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(54) Title: RNAi CONSTRUCTS AND METHODS FOR INHIBITING LPA EXPRESSION

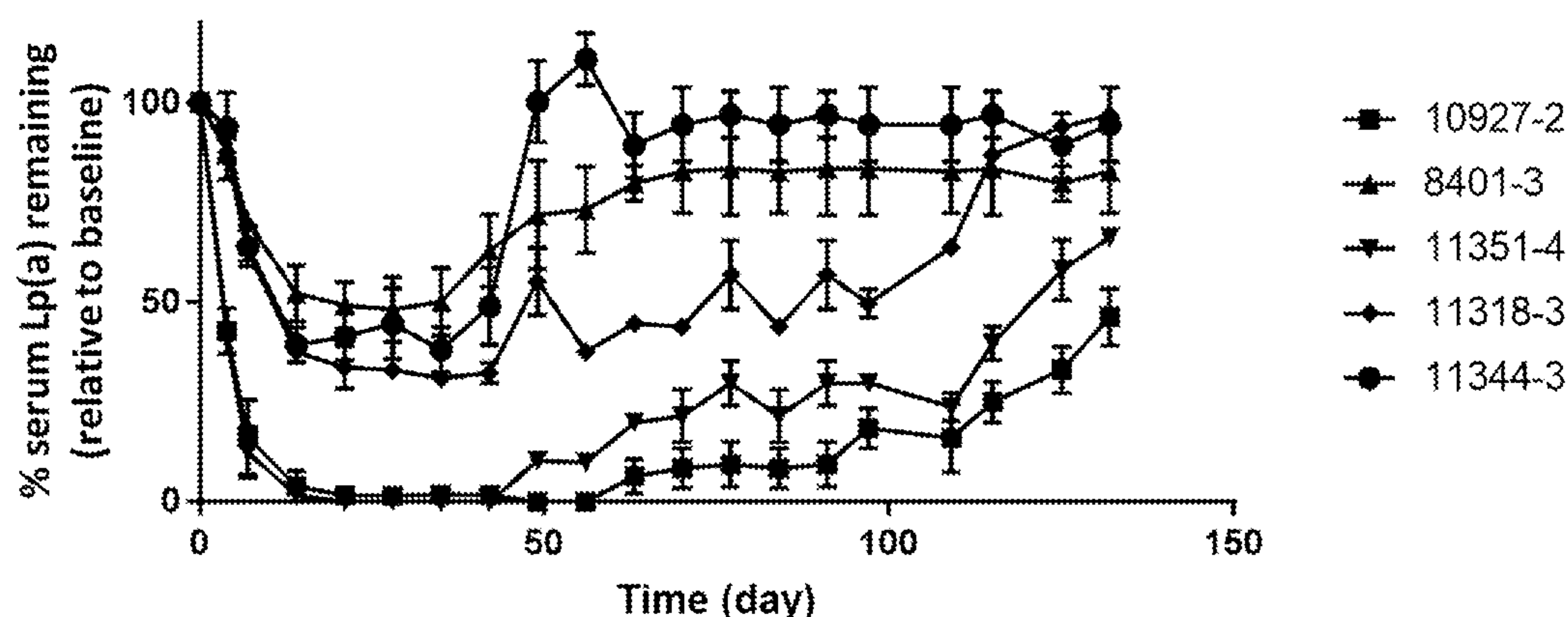


FIG. 3

(57) Abstract: The present invention relates to RNAi constructs for reducing expression of the *LPA* gene, which encodes apolipoprotein(a), a component of lipoprotein(a) (Lp(a)) particles. Methods of using such RNAi constructs to treat or prevent cardiovascular disease, such as coronary artery disease, peripheral artery disease, stroke, and myocardial infarction, and to reduce serum Lp(a) levels are also described.

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RNAi CONSTRUCTS AND METHODS FOR INHIBITING LPA EXPRESSION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/945,777, filed December 9, 2019, which is hereby incorporated by reference in its entirety.

DESCRIPTION OF THE TEXT FILE SUBMITTED ELECTRONICALLY

[0002] The present application contains a Sequence Listing, which has been submitted electronically in ASCII format and is hereby incorporated by reference in its entirety. The computer readable format copy of the Sequence Listing, which was created on December 8, 2020, is named A-2425-WO-PCT_ST25 and is 190 kilobytes in size.

FIELD OF THE INVENTION

[0003] The present invention relates to compositions and methods for modulating liver expression of the *LPA* gene, which encodes apolipoprotein (a) (apo(a)). In particular, the present invention relates to nucleic acid-based therapeutics for reducing *LPA* gene expression via RNA interference and methods of using such nucleic acid-based therapeutics to reduce circulating levels of lipoprotein (a) (Lp(a)) and to treat or prevent cardiovascular disease.

BACKGROUND OF THE INVENTION

[0004] Lp(a) is a low-density lipoprotein consisting of an LDL particle and the glycoprotein apo(a), which is linked to the apolipoprotein B of the LDL particle by a disulfide bond. Apo(a) is encoded by the *LPA* gene and is expressed almost exclusively in primates, including humans. Apo(a) exhibits homology to plasminogen and is present in various isoforms due to a size polymorphism in the gene, which is caused by a variable number of kringle-IV, type 2 (KIV-2) domain repeats (*see* Kronenberg and Utermann, J. Intern. Med., Vol. 273:6-30, 2013). An inverse correlation has been observed between the size of the apo(a) isoform and the plasma levels of Lp(a) particles (Sandholzer *et al.*, Hum. Genet., Vol. 86: 607-614, 1991).

[0005] The physiological function of Lp(a) is unclear, but Lp(a) has been shown to have a pathogenic role in atherosclerosis and thrombosis formation (Nordestgaard and Langsted, Lipid Res., Vol. 57:1953-75, 2016). The connection between Lp(a) levels and coronary artery disease,

myocardial infarction, stroke, peripheral vascular disease, and aortic valve stenosis has been described in several genetic and observational studies (Schmidt *et al.*, J. Lipid Res., Vol. 57:1339-1359, 2016). It has been noted that this risk relationship is continuous and becomes proportionally more impactful with higher Lp(a) levels. The association persists after correction for other lipid parameters (Emerging Risk Factors Collaboration, JAMA, Vol. 302:412-423, 2009).

[0006] High plasma Lp(a) concentration is genetically defined, remains at stable levels, cannot be controlled by habit modifications (diet, exercise, or other environmental factors), and is not effectively controlled by any of the currently available lipid reducing medications. Currently, there are no approved therapies indicated to reduce the risk of cardiovascular events through reductions in Lp(a). Moderate decreases in Lp(a) have been observed with proprotein convertase subtilisin/kexin type 9 (PCSK9) inhibitors, niacin, and mipomersen (Santos *et al.*, Arterioscler. Thromb. Vasc. Biol., Vol. 35:689-699, 2015; Yeang *et al.*, Curr. Opin. Lipidol., Vol. 26:169-178, 2015; and Landray *et al.*, N. Engl. J. Med., Vol. 371:203-212, 2014). While apheresis is effective in lowering Lp(a), it is currently used only in a few countries with limited access (Julius, J. Cardiovasc. Dev. Dis., Vol. 5:27-37, 2018). In addition, it is an invasive, very expensive procedure requiring frequent visits, which makes it unfeasible as a long-term treatment for subjects who need lifelong therapy (Khan *et al.*, Eur. Heart J., Vol. 38:1561-1569, 2017; Roeseler *et al.*, Arterioscler. Thromb. Vasc. Biol., Vol. 36:2019-2027, 2016; Leebmann *et al.*, Circulation, Vol. 128:2567-2576, 2013; Safarova *et al.*, Atheroscler. Suppl., Vol. 14:93-99, 2013).

[0007] Accordingly, there is a need in the art for novel agents that potently lower high Lp(a) concentrations for prolonged durations to confer additional protection against cardiovascular disease.

SUMMARY OF THE INVENTION

[0008] The present invention is based, in part, on the design and generation of RNAi constructs that target the *LPA* gene and reduce expression of the encoded apo(a) protein in liver cells. The sequence-specific inhibition of *LPA* gene expression is useful for treating or preventing conditions associated with elevated Lp(a) levels, such as cardiovascular disease. Accordingly, in one embodiment, the present invention provides an RNAi construct comprising a sense strand

and an antisense strand, wherein the antisense strand comprises a region having a sequence that is complementary to an *LPA* mRNA sequence. In certain embodiments, the antisense strand comprises or consists of a sequence selected from any of the antisense sequences listed in Table 1 or Table 2.

[0009] In some embodiments, the sense strand of the RNAi constructs described herein comprises a sequence that is sufficiently complementary to the sequence of the antisense strand to form a duplex region of about 15 to about 30 base pairs in length. In these and other embodiments, the sense and antisense strands are each independently about 19 to about 30 nucleotides in length. In some embodiments, the RNAi constructs comprise one or two blunt ends. In other embodiments, the RNAi constructs comprise one or two nucleotide overhangs. Such nucleotide overhangs may comprise 1 to 6 unpaired nucleotides and can be located at the 3' end of the sense strand, the 3' end of the antisense strand, or the 3' end of both the sense and antisense strand. In certain embodiments, the RNAi constructs comprise an overhang of two unpaired nucleotides at the 3' end of the sense strand and the 3' end of the antisense strand. In other embodiments, the RNAi constructs comprise an overhang of two unpaired nucleotides at the 3' end of the antisense strand and a blunt end at the 3' end of the sense strand/5' end of the antisense strand.

[0010] The RNAi constructs of the invention may comprise one or more modified nucleotides, including nucleotides having modifications to the ribose ring, nucleobase, or phosphodiester backbone. In some embodiments, the RNAi constructs comprise one or more 2'-modified nucleotides. Such 2'-modified nucleotides can include 2'-fluoro modified nucleotides, 2'-O-methyl modified nucleotides, 2'-O-methoxyethyl modified nucleotides, 2'-O-alkyl modified nucleotides, 2'-O-allyl modified nucleotides, bicyclic nucleic acids (BNA), deoxyribonucleotides, or combinations thereof. In one particular embodiment, the RNAi constructs comprise one or more 2'-fluoro modified nucleotides, 2'-O-methyl modified nucleotides, or combinations thereof. In some embodiments, all of the nucleotides in the sense and antisense strand of the RNAi construct are modified nucleotides. Abasic nucleotides may be incorporated into the RNAi constructs of the invention, for example, as the terminal nucleotide at the 3' end, the 5' end, or both the 3' end and the 5' end of the sense strand. In such embodiments, the abasic nucleotide may be inverted, e.g. linked to the adjacent nucleotide through a 3'-3' internucleotide linkage or a 5'-5' internucleotide linkage.

[0011] In some embodiments, the RNAi constructs comprise at least one backbone modification, such as a modified internucleotide or internucleoside linkage. In certain embodiments, the RNAi constructs described herein comprise at least one phosphorothioate internucleotide linkage. In particular embodiments, the phosphorothioate internucleotide linkages may be positioned at the 3' or 5' ends of the sense and/or antisense strands.

[0012] In certain embodiments, the antisense strand and/or the sense strand of the RNAi constructs of the invention may comprise or consist of a sequence from the antisense and sense sequences listed in Table 1 or Table 2. In certain embodiments, the RNAi construct may be any one of the duplex compounds listed in any one of Tables 1 to 15. In one embodiment, the RNAi construct is 4601, 4613, 4930, 4970, 6150, 6182, 6247, 8395, 8401, 10927, 11318, 11344, 11351, 11374, 11580, 17188, 17205, 18436, 18444, or 18446. In another embodiment, the RNAi construct is 4601, 4613, 10927, 11351, 11374, 11580, 18436, or 18444.

[0013] The RNAi constructs may further comprise a ligand to facilitate delivery or uptake of the RNAi constructs to specific tissues or cells, such as liver cells. In certain embodiments, the ligand targets delivery of the RNAi constructs to hepatocytes. In these and other embodiments, the ligand may comprise galactose, galactosamine, or N-acetyl-galactosamine (GalNAc). In certain embodiments, the ligand comprises a multivalent galactose or multivalent GalNAc moiety, such as a trivalent or tetravalent galactose or GalNAc moiety. The ligand may be covalently attached to the 5' or 3' end of the sense strand of the RNAi construct, optionally through a linker. In certain embodiments, the ligand comprises a structure of Structure 1 as described herein. In one such embodiment, the ligand having this structure is covalently attached to the 5' end of the sense strand, optionally via a linker, such as an aminohexyl linker. In some embodiments, the RNAi constructs comprise a ligand and linker having a structure according to any one of Formulas I to IX described herein. In certain embodiments, the RNAi constructs comprise a ligand and linker having a structure according to Formula VII. In other embodiments, the RNAi constructs comprise a ligand and linker having a structure according to Formula IV.

[0014] The present invention also provides pharmaceutical compositions comprising any of the RNAi constructs described herein and a pharmaceutically acceptable carrier, excipient, or diluent. Such pharmaceutical compositions are particularly useful for reducing expression of the *LPA* gene in the cells (e.g. liver cells) of a patient in need thereof. Patients who may be administered a pharmaceutical composition of the invention can include patients with a history

of myocardial infarction, patients diagnosed with or at risk for coronary artery disease or other form of cardiovascular disease, and patients with elevated levels of serum or plasma Lp(a). Accordingly, the present invention includes methods of treating or preventing cardiovascular disease in a patient in need thereof by administering an RNAi construct or pharmaceutical composition described herein. In certain embodiments, the present invention provides methods for reducing Lp(a) levels in a patient in need thereof by administering an RNAi construct or pharmaceutical composition described herein.

[0015] The use of LPA-targeting RNAi constructs in any of the methods described herein or for preparation of medicaments for administration according to the methods described herein is specifically contemplated. For instance, the present invention includes an LPA-targeting RNAi construct for use in a method for treating or preventing cardiovascular disease, including coronary artery disease, peripheral artery disease, myocardial infarction, or stroke, in a patient in need thereof. The present invention also includes an LPA-targeting RNAi construct for use in a method for reducing Lp(a) levels in a patient in need thereof. In some embodiments, the present invention provides an LPA-targeting RNAi construct for use in a method for reducing the risk of myocardial infarction in a patient in need thereof.

[0016] The present invention also encompasses the use of an LPA-targeting RNAi construct in the preparation of a medicament for treating or preventing cardiovascular disease, including coronary artery disease, peripheral artery disease, myocardial infarction, or stroke, in a patient in need thereof. In certain embodiments, the present invention provides the use of an LPA-targeting RNAi construct in the preparation of a medicament for reducing Lp(a) levels in a patient in need thereof. In certain other embodiments, the present invention provides the use of an LPA-targeting RNAi construct in the preparation of a medicament for reducing the risk of myocardial infarction in a patient in need thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] **Figure 1** shows the nucleotide sequence of a transcript of human *LPA* (NCBI Reference Sequence No. NM_005577.4; SEQ ID NO: 1). The transcript sequence is depicted as the complementary DNA (cDNA) sequence with thymine bases replacing uracil bases.

[0018] **Figure 2** shows the percentage of serum Lp(a) remaining relative to pre-dose baseline levels in cynomolgus monkeys following administration of a single subcutaneous injection of 2 mg/kg of the indicated LPA RNAi constructs on day 1.

[0019] **Figure 3** shows the percentage of serum Lp(a) remaining relative to pre-dose baseline levels in cynomolgus monkeys following administration of a single subcutaneous injection of 2 mg/kg of the indicated LPA RNAi constructs on day 1.

[0020] **Figure 4** shows the percentage of serum Lp(a) remaining relative to pre-dose baseline levels in cynomolgus monkeys following administration of a single subcutaneous injection of 2 mg/kg of the indicated LPA RNAi constructs on day 1.

DETAILED DESCRIPTION

[0021] The present invention is directed to compositions and methods for regulating the expression of the *LPA* gene in a cell or mammal. In some embodiments, compositions of the invention comprise RNAi constructs that target a mRNA transcribed from the *LPA* gene, which encodes the apo(a) protein, and reduce apo(a) expression in a cell or mammal. Such RNAi constructs are useful for reducing Lp(a) serum levels and treating or preventing various forms of cardiovascular disease, such as atherosclerosis, coronary artery disease, peripheral artery disease, aortic stenosis, and reducing the risk of myocardial infarction or stroke.

[0022] As used herein, the term “RNAi construct” refers to an agent comprising an RNA molecule that is capable of downregulating expression of a target gene (e.g. *LPA* gene) via an RNA interference mechanism when introduced into a cell. RNA interference is the process by which a nucleic acid molecule induces the cleavage and degradation of a target RNA molecule (e.g. messenger RNA or mRNA molecule) in a sequence-specific manner, e.g. through an RNA-induced silencing complex (RISC) pathway. In some embodiments, the RNAi construct comprises a double-stranded RNA molecule comprising two antiparallel strands of contiguous nucleotides that are sufficiently complementary to each other to hybridize to form a duplex region. “Hybridize” or “hybridization” refers to the pairing of complementary polynucleotides, typically via hydrogen bonding (e.g. Watson-Crick, Hoogsteen or reversed Hoogsteen hydrogen bonding) between complementary bases in the two polynucleotides. The strand comprising a region having a sequence that is substantially complementary to a target sequence (e.g. target mRNA) is referred to as the “antisense strand.” The “sense strand” refers to the strand that

includes a region that is substantially complementary to a region of the antisense strand. In some embodiments, the sense strand may comprise a region that has a sequence that is substantially identical to the target sequence.

[0023] A double-stranded RNA molecule may include chemical modifications to ribonucleotides, including modifications to the ribose sugar, base, or backbone components of the ribonucleotides, such as those described herein or known in the art. Any such modifications, as used in a double-stranded RNA molecule (e.g. siRNA, shRNA, or the like), are encompassed by the term “double-stranded RNA” for the purposes of this disclosure.

[0024] As used herein, a first sequence is “complementary” to a second sequence if a polynucleotide comprising the first sequence can hybridize to a polynucleotide comprising the second sequence to form a duplex region under certain conditions, such as physiological conditions. Other such conditions can include moderate or stringent hybridization conditions, which are known to those of skill in the art. A first sequence is considered to be fully complementary (100% complementary) to a second sequence if a polynucleotide comprising the first sequence base pairs with a polynucleotide comprising the second sequence over the entire length of one or both nucleotide sequences without any mismatches. A sequence is “substantially complementary” to a target sequence if the sequence is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% complementary to a target sequence. Percent complementarity can be calculated by dividing the number of bases in a first sequence that are complementary to bases at corresponding positions in a second or target sequence by the total length of the first sequence. A sequence may also be said to be substantially complementary to another sequence if there are no more than 5, 4, 3, or 2 mismatches over a 30 base pair duplex region when the two sequences are hybridized. Generally, if any nucleotide overhangs, as defined herein, are present, the sequence of such overhangs is not considered in determining the degree of complementarity between two sequences. By way of example, a sense strand of 21 nucleotides in length and an antisense strand of 21 nucleotides in length that hybridize to form a 19 base pair duplex region with a 2-nucleotide overhang at the 3' end of each strand would be considered to be fully complementary as the term is used herein.

[0025] In some embodiments, a region of the antisense strand comprises a sequence that is substantially or fully complementary to a region of the target RNA sequence (e.g. *LPA* mRNA). In such embodiments, the sense strand may comprise a sequence that is fully complementary to

the sequence of the antisense strand. In other such embodiments, the sense strand may comprise a sequence that is substantially complementary to the sequence of the antisense strand, e.g. having 1, 2, 3, 4, or 5 mismatches in the duplex region formed by the sense and antisense strands. In certain embodiments, it is preferred that any mismatches occur within the terminal regions (e.g. within 6, 5, 4, 3, or 2 nucleotides of the 5' and/or 3' ends of the strands). In one embodiment, any mismatches in the duplex region formed from the sense and antisense strands occur within 6, 5, 4, 3, or 2 nucleotides of the 5' end of the antisense strand.

[0026] In certain embodiments, the sense strand and antisense strand of the double-stranded RNA may be two separate molecules that hybridize to form a duplex region but are otherwise unconnected. Such double-stranded RNA molecules formed from two separate strands are referred to as “small interfering RNAs” or “short interfering RNAs” (siRNAs). Thus, in some embodiments, the RNAi constructs of the invention comprise an siRNA.

[0027] In other embodiments, the sense strand and the antisense strand that hybridize to form a duplex region may be part of a single RNA molecule, i.e. the sense and antisense strands are part of a self-complementary region of a single RNA molecule. In such cases, a single RNA molecule comprises a duplex region (also referred to as a stem region) and a loop region. The 3' end of the sense strand is connected to the 5' end of the antisense strand by a contiguous sequence of unpaired nucleotides, which will form the loop region. The loop region is typically of a sufficient length to allow the RNA molecule to fold back on itself such that the antisense strand can base pair with the sense strand to form the duplex or stem region. The loop region can comprise from about 3 to about 25, from about 5 to about 15, or from about 8 to about 12 unpaired nucleotides. Such RNA molecules with at least partially self-complementary regions are referred to as “short hairpin RNAs” (shRNAs). In certain embodiments, the RNAi constructs of the invention comprise a shRNA. The length of a single, at least partially self-complementary RNA molecule can be from about 40 nucleotides to about 100 nucleotides, from about 45 nucleotides to about 85 nucleotides, or from about 50 nucleotides to about 60 nucleotides and comprise a duplex region and loop region each having the lengths recited herein.

[0028] In some embodiments, the RNAi constructs of the invention comprise a sense strand and an antisense strand, wherein the antisense strand comprises a region having a sequence that is substantially or fully complementary to an *LPA* messenger RNA (mRNA) sequence. As used herein, an “*LPA* mRNA sequence” refers to any messenger RNA sequence, including allelic

variants and splice variants, encoding an apo(a) protein, including apo(a) protein variants or isoforms from any species (e.g. non-human primate, human). The *LPA* gene (also known as AK38, APOA, and LP) encodes the apo(a) protein, which is a primary component of the low-density lipoprotein particle known as lipoprotein (a) or Lp(a). In humans, the *LPA* gene is found on chromosome 6 at locus 6q25.3-q26. The *LPA* gene is highly polymorphic with alleles of the gene differing in numbers of copies of the kringle IV type 2 (KIV-2) domain, which can range from two to over 40 copies among individuals (*see, e.g.*, Kronenberg and Utermann, J. Intern. Med., Vol. 273:6-30, 2013).

[0029] An *LPA* mRNA sequence also includes the transcript sequence expressed as its complementary DNA (cDNA) sequence. A cDNA sequence refers to the sequence of an mRNA transcript expressed as DNA bases (e.g. guanine, adenine, thymine, and cytosine) rather than RNA bases (e.g. guanine, adenine, uracil, and cytosine). Thus, the antisense strand of the RNAi constructs of the invention may comprise a region having a sequence that is substantially or fully complementary to a target *LPA* mRNA sequence or *LPA* cDNA sequence. An *LPA* mRNA or cDNA sequence can include, but is not limited to, any *LPA* mRNA or cDNA sequence selected from the NCBI Reference sequences NM_005577.4 (human; Figure 1, SEQ ID NO: 1), XM_015448520.1 (cynomolgus monkey), XM_028847001.1 (rhesus monkey), XM_024357489.1 (chimpanzee), and XM_031012244.1 (gorilla). In certain embodiments, the *LPA* mRNA sequence is the human transcript listed in the NCBI database as Reference Sequence NM_005577.4 (see Figure 1; SEQ ID NO: 1).

[0030] A region of the antisense strand can be substantially complementary or fully complementary to at least 15 consecutive nucleotides of the *LPA* mRNA sequence. In some embodiments, the target region of the *LPA* mRNA sequence to which the antisense strand comprises a region of complementarity can range from about 15 to about 30 consecutive nucleotides, from about 16 to about 28 consecutive nucleotides, from about 18 to about 26 consecutive nucleotides, from about 17 to about 24 consecutive nucleotides, from about 19 to about 30 consecutive nucleotides, from about 19 to about 25 consecutive nucleotides, from about 19 to about 23 consecutive nucleotides, or from about 19 to about 21 consecutive nucleotides. In certain embodiments, the region of the antisense strand comprising a sequence that is substantially or fully complementary to an *LPA* mRNA sequence may, in some embodiments, comprise at least 15 contiguous nucleotides from an antisense sequence listed in Table 1 or Table

2. In other embodiments, the antisense sequence comprises at least 16, at least 17, at least 18, or at least 19 contiguous nucleotides from an antisense sequence listed in Table 1 or Table 2.

[0031] The sense strand of the RNAi construct typically comprises a sequence that is sufficiently complementary to the sequence of the antisense strand such that the two strands hybridize under physiological conditions to form a duplex region. A “duplex region” refers to the region in two complementary or substantially complementary polynucleotides that form base pairs with one another, either by Watson-Crick base pairing or other hydrogen bonding interaction, to create a duplex between the two polynucleotides. The duplex region of the RNAi construct should be of sufficient length to allow the RNAi construct to enter the RNA interference pathway, e.g. by engaging the Dicer enzyme and/or the RISC complex. For instance, in some embodiments, the duplex region is about 15 to about 30 base pairs in length. Other lengths for the duplex region within this range are also suitable, such as about 15 to about 28 base pairs, about 15 to about 26 base pairs, about 15 to about 24 base pairs, about 15 to about 22 base pairs, about 17 to about 28 base pairs, about 17 to about 26 base pairs, about 17 to about 24 base pairs, about 17 to about 23 base pairs, about 17 to about 21 base pairs, about 19 to about 25 base pairs, about 19 to about 23 base pairs, or about 19 to about 21 base pairs. In certain embodiments, the duplex region is about 17 to about 24 base pairs in length. In other embodiments, the duplex region is about 19 to about 21 base pairs in length. In one embodiment, the duplex region is about 19 base pairs in length. In another embodiment, the duplex region is about 21 base pairs in length.

[0032] For embodiments in which the sense strand and antisense strand are two separate molecules (e.g. RNAi construct comprises an siRNA), the sense strand and antisense strand need not be the same length as the length of the duplex region. For instance, one or both strands may be longer than the duplex region and have one or more unpaired nucleotides or mismatches flanking the duplex region. Thus, in some embodiments, the RNAi construct comprises at least one nucleotide overhang. As used herein, a “nucleotide overhang” refers to the unpaired nucleotide or nucleotides that extend beyond the duplex region at the terminal ends of the strands. Nucleotide overhangs are typically created when the 3' end of one strand extends beyond the 5' end of the other strand or when the 5' end of one strand extends beyond the 3' end of the other strand. The length of a nucleotide overhang is generally between 1 and 6 nucleotides, 1 and 5 nucleotides, 1 and 4 nucleotides, 1 and 3 nucleotides, 2 and 6 nucleotides, 2 and 5 nucleotides, or 2 and 4 nucleotides. In some embodiments, the nucleotide overhang comprises 1,

2, 3, 4, 5, or 6 nucleotides. In one particular embodiment, the nucleotide overhang comprises 1 to 4 nucleotides. In certain embodiments, the nucleotide overhang comprises 2 nucleotides. In certain other embodiments, the nucleotide overhang comprises a single nucleotide.

[0033] The nucleotides in the overhang can be ribonucleotides or modified nucleotides as described herein. In some embodiments, the nucleotides in the overhang are 2'-modified nucleotides (e.g. 2'-fluoro modified nucleotides, 2'-O-methyl modified nucleotides), deoxyribonucleotides, abasic nucleotides, inverted nucleotides (e.g. inverted abasic nucleotides, inverted deoxyribonucleotides), or combinations thereof. For instance, in one embodiment, the nucleotides in the overhang are deoxyribonucleotides, e.g. deoxythymidine. In another embodiment, the nucleotides in the overhang are 2'-O-methyl modified nucleotides, 2'-fluoro modified nucleotides, 2'-methoxyethyl modified nucleotides, or combinations thereof. In other embodiments, the overhang comprises a 5'-uridine-uridine-3' (5'-UU-3') dinucleotide. In such embodiments, the UU dinucleotide may comprise ribonucleotides or modified nucleotides, e.g. 2'-modified nucleotides. In other embodiments, the overhang comprises a 5'-deoxythymidine-deoxythymidine-3' (5'-dTdT-3') dinucleotide. When a nucleotide overhang is present in the antisense strand, the nucleotides in the overhang can be complementary to the target gene sequence, form a mismatch with the target gene sequence, or comprise some other sequence (e.g. polypyrimidine or polypurine sequence, such as UU, TT, AA, GG, etc.).

[0034] The nucleotide overhang can be at the 5' end or 3' end of one or both strands. For example, in one embodiment, the RNAi construct comprises a nucleotide overhang at the 5' end and the 3' end of the antisense strand. In another embodiment, the RNAi construct comprises a nucleotide overhang at the 5' end and the 3' end of the sense strand. In some embodiments, the RNAi construct comprises a nucleotide overhang at the 5' end of the sense strand and the 5' end of the antisense strand. In other embodiments, the RNAi construct comprises a nucleotide overhang at the 3' end of the sense strand and the 3' end of the antisense strand.

[0035] The RNAi constructs may comprise a single nucleotide overhang at one end of the double-stranded RNA molecule and a blunt end at the other. A "blunt end" means that the sense strand and antisense strand are fully base-paired at the end of the molecule and there are no unpaired nucleotides that extend beyond the duplex region. In some embodiments, the RNAi construct comprises a nucleotide overhang at the 3' end of the sense strand and a blunt end at the 5' end of the sense strand and 3' end of the antisense strand. In other embodiments, the RNAi

construct comprises a nucleotide overhang at the 3' end of the antisense strand and a blunt end at the 5' end of the antisense strand and the 3' end of the sense strand. In certain embodiments, the RNAi construct comprises a blunt end at both ends of the double-stranded RNA molecule. In such embodiments, the sense strand and antisense strand have the same length and the duplex region is the same length as the sense and antisense strands (i.e. the molecule is double stranded over its entire length).

[0036] The sense strand and antisense strand in the RNAi constructs of the invention can each independently be about 15 to about 30 nucleotides in length, about 19 to about 30 nucleotides in length, about 18 to about 28 nucleotides in length, about 19 to about 27 nucleotides in length, about 19 to about 25 nucleotides in length, about 19 to about 23 nucleotides in length, about 19 to about 21 nucleotides in length, about 21 to about 25 nucleotides in length, or about 21 to about 23 nucleotides in length. In certain embodiments, the sense strand and antisense strand are each independently about 18, about 19, about 20, about 21, about 22, about 23, about 24, or about 25 nucleotides in length. In some embodiments, the sense strand and antisense strand have the same length but form a duplex region that is shorter than the strands such that the RNAi construct has two nucleotide overhangs. For instance, in one embodiment, the RNAi construct comprises (i) a sense strand and an antisense strand that are each 21 nucleotides in length, (ii) a duplex region that is 19 base pairs in length, and (iii) nucleotide overhangs of 2 unpaired nucleotides at both the 3' end of the sense strand and the 3' end of the antisense strand. In another embodiment, the RNAi construct comprises (i) a sense strand and an antisense strand that are each 23 nucleotides in length, (ii) a duplex region that is 21 base pairs in length, and (iii) nucleotide overhangs of 2 unpaired nucleotides at both the 3' end of the sense strand and the 3' end of the antisense strand. In other embodiments, the sense strand and antisense strand have the same length and form a duplex region over their entire length such that there are no nucleotide overhangs on either end of the double-stranded molecule. In one such embodiment, the RNAi construct is blunt ended and comprises (i) a sense strand and an antisense strand, each of which is 21 nucleotides in length, and (ii) a duplex region that is 21 base pairs in length. In another such embodiment, the RNAi construct is blunt ended and comprises (i) a sense strand and an antisense strand, each of which is 23 nucleotides in length, and (ii) a duplex region that is 23 base pairs in length. In still another such embodiment, the RNAi construct is blunt ended and comprises (i) a sense strand

and an antisense strand, each of which is 19 nucleotides in length, and (ii) a duplex region that is 19 base pairs in length.

[0037] In other embodiments, the sense strand or the antisense strand is longer than the other strand and the two strands form a duplex region having a length equal to that of the shorter strand such that the RNAi construct comprises at least one nucleotide overhang. For example, in one embodiment, the RNAi construct comprises (i) a sense strand that is 19 nucleotides in length, (ii) an antisense strand that is 21 nucleotides in length, (iii) a duplex region of 19 base pairs in length, and (iv) a nucleotide overhang of 2 unpaired nucleotides at the 3' end of the antisense strand. In another embodiment, the RNAi construct comprises (i) a sense strand that is 21 nucleotides in length, (ii) an antisense strand that is 23 nucleotides in length, (iii) a duplex region of 21 base pairs in length, and (iv) a nucleotide overhang of 2 unpaired nucleotides at the 3' end of the antisense strand.

[0038] The antisense strand of the RNAi constructs of the invention can comprise or consist of the sequence of any one of the antisense sequences listed in Table 1 or Table 2, the sequence of nucleotides 1-19 of any of these antisense sequences, or the sequence of nucleotides 2-19 of any of these antisense sequences. Thus, in some embodiments, the antisense strand comprises or consists of a sequence selected from SEQ ID NOs: 134-241, 437-601, 611, or 617-619. In other embodiments, the antisense strand comprises or consists of a sequence of nucleotides 1-19 of any one of SEQ ID NOs: 134-241, 437-601, 611, or 617-619. In still other embodiments, the antisense strand comprises or consists of a sequence of nucleotides 2-19 of any one of SEQ ID NOs: 134-241, 437-601, 611, or 617-619. In certain embodiments, the antisense strand comprises or consists of a sequence selected from SEQ ID NO: 137, SEQ ID NO: 145, SEQ ID NO: 164, SEQ ID NO: 175, SEQ ID NO: 177, SEQ ID NO: 178, SEQ ID NO: 189, SEQ ID NO: 194, SEQ ID NO: 196, SEQ ID NO: 198, SEQ ID NO: 200, SEQ ID NO: 205, SEQ ID NO: 216, SEQ ID NO: 224, SEQ ID NO: 225, SEQ ID NO: 440, SEQ ID NO: 448, SEQ ID NO: 471, SEQ ID NO: 492, SEQ ID NO: 497, SEQ ID NO: 499, SEQ ID NO: 515, SEQ ID NO: 525, SEQ ID NO: 530, SEQ ID NO: 536, SEQ ID NO: 540, SEQ ID NO: 546, SEQ ID NO: 547, SEQ ID NO: 550, SEQ ID NO: 568, SEQ ID NO: 576, or SEQ ID NO: 577. In some embodiments, the antisense strand comprises or consists of a sequence selected from SEQ ID NO: 145, SEQ ID NO: 175, SEQ ID NO: 177, SEQ ID NO: 194, SEQ ID NO: 196, SEQ ID NO: 198, SEQ ID NO:

200, SEQ ID NO: 448, SEQ ID NO: 492, SEQ ID NO: 497, SEQ ID NO: 525, SEQ ID NO: 530, SEQ ID NO: 536, or SEQ ID NO: 540.

[0039] In these and other embodiments, the sense strand of the RNAi constructs of the invention can comprise or consist of the sequence of any one of the sense sequences listed in Table 1 or Table 2, the sequence of nucleotides 1-19 of any of these sense sequences, or the sequence of nucleotides 2-19 of any of these sense sequences. Thus, in some embodiments, the sense strand comprises or consists of a sequence selected from SEQ ID NOs: 2-133, 242-436, 610, or 612-616. In other embodiments, the sense strand comprises or consists of a sequence of nucleotides 1-19 of any one of SEQ ID NOs: 2-133, 242-436, 610, or 612-616. In still other embodiments, the sense strand comprises or consists of a sequence of nucleotides 2-19 of any one of SEQ ID NOs: 2-133, 242-436, 610, or 612-616. In certain embodiments, the sense strand comprises or consists of a sequence selected from SEQ ID NO: 5, SEQ ID NO: 13, SEQ ID NO: 35, SEQ ID NO: 49, SEQ ID NO: 51, SEQ ID NO: 53, SEQ ID NO: 54, SEQ ID NO: 71, SEQ ID NO: 78, SEQ ID NO: 79, SEQ ID NO: 83, SEQ ID NO: 85, SEQ ID NO: 86, SEQ ID NO: 91, SEQ ID NO: 106, SEQ ID NO: 115, SEQ ID NO: 117, SEQ ID NO: 245, SEQ ID NO: 253, SEQ ID NO: 282, SEQ ID NO: 304, SEQ ID NO: 307, SEQ ID NO: 312, SEQ ID NO: 314, SEQ ID NO: 341, SEQ ID NO: 350, SEQ ID NO: 357, SEQ ID NO: 362, SEQ ID NO: 364, SEQ ID NO: 370, SEQ ID NO: 372, SEQ ID NO: 377, SEQ ID NO: 378, SEQ ID NO: 404, SEQ ID NO: 413, or SEQ ID NO: 415. In certain other embodiments, the sense strand comprises or consists of a sequence selected from SEQ ID NO: 13, SEQ ID NO: 49, SEQ ID NO: 51, SEQ ID NO: 53, SEQ ID NO: 78, SEQ ID NO: 79, SEQ ID NO: 83, SEQ ID NO: 85, SEQ ID NO: 106, SEQ ID NO: 253, SEQ ID NO: 304, SEQ ID NO: 307, SEQ ID NO: 312, SEQ ID NO: 350, SEQ ID NO: 357, SEQ ID NO: 362, SEQ ID NO: 370, or SEQ ID NO: 404.

