs)dTsdTsdTs(m5dCs)usgsgsus c	379	AUGAGACACUCUUUC UGGUC	649	GACCAGAAAGAGUGUC UCAU	919
NM_0006 88.5_915-934_aso	915	gsasusgsasdGsdAs(m5dCs)dAs(m5dC s)dTs(m5dCs)dTsdTsdTscsusgsgsu	380	GAUGAGACACUCUUU CUGGU	650	ACCAGAAAGAGUGUCU CAUC	920
NM_0006 88.5_916-935_aso	916	asgsasusgsdAsdGsdAs(m5dCs)dAs(m 5dCs)dTs(m5dCs)dTsdTsuscsusgsg	381	AGAUGAGACACUCUU UCUGG	651	CCAGAAAGAGUGUCUC AUCU	921
NM_0006 88.5_917-936_aso	917	asasgsasusdGsdAsdGsdAs(m5dCs)dA s(m5dCs)dTs(m5dCs)dTsususcsusg	382	AAGAUGAGACACUCU UUCUG	652	CAGAAAGAGUGUCUCA UCUU	922
NM_0006 88.5_918-937_aso	918	gsasasgsasdTsdGsdAsdGsdAs(m5dCs) dAs(m5dCs)dTs(m5dCs)usususcsu	383	GAAGAUGAGACACUC UUUCU	653	AGAAAGAGUGUCUCAU CUUC	923
NM_0006	919	asgsasasgsdAsdTsdGsdAsdGsdAs(m5	384	AGAAGAUGAGACACU	654	GAAAGAGUGUCUCAUC	924

88.5_919-938_aso		dCs)dAs(m5dCs)dTscsusususc		CUUUC		UUCU	
NM_000688.5_920-939_aso	920	asasgsasasdGsdAsdTsdGsdAsdGsdAs(m5dCs)dAs(m5dCs)uscsususu	385	AAGAAGAUGAGACAC UCUUU	655	AAAGAGUGUCUCAUCU UCUU	925
NM_000688.5_921-940_aso	921	gsasasgsasdAsdGsdAsdTsdGsdAsdGsdAs(m5dCs)dAscsuscsusu	386	GAAGAAGAUGAGACA CUCUU	656	AAGAGUGUCUCAUCUU CUUC	926
NM_000688.5_922-941_aso	922	usgsasasgsdAsdAsdGsdAsdTsdGsdAs dGsdAs(m5dCs)ascsuscsu	387	UGAAGAAGAUGAGAC ACUCU	657	AGAGUGUCUCAUCUUC UUCA	927
NM_000688.5_923-942_aso	923	ususgsasasdGsdAsdAsdGsdAsdTsdGs dAsdGsdAscsascsusc	388	UUGAAGAAGAUGAGA CACUC	658	GAGUGUCUCAUCUUCU UCAA	928
NM_000688.5_924-943_aso	924	csususgsasdAsdGsdAsdAsdGsdAsdTs dGsdAsdGsascsascsu	389	CUUGAAGAAGAUGAG ACACU	659	AGUGUCUCAUCUUCUU CAAG	929
NM_000688.5_925-944_aso	925	uscsususgsdAsdAsdGsdAsdAsdGsdAs dTsdGsdAsgsascsasc	390	UCUUGAAGAAGAUGA GACAC	660	GUGUCUCAUCUUCUUC AAGA	930
NM_000688.5_926-945_aso	926	asuscsususdGsdAsdAsdGsdAsdAsdGs dAsdTsdGsasgsascsa	391	AUCUUGAAGAAGAUG AGACA	661	UGUCUCAUCUUCUUCA AGAU	931
NM_000688.5_927-946_aso	927	usasuscsusdTsdGsdAsdAsdGsdAsdAs dGsdAsdTsgsasgsasc	392	UAUCUUGAAGAAGAU GAGAC	662	GUCUCAUCUUCUUCAA GAUA	932
NM_000688.5_928-947_aso	928	ususasuscsdTsdTsdGsdAsdAsdGsdAs dAsdGsdAsusgsasgsa	393	UUAUCUUGAAGAAGA UGAGA	663	UCUCAUCUUCUUCAAG AUAA	933
NM_000688.5_929-948_aso	929	gsususasus(m5dCs)dTsdTsdGsdAsdAs dGsdAsdAsdGsasusgsasg	394	GUUAUCUUGAAGAAG AUGAG	664	CUCAUCUUCUUCAAGA UAAC	934
NM_000688.5_930-949_aso	930	asgsusasasdTs(m5dCs)dTsdTsdGsdAs dAsdGsdAsdAsgsasusgsa	395	AGUUAUCUUGAAGAA GAUGA	665	UCAUCUUCUUCAAGAU AACU	935
NM_000688.5_931-938_aso	931	asasgsususdAsdTs(m5dCs)dTsdTsdGs dAsdAsdGsdAsasgsasusg	396	AAGUUAUCUUGAAGA AGAUG	666	CAUCUUCUUCAAGAUA ACUU	936

950_aso							
NM_000688.5_940-959_aso	940	gsasusususdTsdGsdGs(m5dCs)dAsdAsdGsdTsdTsdAsuscsususg	397	GAUUUUGGCAAGUUAUCUUG	667	CAAGAUAACUUGCCAAAAUC	937
NM_000688.5_950-969_aso	950	asgsusgsgsdAsdAsdAs(m5dCs)dAsdGsdAsdTsdTsdTsusgsgscsa	398	AGUGGAAACAGAUUUUGGCA	668	UGCCAAAAUCUGUUUCCACU	938
NM_000688.5_960-979_aso	960	csasusascsdTsdGsdAsdAsdAsdAsdGsdTsdGsdGsasasascsa	399	CAUACUGAAAAGUGGAAACA	669	UGUUUCCACUUUUCAGUAUG	939
NM_000688.5_970-989_aso	970	asasgsasasdAs(m5dCs)dGsdAsdTs(m5dCs)dAsdTsdAs(m5dCs)usgsasasa	400	AAGAAACGAUCAUACUGAAA	670	UUUCAGUAUGAUCGUUUCUU	940
NM_000688.5_980-999_aso	980	usususususdTs(m5dCs)dTs(m5dCs)dAsdAsdAsdGsdAsdAsascsgsasu	401	UUUUUUCUCAAAGAAACGAU	671	AUCGUUUCUUUGAGAAAAAA	941
NM_000688.5_990-1009_aso	990	uscsuscsasdTs(m5dCs)dAsdAsdTsdTsdTsdTsdTsuscsuscsa	402	UCUCAUCAAUUUUUUUCUCA	672	UGAGAAAAAAAUUGAUGAGA	942
NM_000688.5_1000-1019_aso	1000	uscsasusus(m5dCs)dTsdTsdTsdTsdTs(m5dCs)dTs(m5dCs)dAsuscsasasu	403	UCAUUCUUUUUCUCAUCAAU	673	AUUGAUGAGAAAAAGAAUGA	943
NM_000688.5_1010-1029_aso	1010	asusasgsgsdTsdGsdTsdGsdGsdTs(m5dCs)dAsdTsdTscsusususu	404	AUAGGUGUGGUCAUUCUUUU	674	AAAAGAAUGACCACACCUAU	944
NM_000688.5_1020-1039_aso	1020	usasasasasdAs(m5dCs)dTs(m5dCs)dGsdAsdTsdAsdGsdGsusgsusgsg	405	UAAAAACUCGAUAGGUGUGG	675	CCACACCUAUCGAGUUUUUA	945
NM_000688.5_1030-1049_aso	1030	ususcsascsdAsdGsdTsdTsdTsdTsdAsdAsdAsdAsascsuscsg	406	UUCACAGUUUUAAAAACUCG	676	CGAGUUUUUAAAACUGUGAA	946
NM_000688.5_1040-1059_aso	1040	usgscsuscsdGs(m5dCs)(m5dCs)dGsdGsdTsdTs(m5dCs)dAs(m5dCs)asgsususu	407	UGCUCGCCGGUUCACAGUUU	677	AAACUGUGAACCGGCGAGCA	947
NM_000688.5_1050-1069_aso	1050	gsgsasasgsdAsdTsdGsdTsdGsdTsdGs(m5dCs)dTs(m5dCs)gscscsgsg	408	GGAAGAUGUGUGCUCGCCGG	678	CCGGCGAGCACACAUCUUCC	948

NM_0006 88.5_1060 -1079_aso	1060	uscsusgscs(m5dCs)dAsdTsdGsdGsdGs dGsdAsdAsdGsasusgsusg	409	UCUGCCAUGGGGAAG AUGUG	679	CACAUCUUCCCCAUGG CAGA	949
NM_0006 88.5_1070 -1089_aso	1070	usgsasasusdAsdGsdTs(m5dCs)dAsdTs (m5dCs)dTsdGs(m5dCs)csasusgsg	410	UGAAUAGUCAUCUGC CAUGG	680	CCAUGGCAGAUGACUA UUCA	950
NM_0006 88.5_1080 -1099_aso	1080	usgsasgsgsdGsdAsdGsdTs(m5dCs)dTs dGsdAsdAsdTsasgsuscsa	411	UGAGGGAGUCUGAAU AGUCA	681	UGACUAUUCAGACUCC CUCA	951
NM_0006 88.5_1090 -1109_aso	1090	usususususdGsdGsdTsdGsdAsdTsdGs dAsdGsdGsgsasgsusc	412	UUUUUGGUGAUGAGG GAGUC	682	GACUCCCUCAUCACCA AAAA	952
NM_0006 88.5_1100 -1119_aso	1100	usgsascsas(m5dCs)dTsdTsdGs(m5dCs)dTsdTsdTsdTsdTsgsgsusgsa	413	UGACACUUGCUUUUU GGUGA	683	UCACCAAAAAGCAAGU GUCA	953
NM_0006 88.5_1110 -1129_aso	1110	usgscsascs(m5dCs)dAsdGsdAs(m5dCs)dTsdGsdAs(m5dCs)dAscsususgsc	414	UGCACCAGACUGACAC UUGC	684	GCAAGUGUCAGUCUGG UGCA	954
NM_0006 88.5_1120 -1139_aso	1120	usasgsuscsdAsdTsdTsdAs(m5dCs)dTs dGs(m5dCs)dAs(m5dCs)csasgsasc	415	UAGUCAUUACUGCACC AGAC	685	GUCUGGUGCAGUAAUG ACUA	955
NM_0006 88.5_1130 -1149_aso	1130	csasususcs(m5dCs)dTsdAsdGsdGsdTs dAsdGsdTs(m5dCs)asususasc	416	CAUUCCUAGGUAGUC AUUAC	686	GUAAUGACUACCUAGG AAUG	956
NM_0006 88.5_1140 -1159_aso	1140	gsgsusgsgs(m5dCs)dGsdAs(m5dCs)dT s(m5dCs)dAsdTsdTs(m5dCs)csusasgs g	417	GGUGGCGACUCAUUCC UAGG	687	CCUAGGAAUGAGUCGC CACC	957
NM_0006 88.5_1150 -1169_aso	1150	csascsascs(m5dCs)(m5dCs)dGsdTsdG sdGsdGsdTsdGsdGscsgsascsu	418	CACACCCGUGGGUGGC GACU	688	AGUCGCCACCCACGGG UGUG	958
NM_0006 88.5_1160 -1179_aso	1160	asascsusgs(m5dCs)(m5dCs)(m5dCs)(m5dCs)dAs(m5dCs)dAs(m5dCs)dAs(m5dCs)cscsgsusg	419	AACUGCCCCACACACC CGUG	689	CACGGGUGUGUGGGGC AGUU	959
NM_0006 88.5_1170 -1189_aso	1170	asasgsusgsdTs(m5dCs)(m5dCs)dAsdT sdAsdAs(m5dCs)dTsdGscscscscsa	420	AAGUGUCCAUAACUG CCCCA	690	UGGGGCAGUUAUGGAC ACUU	960
NM_0006	1180	usgsusgsdTsdTsdTs(m5dCs)dAsdAs	421	UGUUGUUUCAAAGUG	691	AUGGACACUUUGAAAC	961

