LIPID COMPOUNDS AND LIPID NANOPARTICLE COMPOSITIONS

1. CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to International Patent Application No. PCT/CN2022/072694, filed on January 19, 2022, and International Patent Application No. PCT/CN2022/116960, filed on September 5, 2022, the entireties of which are incorporated herein by reference.

2. FIELD

[0002] The present disclosure generally relates to lipid compounds that can be used in combination with other lipid components, such as neutral lipids, cholesterol and polymer conjugated lipids, to form lipid nanoparticles for delivery of therapeutic agents (*e.g.*, nucleic acid molecules, including nucleic acid mimics such as locked nucleic acids (LNAs), peptide nucleic acids (PNAs), and morpholinos), both *in vitro* and *in vivo*, for therapeutic or prophylactic purposes, including vaccination.

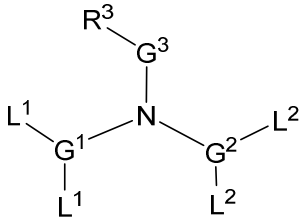
3. BACKGROUND

[0003] Therapeutic nucleic acids have the potential to revolutionize vaccination, gene therapies, protein replacement therapies, and other treatments of genetic diseases. Since the commencement of the first clinical studies on therapeutic nucleic acids in the 2000s, significant progresses have been made through the design of nucleic acid molecules and delivery methods thereof. However, nucleic acid therapeutics still face several challenges, including low cell permeability and high susceptibility to degradation of certain nucleic acids molecules, including RNAs. Thus, there exists a need to develop new nucleic acid molecules, as well as related methods and compositions that facilitate their delivery *in vitro* or *in vivo* for therapeutic and/or prophylactic purposes. Lipid compounds that can be used in combination with other lipid components, such as neutral lipids, cholesterol and polymer conjugated lipids, to form lipid nanoparticles for delivery of therapeutic agents. There exists a need to develop new lipid compounds (*e.g.*, cationic lipid compounds) that afford efficient delivery of the therapeutic agents, sufficient activity of the therapeutic agents (*e.g.*, expression of mRNA after delivery), optimal pharmacokinetics, and/or other suitable physiological, biological, and/or therapeutic properties.

4. SUMMARY

[0004] In one embodiment, provided herein are lipid compounds, including pharmaceutically acceptable salts, prodrugs or stereoisomers thereof, which can be used alone or in combination with other lipid components such as neutral lipids, charged lipids, steroids (including for example, all sterols) and/or their analogs, and/or polymer conjugated lipids and/or polymers to form lipid nanoparticles for the delivery of therapeutic agents (*e.g.*, nucleic acid molecules, including nucleic acid mimics such as locked nucleic acids (LNAs), peptide nucleic acids (PNAs), and morpholinos). In some instances, the lipid nanoparticles are used to deliver nucleic acids such as antisense and/or messenger RNA. Methods for use of such lipid nanoparticles for treatment of various diseases or conditions, such as those caused by infectious entities and/or insufficiency of a protein, are also provided.

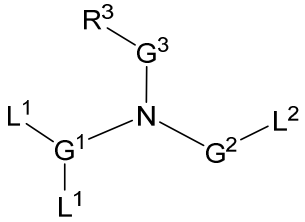
[0005] In one embodiment, provided herein is a compound of Formula (I):



(I),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof, wherein G^1, G^2, G^3, L^1, L^2, and R^3 are as defined herein or elsewhere.

[0006] In one embodiment, provided herein is a compound of Formula (II):



(II),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof, wherein G^1, G^2, G^3, L^1, L^2, and R^3 are as defined herein or elsewhere.

[0007] In one embodiment, provided herein is a nanoparticle composition comprising a compound provided herein, and a therapeutic or prophylactic agent. In one embodiment, the therapeutic or prophylactic agent comprises at least one mRNA encoding an antigen or a fragment or epitope thereof.

[0008] Additional features of the present disclosure will become apparent to those skilled in the art upon consideration of the following detailed description of particular embodiments.

5. DETAILED DESCRIPTION

5.1 *General Techniques*

[0009] Techniques and procedures described or referenced herein include those that are generally well understood and/or commonly employed using conventional methodology by those skilled in the art, such as, for example, the widely utilized methodologies described in Sambrook *et al.*, *Molecular Cloning: A Laboratory Manual* (3d ed. 2001); *Current Protocols in Molecular Biology* (Ausubel *et al.* eds., 2003).

5.2 *Terminology*

[0010] Unless described otherwise, all technical and scientific terms used herein have the same meaning as is commonly understood by one of ordinary skill in the art. For purposes of interpreting this specification, the following description of terms will apply and whenever appropriate, terms used in the singular will also include the plural and *vice versa*. All patents, applications, published applications, and other publications are incorporated by reference in their entirety. In the event that any description of terms set forth conflicts with any document incorporated herein by reference, the description of term set forth below shall control.