[0040] In certain embodiments of the invention, the RNAi constructs comprise (i) a sense strand comprising or consisting of a sequence selected from 2-133, 242-436, 610, or 612-616 and (ii) an antisense strand comprising or consisting of a sequence selected from SEQ ID NOs: 134-241, 437-601, 611, or 617-619. In some embodiments, the RNAi constructs comprise (i) a sense strand comprising or consisting of a sequence selected from SEQ ID NO: 5, SEQ ID NO: 13, SEQ ID NO: 35, SEQ ID NO: 49, SEQ ID NO: 51, SEQ ID NO: 53, SEQ ID NO: 54, SEQ ID NO: 71, SEQ ID NO: 78, SEQ ID NO: 79, SEQ ID NO: 83, SEQ ID NO: 85, SEQ ID NO: 86, SEQ ID NO: 91, SEQ ID NO: 106, SEQ ID NO: 115, SEQ ID NO: 117, SEQ ID NO: 245, SEQ

ID NO: 253, SEQ ID NO: 282, SEQ ID NO: 304, SEQ ID NO: 307, SEQ ID NO: 312, SEQ ID NO: 314, SEQ ID NO: 341, SEQ ID NO: 350, SEQ ID NO: 357, SEQ ID NO: 362, SEQ ID NO: 364, SEQ ID NO: 370, SEQ ID NO: 372, SEQ ID NO: 377, SEQ ID NO: 378, SEQ ID NO: 404, SEQ ID NO: 413, or SEQ ID NO: 415 and (ii) an antisense strand comprising or consisting of a sequence selected from SEQ ID NO: 137, SEQ ID NO: 145, SEQ ID NO: 164, SEQ ID NO: 175, SEQ ID NO: 177, SEQ ID NO: 178, SEQ ID NO: 189, SEQ ID NO: 194, SEQ ID NO: 196, SEQ ID NO: 198, SEQ ID NO: 200, SEQ ID NO: 205, SEQ ID NO: 216, SEQ ID NO: 224, SEQ ID NO: 225, SEQ ID NO: 440, SEQ ID NO: 448, SEQ ID NO: 471, SEQ ID NO: 492, SEQ ID NO: 497, SEQ ID NO: 499, SEQ ID NO: 515, SEQ ID NO: 525, SEQ ID NO: 530, SEQ ID NO: 536, SEQ ID NO: 540, SEQ ID NO: 546, SEQ ID NO: 547, SEQ ID NO: 550, SEQ ID NO: 568, SEQ ID NO: 576, or SEQ ID NO: 577. In other embodiments, the RNAi constructs comprise (i) a sense strand comprising or consisting of a sequence selected from SEQ ID NO: 13, SEQ ID NO: 49, SEQ ID NO: 51, SEQ ID NO: 53, SEQ ID NO: 78, SEQ ID NO: 79, SEQ ID NO: 83, SEQ ID NO: 85, SEQ ID NO: 106, SEQ ID NO: 253, SEQ ID NO: 304, SEQ ID NO: 307, SEQ ID NO: 312, SEQ ID NO: 350, SEQ ID NO: 357, SEQ ID NO: 362, SEQ ID NO: 370, or SEQ ID NO: 404 and (ii) an antisense strand comprising or consisting of a sequence selected from SEQ ID NO: 145, SEQ ID NO: 175, SEQ ID NO: 177, SEQ ID NO: 194, SEQ ID NO: 196, SEQ ID NO: 198, SEQ ID NO: 200, SEQ ID NO: 448, SEQ ID NO: 492, SEQ ID NO: 497, SEQ ID NO: 525, SEQ ID NO: 530, SEQ ID NO: 536, or SEQ ID NO: 540.

[0041] In certain embodiments, the RNAi constructs of the invention comprise: (i) a sense strand comprising or consisting of the sequence of SEQ ID NO: 13 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 145; (ii) a sense strand comprising or consisting of the sequence of SEQ ID NO: 35 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 164; (iii) a sense strand comprising or consisting of the sequence of SEQ ID NO: 53 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 177; (iv) a sense strand comprising or consisting of the sequence of SEQ ID NO: 91 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 205; (v) a sense strand comprising or consisting of the sequence of SEQ ID NO: 49 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 175; (vi) a sense strand comprising or consisting of the sequence of SEQ ID NO: 71 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 189; (vii) a sense strand comprising or consisting of the sequence of SEQ ID NO: 51 and an

antisense strand comprising or consisting of the sequence of SEQ ID NO: 175; (viii) a sense strand comprising or consisting of the sequence of SEQ ID NO: 79 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 194; (ix) a sense strand comprising or consisting of the sequence of SEQ ID NO: 85 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 198; (x) a sense strand comprising or consisting of the sequence of SEQ ID NO: 106 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 216; (xi) a sense strand comprising or consisting of the sequence of SEQ ID NO: 83 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 200; (xii) a sense strand comprising or consisting of the sequence of SEQ ID NO: 78 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 196; (xiii) a sense strand comprising or consisting of the sequence of SEQ ID NO: 5 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 137; (xiv) a sense strand comprising or consisting of the sequence of SEQ ID NO: 117 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 225; (xv) a sense strand comprising or consisting of the sequence of SEQ ID NO: 115 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 224; (xvi) a sense strand comprising or consisting of the sequence of SEQ ID NO: 54 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 178, or (xvii) a sense strand comprising or consisting of the sequence of SEQ ID NO: 86 and an antisense strand comprising or consisting of the sequence of SEQ ID NO: 198.

[0042] In some embodiments, the RNAi constructs of the invention comprise: (i) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 253 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 448; (ii) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 282 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 471; (iii) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 312 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 497; (iv) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 378 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 547; (v) a sense strand comprising or consisting of the sequence of modified nucleotides according to

SEQ ID NO: 304 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 492; (vi) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 341 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 515; (vii) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 377 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 550; (viii) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 307 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 492; (ix) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 350 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 525; (x) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 362 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 536; (xi) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 404 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 568; (xii) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 370 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 540; (xiii) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 357 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 530; (xiv) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 245 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 440; (xv) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 415 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 577; (xvi) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 413 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 576; (xvii) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 314 and an antisense strand comprising or consisting of the sequence of modified

nucleotides according to SEQ ID NO: 499; (xviii) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 377 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 546; (xix) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 364 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 536; or (xx) a sense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 372 and an antisense strand comprising or consisting of the sequence of modified nucleotides according to SEQ ID NO: 540.

[0043] The RNAi construct of the invention can be any one of the duplex compounds listed in Tables 1 to 15 (including the unmodified nucleotide sequences and/or modified nucleotide sequences of the compounds). In some embodiments, the RNAi construct is any of the duplex compounds listed in Table 1. In other embodiments, the RNAi construct is any of the duplex compounds listed in Table 2 (including the unmodified nucleotide sequences and/or modified nucleotide sequences of the compounds). In certain embodiments, the RNAi construct is 4601, 4613, 4930, 4970, 6150, 6182, 6247, 8395, 8401, 10927, 11318, 11344, 11351, 11374, 11580, 17188, 17205, 18436, 18444 or 18446. In one particular embodiment, the RNAi construct is 4601. In another particular embodiment, the RNAi construct is 4613. In another embodiment, the RNAi construct is 10927. In another embodiment, the RNAi construct is 11351. In another embodiment, the RNAi construct is 11374. In still another embodiment, the RNAi construct is 11580. In yet another embodiment, the RNAi construct is 18436. In another embodiment, the RNAi construct is 18444.

[0044] The RNAi constructs of the invention may comprise one or more modified nucleotides. A “modified nucleotide” refers to a nucleotide that has one or more chemical modifications to the nucleoside, nucleobase, pentose ring, or phosphate group. As used herein, modified nucleotides do not encompass ribonucleotides containing adenosine monophosphate, guanosine monophosphate, uridine monophosphate, and cytidine monophosphate. However, the RNAi constructs may comprise combinations of modified nucleotides and ribonucleotides. Incorporation of modified nucleotides into one or both strands of double-stranded RNA molecules can improve the *in vivo* stability of the RNA molecules, e.g., by reducing the molecules’ susceptibility to nucleases and other degradation processes. The potency of RNAi

constructs for reducing expression of the target gene can also be enhanced by incorporation of modified nucleotides.

[0045] In certain embodiments, the modified nucleotides have a modification of the ribose sugar. These sugar modifications can include modifications at the 2' and/or 5' position of the pentose ring as well as bicyclic sugar modifications. A 2'-modified nucleotide refers to a nucleotide having a pentose ring with a substituent at the 2' position other than OH. Such 2'-modifications include, but are not limited to, 2'-H (e.g. deoxyribonucleotides), 2'-O-alkyl (e.g. O-C₁-C₁₀ or O-C₁-C₁₀ substituted alkyl), 2'-O-allyl (O-CH₂CH=CH₂), 2'-C-allyl, 2'-deoxy-2'-fluoro (also referred to as 2'-F or 2'-fluoro), 2'-O-methyl (OCH₃), 2'-O-methoxyethyl (O-(CH₂)₂OCH₃), 2'-OCF₃, 2'-O(CH₂)₂SCH₃, 2'-O-aminoalkyl, 2'-amino (e.g. NH₂), 2'-O-ethylamine, and 2'-azido. Modifications at the 5' position of the pentose ring include, but are not limited to, 5'-methyl (R or S), 5'-vinyl, and 5'-methoxy.

[0046] A “bicyclic sugar modification” refers to a modification of the pentose ring where a bridge connects two atoms of the ring to form a second ring resulting in a bicyclic sugar structure. In some embodiments the bicyclic sugar modification comprises a bridge between the 4' and 2' carbons of the pentose ring. Nucleotides comprising a sugar moiety with a bicyclic sugar modification are referred to herein as bicyclic nucleic acids or BNAs. Exemplary bicyclic sugar modifications include, but are not limited to, α-L-Methyleneoxy (4'-CH₂—O-2') bicyclic nucleic acid (BNA); β-D-Methyleneoxy (4'-CH₂—O-2') BNA (also referred to as a locked nucleic acid or LNA); Ethyleneoxy (4'-(CH₂)₂—O-2') BNA; Aminooxy (4'-CH₂—O—N(R)- 2') BNA; Oxyamino (4'-CH₂—N(R) —O-2') BNA; Methyl(methyleneoxy) (4'-CH(CH₃) —O-2') BNA (also referred to as constrained ethyl or cEt); methylene-thio (4'-CH₂—S-2') BNA; methylene-amino (4'-CH₂-N(R)- 2') BNA; methyl carbocyclic (4'-CH₂—CH(CH₃)- 2') BNA; propylene carbocyclic (4'-(CH₂)₃-2') BNA; and Methoxy(ethyleneoxy) (4'-CH(CH₂OMe)-O-2') BNA (also referred to as constrained MOE or cMOE). These and other sugar-modified nucleotides that can be incorporated into the RNAi constructs of the invention are described in U.S. Patent No. 9,181,551, U.S. Patent Publication No. 2016/0122761, and Deleavey and Damha, Chemistry and Biology, Vol. 19: 937-954, 2012, all of which are hereby incorporated by reference in their entireties.

[0047] In some embodiments, the RNAi constructs comprise one or more 2'-fluoro modified nucleotides, 2'-O-methyl modified nucleotides, 2'-O-methoxyethyl modified nucleotides, 2'-O-

alkyl modified nucleotides, 2'-O-allyl modified nucleotides, bicyclic nucleic acids (BNAs), deoxyribonucleotides, or combinations thereof. In certain embodiments, the RNAi constructs comprise one or more 2'-fluoro modified nucleotides, 2'-O-methyl modified nucleotides, 2'-O-methoxyethyl modified nucleotides, or combinations thereof. In one particular embodiment, the RNAi constructs comprise one or more 2'-fluoro modified nucleotides, 2'-O-methyl modified nucleotides or combinations thereof.

[0048] Both the sense and antisense strands of the RNAi constructs can comprise one or multiple modified nucleotides. For instance, in some embodiments, the sense strand comprises 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more modified nucleotides. In certain embodiments, all nucleotides in the sense strand are modified nucleotides. In some embodiments, the antisense strand comprises 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more modified nucleotides. In other embodiments, all nucleotides in the antisense strand are modified nucleotides. In certain other embodiments, all nucleotides in the sense strand and all nucleotides in the antisense strand are modified nucleotides. In these and other embodiments, the modified nucleotides can be 2'-fluoro modified nucleotides, 2'-O-methyl modified nucleotides, or combinations thereof.

[0049] In certain embodiments, the modified nucleotides incorporated into one or both of the strands of the RNAi constructs of the invention have a modification of the nucleobase (also referred to herein as "base"). A "modified nucleobase" or "modified base" refers to a base other than the naturally occurring purine bases adenine (A) and guanine (G) and pyrimidine bases thymine (T), cytosine (C), and uracil (U). Modified nucleobases can be synthetic or naturally occurring modifications and include, but are not limited to, universal bases, 5-methylcytosine (5-me-C), 5-hydroxymethyl cytosine, xanthine (X), hypoxanthine (I), 2-aminoadenine, 6-methyladenine, 6-methylguanine, 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 and 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-deazaadenine and 3-deazaguanine and 3-deazaadenine.

[0050] In some embodiments, the modified base is a universal base. A “universal base” refers to a base analog that indiscriminately forms base pairs with all of the natural bases in RNA and DNA without altering the double helical structure of the resulting duplex region. Universal bases are known to those of skill in the art and include, but are not limited to, inosine, C-phenyl, C-naphthyl and other aromatic derivatives, azole carboxamides, and nitroazole derivatives, such as 3-nitropyrrole, 4-nitroindole, 5-nitroindole, and 6-nitroindole.

[0051] Other suitable modified bases that can be incorporated into the RNAi constructs of the invention include those described in Herdewijn, *Antisense Nucleic Acid Drug Dev.*, Vol. 10: 297–310, 2000 and Peacock *et al.*, *J. Org. Chem.*, Vol. 76: 7295–7300, 2011, both of which are hereby incorporated by reference in their entireties. The skilled person is well aware that guanine, cytosine, adenine, thymine, and uracil may be replaced by other nucleobases, such as the modified nucleobases described above, without substantially altering the base pairing properties of a polynucleotide comprising a nucleotide bearing such replacement nucleobase.

[0052] In some embodiments, the sense and antisense strands of the RNAi constructs may comprise one or more abasic nucleotides. An “abasic nucleotide” or “abasic nucleoside” is a nucleotide or nucleoside that lacks a nucleobase at the 1' position of the ribose sugar. In certain embodiments, the abasic nucleotides are incorporated into the terminal ends of the sense and/or antisense strands of the RNAi constructs. In one embodiment, the sense strand comprises an abasic nucleotide as the terminal nucleotide at its 3' end, its 5' end, or both its 3' and 5' ends. In another embodiment, the antisense strand comprises an abasic nucleotide as the terminal nucleotide at its 3' end, its 5' end, or both its 3' and 5' ends. In such embodiments in which the abasic nucleotide is a terminal nucleotide, it may be an inverted nucleotide – that is, linked to the adjacent nucleotide through a 3'-3' internucleotide linkage (when on the 3' end of a strand) or through a 5'-5' internucleotide linkage (when on the 5' end of a strand) rather than the natural 3'-5' internucleotide linkage. Abasic nucleotides may also comprise a sugar modification, such as any of the sugar modifications described above. In certain embodiments, abasic nucleotides comprise a 2'-modification, such as a 2'-fluoro modification, 2'-O-methyl modification, or a 2'-H (deoxy) modification. In one embodiment, the abasic nucleotide comprises a 2'-O-methyl modification. In another embodiment, the abasic nucleotide comprises a 2'-H modification (i.e. a deoxy abasic nucleotide).

[0053] The RNAi constructs of the invention may also comprise one or more modified internucleotide linkages. As used herein, the term “modified internucleotide linkage” refers to an internucleotide linkage other than the natural 3′ to 5′ phosphodiester linkage. In some embodiments, the modified internucleotide linkage is a phosphorous-containing internucleotide linkage, such as a phosphotriester, aminoalkylphosphotriester, an alkylphosphonate (e.g. methylphosphonate, 3′-alkylene phosphonate), a phosphinate, a phosphoramidate (e.g. 3′-amino phosphoramidate and aminoalkylphosphoramidate), a phosphorothioate (P=S), a chiral phosphorothioate, a phosphorodithioate, a thionophosphoramidate, a thionoalkylphosphonate, a thionoalkylphosphotriester, and a boranophosphate. In one embodiment, a modified internucleotide linkage is a 2′ to 5′ phosphodiester linkage. In other embodiments, the modified internucleotide linkage is a non-phosphorous-containing internucleotide linkage and thus can be referred to as a modified internucleoside linkage. Such non-phosphorous-containing linkages include, but are not limited to, morpholino linkages (formed in part from the sugar portion of a nucleoside); siloxane linkages ($\text{—O—Si(H)}_2\text{—O—}$); sulfide, sulfoxide and sulfone linkages; formacetyl and thioformacetyl linkages; alkene containing backbones; sulfamate backbones; methylenemethylimino ($\text{—CH}_2\text{—N(CH}_3\text{)—O—CH}_2\text{—}$) and methylenehydrazino linkages; sulfonate and sulfonamide linkages; amide linkages; and others having mixed N, O, S and CH_2 component parts. In one embodiment, the modified internucleoside linkage is a peptide-based linkage (e.g. aminoethylglycine) to create a peptide nucleic acid or PNA, such as those described in U.S. Patent Nos. 5,539,082; 5,714,331; and 5,719,262. Other suitable modified internucleotide and internucleoside linkages that may be employed in the RNAi constructs of the invention are described in U.S. Patent No. 6,693,187, U.S. Patent No. 9,181,551, U.S. Patent Publication No. 2016/0122761, and Deleavey and Damha, Chemistry and Biology, Vol. 19: 937-954, 2012, all of which are hereby incorporated by reference in their entireties.

[0054] In certain embodiments, the RNAi constructs of the invention comprise one or more phosphorothioate internucleotide linkages. The phosphorothioate internucleotide linkages may be present in the sense strand, antisense strand, or both strands of the RNAi constructs. For instance, in some embodiments, the sense strand comprises 1, 2, 3, 4, 5, 6, 7, 8, or more phosphorothioate internucleotide linkages. In other embodiments, the antisense strand comprises 1, 2, 3, 4, 5, 6, 7, 8, or more phosphorothioate internucleotide linkages. In still other embodiments, both strands comprise 1, 2, 3, 4, 5, 6, 7, 8, or more phosphorothioate

internucleotide linkages. The RNAi constructs can comprise one or more phosphorothioate internucleotide linkages at the 3'-end, the 5'-end, or both the 3'- and 5'-ends of the sense strand, the antisense strand, or both strands. For instance, in certain embodiments, the RNAi construct comprises about 1 to about 6 or more (e.g., about 1, 2, 3, 4, 5, 6 or more) consecutive phosphorothioate internucleotide linkages at the 3'-end of the sense strand, the antisense strand, or both strands. In other embodiments, the RNAi construct comprises about 1 to about 6 or more (e.g., about 1, 2, 3, 4, 5, 6 or more) consecutive phosphorothioate internucleotide linkages at the 5'-end of the sense strand, the antisense strand, or both strands.

[0055] In some embodiments, the RNAi construct comprises a single phosphorothioate internucleotide linkage between the terminal nucleotides at the 3' end of the sense strand. In other embodiments, the RNAi construct comprises two consecutive phosphorothioate internucleotide linkages between the terminal nucleotides at the 3' end of the sense strand. In one embodiment, the RNAi construct comprises a single phosphorothioate internucleotide linkage between the terminal nucleotides at the 3' end of the sense strand and a single phosphorothioate internucleotide linkage between the terminal nucleotides at the 3' end of the antisense strand. In another embodiment, the RNAi construct comprises two consecutive phosphorothioate internucleotide linkages between the terminal nucleotides at the 3' end of the antisense strand (i.e. a phosphorothioate internucleotide linkage at the first and second internucleotide linkages at the 3' end of the antisense strand). In another embodiment, the RNAi construct comprises two consecutive phosphorothioate internucleotide linkages between the terminal nucleotides at both the 3' and 5' ends of the antisense strand. In yet another embodiment, the RNAi construct comprises two consecutive phosphorothioate internucleotide linkages between the terminal nucleotides at both the 3' and 5' ends of the antisense strand and two consecutive phosphorothioate internucleotide linkages at the 5' end of the sense strand. In still another embodiment, the RNAi construct comprises two consecutive phosphorothioate internucleotide linkages between the terminal nucleotides at both the 3' and 5' ends of the antisense strand and two consecutive phosphorothioate internucleotide linkages between the terminal nucleotides at the 3' end of the sense strand. In another embodiment, the RNAi construct comprises two consecutive phosphorothioate internucleotide linkages between the terminal nucleotides at both the 3' and 5' ends of the antisense strand and two consecutive phosphorothioate internucleotide linkages between the terminal nucleotides at both the 3' and 5'

ends of the sense strand (i.e. a phosphorothioate internucleotide linkage at the first and second internucleotide linkages at both the 5' and 3' ends of the antisense strand and a phosphorothioate internucleotide linkage at the first and second internucleotide linkages at both the 5' and 3' ends of the sense strand). In yet another embodiment, the RNAi construct comprises two consecutive phosphorothioate internucleotide linkages between the terminal nucleotides at both the 3' and 5' ends of the antisense strand and a single phosphorothioate internucleotide linkage between the terminal nucleotides at the 3' end of the sense strand. In any of the embodiments in which one or both strands comprise one or more phosphorothioate internucleotide linkages, the remaining internucleotide linkages within the strands can be the natural 3' to 5' phosphodiester linkages. For instance, in some embodiments, each internucleotide linkage of the sense and antisense strands is selected from phosphodiester and phosphorothioate, wherein at least one internucleotide linkage is a phosphorothioate.

[0056] In embodiments in which the RNAi construct comprises a nucleotide overhang, two or more of the unpaired nucleotides in the overhang can be connected by a phosphorothioate internucleotide linkage. In certain embodiments, all the unpaired nucleotides in a nucleotide overhang at the 3' end of the antisense strand and/or the sense strand are connected by phosphorothioate internucleotide linkages. In other embodiments, all the unpaired nucleotides in a nucleotide overhang at the 5' end of the antisense strand and/or the sense strand are connected by phosphorothioate internucleotide linkages. In still other embodiments, all the unpaired nucleotides in any nucleotide overhang are connected by phosphorothioate internucleotide linkages.

[0057] In some embodiments of the RNAi constructs of the invention, the 5' end of the sense strand, antisense strand, or both the antisense and sense strands comprises a phosphate moiety. As used herein, the term "phosphate moiety" refers to a terminal phosphate group that includes unmodified phosphates (—O—P=O(OH)OH) as well as modified phosphates. Modified phosphates include phosphates in which one or more of the O and OH groups is replaced with H, O, S, N(R) or alkyl where R is H, an amino protecting group or unsubstituted or substituted alkyl. Exemplary phosphate moieties include, but are not limited to, 5'-monophosphate; 5'-diphosphate; 5'-triphosphate; 5'-guanosine cap (7-methylated or non-methylated); 5'-adenosine cap or any other modified or unmodified nucleotide cap structure; 5'-monothiophosphate (phosphorothioate); 5'-monodithiophosphate (phosphorodithioate); 5'-alpha-thiotriphosphate; 5'-

gamma-thiotriphosphate, 5'-phosphoramidates; 5'-vinylphosphates; 5'-alkylphosphonates (e.g., alkyl = methyl, ethyl, isopropyl, propyl, etc.); and 5'-alkyletherphosphonates (e.g., alkylether = methoxymethyl, ethoxymethyl, etc.).

[0058] The modified nucleotides that can be incorporated into the RNAi constructs of the invention may have more than one chemical modification described herein. For instance, the modified nucleotide may have a modification to the ribose sugar as well as a modification to the nucleobase. By way of example, a modified nucleotide may comprise a 2' sugar modification (e.g. 2'-fluoro or 2'-O-methyl) and comprise a modified base (e.g. 5-methyl cytosine or pseudouracil). In other embodiments, the modified nucleotide may comprise a sugar modification in combination with a modification to the 5' phosphate that would create a modified internucleotide or internucleoside linkage when the modified nucleotide was incorporated into a polynucleotide. For instance, in some embodiments, the modified nucleotide may comprise a sugar modification, such as a 2'-fluoro modification, a 2'-O-methyl modification, or a bicyclic sugar modification, as well as a 5' phosphorothioate group. Accordingly, in some embodiments, one or both strands of the RNAi constructs of the invention comprise a combination of 2' modified nucleotides or BNAs and phosphorothioate internucleotide linkages. In certain embodiments, both the sense and antisense strands of the RNAi constructs of the invention comprise a combination of 2'-fluoro modified nucleotides, 2'-O-methyl modified nucleotides, and phosphorothioate internucleotide linkages. Exemplary RNAi constructs comprising modified nucleotides and internucleotide linkages are shown in Table 2.

[0059] The RNAi constructs of the invention can readily be made using techniques known in the art, for example, using conventional nucleic acid solid phase synthesis. The polynucleotides of the RNAi constructs can be assembled on a suitable nucleic acid synthesizer utilizing standard nucleotide or nucleoside precursors (e.g. phosphoramidites). Automated nucleic acid synthesizers are sold commercially by several vendors, including DNA/RNA synthesizers from Applied Biosystems (Foster City, CA), MerMade synthesizers from BioAutomation (Irving, TX), and OligoPilot synthesizers from GE Healthcare Life Sciences (Pittsburgh, PA). An exemplary method for synthesizing the RNAi constructs of the invention is described in Example 1.

[0060] A 2' silyl protecting group can be used in conjunction with acid labile dimethoxytrityl (DMT) at the 5' position of ribonucleosides to synthesize oligonucleotides via phosphoramidite

chemistry. Final deprotection conditions are known not to significantly degrade RNA products. All syntheses can be conducted in any automated or manual synthesizer on large, medium, or small scale. The syntheses may also be carried out in multiple well plates, columns, or glass slides.

[0061] The 2'-O-silyl group can be removed via exposure to fluoride ions, which can include any source of fluoride ion, e.g., those salts containing fluoride ion paired with inorganic counterions e.g., cesium fluoride and potassium fluoride or those salts containing fluoride ion paired with an organic counterion, e.g., a tetraalkylammonium fluoride. A crown ether catalyst can be utilized in combination with the inorganic fluoride in the deprotection reaction. Preferred fluoride ion sources are tetrabutylammonium fluoride or aminohydrofluorides (e.g., combining aqueous HF with triethylamine in a dipolar aprotic solvent, e.g., dimethylformamide).

[0062] The choice of protecting groups for use on the phosphite triesters and phosphotriesters can alter the stability of the triesters towards fluoride. Methyl protection of the phosphotriester or phosphitetriester can stabilize the linkage against fluoride ions and improve process yields.

[0063] Since ribonucleosides have a reactive 2' hydroxyl substituent, it can be desirable to protect the reactive 2' position in RNA with a protecting group that is orthogonal to a 5'-O-dimethoxytrityl protecting group, e.g., one stable to treatment with acid. Silyl protecting groups meet this criterion and can be readily removed in a final fluoride deprotection step that can result in minimal RNA degradation.

[0064] Tetrazole catalysts can be used in the standard phosphoramidite coupling reaction. Preferred catalysts include, e.g., tetrazole, S-ethyl-tetrazole, benzylthiotetrazole, p-nitrophenyltetrazole.

[0065] As can be appreciated by the skilled artisan, further methods of synthesizing the RNAi constructs described herein will be evident to those of ordinary skill in the art. Additionally, the various synthetic steps may be performed in an alternate sequence or order to give the desired compounds. Other synthetic chemistry transformations, protecting groups (e.g., for hydroxyl, amino, etc. present on the bases) and protecting group methodologies (protection and deprotection) useful in synthesizing the RNAi constructs described herein are known in the art and include, for example, those such as described in R. Larock, *Comprehensive Organic Transformations*, VCH Publishers (1989); T. W. Greene and P. G. M. Wuts, *Protective Groups in Organic Synthesis*, 2d. Ed., John Wiley and Sons (1991); L. Fieser and M. Fieser, *Fieser and*

Fieser's Reagents for Organic Synthesis, John Wiley and Sons (1994); and L. Paquette, ed., Encyclopedia of Reagents for Organic Synthesis, John Wiley and Sons (1995), and subsequent editions thereof. Custom synthesis of RNAi agents is also available from several commercial vendors, including Dharmacon, Inc. (Lafayette, CO), AxoLabs GmbH (Kulmbach, Germany), and Ambion, Inc. (Foster City, CA).

[0066] The RNAi constructs of the invention may comprise a ligand. As used herein, a “ligand” refers to any compound or molecule that is capable of interacting with another compound or molecule, directly or indirectly. The interaction of a ligand with another compound or molecule may elicit a biological response (e.g. initiate a signal transduction cascade, induce receptor-mediated endocytosis) or may just be a physical association. The ligand can modify one or more properties of the double-stranded RNA molecule to which is attached, such as the pharmacodynamic, pharmacokinetic, binding, absorption, cellular distribution, cellular uptake, charge and/or clearance properties of the RNA molecule.

[0067] The ligand may comprise a serum protein (e.g., human serum albumin, low-density lipoprotein, globulin), a cholesterol moiety, a vitamin (biotin, vitamin E, vitamin B₁₂), a folate moiety, a steroid, a bile acid (e.g. cholic acid), a fatty acid (e.g., palmitic acid, myristic acid), a carbohydrate (e.g., a dextran, pullulan, chitin, chitosan, inulin, cyclodextrin or hyaluronic acid), a glycoside, a phospholipid, or antibody or binding fragment thereof (e.g. antibody or binding fragment that targets the RNAi construct to a specific cell type, such as liver). 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. adamantane acetic acid, 1-pyrene butyric acid, dihydrotestosterone, 1,3-Bis-O(hexadecyl)glycerol, geranyloxyhexyl group, hexadecylglycerol, borneol, menthol, 1,3-propanediol, heptadecyl group, O3-(oleoyl)lithocholic acid, O3-(oleoyl)cholenic acid, dimethoxytrityl, or phenoxazine), peptides (e.g., antennapedia peptide, Tat peptide, RGD peptides), alkylating agents, polymers, such as polyethylene glycol (PEG) (e.g., PEG-40K), polyamino acids, and polyamines (e.g. spermine, spermidine).

[0068] In certain embodiments, the ligands have endosomolytic properties. The endosomolytic ligands promote the lysis of the endosome and/or transport of the RNAi construct of the invention, or its components, from the endosome to the cytoplasm of the cell. The

endosomolytic ligand may be a polycationic peptide or peptidomimetic, which shows pH-dependent membrane activity and fusogenicity. In one embodiment, the endosomolytic ligand assumes its active conformation at endosomal pH. The “active” conformation is that conformation in which the endosomolytic ligand promotes lysis of the endosome and/or transport of the RNAi construct of the invention, or its components, from the endosome to the cytoplasm of the cell. Exemplary endosomolytic ligands include the GALA peptide (Subbarao *et al.*, *Biochemistry*, Vol. 26: 2964-2972, 1987), the EALA peptide (Vogel *et al.*, *J. Am. Chem. Soc.*, Vol. 118: 1581-1586, 1996), and their derivatives (Turk *et al.*, *Biochem. Biophys. Acta*, Vol. 1559: 56-68, 2002). In one embodiment, the endosomolytic component may contain a chemical group (e.g., an amino acid) which will undergo a change in charge or protonation in response to a change in pH. The endosomolytic component may be linear or branched.

[0069] In some embodiments, the ligand comprises a lipid or other hydrophobic molecule. In one embodiment, the ligand comprises a cholesterol moiety or other steroid. Cholesterol-conjugated oligonucleotides have been reported to be more active than their unconjugated counterparts (Manoharan, *Antisense Nucleic Acid Drug Development*, Vol. 12: 103-228, 2002). Ligands comprising cholesterol moieties and other lipids for conjugation to nucleic acid molecules have also been described in U.S. Patent Nos. 7,851,615; 7,745,608; and 7,833,992, all of which are hereby incorporated by reference in their entireties. In another embodiment, the ligand comprises a folate moiety. Polynucleotides conjugated to folate moieties can be taken up by cells via a receptor-mediated endocytosis pathway. Such folate-polynucleotide conjugates are described in U.S. Patent No. 8,188,247, which is hereby incorporated by reference in its entirety.

[0070] The *LPA* gene is expressed predominantly in the liver. Thus, in certain embodiments, it is desirable to specifically deliver the RNAi constructs of the invention to liver cells. Accordingly, in certain embodiments, the ligand targets delivery of the RNAi construct specifically to liver cells (e.g. hepatocytes) using various approaches as described in more detail below. In certain embodiments, the RNAi constructs are targeted to liver cells with a ligand that binds to the surface-expressed asialoglycoprotein receptor (ASGR) or component thereof (e.g. ASGR1, ASGR2).

[0071] In some embodiments, RNAi constructs can be specifically targeted to the liver by employing ligands that bind to or interact with proteins expressed on the surface of liver cells. For example, in certain embodiments, the ligands may comprise antigen binding proteins (e.g.

antibodies or binding fragments thereof (e.g. Fab, scFv)) that specifically bind to a receptor expressed on hepatocytes, such as the asialoglycoprotein receptor and the LDL receptor. In one particular embodiment, the ligand comprises an antibody or binding fragment thereof that specifically binds to ASGR1 and/or ASGR2. In another embodiment, the ligand comprises a Fab fragment of an antibody that specifically binds to ASGR1 and/or ASGR2. A “Fab fragment” is comprised of one immunoglobulin light chain (i.e. light chain variable region (VL) and constant region (CL)) and the CH1 region and variable region (VH) of one immunoglobulin heavy chain. In another embodiment, the ligand comprises a single-chain variable antibody fragment (scFv fragment) of an antibody that specifically binds to ASGR1 and/or ASGR2. An “scFv fragment” comprises the VH and VL regions of an antibody, wherein these regions are present in a single polypeptide chain, and optionally comprising a peptide linker between the VH and VL regions that enables the Fv to form the desired structure for antigen binding. Exemplary antibodies and binding fragments thereof that specifically bind to ASGR1 that can be used as ligands for targeting the RNAi constructs of the invention to the liver are described in WIPO Publication No. WO 2017/058944, which is hereby incorporated by reference in its entirety. Other antibodies or binding fragments thereof that specifically bind to ASGR1, LDL receptor, or other liver surface-expressed proteins suitable for use as ligands in the RNAi constructs of the invention are commercially available.

[0072] In certain embodiments, the ligand comprises a carbohydrate. A “carbohydrate” refers to a compound 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. Carbohydrates include, but are not limited to, the sugars (e.g., monosaccharides, disaccharides, trisaccharides, tetrasaccharides, and oligosaccharides containing from about 4, 5, 6, 7, 8, or 9 monosaccharide units), and polysaccharides, such as starches, glycogen, cellulose and polysaccharide gums. In some embodiments, the carbohydrate incorporated into the ligand is a monosaccharide selected from a pentose, hexose, or heptose and di- and tri-saccharides including such monosaccharide units. In other embodiments, the carbohydrate incorporated into the ligand is an amino sugar, such as galactosamine, glucosamine, N-acetylgalactosamine, and N-acetylglucosamine.

[0073] In some embodiments, the ligand comprises a hexose or hexosamine. The hexose may be selected from glucose, galactose, mannose, fucose, or fructose. The hexosamine may be selected

from fructosamine, galactosamine, glucosamine, or mannosamine. In certain embodiments, the ligand comprises glucose, galactose, galactosamine, or glucosamine. In one embodiment, the ligand comprises glucose, glucosamine, or N-acetylglucosamine. In another embodiment, the ligand comprises galactose, galactosamine, or N-acetyl-galactosamine. In particular embodiments, the ligand comprises N-acetyl-galactosamine. Ligands comprising glucose, galactose, and N-acetyl-galactosamine (GalNAc) are particularly effective in targeting compounds to liver cells because such ligands bind to the ASGR expressed on the surface of hepatocytes. *See, e.g.*, D'Souza and Devarajan, J. Control Release, Vol. 203: 126-139, 2015. Examples of GalNAc- or galactose-containing ligands that can be incorporated into the RNAi constructs of the invention are described in U.S. Patent Nos. 7,491,805; 8,106,022; and 8,877,917; U.S. Patent Publication No. 20030130186; and WIPO Publication No. WO 2013166155, all of which are hereby incorporated by reference in their entireties.