88.5_1180 -1199_aso		dAsdGsdTsdGsuscscsasu		UCCAU		AACA	
NM_0006 88.5_1190 -1209_aso	1190	cscscsasgs(m5dCs)dAs(m5dCs)(m5dCs)dAsdTsdGsdTsdTsdGsusususcsa	422	CCCAGCACCAUGUUGU UUCA	692	UGAAACAACAUGGUGC UGGG	962
NM_0006 88.5_1200 -1219_aso	1200	usascscsas(m5dCs)(m5dCs)dTsdGs(m5dCs)(m5dCs)(m5dCs)(m5dCs)dAsdGscsascscsa	423	UACCACCUGCCCCAGC ACCA	693	UGGUGCUGGGGCAGGU GGUA	963
NM_0006 88.5_1210 -1229_aso	1210	asusasususdTs(m5dCs)dTsdAsdGsdTsdAs(m5dCs)(m5dCs)dAscscsusgsc	424	AUAUUUCUAGUACCA CCUGC	694	GCAGGUGGUACUAGAA AUAU	964
NM_0006 88.5_1220 -1239_aso	1220	asgsususcs(m5dCs)dAsdGsdAsdAsdAsdTsdAsdTsdTsuscsusasg	425	AGUUCCAGAAAUAUU UCUAG	695	CUAGAAAUAUUUCUGG AACU	965
NM_0006 88.5_1230 -1249_aso	1230	gsgsasasusdTsdTsdAs(m5dCs)dTsdAsdGsdTsdTs(m5dCs)csasgsasa	426	GGAAUUUACUAGUUC CAGAA	696	UUCUGGAACUAGUAAA UUCC	966
NM_0006 88.5_1240 -1259_aso	1240	asasgsuscs(m5dCs)dAs(m5dCs)dAsdTsdGsdGsdAsdAsdTsususascsu	427	AAGUCCACAUGGAAU UUACU	697	AGUAAAUUCCAUGUGG ACUU	967
NM_0006 88.5_1250 -1269_aso	1250	csuscscscsdGs(m5dCs)dTs(m5dCs)dTsdAsdAsdGsdTs(m5dCs)csascsasu	428	CUCCCGCUCUAAGUCC ACAU	698	AUGUGGACUUAGAGCG GGAG	968
NM_0006 88.5_1260 -1279_aso	1260	gsgsuscsusdGs(m5dCs)(m5dCs)dAsdGs(m5dCs)dTs(m5dCs)(m5dCs)(m5dCs)gscsuscsu	429	GGUCUGCCAGCUCCCG CUCU	699	AGAGCGGGAGCUGGCA GACC	969
NM_0006 88.5_1270 -1289_aso	1270	ususcscscsdAsdTsdGsdGsdAsdGsdGsdTs(m5dCs)dTsgscscsasg	430	UUCCCAUGGAGGUCU GCCAG	700	CUGGCAGACCUCCAUG GGAA	970
NM_0006 88.5_1280 -1299_aso	1280	usgscsgsgs(m5dCs)dAsdTs(m5dCs)dTsdTsdTs(m5dCs)(m5dCs)(m5dCs)(m5dCs)asusggsga	431	UGCGGCAUCUUUCCCA UGGA	701	UCCAUGGGAAAGAUGC CGCA	971
NM_0006 88.5_1290 -1309_aso	1290	asasasascsdAsdAsdGsdAsdGsdTsdGs(m5dCs)dGsdGscsasuscsu	432	AAAACAAGAGUGCGG CAUCU	702	AGAUGCCGCACUCUUG UUUU	972
NM_0006 88.5_1300	1300	asasgscsas(m5dCs)dGsdAsdGsdGsdAsdAsdAsdAsdAs(m5dCs)asasgsasg	433	AAGCACGAGGAAAAC AAGAG	703	CUCUUGUUUUCCUCGU GCUU	973

-1319_aso							
NM_000688.5_1310-1329_aso	1310	asususgsgs(m5dCs)(m5dCs)dAs(m5dCs)dAsdAsdAsdGs(m5dCs)dAscsgsasgsg	434	AUUGGCCACAAAGCACGAGG	704	CCUCGUGCUUUGUGGCCAAU	974
NM_000688.5_1320-1339_aso	1320	gsgsgsususdGsdAsdGsdTs(m5dCs)dAsdTsdTsdGsdGscscsascsa	435	GGGUUGAGUCAUUGGCCACA	705	UGUGGCCAAUGACUCAACCC	975
NM_000688.5_1330-1349_aso	1330	asgsgsgsusdGsdAsdAsdGsdAsdGsdGsdGsdTsdTsgsasgsusc	436	AGGGUGAAGAGGGUUGAGUC	706	GACUCAACCCUCUUCACCCU	976
NM_000688.5_1340-1359_aso	1340	csasuscsusdTsdAsdGs(m5dCs)(m5dCs)dAsdGsdGsdGsdTsgsasasgsa	437	CAUCUUAGCCAGGGUGAAGA	707	UCUUCACCCUGGCUAAGAUG	977
NM_000688.5_1350-1369_aso	1350	asgscscsusdGsdGs(m5dCs)dAsdTs(m5dCs)dAsdTs(m5dCs)dTsusasgscsc	438	AGCCUGGCAUCAUCUUAGCC	708	GGCUAAGAUGAUGCCAGGCU	978
NM_000688.5_1360-1379_aso	1360	usasasasus(m5dCs)dTs(m5dCs)dAs(m5dCs)dAsdGs(m5dCs)(m5dCs)dTsgsgscsasu	439	UAAAUCUCACAGCCUGGCAU	709	AUGCCAGGCUGUGAGAUUUA	979
NM_000688.5_1370-1389_aso	1370	asgsasasus(m5dCs)dAsdGsdAsdGsdTsdAsdAsdAsdTscsuscsasc	440	AGAAUCAGAGUAAAUCUCAC	710	GUGAGAUUUACUCUGAUUCU	980
NM_000688.5_1380-1399_aso	1380	csasusgsgsdTsdTs(m5dCs)(m5dCs)(m5dCs)dAsdGsdAsdAsdTscsasgsasg	441	CAUGGUUCCCAGAAUCAGAG	711	CUCUGAUUCUGGGAACCAUG	981
NM_000688.5_1390-1409_aso	1390	asuscsasusdGsdGsdAsdGsdGs(m5dCs)dAsdTsdGsdGsususcscsc	442	AUCAUGGAGGCAUGGUUCCC	712	GGGAACCAUGCCUCCAUGAU	982
NM_000688.5_1400-1419_aso	1400	asasuscscs(m5dCs)dTsdTsdGsdGsdAsdTs(m5dCs)dAsdTsgsgsasgsg	443	AAUCCCUUGGAUCAUGGAGG	713	CCUCCAUGAUCCAAGGGAUU	983
NM_000688.5_1410-1429_aso	1410	gsgscsusgsdTsdTsdTs(m5dCs)dGsdAsdAsdTs(m5dCs)(m5dCs)csususgsg	444	GGCUGUUUCGAAUCCCUUGG	714	CCAAGGGAUUCGAAACAGCC	984
NM_000688.5_1420-1439_aso	1420	usususgsgs(m5dCs)dAs(m5dCs)dTs(m5dCs)dGsdGs(m5dCs)dTsdGsusususcsg	445	UUUGGCACUCGGCUGUUUCG	715	CGAAACAGCCGAGUGCCAAA	985