[0011] As used herein and unless otherwise specified, the term "lipid" refers to a group of organic compounds that include, but are not limited to, esters of fatty acids and are generally characterized by being poorly soluble in water, but soluble in many nonpolar organic solvents. While lipids generally have poor solubility in water, there are certain categories of lipids (*e.g.*, lipids modified by polar groups, *e.g.*, DMG-PEG2000) that have limited aqueous solubility and can dissolve in water under certain conditions. Known types of lipids include biological molecules such as fatty acids, waxes, sterols, fat-soluble vitamins, monoglycerides, diglycerides, triglycerides, and phospholipids. Lipids can be divided into at least three classes: (1) "simple lipids," which include fats and oils as well as waxes; (2) "compound lipids," which include phospholipids and glycolipids (*e.g.*, DMPE-PEG2000); and (3) "derived lipids" such as steroids. Further, as used herein, lipids also encompass lipidoid compounds. The term "lipidoid compound," also simply "lipidoid", refers to a lipid-like compound (*e.g.* an amphiphilic compound with lipid-like physical properties).

[0012] The term "lipid nanoparticle" or "LNP" refers to a particle having at least one dimension on the order of nanometers (nm) (*e.g.*, 1 to 1,000 nm), which contains one or more

types of lipid molecules. The LNP provided herein can further contain at least one non-lipid payload molecule (*e.g.*, one or more nucleic acid molecules). In some embodiments, the LNP comprises a non-lipid payload molecule either partially or completely encapsulated inside a lipid shell. Particularly, in some embodiments, wherein the payload is a negatively charged molecule (*e.g.*, mRNA encoding a viral protein), and the lipid components of the LNP comprise at least one cationic lipid. Without being bound by the theory, it is contemplated that the cationic lipids can interact with the negatively charged payload molecules and facilitates incorporation and/or encapsulation of the payload into the LNP during LNP formation. Other lipids that can form part of a LNP as provided herein include but are not limited to neutral lipids and charged lipids, such as steroids, polymer conjugated lipids, and various zwitterionic lipids. In certain embodiments, a LNP according to the present disclosure comprises one or more lipids of Formula (I) or (II) (and sub-formulas thereof) as described herein.

[0013] The term "cationic lipid" refers to a lipid that is either positively charged at any pH value or hydrogen ion activity of its environment, or capable of being positively charged in response to the pH value or hydrogen ion activity of its environment (*e.g.*, the environment of its intended use). Thus, the term "cationic" encompasses both "permanently cationic" and "cationisable." In certain embodiments, the positive charge in a cationic lipid results from the presence of a quaternary nitrogen atom. In certain embodiments, the cationic lipid comprises a zwitterionic lipid that assumes a positive charge in the environment of its intended use (*e.g.*, at physiological pH). In certain embodiments, the cationic lipid is one or more lipids of Formula (I) or (II) (and sub-formulas thereof) as described herein.

[0014] The term "polymer conjugated lipid" refers to a molecule comprising both a lipid portion and a polymer portion. An example of a polymer conjugated lipid is a pegylated lipid (PEG-lipid), in which the polymer portion comprises a polyethylene glycol.

[0015] The term "neutral lipid" encompasses any lipid molecules existing in uncharged forms or neutral zwitterionic forms at a selected pH value or within a selected pH range. In some embodiments, the selected useful pH value or range corresponds to the pH condition in an environment of the intended uses of the lipids, such as the physiological pH. As non-limiting examples, neutral lipids that can be used in connection with the present disclosure include, but are not limited to, phosphotidylcholines such as 1,2-distearoyl-sn-glycero-3-phosphocholine (DSPC), 1,2-dipalmitoyl-sn-glycero-3-phosphocholine (DPPC), 1,2-dimyristoyl-sn-glycero-3-phosphocholine (DMPC), 1-palmitoyl-2-oleoyl-sn-glycero-3-

phosphocholine (POPC), 1,2-dioleoyl-sn-glycero-3-phosphocholine (DOPC), phophatidylethanolamines such as 1,2-dioleoyl-sn-glycero-3-phosphoethanolamine (DOPE), 2-((2,3-bis(oleoyloxy)propyl)dimethylammonio)ethyl hydrogen phosphate (DOCP), sphingomyelins (SM), ceramides, steroids such as sterols and their derivatives. Neutral lipids as provided herein may be synthetic or derived (isolated or modified) from a natural source or compound.

[0016] The term "charged lipid" encompasses any lipid molecules that exist in either positively charged or negatively charged forms at a selected pH or within a selected pH range. In some embodiments, the selected pH value or range corresponds to the pH condition in an environment of the intended uses of the lipids, such as the physiological pH. As non-limiting examples, charged lipids that can be used in connection with the present disclosure include, but are not limited to, phosphatidylserines, phosphatidic acids, phosphatidylglycerols, phosphatidylinositols, sterol hemisuccinates, dialkyl trimethylarnmonium-propanes, (*e.g.*, DOTAP, DOTMA), dialkyl dimethylaminopropanes, ethyl phosphocholines, dimethylaminoethane carbamoyl sterols (*e.g.*, DC-Chol), 1,2-dioleoyl-sn-glycero-3-phospho-L-serine sodium salt (DOPS-Na), 1,2-dioleoyl-sn-glycero-3-phospho-(1'-rac-glycerol) sodium salt (DOPG-Na), and 1,2-dioleoyl-sn-glycero-3-phosphate sodium salt (DOPA-Na). Charged lipids as provided herein may be synthetic or derived (isolated or modified) from a natural source or compound.