[0074] In certain embodiments, the ligand comprises a multivalent carbohydrate moiety. As used herein, a “multivalent carbohydrate moiety” refers to a moiety comprising two or more carbohydrate units capable of independently binding or interacting with other molecules. For example, a multivalent carbohydrate moiety comprises two or more binding domains comprised of carbohydrates that can bind to two or more different molecules or two or more different sites on the same molecule. The valency of the carbohydrate moiety denotes the number of individual binding domains within the carbohydrate moiety. For instance, the terms “monovalent,” “bivalent,” “trivalent,” and “tetravalent” with reference to the carbohydrate moiety refer to carbohydrate moieties with one, two, three, and four binding domains, respectively. The multivalent carbohydrate moiety may comprise a multivalent lactose moiety, a multivalent galactose moiety, a multivalent glucose moiety, a multivalent N-acetyl-galactosamine moiety, a multivalent N-acetyl-glucosamine moiety, a multivalent mannose moiety, or a multivalent fucose moiety. In some embodiments, the ligand comprises a multivalent galactose moiety. In other embodiments, the ligand comprises a multivalent N-acetyl-galactosamine moiety. In these and other embodiments, the multivalent carbohydrate moiety can be bivalent, trivalent, or tetravalent. In such embodiments, the multivalent carbohydrate moiety can be bi-antennary or tri-antennary. In one particular embodiment, the multivalent N-acetyl-galactosamine moiety is trivalent or tetravalent. In another particular embodiment, the multivalent galactose moiety is trivalent or

tetravalent. Exemplary trivalent and tetravalent GalNAc-containing ligands for incorporation into the RNAi constructs of the invention are described in detail below.

[0075] The ligand can be attached or conjugated to the RNA molecule of the RNAi construct directly or indirectly. For instance, in some embodiments, the ligand is covalently attached directly to the sense or antisense strand of the RNAi construct. In other embodiments, the ligand is covalently attached via a linker to the sense or antisense strand of the RNAi construct. The ligand can be attached to nucleobases, sugar moieties, or internucleotide linkages of polynucleotides (e.g. sense strand or antisense strand) of the RNAi constructs of the invention. Conjugation or attachment to purine nucleobases or derivatives thereof can occur at any position including, endocyclic and exocyclic atoms. In certain embodiments, the 2-, 6-, 7-, or 8-positions of a purine nucleobase are attached to a ligand. Conjugation or attachment to pyrimidine nucleobases or derivatives thereof can also occur at any position. In some embodiments, the 2-, 5-, and 6-positions of a pyrimidine nucleobase can be attached to a ligand. Conjugation or attachment to sugar moieties of nucleotides can occur at any carbon atom. Exemplary carbon atoms of a sugar moiety that can be attached to a ligand include the 2', 3', and 5' carbon atoms. The 1' position can also be attached to a ligand, such as in an abasic nucleotide. Internucleotide linkages can also support ligand attachments. For phosphorus-containing linkages (e.g., phosphodiester, phosphorothioate, phosphorodithiotate, phosphoroamidate, and the like), the ligand can be attached directly to the phosphorus atom or to an O, N, or S atom bound to the phosphorus atom. For amine- or amide-containing internucleoside linkages (e.g., PNA), the ligand can be attached to the nitrogen atom of the amine or amide or to an adjacent carbon atom.

[0076] In some embodiments, the ligand may be attached to the 3' or 5' end of either the sense or antisense strand. In certain embodiments, the ligand is covalently attached to the 5' end of the sense strand. In such embodiments, the ligand is attached to the 5'-terminal nucleotide of the sense strand. In these and other embodiments, the ligand is attached at the 5'-position of the 5'-terminal nucleotide of the sense strand. In embodiments in which an inverted abasic nucleotide is the 5'-terminal nucleotide of the sense strand and linked to the adjacent nucleotide via a 5'-5' internucleotide linkage, the ligand can be attached at the 3'-position of the inverted abasic nucleotide. In other embodiments, the ligand is covalently attached to the 3' end of the sense strand. For example, in some embodiments, the ligand is attached to the 3'-terminal nucleotide of the sense strand. In certain such embodiments, the ligand is attached at the 3'-position of the

3'-terminal nucleotide of the sense strand. In embodiments in which an inverted abasic nucleotide is the 3'-terminal nucleotide of the sense strand and linked to the adjacent nucleotide via a 3'-3' internucleotide linkage, the ligand can be attached at the 5'-position of the inverted abasic nucleotide. In alternative embodiments, the ligand is attached near the 3' end of the sense strand, but before one or more terminal nucleotides (i.e. before 1, 2, 3, or 4 terminal nucleotides). In some embodiments, the ligand is attached at the 2'-position of the sugar of the 3'-terminal nucleotide of the sense strand. In other embodiments, the ligand is attached at the 2'-position of the sugar of the 5'-terminal nucleotide of the sense strand.

[0077] In certain embodiments, the ligand is attached to the sense or antisense strand via a linker. A "linker" is an atom or group of atoms that covalently joins a ligand to a polynucleotide component of the RNAi construct. The linker may be from about 1 to about 30 atoms in length, from about 2 to about 28 atoms in length, from about 3 to about 26 atoms in length, from about 4 to about 24 atoms in length, from about 6 to about 20 atoms in length, from about 7 to about 20 atoms in length, from about 8 to about 20 atoms in length, from about 8 to about 18 atoms in length, from about 10 to about 18 atoms in length, and from about 12 to about 18 atoms in length. In some embodiments, the linker may comprise a bifunctional linking moiety, which generally comprises an alkyl moiety with two functional groups. One of the functional groups is selected to bind to the compound of interest (e.g. sense or antisense strand of the RNAi construct) and the other is selected to bind essentially any selected group, such as a ligand as described herein. In certain embodiments, the linker comprises a chain structure or an oligomer of repeating units, such as ethylene glycol or amino acid units. Examples of functional groups that are typically employed in a bifunctional linking moiety include, but are not limited to, electrophiles for reacting with nucleophilic groups and nucleophiles for reacting with electrophilic groups. In some embodiments, bifunctional linking moieties include amino, hydroxyl, carboxylic acid, thiol, unsaturations (e.g., double or triple bonds), and the like.

[0078] Linkers that may be used to attach a ligand to the sense or antisense strand in the RNAi constructs of the invention include, but are not limited to, pyrrolidine, 8-amino-3,6-dioxaoctanoic acid, succinimidyl 4-(N-maleimidomethyl)cyclohexane-1-carboxylate, 6-aminohexanoic acid, substituted C₁-C₁₀ alkyl, substituted or unsubstituted C₂-C₁₀ alkenyl or substituted or unsubstituted C₂-C₁₀ alkynyl. Preferred substituent groups for such linkers include,

but are not limited to, hydroxyl, amino, alkoxy, carboxy, benzyl, phenyl, nitro, thiol, thioalkoxy, halogen, alkyl, aryl, alkenyl and alkynyl.

[0079] In certain embodiments, the linkers are cleavable. A cleavable linker 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 some embodiments, the cleavable linker is cleaved at least 10 times, 20 times, 30 times, 40 times, 50 times, 60 times, 70 times, 80 times, 90 times, or more, or at least 100 times faster in the 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).

[0080] Cleavable linkers 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 linker 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 linker by acting as a general acid, peptidases (which can be substrate specific), and phosphatases.

[0081] A cleavable linker may comprise a moiety that is 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 group that is cleaved at a preferred pH, thereby releasing the RNA molecule from the ligand inside the cell, or into the desired compartment of the cell.

[0082] A linker can include a cleavable group that is cleavable by a particular enzyme. The type of cleavable group incorporated into a linker can depend on the cell to be targeted. For example, liver-targeting ligands can be linked to RNA molecules 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 types of cells rich in esterases

include cells of the lung, renal cortex, and testis. Linkers that contain peptide bonds can be used when targeting cells rich in peptidases, such as liver cells and synoviocytes.

[0083] In general, the suitability of a candidate cleavable linker can be evaluated by testing the ability of a degradative agent (or condition) to cleave the candidate linker. It will also be desirable to also test the candidate cleavable linker 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 may be useful to make initial evaluations in cell-free or culture conditions and to confirm by further evaluations in whole animals. In some embodiments, useful candidate linkers are cleaved at least 2, 4, 10, 20, 50, 70, or 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).

[0084] In other embodiments, redox cleavable linkers are utilized. Redox cleavable linkers are cleaved upon reduction or oxidation. An example of a reductively cleavable group is a disulfide linking group (-S-S-). To determine if a candidate cleavable linker is a suitable “reductively cleavable linker,” or for example is suitable for use with a particular RNAi construct and particular ligand, one can use one or more methods described herein. For example, a candidate linker can be evaluated by incubation with dithiothreitol (DTT), or other reducing agent known in the art, which mimics the rate of cleavage that would be observed in a cell, e.g., a target cell. The candidate linkers can also be evaluated under conditions which are selected to mimic blood or serum conditions. In a specific embodiment, candidate linkers are cleaved by at most 10% in the blood. In other embodiments, useful candidate linkers are degraded at least 2, 4, 10, 20, 50, 70, or 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).

[0085] In yet other embodiments, phosphate-based cleavable linkers, which are cleaved by agents that degrade or hydrolyze the phosphate group, are employed to covalently attach a ligand to the sense or antisense strand of the RNAi construct. An example of an agent that hydrolyzes

phosphate groups in cells are enzymes, such as phosphatases in cells. Examples of phosphate-based cleavable groups are $-\text{O}-\text{P}(\text{O})(\text{ORk})-\text{O}-$, $-\text{O}-\text{P}(\text{S})(\text{ORk})-\text{O}-$, $-\text{O}-\text{P}(\text{S})(\text{SRk})-\text{O}-$, $-\text{S}-\text{P}(\text{O})(\text{ORk})-\text{O}-$, $-\text{O}-\text{P}(\text{O})(\text{ORk})-\text{S}-$, $-\text{S}-\text{P}(\text{O})(\text{ORk})-\text{S}-$, $-\text{O}-\text{P}(\text{S})(\text{ORk})-\text{S}-$, $-\text{S}-\text{P}(\text{S})(\text{ORk})-\text{O}-$, $-\text{O}-\text{P}(\text{O})(\text{Rk})-\text{O}-$, $-\text{O}-\text{P}(\text{S})(\text{Rk})-\text{O}-$, $-\text{S}-\text{P}(\text{O})(\text{Rk})-\text{O}-$, $-\text{S}-\text{P}(\text{S})(\text{Rk})-\text{O}-$, $-\text{S}-\text{P}(\text{O})(\text{Rk})-\text{S}-$, and $-\text{O}-\text{P}(\text{S})(\text{Rk})-\text{S}-$, where Rk can be hydrogen or alkyl. Specific embodiments include $-\text{O}-\text{P}(\text{O})(\text{OH})-\text{O}-$, $-\text{O}-\text{P}(\text{S})(\text{OH})-\text{O}-$, $-\text{O}-\text{P}(\text{S})(\text{SH})-\text{O}-$, $-\text{S}-\text{P}(\text{O})(\text{OH})-\text{O}-$, $-\text{O}-\text{P}(\text{O})(\text{OH})-\text{S}-$, $-\text{S}-\text{P}(\text{O})(\text{OH})-\text{S}-$, $-\text{O}-\text{P}(\text{S})(\text{OH})-\text{S}-$, $-\text{S}-\text{P}(\text{S})(\text{OH})-\text{O}-$, $-\text{O}-\text{P}(\text{O})(\text{H})-\text{O}-$, $-\text{O}-\text{P}(\text{S})(\text{H})-\text{O}-$, $-\text{S}-\text{P}(\text{O})(\text{H})-\text{O}-$, $-\text{S}-\text{P}(\text{S})(\text{H})-\text{O}-$, $-\text{S}-\text{P}(\text{O})(\text{H})-\text{S}-$, and $-\text{O}-\text{P}(\text{S})(\text{H})-\text{S}-$. Another specific embodiment is $-\text{O}-\text{P}(\text{O})(\text{OH})-\text{O}-$. These candidate linkers can be evaluated using methods analogous to those described above.

[0086] In other embodiments, the linkers may comprise acid cleavable groups, which are groups that are cleaved under acidic conditions. In some embodiments, acid cleavable groups are cleaved in an acidic environment with a pH of about 6.5 or lower (e.g., about 6.0, 5.5, 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 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 $-\text{C}=\text{NN}-$, $\text{C}(\text{O})\text{O}$, or $-\text{OC}(\text{O})$. A specific 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.

[0087] In other embodiments, the linkers may comprise ester-based cleavable groups, which are cleaved by enzymes, such as esterases and amidases in cells. Examples of ester-based cleavable groups include, but are not limited to, esters of alkylene, alkenylene and alkynylene groups. Ester cleavable groups have the general formula $-\text{C}(\text{O})\text{O}-$, or $-\text{OC}(\text{O})-$. These candidate linkers can be evaluated using methods analogous to those described above.

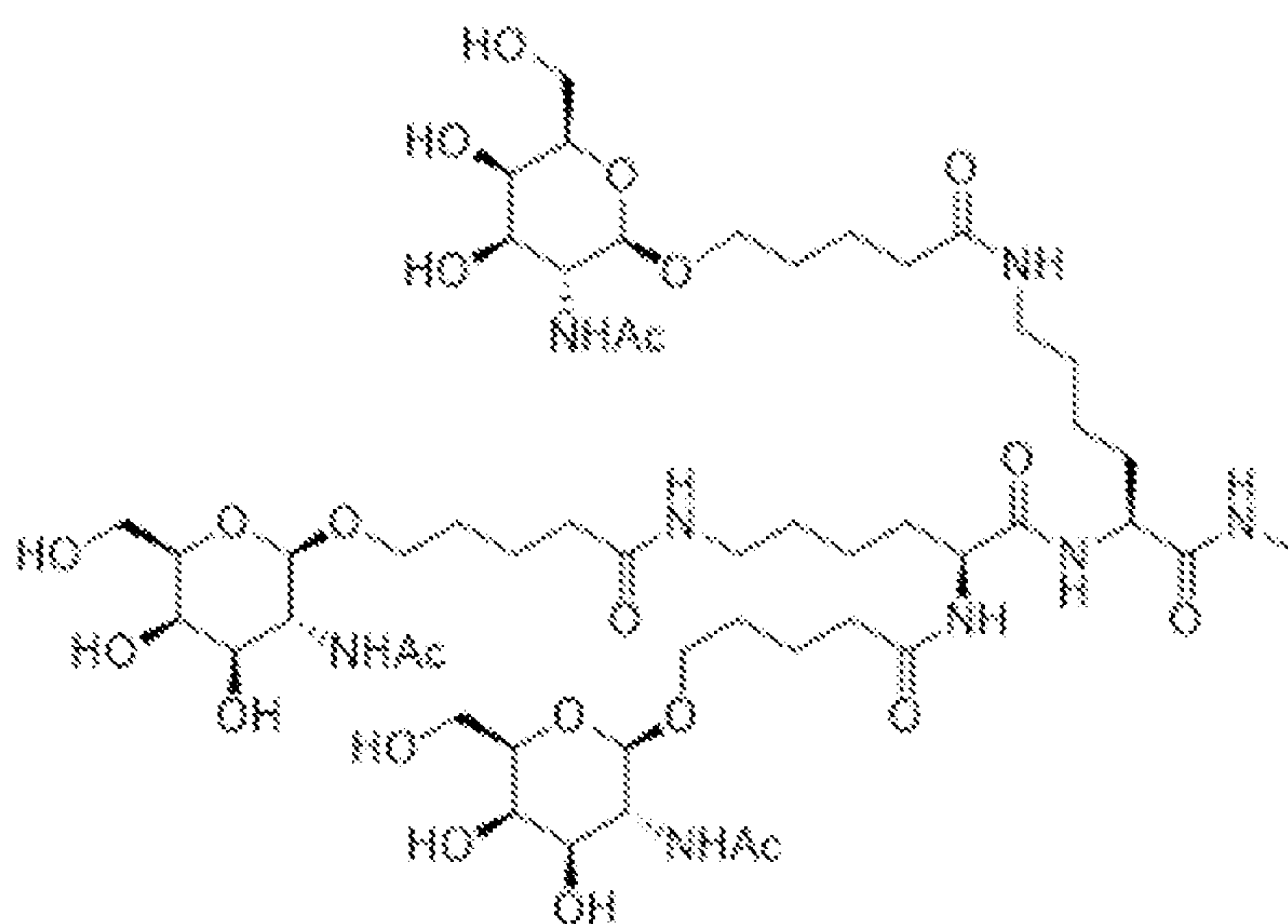
[0088] In further embodiments, the linkers may comprise peptide-based cleavable groups, which are cleaved by enzymes, such as peptidases and proteases in cells. Peptide-based cleavable groups are peptide bonds formed between amino acids to yield oligopeptides (e.g., dipeptides, tripeptides etc.) and polypeptides. Peptide-based cleavable groups include the amide group ($-\text{C}(\text{O})\text{NH}-$). The amide group can be formed between any alkylene, alkenylene or alkynylene. 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. Peptide-based cleavable linking groups have the general formula $\text{--NHCHR}^{\text{A}}\text{C(O)NHCHR}^{\text{B}}\text{C(O) --}$, where R^{A} and R^{B} are the side chains of the two adjacent amino acids. These candidates can be evaluated using methods analogous to those described above.

[0089] Other types of linkers suitable for attaching ligands to the sense or antisense strands in the RNAi constructs of the invention are known in the art and can include the linkers described in U.S. Patent Nos. 7,723,509; 8,017,762; 8,828,956; 8,877,917; and 9,181,551, all of which are hereby incorporated by reference in their entireties.

[0090] In certain embodiments, the ligand covalently attached to the sense or antisense strand of the RNAi constructs of the invention comprises a GalNAc moiety, e.g., a multivalent GalNAc moiety. In some embodiments, the multivalent GalNAc moiety is a trivalent GalNAc moiety and is attached to the 3' end of the sense strand. In other embodiments, the multivalent GalNAc moiety is a trivalent GalNAc moiety and is attached to the 5' end of the sense strand. In yet other embodiments, the multivalent GalNAc moiety is a tetravalent GalNAc moiety and is attached to the 3' end of the sense strand. In still other embodiments, the multivalent GalNAc moiety is a tetravalent GalNAc moiety and is attached to the 5' end of the sense strand.

[0091] In certain embodiments, the RNAi constructs of the invention comprise a ligand having the structure of Structure 1:

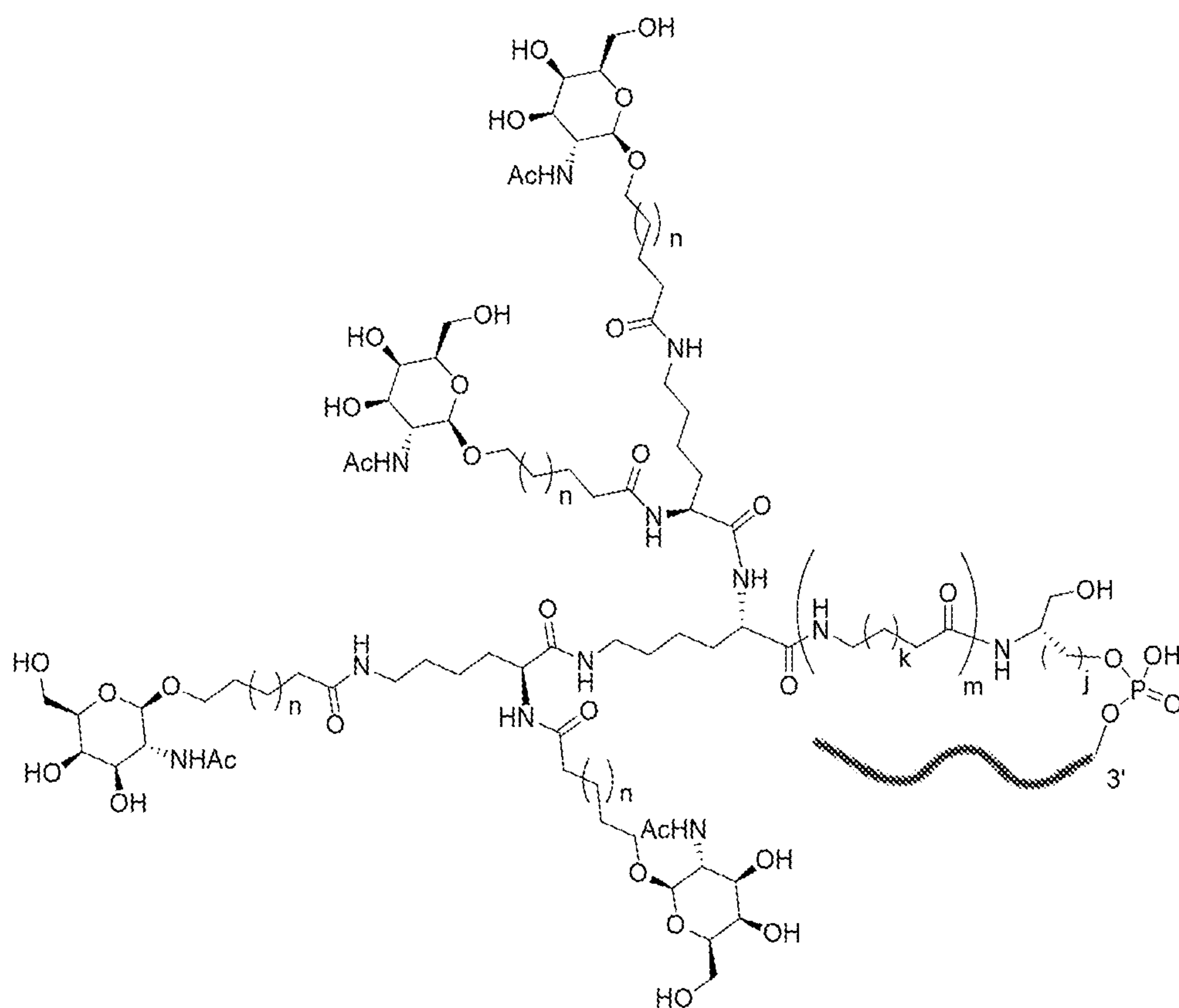


[Structure 1]

In preferred embodiments, the ligand having this structure is covalently attached to the 5' end of the sense strand via a linker, such as the linkers described herein. In one embodiment, the linker is an aminohexyl linker.

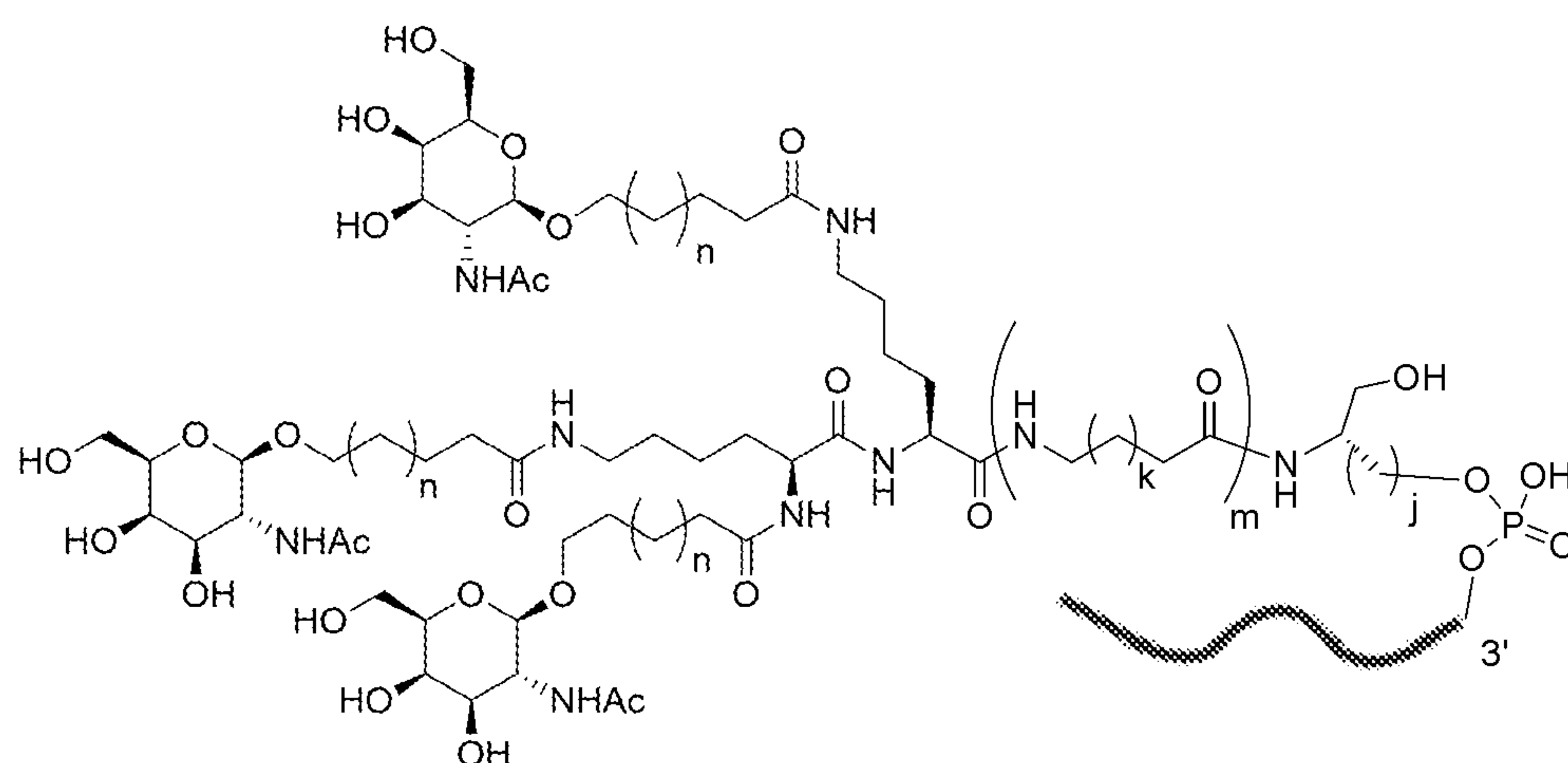
[0092] Exemplary trivalent and tetravalent GalNAc moieties and linkers that can be attached to the double-stranded RNA molecules in the RNAi constructs of the invention are provided in the structural formulas I-IX below. "Ac" in the formulas listed herein represents an acetyl group.

[0093] In one embodiment, the RNAi construct comprises a ligand and linker having the following structure of Formula I, wherein each n is independently 1 to 3, k is 1 to 3, m is 1 or 2, j is 1 or 2, and the ligand is attached to the 3' end of the sense strand of the double-stranded RNA molecule (represented by the solid wavy line):



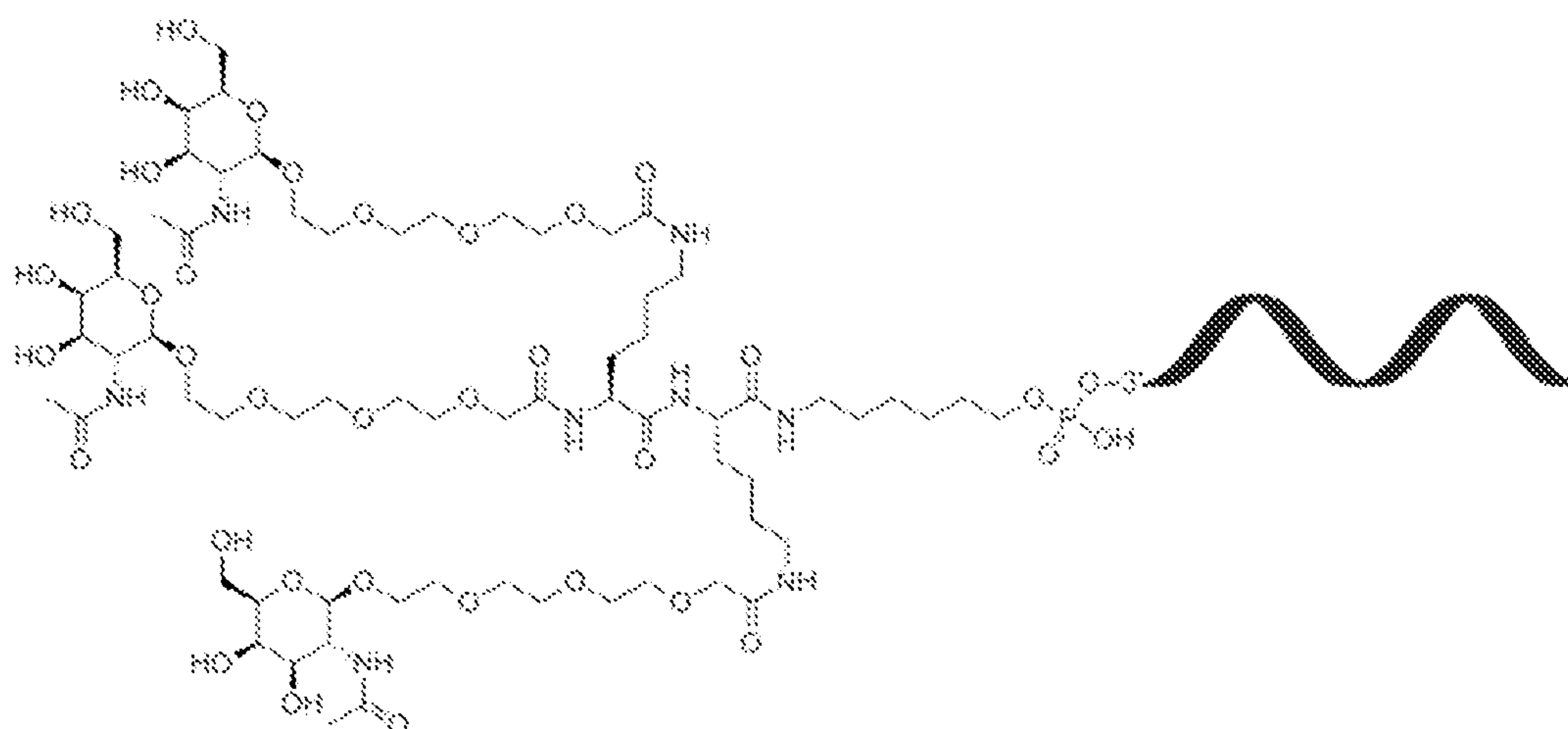
FORMULA I

[0094] In another embodiment, the RNAi construct comprises a ligand and linker having the following structure of Formula II, wherein each n is independently 1 to 3, k is 1 to 3, m is 1 or 2, j is 1 or 2, and the ligand is attached to the 3' end of the sense strand of the double-stranded RNA molecule (represented by the solid wavy line):



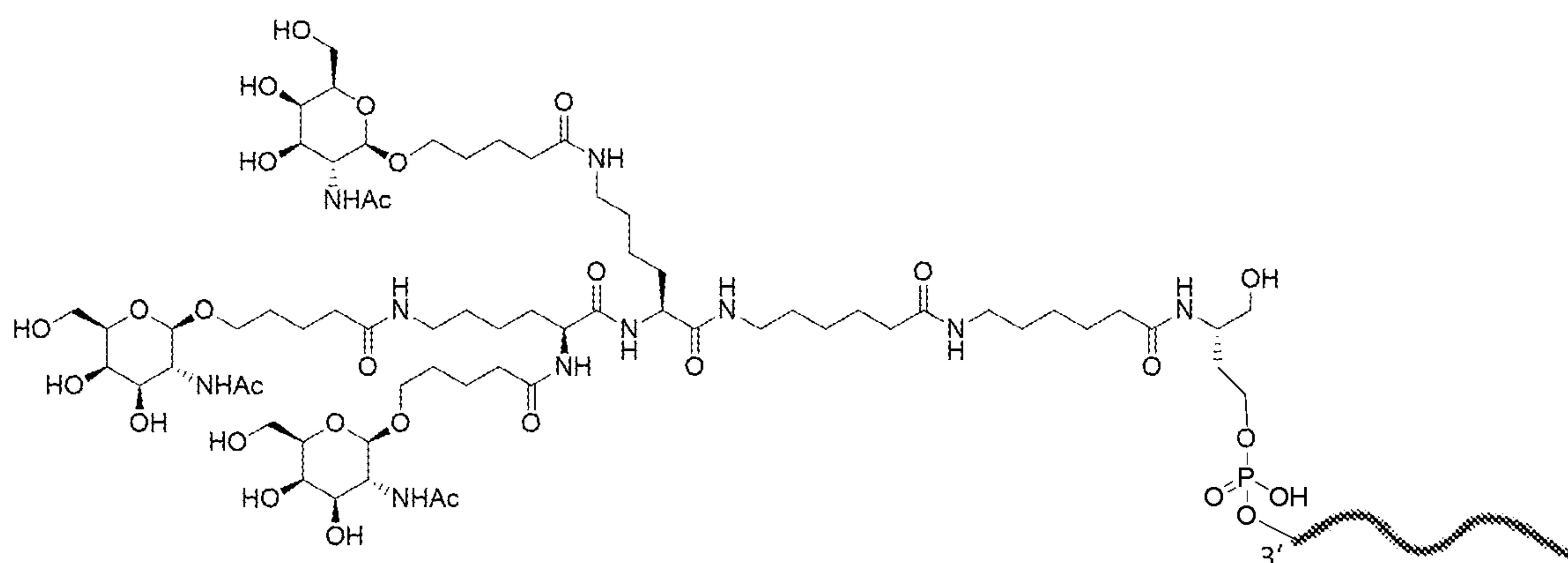
FORMULA II

[0095] In yet another embodiment, the RNAi construct comprises a ligand and linker having the following structure of Formula III, wherein the ligand is attached to the 3' end of the sense strand of the double-stranded RNA molecule (represented by the solid wavy line):



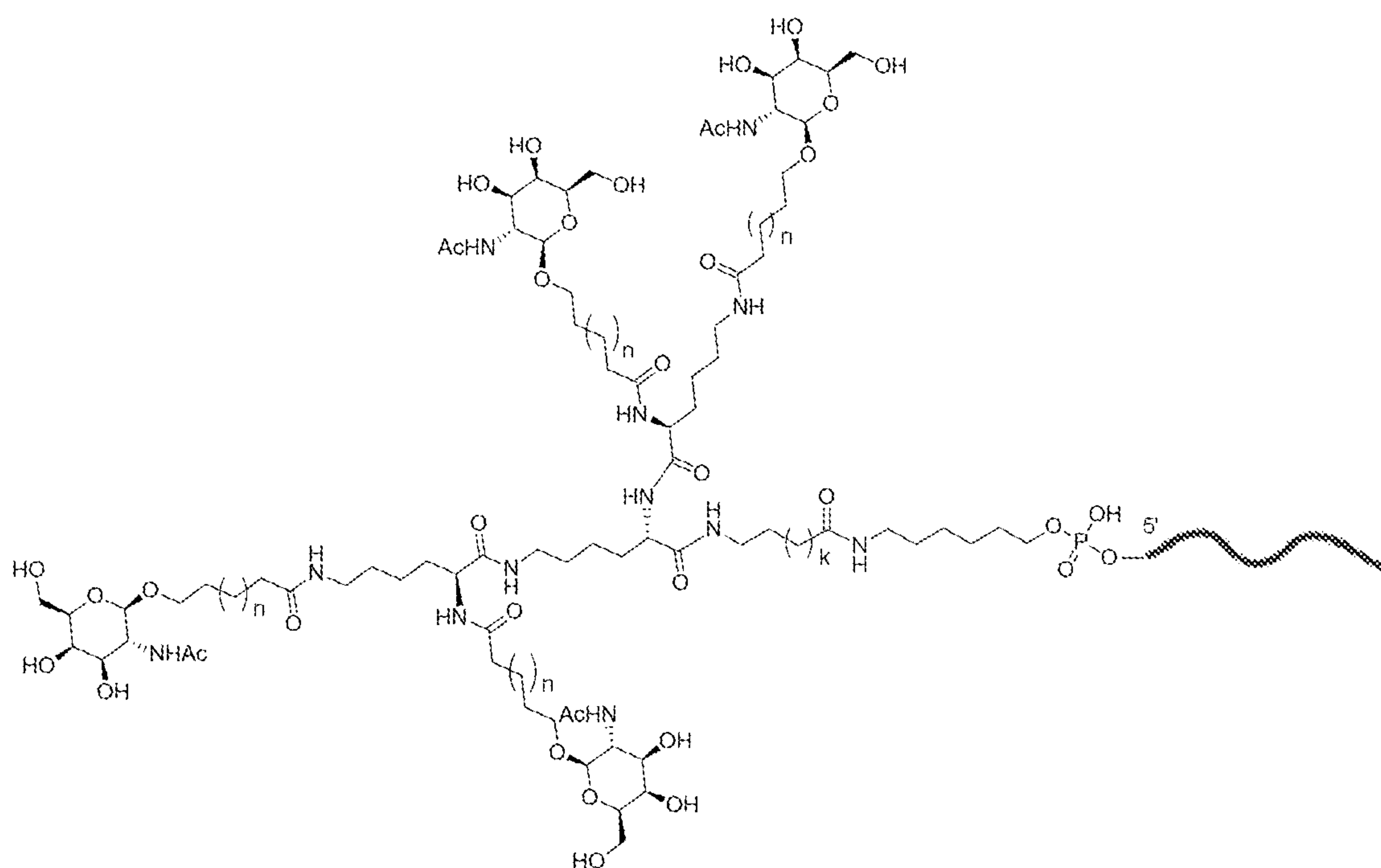
FORMULA III

[0096] In still another embodiment, the RNAi construct comprises a ligand and linker having the following structure of Formula IV, wherein the ligand is attached to the 3' end of the sense strand of the double-stranded RNA molecule (represented by the solid wavy line):