NM_0006 88.5_1430 -1449_aso	1430	gsasasgsasdTsdGsdTsdAs(m5dCs)dTs dTsdTsdGsdGscsascsusc	446	GAAGAUGUACUUUGG CACUC	716	GAGUGCCAAAGUACAU CUUC	986
NM_0006 88.5_1440 -1459_aso	1440	csasususgsdTsdGsdGs(m5dCs)dGsdGs dAsdAsdGsdAsusgsusasc	447	CAUUGUGGCGGAAGA UGUAC	717	GUACAUCUUCCGCCAC AAUG	987
NM_0006 88.5_1450 -1469_aso	1450	usgsgscsusdGsdAs(m5dCs)dAsdTs(m 5dCs)dAsdTsdTsdGsusgsgscsg	448	UGGCUGACAUCAUUG UGGCG	718	CGCCACAAUGAUGUCA GCCA	988
NM_0006 88.5_1460 -1479_aso	1460	ususcsuscsdTsdGsdAsdGsdGsdTsdGs dGs(m5dCs)dTsgsascsasu	449	UUCUCUGAGGUGGCU GACAU	719	AUGUCAGCCACCUCAG AGAA	989
NM_0006 88.5_1470 -1489_aso	1470	usususgscsdAsdGs(m5dCs)dAsdGsdT sdTs(m5dCs)dTs(m5dCs)usgsasgsg	450	UUUGCAGCAGUUCUC UGAGG	720	CCUCAGAGAACUGCUG CAAA	990
NM_0006 88.5_1480 -1499_aso	1480	gsgsgsuscsdAsdGsdAsdTs(m5dCs)dTs dTsdTsdGs(m5dCs)asgscsasg	451	GGGUCAGAUCUUUGC AGCAG	721	CUGCUGCAAAGAUCUG ACCC	991
NM_0006 88.5_1490 -1509_aso	1490	gsgsgsgsas(m5dCs)dTsdGsdAsdGsdG sdGsdGsdTs(m5dCs)asgsasusc	452	GGGGACUGAGGGGUC AGAUC	722	GAUCUGACCCCUCAGU CCCC	992
NM_0006 88.5_1500 -1519_aso	1500	cscsascsasdAsdTs(m5dCs)dTsdTsdGs dGsdGsdGsdAscsusgsasg	453	CCACAAUCUUGGGGAC UGAG	723	CUCAGUCCCCAAGAUU GUGG	993
NM_0006 88.5_1510 -1529_aso	1510	gsusususcsdAsdAsdAsdTsdGs(m5dCs)(m5dCs)dAs(m5dCs)dAsasuscsusu	454	GUUUCAAAAUGCCACA AUCUU	724	AAGAUUGUGGGCAUUUG AAAC	994
NM_0006 88.5_1520 -1539_aso	1520	usgsasasusdGsdGsdAs(m5dCs)dAsdG sdTsdTsdTs(m5dCs)asasasusg	455	UGAAUGGACAGUUUC AAAUG	725	CAUUUGAAACUGUCCA UUCA	995
NM_0006 88.5_1530 -1549_aso	1530	cscscscsasdTs(m5dCs)(m5dCs)dAsdTs dTsdGsdAsdAsdTsgsgsascsa	456	CCCCAUCCAUUGAAUG GACA	726	UGUCCAUUCAAUGGAU GGGG	996
NM_0006 88.5_1540 -1559_aso	1540	gsgsgscsas(m5dCs)dAs(m5dCs)(m5dC s)dGs(m5dCs)(m5dCs)(m5dCs)(m5dC s)dAsuscscsasu	457	GGGCACACCGCCCCCAU CCAU	727	AUGGAUGGGGGCGGUGU GCCC	997
NM_0006	1550	csuscsusus(m5dCs)(m5dCs)dAsdGsdT	458	CUCUUCCAGUGGGGCAC	728	CGGUGUGCCCACUGGA	998

88.5_1550-1569_aso		sdGsdGsdGs(m5dCs)dAscsascscsg		ACCG		AGAG	
NM_000688.5_1560-1579_aso	1560	csasuscsas(m5dCs)dAs(m5dCs)dAsdGs(m5dCs)dTs(m5dCs)dTsdTscscsasgsu	459	CAUCACACAGCUCUUCCAGU	729	ACUGGAAGAGCUGUGUGAUG	999
NM_000688.5_1570-1589_aso	1570	uscsasusgsdGsdGs(m5dCs)(m5dCs)dAs(m5dCs)dAsdTs(m5dCs)dAscsascsasg	460	UCAUGGGCCACAUCACACAG	730	CUGUGUGAUGUGGCCCAUGA	1000
NM_000688.5_1580-1599_aso	1580	usgscsuscs(m5dCs)dAsdAsdAs(m5dCs)dTs(m5dCs)dAsdTsdGsgsgscscsa	461	UGCUCCAAACUCAUGGGCCA	731	UGGCCCAUGAGUUUGGAGCA	1001
NM_000688.5_1590-1609_aso	1590	csgsasasgsdGsdTsdGsdAsdTsdTsdGs(m5dCs)dTs(m5dCs)csasasasc	462	CGAAGGUGAUUGCUCCAAAC	732	GUUUGGAGCAAUCACCUUCG	1002
NM_000688.5_1600-1619_aso	1600	ascscsuscsdAsdTs(m5dCs)(m5dCs)dAs(m5dCs)dGsdAsdAsdGsgsusgsasu	463	ACCUCAUCCACGAAGGUGAU	733	AUCACCUUCGUGGAUGAGGU	1003
NM_000688.5_1610-1629_aso	1610	csascsusgs(m5dCs)dGsdTsdGsdGsdAs(m5dCs)(m5dCs)dTs(m5dCs)asuscscsa	464	CACUGCGUGGACCUCAUCCA	734	UGGAUGAGGUCCACGCAGUG	1004
NM_000688.5_1620-1639_aso	1620	csasusasasdAsdGs(m5dCs)(m5dCs)(m5dCs)(m5dCs)dAs(m5dCs)dTsdGscsgsusgsg	465	CAUAAAGCCCCACUGCGUGG	735	CCACGCAGUGGGGCUUUAUG	1005
NM_000688.5_1630-1649_aso	1630	cscsuscsgsdAsdGs(m5dCs)(m5dCs)(m5dCs)(m5dCs)dAsdTsdAsdAsasgscscsc	466	CCUCGAGCCCCAUAAAGCCC	736	GGGCUUUAUGGGGCUCGAGG	1006
NM_000688.5_1640-1659_aso	1640	asasuscscs(m5dCs)dTs(m5dCs)(m5dCs)dGs(m5dCs)(m5dCs)dTs(m5dCs)dGsasgscscsc	467	AAUCCCUCCGCCUCGAGCCC	737	GGGCUCGAGGCGGAGGGAUU	1007
NM_000688.5_1650-1669_aso	1650	cscscsgsasdTs(m5dCs)(m5dCs)(m5dCs)(m5dCs)dAsdAsdTs(m5dCs)(m5dCs)csuscscsg	468	CCCGAUCCCCAAUCCCUCCG	738	CGGAGGGAUUGGGGAUCGGG	1008
NM_000688.5_1660-1679_aso	1660	asusgsascsdTs(m5dCs)(m5dCs)dAsdTs(m5dCs)(m5dCs)(m5dCs)dGsdAsuscscscsc	469	AUGACUCCAUCCCGAUCCCC	739	GGGGAUCGGGAUGGAGUCAU	1009
NM_000688.5_1670	1670	csasususdTsdTsdGsdGs(m5dCs)dAsdTsdGsdAs(m5dCs)uscscsasu	470	CAUUUUUGGCAUGACUCCAU	740	AUGGAGUCAUGCCAAAAAUG	1010

-1689_aso							
NM_000688.5_1680-1699_aso	1680	asasasusgsdAsdTsdGsdTs(m5dCs)(m5dCs)dAsdTsdTsdTsususgsgsc	471	AAAUGAUGUCCAUUUUUGGC	741	GCCAAAAAUGGACAUCAUUU	1011
NM_000688.5_1690-1709_aso	1690	asgsusgsusdTs(m5dCs)(m5dCs)dAsdGsdAsdAsdAsdTsdGsasusgsusc	472	AGUGUUCCAGAAAUGAUGUC	742	GACAUCAUUUCUGGAACACU	1012
NM_000688.5_1700-1719_aso	1700	gsgscsususdTsdGs(m5dCs)(m5dCs)dAsdAsdGsdTsdGsdTsuscscsasg	473	GGCUUUGCCAAGUGUUCCAG	743	CUGGAACACUUGGCAAAGCC	1013
NM_000688.5_1710-1729_aso	1710	csascsasas(m5dCs)(m5dCs)dAsdAsdAsdGsdGs(m5dCs)dTsdTsusgscscsa	474	CACAACCAAAGGCUUUGCCA	744	UGGCAAAGCCUUUGGUUGUG	1014
NM_000688.5_1720-1739_aso	1720	usascscscsdTs(m5dCs)(m5dCs)dAsdAs(m5dCs)dAs(m5dCs)dAsdAscscsasasa	475	UACCCUCCAACACAACCAAA	745	UUUGGUUGUGUUGGAGGGUA	1015
NM_000688.5_1730-1749_aso	1730	gscsusgsgs(m5dCs)dGsdAsdTsdGsdTsdAs(m5dCs)(m5dCs)(m5dCs)uscscsasa	476	GCUGGCGAUGUACCCUCCAA	746	UUGGAGGGUACAUCGCCAGC	1016
NM_000688.5_1740-1759_aso	1740	gsasgsasas(m5dCs)dTs(m5dCs)dGsdTsdGs(m5dCs)dTsdGsdGscsgsasusg	477	GAGAACUCGUGCUGGCGAUG	747	CAUCGCCAGCACGAGUUCUC	1017
NM_000688.5_1750-1769_aso	1750	gsusgsuscsdAsdAsdTs(m5dCs)dAsdGsdAsdGsdAsdAscsuscsgsu	478	GUGUCAAUCAGAGAACUCGU	748	ACGAGUUCUCUGAUUGACAC	1018
NM_000688.5_1760-1779_aso	1760	gsgsascscsdGsdTsdAs(m5dCs)dGsdGsdTsdGsdTs(m5dCs)asasuscsa	479	GGACCGUACGGUGUCAAUCA	749	UGAUUGACACCGUACGGUCC	1019
NM_000688.5_1770-1789_aso	1770	csasgscsasdGs(m5dCs)dAsdTsdAsdGsdGsdAs(m5dCs)(m5dCs)gsusascsg	480	CAGCAGCAUAGGACCGUACG	750	CGUACGGUCCUAUGCUGCUG	1020
NM_000688.5_1780-1799_aso	1780	asasgsasusdGsdAsdAsdGs(m5dCs)(m5dCs)dAsdGs(m5dCs)dAsgscsasusa	481	AAGAUGAAGCCAGCAGCAUA	751	UAUGCUGCUGGCUUCAUCUU	1021
NM_000688.5_1790-1809_aso	1790	asgsasgsgsdTsdGsdGsdTsdGsdAsdAsdGsdAsdTsgsasasgsc	482	AGAGGUGGUGAAGAUGAAGC	752	GCUUCAUCUUCACCACCUCU	1022