[0017] As used herein, and unless otherwise specified, the term "alkyl" refers to a straight or branched hydrocarbon chain radical consisting solely of carbon and hydrogen atoms, which is saturated. In one embodiment, the alkyl group has, for example, from one to twenty-four carbon atoms (C_1-C_{24} alkyl), four to twenty carbon atoms (C_4-C_{20} alkyl), six to sixteen carbon atoms (C_6-C_{16} alkyl), six to nine carbon atoms (C_6-C_9 alkyl), one to fifteen carbon atoms (C_1-C_{15} alkyl), one to twelve carbon atoms (C_1-C_{12} alkyl), one to eight carbon atoms (C_1-C_8 alkyl) or one to six carbon atoms (C_1-C_6 alkyl) and which is attached to the rest of the molecule by a single bond. Examples of alkyl groups include, but are not limited to, methyl, ethyl, n-propyl, 1-methylethyl (isopropyl), n-butyl, n-pentyl, 1,1-dimethylethyl (t-butyl), 3-methylhexyl, 2-methylhexyl, and the like. Unless otherwise specified, an alkyl group is optionally substituted.

[0018] As used herein, and unless otherwise specified, the term "alkenyl" refers to a straight or branched hydrocarbon chain radical consisting solely of carbon and hydrogen atoms, which contains one or more carbon-carbon double bonds. The term "alkenyl" also

embraces radicals having "*cis*" and "*trans*" configurations, or alternatively, "E" and "Z" configurations, as appreciated by those of ordinary skill in the art. In one embodiment, the alkenyl group has,, for example, from two to twenty-four carbon atoms (C_2-C_{24} alkenyl), four to twenty carbon atoms (C_4-C_{20} alkenyl), six to sixteen carbon atoms (C_6-C_{16} alkenyl), six to nine carbon atoms (C_6-C_9 alkenyl), two to fifteen carbon atoms (C_2-C_{15} alkenyl), two to twelve carbon atoms (C_2-C_{12} alkenyl), two to eight carbon atoms (C_2-C_8 alkenyl) or two to six carbon atoms (C_2-C_6 alkenyl) and which is attached to the rest of the molecule by a single bond. Examples of alkenyl groups include, but are not limited to, ethenyl, prop-1-enyl, but-1-enyl, pent-1-enyl, penta-1,4-dienyl, and the like. Unless otherwise specified, an alkenyl group is optionally substituted.

[0019] As used herein, and unless otherwise specified, the term "alkynyl" refers to a straight or branched hydrocarbon chain radical consisting solely of carbon and hydrogen atoms, which contains one or more carbon-carbon triple bonds. In one embodiment, the alkynyl group has, for example, from two to twenty-four carbon atoms (C_2-C_{24} alkynyl), four to twenty carbon atoms (C_4-C_{20} alkynyl), six to sixteen carbon atoms (C_6-C_{16} alkynyl), six to nine carbon atoms (C_6-C_9 alkynyl), two to fifteen carbon atoms (C_2-C_{15} alkynyl), two to twelve carbon atoms (C_2-C_{12} alkynyl), two to eight carbon atoms (C_2-C_8 alkynyl) or two to six carbon atoms (C_2-C_6 alkynyl) and which is attached to the rest of the molecule by a single bond. Examples of alkynyl groups include, but are not limited to, ethynyl, propynyl, butynyl, pentynyl, and the like. Unless otherwise specified, an alkynyl group is optionally substituted.

[0020] As used herein, and unless otherwise specified, the term "alkylene" or "alkylene chain" refers to a straight or branched multivalent (*e.g.*, divalent or trivalent) hydrocarbon chain linking the rest of the molecule to a radical group (or groups), consisting solely of carbon and hydrogen, which is saturated. In one embodiment, the alkylene has, for example, from one to twenty-four carbon atoms (C_1-C_{24} alkylene), one to fifteen carbon atoms (C_1-C_{15} alkylene), one to twelve carbon atoms (C_1-C_{12} alkylene), one to eight carbon atoms (C_1-C_8 alkylene), one to six carbon atoms (C_1-C_6 alkylene), two to four carbon atoms (C_2-C_4 alkylene), one to two carbon atoms (C_1-C_2 alkylene). Examples of alkylene groups include, but are not limited to, methylene, ethylene, propylene, n-butylene, and the like. The alkylene chain is attached to the rest of the molecule through a single bond and to the radical group through a single bond. The points of attachment of the alkylene chain to the rest of the molecule and to the radical group(s) can be through one carbon or any two (or more) carbons within the chain. Unless otherwise specified, an alkylene chain is optionally substituted.