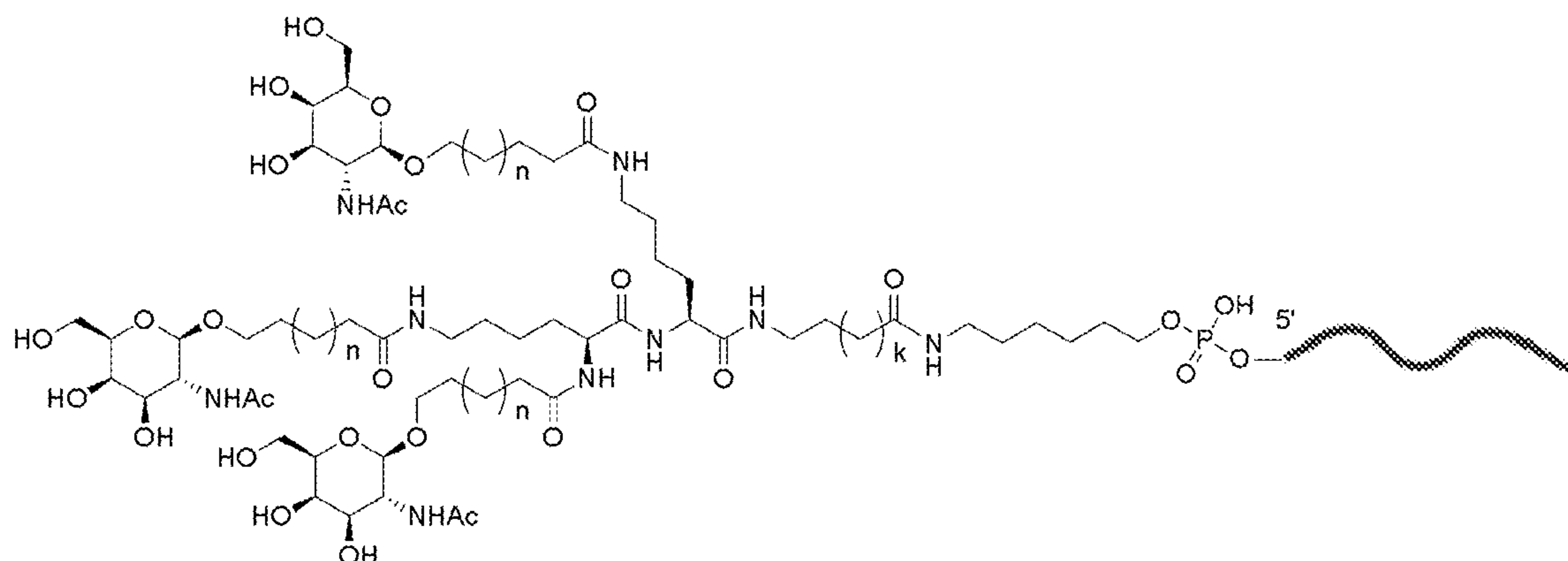
FORMULA IV

[0097] In certain embodiments, the RNAi construct comprises a ligand and linker having the following structure of Formula V, wherein each n is independently 1 to 3, k is 1 to 3, and the ligand is attached to the 5' end of the sense strand of the double-stranded RNA molecule (represented by the solid wavy line):



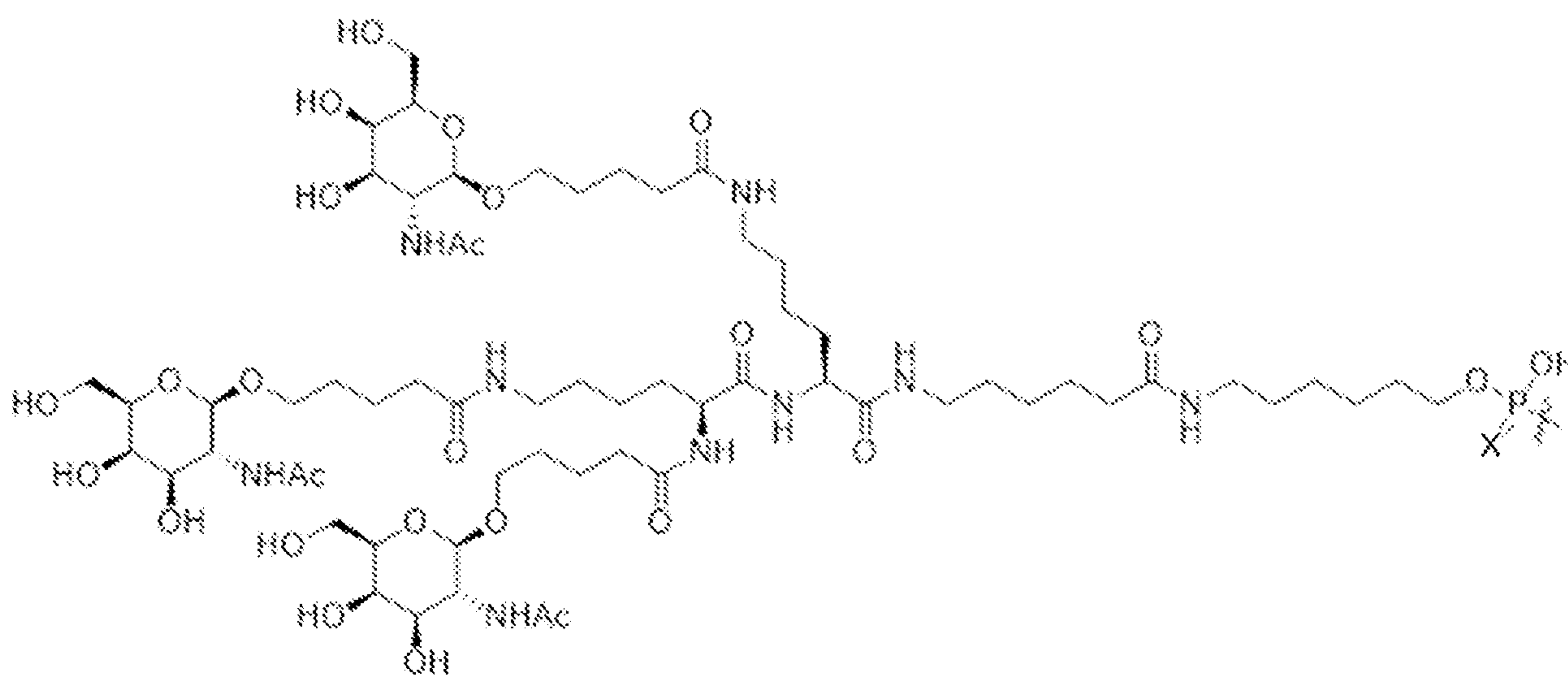
FORMULA V

[0098] In other embodiments, the RNAi construct comprises a ligand and linker having the following structure of Formula VI, wherein each n is independently 1 to 3, k is 1 to 3, and the ligand is attached to the 5' end of the sense strand of the double-stranded RNA molecule (represented by the solid wavy line):



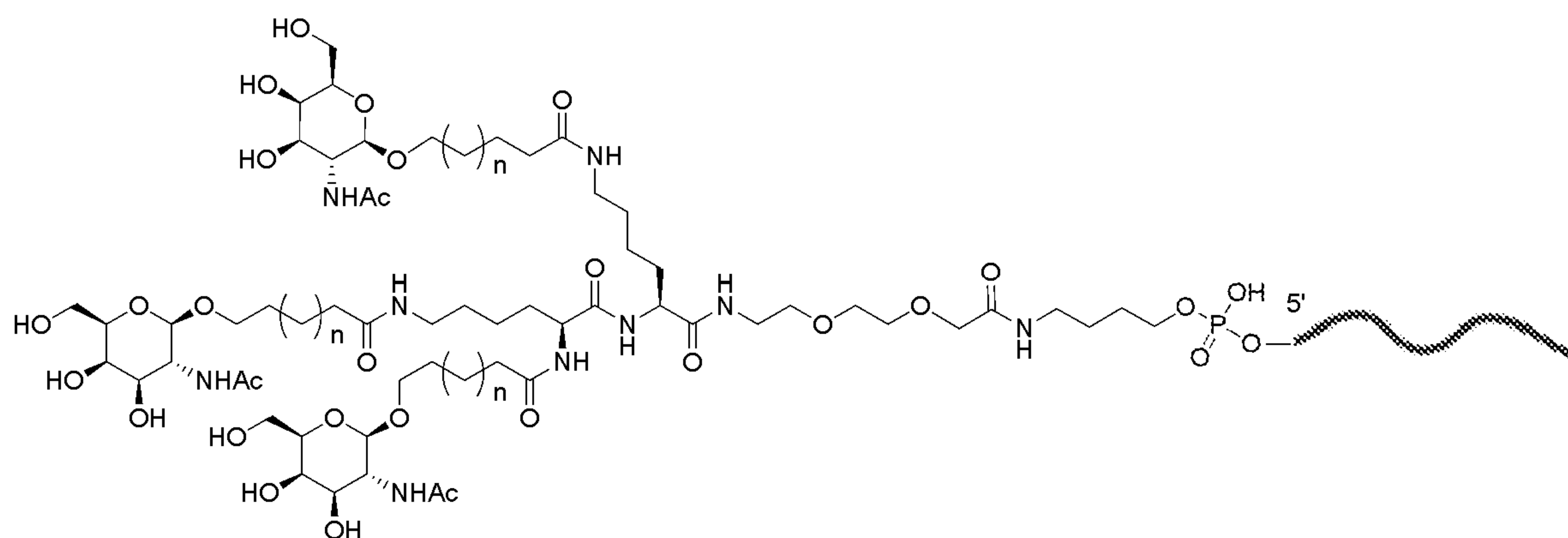
FORMULA VI

[0099] In one particular embodiment, the RNAi construct comprises a ligand and linker having the following structure of Formula VII, wherein $X = O$ or S and wherein the ligand is attached to the 5' end of the sense strand of the double-stranded RNA molecule (represented by the squiggly line):



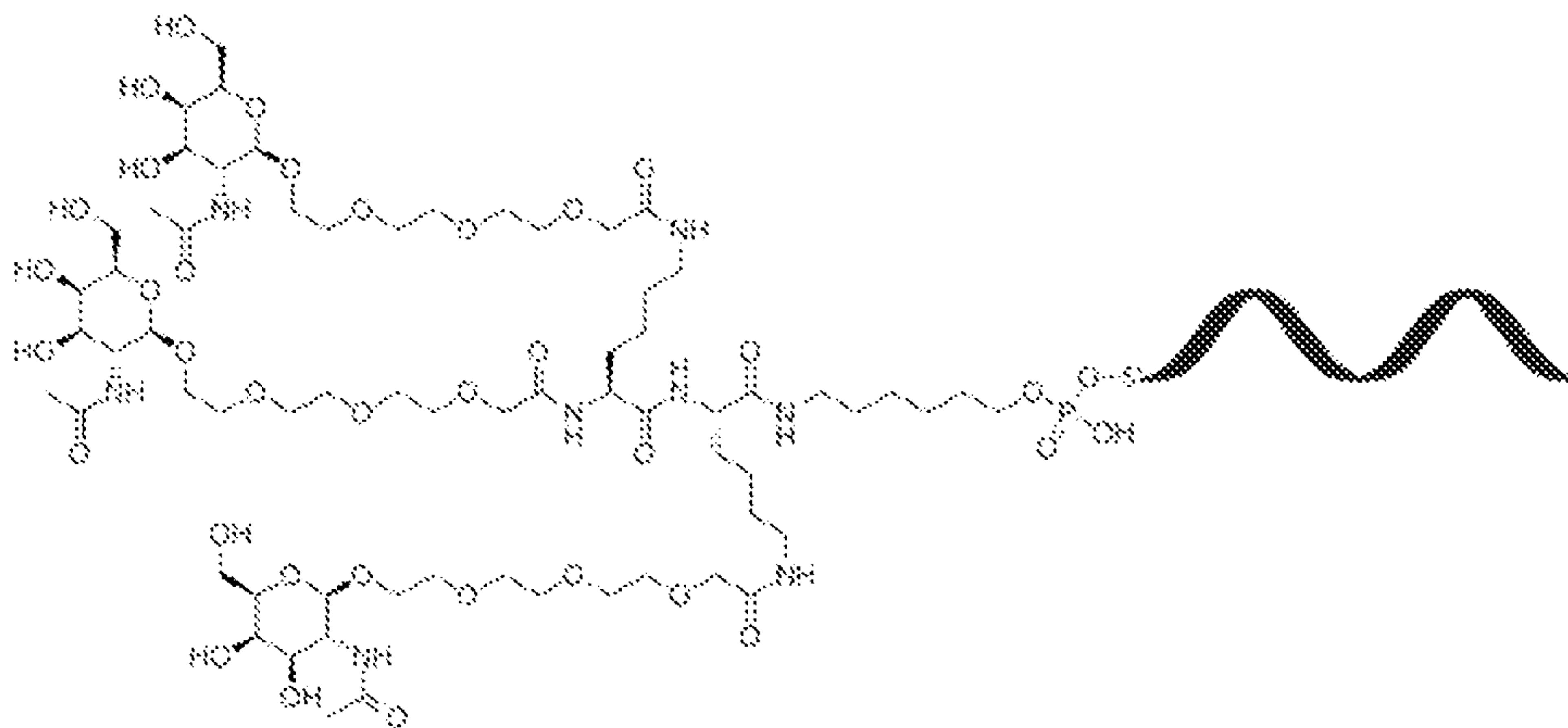
FORMULA VII

[0100] In some embodiments, the RNAi construct comprises a ligand and linker having the following structure of Formula VIII, wherein each n is independently 1 to 3 and the ligand is attached to the 5' end of the sense strand of the double-stranded RNA molecule (represented by the solid wavy line):



FORMULA VIII

[0101] In certain embodiments, the RNAi construct comprises a ligand and linker having the following structure of Formula IX, wherein the ligand is attached to the 5' end of the sense strand of the double-stranded RNA molecule (represented by the solid wavy line):



FORMULA IX

[0102] A phosphorothioate bond can be substituted for the phosphodiester bond shown in any one of Formulas I-IX to covalently attach the ligand and linker to the nucleic acid strand.

[0103] The present invention also includes pharmaceutical compositions and formulations comprising the RNAi constructs described herein and pharmaceutically acceptable carriers, excipients, or diluents. Such compositions and formulations are useful for reducing expression of the *LPA* gene in a patient in need thereof. Where clinical applications are contemplated, pharmaceutical compositions and formulations will be prepared in a form appropriate for the intended application. Generally, this will entail preparing compositions that are essentially free of pyrogens, as well as other impurities that could be harmful to humans or animals.

[0104] The phrases “pharmaceutically acceptable” or “pharmacologically acceptable” refer to molecular entities and compositions that do not produce adverse, allergic, or other untoward

reactions when administered to an animal or a human. As used herein, “pharmaceutically acceptable carrier, excipient, or diluent” includes solvents, buffers, solutions, dispersion media, coatings, antibacterial and antifungal agents, isotonic and absorption delaying agents and the like acceptable for use in formulating pharmaceuticals, such as pharmaceuticals suitable for administration to humans. The use of such media and agents for pharmaceutically active substances is well known in the art. Except insofar as any conventional media or agent is incompatible with the RNAi constructs of the present invention, its use in therapeutic compositions is contemplated. Supplementary active ingredients also can be incorporated into the compositions, provided they do not inactivate the RNAi constructs of the compositions.

[0105] Compositions and methods for the formulation of pharmaceutical compositions depend on a number of criteria, including, but not limited to, route of administration, type and extent of disease or disorder to be treated, or dose to be administered. In some embodiments, the pharmaceutical compositions are formulated based on the intended route of delivery. For instance, in certain embodiments, the pharmaceutical compositions are formulated for parenteral delivery. Parenteral forms of delivery include intravenous, intraarterial, subcutaneous, intrathecal, intraperitoneal or intramuscular injection or infusion. In one embodiment, the pharmaceutical composition is formulated for intravenous delivery. In such an embodiment, the pharmaceutical composition may include a lipid-based delivery vehicle. In another embodiment, the pharmaceutical composition is formulated for subcutaneous delivery. In such an embodiment, the pharmaceutical composition may include a targeting ligand (e.g. GalNAc-containing or antibody-containing ligands described herein).

[0106] In some embodiments, the pharmaceutical compositions comprise an effective amount of an RNAi construct described herein. An “effective amount” is an amount sufficient to produce a beneficial or desired clinical result. In some embodiments, an effective amount is an amount sufficient to reduce *LPA* gene expression in a particular tissue or cell-type (e.g. liver or hepatocytes) of a patient. An effective amount of an RNAi construct of the invention may be from about 0.01 mg/kg body weight to about 100 mg/kg body weight, and may be administered daily, weekly, monthly, or at longer intervals. The precise determination of what would be considered an effective amount and frequency of administration may be based on several factors, including a patient’s size, age, and general condition, type of disorder to be treated (e.g.

myocardial infarction, coronary artery disease, peripheral artery disease, stroke), particular RNAi construct employed, and route of administration.

[0107] Administration of the pharmaceutical compositions of the present invention may be via any common route so long as the target tissue is available via that route. Such routes include, but are not limited to, parenteral (e.g., subcutaneous, intramuscular, intraperitoneal or intravenous), oral, nasal, buccal, intradermal, transdermal, and sublingual routes, or by direct injection into liver tissue or delivery through the hepatic portal vein. In some embodiments, the pharmaceutical composition is administered parenterally. For instance, in certain embodiments, the pharmaceutical composition is administered intravenously. In other embodiments, the pharmaceutical composition is administered subcutaneously.

[0108] Colloidal dispersion systems, such as macromolecule complexes, nanocapsules, microspheres, beads, and lipid-based systems, including oil-in-water emulsions, micelles, mixed micelles, and liposomes, may be used as delivery vehicles for the RNAi constructs of the invention. Commercially available fat emulsions that are suitable for delivering the nucleic acids of the invention include Intralipid[®] (Baxter International Inc.), Liposyn[®] (Abbott Pharmaceuticals), Liposyn[®] II (Hospira), Liposyn[®] III (Hospira), Nutrilipid (B. Braun Medical Inc.), and other similar lipid emulsions. A preferred colloidal system for use as a delivery vehicle *in vivo* is a liposome (i.e., an artificial membrane vesicle). The RNAi constructs of the invention may be encapsulated within liposomes or may form complexes thereto, in particular to cationic liposomes. Alternatively, RNAi constructs of the invention may be complexed to lipids, in particular to cationic lipids. Suitable lipids and liposomes include neutral (e.g., dioleoylphosphatidyl ethanolamine (DOPE), dimyristoylphosphatidyl choline (DMPC), and dipalmitoyl phosphatidylcholine (DPPC)), distearoylphosphatidyl choline), negative (e.g., dimyristoylphosphatidyl glycerol (DMPG)), and cationic (e.g., dioleoyltetramethylaminopropyl (DOTAP) and dioleoylphosphatidyl ethanolamine (DOTMA)). The preparation and use of such colloidal dispersion systems are well known in the art. Exemplary formulations are also disclosed in U.S. Pat. No. 5,981,505; U.S. Pat. No. 6,217,900; U.S. Pat. No. 6,383,512; U.S. Pat. No. 5,783,565; U.S. Pat. No. 7,202,227; U.S. Pat. No. 6,379,965; U.S. Pat. No. 6,127,170; U.S. Pat. No. 5,837,533; U.S. Pat. No. 6,747,014; and WO03/093449.

[0109] In some embodiments, the RNAi constructs of the invention are fully encapsulated in a lipid formulation, e.g., to form a SNALP or other nucleic acid-lipid particle. As used herein, the

term “SNALP” refers to a stable nucleic acid-lipid particle. SNALPs typically contain a cationic lipid, a non-cationic lipid, and a lipid that prevents aggregation of the particle (e.g., a PEG-lipid conjugate). SNALPs are exceptionally useful for systemic applications, as they exhibit extended circulation lifetimes following intravenous injection and accumulate at distal sites (e.g., sites physically separated from the administration site). The nucleic acid-lipid particles typically have a mean diameter of about 50 nm to about 150 nm, about 60 nm to about 130 nm, about 70 nm to about 110 nm, or about 70 nm to about 90 nm, and are substantially nontoxic. In addition, the nucleic acids when present in the nucleic acid-lipid particles 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; and PCT Publication No. WO 96/40964.

[0110] The pharmaceutical compositions suitable for injectable use include, for example, sterile aqueous solutions or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersions. Generally, these preparations are sterile and fluid to the extent that easy injectability exists. Preparations should be stable under the conditions of manufacture and storage and should be preserved against the contaminating action of microorganisms, such as bacteria and fungi. Appropriate solvents or dispersion media may contain, for example, water, ethanol, polyol (for example, glycerol, propylene glycol, and liquid polyethylene glycol, and the like), suitable mixtures thereof, and vegetable oils. The proper fluidity can be maintained, for example, by the use of a coating, such as lecithin, by the maintenance of the required particle size in the case of dispersion and by the use of surfactants. The prevention of the action of microorganisms can be brought about by various antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, sorbic acid, thimerosal, and the like. In many cases, it will be preferable to include isotonic agents, for example, sugars or sodium chloride. Prolonged absorption of the injectable compositions can be brought about by the use in the compositions of agents delaying absorption, for example, aluminum monostearate and gelatin.

[0111] Sterile injectable solutions may be prepared by incorporating the active compounds in an appropriate amount into a solvent along with any other ingredients (for example as enumerated above) as desired, followed by filtered sterilization. Generally, dispersions are prepared by incorporating the various sterilized active ingredients into a sterile vehicle which contains the

basic dispersion medium and the desired other ingredients, e.g., as enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, the preferred methods of preparation include vacuum-drying and freeze-drying techniques which yield a powder of the active ingredient(s) plus any additional desired ingredient from a previously sterile-filtered solution thereof.

[0112] The compositions of the present invention generally may be formulated in a neutral or salt form. Pharmaceutically-acceptable salts include, for example, acid addition salts (formed with free amino groups) derived from inorganic acids (e.g., hydrochloric or phosphoric acids), or from organic acids (e.g., acetic, oxalic, tartaric, mandelic, and the like). Salts formed with the free carboxyl groups can also be derived from inorganic bases (e.g., sodium, potassium, ammonium, calcium, or ferric hydroxides) or from organic bases (e.g., isopropylamine, trimethylamine, histidine, procaine and the like). In some embodiments, the RNAi constructs of the invention are formulated as a sodium salt.

[0113] For parenteral administration in an aqueous solution, for example, the solution generally is suitably buffered and the liquid diluent first rendered isotonic for example with sufficient saline or glucose. Such aqueous solutions may be used, for example, for intravenous, intramuscular, subcutaneous and intraperitoneal administration. Preferably, sterile aqueous media are employed as is known to those of skill in the art, particularly in light of the present disclosure. By way of illustration, a single dose may be dissolved in 1 ml of isotonic NaCl solution and either added to 1000 ml of hypodermoclysis fluid or injected at the proposed site of infusion, (see for example, "Remington's Pharmaceutical Sciences" 15th Edition, pages 1035-1038 and 1570-1580). For human administration, preparations should meet sterility, pyrogenicity, general safety and purity standards as required by FDA standards. In certain embodiments, a pharmaceutical composition of the invention comprises or consists of a sterile saline solution and an RNAi construct described herein. In other embodiments, a pharmaceutical composition of the invention comprises or consists of an RNAi construct described herein and sterile water (e.g. water for injection, WFI). In still other embodiments, a pharmaceutical composition of the invention comprises or consists of an RNAi construct described herein and phosphate-buffered saline (PBS).

[0114] In some embodiments, the pharmaceutical compositions of the invention are packaged with or stored within a device for administration. Devices for injectable formulations include, but

are not limited to, injection ports, pre-filled syringes, autoinjectors, injection pumps, on-body injectors, and injection pens. Devices for aerosolized or powder formulations include, but are not limited to, inhalers, insufflators, aspirators, and the like. Thus, the present invention includes administration devices comprising a pharmaceutical composition of the invention for treating or preventing one or more of the diseases or disorders described herein.

[0115] The present invention provides a method for reducing or inhibiting expression of the *LPA* gene, and thus the production of apo(a) protein, in a cell (e.g. liver cell) by contacting the cell with any one of the RNAi constructs described herein. The cell may be *in vitro* or *in vivo*. *LPA* gene expression can be assessed by measuring the amount or level of *LPA* mRNA, apo(a) protein, or another biomarker linked to *LPA* expression, such as serum levels of Lp(a). The reduction of *LPA* expression in cells or animals treated with an RNAi construct of the invention can be determined relative to the *LPA* expression in cells or animals not treated with the RNAi construct or treated with a control RNAi construct. For instance, in some embodiments, reduction of *LPA* expression is assessed by (a) measuring the amount or level of *LPA* mRNA in liver cells treated with a RNAi construct of the invention, (b) measuring the amount or level of *LPA* mRNA in liver cells treated with a control RNAi construct (e.g. RNAi construct directed to an RNA molecule not expressed in liver cells or a RNAi construct having a nonsense or scrambled sequence) or no construct, and (c) comparing the measured *LPA* mRNA levels from treated cells in (a) to the measured *LPA* mRNA levels from control cells in (b). The *LPA* mRNA levels in the treated cells and controls cells can be normalized to RNA levels for a control gene (e.g. 18S ribosomal RNA or housekeeping gene) prior to comparison. *LPA* mRNA levels can be measured by a variety of methods, including Northern blot analysis, nuclease protection assays, fluorescence *in situ* hybridization (FISH), reverse-transcriptase (RT)-PCR, real-time RT-PCR, quantitative PCR, droplet digital PCR, and the like.

[0116] In other embodiments, reduction of *LPA* expression is assessed by (a) measuring the amount or level of apo(a) protein in liver cells treated with a RNAi construct of the invention, (b) measuring the amount or level of apo(a) protein in liver cells treated with a control RNAi construct (e.g. RNAi construct directed to a RNA molecule not expressed in liver cells or a RNAi construct having a nonsense or scrambled sequence) or no construct, and (c) comparing the measured apo(a) protein levels from treated cells in (a) to the measured apo(a) protein levels from control cells in (b). Methods of measuring apo(a) protein levels are known to those of skill

in the art, and include Western Blots, immunoassays (e.g. ELISA), and flow cytometry. Any method capable of measuring *LPA* mRNA or apo(a) protein can be used to assess the efficacy of the RNAi constructs of the invention.

[0117] In some embodiments, the methods to assess *LPA* expression levels are performed *in vitro* in cells that natively express the *LPA* gene (e.g. liver cells) or cells that have been engineered to express the *LPA* gene. In certain embodiments, the methods are performed *in vitro* in liver cells. Suitable liver cells include, but are not limited to, primary hepatocytes (e.g. human or non-human primate hepatocytes), HepAD38 cells, HuH-6 cells, HuH-7 cells, HuH-5-2 cells, BNLCL2 cells, Hep3B cells, or HepG2 cells. In one embodiment, the liver cells are HuH-7 cells. In another embodiment, the liver cells are human primary hepatocytes.

[0118] In other embodiments, the methods to assess *LPA* expression levels are performed *in vivo*. The RNAi constructs and any control RNAi constructs can be administered to an animal (e.g. transgenic animal expressing an *LPA* gene or non-human primate) and *LPA* mRNA or apo(a) protein levels assessed in liver tissue harvested from the animal following treatment. Alternatively or additionally, a biomarker or functional phenotype associated with *LPA* expression can be assessed in the treated animals. For instance, apo(a) protein is a primary component of Lp(a) present in the serum or plasma. Thus, serum or plasma levels of Lp(a) can be measured in animals treated with RNAi constructs of the invention to assess the functional efficacy of reducing *LPA* expression. Exemplary methods for measuring serum or plasma Lp(a) levels are described in Examples 3 and 4.

[0119] In certain embodiments, expression of *LPA* is reduced in liver cells by at least 40%, at least 45%, or at least 50% by an RNAi construct of the invention. In some embodiments, expression of *LPA* is reduced in liver cells by at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, or at least 85% by an RNAi construct of the invention. In other embodiments, the expression of *LPA* is reduced in liver cells by about 90% or more, e.g., 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or more by an RNAi construct of the invention. The percent reduction of *LPA* expression can be measured by any of the methods described herein as well as others known in the art.

[0120] The present invention provides methods for reducing or inhibiting expression of the *LPA* gene, and thus the production of apo(a) protein, in a patient in need thereof as well as methods of treating or preventing conditions, diseases, or disorders associated with *LPA* expression or apo(a)

activity. A “condition, disease, or disorder associated with *LPA* expression” refers to conditions, diseases, or disorders in which *LPA* expression levels are altered or where elevated expression levels of *LPA* are associated with an increased risk of developing the condition, disease or disorder. A condition, disease, or disorder associated with *LPA* expression can also include conditions, diseases, or disorders resulting from aberrant changes in lipoprotein metabolism, such as changes resulting in abnormal or elevated levels of Lp(a), cholesterol, lipids, triglycerides, etc. or impaired clearance of these molecules. Apo(a) protein is a primary component of Lp(a) and elevated levels of Lp(a) have been associated with increased risk of cardiovascular disease (*see, e.g.*, Nordestgaard *et al.*, Eur. Heart J., Vol. 31: 2844–2853, 2010; Kronenberg and Utermann, J. Intern. Med., Vol. 273:6-30, 2013; Nordestgaard *et al.*, J. Lipid Res., Vol. 57:1953-1975, 2016; and Tsimikas, J. Am. Coll. Cardiol., Vol. 69:692–711, 2017). Thus, in certain embodiments, the RNAi constructs of the invention are particularly useful for treating or preventing cardiovascular disease (e.g. coronary artery disease and myocardial infarction) and reducing circulating levels of Lp(a).

[0121] Conditions, diseases, and disorders associated with *LPA* expression that can be treated or prevented according to the methods of the invention include, but are not limited to, cardiovascular disease, such as myocardial infarction, heart failure, stroke (ischemic and hemorrhagic), atherosclerosis, coronary artery disease, peripheral vascular disease (e.g. peripheral artery disease), cerebrovascular disease, vulnerable plaque, and aortic valve stenosis; familial hypercholesterolemia; venous thrombosis; hypercholesterolemia; hyperlipidemia; and dyslipidemia.

[0122] In certain embodiments, the present invention provides a method for reducing the expression of *LPA* in a patient in need thereof comprising administering to the patient any of the RNAi constructs described herein. The term “patient,” as used herein, refers to a mammal, including humans, and can be used interchangeably with the term “subject.” Preferably, the expression level of *LPA* in hepatocytes in the patient is reduced following administration of the RNAi construct as compared to the *LPA* expression level in a patient not receiving the RNAi construct or as compared to the *LPA* expression level in the patient prior to administration of the RNAi construct. In some embodiments, following administration of an RNAi construct of the invention, expression of *LPA* is reduced in the patient by 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%, or at least 90%, e.g., 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99%. The percent reduction of *LPA* expression can be measured by any of the methods described herein as well as others known in the art. In certain embodiments, the percent reduction of *LPA* expression is determined by assessing Lp(a) levels in the serum or plasma of the patient according to methods described herein.

[0123] In some embodiments, a patient in need of reduction of *LPA* expression is a patient who is at risk of having a myocardial infarction. A patient who is at risk of having a myocardial infarction may be a patient who has a history of myocardial infarction (e.g. has had a previous myocardial infarction). A patient at risk of having a myocardial infarction may also be a patient who has a familial history of myocardial infarction or who has one or more risk factors of myocardial infarction. Such risk factors include, but are not limited to, hypertension, elevated levels of non-HDL cholesterol, elevated levels of triglycerides, diabetes, obesity, or history of autoimmune diseases (e.g. rheumatoid arthritis, lupus). In one embodiment, a patient who is at risk of having a myocardial infarction is a patient who has or is diagnosed with coronary artery disease. The risk of myocardial infarction in these and other patients can be reduced by administering to the patients any of the RNAi constructs described herein. Accordingly, the present invention provides a method for reducing the risk of myocardial infarction in a patient in need thereof comprising administering to the patient an RNAi construct described herein. In some embodiments, the present invention includes use of any of the RNAi constructs described herein in the preparation of a medicament for reducing the risk of myocardial infarction in a patient in need thereof. In other embodiments, the present invention provides an *LPA*-targeting RNAi construct for use in a method for reducing the risk of myocardial infarction in a patient in need thereof.

[0124] In certain embodiments, a patient in need of reduction of *LPA* expression is a patient who is diagnosed with or at risk of cardiovascular disease. Thus, the present invention includes a method for treating or preventing cardiovascular disease in a patient in need thereof by administering any of the RNAi constructs of the invention. In some embodiments, the present invention includes use of any of the RNAi constructs described herein in the preparation of a medicament for treating or preventing cardiovascular disease in a patient in need thereof. In other embodiments, the present invention provides an *LPA*-targeting RNAi construct for use in a method for treating or preventing cardiovascular disease in a patient in need thereof.

Cardiovascular disease includes, but is not limited to, myocardial infarction, heart failure, stroke (ischemic and hemorrhagic), atherosclerosis, coronary artery disease, peripheral vascular disease (e.g. peripheral artery disease), cerebrovascular disease, vulnerable plaque, and aortic valve stenosis. In some embodiments, the cardiovascular disease to be treated or prevented according to the methods of the invention is coronary artery disease. In other embodiments, the cardiovascular disease to be treated or prevented according to the methods of the invention is myocardial infarction. In yet other embodiments, the cardiovascular disease to be treated or prevented according to the methods of the invention is stroke. In still other embodiments, the cardiovascular disease to be treated or prevented according to the methods of the invention is peripheral artery disease. In certain embodiments, administration of the RNAi constructs described herein reduces the risk of non-fatal myocardial infarctions, fatal and non-fatal strokes, certain types of heart surgery (e.g. angioplasty, bypass), hospitalization for heart failure, chest pain in patients with heart disease, and/or cardiovascular events in patients with established heart disease (e.g. prior myocardial infarction, prior heart surgery, and/or chest pain with evidence of blocked arteries). In some embodiments, administration of the RNAi constructs described herein according to the methods of the invention can be used to reduce the risk of recurrent cardiovascular events.

[0125] In certain other embodiments, a patient in need of reduction of *LPA* expression is a patient who has elevated levels of circulating Lp(a). Accordingly, in some embodiments, the present invention provides a method for reducing Lp(a) serum or plasma levels in a patient in need thereof by administering to the patient any of the RNAi constructs described herein. In some embodiments, the present invention includes use of any of the RNAi constructs described herein in the preparation of a medicament for reducing Lp(a) serum or plasma levels in a patient in need thereof. In other embodiments, the present invention provides an LPA-targeting RNAi construct for use in a method for reducing Lp(a) serum or plasma levels in a patient in need thereof. As described above, elevated levels of circulating Lp(a) are associated with an increased risk of cardiovascular disease. In some embodiments, Lp(a) levels in serum or plasma are reduced in the patient following administration of the RNAi construct as compared to the Lp(a) levels in serum or plasma in the patient prior to administration of the RNAi construct or as compared to the Lp(a) levels in serum or plasma in a patient not receiving the RNAi construct. In certain embodiments, following administration of an RNAi construct of the invention, Lp(a)

levels in serum or plasma are reduced in the patient to about 150 nmol/L or less, about 125 nmol/L or less, about 100 nmol/L or less, about 75 nmol/L or less, about 70 nmol/L or less, about 65 nmol/L or less, about 60 nmol/L or less, about 55 nmol/L or less, about 50 nmol/L, about 45 nmol/L or less, about 40 nmol/L or less, about 35 nmol/L or less, or about 30 nmol/L or less. Although there is a preference to measure Lp(a) levels in units of particle concentration (e.g. nmol/L)(*see, e.g.,* Wilson *et al.*, Journal of Clinical Lipidology, Vol. 13: 374-392, 2019), Lp(a) levels may be measured in units of mass concentration (e.g. mg/dL). In such embodiments, an RNAi construct of the invention may reduce Lp(a) levels in serum or plasma in the patient to about 100 mg/dL or less, about 90 mg/dL or less, about 80 mg/dL or less, about 70 mg/dL or less, about 60 mg/dL or less, about 50 mg/dL or less, about 45 mg/dL or less, about 40 mg/dL or less, about 35 mg/dL or less, about 30 mg/dL or less, about 25 mg/dL or less, about 20 mg/dL or less, or about 15 mg/dL or less following administration. Lp(a) levels can be measured in plasma or serum samples using commercially available kits, such as the Lp(a) ELISA assay kit from Mercodia AB (Uppsala, Sweden), the Lp(a) immunoturbidimetric assay from Randox Laboratories Ltd. (Crumlin, United Kingdom), or the Tina-quant[®] Lp(a) assay from F. Hoffmann- La Roche Ltd. (Basel, Switzerland), or using other methods known in the art, such as those described Marcovina and Albers, J. Lipid Res., Vol. 57:526-537, 2016.