NM_0006 88.5_1800 -1819_aso	1800	usgsgsgsusdGsdGs(m5dCs)dAsdGsdA sdGsdAsdGsdGsusgsgsusg	483	UGGGUGGCAGAGAGG UGGUG	753	CACCACCUCUCUGCCA CCCA	1023
NM_0006 88.5_1810 -1829_aso	1810	gscscsasgs(m5dCs)dAsdGs(m5dCs)dA sdTsdGsdGsdGsdTsgsgscsasg	484	GCCAGCAGCAUGGGU GGCAG	754	CUGCCACCCAUGCUGC UGGC	1024
NM_0006 88.5_1820 -1839_aso	1820	csasgsgsgs(m5dCs)dTs(m5dCs)(m5dC s)dAsdGs(m5dCs)(m5dCs)dAsdGscsa sgscsa	485	CAGGGCUCCAGCCAGC AGCA	755	UGCUGCUGGCUGGAGC CCUG	1025
NM_0006 88.5_1830 -1849_aso	1830	gscsascsasdGsdAs(m5dCs)dTs(m5dCs)(m5dCs)dAsdGsdGsdGscsuscscsa	486	GCACAGACUCCAGGGC UCCA	756	UGGAGCCCUGGAGUCU GUGC	1026
NM_0006 88.5_1840 -1859_aso	1840	ususcsasgsdGsdAsdTs(m5dCs)(m5dCs)dGs(m5dCs)dAs(m5dCs)dAsgsascsus c	487	UUCAGGAUCCGCACAG ACUC	757	GAGUCUGUGCGGAUCC UGAA	1027
NM_0006 88.5_1850 -1869_aso	1850	csuscsasgs(m5dCs)dGs(m5dCs)dTs(m 5dCs)dTsdTs(m5dCs)dAsdGsgsasuscs c	488	CUCAGCGCUCUUCAGG AUCC	758	GGAUCCUGAAGAGCGC UGAG	1028
NM_0006 88.5_1860 -1879_aso	1860	gscsascscs(m5dCs)dGsdTs(m5dCs)(m 5dCs)(m5dCs)dTs(m5dCs)dAsdGscsg scsusc	489	GCACCCGUCCCUCAGC GCUC	759	GAGCGCUGAGGGACGG GUGC	1029
NM_0006 88.5_1870 -1889_aso	1870	usgsgscsgsdGs(m5dCs)dGsdAsdAsdG s(m5dCs)dAs(m5dCs)(m5dCs)csgsusc sc	490	UGGCGGCGAAGCACCC GUCC	760	GGACGGGUGCUUCGCC GCCA	1030
NM_0006 88.5_1880 -1899_aso	1880	gscsgscsusdGsdGsdTsdGs(m5dCs)dTs dGsdGs(m5dCs)dGsgscsgsasa	491	GCGCUGGUGCUGGCG GCGAA	761	UUCGCCGCCAGCACCA GCGC	1031
NM_0006 88.5_1890 -1909_aso	1890	gsusususgsdAs(m5dCs)dGsdTsdTsdGs (m5dCs)dGs(m5dCs)dTsgsgsusgsc	492	GUUUGACGUUGCGCU GGUGC	762	GCACCAGCGCAACGUC AAAC	1032
NM_0006 88.5_1900 -1919_aso	1900	usgsuscsus(m5dCs)dAsdTsdGsdAsdG sdTsdTsdTsdGsascsgsusu	493	UGUCUCAUGAGUUUG ACGUU	763	AACGUCAAACUCAUGA GACA	1033
NM_0006 88.5_1910 -1929_aso	1910	csasususasdGs(m5dCs)dAsdTs(m5dCs)dTsdGsdTs(m5dCs)dTscsasusgsa	494	CAUUAGCAUCUGUCUC AUGA	764	UCAUGAGACAGAUGCU AAUG	1034
NM_0006	1920	gsgscscsgsdGs(m5dCs)dAsdTs(m5dCs	495	GGCCGGCAUCCAUUAG	765	GAUGCUAAUGGAUGCC	1035

88.5_1920-1939_aso		)(m5dCs)dAsdTsdTsdAsgscsasusc		CAUC		GGCC	
NM_0006 88.5_1930-1949_aso	1930	ascsasascsdAsdGsdGsdGsdAsdGsdGs(m5dCs)(m5dCs)dGsgscsasusc	496	ACAACAGGGAGGCCG GCAUC	766	GAUGCCGGCCUCCCUG UUGU	1036
NM_0006 88.5_1940-1959_aso	1940	gsgsgsgscsdAsdGsdTsdGsdGsdAs(m5dCs)dAsdAs(m5dCs)asgsgsgsa	497	GGGGCAGUGGACAAC AGGGA	767	UCCCUGUUGUCCACUG CCCC	1037
NM_0006 88.5_1950-1969_aso	1950	usgsasusgsdTsdGsdGs(m5dCs)dTsdGsdGsdGsdGs(m5dCs)asgsusgsg	498	UGAUGUGGGCUGGGGC AGUGG	768	CCACUGCCCCAGCCAC AUCA	1038
NM_0006 88.5_1960-1979_aso	1960	csgscsascsdAsdGsdGsdGsdAsdTsdGsdAsdTsdGsusgsgscsu	499	CGCACAGGGAUGAUG UGGCU	769	AGCCACAUCAUCCCUG UGCG	1039
NM_0006 88.5_1970-1989_aso	1970	asuscsusgs(m5dCs)dAsdAs(m5dCs)(m5dCs)(m5dCs)dGs(m5dCs)dAs(m5dCs)asgsgsgsa	500	AUCUGCAACCCGCACA GGGA	770	UCCCUGUGCGGGUUGC AGAU	1040
NM_0006 88.5_1980-1999_aso	1980	ususususasdGs(m5dCs)dAsdGs(m5dCs)dAsdTs(m5dCs)dTsdGscsasascsc	501	UUUUAGCAGCAUCUG CAACC	771	GGUUGCAGAUGCUGCU AAAA	1041
NM_0006 88.5_1990-2009_aso	1990	ascsususcsdTsdGsdTsdGsdTsdTsdTsdTsdTsdAsgscsasgsc	502	ACUUCUGUGUUUUUA GCAGC	772	GCUGCUAAAAAACACAG AAGU	1042
NM_0006 88.5_2000-2019_aso	2000	ususcsasus(m5dCs)dAs(m5dCs)dAsdGsdAs(m5dCs)dTsdTs(m5dCs)usgsusgsu	503	UUCAUCACAGACUUCU GUGU	773	ACACAGAAGUCUGUGA UGAA	1043
NM_0006 88.5_2010-2029_aso	2010	usgscsuscsdAsdTsdTsdAsdGsdTsdTs(m5dCs)dAsdTscsascsasg	504	UGCUCAUUAGUUCAU CACAG	774	CUGUGAUGAACUAAUG AGCA	1044
NM_0006 88.5_2020-2039_aso	2020	asusgsususdAsdTsdGsdTs(m5dCs)dTsdGs(m5dCs)dTs(m5dCs)asususasg	505	AUGUUAUGUCUGCUC AUUAG	775	CUAAUGAGCAGACAUA ACAU	1045
NM_0006 88.5_2030-2049_aso	2030	ususgscsas(m5dCs)dGsdTsdAsdGsdAsdTsdGsdTsdTsasusgsusc	506	UUGCACGUAGAUGUU AUGUC	776	GACAUAACAUCUACGU GCAA	1046
NM_0006 88.5_2040	2040	asasususgsdAsdTsdTsdGs(m5dCs)dTsdTsdGs(m5dCs)dAscsgsusasg	507	AAUUGAUUGCUUGCA CGUAG	777	CUACGUGCAAGCAAUC AAUU	1047

-2059_aso							
NM_000688.5_2050-2069_aso	2050	ascscsgsusdAsdGsdGsdGsdTsdAsdAsdTsdTsdGsasususgsc	508	ACCGUAGGGUAAUUGAUUGC	778	GCAAUCAAUUACCCUACGGU	1048
NM_000688.5_2060-2079_aso	2060	uscscscscsdGsdGsdGsdGs(m5dCs)dAs(m5dCs)(m5dCs)dGsdTsasgsgsgsu	509	UCCCCGGGGCACCGUAGGGU	779	ACCCUACGGUGCCCCGGGGA	1049
NM_000688.5_2070-2089_aso	2070	gsgsasgscsdTs(m5dCs)dTsdTs(m5dCs)dTs(m5dCs)(m5dCs)(m5dCs)(m5dCs)gsgsgsgsc	510	GGAGCUCUUCUCCCCGGGGC	780	GCCCCGGGGAGAAGAGCUCC	1050
NM_000688.5_2080-2099_aso	2080	gscsasasus(m5dCs)(m5dCs)dGsdTsdAsdGsdGsdAsdGs(m5dCs)uscsususc	511	GCAAUCCGUAGGAGCUCUUC	781	GAAGAGCUCCUACGGAUUGC	1051
NM_000688.5_2090-2109_aso	2090	asgsgsgsgsdTsdGsdGsdGsdGsdGs(m5dCs)dAsdAsdTscscsgsusa	512	AGGGGUGGGGGCAAUCCGUA	782	UACGGAUUGCCCCCACCCCU	1052
NM_000688.5_2100-2119_aso	2100	gsusgsusgsdTsdGsdGsdTsdGsdAsdGsdGsdGsdGsusgsgsgsg	513	GUGUGUGGUGAGGGGUGGGG	783	CCCCACCCCUCACCACACAC	1053
NM_000688.5_2110-2129_aso	2110	asuscsasus(m5dCs)dTsdGsdGsdGsdGsdTsdGsdTsdGsusgsgsusg	514	AUCAUCUGGGGUGUGUGGUG	784	CACCACACACCCCAGAUGAU	1054
NM_000688.5_2120-2139_aso	2120	gsasasgsusdAsdGsdTsdTs(m5dCs)dAsdTs(m5dCs)dAsdTscsusgsgsg	515	GAAGUAGUUCAUCAUCUGGG	785	CCCAGAUGAUGAACUACUUC	1055
NM_000688.5_2130-2149_aso	2130	gsasususcsdTs(m5dCs)dAsdAsdGsdGsdAsdAsdGsdTsasgsususc	516	GAUUCUCAAGGAAGUAGUUC	786	GAACUACUUCCUUGAGAAUC	1056
NM_000688.5_2140-2159_aso	2140	gsusgsascsdTsdAsdGs(m5dCs)dAsdGsdAsdTsdTs(m5dCs)uscsasasg	517	GUGACUAGCAGAUUCUCAAG	787	CUUGAGAAUCUGCUAGUCAC	1057
NM_000688.5_2150-2169_aso	2150	ususgscsusdTs(m5dCs)(m5dCs)dAsdTsdGsdTsdGsdAs(m5dCs)usasgscsa	518	UUGCUUCCAUGUGACUAGCA	788	UGCUAGUCACAUGGAAGCAA	1058
NM_000688.5_2160-2179_aso	2160	cscsasgscs(m5dCs)(m5dCs)(m5dCs)dAs(m5dCs)dTsdTsdGs(m5dCs)dTsuscscsasu	519	CCAGCCCCACUUGCUUCCAU	789	AUGGAAGCAAGUGGGGCUGG	1059