[0021] As used herein, and unless otherwise specified, the term "alkenylene" refers to a straight or branched multivalent (*e.g.*, divalent or trivalent) hydrocarbon chain linking the rest of the molecule to a radical group (or groups), consisting solely of carbon and hydrogen, which contains one or more carbon-carbon double bonds. In one embodiment, the alkenylene has, for example, from two to twenty-four carbon atoms (C_2-C_{24} alkenylene), two to fifteen carbon atoms (C_2-C_{15} alkenylene), two to twelve carbon atoms (C_2-C_{12} alkenylene), two to eight carbon atoms (C_2-C_8 alkenylene), two to six carbon atoms (C_2-C_6 alkenylene) or two to four carbon atoms (C_2-C_4 alkenylene). Examples of alkenylene include, but are not limited to, ethenylene, propenylene, n-butenylene, and the like. The alkenylene is attached to the rest of the molecule through a single or double bond and to the radical group through a single or double bond. The points of attachment of the alkenylene to the rest of the molecule and to the radical group(s) can be through one carbon or any two (or more) carbons within the chain. Unless otherwise specified, an alkenylene is optionally substituted.

[0022] As used herein, and unless otherwise specified, the term "cycloalkyl" refers to a non-aromatic monocyclic or polycyclic hydrocarbon radical consisting solely of carbon and hydrogen atoms, and which is saturated. Cycloalkyl group may include fused or bridged ring systems. In one embodiment, the cycloalkyl has, for example, from 3 to 15 ring carbon atoms (C_3-C_{15} cycloalkyl), from 3 to 10 ring carbon atoms (C_3-C_{10} cycloalkyl), or from 3 to 8 ring carbon atoms (C_3-C_8 cycloalkyl). The cycloalkyl is attached to the rest of the molecule by a single bond. Examples of monocyclic cycloalkyl radicals include, but are not limited to, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, and cyclooctyl. Examples of polycyclic cycloalkyl radicals include, but are not limited to, adamantyl, norbornyl, decalinyl, 7,7-dimethyl-bicyclo[2.2.1]heptanyl, bicyclo[1.1.1]pentyl and the like. Unless otherwise specified, a cycloalkyl group is optionally substituted.

[0023] As used herein, and unless otherwise specified, the term "cycloalkylene" is a multivalent (*e.g.*, divalent or trivalent) cycloalkyl group. Unless otherwise specified, a cycloalkylene group is optionally substituted.

[0024] As used herein, and unless otherwise specified, the term "cycloalkenyl" refers to a non-aromatic monocyclic or polycyclic hydrocarbon radical consisting solely of carbon and hydrogen atoms, and which includes one or more carbon-carbon double bonds. Cycloalkenyl may include fused or bridged ring systems. In one embodiment, the cycloalkenyl has, for example, from 3 to 15 ring carbon atoms (C_3-C_{15} cycloalkenyl), from 3 to 10 ring carbon atoms (C_3-C_{10} cycloalkenyl), or from 3 to 8 ring carbon atoms (C_3-C_8 cycloalkenyl). The

cycloalkenyl is attached to the rest of the molecule by a single bond. Examples of monocyclic cycloalkenyl radicals include, but are not limited to, cyclopropenyl, cyclobutenyl, cyclopentenyl, cyclohexenyl, cycloheptenyl, cyclooctenyl, and the like. Unless otherwise specified, a cycloalkenyl group is optionally substituted.

[0025] As used herein, and unless otherwise specified, the term "cycloalkenylene" is a multivalent (*e.g.*, divalent or trivalent) cycloalkenyl group. Unless otherwise specified, a cycloalkenylene group is optionally substituted.

[0026] As used herein, and unless otherwise specified, the term "heterocyclyl" refers to a non-aromatic radical monocyclic or polycyclic moiety that contains one or more (*e.g.*, one, one or two, one to three, or one to four) heteroatoms independently selected from nitrogen, oxygen, phosphorous, and sulfur. The heterocyclyl may be attached to the main structure at any heteroatom or carbon atom. A heterocyclyl group can be a monocyclic, bicyclic, tricyclic, tetracyclic, or other polycyclic ring system, wherein the polycyclic ring systems can be a fused, bridged or spiro ring system. Heterocyclyl polycyclic ring systems can include one or more heteroatoms in one or more rings. A heterocyclyl group can be saturated or partially unsaturated. Saturated heterocycloalkyl groups can be termed "heterocycloalkyl". Partially unsaturated heterocycloalkyl groups can be termed "heterocycloalkenyl" if the heterocyclyl contains at least one double bond, or "heterocycloalkynyl" if the heterocyclyl contains at least one triple bond. In one embodiment, the heterocyclyl has, for example, 3 to 18 ring atoms (3- to 18-membered heterocyclyl), 4 to 18 ring atoms (4- to 18-membered heterocyclyl), 5 to 18 ring atoms (3- to 18-membered heterocyclyl), 4 to 8 ring atoms (4- to 8-membered heterocyclyl), or 5 to 8 ring atoms (5- to 8-membered heterocyclyl). Whenever it appears herein, a numerical range such as "3 to 18" refers to each integer in the given range; *e.g.*, "3 to 18 ring atoms" means that the heterocyclyl group can consist of 3 ring atoms, 4 ring atoms, 5 ring atoms, 6 ring atoms, 7 ring atoms, 8 ring atoms, 9 ring atoms, 10 ring atoms, etc., up to and including 18 ring atoms. Examples of heterocyclyl groups include, but are not limited to, imidazolyl, imidazolidinyl, oxazolyl, oxazolidinyl, thiazolyl, thiazolidinyl, pyrazolidinyl, pyrazolyl, isoxazolidinyl, isoxazolyl, isothiazolidinyl, isothiazolyl, morpholinyl, pyrrolyl, pyrrolidinyl, furyl, tetrahydrofuryl, thiophenyl, pyridinyl, piperidinyl, quinolyl, and isoquinolyl. Unless otherwise specified, a heterocyclyl group is optionally substituted.