[0126] In some embodiments, a patient to be treated according to the methods of the invention is a patient who has elevated circulating levels of Lp(a) (e.g. elevated serum or plasma levels of Lp(a)). A patient to be treated according to the methods of the invention may have circulating Lp(a) levels of about 50 nmol/L or greater, about 55 nmol/L or greater, about 60 nmol/L or greater, about 65 nmol/L or greater, about 70 nmol/L or greater, about 75 nmol/L or greater, about 100 nmol/L or greater, about 125 nmol/L or greater, about 150 nmol/L or greater, about 175 nmol/L or greater, or about 200 nmol/L or greater. In certain embodiments, a patient is administered an RNAi construct of the invention if the patient has a serum or plasma Lp(a) level of about 100 nmol/L or greater. In one embodiment, a patient is administered an RNAi construct of the invention if the patient has a serum or plasma Lp(a) level of about 125 nmol/L or greater. In another embodiment, a patient is administered an RNAi construct of the invention if the patient has a serum or plasma Lp(a) level of about 150 nmol/L or greater. In embodiments in which circulating Lp(a) levels are measured in mass concentration units, a patient to be treated according to the methods of the invention may have circulating Lp(a) levels of about 30 mg/dL

or greater, about 35 mg/dL or greater, about 40 mg/dL or greater, about 45 mg/dL or greater, about 50 mg/dL or greater, about 55 mg/dL or greater, about 60 mg/dL or greater, about 65 mg/dL or greater, about 70 mg/dL or greater, about 75 mg/dL or greater, or about 100 mg/dL or greater. In one embodiment, a patient is administered an RNAi construct of the invention if the patient has a serum or plasma Lp(a) level of about 50 mg/dL or greater. In another embodiment, a patient is administered an RNAi construct of the invention if the patient has a serum or plasma Lp(a) level of about 70 mg/dL or greater.

[0127] In certain embodiments, a patient to be treated according to the methods of the invention is a patient who has a vulnerable plaque (also referred to as unstable plaque). Vulnerable plaques are a build-up of macrophages and lipids containing predominantly cholesterol that lie underneath the endothelial lining of the arterial wall. These vulnerable plaques can rupture resulting in the formation of a blood clot, which can potentially block blood flow through the artery and cause a myocardial infarction or stroke. Vulnerable plaques can be identified by methods known in the art, including, but not limited to, intravascular ultrasound and computed tomography (Sahara *et al.*, European Heart Journal, Vol. 25: 2026-2033, 2004; Budhoff, J. Am. Coll. Cardiol., Vol. 48: 319-321, 2006; Hausleiter *et al.*, J. Am. Coll. Cardiol., Vol. 48: 312-318, 2006).

[0128] The following examples, including the experiments conducted and the results achieved, are provided for illustrative purposes only and are not to be construed as limiting the scope of the appended claims.

EXAMPLES

Example 1. Design and Synthesis of LPA RNAi Constructs

[0129] Candidate sequences for the design of therapeutic siRNA molecules targeting the human *LPA* gene were identified using a bioinformatics analysis of the human *LPA* transcript, the sequence of which is provided herein as SEQ ID NO: 1 (NCBI Reference Sequence No. NM_005577.4; see Figure 1). The human *LPA* gene is highly polymorphic with alleles of the gene differing in numbers of repeats of the kringle IV-2 (KIV-2) domain among individuals. KIV-2 domain repeats can range from 2 to 43 copies among individuals. The transcript provided herein as SEQ ID NO: 1 is from an allelic variant containing 15 copies of the KIV-2 domain. Sequences were analyzed using an in-house siRNA design algorithm and selected if certain

criteria were met. Sequences were also evaluated for cross-reactivity with the *LPA* gene from cynomolgus monkeys (NCBI Reference Sequence No. XM_015448520.1), sequence identity to other human gene sequences and seed region matches to human microRNA (miRNA) sequences to predict off-target effects, and for overlap with known single nucleotide polymorphisms. Based on the results of the bioinformatics analysis, 465 sequences were selected, of which 320 sequences were prioritized for initial synthesis and *in vitro* testing.

[0130] RNAi constructs were synthesized using solid phase phosphoramidite chemistry. Synthesis was performed on a MerMade12 or MerMade192X (Bioautomation) instrument. Various chemical modifications, including 2'-fluoro modified nucleotides, 2'-O-methyl modified nucleotides, abasic nucleotides, and phosphorothioate internucleotide linkages, were incorporated into the molecules. The RNAi constructs were generally formatted to be duplexes of 19-21 base pairs when annealed with either no overhangs (double bluntmer) or one or two overhangs of 2 nucleotides at the 3' end of the antisense strand and/or the sense strand. The sense strands of the RNAi constructs were conjugated to a trivalent N-acetyl-galactosamine (GalNAc) moiety as described further below.

Materials

[0131] Acetonitrile (DNA Synthesis Grade, AXO152-2505, EMD)

[0132] Capping Reagent A (80:10:10 (v/v/v) tetrahydrofuran/lutidine/acetic anhydride, BIO221/4000, EMD)

[0133] Capping Reagent B (16% 1-methylimidazole/tetrahydrofuran, BIO345/4000, EMD)

[0134] Activator Solution (0.25 M 5-(ethylthio)-1H-tetrazole (ETT) in acetonitrile, BIO152/0960, EMD)

[0135] Detritylation Reagent (3% dichloroacetic acid in dichloromethane, BIO830/4000, EMD)

[0136] Oxidation Reagent (0.02 M iodine in 70:20:10 (v/v/v) tetrahydrofuran/pyridine/water, BIO420/4000, EMD)

[0137] Diethylamine solution (20% DEA in acetonitrile, NC0017-0505, EMD)

[0138] Thiolation Reagent (0.05 M 5-N-[(dimethylamino)methylene]amino-3H-1,2,4-dithiazole-3-thione (BIOSULII/160K) in 40:60 (v/v) pyridine/acetonitrile)

[0139] 5'-Aminohexyl linker phosphoramidite, phosphorylating phosphoramidite, 2'-deoxythymidine phosphoramidite, and 2'-methoxy and 2'-fluoro phosphoramidites of adenosine,

guanosine, cytosine, and uridine (Thermo Fisher Scientific), 0.10 M in acetonitrile over ~10 mL of molecular sieves (3 Å, J. T. Baker)

[0140] CPG Support (Hi-Load Universal Support, 500A (BH5-3500-G1), 79.6 µmol/g, 0.126 g (10 µmol))

[0141] Ammonium hydroxide (concentrated, J. T. Baker)

Synthesis

[0142] Reagent solutions, phosphoramidite solutions, and solvents were attached to the MerMade12 instrument. Solid support was added to each column (4 mL SPE tube with top and bottom frit), and the columns were affixed to the instrument. The columns were washed twice with acetonitrile. The phosphoramidite and reagent solution lines were purged. The synthesis was initiated using the Poseidon software. The synthesis was accomplished by repetition of the deprotection /coupling/oxidation/capping synthesis cycle. Specifically, to the solid support was added detritylation reagent to remove the 5'-dimethoxytrityl (DMT) protecting group. The solid support was washed with acetonitrile. To the support was added phosphoramidite and activator solution followed by incubation to couple the incoming nucleotide to the free 5'-hydroxyl group. The support was washed with acetonitrile. To the support was added oxidation or thiolation reagent to convert the phosphite triester to the phosphate triester or phosphorothioate. To the support was added capping reagents A and B to terminate any unreacted oligonucleotide chains. The support was washed with acetonitrile. After the final reaction cycle, the resin was washed with diethylamine solution to remove the 2-cyanoethyl protecting groups. The support was washed with acetonitrile and dried under vacuum.

GalNAc conjugation

[0143] Sense strands for conjugation to a trivalent GalNAc moiety (structure shown in Formula VII below) were prepared with a 5'-aminohexyl linker. After automated synthesis, the column was removed from the instrument and transferred to a vacuum manifold in a hood. The 5'-monomethoxytrityl (MMT) protecting group was removed from the solid support by successive treatments with 2 mL aliquots of 1% trifluoroacetic acid (TFA) in dichloromethane (DCM) with vacuum filtration. When the orange/yellow color was no longer observable in the eluent, the resin was washed with dichloromethane. The resin was washed with 5 mL of 2%

diisopropylethylamine in N,N-dimethylformamide (DMF). In a separate vial a solution of GalNAc3-Lys2-Ahx (67 mg, 40 μ mol) in DMF (0.5 mL), the structure and synthesis of which is described below, was prepared with 1,1,3,3-tetramethyluronium tetrafluoroborate (TATU, 12.83 mg, 40 μ mol) and diisopropylethylamine (DIEA)(13.9 μ L, 80 μ mol). The activated coupling solution was added to the resin, and the column was capped and incubated at room temperature overnight. The resin was washed with DMF, DCM, and dried under vacuum.

Cleavage

[0144] The synthesis columns were removed from the synthesizer or vacuum manifold. The solid support from each column was transferred to a 10 mL vial. To the solid support was added 4 mL of concentrated ammonium hydroxide. The cap was tightly affixed to the bottle, and the mixture was heated at 55°C for 4h. The bottle was moved to the freezer and cooled for 20 minutes before opening in the hood. The mixture was filtered through an 8 mL SPE tube to remove the solid support. The vial and solid support were rinsed with 1 mL of 50:50 ethanol/water.

Analysis and Purification

[0145] A portion of the combined filtrate was analyzed and purified by anion exchange chromatography. The pooled fractions were desalted by size exclusion chromatography and analyzed by ion pair-reversed phase high-performance liquid chromatograph-mass spectrometry (HPLC-MS). The pooled fractions were lyophilized to obtain a white amorphous powder.

Analytical anion exchange chromatography (AEX):

[0146] Column: Thermo DNAPac PA200RS (4.6 x 50 mm, 4 μ m)

[0147] Instrument: Agilent 1100 HPLC

[0148] Buffer A: 20 mM sodium phosphate, 10% acetonitrile, pH 8.5

[0149] Buffer B: 20 mM sodium phosphate, 10% acetonitrile, pH 8.5, 1 M sodium bromide

[0150] Flow rate: 1 mL/min at 40°C

[0151] Gradient: 20-65% B in 6.2 min

Preparative anion exchange chromatography (AEX):

[0152] Column: Tosoh TSK Gel SuperQ-5PW, 21 x 150 mm, 13 μ m

[0153] Instrument: Agilent 1200 HPLC

[0154] Buffer A: 20 mM sodium phosphate, 10% acetonitrile, pH 8.5

[0155] Buffer B: 20 mM sodium phosphate, 10% acetonitrile, pH 8.5, 1 M sodium bromide

[0156] Flow rate: 8 mL/min

[0157] Injection volume: 5 mL

[0158] Gradient: 35-55% B over 20 min

Preparative size exclusion chromatography (SEC):

[0159] Column: GE Hi-Prep 26/10

[0160] Instrument: GE AKTA Pure

[0161] Buffer: 20% ethanol in water

[0162] Flow Rate: 10 mL/min

[0163] Injection volume: 15 mL using sample loading pump

Ion Pair-Reversed Phase (IP-RP) HPLC:

[0164] Column: Water Xbridge BEH OST C18, 2.5 μ m, 2.1 x 50 mm

[0165] Instrument: Agilent 1100 HPLC

[0166] Buffer A: 15.7 mM DIEA, 50 mM hexafluoroisopropanol (HFIP) in water

[0167] Buffer B: 15.7 mM DIEA, 50 mM HFIP in 50:50 water/acetonitrile

[0168] Flow rate: 0.5 mL/min

[0169] Gradient: 10-30% B over 6 min

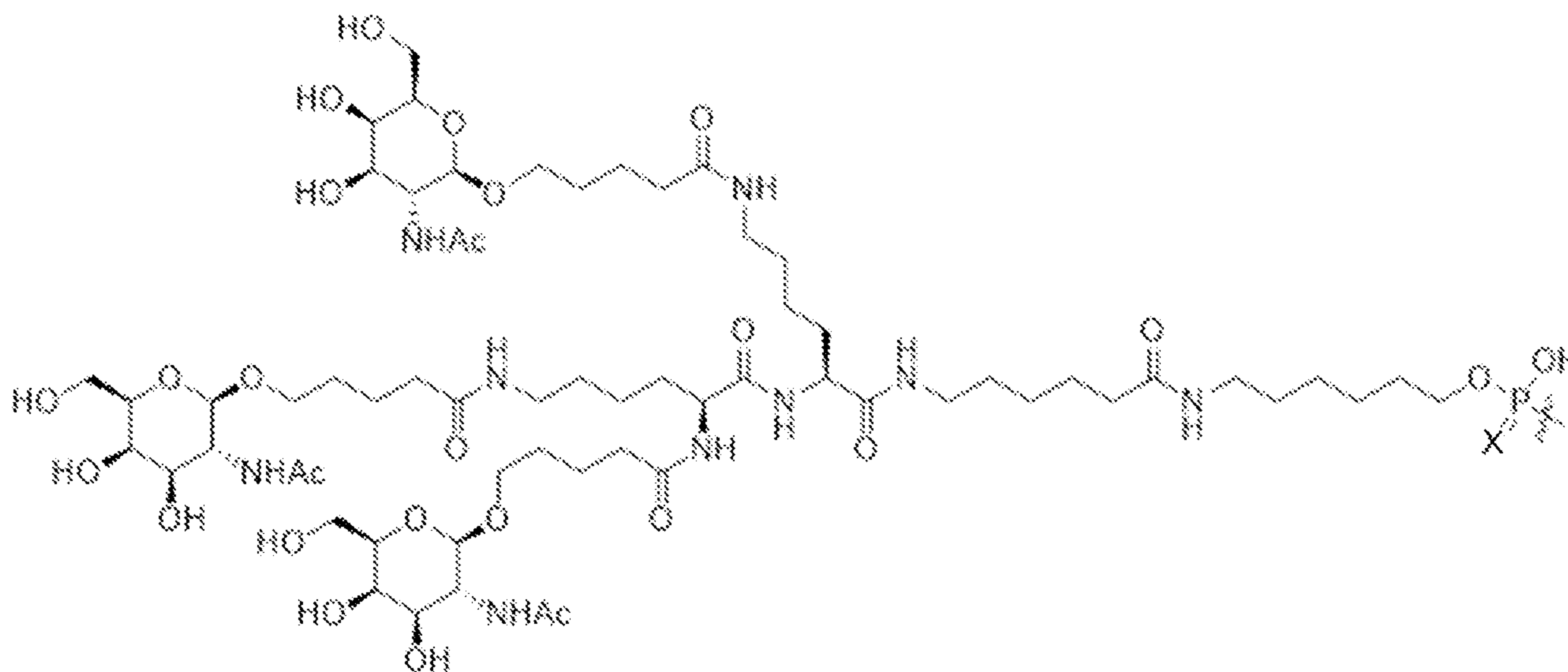
Annealing

[0170] A small amount of the sense strand and the antisense strand were weighed into individual vials. To the vials was added siRNA reconstitution buffer (Qiagen) or phosphate buffered saline (PBS) to an approximate concentration of 2 mM based on the dry weight. The actual sample concentration was measured on the NanoDrop One (ssDNA, extinction coefficient = 33 μ g/OD₂₆₀). The two strands were then mixed in an equimolar ratio, and the sample was heated for 5 minutes in a 90°C incubator and allowed to cool slowly to room temperature. The sample

was analyzed by AEX. The duplex was registered and submitted for *in vitro* and *in vivo* testing as described in more detail below.

Preparation of GalNAc3-Lys2-Ahx

Formula VII



wherein X = O or S. The squiggly line represents the point of attachment to the 5' terminal nucleotide of the sense strand of the RNAi construct.

[0171] To a 50 mL falcon tube was added Fmoc-Ahx-OH (1.13 g, 3.19 mmol) in DCM (30 mL) followed by DIEA (2.23 mL, 12.78 mmol). The solution was added to 2-Cl Trityl chloride resin (3.03 g, 4.79 mmol) in a 50 mL centrifuge tube and loaded onto a shaker for 2 h. The solvent was drained and the resin was washed with 17:2:1 DCM/MeOH/DIEA (30 ml x2), DCM (30 mL x4) and dried. The loading was determined to be 0.76 mmol/g with UV spectrophotometric detection at 290 nm.

[0172] 3 g of the loaded 2-Cl Trityl resin was suspended in 20% 4-methylpiperidine in DMF (20 mL), and after 30 min the solvent was drained. The process was repeated one more time, and the resin was washed with DMF (30 mL x3) and DCM (30 mL x3).

[0173] To a solution of Fmoc-Lys(ivDde)-OH (3.45 g, 6 mmol) in DMF (20 mL) was added TATU (1.94 g, 6 mmol) followed by DIEA (1.83 mL, 10.5 mmol). The solution was then added to the above deprotected resin, and the suspension was set on a shaker overnight. The solvent was drained and the resin was washed with DMF (30 mL x3) and DCM (30 mL x3).

[0174] The resin was treated with 20% 4-methylpiperidine in DMF (15 mL) and after 10 min the solvent was drained. The process was repeated one more time and the resin was washed with DMF (15 mL x4) and DCM (15 mL x4).

[0175] To a solution of Fmoc-Lys(Fmoc)-OH (3.54 g, 6 mmol) in DMF (20 mL) was added TATU (1.94 g, 6 mmol) followed by DIEA (1.83 mL, 10.5 mmol). The solution was then added to the above deprotected resin and the suspension was set on a shaker overnight. The solvent was drained and the resin was washed with DMF (30 mL x3) and DCM (30 mL x3).

[0176] The resin was treated with 5% hydrazine in DMF (20 mL) and after 5 min, the solvent was drained. The process was repeated four more times and the resin was washed with DMF (30 mL x4) and DCM (30 mL x 4).

[0177] To a solution of 5-(((2R,3R,4R,5R,6R)-3-acetamido-4,5-diacetoxy-6-(acetoxymethyl)tetrahydro-2H-pyran-2-yl)oxy)pentanoic acid (4.47 g, 10 mmol) in DMF (40 mL) was added TATU (3.22 g, 10 mmol), and the solution was stirred for 5 min. DIEA (2.96 mL, 17 mmol) was added to the solution, and the mixture was then added to the resin above. The suspension was kept at room temperature overnight and the solvent was drained. The resin was washed with DMF (3 x 30 mL) and DCM (3 x 30 mL).

[0178] The resin was treated with 1% TFA in DCM (30 mL with 3% Triisopropylsilane) and after 5 min, the solvent was drained. The process was repeated three more times, and the combined filtrate was concentrated in vacuo. The residue was triturated with diethyl ether (50 mL) and the suspension was filtered and dried to give the crude product. The crude product was purified with reverse phase chromatography and eluted with 0-20% of MeCN in water. The fractions were combined and lyophilized to give the product as a white solid.

[0179] Based on activity in *in vitro* cell-based assays as described in Example 2 and *in vivo* transgenic mouse studies as described in Example 3, 137 sequences targeting specific regions of the human *LPA* transcript were selected for structure-activity relationship (SAR) studies. Table 1 below lists the unmodified sense and antisense sequences for molecules in each of the 137 sequence families. The range of nucleotides targeted by siRNA molecules in each sequence family within the human *LPA* transcript (SEQ ID NO: 1) is also shown in Table 1. As discussed above, the human *LPA* gene contains repeats of the KIV-2 domain and thus, the siRNA molecules may have more than one target site within the transcript if the target site lies within

the KIV-2 domain or a conserved region among the other KIV domains. For clarity, only the first target site within the transcript is shown.

[0180] Table 2 provides the sequences of the sense and antisense strands with chemical modifications for exemplary duplexes resulting from the SAR studies. The nucleotide sequences are listed according to the following notations: a, u, g, and c = corresponding 2'-O-methyl ribonucleotide; Af, Uf, Gf, and Cf = corresponding 2'-deoxy-2'-fluoro (“2'-fluoro”) ribonucleotide; Phos = terminal nucleotide has a monophosphate group at its 5' end; and invAb = inverted abasic nucleotide (i.e. abasic nucleotide linked to adjacent nucleotide via a substituent at its 3' position (a 3'-3' linkage) when on the 3' end of a strand or linked to adjacent nucleotide via a substituent at its 5' position (a 5'-5' internucleotide linkage) when on the 5' end of a strand. Insertion of an “s” in the sequence indicates that the two adjacent nucleotides are connected by a phosphorothiodiester group (e.g. a phosphorothioate internucleotide linkage). Unless indicated otherwise, all other nucleotides are connected by 3'-5' phosphodiester groups. [GalNAc3] represents the GalNAc moiety shown in Formula VII, which was covalently attached to the 5' end of the sense strand via a phosphodiester bond or a phosphorothioate bond when an “s” follows the [GalNAc3] notation.

Table 1. Unmodified LPA siRNA sequences

Duplex No.	Target site within NM_005577.4	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
6078	116-134	CCUGAGCAAAGCCAUGUGAUU	2	UCACAUGGCUUUGCUCAGGUU	134
5037	117-135	CUGAGCAAAGCCAUGUGGUUU	3	ACCACAUGGCUUUGCUCAGUU	135
5125	131-149	GUGGUCCAGGAUUGCUACUUU	4	AGUAGCAAUCCUGGACCACUU	136
4930	249-267	CCACAGAAAACUACCCAAAUU	5	UUUGGGUAGUUUUCUGUGGUU	137
5126	384-402	CAGAAGGGACUGCCGUCGUUU	6	ACGACGGCAGUCCCUUCUGUU	138
4932	385-402	AGAAGGGACUGCCGUCGCGUU	7	CGCGACGGCAGUCCCUUCUUU	139
6079	385-402	AGAAGGGACUGCCGUCGCAUU	8	UGCGACGGCAGUCCCUUCUUU	140
4776	437-455	GUCCCUUCCGAACAAGCAUUU	9	AUGCUUGUUCGGAAGGAGCUU	141
4777	438-456	CUCCUUCCGAACAAGCACUUU	10	AGUGCUUGUUCGGAAGGAGUU	142
4938	441-459	CUUCCGAACAAGCACCGACUU	11	GUCGGUGCUUGUUCGGAAGUU	143
4778	441-459	CUUCCGAACAAGCACCGAUUU	12	AUCGGUGCUUGUUCGGAAGUU	144
4613; 6279	442-460	UUCCGAACAAGCACCGACUUU	13	AGUCGGUGCUUGUUCGGAUUU	145
6249; 6280;	440-460	CCUUCCGAACAAGCACCGACU	14	AGUCGGUGCUUGUUCGGAAGGUU	146

Duplex No.	Target site within NM_005577.4	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
6282					
6281	440-460	CCUUCCGAACAAGCACCGAC	15	AGUCGGUGCUUGUUCGGAAGGUU	146
6081	443-461	UCCGAACAAGCACCGACUAUU	16	UAGUCGGUGCUUGUUCGGAUU	147
4941	445-463	CGAACAAGCACCGACUGAGUU	17	CUCAGUCGGUGCUUGUUCGUU	148
6084	451-469	AGCACCGACUGAGCAAAGAUU	18	UCUUUGCUCAGUCGGUGCUUU	149
4816	452-470	GCACCGACUGAGCAAAGGUUU	19	ACCUUUGCUCAGUCGGUGCUU	150
4948	453-471	CACCGACUGAGCAAAGGCCUU	20	GGCCUUUGCUCAGUCGGUGUU	151
6086	466-484	AAGGCCUGGGGUGCAGGAAUU	21	UUCCUGCACCCCAGGCCUUUU	152
4956	471-489	CUGGGGUGCAGGAGUGCUAUU	22	UAGCACUCCUGCACCCCAGUU	153
11741	471-489	CUGGGGUGCAGGAGUGCUAU	23	UAGCACUCCUGCACCCCAGUU	153
4614	473-491	GGGGUGCAGGAGUGCUACCUU	24	GGUAGCACUCCUGCACCCCUU	154
4961	2689-2707	GAAUCCAGAUCCUGUGGCAUU	25	UGCCACAGGAUCUGGAUUCUU	155
5133	2699-2717	CCUGUGGCAGCCCCUUAUUUU	26	AAUAAGGGGCUGCCACAGGUU	156
4966; 5042; 5413	2704-2722	GGCAGCCCCUUAUUGUUAUUU	27	AUAACAAUAAGGGGCUGCCUU	157
5414; 6244	2702-2722	GUGGCAGCCCCUUAUUGUUAU	28	AUAACAAUAAGGGGCUGCCACUU	158
5417	2702-2722	GUGGCAGCCCCUUAUUGUUA	29	AUAACAAUAAGGGGCUGCCACUU	158
4967	2705-2723	GCAGCCCCUUAUUGUUAUAUU	30	UAUAACAAUAAGGGGCUGCUU	159
4599	2707-2725	AGCCCCUUAUUGUUAUACGUU	31	CGUAUAACAAUAAGGGGCUUU	160
6087	2707-2725	AGCCCCUUAUUGUUAUACAUU	32	UGUAUAACAAUAAGGGGCUUU	161
4969; 5409	2708-2726	GCCCCUUAUUGUUAUACGAUU	33	UCGUUAACAAUAAGGGGCUU	162
5410	2706-2726	CAGCCCCUUAUUGUUAUACG	34	UCGUUAACAAUAAGGGGCUGUU	163
4970	2709-2727	CCCCUUAUUGUUAUACGAGUU	35	CUCGUUAACAAUAAGGGGUU	164
5430; 6245	2707-2727	AGCCCCUUAUUGUUAUACGAG	36	CUCGUUAACAAUAAGGGGCUUU	165
5433	2707-2727	AGCCCCUUAUUGUUAUACGA	37	CUCGUUAACAAUAAGGGGCUUU	165
6088	2709-2727	CCCCUUAUUGUUAUACGAAUU	38	UUCGUUAACAAUAAGGGGUU	166
4971; 6183	2759-2777	CUGACACAAUGCUCAGACGUU	39	CGUCUGAGCAUUGUGUCAGUU	167
6089; 6138	2759-2777	CUGACACAAUGCUCAGACAUU	40	UGUCUGAGCAUUGUGUCAGUU	168
6139; 6140; 6143; 6144; 6145; 6146; 6147; 6148	2757-2777	ACCUGACACAAUGCUCAGACA	41	UGUCUGAGCAUUGUGUCAGGUUU	169
6141	2757-2777	ACCUGACACAAUGCUCAGAC	42	UGUCUGAGCAUUGUGUCAGGUUU	169
6174	2757-2777	ACCUGACACAAUGCUCAGAC	42	CGUCUGAGCAUUGUGUCAGGUUU	170

Duplex No.	Target site within NM_005577.4	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
6236; 6246	2757-2777	ACCUGACACAAUGCUCAGACG	43	CGUCUGAGCAUUGUGUCAGGUUU	170
4972	2761-2779	GACACAAUGCUCAGACGCAUU	44	UGCGUCUGAGCAUUGUGUCUU	171
4973	2762-2780	ACACAAUGCUCAGACGCAGUU	45	CUGCGUCUGAGCAUUGUGUUU	172
6248	2760-2780	UGACACAAUGCUCAGACGCAG	46	CUGCGUCUGAGCAUUGUGUCAUU	173
7932; 7936; 7938; 11357	2760-2780	UGACACAAUGCUCAGACGCAA	47	UUGCGUCUGAGCAUUGUGUCAUU	174
7934; 8278; 11356	2760-2780	UGACACAAUGCUCAGACGCA	48	UUGCGUCUGAGCAUUGUGUCAUU	174
18448	2760-2780	UGACACAAUGCUCAGACGCA	48	UUGCGUCUGAGCAUUGUGUCA	176
10927; 11350	2762-2780	ACACAAUGCUCAGACGCAAU	49	UUGCGUCUGAGCAUUGUGUUU	175
11347; 11348; 11349	2762-2780	ACACAAUGCUCAGACGCAAUU	50	UUGCGUCUGAGCAUUGUGUUU	175
11351	2762-2780	ACACAAUGCUCAGACGCA	51	UUGCGUCUGAGCAUUGUGUUU	175
11352; 11354	2762-2780	ACACAAUGCUCAGACGCAA	52	UUGCGUCUGAGCAUUGUGUUU	175
4601; 5043; 6276; 7900	2824-2842	CCUAGAGGCUCCUUCUGAAUU	53	UUCAGAAGGAGCCUCUAGGUU	177
6247; 6278	2822-2842	AGCCUAGAGGCUCCUUCUGAA	54	UUCAGAAGGAGCCUCUAGGCUUU	178
6277; 7902	2822-2842	AGCCUAGAGGCUCCUUCUGA	55	UUCAGAAGGAGCCUCUAGGCUUU	178
4978	2827-2845	AGAGGCUCCUUCUGAACAAUU	56	UUGUUCAGAAGGAGCCUCUUU	179
6091	2845-2863	AGCACCAACUGAGCAAAGAUU	57	UCUUUGCUCAGUUGGUGCUUU	180
4984	3031-3049	AAAUCCAGAUCCUGUGGCAUU	58	UGCCACAGGAUCUGGAUUUUU	181
5044	3046-3064	GGCAGCCCCUUGGUGUUAUUU	59	AUAACACCAAGGGGCUGCCUU	182
4683; 6180	3278-3296	AGAACUUGCCAAGCUUGGUUU	60	ACCAAGCUUGGCAAGUUCUUU	183
6274; 6347	3276-3296	GAAGAACUUGCCAAGCUUGGU	61	ACCAAGCUUGGCAAGUUCUUCUU	184
6172	3276-3296	GAAGAACUUGCCAAGCUUGG	62	ACCAAGCUUGGCAAGUUCUUCUU	184
4792; 6181	3279-3297	GAACUUGCCAAGCUUGGUUUU	63	AACCAAGCUUGGCAAGUUCUU	185
6348; 6235	3277-3297	AAGAACUUGCCAAGCUUGGUU	64	AACCAAGCUUGGCAAGUUCUUUU	186
6173	3277-3297	AAGAACUUGCCAAGCUUGGU	65	AACCAAGCUUGGCAAGUUCUUUU	186
4818	3310-3328	ACACCAGCAUAGUCGGACUUU	66	AGUCCGACUAUGCUGGUGUUU	187
5129	3311-3329	CACCAGCAUAGUCGGACCUUU	67	AGGUCCGACUAUGCUGGUGUU	188
4705; 11313	3392-3410	CGCCCUUGGUGUUAACACCAUU	68	UGGUGUAACACCAAGGGCGUU	189

Duplex No.	Target site within NM_005577.4	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
20022	3392-3410	CGCCCUUGGUGUUACACCAU	610	UGGUGUAAACACCAAGGGCGUU	189
8336	3390-3410	UUCGCCCUUGGUGUUACACCA	69	UGGUGUAAACACCAAGGGCGAAUU	190
11315; 20033	3392-3410	CGCCCUUGGUGUUACACC	70	UGGUGUAAACACCAAGGGCGUU	189
11316; 11318	3392-3410	CGCCCUUGGUGUUACACCA	71	UGGUGUAAACACCAAGGGCGUU	189
11320; 11322; 20027	3390-3410	UUCGCCCUUGGUGUUACACC	72	UGGUGUAAACACCAAGGGCGAAUU	190
20040; 20047	3390-3410	UUCGCCCUUGGUGUUACACC	72	UGGUGUAAACACCAAGGGCGAA	611
4706	3393-3411	GCCCUUGGUGUUACACCAUUU	73	AUGGUGUAAACACCAAGGGCUU	191
8207; 8213	3391-3411	UCGCCCUUGGUGUUACACCA	74	AUGGUGUAAACACCAAGGGCGAAU	192
8918	3393-3411	GCCCUUGGUGUUACACCAUU	75	AUGGUGUAAACACCAAGGGCUU	191
4800	3399-3417	GGUGUUACACCAUGGAUCUUU	76	AGAUCCAUGGUGUAAACACCUU	193
4629; 17183	3464-3482	GAAUCAAGUGUCCUUGCAAUU	77	UUGCAAGGACACUUGAUUCUU	194
11372; 11582; 17203	3462-3482	CAGAAUCAAGUGUCCUUGCA	78	UUGCAAGGACACUUGAUUCUGUU	195
18434; 18439; 18444	3462-3482	CAGAAUCAAGUGUCCUUGCA	78	UUGCAAGGACACUUGAUUCUG	196
11374; 17194	3464-3482	GAAUCAAGUGUCCUUGCAAU	79	UUGCAAGGACACUUGAUUCUU	194
17197; 17198; 17201	3464-3482	GAAUCAAGUGUCCUUGCA	80	UUGCAAGGACACUUGAUUCUU	194
4630	3465-3483	AAUCAAGUGUCCUUGCAACUU	81	GUUGCAAGGACACUUGAUUUU	197
4804; 17184	3465-3483	AAUCAAGUGUCCUUGCAAUUU	82	AUUGCAAGGACACUUGAUUUU	198
11368; 17189	3463-3483	AGAAUCAAGUGUCCUUGCAA	83	AUUGCAAGGACACUUGAUUCUUU	199
18436; 18442; 18446	3465-3483	AGAAUCAAGUGUCCUUGCAA	83	AUUGCAAGGACACUUGAUUCU	200
11370	3463-3483	AGAAUCAAGUGUCCUUGCAAU	84	AUUGCAAGGACACUUGAUUCUUU	199
11580; 17187; 17190; 17192	3465-3483	AAUCAAGUGUCCUUGCAAUU	85	AUUGCAAGGACACUUGAUUUU	198
17188; 17191; 17193	3465-3483	AAUCAAGUGUCCUUGCAA	86	AUUGCAAGGACACUUGAUUUU	198
4805	3467-3485	UCAAGUGUCCUUGCAACUUUU	87	AAGUUGCAAGGACACUUGAUU	201
4823	3519-3537	CUUCUGAAGAAGCACCAAUUU	88	AUUGGUGCUUCUUCAGAAGUU	202
6093	3520-3538	UUCUGAAGAAGCACCAACAUU	89	UGUUGGUGCUUCUUCAGAAGUU	203

Duplex No.	Target site within NM_005577.4	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
5137; 11337	3632-3650	UCUUGGUCCUCUAUGACAUUU	90	AUGUCAUAGAGGACCAAGAUU	204
8395; 8401; 11344	3630-3650	AGUCUUGGUCCUCUAUGACA	91	AUGUCAUAGAGGACCAAGACUUU	205
11338	3632-3650	UCUUGGUCCUCUAUGACAUU	92	AUGUCAUAGAGGACCAAGAUU	204
11340; 11342	3632-3650	UCUUGGUCCUCUAUGACAU	93	AUGUCAUAGAGGACCAAGAUU	204
11341	3632-3650	UCUUGGUCCUCUAUGACA	94	AUGUCAUAGAGGACCAAGAUU	204
5134	3645-3663	UGACACCACACUGGCAUCAUU	95	UGAUGCCAGUGUGGUGUCAUU	206
11835	3667-3685	GACAACAGAAUAUUAUCCAU	96	UGGAUAAUAUUCUGUUGUCUU	207
4835	3780-3798	GCAACCUGACACAAUGUCUUU	97	AGACAUUGUGUCAGGUUGCUU	208
5102	3788-3806	ACACAAUGUCCAGUGACAGUU	98	CUGUCACUGGACAUUGUGUUU	209
6100	3788-3806	ACACAAUGUCCAGUGACAAUU	99	UUGUCACUGGACAUUGUGUUU	210
4733	3793-3811	AUGUCCAGUGACAGAAUCAUU	100	UGAUUCUGUCACUGGACAUUU	211
5105	3795-3813	GUCCAGUGACAGAAUCAAGUU	101	CUUGAUUCUGUCACUGGACUU	212
6101	3795-3813	GUCCAGUGACAGAAUCAAAUU	102	UUUGAUUCUGUCACUGGACUU	213
5106	3796-3814	UCCAGUGACAGAAUCAAGUUU	103	ACUUGAUUCUGUCACUGGAUU	214
5147; 17185	3797-3815	CCAGUGACAGAAUCAAGUAUU	104	UACUUGAUUCUGUCACUGGUU	215
11379	3795-3815	GUCCAGUGACAGAAUCAAGUA	105	UACUUGAUUCUGUCACUGGACUU	216
11838; 11839; 17204; 17205	3795-3815	GUCCAGUGACAGAAUCAAGU	106	UACUUGAUUCUGUCACUGGACUU	216
18450; 18455	3795-3815	GUCCAGUGACAGAAUCAAGU	106	UACUUGAUUCUGUCACUGGAC	217
11745; 17195; 17196	3797-3815	CCAGUGACAGAAUCAAGUAU	107	UACUUGAUUCUGUCACUGGUU	215
17199; 17200; 17202	3797-3815	CCAGUGACAGAAUCAAGU	108	UACUUGAUUCUGUCACUGGUU	215
5116	3922-3940	CACCACUGUUACAGGAAGGUU	109	CCUUCCUGUAAACAGUGGUGUU	218
6102	3922-3940	CACCACUGUUACAGGAAGAUU	110	UCUUCCUGUAAACAGUGGUGUU	219
11743	3990-4010	CAGAAUACUACCCAAUUGGU	111	UACCAUUUGGGUAGUAUUCUGUU	220
5122	4000-4018	CCCAAUUGGUGGCCUGACCUU	112	GGUCAGGCCACCAUUUGGGUU	221
5124	4064-4082	UAUACCAUGGAUCCAGUGUU	113	CACUGGGAUCCAUGGUUAUUAU	222
6106	4064-4082	UAUACCAUGGAUCCAGUAUU	114	UACUGGGAUCCAUGGUUAUUAU	223
4995; 6182; 7915	4180-4198	UUCUGAAGAAGCACCAACUUU	115	AGUUGGUGCUUCUUCAGAAUU	224
6149; 6152; 6153; 6154;	4178-4198	CCUUCUGAAGAAGCACCAACU	116	AGUUGGUGCUUCUUCAGAAGGUU	225