NM_0006 88.5_2170 -2189_aso	2170	gsgscsusus(m5dCs)dAsdGsdTsdTs(m5dCs)(m5dCs)dAsdGs(m5dCs)cscscsas c	520	GGCUUCAGUUCCAGCC CCAC	790	GUGGGGCUGGAACUGA AGCC	1060
NM_0006 88.5_2180 -2199_aso	2180	usgsasgsgsdAsdAsdTsdGsdAsdGsdGs (m5dCs)dTsdTscsasgsusu	521	UGAGGAAUGAGGCUU CAGUU	791	AACUGAAGCCUCAUUC CUCA	1061
NM_0006 88.5_2190 -2209_aso	2190	usgscsascsdTs(m5dCs)dAsdGs(m5dCs)dTsdGsdAsdGsdGsasasusgsa	522	UGCACUCAGCUGAGG AAUGA	792	UCAUUCCUCAGCUGAG UGCA	1062
NM_0006 88.5_2200 -2219_aso	2200	csusgscsasdGsdAsdAsdGsdTsdTsdGs(m5dCs)dAs(m5dCs)uscsasgsc	523	CUGCAGAAGUUGCAC UCAGC	793	GCUGAGUGCAACUUCU GCAG	1063
NM_0006 88.5_2210 -2229_aso	2210	csasgsusgsdGs(m5dCs)(m5dCs)dTs(m 5dCs)(m5dCs)dTsdGs(m5dCs)dAsgsa sasgsu	524	CAGUGGCCUCCUGCAG AAGU	794	ACUUCUGCAGGAGGCC ACUG	1064
NM_0006 88.5_2220 -2239_aso	2220	csususcsasdAsdAsdAsdTsdGs(m5dCs) dAsdGsdTsdGsgscscsusc	525	CUUCAAAAAUGCAGUG GCCUC	795	GAGGCCACUGCAUUUU GAAG	1065
NM_0006 88.5_2230 -2249_aso	2230	uscsascsus(m5dCs)dAsdTs(m5dCs)dA s(m5dCs)dTsdTs(m5dCs)dAsasasasus g	526	UCACUCAUCACUUCAA AAUG	796	CAUUUUGAAGUGAUGA GUGA	1066
NM_0006 88.5_2240 -2259_aso	2240	csususcsus(m5dCs)dTs(m5dCs)dTsdT sdTs(m5dCs)dAs(m5dCs)dTscsasuscs a	527	CUUCUCUCUUUCACUC AUCA	797	UGAUGAGUGAAAGAGA GAAG	1067
NM_0006 88.5_2250 -2269_aso	2250	asgsasasasdTsdAsdGsdGsdAs(m5dCs) dTsdTs(m5dCs)dTscsuscsusu	528	AGAAAUAGGACUUCU CUCUU	798	AAGAGAGAAGUCCUAU UUCU	1068
NM_0006 88.5_2260 -2279_aso	2260	csuscsasasdGs(m5dCs)(m5dCs)dTsdG sdAsdGsdAsdAsdAsusasgsgsa	529	CUCAAGCCUGAGAAA UAGGA	799	UCCUAUUUCUCAGGCU UGAG	1069
NM_0006 88.5_2270 -2289_aso	2270	usascscsasdAs(m5dCs)dTsdTsdGs(m5 dCs)dTs(m5dCs)dAsdAsgscscsusg	530	UACCAACUUGCUCAAG CCUG	800	CAGGCUUGAGCAAGUU GGUA	1070
NM_0006 88.5_2280 -2299_aso	2280	cscsusgsasdGs(m5dCs)dAsdGsdAsdTs dAs(m5dCs)(m5dCs)dAsascsususg	531	CCUGAGCAGAUACCAA CUUG	801	CAAGUUGGUAUCUGCU CAGG	1071
NM_0006	2290	csasusgscsdTs(m5dCs)dAsdGsdGs(m5	532	CAUGCUCAGGCCUGAG	802	UCUGCUCAGGCCUGAG	1072

88.5_2290-2309_aso		dCs)(m5dCs)dTsdGsdAsgscsasgsa		CAGA		CAUG	
NM_000688.5_2300-2319_aso	2300	usasasususdGsdAsdGsdGsdTs(m5dCs)dAsdTsdGs(m5dCs)uscsasgsg	533	UAAUUGAGGUCAUGCUCAGG	803	CCUGAGCAUGACCUCAAUUA	1073
NM_000688.5_2310-2329_aso	2310	ususasasgsdTsdGsdAsdAsdAsdTsdAsdAsdTsdTsgsasgsgsu	534	UUAAGUGAAAUAAUUGAGGU	804	ACCUCAAUUAUUUCACUUAA	1074
NM_000688.5_2320-2339_aso	2320	usgsgscscsdTsdGsdGsdGsdGsdTsdTsdAsdAsdGsusgsasasa	535	UGGCCUGGGGUUAAGUGAAA	805	UUUCACUUAACCCCAGGCCA	1075
NM_000688.5_2330-2349_aso	2330	gsasusasusdGsdAsdTsdAsdAsdTsdGsdGs(m5dCs)(m5dCs)usgsgsgsg	536	GAUAUGAUAAUGGCCUGGGG	806	CCCCAGGCCAUUAUCAUAUC	1076
NM_000688.5_2340-2359_aso	2340	asgsascscsdAsdTs(m5dCs)dTsdGsdGsdAsdTsdAsdTsgsasusasa	537	AGACCAUCUGGAUAUGAUAA	807	UUAUCAUAUCCAGAUGGUCU	1077
NM_000688.5_2350-2369_aso	2350	ascsasascsdTs(m5dCs)dTsdGsdAsdAsdGsdAs(m5dCs)(m5dCs)asuscsusg	538	ACAACUCUGAAGACCAUCUG	808	CAGAUGGUCUUCAGAGUUGU	1078
NM_000688.5_2360-2379_aso	2360	ascsasusasdTsdAsdAsdAsdGsdAs(m5dCs)dAsdAs(m5dCs)uscsusgsa	539	ACAUAUAAAGACAACUCUGA	809	UCAGAGUUGUCUUUAUAUGU	1079
NM_000688.5_2370-2389_aso	2370	asascsususdAsdAsdTsdTs(m5dCs)dAs(m5dCs)dAsdTsdAsusasasasg	540	AACUUAAUUCACAUAUAAAG	810	CUUUAUAUGUGAAUUAAGUU	1080
NM_000688.5_2380-2399_aso	2380	asasususdAsdAsdTsdAsdTsdAsdAs(m5dCs)dTsdTsasasususc	541	AAUUUAAUAUAACUUAAUUC	811	GAAUUAAGUUAUAUUAAAUU	1081
NM_000688.5_2390-2409_aso	2390	usasusasgsdAsdTsdTsdAsdAsdAsdAsdTsdTsdTsasasusasu	542	UAUAGAUUAAAAUUUAAUAU	812	AUAUUAAAUUUUAAUCUAUA	1082
NM_000688.5_2400-2419_aso	2400	asusgsususdTsdTsdTsdAs(m5dCs)dTsdAsdTsdAsdGsasususasa	543	AUGUUUUUACUAUAGAUUAA	813	UUAAUCUAUAGUAAAAACAU	1083
NM_000688.5_2410	2410	ususcscsasdGsdGsdAs(m5dCs)dTsdAsdTsdGsdTsdTsususususasc	544	UUCCAGGACUAUGUUUUUAC	814	GUAAAAACAUAGUCCUGGAA	1084

-2429_aso							
NM_000688.5_2420-2439_aso	2420	asasgsasasdTsdTsdTsdTsdAsdTsdTsdTs(m5dCs)(m5dCs)dAsgsgsascsu	545	AAGAAUUUAUUUCCAGGACU	815	AGUCCUGGAAAUAAAUUCUU	1085
NM_000688.5_2430-2449_aso	2430	cscsasususdTsdAsdAsdGs(m5dCs)dAsdAsdGsdAsdAsususususasu	546	CCAUUUAAGCAAGAAUUUAU	816	AUAAAUUCUUGCUUAAAUGG	1086

Example 2. *In vitro* Screening

In vitro screening of the antisense polynucleotides was performed by transfecting Hep3B cells with a single 5nM dose of an antisense polynucleotide using methods well known in the art.

Briefly, a single 5 nM dose screen of each of 270 ALAS1 oligos was performed in Hep3B cells by seeding about 15,000 cells per well in 96 well plates. Each oligo was transfected in quadruplicate with 0.5 µl Lipofectamine 2000/well. Transfections were harvested 24 hours after seeding/transfection. Transfection of an Aha1 LNA gapmer as a control transfection, and mock transfections were performed in quadruplicate on each plate. Mean values of ALAS1/GAPDH from Aha1-LNA transfection was set as 100% ALAS1 expression, which is the reference for all other mean values shown in Table 5. At the same time, the AhaI LNA also served as a transfection control on each plate.

The complete screen was performed in two transfection "sessions". Overall, transfection efficiency with an Aha1-oligo was between ~90-95% at 5 nM. All ALAS1 oligos were less efficient than the Aha1-LNA at the same concentration, the best producing a KD of ~70%.

Table 5 shows the results of a single dose transfection screen in cells transfected with the indicated antisense polynucleotide.