[0027] As used herein, and unless otherwise specified, the term "heterocyclylene" is a multivalent (*e.g.*, divalent or trivalent) heterocyclyl group. Unless otherwise specified, a heterocyclylene group is optionally substituted.

[0028] As used herein, and unless otherwise specified, the term "aryl" refers to a monocyclic aromatic group and/or multicyclic monovalent aromatic group that contain at least one aromatic hydrocarbon ring. In certain embodiments, the aryl has from 6 to 18 ring carbon atoms (C_6-C_{18} aryl), from 6 to 14 ring carbon atoms (C_6-C_{14} aryl), or from 6 to 10 ring carbon atoms (C_6-C_{10} aryl). Examples of aryl groups include, but are not limited to, phenyl, naphthyl, fluorenyl, azulenyl, anthryl, phenanthryl, pyrenyl, biphenyl, and terphenyl. The term "aryl" also refers to bicyclic, tricyclic, or other multicyclic hydrocarbon rings, where at least one of the rings is aromatic and the others of which may be saturated, partially unsaturated, or aromatic, for example, dihydronaphthyl, indenyl, indanyl, or tetrahydronaphthyl (tetralinyl). Unless otherwise specified, an aryl group is optionally substituted.

[0029] As used herein, and unless otherwise specified, the term "arylene" is a multivalent (*e.g.*, divalent or trivalent) aryl group. Unless otherwise specified, an arylene group is optionally substituted.

[0030] As used herein, and unless otherwise specified, the term "heteroaryl" refers to a monocyclic aromatic group and/or multicyclic aromatic group that contains at least one aromatic ring, wherein at least one aromatic ring contains one or more (*e.g.*, one, one or two, one to three, or one to four) heteroatoms independently selected from O, S, and N. The heteroaryl may be attached to the main structure at any heteroatom or carbon atom. In certain embodiments, the heteroaryl has from 5 to 20, from 5 to 15, or from 5 to 10 ring atoms. The term "heteroaryl" also refers to bicyclic, tricyclic, or other multicyclic rings, where at least one of the rings is aromatic and the others of which may be saturated, partially unsaturated, or aromatic, wherein at least one aromatic ring contains one or more heteroatoms independently selected from O, S, and N. Examples of monocyclic heteroaryl groups include, but are not limited to, pyrrolyl, pyrazolyl, pyrazolinyl, imidazolyl, oxazolyl, isoxazolyl, thiazolyl, thiadiazolyl, isothiazolyl, furanyl, thienyl, oxadiazolyl, pyridyl, pyrazinyl, pyrimidinyl, pyridazinyl, and triazinyl. Examples of bicyclic heteroaryl groups include, but are not limited to, indolyl, benzothiazolyl, benzoxazolyl, benzothienyl, quinolinyl, tetrahydroisoquinolinyl, isoquinolinyl, benzimidazolyl, benzopyranyl, indolizinyl, benzofuranyl, isobenzofuranyl, chromonyl, coumarinyl, cinnolinyl, quinoxalinyl, indazolyl, purinyl, pyrrolopyridinyl,

furopyridinyl, thienopyridinyl, dihydroisoindolyl, and tetrahydroquinolinyl. Examples of tricyclic heteroaryl groups include, but are not limited to, carbazolyl, benzindolyl, phenanthrollinyl, acridinyl, phenanthridinyl, and xanthenyl. Unless otherwise specified, a heteroaryl group is optionally substituted.

[0031] As used herein, and unless otherwise specified, the term "heteroarylene" is a multivalent (*e.g.*, divalent or trivalent) heteroaryl group. Unless otherwise specified, a heteroarylene group is optionally substituted.