Duplex No.	Target site within NM_005577.4	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
6155; 6156; 7922					
6150; 6151; 7919	4178-4198	CCUUCUGAAGAAGCACCAAC	117	AGUUGGUGCUUCUUCAGAAGGUU	225
5049	4182-4200	CUGAAGAAGCACCAACUGAUU	118	UCAGUUGGUGCUUCUUCAGUU	226
4849	4189-4207	AGCACCAACUGAAAACAGUUU	119	ACUGUUUUCAGUUGGUGCUUU	227
11836	4187-4207	GAAGCACCAACUGAAAACAG	120	ACUGUUUUCAGUUGGUGCUUCUU	228
6109	4498-4516	CCCGGUUCCAAGCACAGAAUU	121	UUCUGUGCUUGGAACCGGGUU	229
6110	4508-4526	AGCACAGAGGCUCCUUCUAUU	122	UAGAAGGAGCCUCUGUGCUUU	230
4815	4520-4538	CCUUCUGAACAAGCACCAUUU	123	GUGGUGCUUGUUCAGAAGGUU	231
4852	4520-4538	CCUUCUGAACAAGCACCAUUU	124	AUGGUGCUUGUUCAGAAGGUU	232
6113	4799-4817	UCAGAAACAGAAUCAGGUUU	125	UACCUGAUUCUGUUUCUGAUU	233
5142	4806-4824	CAGAAUCAGGUGUCCUAGA UU	126	UCUAGGACACCUGAUUCUGUU	234
4861	4929-4947	GUUAUCGAGGCACAUUCUUUU	127	AAGAAUGUGCCUCGAUAACUU	235
5015	4930-4948	UUAUCGAGGCACAUUCUCCUU	128	GGAGAAUGUGCCUCGAUAAUU	236
4862	4930-4948	UUAUCGAGGCACAUUCUCUUU	129	AGAGAAUGUGCCUCGAUAAUU	237
6115	5132-5150	ACGCGAUGCUCAGACACAAUU	130	UUGUGUCUGAGCAUCGCGUUU	238
6116	5143-5161	AGACACAGAAGGGACUGUAUU	131	UACAGUCCCUUCUGUGUCUUU	239
6117	5507-5525	UGUCCUGGAAGCAUUGUAAUU	132	UUACAAUGCUUCCAGGACAUU	240
5140	5575-5593	AACAAGGUUUGGAAAGCAUUU	133	AUGCUUUCCAAACCUUGUUUU	241

Table 2. Modified LPA siRNA sequences

Duplex No.	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
6078	[GalNAc3]ccugagCfaAfAfGfCfcaugugasusu	242	[Phos]usCfsaCfaUfGfgcuUfGfCfucaggsusu	437
5037	[GalNAc3]CfuGfaGfcAfaAfGfCfCfauGfuGfgUfsusUf	243	[Phos]asCfscAfcAfUfggcuUfuGfcUfcAfgsUfsu	438
5125	[GalNAc3]guggucCfaGfGfAfUfugcuacususu	244	[Phos]asGfsuAfgCfAfauccUfgGfaccacsusu	439
4930	[GalNAc3]ccacagAfaAfAfCfUfacccaaasusu	245	[Phos]usUfsuGfgGfUfaguuUfuCfuguggsusu	440
5126	[GalNAc3]cagaagGfgAfCfUfGfccgucgususu	246	[Phos]asCfsgAfcGfGfcaguCfcCfuucgususu	441
4932	[GalNAc3]agaaggGfaCfUfGfCfcgucgcgsusu	247	[Phos]csGfscGfaCfGfgcagUfcCfcuucususu	442
6079	[GalNAc3]agaaggGfaCfUfGfCfcgucgcasusu	248	[Phos]usGfscGfaCfGfgcagUfcCfcuucususu	443
4776	[GalNAc3]gcuccuUfcCfGfAfAfcaagcaususu	249	[Phos]asUfsgCfuUfGfuucgGfaAfggagcsusu	444
4777	[GalNAc3]cuccuuCfcGfAfAfCfaagcacususu	250	[Phos]asGfsuGfcUfUfguucGfgAfggagsusu	445
4938	[GalNAc3]cuuccgAfaCfAfAfGfcaccgacsusu	251	[Phos]gsUfscGfgUfGfcuugUfuCfpgaagsusu	446
4778	[GalNAc3]cuuccgAfaCfAfAfGfcaccgaususu	252	[Phos]asUfscGfgUfGfcuugUfuCfpgaagsusu	447
4613	[GalNAc3]uuccgaAfcAfAfGfCfaccgacususu	253	[Phos]asGfsuCfgGfUfgcuUGfuUfcggaasusu	448

Duplex No.	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
6249	[GalNAc3][invAb]CfcUfuCfcGfaAfcAfAfGfCfacCfGfscsUf	254	[Phos]asGfsuCfGfUfgcuUGfuUfcGfgAfaGfgsUfsu	449
6279	[GalNAc3][invAb]uuccgAfcAfAfGfCfaccgacususu	255	[Phos]asGfsuCfGfUfgcuUGfuUfcggaasusu	448
6280	[GalNAc3]ccuuccgAfcAfAfGfCfaccgascsu	256	[Phos]asGfsuCfGfUfgcuUGfuUfcggaaggsusu	450
6281	[GalNAc3][invAb]ccuuccgAfcAfAfGfCfaccgacs[invAb]	257	[Phos]asGfsuCfGfUfgcuUGfuUfcggaaggsusu	450
6282	[GalNAc3][invAb]ccuuccgAfcAfAfGfCfaccgascsu	258	[Phos]asGfsuCfGfUfgcuUGfuUfcggaaggsusu	450
6081	[GalNAc3]uccgaaCfaAfGfCfAfcgacuasusu	259	[Phos]usAfsGUfcGfGfugcuUfgUfucggasusu	451
4941	[GalNAc3]cgaacaAfgCfAfCfCfGacugagsusu	260	[Phos]csUfscAfgUfCfGgugCfuUfguucgsusu	452
6084	[GalNAc3]agcaccGfaCfUfGfAfgcaaagasusu	261	[Phos]usCfsuUfuGfCfucagUfcGfgugcususu	453
4816	[GalNAc3]gcaccgAfcUfGfAfgcaaaggususu	262	[Phos]asCfscUfuUfGfcucaGfuCfGgugcsusu	454
4948	[GalNAc3]caccgACfuGfAfGfCfaaaggccsusu	263	[Phos]gsGfscCfuUfUfgcucAfgUfcggugsusu	455
6086	[GalNAc3]aaggccUfgGfGfGfUfgcaggaasusu	264	[Phos]usUfscCfuGfCfaccCfaGfgccuususu	456
4956	[GalNAc3]cuggggUfgCfAfGfGfagugcuasusu	265	[Phos]usAfsGfCfCfUfccugCfaCfcccagsusu	457
11741	[GalNAc3]scuggggUfgCfAfGfGfagugcuas[invAb]	266	usAfsGcacUfccugCfaCfcccagsusu	458
4614	[GalNAc3]ggggugCfaGfGfAfGfugcuaccsusu	267	[Phos]gsGfsuAfgCfAfcuccUfgCfaccsusu	459
4961	[GalNAc3]gaauccAfgAfUfCfCfuguggcasusu	268	[Phos]usGfscCfaCfAfggauCfuGfgauucsusu	460
5133	[GalNAc3]ccugugGfCfAfGfCfCccuuauususu	269	[Phos]asAfsuAfaGfGfggcuGfcCfacaggsusu	461
4966	[GalNAc3]ggcagcCfcCfUfUfAfuuguuaususu	270	[Phos]asUfsaAfcAfAfuaagGfgGfcugccsusu	462
5042	[GalNAc3]GfgCfaGfcCfcCfUfUfAfuUGfuUfaUfsusUf	271	[Phos]asUfsaAfcAfAfuaagGfgGfcUfgCfcsUfsu	463
5413	[GalNAc3][invAb]ggcagcCfcCfUfUfAfuuguuaususu	272	[Phos]asUfsaAfcAfAfuaagGfgGfcugccsusu	462
5414	[GalNAc3]guggcagcCfcCfUfUfAfuuguuasusu	273	[Phos]asUfsaAfcAfAfuaagGfgGfcugccacsusu	464
5417	[GalNAc3][invAb]guggcagcCfcCfUfUfAfuuguuas[invAb]	274	[Phos]asUfsaAfcAfAfuaagGfgGfcugccacsusu	464
6244	[GalNAc3][invAb]GfuGfgCfaGfcCfcCfUfUfAfuUGfuUfsasUf	275	[Phos]asUfsaAfcAfAfuaagGfgGfcUfgCfcsUfsu	465
4967	[GalNAc3]gcagccCfcUfUfAfuUfuguauasusu	276	[Phos]usAfsuAfaCfAfaaGfgGfgcugcsusu	466
4599	[GalNAc3]agccccUfuAfUfUfGfuauacgsusu	277	[Phos]csGfsuAfuAfAfcaauAfaGfgggcususu	467
6087	[GalNAc3]agccccUfuAfUfUfGfuauacgasusu	278	[Phos]usGfsuAfuAfAfcaauAfaGfgggcususu	468
4969	[GalNAc3]gccccUfaUfUfGfUfuauacgasusu	279	[Phos]usCfsgUfaUfAfacaaUfaAfggggcsusu	469
5409	[GalNAc3][invAb]gccccUfaUfUfGfUfuauacgasusu	280	[Phos]usCfsgUfaUfAfacaaUfaAfggggcsusu	469
5410	[GalNAc3]cagcccCfuUfAfUfUfguuauacgs[invAb]	281	[Phos]usCfsgUfaUfaAfCfaaUfaGfggugcsusu	470
4970	[GalNAc3]ccccuuAfuUfGfUfUfauacgagsusu	282	[Phos]csUfscGfuAfUfaacaAfuAfaggggsusu	471
5430	[GalNAc3]agccccuuAfuUfGfUfUfauacgsasg	283	[Phos]csUfscGfuAfUfaacaAfuAfaggggcsusu	472
5433	[GalNAc3][invAb]agccccuuAfuUfGfUfUfauacgas[invAb]	284	[Phos]csUfscGfuAfUfaacaAfuAfaggggcsusu	472
6088	[GalNAc3]ccccuuAfuUfGfUfUfauacgaasusu	285	[Phos]usUfscGfuAfUfaacaAfuAfaggggsusu	473
6245	[GalNAc3][invAb]agccccuuAfuUfGfUfUfauacgsasg	286	[Phos]csUfscGfuAfUfaacaAfuAfaggggcsusu	472
4971	[GalNAc3]cugacaCfaAfUfGfCfucagacgsusu	287	[Phos]csGfsuCfuGfAfgcaUfgUfgucagsusu	474
6089	[GalNAc3]cugacaCfaAfUfGfCfucagacasusu	288	[Phos]usGfsuCfuGfAfgcaUfgUfgucagsusu	475
6138	[GalNAc3][invAb]cugacaCfaAfUfGfCfucagacasusu	289	[Phos]usGfsuCfuGfAfgcaUfgUfgucagsusu	475
6139	[GalNAc3]accugacaCfaAfUfGfCfucagascsa	290	[Phos]usGfsuCfuGfAfgcaUfgUfgucaggususu	476
6140	[GalNAc3][invAb]AfcCfuGfaCfaCfaAfuGfCfucAfgAfscsAf	291	[Phos]usGfsuCfuGfAfgcAfuUfgUfgUfcAfgGfusUfsu	477

Duplex No.	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
6141	[GalNAc3][invAb]accugacaCfaAfUfGfCfucagacs[invAb]	292	[Phos]usGfsuCfuGfAfgcaUfgUfgucaggususu	476
6143	[GalNAc3][invAb]accugacaCfaAfUfGfCfucagascsa	293	[Phos]usGfsuCfuGfAfgcaUfgUfgucaggususu	476
6144	[GalNAc3][invAb]accugacaCfaAfUfGfCfucagascsa	293	[Phos]usGfsuCfugAfgcaUfgUfgucaggususu	478
6145	[GalNAc3][invAb]accugacaCfaAfUfGfCfucagascsa	293	[Phos]usGfsucGfAfgcaUfgUfgucaggususu	479
6146	[GalNAc3][invAb]accugacaCfaAfUfGfCfucagascsa	293	[Phos]usGfsucugAfgcaUfgUfgucaggususu	480
6147	[GalNAc3][invAb]accugacaCfaAfUfGfCfucagascsa	293	[Phos]usGfsuCfuGfAfgcAfuUfgUfgucaggususu	481
6148	[GalNAc3][invAb]accugacaCfaAfUfGfCfucagascsa	293	[Phos]UfsgsUfcUfgAfgcaUfgUfgucaggususu	482
6183	[GalNAc3][invAb]cugacaCfaAfUfGfCfucagacgsusu	294	[Phos]csGfsuCfuGfAfgcaUfgUfgucagsusu	474
6174	[GalNAc3][invAb]accugacaCfaAfUfGfCfucagacs[invAb]	292	[Phos]csGfsuCfuGfAfgcaUfgUfgucaggususu	483
6236	[GalNAc3][invAb]accugacaCfaAfUfGfCfucagascsg	295	[Phos]csGfsuCfuGfAfgcaUfgUfgucaggususu	483
6246	[GalNAc3]accugacaCfaAfUfGfCfucagascsg	296	[Phos]csGfsuCfuGfAfgcaUfgUfgucaggususu	483
4972	[GalNAc3]gacacaAfuGfCfUfcagacgcasusu	297	[Phos]usGfscGfuCfUfgagcAfuUfgugucsusu	484
4973	[GalNAc3]acacaaUfgCfUfcAfgacgcagsusu	298	[Phos]csUfsgCfUfcUfgagCfaUfugugususu	485
6248	[GalNAc3][invAb]ugacacaaUfgCfUfcAfgacgcasg	299	[Phos]csUfsgCfUfcUfgagCfaUfugugucasusu	486
7932	[GalNAc3]sugacacaaUfgCfUfcAfgacgcasasa	300	usUfsgCfUfcUfgagCfaUfugugucasusu	487
7934	[GalNAc3]sugacacAfaUfGfCfUfcagacgcas[invAb]	301	usUfsgCfUfcUfgagcaUfuGfugucasusu	488
7936	[GalNAc3]s[invAb]ugacacaaUfgCfUfcAfgacgcasasa	302	usUfsgCfUfcUfgagCfaUfugugucasusu	489
7938	[GalNAc3]s[invAb]ugacacaaUfgCfUfcAfgacgcasasa	302	usUfsgCfUfcUfgagCfaUfugugucasusu	490
8278	[GalNAc3]sugacacaaUfgCfUfcAfgacgcas[invAb]	303	usUfsgcguCfugagCfaUfugugucasusu	491
10927	[GalNAc3]sacacaaUfgCfUfcAfgacgcaaus[invAb]	304	usUfsgcguCfugagCfaUfugugususu	492
11347	[GalNAc3]s[invAb]acacaaUfgCfUfcAfgacgcaasusu	305	usUfsgcguCfugagCfaUfugugususu	492
11348	[GalNAc3]s[invAb]acacaaUfgCfUfcAfgacgcaasusu	305	usUfsgcguCfugagcaUfuGfugususu	493
11349	[GalNAc3]s[invAb]acacaaUfgCfUfcagacgcaasusu	306	usUfsgcguCfugagCfaUfugugususu	492
11350	[GalNAc3]sacacaaUfgCfUfcAfgacgcaaus[invAb]	304	usUfsgcguCfugagcaUfuGfugususu	493
11351	{GalNAc3}sacacaaUfgCfUfcAfgacgcas[invAb]	307	usUfsgcguCfugagCfaUfugugususu	492
11352	[GalNAc3]s[invAb]acacaaUfgCfUfcAfgacgcasasa	308	usUfsgcguCfugagCfaUfugugususu	492
11354	[GalNAc3]s[invAb]acacaaUfgCfUfcagacgcasasa	309	usUfsgcguCfugagcaUfuGfugususu	493
11356	[GalNAc3]sugacacAfaUfGfCfUfcagacgcas[invAb]	301	usUfsgCfUfcUfgagcaUfuGfugucasusu	494
11357	[GalNAc3]s[invAb]ugacacAfaUfGfCfUfcagacgcasasa	310	usUfsgcguCfugagcaUfuGfugucasusu	495
18448	[GalNAc3]sugacacaaUfgCfUfcAfgacgcas[invAb]	311	usUfsgcguCfugagCfaUfuguguscsa	496
4601	[GalNAc3]ccuagaGfgCfUfcCfuucugaasusu	312	[Phos]usUfscAfgAfaAfggagCfcUfcuaggsusu	497
5043	[GalNAc3]CfcUfaGfaGfgCfUfcCfuuCfuGfaAfsusUf	313	[Phos]usUfscAfgAfaAfggagCfcUfcUfaGfgsUfsu	498
6247	[GalNAc3]agccuagaGfgCfUfcCfuucugsasa	314	[Phos]usUfscAfgAfaAfggagCfcUfcuaggcususu	499
6276	[GalNAc3][invAb]ccuagaGfgCfUfcCfuucugaasusu	315	[Phos]usUfscAfgAfaAfggagCfcUfcuaggsusu	497
6277	[GalNAc3][invAb]agccuagaGfgCfUfcCfuucugas[invAb]	316	[Phos]usUfscAfgAfaAfggagCfcUfcuaggcususu	499
6278	[GalNAc3][invAb]agccuagaGfgCfUfcCfuucugsasa	317	[Phos]usUfscAfgAfaAfggagCfcUfcuaggcususu	499
7900	[GalNAc3]s[invAb]ccuagaGfgCfUfcCfuucugaasusu	318	usUfscAfgAfaAfggagCfcUfcuaggsusu	500
7902	[GalNAc3]sagccuaGfaGfGfCfUfcuucugas[invAb]	319	usUfscAfgAfaGfGfagccUfcUfaggcususu	501

Duplex No.	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
4978	[GalNAc3]agaggcUfcCfUfUfCfugaacaasusu	320	[Phos]usUfsgUfuCfAfgaagGfaGfccucususu	502
6091	[GalNAc3]agcaccAfaCfUfGfAfgcaaagasusu	321	[Phos]usCfsuUfuGfCfucagUfuGfgugcucususu	503
4984	[GalNAc3]aaauccAfgAfUfCfCfuguggcasusu	322	[Phos]usGfscCfaCfAfggauCfuGfgauuususu	504
5044	[GalNAc3]GfgCfaGfcCfcCfUfUfGfgUGfuUfaUfsusUf	323	[Phos]asUfscAfaCfCfaagGfgGfcUfgCfcsUfsu	505
4683	[GalNAc3]agaacuUfgCfCfAfAfgcuuggusususu	324	[Phos]asCfscAfaGfCfuuggCfaAfguucucususu	506
6180	[GalNAc3][invAb]agaacuUfgCfCfAfAfgcuuggusususu	325	[Phos]asCfscAfaGfCfuuggCfaAfguucucususu	506
6274	[GalNAc3]gaagaacuUfgCfCfAfAfgcuugsgsu	326	[Phos]asCfscAfaGfCfuuggCfaAfguucucucususu	507
6172	[GalNAc3][invAb]gaagaacuUfgCfCfAfAfgcuuggs[invAb]	327	[Phos]asCfscAfaGfCfuuggCfaAfguucucucususu	507
6347	[GalNAc3][invAb]gaagaacuUfgCfCfAfAfgcuugsgsu	328	[Phos]asCfscAfaGfCfuuggCfaAfguucucucususu	507
4792	[GalNAc3]gaacuuGfcCfAfAfGfcuugguusususu	329	[Phos]asAfscCfaAfGfcuugGfcAfaguucucususu	508
6181	[GalNAc3][invAb]gaacuuGfcCfAfAfGfcuugguusususu	330	[Phos]asAfscCfaAfGfcuugGfcAfaguucucususu	508
6348	[GalNAc3]aagaacuuGfcCfAfAfGfcuuggsususu	331	[Phos]asAfscCfaAfGfcuugGfcAfaguucucucususu	509
6173	[GalNAc3][invAb]aagaacuuGfcCfAfAfGfcuuggs[invAb]	332	[Phos]asAfscCfaAfGfcuugGfcAfaguucucucususu	509
6235	[GalNAc3][invAb]aagaacuuGfcCfAfAfGfcuuggsususu	333	[Phos]asAfscCfaAfGfcuugGfcAfaguucucucususu	509
4818	[GalNAc3]acaccaGfcAfUfAfGfucggacucususu	334	[Phos]asGfsuCfcGfAfcuauGfcUfggugucususu	510
5129	[GalNAc3]caccagCfaUfAfGfUfcggaccucususu	335	[Phos]asGfsgUfcCfGfacuaUfgCfuggugcucususu	511
4705	[GalNAc3]cgcccuUfgGfUfGfUfuacaccasusu	336	[Phos]usGfsgUfgUfAfacacCfaAfgggcgcsusu	512
8336	[GalNAc3][invAb]uucgcccuUfgGfUfGfUfuacacscsa	337	usGfsguguAfacacCfaAfgggcgcaasusu	513
11313	[GalNAc3]s[invAb]cgcccuUfGfGfUfguuacaccasusu	338	usGfsguguAfacacCfaAfgggcgcsusu	514
11315	[GalNAc3]scgcccuUfgGfUfGfUfuacacccs[invAb]	339	usGfsguguAfacacCfaAfgggcgcsusu	514
11316	[GalNAc3]s[invAb]cgcccuUfgGfUfGfUfuacacscsa	340	usGfsguguAfacacCfaAfgggcgcsusu	514
11318	[GalNAc3]s[invAb]cgcccuUfGfGfUfguuacacscsa	341	usGfsguguAfacaccaAfgGfgcgcsusu	515
11320	[GalNAc3]suucgccCfuUfGfGfUfguuacacccs[invAb]	342	usGfsgUfgUfaacaccaAfgGfgcgcaasusu	516
11322	[GalNAc3]suucgccCfuUfGfGfUfguuacacccs[invAb]	342	usGfsguguaAfCfaccaAfgGfgcgcaasusu	517
4706	[GalNAc3]gcccuuGfgUfGfUfUfacaccausususu	343	[Phos]asUfsgGfuGfUfaacaCfcAfagggcsusu	518
8207	[GalNAc3]sucgcccUfuGfGfUfGfuuacaccas[invAb]	344	asUfsgGfuGfuAfAfcaccAfaGfggcgasusu	519
8213	[GalNAc3]sucgcccuuGfgUfGfUfUfacaccas[invAb]	345	asUfsggugUfaacaCfcAfagggcgasusu	520
8918	[GalNAc3]sgcccuGfgUfGfUfUfacaccauus[invAb]	346	asUfsggugUfaacaCfcAfagggcsusu	521
4800	[GalNAc3]gguguuAfcAfCfCfAfuggaucusususu	347	[Phos]asGfsaUfcCfAfugguGfuAfacaccsususu	522
4629	[GalNAc3]gaaucaAfgUfGfUfCfcuugcaasusu	348	[Phos]usUfsgCfaAfGfgacaCfuUfgauucsususu	523
11372	[GalNAc3]scagaauCfaAfGfUfGfuccuugcas[invAb]	349	usUfsgCfaAfgGfAfcacuUfgAfuucugsusu	524
11374	[GalNAc3]sgaaucaAfgUfGfUfCfcuugcaaus[invAb]	350	usUfsgcaaGfgacaCfuUfgauucsususu	525
11582	[GalNAc3]scagaaucaAfgUfGfUfCfcuugcas[invAb]	351	usUfsgcaaGfgacaCfuUfgauucugsusu	526
17183	[GalNAc3]s[invAb]gaaucaAfGfUfGfuccuugcaasusu	352	usUfsgcaaGfgacaCfuUfgauucsususu	525
17194	[GalNAc3]sgaaucaAfgUfGfUfCfcuugcaaus[invAb]	350	usUfsgcaaGfgacaCfuUfgAfuucsususu	527
17197	[GalNAc3]sgaaucaAfgUfGfUfCfcuugcas[invAb]	353	usUfsgcaaGfgacaCfuUfgauucsususu	525
17198	[GalNAc3]sgaaucaAfgUfgUfCfcuugcas[invAb]	354	usUfsgcaaGfgacaCfuUfgauucsususu	525
17201	[GalNAc3]sgaaucaAfGfUfGfuccuugcas[invAb]	355	usUfsgcaaGfgacacuUfgAfuucsususu	528

Duplex No.	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
17203	[GalNAc3]scagaauCfaAfGfUfGfuccuugcas[invAb]	349	usUfsgcaaGfgacacuUfgAfuucugsusu	529
18434	[GalNAc3]scagaaucaAfgUfGfUfCfcuugcas[invAb]	351	usUfsgcaaGfgacaCfuUfgauucsusg	530
18439	[GalNAc3]scagaaucaagUfGfUfCfcuugcas[invAb]	356	usUfsgCfaAfggacaCfuUfgAfuucsusg	531
18444	[GalNAc3]scagaaucaAfGfUfGfuccuugcas[invAb]	357	usUfsgcaaGfgacaCfuUfgauucsusg	530
4630	[GalNAc3]aaucaaGfuGfUfCfCfuugcaacsusu	358	[Phos]gsUfsuGfcAfAfggacAfcUfugauususu	532
4804	[GalNAc3]aaucaaGfuGfUfCfCfuugcaaususu	359	[Phos]asUfsuGfcAfAfggacAfcUfugauususu	533
11368	[GalNAc3]s[invAb]agaaucaaGfuGfUfCfCfuugcaas[invAb]	360	asUfsuGfcAfAfggacAfcUfugauucususu	534
11370	[GalNAc3]s[invAb]agaaucaaGfuGfUfCfCfuugcasasu	361	asUfsugcaAfggacAfcUfugauucususu	535
11580	[GalNAc3]saaucaaGfuGfUfCfCfuugcaauus[invAb]	362	asUfsugcaAfggacAfcUfugauususu	536
17184	[GalNAc3]s[invAb]aaucaaGfUfGfUfccuugcaaususu	363	asUfsugcaAfggacAfcUfugauususu	536
17187	[GalNAc3]saaucaaGfuGfUfCfCfuugcaauus[invAb]	362	asUfsugcaAfggacAfcUfuGfauususu	537
17188	[GalNAc3]saaucaaGfuGfUfCfCfuugcaas[invAb]	364	asUfsugcaAfggacAfcUfugauususu	536
17189	[GalNAc3]sagaaucaAfaGfuGfUfccuugcaas[invAb]	365	asUfsugcaAfggacAfcUfuGfauucususu	538
17190	[GalNAc3]saaucaaGfuGfUfCfCfuugcaauus[invAb]	366	asUfsugcaAfggacAfcUfugauususu	536
17191	[GalNAc3]saaucaaGfuGfUfccuugcaas[invAb]	367	asUfsugcaAfggacAfcUfuGfauususu	537
17192	[GalNAc3]saaucaaGfUfGfUfccuugcaauus[invAb]	368	asUfsugcaAfggacacUfuGfauususu	539
17193	[GalNAc3]saaucaaGfUfGfUfccuugcaas[invAb]	369	asUfsugcaAfggacacUfuGfauususu	539
18436	[GalNAc3]sagaaucaaGfuGfUfCfCfuugcaas[invAb]	370	asUfsugcaAfggacAfcUfugauuscsu	540
18442	[GalNAc3]sagaaucaaguGfUfCfCfuugcaas[invAb]	371	asUfsuGfcAfaggacAfcUfuGfauuscsu	541
18446	[GalNAc3]sagaaucaaGfUfGfUfccuugcaas[invAb]	372	asUfsugcaAfggacAfcUfugauuscsu	540
4805	[GalNAc3]ucaaguGfuCfCfUfUfgcaacuususu	373	[Phos]asAfsgUfuGfCfaaggAfcAfcuugasusu	542
4823	[GalNAc3]cuucugAfaGfAfAfGfcaccaaususu	374	[Phos]asUfsuGfgUfGfcuucUfuCfagaagsusu	543
6093	[GalNAc3]uucugaAfgAfAfGfCfaccacacacusu	375	[Phos]usGfsuUfgGfUfgcuuCfuUfcagaasusu	544
5137	[GalNAc3]ucuuggUfcCfUfCfUfaugacaususu	376	[Phos]asUfsgUfcAfUfagagGfaCfcaagasusu	545
8395	[GalNAc3]sagucuuGfgUfCfCfUfcuaugacas[invAb]	377	asUfsgUfcAfUfAfGfaggaCfcAfagacususu	546
8401	[GalNAc3]sagucuuuggUfcCfUfCfUfaugacas[invAb]	378	asUfsgucaUfagagGfaCfcaagacususu	547
11337	[GalNAc3]s[invAb]ucuuggUfcCfUfCfUfcuaugacacacusu	379	asUfsgucaUfagagGfaCfcaagasusu	548
11338	[GalNAc3]sucuuggUfcCfUfCfUfaugacacacusu	380	asUfsgucaUfagaggaCfcAfagasusu	549
11340	[GalNAc3]s[invAb]ucuuggUfcCfUfCfUfaugacsasu	381	asUfsgucaUfagagGfaCfcaagasusu	548
11341	[GalNAc3]sucuuggUfcCfUfCfUfaugacacacusu	382	asUfsgucaUfagaggaCfcAfagasusu	549
11342	[GalNAc3]s[invAb]ucuuggUfcCfUfCfUfcuaugacsasu	383	asUfsgucaUfagaggaCfcAfagasusu	549
11344	[GalNAc3]sagucuuGfgUfCfCfUfcuaugacas[invAb]	377	asUfsgUfcAfuaagaggaCfcAfagacususu	550
5134	[GalNAc3]ugacacCfaCfAfCfUfggcaucasusu	384	[Phos]usGfsaUfgCfCfagugUfgGfugucasusu	551
11835	[GalNAc3]sgacaacAfgAfAfUfAfuaucacac[invAb]	385	usGfsgauaAfuauuUfcUfugucacacusu	552
4835	[GalNAc3]gcaaccUfgAfCfAfCfaaugucacacusu	386	[Phos]asGfsaCfaUfUfguguCfaGfguugcacacusu	553
5102	[GalNAc3]acacaaUfgUfCfCfAfgugacacacusu	387	[Phos]csUfsgUfcAfCfuggaCfaUfugugacacusu	554
6100	[GalNAc3]acacaaUfgUfCfCfAfgugacacacusu	388	[Phos]usUfsgUfcAfCfuggaCfaUfugugacacusu	555
4733	[GalNAc3]auguccAfgUfGfAfCfagaacacacusu	389	[Phos]usGfsaUfuCfUfgucaCfuGfgacacacusu	556

Duplex No.	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
5105	[GalNAc3]guccagUfgAfCfAfGfaaucaagsusu	390	[Phos]csUfsuGfaUfUfcuguCfaCfuggacsusu	557
6101	[GalNAc3]guccagUfgAfCfAfGfaaucaasusu	391	[Phos]usUfsuGfaUfUfcuguCfaCfuggacsusu	558
5106	[GalNAc3]uccaguGfaCfAfGfAfaucaagususu	392	[Phos]asCfsuUfgAfUfucugUfcAfcuggasusu	559
5147	[GalNAc3]ccagugAfcAfGfAfAfucaaguasusu	393	[Phos]usAfscUfuGfAfuuGfuCfacugggsusu	560
11379	[GalNAc3]s[invAb]guccagugAfcAfGfAfAfucaagsusa	394	usAfscuugAfuucuGfuCfacuggacsusu	561
11838	[GalNAc3]sguccagUfgAfCfAfGfaaucaagus[invAb]	395	usAfscUfuGfaUfUfcuguCfaCfuggacsusu	562
11839	[GalNAc3]sguccagugAfcAfGfAfAfucaagus[invAb]	396	usAfscuugAfuucuGfuCfacuggacsusu	561
11745	[GalNAc3]sccagugAfcAfGfAfAfucaaguaus[invAb]	397	usAfscuugAfuucuGfuCfacugggsusu	563
17185	[GalNAc3]s[invAb]ccagugAfcAfGfAfGfaaucaaguasusu	398	usAfscuugAfuucuGfuCfacugggsusu	563
17195	[GalNAc3]sccagugAfcAfGfAfAfucaaguaus[invAb]	399	usAfscuugAfuucuGfuCfacugggsusu	563
17196	[GalNAc3]sccagugAfcAfGfAfGfaaucaaguaus[invAb]	400	usAfscuugAfuucuguCfaCfugggsusu	564
17199	[GalNAc3]sccagugAfcAfGfAfAfucaagus[invAb]	401	usAfscuugAfuucuGfuCfacugggsusu	563
17200	[GalNAc3]sccagugAfcAfGfAfGfaaucaagus[invAb]	402	usAfscuugAfuucuGfuCfaCfugggsusu	565
17202	[GalNAc3]sccagugAfcAfGfAfGfaaucaagus[invAb]	403	usAfscuugaUfUfcuguCfaCfugggsusu	566
17204	[GalNAc3]sguccagUfgAfCfAfGfaaucaagus[invAb]	395	usAfscuugAfuucuguCfaCfuggacsusu	567
17205	[GalNAc3]sguccagUfgAfCfAfGfaaucaagus[invAb]	404	usAfscuugAfuucuGfuCfaCfuggacsusu	568
18450	[GalNAc3]sguccagugAfcAfGfAfAfucaagus[invAb]	396	usAfscuugAfuucuGfuCfacuggsasc	569
18455	[GalNAc3]sguccagugAfcAfGfAfGfaaucaagus[invAb]	405	usAfscuugAfuucuGfuCfacuggsasc	569
5116	[GalNAc3]caccacUfgUfUfAfCfaggaaggsusu	406	[Phos]csCfsuUfcCfUfguaaCfaGfuggugsusu	570
6102	[GalNAc3]caccacUfgUfUfAfCfaggaagasusu	407	[Phos]usCfsuUfcCfUfguaaCfaGfuggugsusu	571
11743	[GalNAc3]scagaauAfcUfAfCfCfcaauuggus[invAb]	408	usAfscCfaUfuUfGfgguaGfuAfuucugsusu	572
5122	[GalNAc3]cccaaaUfgGfUfGfGfcugaccsusu	409	[Phos]gsGfsuCfaGfGfccacCfaUfuugggsusu	573
5124	[GalNAc3]uauaccAfuGfGfAfUfccagugsusu	410	[Phos]csAfscUfgGfGfauccAfuGfguauasusu	574
6106	[GalNAc3]uauaccAfuGfGfAfUfccaguasusu	411	[Phos]usAfscUfgGfGfauccAfuGfguauasusu	575
4995	[GalNAc3]uucugaAfgAfAfGfCfaccaacususu	412	[Phos]asGfsuUfgGfUfgcuuCfuUfcagaasusu	576
6182	[GalNAc3][invAb]uucugaAfgAfAfGfCfaccaacususu	413	[Phos]asGfsuUfgGfUfgcuuCfuUfcagaasusu	576
6149	[GalNAc3]ccuucugaAfgAfAfGfCfaccaascsu	414	[Phos]asGfsuUfgGfUfgcuuCfuUfcagaaggsusu	577
6150	[GalNAc3][invAb]ccuucugaAfgAfAfGfCfaccaacs[invAb]	415	[Phos]asGfsuUfgGfUfgcuuCfuUfcagaaggsusu	577
6151	[GalNAc3]ccuucuGfaAfGfAfAfGfcaccaacs[invAb]	416	[Phos]asGfsuUfgGfUfgcuuCfuUfcagaaggsusu	578
6152	[GalNAc3][invAb]ccuucugaAfgAfAfGfCfaccaascsu	417	[Phos]asGfsuUfgGfUfgcuuCfuUfcagaaggsusu	577
6153	[GalNAc3][invAb]ccuucugaAfgAfAfGfCfaccaascsu	417	[Phos]asGfsuUfgGfUfgcuuCfuUfcagaaggsusu	579
6154	[GalNAc3][invAb]ccuucugaAfgAfAfGfCfaccaascsu	417	[Phos]asGfsuugGfUfgcuuCfuUfcagaaggsusu	580
6155	[GalNAc3][invAb]ccuucugaAfgAfAfGfCfaccaascsu	417	[Phos]asGfsuuggUfgcuuCfuUfcagaaggsusu	581
6156	[GalNAc3][invAb]ccuucugaAfgAfAfGfCfaccaascsu	417	[Phos]asGfsuUfgGfUfgcUfuCfuUfcagaaggsusu	582
7915	[GalNAc3]s[invAb]uucugaAfgAfAfGfCfaccaacususu	418	asGfsuUfgGfUfgcuuCfuUfcagaasusu	583
7919	[GalNAc3]sccuucugaAfgAfAfGfCfaccaacs[invAb]	419	asGfsuUfgGfUfgcuuCfuUfcagaaggsusu	584
7922	[GalNAc3]s[invAb]ccuucugaAfgAfAfGfCfaccaascsu	420	asGfsuUfgGfUfgcUfuCfuUfcagaaggsusu	585
5049	[GalNAc3]CfuGfaAfgAfaGfCfAfCfaAfcUfgAfsusUf	421	[Phos]usCfsaGfuUfGfgugcUfuCfuUfcAfgsUfsu	586