Table 5.

	meanval% (w/o correction)	sd%	Corrected transfection efficiency (tfe)
X10361K2	97	7	96
X10362K2	86	5	85
X10363K2	95	4	94
X10364K2	81	7	80
X10365K2	93	4	92
X10366K2	92	9	91
X10367K2	79	9	78
X10368K2	77	6	76
X10369K2	91	9	90
X10370K2	87	6	86
X10371K2	68	5	67
X10372K2	85	12	84
X10373K2	89	7	88
X10374K2	87	5	86
X10375K2	90	11	89
X10376K2	90	7	89
X10377K2	94	8	93

X10378K2	54	4	53
X10379K2	81	3	80
X10380K2	82	6	81
X10381K2	91	4	89
X10382K2	92	2	90
X10383K2	101	5	100
X10384K2	99	11	97
X10385K2	97	6	95
X10386K2	95	3	94
X10387K2	87	4	85
X10388K2	91	9	90
X10389K2	75	5	74
X10390K2	70	3	68
X10391K2	85	18	84
X10392K2	88	8	86
X10393K2	92	4	90
X10394K2	85	14	83
X10395K2	92	7	91
X10396K2	96	4	95
X10397K2	85	3	83
X10398K2	73	4	71
X10399K2	90	5	88
X10400K2	94	6	92
X10401K2	86	9	86
X10402K2	75	12	75
X10403K2	64	10	64
X10404K2	97	12	97
X10405K2	96	9	96
X10406K2	111	13	111
X10407K2	90	12	90
X10408K2	116	19	116
X10409K2	106	16	106
X10410K2	107	12	107
X10411K2	59	6	59
X10412K2	65	7	65
X10413K2	85	13	85
X10414K2	86	10	86
X10415K2	90	9	90
X10416K2	63	3	63
X10417K2	91	7	91
X10418K2	73	3	73
X10419K2	80	7	80
X10420K2	91	7	91
X10421K2	68	8	67

X10422K2	60	4	59
X10423K2	64	5	63
X10424K2	80	8	79
X10425K2	88	2	87
X10426K2	75	6	74
X10427K2	93	6	92
X10428K2	94	8	93
X10429K2	92	5	91
X10430K2	71	7	70
X10431K2	67	14	66
X10432K2	59	4	59
X10433K2	74	9	73
X10434K2	64	6	63
X10435K2	74	8	73
X10436K2	91	19	90
X10437K2	92	7	91
X10438K2	88	10	87
X10439K2	108	9	107
X10440K2	101	8	100
X10441K2	88	7	88
X10442K2	57	1	56
X10443K2	78	5	77
X10444K2	81	3	81
X10445K2	61	7	60
X10446K2	71	6	71
X10447K2	69	4	68
X10448K2	102	5	101
X10449K2	73	4	73
X10450K2	65	3	65
X10451K2	66	5	66
X10452K2	73	3	73
X10453K2	75	5	75
X10454K2	96	8	96
X10455K2	92	4	91
X10456K2	79	5	79
X10457K1	70	2	70
X10458K1	56	4	55
X10459K1	61	5	60
X10460K1	76	5	75
X10461K1	97	3	94
X10462K1	98	4	95
X10463K1	93	15	90
X10464K1	95	10	92
X10465K1	86	12	83

X10466K1	100	6	97
X10467K1	97	8	95
X10468K1	98	4	95
X10469K1	90	4	87
X10470K1	99	2	96
X10471K1	110	4	107
X10472K1	122	2	119
X10473K1	117	9	114
X10474K1	119	7	116
X10475K1	116	6	113
X10476K1	111	11	108
X10477K1	108	8	105
X10478K1	108	8	106
X10479K1	108	10	105
X10480K1	105	6	102
X10481K1	77	3	75
X10482K1	83	7	81
X10483K1	98	5	95
X10484K1	102	10	99
X10485K1	107	11	104
X10486K1	111	12	109
X10487K1	112	8	109
X10488K1	71	4	69
X10489K1	81	8	79
X10490K1	106	9	103
X10491K1	73	8	71
X10492K1	56	4	53
X10493K1	88	9	85
X10494K1	68	8	65
X10495K1	85	9	82
X10496K1	94	13	91
X10497K1	89	8	86
X10498K1	67	3	65
X10499K1	65	4	63
X10500K1	102	11	100
X10501K1	56	9	53
X10502K1	78	6	75
X10503K1	68	7	65
X10504K1	58	6	55
X10505K2	88	4	85
X10506K2	70	6	67
X10507K2	52	8	49
X10508K2	89	8	86
X10509K2	97	5	94

X10510K2	88	8	85
X10511K2	70	14	67
X10512K2	65	14	62
X10513K2	47	11	44
X10514K2	64	11	61
X10515K2	50	9	47
X10516K1	77	11	74
X10517K2	73	5	70
X10518K2	42	6	39
X10519K2	33	7	30
X10520K2	94	10	91
X10521K2	126	7	125
X10522K2	102	9	100
X10523K2	89	9	88
X10524K2	113	4	112
X10525K2	67	3	66
X10526K2	73	5	72
X10527K2	76	5	75
X10528K2	39	3	38
X10529K2	77	10	76
X10530K1	74	8	73
X10531K2	91	10	90
X10532K2	75	12	74
X10533K2	91	7	90
X10534K2	76	5	75
X10535K2	65	1	64
X10536K2	81	22	80
X10537K1	61	6	60
X10538K1	92	4	91
X10539K2	91	1	90
X10540K1	86	2	85
X10541K2	77	4	76
X10542K2	60	3	60
X10543K2	83	7	82
X10544K2	38	1	37
X10545K2	64	4	63
X10546K2	54	8	53
X10547K2	94	5	93
X10548K2	54	3	53
X10549K1	62	2	61
X10550K2	46	2	45
X10551K1	53	6	52
X10552K1	50	6	49
X10553K1	78	8	77

X10554K1	79	9	78
X10555K1	72	6	71
X10556K1	76	10	75
X10557K1	68	9	67
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X10566K1	93	11	92
X10567K1	93	10	92
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X10579K1	74	6	72
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X10594K1	75	3	66
X10595K1	127	14	118
X10596K1	117	16	108
X10597K2	124	16	115

X10598K1	121	13	112
X10599K1	120	10	110
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X10603K1	74	3	67
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X10607K1	88	11	80
X10608K1	87	7	80
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X10611K1	71	21	63
X10612K1	84	28	77
X10613K1	88	21	80
X10614K1	95	12	87
X10615K1	91	4	84
X10616K1	89	5	82
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X10618K1	99	4	91
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X10620K1	85	4	78
X10621K1	87	11	80
X10622K1	83	6	77
X10623K1	94	7	87
X10624K1	96	9	90
X10625K1	97	7	91
X10626K1	99	4	92
X10627K1	100	9	94
X10628K1	98	7	91
X10629K1	106	8	100
X10630K1	102	7	95

EQUIVALENTS

Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments and methods described herein. Such equivalents are intended to be encompassed by the scope of the following claims.

We claim:

1. An antisense polynucleotide agent for inhibiting expression of an aminolevulinic acid synthase-1 (ALAS1) gene, wherein the agent comprises about 4 to about 50 contiguous nucleotides, wherein at least one of the contiguous nucleotides is a modified nucleotide, and wherein the nucleotide sequence of the agent is about 80% complementary over its entire length to the equivalent region of the nucleotide sequence of any one of SEQ ID NOs:1-2.

2. The agent of claim 1, wherein the equivalent region is one of the target regions of SEQ ID NO:1 provided in Tables 3 and 4.

3. An antisense polynucleotide agent for inhibiting expression of aminolevulinic acid synthase-1 (ALAS1), wherein the agent comprises at least 8 contiguous nucleotides differing by no more than 3 nucleotides from any one of the nucleotide sequences listed in Tables 3 and 4.

4. The agent of claim 1, wherein substantially all of the nucleotides of the antisense polynucleotide agent are modified nucleotides.

5. The agent of claim 1, wherein all of the nucleotides of the antisense polynucleotide agent are modified nucleotides.

6. The agent of claim 1, which is 10 to 40 nucleotides in length.

7. The agent of claim 1, which is 10 to 30 nucleotides in length.

8. The agent of claim 1, which is 18 to 30 nucleotides in length.

9. The agent of claim 1, which is 10 to 24 nucleotides in length.

10. The agent of claim 1, which is 18 to 24 nucleotides in length.

11. The agent of claim 1, which is 20 nucleotides in length.

12. The agent of claim 1, which is 21 nucleotides in length.

13. The agent of claim 1, wherein the modified nucleotide comprises a modified sugar moiety selected from the group consisting of: a 2′-O-methoxyethyl modified sugar moiety, a 2′-methoxy modified sugar moiety, a 2′-O-alkyl modified sugar moiety, and a bicyclic sugar moiety.

14. The agent of claim 13, wherein the bicyclic sugar moiety has a (-CRH-)n group forming a bridge between the 2' oxygen and the 4' carbon atoms of the sugar ring, wherein n is 1 or 2 and wherein R is H, CH3 or CH_3OCH_3.

15. The agent of claim 1, wherein the modified nucleotide is a 5-methylcytosine.

16. The agent of claim 1, wherein the modified nucleotide comprises a modified internucleoside linkage.

17. The agent of claim 16, wherein the modified internucleoside linkage is a phosphorothioate internucleoside linkage.

18. The agent of claim 1, comprising a plurality of 2′-deoxynucleotides flanked on each side by at least one nucleotide having a modified sugar moiety.

19. The agent of claim 18, wherein the agent is a gapmer comprising a gap segment comprised of linked 2′-deoxynucleotides positioned between a 5′ and a 3′ wing segment.

20. The agent of claim 18, wherein the modified sugar moiety is selected from the group consisting of a 2′-O-methoxyethyl modified sugar moiety, a 2′-methoxy modified sugar moiety, a 2′-O-alkyl modified sugar moiety, and a bicyclic sugar moiety.

21. The agent of claim 19, wherein the 5’-wing segment is 1 to 6 nucleotides in length.

22. The agent of claim 19, wherein the 3’-wing segment is 1 to 6 nucleotides in length.

23. The agent of claim 19, wherein the gap segment is 5 to 14 nucleotides in length.

24. The agent of claim 19, wherein the 5’-wing segment is 3 nucleotides in length.

25. The agent of claim 19, wherein the 3'-wing segment is 3 nucleotides in length.

26. The agent of claim 19, wherein the 5'-wing segment is 4 nucleotides in length.

27. The agent of claim 19, wherein the 3'-wing segment is 4 nucleotides in length.

28. The agent of claim 19, wherein the 5'-wing segment is 5 nucleotides in length.

29. The agent of claim 19, wherein the 3'-wing segment is 5 nucleotides in length.

30. The agent of claim 19, wherein the 5'-wing segment is 6 nucleotides in length.

31. The agent of claim 19, wherein the 3'-wing segment is 6 nucleotides in length.

32. The agent of claim 19, wherein the gap segment is 11 nucleotides in length.

33. The agent of claim 19, wherein the gap segment is 10 nucleotides in length.

34. An antisense polynucleotide agent for inhibiting aminolevulinic acid synthase-1 (ALAS1) expression, comprising

a gap segment consisting of linked deoxynucleotides;

a 5'-wing segment consisting of linked nucleotides;

a 3'-wing segment consisting of linked nucleotides;

wherein the gap segment is positioned between the 5'-wing segment and the 3'-wing segment and wherein each nucleotide of each wing segment comprises a modified sugar.