[0032] When the groups described herein are said to be "substituted," they may be substituted with any appropriate substituent or substituents. Illustrative examples of substituents include, but are not limited to, those found in the exemplary compounds and embodiments provided herein, as well as: a halogen atom such as F, CI, Br, or I; cyano; oxo (=O); hydroxyl (-OH); alkyl; alkenyl; alkynyl; cycloalkyl; aryl; -(C=O)OR'; -O(C=O)R'; -C(=O)R'; -OR'; -$S(O)_x$R'; -S-SR'; -C(=O)SR'; -SC(=O)R'; -NR'R'; -NR'C(=O)R'; -C(=O)NR'R'; -NR'C(=O)NR'R'; -OC(=O)NR'R'; -NR'C(=O)OR'; -NR'$S(O)_x$NR'R'; -NR'$S(O)_x$R'; and -$S(O)_x$NR'R', wherein: R' is, at each occurrence, independently H, C_1-C_{15} alkyl or cycloalkyl, and x is 0, 1 or 2. In some embodiments the substituent is a C_1-C_{12} alkyl group. In other embodiments, the substituent is a cycloalkyl group. In other embodiments, the substituent is a halo group, such as fluoro. In other embodiments, the substituent is an oxo group. In other embodiments, the substituent is a hydroxyl group. In other embodiments, the substituent is an alkoxy group (-OR'). In other embodiments, the substituent is a carboxyl group. In other embodiments, the substituent is an amino group (-NR'R').

[0033] As used herein, and unless otherwise specified, the term "optional" or "optionally" (*e.g.*, optionally substituted) means that the subsequently described event of circumstances may or may not occur, and that the description includes instances where said event or circumstance occurs and instances in which it does not. For example, "optionally substituted alkyl" means that the alkyl radical may or may not be substituted and that the description includes both substituted alkyl radicals and alkyl radicals having no substitution.

[0034] As used herein, and unless otherwise specified, the term "prodrug" of a biologically active compound refers to a compound that may be converted under physiological conditions or by solvolysis to the biologically active compound. In one embodiment, the term "prodrug" refers to a metabolic precursor of the biologically active

compound that is pharmaceutically acceptable. A prodrug may be inactive when administered to a subject in need thereof, but is converted *in vivo* to the biologically active compound. Prodrugs are typically rapidly transformed *in vivo* to yield the parent biologically active compound, for example, by hydrolysis in blood. The prodrug compound often offers advantages of solubility, tissue compatibility or delayed release in a mammalian organism (see, Bundgard, H., Design of Prodrugs (1985), pp. 7-9, 21-24 (Elsevier, Amsterdam)). A discussion of prodrugs is provided in Higuchi, T., et al., A.C.S. Symposium Series, Vol. 14, and in Bioreversible Carriers in Drug Design, Ed. Edward B. Roche, American Pharmaceutical Association and Pergamon Press, 1987.

[0035] In one embodiment, the term "prodrug" is also meant to include any covalently bonded carriers, which release the active compound *in vivo* when such prodrug is administered to a mammalian subject. Prodrugs of a compound may be prepared by modifying functional groups present in the compound in such a way that the modifications are cleaved, either in routine manipulation or *in vivo*, to the parent compound. Prodrugs include compounds wherein a hydroxyl, amino or mercapto group is bonded to any group that, when the prodrug of the compound is administered to a mammalian subject, cleaves to form a free hydroxyl, free amino or free mercapto group, respectively.

[0036] Examples of prodrugs include, but are not limited to, acetate, formate and benzoate derivatives of alcohol or amide derivatives of amine functional groups in the compounds provided herein.

[0037] As used herein, and unless otherwise specified, the term "pharmaceutically acceptable salt" includes both acid and base addition salts.

[0038] Examples of pharmaceutically acceptable acid addition salts include, but are not limited to, hydrochloric acid, hydrobromic acid, sulfuric acid, nitric acid, phosphoric acid and the like, and organic acids such as, but not limited to, acetic acid, 2,2-dichloroacetic acid, adipic acid, alginic acid, ascorbic acid, aspartic acid, benzenesulfonic acid, benzoic acid, 4-acetamidobenzoic acid, camphoric acid, camphor-10-sulfonic acid, capric acid, caproic acid, caprylic acid, carbonic acid, cinnamic acid, citric acid, cyclamic acid, dodecylsulfuric acid, ethane-1,2-disulfonic acid, ethanesulfonic acid, 2-hydroxyethanesulfonic acid, formic acid, fumaric acid, galactaric acid, gentisic acid, glucoheptonic acid, gluconic acid, glucuronic acid, glutamic acid, glutaric acid, 2-oxo-glutaric acid, glycerophosphoric acid, glycolic acid, hippuric acid, isobutyric acid, lactic acid, lactobionic acid, lauric acid, maleic acid, malic

acid, malonic acid, mandelic acid, methanesulfonic acid, mucic acid, naphthalene-1,5-disulfonic acid, naphthalene-2-sulfonic acid, 1-hydroxy-2-naphthoic acid, nicotinic acid, oleic acid, orotic acid, oxalic acid, palmitic acid, pamoic acid, propionic acid, pyroglutamic acid, pyruvic acid, salicylic acid, 4-aminosalicylic acid, sebacic acid, stearic acid, succinic acid, tartaric acid, thiocyanic acid, p-toluenesulfonic acid, trifluoroacetic acid, undecylenic acid, and the like.