Duplex No.	Sense Sequence (5'-3')	SEQ ID NO:	Antisense Sequence (5'-3')	SEQ ID NO:
4849	[GalNAc3]agcaccAfaCfUfGfAfaaacagususu	422	[Phos]asCfsuGfuUfUfucagUfuGfgugcususu	587
11836	[GalNAc3]s[invAb]gaagcaccAfaCfUfGfAfaaacags[invAb]	423	asCfsuGfuUfUfucagUfuGfgugcuucsusu	588
6109	[GalNAc3]cccggUfcCfAfAfGfcacagaasusu	424	[Phos]usUfscUfgUfGfcuugGfaAfccgggsusu	589
6110	[GalNAc3]agcacaGfaGfGfCfUfccuucuasusu	425	[Phos]usAfsgAfaGfGfagccUfcUfgugcususu	590
4815	[GalNAc3]ccuucuGfaAfCfAfAfgcaccacsusu	426	[Phos]gsUfsgGfuGfCfuuguUfcAfgaaggsusu	591
4852	[GalNAc3]ccuucuGfaAfCfAfAfgcaccaususu	427	[Phos]asUfsgGfuGfCfuuguUfcAfgaaggsusu	592
6113	[GalNAc3]ucagaaAfcAfGfAfAfucagguasusu	428	[Phos]usAfscCfuGfaFuucuGfuUfucugasusu	593
5142	[GalNAc3]cagaauCfaGfGfUfGfuccuagasusu	429	[Phos]usCfsuAfgGfAfcaccUfgAfuucugsusu	594
4861	[GalNAc3]guuauCgfaGfGfCfAfcuuucuususu	430	[Phos]asAfsgAfaUfGfugccUfcGfauaacsusu	595
5015	[GalNAc3]uuauCgAfgGfCfAfCfauucuccsusu	431	[Phos]gsGfsaGfaAfUfgugcCfuCfgauaasusu	596
4862	[GalNAc3]uuauCgAfgGfCfAfCfauucucususu	432	[Phos]asGfsaGfaAfUfgugcCfuCfgauaasusu	597
6115	[GalNAc3]acgcgaUfgCfUfCfAfgacacaasusu	433	[Phos]usUfsgUfgUfCfugagCfaUfcgcgususu	598
6116	[GalNAc3]agacacAfgAfAfGfGfgacuguasusu	434	[Phos]usAfscAfgUfCfccuuCfuGfugucususu	599
6117	[GalNAc3]uguccuGfgAfAfGfCfauuguaasusu	435	[Phos]usUfsaCfaAfUfgcuuCfcAfggacasusu	600
5140	[GalNAc3]aacaagGfuUfUfGfGfaaagcaususu	436	[Phos]asUfsgCfuUfUfccaaAfcCfuuguususu	601
20022	[GalNAc3]scgcccuUfgGfuGfUfuacaccaus[invAb]	612	usGfsguguAfacacCfaAfgggcgsusu	514
20027	[GalNAc3]suucgccCfuUfgGfUfguuacaccs[invAb]	613	usGfsguguAfacacCfaAfgGfgcgaasusu	617
20033	[GalNAc3]scgcccuUfgGfUfguuacaccs[invAb]	614	usGfsguguAfacacCfaAfgGfgcgsusu	618
20040	[GalNAc3]suucgcccuUfgGfUfguuacaccs[invAb]	615	usGfsguguAfacacCfaAfgggcgsasa	619
20047	[GalNAc3]suucgcccuUfgGfUfgUfuacaccs[invAb]	616	usGfsguguAfacacCfaAfgggcgsasa	619

Example 2. In Vitro Evaluation of LPA RNAi Constructs in Cell-Based Assays

[0181] Initially, 400 GalNAc-conjugated LPA siRNA molecules, which were based on 320 different sequences prioritized from the bioinformatics analysis described in Example 1, were evaluated at a single concentration (12 nM) for inhibition of *LPA* mRNA synthesis in an *in vitro* primary human hepatocyte assay. Following the manufacturers protocol, human primary hepatocyte cells (Xenotech/Sekisui donor lot# HC10-23) were thawed in OptiThaw media (Xenotech cat#K8000). Cells were centrifuged and post media aspiration, resuspended in OptiPlate hepatocyte media (Xenotech cat#K8200) and plated into 96 well collagen coated plates (Greiner cat#655950). Following a 3-4 hour incubation period, media was removed and replaced with OptiCulture hepatocyte media (Xenotech cat#K8300). 3-5 hours following the addition of OptiCulture media, GalNAc-conjugated siRNAs were delivered to cells via free uptake (no transfection reagent) in either single point (12 nM) or dose response format (0.2 μM to 4 μM). Cells were incubated approximately 66-72 hours at 37°C and 5% CO₂. RNA extraction was

performed on either a Qiagen QIAcube HT (9001793) or a ThermoFisher KingFisher Flex (5400630) instrument. Using the Qiagen QIAcube HT system, cells were lysed with Qiagen RLT buffer (79216) +1% 2-mercaptoethanol (Sigma, M-3148), and the lysates were stored at -20°C. RNA was purified using a Qiagen QIAcube HT Kit (74171) on the Qiagen QIAcube HT instrument according to manufacturer's instructions. Samples were analyzed using a QIAxpert system (9002340). Using the ThermoFisher KingFisher Flex system, cells were lysed using lysis/binding concentrate (ThermoFisher Scientific AM8500). Cell lysates were stored at -20°C or in some cases, RNA extraction was performed immediately after cell lysis. RNA was purified using a ThermoFisher Scientific MagMAX™-96 Total RNA Isolation Kit (ThermoFisher Scientific AM1830) on a KingFisher Flex instrument according to manufacturer's instructions.

[0182] cDNA was synthesized from RNA samples using the Applied Biosystems High Capacity cDNA Reverse Transcription kit (4368813), reactions were assembled according to manufacturer's instructions, input RNA concentration varied by sample. Reverse transcription was carried out on a BioRad tetrad thermal cycler (model# PTC-0240G) under the following conditions: 25°C 10 minutes, 37°C 120 minutes, 85°C 5 minutes followed by (an optional) 4°C infinite hold. Droplet digital PCR (ddPCR) was performed using BioRad's QX200 AutoDG droplet digital PCR system according to manufacturer's instructions. Reactions were assembled into an Eppendorf clear 96 well PCR plate (951020303) using BioRad ddPCR Supermix for Probes (1863010), fluorescently labeled qPCR assays for LPA (IDT Hs.PT.58.1145110, ordered with primer to probe ratio 3.6:1, 45 nanomoles each forward and reverse primer, 12.5 nanomoles 6-FAM/ZEN/IBFQ labeled probe) and TATA Box binding protein (TBP) (IDT Hs.PT.53a.20105486, ordered with primer to probe ratio 3.6:1, 45 nanomoles each forward and reverse primer, 12.5 nanomoles HEX/ZEN/IBFQ labeled probe) and RNase free water (Ambion, AM9937). Primer/probe sequences are shown below. Final primer/probe concentration was 900nM/250nM respectively, input cDNA concentration varied among wells.

[0183] Droplets were formed using a BioRad Auto DG droplet generator (1864101) set up with manufacturer recommended consumables (BioRad DG32 cartridges 1864108, BioRad tips 1864121, Eppendorf blue 96well PCR plate 951020362, BioRad droplet generation oil for probes 1864110 and a BioRad droplet plate assembly). Droplets were amplified on a BioRad C1000 touch thermal cycler (1851197) using the following conditions: enzyme activation 95°C 10 minutes, denaturation 94°C 30 seconds followed by annealing/extension 60°C for one minute, 40

cycles using a 2°C/second ramp rate, enzyme deactivation 98°C 10 minutes followed by (an optional) 4°C infinite hold. Samples were then read on a BioRad QX200 Droplet Reader measuring FAM/HEX signal that correlated to LPA or TBP mRNA concentration, respectively. Data was analyzed using BioRad's QuantaSoft software package. Samples were gated by channel (fluorescent label) to determine the concentration per sample. Each sample was then expressed as the ratio of the concentration of the gene of interest (LPA)/concentration of the housekeeping gene (TBP) to control for differences in sample loading. Data was then imported into Genedata Screener, where each test siRNA was normalized to the median of the neutral control wells (buffer only or control siRNA) and was expressed as the POC (percent of control).

ddPCR Assay Sequences

LPA:

Primer 1: 5'-CAAAATGGAACATAAGGAAGTGGT-3' (SEQ ID NO: 602)

Primer 2: 5'-GTGACAGTGGTGGAGTACG-3' (SEQ ID NO: 603)

Probe: 5'-/56-FAM/CATGGCTTT (SEQ ID NO: 604) /ZEN/GCTCAGGTGCTGC (SEQ ID NO: 605) /3IABkFQ/-3'

TBP:

Primer 1: 5'-ATGACCCCCATCACTCCT-3' (SEQ ID NO: 606)

Primer 2: 5'-TCAAGTTTACAACCAAGATTCACTG-3' (SEQ ID NO: 607)

Probe: 5'-/5HEX/AGCTGCGGT (SEQ ID NO: 608) /ZEN/ACAATCCCAGAACTC (SEQ ID NO: 609)/3IABkFQ/-3'

[0184] Based on the results of the single concentration assay, a subset of the GalNAc-conjugated LPA siRNA molecules was selected for further testing in a 10-point dose response format (0.2 μ M to 4 μ M) of the ddPCR assay in primary human hepatocytes. The ratio of the concentration of *LPA* mRNA to the concentration of *TBP* mRNA was measured after a 72-hour incubation period of the GalNAc-conjugated LPA siRNA molecules with the hepatocytes. EC50 values for each of the GalNAc-conjugated LPA siRNA molecules were calculated from the dose-response curves and are shown in Table 3 below along with the maximum antagonist activity for each molecule expressed as percent of *LPA* mRNA remaining (i.e. percent of control).

Table 3. In vitro inhibition of *LPA* mRNA in primary human hepatocytes

Duplex No.	EC50 (nM)	Max Antagonist Activity (% LPA mRNA remaining)
4599	92.1	35.0
4601	2.4	9.8
4613	14.6	15.0
4629	68.3	34.2
4630	2.98	20.0
4683	14.7	17.5
4733	82.7	43.7
4776	6.39	2.4
4778	6.22	30.0
4792	71.9	12.8
4804	24.6	4.7
4805	2.2	40.8
4815	1.57	27.0
4816	1.44	7.1
4818	49.5	63.5
4823	146	25.9
4849	—	77.6
4852	61.1	35.9
4861	—	48.8
4862	13.7	26.7
4932	8.54	14.5
4938	10.6	4.3
4941	9.53	4.7
4948	99.1	35.3
4956	7.17	3.8
4961	3.74	18.1
4966	19.9	4.1
4967	20.5	9.3
4969	87	13.0
4970	37.5	21.0
4971	3.71	18.3
4972	16.1	40.9
4973	11.8	5.5
4978	20.3	2.1
4984	7.25	14.3
4995	1.9	20.7
5015	7.79	16.5
5037	56.8	41.7

Duplex No.	EC50 (nM)	Max Antagonist Activity (% LPA mRNA remaining)
5042	1.38	8.3
5043	3.43	17.7
5044	101	36.5
5049	7.16	53.3
5102	—	57.6
5105	—	25.4
5106	108	21.7
5116	—	50.0
5122	39.2	10.8
5124	—	92.9
5125	157	37.2
5126	63.7	72.9
5129	836	32.1
5133	110	67.1
5134	—	66.1
5137	45.3	16.4
5140	64.7	35.8
5142	315	54.7
5147	—	49.6
5409	14.5	9.1
5410	2.52	6.2
5413	3.06	11.3
5414	4.2	13.6
5430	—	6.8
6078	28.2	18.3
6079	102	10.3
6081	63.4	24.3
6084	2.95	3.8
6086	—	76.6
6087	—	13.0
6088	17.8	16.2
6089	7.41	17.3
6091	168	15.7
6093	16.7	7.0
6101	25	42.0
6102	311	33.0
6106	—	133.3
6109	50.3	18.9
6110	49.1	30.4

Duplex No.	EC50 (nM)	Max Antagonist Activity (% LPA mRNA remaining)
6113	24.2	36.7
6115	14.8	8.3
6116	262	24.8
6117	8.5	24.8
6138	5.08	7.1
6139	—	8.7
6140	8.32	5.0
6141	2.05	4.4
6143	5.06	6.1
6144	5.06	6.6
6145	18.2	10.5
6146	—	7.1
6147	—	8.3
6148	5.04	21.2
6150	18.1	18.1
6151	28.1	19.5
6153	42.1	20.1
6154	5.45	8.8
6155	37.9	17.1
6156	22.5	13.0
6172	2.63	21.3
6173	121	5.6
6174	4.73	21.9
6180	—	17.5
6181	4.02	11.3
6183	66	7.5
6235	2.81	14.1
6236	27.1	8.3
6244	5.11	19.5
6245	19.9	9.7
6246	33.4	11.7
6248	5.77	18.6
6249	4.16	3.7

[0185] Several of the LPA siRNA molecules exhibited maximum reductions of *LPA* mRNA levels over 85% relative to hepatocytes not treated with the siRNA molecules and had EC50 values in the single-digit nanomolar range.

[0186] A subset of the more potent siRNA molecules from Table 3 were selected and further tested in a second *in vitro* assay, which employed a dual luciferase reporter system. In addition, the dual luciferase reporter assay was used in combination with the transgenic mouse model described in Example 3 for the SAR studies, in which the placement and number of chemical modifications and/or the format of the siRNA molecule (e.g. length of strands and nature of the ends) was altered for select sequence families to optimize the magnitude and duration of inhibition of *LPA* gene expression.

[0187] The dual luciferase reporter plasmid (pMIR0660) was constructed from the commercially-available psiCHECK plasmid (Promega, Madison, WI), which comprises coding DNA sequences (CDS) for both Renilla luciferase and firefly luciferase. The portion of the human *LPA* CDS containing KIV-3 to KIV-10 was cloned into the plasmid to create a fusion of the Renilla luciferase CDS with the human *LPA* CDS. siRNA-mediated inhibition of translation of the *LPA* target sequence caused degradation of the fusion mRNA and a decrease in the Renilla luciferase signal. *LPA* gene knockdown was assessed by measuring Renilla luciferase levels normalized to the levels of firefly luciferase, which is constitutively expressed by the plasmid. Huh7 cells, a human hepatocellular carcinoma cell line, were plated in 96-well plates. After overnight incubation, cells were co-transfected with dual reporter plasmid pMIR0660 and the test siRNA molecule at different concentrations with Lipofectamine™ 2000 Transfection Reagent per manufacturer's instructions. An 8- to 11-point dose titration (0-10 nM) was performed (in triplicate). Dual luciferase activity was measured after a second overnight incubation on the Envision luminometer (Perkin Elmer, Waltham, MA). EC50 values and maximum antagonist activity (measured as the lowest ratio of Renilla luciferase level to firefly luciferase level) for each of the evaluated *LPA* siRNA molecules are reported in Table 4 below.

Table 4. Efficacy of *LPA* RNAi constructs in dual luciferase reporter assay in Huh7 cells

Duplex No.	EC50 (pM)	Max Antagonist Activity (normalized Renilla luciferase- <i>LPA</i> expression level)
4601	1.1	0.24
4613	10.4	0.04
4614	61.3	0.51
4683	1.1	0.27

Duplex No.	EC50 (pM)	Max Antagonist Activity (normalized Renilla luciferase-LPA expression level)
4705	9.9	0.36
4706	1.7	0.39
4776	5.6	0.08
4792	7.4	0.22
4800	57.8	0.42
4804	0.5	0.21
4815	1.9	0.14
4816	10.1	0.18
4818	0.6	0.27
4823	1.6	0.17
4835	27.7	0.34
4852	6.9	0.09
4862	0.7	0.14
4930	12.8	0.44
4941	29.4	0.17
4956	9.8	0.19
4966	—	0.59
4970	6.4	0.47
4971	11.1	0.33
4972		0.67
4973	15.1	0.42
4978	10.5	0.19
4995	35.5	0.29
5043	0.8	0.21
5137	64.4	0.24
5417	—	0.67
5433	11.8	0.29
6149	12.6	0.48
6150	10.5	0.23
6152	16.6	0.47
6182	7.9	0.15
6247	28.2	0.25
6248	10.2	0.28
6249	17.9	0.14
6274	2.4	0.46
6276	5.9	0.36
6277	12.3	0.42
6278	8.6	0.43

Duplex No.	EC50 (pM)	Max Antagonist Activity (normalized Renilla luciferase-LPA expression level)
6279	6.2	0.15
6280	49.8	0.37
6281	17.0	0.40
6282	14.3	0.34
6347	4.2	0.55
6348	13.4	0.49
7900	19.2	0.26
7902	12.5	0.22
7915	60.2	0.29
7919	17.1	0.28
7922	10.7	0.33
7932	43.0	0.43
7934	44.0	0.42
7936	7.2	0.45
7938	32.7	0.37
8207	8.1	0.47
8213	5.0	0.78
8278	14.0	0.35
8336	106.0	0.35
8395	4.0	0.42
8401	2.6	0.45
8918	27.0	0.39
10927	83.9	0.37
11313	88.0	0.31
11315	487.0	0.49
11316	140.0	0.46
11318	17.0	0.33
11320	37.0	0.32
11322	56.7	0.46
11337	15.0	0.36
11338	320.0	0.45
11340	123.0	0.43
11341	206.0	0.41
11342	67.0	0.35
11344	41.0	0.33
11347	124.0	0.45
11348	82.0	0.33
11349	122.0	0.35

Duplex No.	EC50 (pM)	Max Antagonist Activity (normalized Renilla luciferase-LPA expression level)
11350	95.0	0.37
11351	35.0	0.33
11352	65.4	0.40
11354	16.0	0.30
11356	13.0	0.33
11357	55.8	0.32
11368	2.0	0.33
11370	126.0	0.43
11372	80.0	0.44
11374	257.0	0.46
11379	125.0	0.52
11580	37.0	0.41
11582	11.0	0.43
11741	164.0	0.47
11743	10.0	0.39
11745	214.0	0.45
11835	403.0	0.54
11836	96.0	0.61
11838	42.2	0.56
11839	1.7	0.43
17183	39	0.34
17184	2.7	0.28
17185	58	0.33
17187	41	0.34
17188	5.5	0.27
17189	7.4	0.28
17190	23	0.25
17191	6	0.30
17192	23.8	0.33
17193	11.95	0.20
17194	105	0.33
17195	81.5	0.33
17196	211	0.34
17197	16	0.30
17198	0.7	0.36
17199	9	0.34
17200	1.1	0.27
17201	1.5	0.19

Duplex No.	EC50 (pM)	Max Antagonist Activity (normalized Renilla luciferase-LPA expression level)
17202	6.2	0.60
17203	8.9	0.34
17204	125	0.37
17205	41	0.20
18434	4.62	0.32
18436	5.77	0.35
18439	36	0.32
18442	115	0.39
18444	8.19	0.32
18446	0.736	0.30
18448	7.13	0.21
18450	6.91	0.29
18455	5.73	0.36

Example 3. In Vivo Efficacy of LPA RNAi Constructs in Transgenic Mice Expressing Human Apolipoprotein(a)

[0188] To assess the efficacy of the LPA RNAi constructs *in vivo*, a double transgenic mouse model was used. There is no ortholog to the *LPA* gene in mice and apo(a) (encoded by the *LPA* gene) is generally expressed only in primates. Transgenic mice expressing human apo(a) from a yeast artificial chromosome (YAC) containing the full human *LPA* gene (Frazer *et al.*, Nature Genetics, Vol. 9: 424-431, 1995) were crossed with transgenic mice expressing human apoB-100 (Linton *et al.*, J. Clin. Invest., Vol. 92: 3029-3037, 1993). The resultant double transgenic mice express a fully functional human Lp(a) particle with serum baseline Lp(a) levels of about 50-60 mg/dL on average. Female double transgenic mice were randomized to different treatment groups in each study based on baseline Lp(a) serum levels, body weight, and age. Saline or LPA RNAi constructs were administered as a single subcutaneous injection at a dose of 0.5 mg/kg, 1 mg/kg, or 2 mg/kg. Serum samples were taken prior to injection and then post injection at weeks 1, 2, 3, 4, 6, 8, 10, and 12 or until serum Lp(a) levels returned to baseline levels. Lp(a) concentrations were measured in the serum using an Lp(a) ELISA assay (Cat.# 10-1106-01, Mercodia AB, Uppsala, Sweden). A percentage change in Lp(a) level for each animal at a particular time point was calculated based on that animal's baseline Lp(a) level. Results of eleven separate studies in the transgenic mice with different LPA RNAi constructs are shown in

Tables 5-15 below. Data are expressed as average percent change from baseline for each treatment group (n = 4 or 5 animals/group, except for Studies 10 and 11 where n = 6 animals/group).

Table 5. Serum Lp(a) levels in double transgenic mice following administration of LPA RNAi constructs at 2 mg/kg – Study 1

	Average Percent Change in Serum Lp(a) from Baseline			
Treatment	Week 1	Week 2	Week 3	Week 4
Saline	+72%	+29%	+56%	+69%
4601	-92%	-95%	-90%	-76%
4613	-85%	-92%	-85%	-62%
4683	-51%	-46%	+23%	+49%
4792	-59%	-47%	+33%	+54%
4804	+10%	+13%	+75%	+103%
4970	-14%	-76%	-64%	-59%
4971	-47%	-50%	-8%	+56%
4973	-66%	-73%	-50%	+16%
4995	-70%	-70%	-26%	+14%
5042	-77%	-81%	-52%	+46%
5043	-83%	-79%	-40%	-20%

Table 6. Serum Lp(a) levels in double transgenic mice following administration of LPA RNAi constructs at 2 mg/kg – Study 2

	Average Percent Change in Serum Lp(a) from Baseline		
Treatment	Week 1	Week 2	Week 4
Saline	-12%	-20%	+10%
4966	-81%	-83%	-19%
6150	-92%	-93%	-83%
6182	-87%	-82%	-45%

	Average Percent Change in Serum Lp(a) from Baseline		
Treatment	Week 1	Week 2	Week 4
6247	-93%	-95%	-86%
6248	-73%	-77%	-37%
6249	-89%	-89%	+2%

Table 7. Serum Lp(a) levels in double transgenic mice following administration of LPA RNAi constructs at 0.5 mg/kg – Study 3

	Average Percent Change in Serum Lp(a) from Baseline	
Treatment	Week 2	Week 4
Saline	-30%	-4%
5417	-37%	+6%
5433	-16%	-6%
6276	-66%	-20%
6277	-86%	-22%
6279	-26%	+25%
6280	-65%	-21%
6282	-70%	-32%

Table 8. Serum Lp(a) levels in double transgenic mice following administration of LPA RNAi constructs at 2 mg/kg – Study 4

	Average Percent Change in Serum Lp(a) from Baseline		
Treatment	Week 2	Week 3	Week 4
Saline	+28%	+35	0%
4705	-61%	-66%	-45%
4930	-88%	-79%	-67%
5137	-62%	-52%	-46%

Table 9. Serum Lp(a) levels in double transgenic mice following administration of LPA RNAi constructs at 1 mg/kg – Study 5

	Average Percent Change in Serum Lp(a) from Baseline		
Treatment	Week 2	Week 3	Week 4
Saline	+69%	+93%	+105%
4706	+12%	-13%	-13%
8207	+28%	+16%	+33%
8213	0%	0%	+27%
8336	-39%	-59%	-16%
8395	-79%	-84%	-59%
8918	+1%	+18%	+22%

Table 10. Serum Lp(a) levels in double transgenic mice following administration of LPA RNAi constructs at 1 mg/kg – Study 6

	Average Percent Change in Serum Lp(a) from Baseline		
Treatment	Week 2	Week 3	Week 4
Saline	+23%	+50%	+45%
7934	-77%	-76%	-28%
7938	-64%	-73%	+1%
11313	-51%	-54%	+3
11318	-64%	-81%	-64%
11351	-85%	-89%	-68%
11368	-48%	-55%	+22%
11372	-72%	-75%	-13%
11379	-83%	-81%	-20%

Table 11. Serum Lp(a) levels in double transgenic mice following administration of LPA RNAi constructs at 1 mg/kg – Study 7

	Average Percent Change in Serum Lp(a) from Baseline		
Treatment	Week 2	Week 3	Week 4
Saline	-12%	-19%	+60%
8401	-90%	-82%	-58%
10927	-92%	-85%	-77%
11315	-74%	-46%	-12%
11344	-87%	-75%	-67%
11356	-75%	-60%	-23%
11580	-91%	-73%	-31%
11741	-70%	-42%	-11%
11743	-64%	-19%	-8%

Table 12. Serum Lp(a) levels in double transgenic mice following administration of LPA RNAi constructs at 1 mg/kg – Study 8

	Average Percent Change in Serum Lp(a) from Baseline		
Treatment	Week 2	Week 3	Week 4
Saline	+73%	+99%	+82%
11320	-61%	-43%	-34%
11370	-18%	+41%	+51%
11374	-74%	-54%	-47%
11580	-86%	-78%	-74%
11582	-50%	+1%	0%
11745	-50%	-15%	+23%

Table 13. Serum Lp(a) levels in double transgenic mice following administration of LPA RNAi constructs at 1 mg/kg – Study 9

	Average Percent Change in Serum Lp(a) from Baseline		
Treatment	Week 2	Week 3	Week 4
Saline	-5%	+21%	+9%
17183	-56%	-37%	-16%
17190	-81%	-69%	-49%
17205	-59%	-40%	-46%
18436	-87%	-80%	-63%
18444	-75%	-70%	-44%
18455	-43%	-35%	-21%

Table 14. Serum Lp(a) levels in double transgenic mice following administration of LPA RNAi constructs at 1 mg/kg – Study 10

	Average Percent Change in Serum Lp(a) from Baseline		
Treatment	Week 2	Week 3	Week 4
17188	-89%	-75%	-66%
17198	-83%	-58%	-43%
17200	-77%	-23%	-18%
18434	-84%	-53%	-41%
18446	-94%	-79%	-69%

Table 15. Serum Lp(a) levels in double transgenic mice following administration of LPA RNAi constructs at 1 mg/kg – Study 11

	Average Percent Change in Serum Lp(a) from Baseline		
Treatment	Week 2	Week 3	Week 4
11379	-89%	-55%	-46%

	Average Percent Change in Serum Lp(a) from Baseline		
Treatment	Week 2	Week 3	Week 4
17199	-80%	-30%	-20%
20022	-76%	-32%	-43%
20027	-89%	-55%	-45%
20040	-79%	-42%	-38%

[0189] Most of the LPA RNAi constructs tested reduced serum Lp(a) levels by at least 50% two weeks after a single subcutaneous injection of a dose of 1 mg/kg or 2 mg/kg in the transgenic animals. Some RNAi constructs produced prolonged inhibition of Lp(a) serum levels out to four weeks with a single injection. For example, Lp(a) serum levels were still reduced by about 50% or more at 4 weeks following a single 1 mg/kg or 2 mg/kg injection of constructs 4601, 4613, 4930, 4970, 6150, 6182, 6247, 8395, 8401, 10927, 11318, 11344, 11351, 11374, 11580, 17188, 18436, 18444, and 18446.

Example 4. In Vivo Efficacy of LPA RNAi Constructs in Non-Human Primates

[0190] Efficacy of select LPA RNAi constructs was assessed in cynomolgus monkeys in three separate studies. The RNAi constructs had sequences that cross-reacted with the sequence of the cynomolgus *LPA* gene (NCBI Reference Sequence No. XM_015448520.1). In a first study, cynomolgus monkeys (n=3 per treatment group) received a single subcutaneous injection of 2 mg/kg of LPA RNAi constructs 4601, 4613, or 4970. Blood samples were collected on day -1 (prior to dosing) and on day 4, 7, 14, 21, 28, 35, 42, 49, 56, 63, 70, 77, 84, 91, 98, 105, 112, 119, 126, 133, and 140 following dosing on day 1. Lp(a) serum levels in each sample were analyzed using an Lp(a) ELISA assay (Cat.# 10-1106-01, Mercodia AB, Uppsala, Sweden). The results of the first study are shown in Figure 2. Data are expressed as percentage of Lp(a) serum levels remaining relative to pre-dose baseline. Constructs 4601 and 4613 suppressed serum Lp(a) levels over 80% relative to baseline levels for at least six weeks (e.g. out to at least day 42).

[0191] In a second study, cynomolgus monkeys (n =3 per treatment group) received a single subcutaneous injection of 2 mg/kg of LPA RNAi constructs 8401, 10927, 11318, 11344, or 11351. Blood samples were taken at the same time points as in the first study and analyzed for

Lp(a) levels in the serum as described above. The results of the second study are shown in Figure 3. Data are expressed as percentage of Lp(a) serum levels remaining relative to pre-dose baseline. Remarkably, constructs 10927 and 11351 nearly completely suppressed Lp(a) serum levels through eight weeks. Significant reduction in serum Lp(a) levels was still observed through day 112, almost four months after the single dose injection. In contrast, constructs 8401 and 11344 produced more modest and transient reductions in serum Lp(a) levels. Construct 11318 suppressed Lp(a) in the serum to levels that were about 40% of baseline, and this level of reduction was sustained for several weeks.

[0192] In a third study, cynomolgus monkeys (n = 3 per treatment group) received a single subcutaneous injection of 2 mg/kg of LPA RNAi constructs 11374, 11580, 17205, 18444, or 18436. Blood samples were taken at the same time points and analyzed for Lp(a) levels in the serum as in the previous two studies described above. The results of the third study are shown in Figure 4. Data are expressed as percentage of Lp(a) serum levels remaining relative to pre-dose baseline. Construct 11374 was the most potent of this group of molecules, suppressing Lp(a) serum levels to 20% of baseline levels for about six weeks following a single subcutaneous injection.

Example 5. Viscosity Assessment of LPA RNAi Constructs

[0193] The viscosity of LPA RNAi construct 11374 in phosphate buffered saline (PBS) was assessed at different concentrations. Lyophilized 11374 was formulated with PBS to prepare a stock solution. Dilutions of the stock solution with PBS were made to prepare the different formulations of the 11374 construct at concentrations ranging from 150 to 350 mg/mL. For comparison purposes, the viscosity of LPA RNAi construct AD03851 (described in WO 2017/059223) was also assessed in parallel. The modified nucleotide sequences for AD03851 are set forth below:

Sense sequence: 5'- csagcccccUfAfUfuguuauacgs(inv dA) -3' (SEQ ID NO: 620)

Antisense sequence: 5' - usCfsgUfaUfaacaaUfaAfgGfgGfcsUfsg -3' (SEQ ID NO: 621)

where a, u, g, and c = corresponding 2'-O-methyl ribonucleotide; Af, Uf, Gf, and Cf = corresponding 2'-deoxy-2'-fluoro ribonucleotide; inv dA = an inverted deoxyadenosine nucleotide (i.e. 3'-3' linked); and s = a phosphorothioate internucleotide linkage. The 5'

end of the sense strand was covalently attached to a trivalent GalNAc moiety (NAG25, the structure of which is described in WO 2017/059223) via a phosphorothioate bond.

[0194] To calculate the concentration of 11374 formulations, the absorbance of the samples at 260 nm was measured using an Agilent 8453 G1103A UV-Visible spectrophotometer. An approximated extinction coefficient of $19.1 \text{ mL} \cdot \text{mg}^{-1} \cdot \text{cm}^{-1}$, which is the measured extinction coefficient for AD03851 at 260 nm, and a 1 cm pathlength was then used to calculate the formulation concentrations using Beer's law.

[0195] Viscosity of each formulation was measured using an Anton Paar MCR 302 cone and plate rheometer at a shear rate of 1000 s^{-1} at 25°C . The viscosity measurements for the two LPA RNAi constructs at different concentrations in PBS are shown below in Table 16.

Table 16. Viscosity of LPA RNAi Constructs in PBS

Construct 11374		Construct AD03851	
Concentration (mg/mL)	Viscosity (cP)	Concentration (mg/mL)	Viscosity (cP)
144.8	2.4	153.9	3.9
192.1	3.9	202.5	8.3
240.1	6.4	251.5	24.0
287.0	11.4	300.6	200.7
344.8	22.3	341.5	613.8
490.9	1047.2	—	—

[0196] The LPA RNAi construct 11374 has a lower viscosity as a function of concentration in comparison to AD03851, a benchmark RNAi construct, which could enable higher concentration formulations and reduced injection volumes.

[0197] All publications, patents, and patent applications discussed and cited herein are hereby incorporated by reference in their entireties. It is understood that the disclosed invention is not limited to the particular methodology, protocols and materials described as these can vary. It is also understood that the terminology used herein is for the purposes of describing particular embodiments only and is not intended to limit the scope of the appended claims.

[0198] Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments of the invention described herein. Such equivalents are intended to be encompassed by the following claims.

CLAIMS

What is claimed:

1. An RNAi construct comprising a sense strand and an antisense strand, wherein the antisense strand comprises a region having a sequence that is complementary to an *LPA* mRNA sequence, and wherein said region comprises or consists of a sequence selected from the antisense sequences listed in Table 1 or Table 2.
2. The RNAi construct of claim 1, wherein the sense strand comprises a sequence that is sufficiently complementary to the sequence of the antisense strand to form a duplex region of about 15 to about 30 base pairs in length.
3. The RNAi construct of claim 2, wherein the duplex region is about 17 to about 24 base pairs in length.
4. The RNAi construct of claim 2, wherein the duplex region is about 19 to about 21 base pairs in length.
5. The RNAi construct of any one of claims 1 to 4, wherein the sense strand and the antisense strand are each independently about 19 to about 30 nucleotides in length.
6. The RNAi construct of claim 5, wherein the sense strand and the antisense strand are each independently about 19 to about 23 nucleotides in length.
7. The RNAi construct of any one of claims 1 to 6, wherein the RNAi construct comprises one or two blunt ends.
8. The RNAi construct of any one of claims 1 to 6, wherein the RNAi construct comprises one or two nucleotide overhangs of 1 to 4 unpaired nucleotides.

9. The RNAi construct of claim 8, wherein the nucleotide overhang has 2 unpaired nucleotides.
10. The RNAi construct of claim 8 or 9, wherein the RNAi construct comprises a nucleotide overhang at the 3' end of the sense strand, the 3' end of the antisense strand, or the 3' end of both the sense strand and the antisense strand.
11. The RNAi construct of any one of claims 1 to 10, wherein the RNAi construct comprises at least one modified nucleotide.
12. The RNAi construct of claim 11, wherein the modified nucleotide is a 2'-modified nucleotide.
13. The RNAi construct of claim 11, wherein the modified nucleotide is a 2'-fluoro modified nucleotide, a 2'-O-methyl modified nucleotide, a 2'-O-methoxyethyl modified nucleotide, 2'-O-alkyl modified nucleotide, a 2'-O-allyl modified nucleotide, a bicyclic nucleic acid (BNA), a deoxyribonucleotide, or combinations thereof.
14. The RNAi construct of claim 11, wherein all of the nucleotides in the sense and antisense strands are modified nucleotides.
15. The RNAi construct of claim 14, wherein the modified nucleotides are 2'-O-methyl modified nucleotides, 2'-fluoro modified nucleotides, or combinations thereof.
16. The RNAi construct of any one of claims 1 to 15, wherein the sense strand comprises an abasic nucleotide as the terminal nucleotide at its 3' end, its 5' end, or both its 3' and 5' ends.
17. The RNAi construct of claim 16, wherein the abasic nucleotide is linked to the adjacent nucleotide through a 3'-3' internucleotide linkage or a 5'-5' internucleotide linkage.