35. The agent of claim 34, wherein the gap segment is ten 2′-deoxynucleotides in length and each of the wing segments is five nucleotides in length.

36. The agent of claim 34, wherein the gap segment is eleven 2′-deoxynucleotides in length and each of the wing segments is five nucleotides in length.

37. The agent of claim 34, wherein the gap segment is ten 2′-deoxynucleotides in length and each of the wing segments is four nucleotides in length.

38. The agent of claim 34, wherein the gap segment is eleven 2′-deoxynucleotides in length and each of the wing segments is four nucleotides in length.

39. The agent of claim 34, wherein the gap segment is ten 2′-deoxynucleotides in length and each of the wing segments is three nucleotides in length.

40. The agent of claim 34, wherein the gap segment is eleven 2′-deoxynucleotides in length and each of the wing segments is three nucleotides in length.

41. The antisense compound of claim 34, wherein the gap segment is ten 2′-deoxynucleotides in length and each of the wing segments is two nucleotides in length.

42. The antisense compound of claim 34, wherein the gap segment is eleven 2′-deoxynucleotides in length and each of the wing segments is two nucleotides in length.

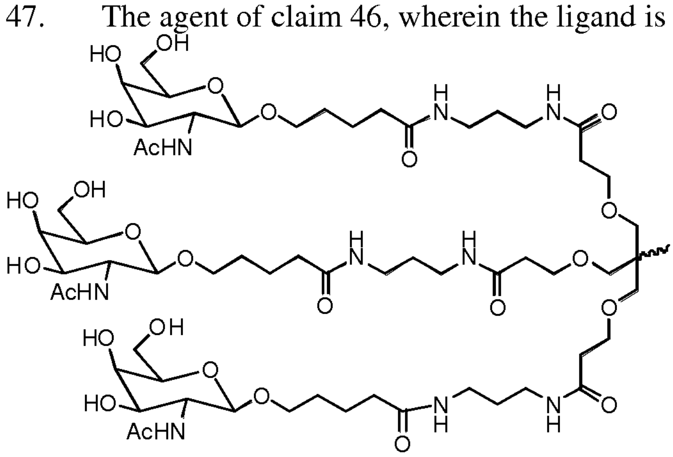
43. The agent of claim 34, wherein the modified sugar moiety is selected from the group consisting of a 2′-O-methoxyethyl modified sugar moiety, a 2′-methoxy modified sugar moiety, a 2′-O-alkyl modified sugar moiety, and a bicyclic sugar moiety.

44. The agent of any one of claims 1 or 34, wherein the agent further comprises a ligand.

45. The agent of claim 44, wherein the antisense polynucleotide agent is conjugated to the ligand at the 3’-terminus.

46. The agent of claim 44, wherein the ligand is an N-acetylgalactosamine (GalNAc) derivative.

47. The agent of claim 46, wherein the ligand is



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48. A pharmaceutical composition for inhibiting expression of a aminolevulinic acid synthase-1 (ALAS1) gene comprising the agent of claim 1 or 3433.

49. The pharmaceutical composition of claim 48, wherein agent is present in an unbuffered solution.

50. The pharmaceutical composition of claim 49, wherein the unbuffered solution is saline or water.

51. The pharmaceutical composition of claim 49, wherein the agent is present in a buffer solution.

52. The pharmaceutical composition of claim 51, wherein the buffer solution comprises acetate, citrate, prolamine, carbonate, or phosphate or any combination thereof.

53. The pharmaceutical composition of claim 51, wherein the buffer solution is phosphate buffered saline (PBS).

54. A pharmaceutical composition comprising the agent of claim 1 or 34, and a lipid formulation.

55. The pharmaceutical composition of claim 54, wherein the lipid formulation comprises a LNP.

56. The pharmaceutical composition of claim 54, wherein the lipid formulation comprises a MC3.

57. A method of inhibiting aminolevulinic acid synthase-1 (ALAS1) expression in a cell, the method comprising:

(a) contacting the cell with the agent of claim 1 or 34 or a pharmaceutical composition of claim 48 or 54; and

(b) maintaining the cell produced in step (a) for a time sufficient to obtain antisense inhibition of an ALAS1 gene, thereby inhibiting expression of the ALAS gene in the cell.

58. The method of claim 57, wherein the cell is within a subject.

59. The method of claim 58, wherein the subject is a human.

60. The method of claim 57, wherein the ALAS1 expression is inhibited by at least about 30%, about 40%, about 50%, about 60%, about 70%, about 80%, about 90%, about 95%, about 98% or about 100%.

61. A method of treating a subject having a disease or disorder that would benefit from reduction in aminolevulinic acid synthase-1 (ALAS1) expression, the method comprising administering to the subject a therapeutically effective amount of the agent of claim 1 or 34 or the pharmaceutical composition of claim 48 or 54, thereby treating the subject.

62. A method of preventing at least one symptom in a subject having a disease or disorder that would benefit from reduction in aminolevulinic acid synthase-1 (ALAS1) expression, the method comprising administering to the subject a prophylactically effective amount of the agent of claim 1 or 34 or the pharmaceutical composition of claim 48 or 54, thereby preventing at least one symptom in the subject having a disorder that would benefit from reduction in ALAS1 expression.

63. The method of claim 61 or 62, wherein the administration of the antisense polynucleotide agent to the subject causes a decrease in ALAS1 protein levels.

64. The method of claim 61 or 62, wherein the disorder is an ALAS1-associated disease.

65. The method of claim 62, wherein the ALAS1-associated disease is porphyria.

66. The method of claim 65, wherein the porphyria is selected from the group consisting of X-linked sideroblastic anemia (XLSA), ALA deyhdratase deficiency porphyria (Doss porphyria), acute intermittent porphyria (AIP), congenital erythropoietic porphyria (CEP), prophyria cutanea tarda (PCT), hereditary coproporphyria (coproporphyria, or HCP), variegate porphyria (VP), erythropoietic protoporphyria (EPP), or transient erythroporphyria of infancy, acute hepatic porphyria, hepatoerythropoietic porphyria, and dual porphyria.

67. The method of any one of claims 61-66, wherein the agent or the composition is administered after an acute attack of porphyria.

68. The method of any one of claims 61-66, wherein the agent or the composition is administered during an acute attack of porphyria.

69. The method of any one of claims 61-66, wherein the agent or the composition is administered prophylactically to prevent an acute attack of porphyria.

70. The method of claim 61 or 62, wherein the subject is human.

71. The method of any one of claims 61-70, wherein the agent is administered at a dose of about 0.01 mg/kg to about 10 mg/kg or about 0.5 mg/kg to about 50 mg/kg.

72. The method of claim 71, wherein the agent is administered at a dose of about 10 mg/kg to about 30 mg/kg.

73. The method of claim 71, wherein the agent is administered to the subject once a week.

74. The method of claim 71, wherein the agent is administered to the subject twice a week.

75. The method of claim 71, wherein the agent is administered to the subject twice a month.

76. The method of any one of claims 61-75, wherein the agent is administered to the subject subcutaneously.

Fig. 1

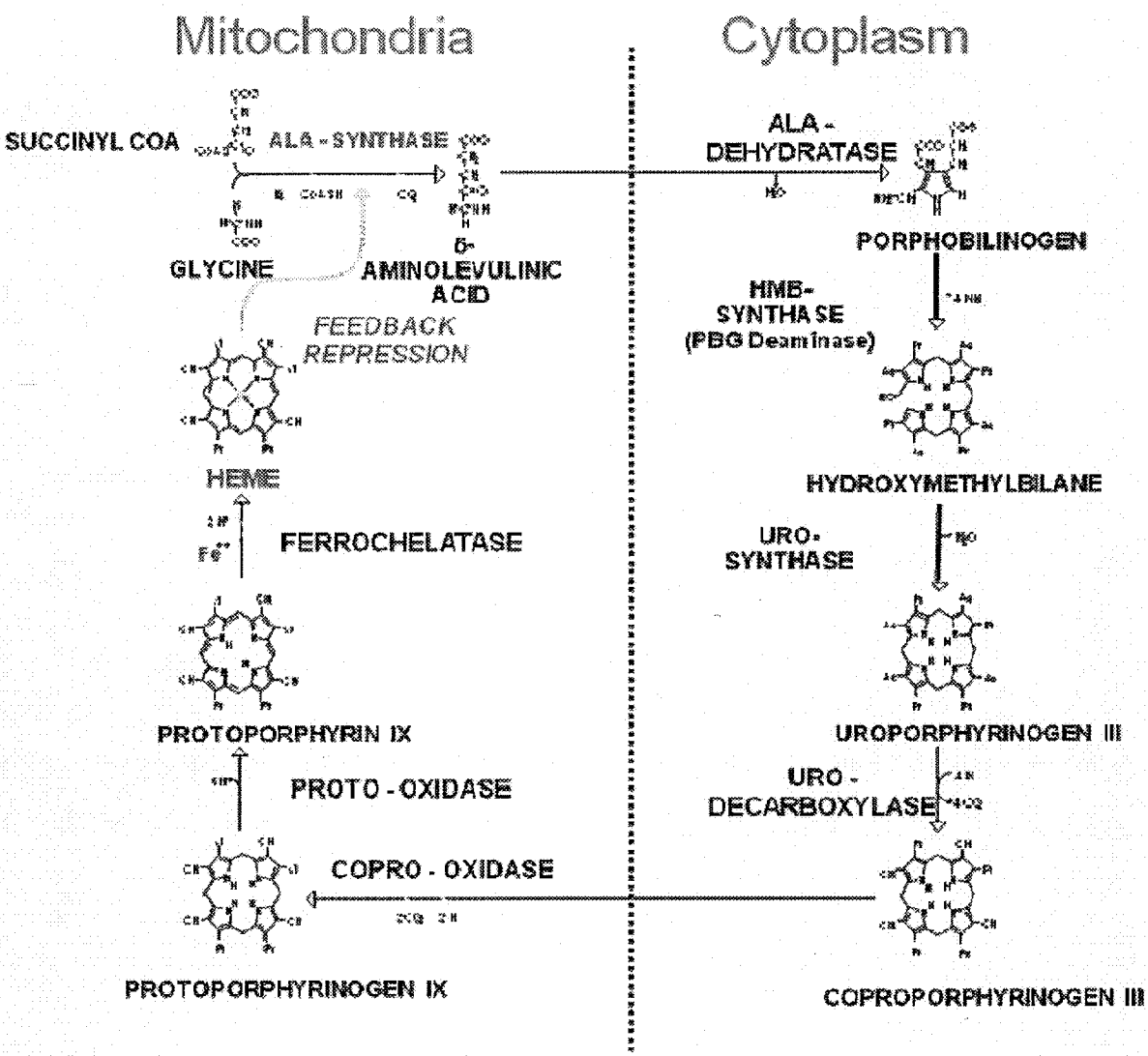
Mitochondria
Cytoplasm
SUCCINYL COA
ALA - SYNTHASE
GLYCINE
AMINOLEVULINIC ACID
FEEDBACK REPRESSION
HEME
FERROCHELATASE
PROTOPORPHYRIN IX
PROTO - OXIDASE
COPRO - OXIDASE
PROTOPORPHYRINOGEN IX
ALA - DEHYDRATASE
PORPHOBILINOGEN
HMB-SYNTHASE (PBG Deaminase)
HYDROXYMETHYLBILANE
URO-SYNTHASE
UROPORPHYRINOGEN III
URO - DECARBOXYLASE
COPROPORPHYRINOGEN III