[0039] Examples of pharmaceutically acceptable base addition salt include, but are not limited to, salts prepared from addition of an inorganic base or an organic base to a free acid compound. Salts derived from inorganic bases include, but are not limited to, the sodium, potassium, lithium, ammonium, calcium, magnesium, iron, zinc, copper, manganese, aluminum salts and the like. In one embodiment, the inorganic salts are the ammonium, sodium, potassium, calcium, and magnesium salts. Salts derived from organic bases include, but are not limited to, salts of primary, secondary, and tertiary amines, substituted amines including naturally occurring substituted amines, cyclic amines and basic ion exchange resins, such as ammonia, isopropylamine, trimethylamine, diethylamine, triethylamine, tripropylamine, diethanolamine, ethanolamine, deanol, 2-dimethylaminoethanol, 2-diethylaminoethanol, dicyclohexylamine, lysine, arginine, histidine, caffeine, procaine, hydrabamine, choline, betaine, benethamine, benzathine, ethylenediamine, glucosamine, methylglucamine, theobromine, triethanolamine, tromethamine, purines, piperazine, piperidine, N-ethylpiperidine, polyamine resins and the like. In one embodiment, the organic bases are isopropylamine, diethylamine, ethanolamine, trimethylamine, dicyclohexylamine, choline and caffeine.

[0040] A compound provided herein may contain one or more asymmetric centers and may thus give rise to enantiomers, diastereomers, and other stereoisomeric forms that may be defined, in terms of absolute stereochemistry, as (R)- or (S)- or, as (D)- or (L)- for amino acids. Unless otherwise specified, a compound provided herein is meant to include all such possible isomers, as well as their racemic and optically pure forms. Optically active (+) and (-), (R)- and (S)-, or (D)- and (L)- isomers may be prepared using chiral synthons or chiral reagents, or resolved using conventional techniques, for example, chromatography and fractional crystallization. Conventional techniques for the preparation/isolation of individual enantiomers include chiral synthesis from a suitable optically pure precursor or resolution of the racemate (or the racemate of a salt or derivative) using, for example, chiral high pressure liquid chromatography (HPLC). When the compounds described herein contain olefinic

double bonds or other centers of geometric asymmetry, and unless specified otherwise, it is intended that the compounds include both E and Z geometric isomers. Likewise, all tautomeric forms are also intended to be included.

[0041] As used herein, and unless otherwise specified, the term "isomer" refers to different compounds that have the same molecular formula. "Stereoisomers" are isomers that differ only in the way the atoms are arranged in space. "Atropisomers" are stereoisomers from hindered rotation about single bonds. "Enantiomers" are a pair of stereoisomers that are non-superimposable mirror images of each other. A mixture of a pair of enantiomers in any proportion can be known as a "racemic" mixture. "Diastereoisomers" are stereoisomers that have at least two asymmetric atoms, but which are not mirror-images of each other.

[0042] "Stereoisomers" can also include E and Z isomers, or a mixture thereof, and cis and trans isomers or a mixture thereof. In certain embodiments, a compound described herein is isolated as either the E or Z isomer. In other embodiments, a compound described herein is a mixture of the E and Z isomers.

[0043] "Tautomers" refers to isomeric forms of a compound that are in equilibrium with each other. The concentrations of the isomeric forms will depend on the environment the compound is found in and may be different depending upon, for example, whether the compound is a solid or is in an organic or aqueous solution.

[0044] It should also be noted a compound described herein can contain unnatural proportions of atomic isotopes at one or more of the atoms. For example, the compounds may be radiolabeled with radioactive isotopes, such as for example tritium (^{3}H), iodine-125 (^{125}I), sulfur-35 (^{35}S), or carbon-14 (^{14}C), or may be isotopically enriched, such as with deuterium (^{2}H), carbon-13 (^{13}C), or nitrogen-15 (^{15}N). As used herein, an "isotopolog" is an isotopically enriched compound. The term "isotopically enriched" refers to an atom having an isotopic composition other than the natural isotopic composition of that atom. "Isotopically enriched" may also refer to a compound containing at least one atom having an isotopic composition other than the natural isotopic composition of that atom. The term "isotopic composition" refers to the amount of each isotope present for a given atom. Radiolabeled and isotopically enriched compounds are useful as therapeutic agents, *e.g.*, cancer therapeutic agents, research reagents, *e.g.*, binding assay reagents, and diagnostic agents, *e.g.*, in vivo imaging agents. All isotopic variations of a compound described herein, whether radioactive or not, are intended to be encompassed within the scope of the

embodiments provided herein. In some embodiments, there are provided isotopologs of a compound described herein, for example, the isotopologs are deuterium, carbon-13, and/or nitrogen-15 enriched. As used herein, "deuterated", means a compound wherein at least one hydrogen (H) has been replaced by deuterium (indicated by D or ^{2}H), that is, the compound is enriched in deuterium in at least one position.

[0045] It should be noted that if there is a discrepancy between a depicted structure and a name for that structure, the depicted structure is to be accorded more weight.

[0046] As used herein, and unless otherwise specified, the term "pharmaceutically acceptable carrier, diluent or excipient" includes without limitation any adjuvant, carrier, excipient, glidant, sweetening agent, diluent, preservative, dye/colorant, flavor enhancer, surfactant, wetting agent, dispersing agent, suspending agent, stabilizer, isotonic agent, solvent, or emulsifier which has been approved by the United States Food and Drug Administration as being acceptable for use in humans or domestic animals.