18. The RNAi construct of any one of claims 1 to 17, wherein the sense strand, the antisense strand, or both the sense and antisense strands comprise one or more phosphorothioate internucleotide linkages.
19. The RNAi construct of claim 18, wherein the antisense strand comprises two consecutive phosphorothioate internucleotide linkages between the terminal nucleotides at both the 3' and 5' ends.
20. The RNAi construct of claim 18 or 19, wherein the sense strand comprises a single phosphorothioate internucleotide linkage between the terminal nucleotides at the 3' end.
21. The RNAi construct of claim 18 or 19, wherein the sense strand comprises two consecutive phosphorothioate internucleotide linkages between the terminal nucleotides at the 3' end.
22. The RNAi construct of any one of claims 1 to 21, wherein the antisense strand comprises or consists of a sequence selected from SEQ ID NO: 137, SEQ ID NO: 145, SEQ ID NO: 164, SEQ ID NO: 175, SEQ ID NO: 177, SEQ ID NO: 178, SEQ ID NO: 189, SEQ ID NO: 194, SEQ ID NO: 196, SEQ ID NO: 198, SEQ ID NO: 200, SEQ ID NO: 205, SEQ ID NO: 216, SEQ ID NO: 224, or SEQ ID NO: 225.
23. The RNAi construct of any one of claims 1 to 22, wherein the sense strand comprises or consists of a sequence selected from the sense sequences listed in Table 1 or Table 2.
24. The RNAi construct of claim 23, wherein the sense strand comprises or consists of a sequence selected from SEQ ID NO: 5, SEQ ID NO: 13, SEQ ID NO: 35, SEQ ID NO: 49, SEQ ID NO: 51, SEQ ID NO: 53, SEQ ID NO: 54, SEQ ID NO: 71, SEQ ID NO: 78, SEQ ID NO: 79, SEQ ID NO: 83, SEQ ID NO: 85, SEQ ID NO: 86, SEQ ID NO: 91, SEQ ID NO: 106, SEQ ID NO: 115, or SEQ ID NO: 117.
25. The RNAi construct of any one of claims 1 to 24, wherein:

- (i) the sense strand comprises or consists of the sequence of SEQ ID NO: 13 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 145;
- (ii) the sense strand comprises or consists of the sequence of SEQ ID NO: 35 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 164;
- (iii) the sense strand comprises or consists of the sequence of SEQ ID NO: 53 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 177;
- (iv) the sense strand comprises or consists of the sequence of SEQ ID NO: 91 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 205;
- (v) the sense strand comprises or consists of the sequence of SEQ ID NO: 49 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 175;
- (vi) the sense strand comprises or consists of the sequence of SEQ ID NO: 71 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 189;
- (vii) the sense strand comprises or consists of the sequence of SEQ ID NO: 51 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 175;
- (viii) the sense strand comprises or consists of the sequence of SEQ ID NO: 79 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 194;
- (ix) the sense strand comprises or consists of the sequence of SEQ ID NO: 85 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 198;
- (x) the sense strand comprises or consists of the sequence of SEQ ID NO: 106 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 216;
- (xi) the sense strand comprises or consists of the sequence of SEQ ID NO: 83 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 200;
- (xii) the sense strand comprises or consists of the sequence of SEQ ID NO: 78 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 196;
- (xiii) the sense strand comprises or consists of the sequence of SEQ ID NO: 5 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 137;
- (xiv) the sense strand comprises or consists of the sequence of SEQ ID NO: 117 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 225;
- (xv) the sense strand comprises or consists of the sequence of SEQ ID NO: 115 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 224;

(xvi) the sense strand comprises or consists of the sequence of SEQ ID NO: 54 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 178; or

(xvii) the sense strand comprises or consists of the sequence of SEQ ID NO: 86 and the antisense strand comprises or consists of the sequence of SEQ ID NO: 198.

26. The RNAi construct of any one of claims 1 to 25, wherein the RNAi construct is any one of the duplex compounds listed in Tables 1-15.

27. The RNAi construct of claim 26, wherein the RNAi construct is 4601, 4613, 4930, 4970, 6150, 6182, 6247, 8395, 8401, 10927, 11318, 11344, 11351, 11374, 11580, 17188, 17205, 18436, 18444, or 18446.

28. The RNAi construct of claim 27, wherein the RNAi construct is 4601, 4613, 10927, 11351, 11374, 11580, 18436, or 18444.

29. The RNAi construct of any one of claims 1 to 28, wherein the RNAi construct further comprises a ligand.

30. The RNAi construct of claim 29, wherein the ligand comprises a cholesterol moiety, a vitamin, a steroid, a bile acid, a folate moiety, a fatty acid, a carbohydrate, a glycoside, or antibody or antigen-binding fragment thereof.

31. The RNAi construct of claim 29, wherein the ligand comprises galactose, galactosamine, or N-acetyl-galactosamine.

32. The RNAi construct of claim 31, wherein the ligand comprises a multivalent galactose moiety or multivalent N-acetyl-galactosamine moiety.

33. The RNAi construct of claim 32, wherein the multivalent galactose moiety or multivalent N-acetyl-galactosamine moiety is trivalent or tetravalent.

34. The RNAi construct of any one of claims 29 to 33, wherein the ligand is covalently attached to the sense strand optionally through a linker.
35. The RNAi construct of claim 34, wherein the ligand is covalently attached to the 5' end of the sense strand.
36. A pharmaceutical composition comprising the RNAi construct of any one of claims 1 to 35 and a pharmaceutically acceptable carrier or excipient.
37. A method for reducing the expression of LPA in a patient in need thereof comprising administering to the patient the RNAi construct of any one of claims 1 to 35.
38. The method of claim 37, wherein the expression level of LPA in hepatocytes is reduced in the patient following administration of the RNAi construct as compared to the LPA expression level in a patient not receiving the RNAi construct.
39. The method of claim 37, wherein the patient is diagnosed with or at risk for cardiovascular disease.
40. The method of claim 37, wherein the patient has serum or plasma Lp(a) levels of 100 nmol/L or greater.
41. The method of claim 37, wherein the patient has a history of myocardial infarction.
42. A method for reducing serum or plasma Lp(a) levels in a patient in need thereof comprising administering to the patient the RNAi construct of any one of claims 1 to 35.
43. The method of claim 42, wherein the patient is diagnosed with or at risk for cardiovascular disease.

44. The method of claim 42, wherein the patient has serum or plasma Lp(a) levels of 100 nmol/L or greater.

45. A method for treating or preventing cardiovascular disease in a patient in need thereof comprising administering to the patient the RNAi construct of any one of claims 1 to 35.

46. The method of claim 45, wherein the cardiovascular disease is coronary artery disease, peripheral artery disease, myocardial infarction, or stroke.

47. A method for reducing the risk of myocardial infarction in a patient in need thereof comprising administering to the patient the RNAi construct of any one of claims 1 to 35.

48. The method of claim 47, wherein the patient is diagnosed with coronary artery disease.

49. The method of claim 47, wherein the patient has serum or plasma Lp(a) levels of 100 nmol/L or greater.

50. The method of any one of claims 37 to 49, wherein the RNAi construct is administered to the patient via a parenteral route of administration.

51. The method of claim 50, wherein the parenteral route of administration is intravenous or subcutaneous.

52. An RNAi construct of any one of claims 1 to 35 for use in a method for reducing serum or plasma Lp(a) levels in a patient in need thereof.

53. An RNAi construct of any one of claims 1 to 35 for use in a method for treating or preventing cardiovascular disease in a patient in need thereof.

54. The RNAi construct of claim 53, wherein the cardiovascular disease is coronary artery disease, peripheral artery disease, myocardial infarction, or stroke.

55. An RNAi construct of any one of claims 1 to 35 for use in a method for reducing the risk of myocardial infarction in a patient in need thereof.
56. The RNAi construct of claim 55, wherein the patient is diagnosed with coronary artery disease.
57. The RNAi construct of any one of claims 52 to 56, wherein the patient has serum or plasma Lp(a) levels of 100 nmol/L or greater.
58. Use of an RNAi construct of any one of claims 1 to 35 in the preparation of a medicament for reducing serum or plasma Lp(a) levels in a patient in need thereof.
59. Use of an RNAi construct of any one of claims 1 to 35 in the preparation of a medicament for treating or preventing cardiovascular disease in a patient in need thereof.
60. The use of claim 59, wherein the cardiovascular disease is coronary artery disease, peripheral artery disease, myocardial infarction, or stroke.
61. Use of an RNAi construct of any one of claims 1 to 35 in the preparation of a medicament for reducing the risk of myocardial infarction in a patient in need thereof.
62. The use of claim 61, wherein the patient is diagnosed with coronary artery disease.
63. The use of any one of claims 58 to 62, wherein the patient has serum or plasma Lp(a) levels of 100 nmol/L or greater.

FIG. 1

1 gtaagtcaac aatgtcctgg gattgggaca cactttctgg gcactgctgg ccagtcccaa aatggaacat aaggaagtgg ttctttact
91 tcttttattt ctgaaatcag cagcacctga gcaaagccat gtggtccagg attgctacca tggtgatgga cagagttatc gaggcacgta
181 ctccaccact gtcacaggaa ggacctgcca agcttgggtca tctatgacac cacatcaaca taataggacc acagaaaaact accaaaatgc
271 tggcttgatc atgaactact gcaggaatcc agatgctgtg gcagctcctt attgttatac gagggatccc ggtgtcaggt gggagtactg
361 caacctgacg caatgctcag acgcagaagg gactgccgtc gcgcctccga ctgttacccc ggttccaagc ctagaggctc ctccgaaca
451 agcaccgact gagcaaaagg ctgggggtgca ggagtgtctac catggtaatg gacagagtta tcgaggcaca tactccacca ctgtcacagg
541 aagaacctgc caagcttgggt catctatgac accacactcg catagtggga cccagaata ctacccaaat gctgggttga tcatgaacta
631 ctgcaggaat ccagatgctg tggcagctcc ttattgttat acgagggatc ccggtgtcag gtgggagtac tgcaaacctga cgcaatgctc
721 agacgcagaa gggactgccg tcgcgcctcc gactgttacc ccggttccaa gcctagaggc tccttccgaa caagcaccca ctgagcaaa
811 gcctgggggtg caggagtgtc accatggtaa tggacagagt tctcgaggca cactccac cactgtcaca ggaagaacct gccagcttg
901 gtcattctatg acaccacact cgcatagtcg gacccagaa tactaccaa atgctggctt gatcatgaac tactgcagga atccagatgc
991 tgtggcagct ccttattgtt atacgaggga tcccgggtc aggtgggagt actgcaacct gacgcaatgc tcagacgcag aagggactgc
1081 cgtcgcgcct ccgactgtta cccgggttc aagcctagag gtcctctccg aacaagcacc gactgagcag aggcctgggg tgcaaggagt
1171 ctaccacggt aatggacaga gttatcgagg cacatactcc accactgtca ctggaagaac ctgccaaagt tggtcatacta tgacaccaca
1261 ctcgcatagt cggaccccag aatactacc aaatgctggc ttgatcatga actactgcag gaatccagat gctgtggcag ctcttattg
1351 ttatacgagg gatcccggtg tcaggtgga gtactgcaac ctgacgcaat gctcagacgc agaagggact gccgtcgcgc ctccgactgt
1441 taccocgggtt ccaagcctag aggtctcttc cgaacaagca ccgactgagc aaaggcctgg ggtgcaggag tgctaccatg gtaatggaca
1531 gagttatcga ggcacatact ccaccactgt cacaggaaga acctgccaa ctggtcatc tatgacacca cactcgcata gtcggacccc
1621 agaatactac ccaaattgtg gcttgatcat gaactactgc aggaatccag atgctgtggc agctccttat tgttatacga gggatcccgg
1711 tgtcagggtgg gagtactgca acctgacgca atgctcagac gcagaaggga ctgccgtcg gcctccgact gttaccccg ttccaagcct
1801 agagggtcct tccgaacaag caccgactga gcaaaggcct ggggtgcagg agtgctacca tggtaatgga cagagttatc gaggcacata
1891 ctccaccact gtcacaggaa gaacctgcca agcttgggtca tctatgacac cacactcgca tagtcggacc ccagaatact accaaaatgc

FIG. 1 (cont.)

1981 tggcttgatc atgaactact gcaggaatcc agatgctgtg gcagctcctt attgtttatac gagggatccc ggtgtcaggt gggagtactg
2071 caacctgacg caatgctcag acgcagaagg gactgccgtc gcgcctccga ctgttaccac ctgttaccac ctccgaaca
2161 agcaccgact gagcaaaaggc ctgggggtgca ggagtgtctac catggtaatg gacagagtta tcgaggcaca tactccacca ctgtcacagg
2251 aagaacctgc caagcttggt catctatgac accacactcg catagtcgga cccagaata ctacccaaat gctggcttga tcatgaacta
2341 ctgcaggaat ccagatgctg tggcagctcc ttattgttat acgagggatc ccggtgtcag gtgggagtac tgcaacctga cgcaatgctc
2431 agacgcagaa gggactgccg tcgcgcctcc gactgttacc ccggttccaa gcctagaggc tccttccgaa caagcaccca ctgagcagag
2521 gcctgggggtg caggagtgtc accacggtaa tggacagagt tatcgaggca cacttccac cactgtcact ggaagaacct gccaaagcttg
2611 gtcatctatg acaccacact cgcatagtcg gacccagaa tactaccaa atgctggctt gatcatgaac tactgcagga atccagatcc
2701 tgtggcagcc ccttattgtt atacgagga tcccagtgtc aggtgggagt actgcaacct gacacaatgc tcagacgcag aagggactgc
2791 cgtcgcgcct ccaactatta cccgattcc aagcctagag gctccttctg aacaagcacc aactgagcaa aggcctgggg tgcaggagtg
2881 ctaccacgga aatggacaga gttatcaagg cacatacttc attactgtca caggaagaac ctgccaaagt tggtcatcta tgacaccaca
2971 ctgcgcatagt cggaccccag catactacc aaatgctggc ttgatcaaga actactgccg aaatccagat cctgtggcag ccccttggtg
3061 ttatacaaca gatcccagtg tcagggtggga gtactgcaac ctgacacgat gctcagatgc agaatggact gccttcgtcc ctccgaatgt
3151 tattctggct ccaagcctag aggctttttt tgaacaaagca ctgactgagg aaacccccgg ggtacaggac tgctactacc attatggaca
3241 gagttaccga ggcacatact ccaccactgt cacaggaaga acttgccaag cttgggtcatc tatgacacca caccagcata gtcggacccc
3331 agaaaaactac ccaaatgctg gcctgaccag gaactactgc aggaatccag atgctgagat tcgcccttgg tgttacacca tggatcccag
3421 tgtcagggtgg gagtactgca acctgacaca atgcctgggtg acagaatcaa gtgtccttgc aactctcacg gtggtcccag atccaaagcac
3511 agaggcttct tctgaagaag caccaacgga gcaaagcccc ggggtccagg attgctacca tggtgatgga cagagttatc gaggtcatt
3601 ctctaccact gtcacaggaa ggacatgtca gtcttgggtcc tctatgacac cacactggca tcagaggaca acagaatatt atccaaatgg
3691 tggcctgacc aggaactact gcaggaatcc agatgctgag attagtccct ggtgtttatac catggatccc aatgtcagat gggagtactg
3781 caacctgaca caatgtccag tgacagaatc aagtgtcctt gcgacgtcca cggctgtttc tgaacaagca ccaacggagc aaagccccac
3871 agtccaggac tgctaccatg gtgatggaca gagttatct ccaccactgt tacagggaagg acatgtcagt ctgggtcctc

FIG. 1 (cont.)

3961 tatgacacca cactggcatc agagaaccac agaatactac ccaaatgggtg gctgaccag gaactactgc aggaatccag atgctgagat
4051 tcgccccttg tgttatacca tggatcccag tgtcagatgg gagtactgca acctgacgca atgtccagtg atggaatcaa ctctcctcac
4141 aactcccacg gtgggtcccag ttccaagcac agagcttcct tctgaagaag caccaactga aaacagcact ggggtccagg actgctaccg
4231 aggtgatgga cagagttatc gaggcacact ctccaccact atcacaggaa gaacatgtca gtcttggtcg tctatgacac cacattggca
4321 tcggaggatc ccattatact atccaaatgc tggcctgacc aggaactact gcagggaatcc agatgctgag attcgccctt ggtgttacac
4411 catggatccc agtgtcaggt gggagtactg caacctgaca cgatgtccag tgacagaatc gagtgtcctc acaactccca cagtggcccc
4501 ggtttccaagc acagaggctc cttctgaaca agcaccacct gagaaaagcc ctgtgggtcca ggattgctac catggtgatg gacggagtta
4591 tcgaggcata tcctccacca ctgtcacagg aaggacctgt caatcttggt catctatgat accacactgg catcagagga cccagaaaa
4681 ctacccaaat gctggcctga ccgagaacta ctgcaggaat ccagattctg ggaaacaacc ctggtgttac acaaccgac cgtgtgtgag
4771 gtgggagtac tgcaatctga cacaatgctc agaaacagaa tcagggtgtcc tagagactcc cactgttgtt ccagttccaa gcatggaggc
4861 tcattctgaa gcagcaccaa ctgagcaaac ccctgtgttc cggcagtgt accatggtaa tggccagagt tatcgaggca cattctccac
4951 cactgtcaca ggaaggacat gtcaatcttg gtcatccatg acaccacacc ggcatcagag gacccagaa aactaccaa atgatggcct
5041 gacaatgaac tactgcagga atccagatgc cgatacaggc ccttggtgtt ttaccatgga cccagcatc aggtgggagt actgcaacct
5131 gacgcgatgc tcagacacag aagggactgt ggtcgctcct ccgactgtca tccaggttcc aagcctaggg cctccttctg aacaagactg
5221 tatgttttggg aatgggaaag gataccgggg caagaaggca accactgtta ctgggacgcc atgccaggaa tgggctgccc aggagccca
5311 tagacacagc acgttcattc cagggacaaa taaatgggca ggtctggaaa aaaattactg ccgtaaccct gatggtgaca tcaatggtec
5401 ctggtgctac acaatgaatc caagaaaact ttttgactac tgtgatatcc ctctctgtgc atcctcttca tttgattgtg ggaagcctca
5491 agtggagccg aagaaatgtc ctggaagcat tgtagggggg tgtgtggccc accacattc ctggccctgg caagtcagtc tcagaacaag
5581 gtttggaaaag cacttctgtg gaggcacctt aatatcccca gagtgggtgc tgactgctgc tcactgcttg aagaagtcct caaggccttc
5671 atcctacaag gtcatcctgg gtgcacacca agaagtgaac ctggaatctc atgttcagga aatagaagtg tctaggctgt tcttgagcc
5761 cacacaagca gatattgcct tgctaaagct aagcaggcct gccgtcatca ctgacaaagt aatgccagct tgtctgccat cccagacta
5851 catggtcacc gccaggactg aatgttacat cactggctgg ggagaaacc caggtaacct tgggactggc cttctcaagg aagccagct

FIG. 1 (cont.)

5941 ccttggttatt gagaatgaag tgtgcaatca ctataagtat atttgtgctg agcatttggc cagaggcact gacagttgcc agggtgacag
6031 tggagggcct ctggtttgct tcgagaaggga caaatacatt ttacaaggag tcacttcttg ggtctttggc tgtgcacgcc ccaataagcc
6121 tgggtgtctat gctcgtgttt caagggttgt tacttggatt gagggaaatga tgagaaaataa ttaattggac gggagacaga gtgaagcatc
6211 aacctactta gaagctgaaa cgtgggtaag gatttagcat gctggaaaata atagacagca atcaaacgaa gacactgttc ccagctacca
6301 gctatgccaa accttggcat ttttgggtatt tttgtgtata agctttttaag gtctgactga caaattctgt attaagggtgt catagctatg
6391 acatttgtta aaaataaaact ctgcacttat tttgatttga a (SEQ ID NO: 1)

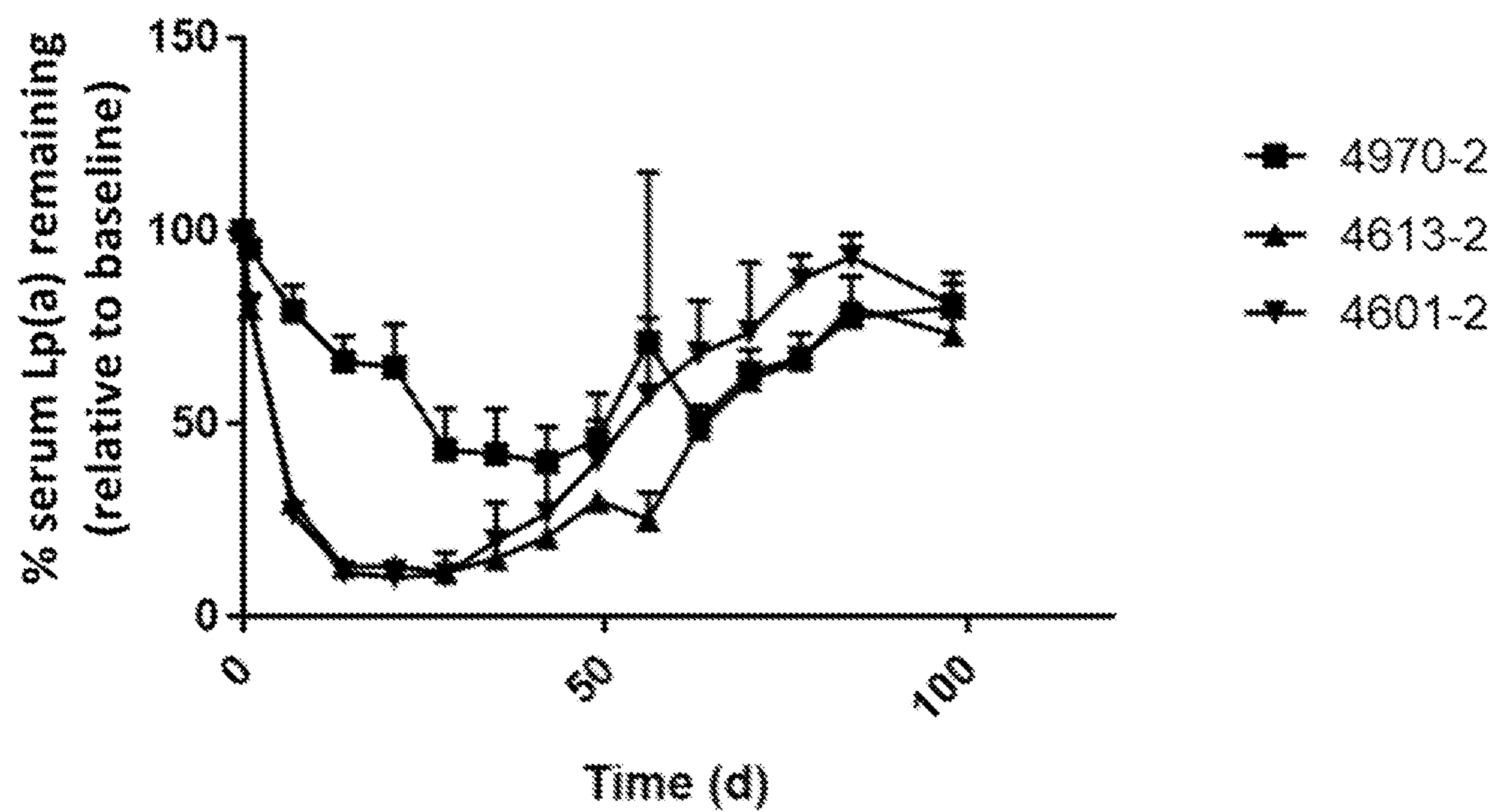


FIG. 2

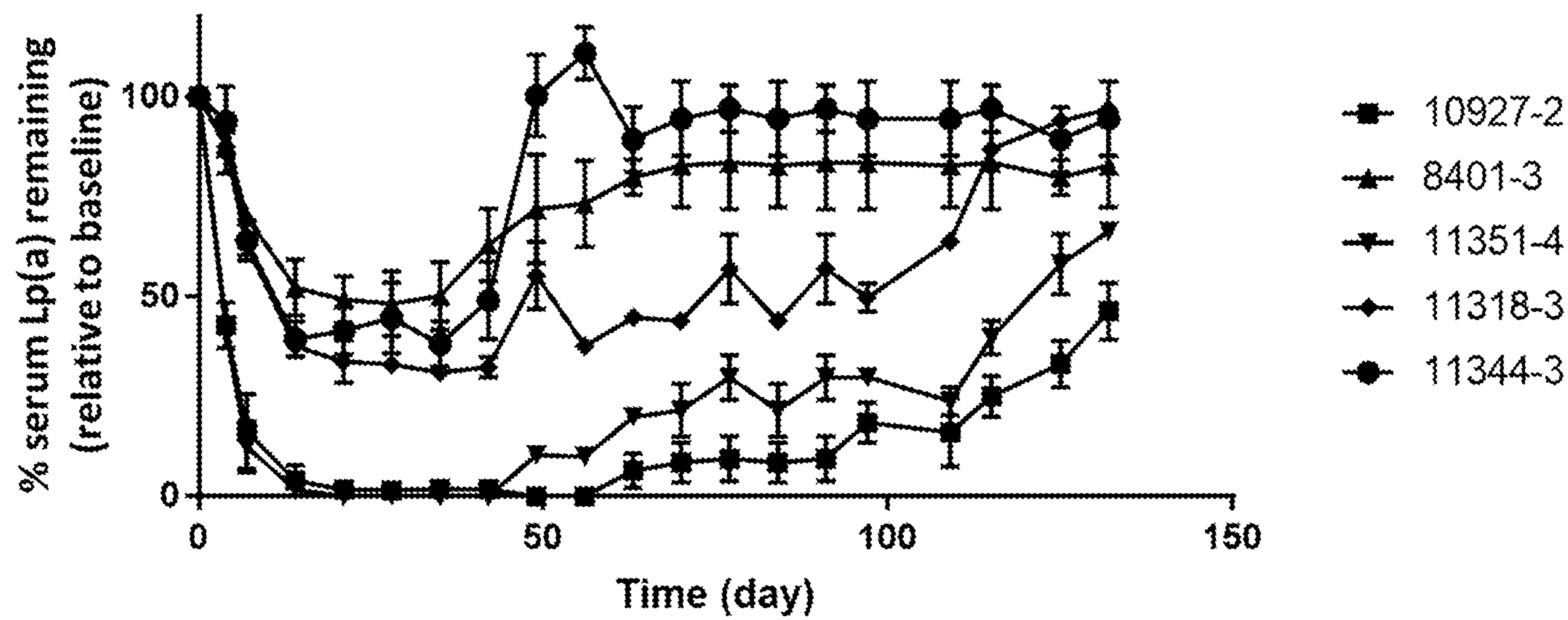


FIG. 3

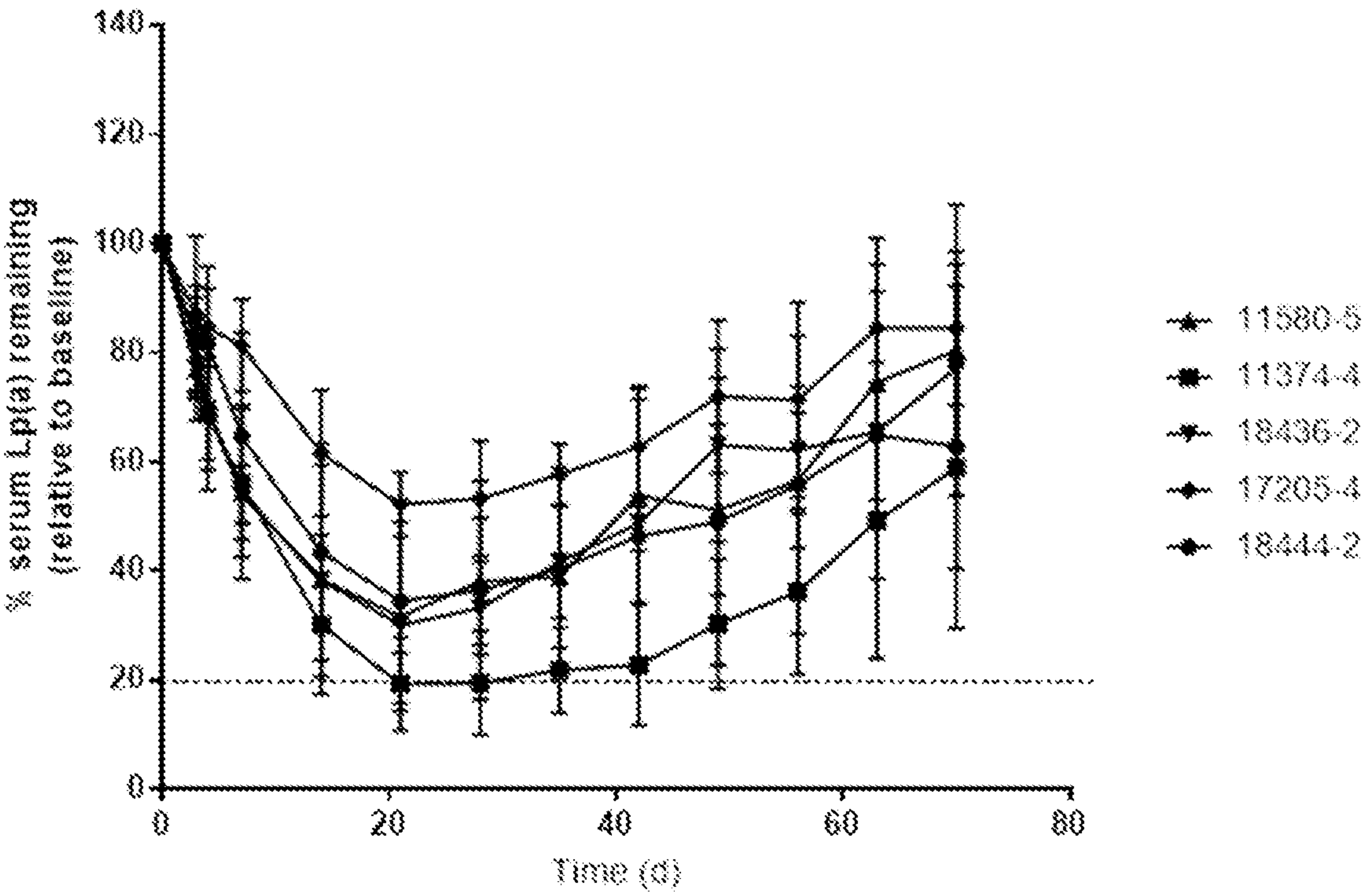


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/063844

A. CLASSIFICATION OF SUBJECT MATTER
INV. C12N15/113 A61K47/54
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, Sequence Search, EMBASE, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2019/092283 A1 (SILENCE THERAPEUTICS GMBH [DE]) 16 May 2019 (2019-05-16) claim 1; figure 1; table 1 the whole document ----- -/--	1-21,23, 26,29-63

☒ 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

22 March 2021

Date of mailing of the international search report

21/05/2021

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
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Fax: (+31-70) 340-3016

Authorized officer

Spindler, Mark-Peter

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/063844

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	TADIN-STRAPPS MARIJA ET AL: "Development of Lipoprotein(a) siRNAs for Mechanism of Action Studies in Non-Human Primate Models of Atherosclerosis", JOURNAL OF CARDIOVASCULAR TRANSLATIONAL RESEARCH, SPRINGER US, BOSTON, vol. 8, no. 1, 21 January 2015 (2015-01-21), pages 44-53, XP035461835, ISSN: 1937-5387, DOI: 10.1007/S12265-014-9605-1 [retrieved on 2015-01-21] table 1 the whole document	1-21,23, 26,29-63
A	----- W0 2019/118638 A2 (AMGEN INC [US]) 20 June 2019 (2019-06-20) table 2 the whole document -----	1-21,23, 26,29-63

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2020/063844

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. ☒ forming part of the international application as filed:
- ☒ 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

International application No.
PCT/US2020/063844

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-21, 23, 26, 29-63(all partially)

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-21, 23, 26, 29-63(all partially)

RNAi construct comprising a sense and an antisense strand wherein the antisense strand comprises a region having a sequence complementary to an LPA mRNA sequence wherein said region comprises or consists of a sequence selected from SEQ ID NO: 134-136 and 437-439 (having a target site within nucleotides 116-149 of NM_005577.4); pharmaceutical composition comprising said RNAi construct; medical implementations of said RNAi construct

2. claims: 1-27, 29-63(all partially)

as in 1) but having a target site within nucleotides 249-267 of NM_005577.4, i.e. the antisense sequence selected from SEQ ID NO: 137 and 440

3. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides 384-402 of NM_005577.4, i.e. the antisense sequence selected from SEQ ID NO: 138-140 and 441-443

4. claims: 1-63(partially)

as in 1) but having a target site within nucleotides 437-471 of NM_005577.4, i.e. the antisense sequence selected from SEQ ID NO: 141-151 and 444-455

5. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides 466-491 of NM_005577.4, i.e. the antisense sequence selected from SEQ ID NO: 152-154 and 456-459

6. claims: 1-27, 29-63(all partially)

as in 1) but having a target site within nucleotides 2689-2727 of NM_005577.4, i.e. the antisense sequence selected from SEQ ID NO: 155-166 and 460-473

7. claims: 1-63(partially)

as in 1) but having a target site within nucleotides 2757-2780 of NM_005577.4, i.e. the antisense sequence selected from SEQ ID NO: 167-176 and 474-493

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

8. claims: 1-63(partially)

as in 1) but having a target site within nucleotides
2822-2845 of NM_005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 177-179 and 494-502

9. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
2845-2863 of NM_005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 180 and 503

10. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
3031-3064 of NM_005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 181-182 and 504-505

11. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
3276-3297 of NM_005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 183-186 and 506-509

12. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
3310-3329 of NM_005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 187-188 and 510-511

13. claims: 1-27, 29-63(all partially)

as in 1) but having a target site within nucleotides
3390-3417 of NM_005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 189-193, 512-522 and 617-619

14. claims: 1-63(partially)

as in 1) but having a target site within nucleotides
3462-3485 of NM_005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 194-201 and 523-542

15. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
3519-3538 of NM_005577.4, i.e. the antisense sequence

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

selected from SEQ ID NO: 202-203 and 543-544

16. claims: 1-27, 29-63(all partially)

as in 1) but having a target site within nucleotides
3632-3650 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 204-205 and 545-550

17. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
3645-3663 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 206 and 551

18. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
3667-3685 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 207 and 552

19. claims: 1-26, 29-63(all partially)

as in 1) but having a target site within nucleotides
3780-3815 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 208-217 and 553-569

20. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
3922-3940 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 218-219 and 570-571

21. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
3990-4018 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 220-221 and 572-573

22. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
4064-4082 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 222-223 and 574-575

23. claims: 1-27, 29-63(all partially)

as in 1) but having a target site within nucleotides

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

4178-4207 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 224-228 and 576-588

24. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
4498-4526 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 229-230 and 589-590

25. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
4520-4538 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 231-232 and 591-592

26. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
4799-4824 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 233-234 and 593-594

27. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
4929-4948 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 235-237 and 595-597

28. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
5132-5161 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 238-239 and 598-599

29. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
5507-5525 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 240 and 600

30. claims: 1-21, 23, 26, 29-63(all partially)

as in 1) but having a target site within nucleotides
5575-5593 of NM 005577.4, i.e. the antisense sequence
selected from SEQ ID NO: 241 and 601

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2020/063844

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2019092283 A1	16-05-2019	AU 2018363840 A1 BR 112020009152 A2 CA 3081905 A1 CN 111465694 A EP 3710586 A1 JP 2021502120 A KR 20200088392 A SG 11202003230U A US 2021123048 A1 WO 2019092283 A1	16-04-2020 27-10-2020 16-05-2019 28-07-2020 23-09-2020 28-01-2021 22-07-2020 28-05-2020 29-04-2021 16-05-2019
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WO 2019118638 A2	20-06-2019	AR 113490 A1 AU 2018386089 A1 BR 112020011686 A2 CA 3084133 A1 CL 2020001543 A1 CN 111699257 A CO 2020008485 A2 CR 20200304 A EA 202091437 A1 EP 3724337 A2 JP 2021506238 A KR 20200097299 A SG 11202005257U A TW 201938792 A UY 38003 A WO 2019118638 A2	06-05-2020 18-06-2020 24-11-2020 20-06-2019 28-08-2020 22-09-2020 31-07-2020 04-09-2020 29-12-2020 21-10-2020 22-02-2021 18-08-2020 29-07-2020 01-10-2019 28-06-2019 20-06-2019
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