Fig. 2

Enzyme, Chromosomal location	Reaction Catalyzed	Associated Porphyria	Type of Porphyria	Typical Inheritance Pattern	Typical Symptoms
δ-aminolevulinate (ALA) synthase 1 3p21	Glycine + SuccinylCoA ↓ δ-aminolevulinic acid (ALA)				
δ-aminolevulinate (ALA) synthase 2 (ALAS2) (erythroid specific) Xp11.21	Glycine + SuccinylCoA ↓ δ-aminolevulinic acid (ALA)	X-linked sideroblastic anemia (XLSA), X-linked protoporphyria (XLP)	Erythropoietic	X-linked	
δ-aminolevulinate dehydratase (ALAD) 9q34	δ-aminolevulinic acid (ALA) ↓ Porphobilinogen (PBG)	ALA dehydratase deficiency porphyria (ADP or Doss porphyria)	Hepatic	Autosomal recessive	Abdominal pain, neuropathy
PBG deaminase (PBGD) or Hydroxymethylbilane synthase (HMBS) 11q23	Porphobilinogen (PBG) ↓ Hydroxymethylbilane (HMB)	Acute intermittent porphyria (AIP)	Hepatic	Autosomal dominant	Periodic abdominal pain, peripheral neuropathy, psychiatric disorders, tachycardia

Fig. 2 continued

Uroporphyrinogen III Synthase (UROS) 10q26	Hydroxymethylbilane ↓ Uroporphyrinogen III (URO)	Congenital erythropoietic porphyria (CEP)	Erythropoietic	Autosomal recessive	Severe photosensitivity with erythema, swelling and blistering. Hemolytic anemia, splenomegaly
Uroporphyrinogen decarboxylase (UROD) 1q34	Uroporphyrinogen III (URO) ↓ Coprophyrinogen III	Porphyria cutanea tarda (PCT)	Hepatic	Autosomal dominant or sporadic	Photosensitivity with vesicles and bullae
Coproporphyrinogen III oxidase (CPOX)3q12	Coprophyrinogen III (COPRO) ↓ Protoporphyrinogen IX	Hereditary coproporphyria (HCP)	Hepatic	Autosomal dominant	Photosensitivity, neurologic symptoms, colic
Protoporphyrinogen oxidase (PPOX) 1q14	Protoporphyrinogen IX (PROTO) ↓ Protoporphyrin IX	Variegate prophyria (VP)	Mixed	Autosomal dominant	Photosensitivity, neurologic symptoms, developmental delay
Ferrochelatase 18q21.3	Protoporphyrin IX ↓ Heme	Erythropoietic protoporphyria (EPP)	Erythropoietic	Autosomal recessive	Photosensitivity with skin lesions. Gallstones, mild liver dysfunction

Fig. 3

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   1 ctgtatatta aggcgccggc gatcgcggcc tgaggctgct cccggacaag ggcaacgagc
  61 gtttcgtttg gacttctcga cttgagtgcc cgcctccttc gccgccgcct ctgcagtcct
 121 cagcgcagtt atgcccagtt cttcccgctg tggggacacg accacggagg aatccttgct
 181 tcagggactc gggaccctgc tggacccctt cctcgggttt aggggatgtg gggaccagga
 241 gaaagtcagg atccctaaga gtcttccctg cctggatgga tgagtggctt cttctccacc
 301 tagattcttt ccacaggagc cagcatactt cctgaacatg gagagtgttg ttcgccgctg
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 421 ctatgcccaa aactgcccca agatgatgga agttggggcc aagccagccc ctcgggcatt
 481 gtccactgca gcagtacact accaacagat caaagaaacc cctccggcca gtgagaaaga
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 661 ccctttcctg gcagcacaga tgaatcagag aggcagcagt gtcttctgca aagccagtct
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1141 cactttgaaa caacatggtg ctggggcagg tggtactaga aatatttctg gaactagtaa
1201 attccatgtg gacttagagc gggagctggc agacctccat gggaaagatg ccgcactctt
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1621 tcgggatgga gtcatgccaa aaatggacat catttctgga acacttggca aagcctttgg
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1861 caaactcatg agacagatgc taatggatgc cggcctccct gttgtccact gccccagcca
1921 catcatccct gtgcgggttg cagatgctgc taaaaacaca gaagtctgtg atgaactaat
1981 gagcagacat aacatctacg tgcaagcaat caattaccct acggtgcccc ggggagaaga
2041 gctcctacgg attgccccca cccctcacca cacaccccag atgatgaact acttccttga
2101 gaatctgcta gtcacatgga agcaagtggg gctggaactg aagcctcatt cctcagctga
2161 gtgcaacttc tgcaggaggc cactgcattt tgaagtgatg agtgaaagag agaagtccta
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Fig. 3 continued

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Fig. 4

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1381 ctctgattct gggaaccatg cctccatgat ccaagggatt cgaaacagcc gagtgccaaa
1441 gtacatcttc cgccacaatg atgtcagcca cctcagagaa ctgctgcaaa gatctgaccc
1501 ctcagtcccc aagattgtgg catttgaaac tgtccattca atggatgggg cggtgtgccc
1561 actggaagag ctgtgtgatg tggcccatga gtttggagca atcaccttcg tggatgaggt
1621 ccacgcagtg gggctttatg gggctcgagg cggagggatt ggggatcggg atggagtcat
1681 gccaaaaatg gacatcattt ctggaacact tggcaaagcc tttggttgtg ttggagggta
1741 catcgccagc acgagttctc tgattgacac cgtacggtcc tatgctgctg gcttcatctt
1801 caccacctct ctgccaccca tgctgctggc tggagccctg gagtctgtgc ggatcctgaa
1861 gagcgctgag ggacgggtgc ttcgccgcca gcaccagcgc aacgtcaaac tcatgagaca
1921 gatgctaatg gatgccggcc tccctgttgt ccactgcccc agccacatca tccctgtgcg
1981 ggttgcagat gctgctaaaa acacagaagt ctgtgatgaa ctaatgagca gacataacat
2041 ctacgtgcaa gcaatcaatt accctacggt gccccgggga gaagagctcc tacggattgc
2101 ccccacccct caccacacac cccagatgat gaactacttc cttgagaatc tgctagtcac
2161 atggaagcaa gtggggctgg aactgaagcc tcattcctca gctgagtgca acttctgcag
2221 gaggccactg cattttgaag tgatgagtga aagagagaag tcctatttct caggcttgag
```

Fig. 4 continued

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2281 caagttggta tctgctcagg cctgagcatg acctcaatta tttcacttaa ccccaggcca
2341 ttatcatatc cagatggtct tcagagttgt ctttatatgt gaattaagtt atattaaatt
2401 ttaatctata gtaaaaacat agtcctggaa ataaattctt gcttaaatgg tgaaaaaa
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(SEQ ID NO: 2)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/055989

A. CLASSIFICATION OF SUBJECT MATTER
INV. C12N15/113 A61K31/712 A61K31/713 A61P43/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C12N A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, BIOSIS, MEDLINE, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2013/155204 A2 (ALNYLAM PHARMACEUTICALS INC [US]; ICAHN SCHOOL MED MOUNT SINAI [US]) 17 October 2013 (2013-10-17) the whole document	1-76
A	RICHARD J HIFT ET AL: "Drugs in porphyria: From observation to a modern algorithm-based system for the prediction of porphyrogenicity", PHARMACOLOGY AND THERAPEUTICS, vol. 132, no. 2, 16 June 2011 (2011-06-16) , pages 158-169, XP028280082, ISSN: 0163-7258, DOI: 10.1016/J.PHARMTHERA.2011.06.001 [retrieved on 2011-06-16] the whole document	57-76

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 January 2016	22/01/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Spindler, Mark-Peter

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/055989

Box No. I Nucleotide and/or amino acid sequence(s) (Continuation of item 1.c of the first sheet)

1. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of a sequence listing:

   a. [X] forming part of the international application as filed:

      [X] in the form of an Annex C/ST.25 text file.

      [ ] on paper or in the form of an image file.

   b. [ ] furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

   c. [ ] furnished subsequent to the international filing date for the purposes of international search only:

      [ ] in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

      [ ] on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

2. [ ] In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

3. Additional comments:

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2015/055989

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2013155204 A2	17-10-2013	AR 090641 A1	26-11-2014
		AU 2013245949 A1	30-10-2014
		CA 2868290 A1	17-10-2013
		CN 104540948 A	22-04-2015
		CO 7121351 A2	20-11-2014
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		HK 1201876 A1	11-09-2015
		JP 2015518373 A	02-07-2015
		KR 20150013159 A	04-02-2015
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		US 2015111841 A1	23-04-2015
		WO 2013155204 A2	17-10-2013