[0047] The term "composition" is intended to encompass a product containing the specified ingredients (*e.g.*, a mRNA molecule provided herein) in, optionally, the specified amounts.

[0048] The term "polynucleotide" or "nucleic acid," as used interchangeably herein, refers to polymers of nucleotides of any length and includes, *e.g.*, DNA and RNA. The nucleotides can be deoxyribonucleotides, ribonucleotides, modified nucleotides or bases, and/or their analogs, or any substrate that can be incorporated into a polymer by DNA or RNA polymerase or by a synthetic reaction. A polynucleotide may comprise modified nucleotides, such as methylated nucleotides and their analogs. Nucleic acid can be in either single- or double-stranded forms. As used herein and unless otherwise specified, "nucleic acid" also includes nucleic acid mimics such as locked nucleic acids (LNAs), peptide nucleic acids (PNAs), and morpholinos. "Oligonucleotide," as used herein, refers to short synthetic polynucleotides that are generally, but not necessarily, fewer than about 200 nucleotides in length. The terms "oligonucleotide" and "polynucleotide" are not mutually exclusive. The description above for polynucleotides is equally and fully applicable to oligonucleotides. Unless specified otherwise, the left-hand end of any single-stranded polynucleotide sequence disclosed herein is the 5' end; the left-hand direction of double-stranded polynucleotide sequences is referred to as the 5' direction. The direction of 5' to 3' addition of nascent RNA transcripts is referred to as the transcription direction; sequence regions on the DNA strand

having the same sequence as the RNA transcript that are 5' to the 5' end of the RNA transcript are referred to as "upstream sequences"; sequence regions on the DNA strand having the same sequence as the RNA transcript that are 3' to the 3' end of the RNA transcript are referred to as "downstream sequences."

[0049] An "isolated nucleic acid" is a nucleic acid, for example, an RNA, DNA, or a mixed nucleic acids, which is substantially separated from other genome DNA sequences as well as proteins or complexes such as ribosomes and polymerases, which naturally accompany a native sequence. An "isolated" nucleic acid molecule is one which is separated from other nucleic acid molecules which are present in the natural source of the nucleic acid molecule. Moreover, an "isolated" nucleic acid molecule, such as an mRNA molecule, can be substantially free of other cellular material, or culture medium when produced by recombinant techniques, or substantially free of chemical precursors or other chemicals when chemically synthesized. In a specific embodiment, one or more nucleic acid molecules encoding an antigen as described herein are isolated or purified. The term embraces nucleic acid sequences that have been removed from their naturally occurring environment, and includes recombinant or cloned DNA or RNA isolates and chemically synthesized analogues or analogues biologically synthesized by heterologous systems. A substantially pure molecule may include isolated forms of the molecule.

[0050] The term "encoding nucleic acid" or grammatical equivalents thereof as it is used in reference to nucleic acid molecule encompasses (a) a nucleic acid molecule in its native state or when manipulated by methods well known to those skilled in the art that can be transcribed to produce mRNA which is then translated into a peptide and/or polypeptide, and (b) the mRNA molecule itself. The antisense strand is the complement of such a nucleic acid molecule, and the encoding sequence can be deduced therefrom. The term "coding region" refers to a portion in an encoding nucleic acid sequence that is translated into a peptide or polypeptide. The term "untranslated region" or "UTR" refers to the portion of an encoding nucleic acid that is not translated into a peptide or polypeptide. Depending on the orientation of a UTR with respect to the coding region of a nucleic acid molecule, a UTR is referred to as the 5'-UTR if located to the 5'-end of a coding region, and a UTR is referred to as the 3'-UTR if located to the 3'-end of a coding region.

[0051] The term "mRNA" as used herein refers to a message RNA molecule comprising one or more open reading frame (ORF) that can be translated by a cell or an organism provided with the mRNA to produce one or more peptide or protein product. The region

containing the one or more ORFs is referred to as the coding region of the mRNA molecule. In certain embodiments, the mRNA molecule further comprises one or more untranslated regions (UTRs).

[0052] In certain embodiments, the mRNA is a monocistronic mRNA that comprises only one ORF. In certain embodiments, the monocistronic mRNA encodes a peptide or protein comprising at least one epitope of a selected antigen (*e.g.*, a pathogenic antigen or a tumor associated antigen). In other embodiments, the mRNA is a multicistronic mRNA that comprises two or more ORFs. In certain embodiments, the multiecistronic mRNA encodes two or more peptides or proteins that can be the same or different from each other. In certain embodiments, each peptide or protein encoded by a multicistronic mRNA comprises at least one epitope of a selected antigen. In certain embodiments, different peptide or protein encoded by a multicistronic mRNA each comprises at least one epitope of different antigens. In any of the embodiments described herein, the at least one epitope can be at least 2, at least 3, at least 4, at least 5, at least 6, at least 7, at least 8, at least 9, or at least 10 epitopes of an antigen.

[0053] The term "nucleobases" encompasses purines and pyrimidines, including natural compounds adenine, thymine, guanine, cytosine, uracil, inosine, and natural or synthetic analogs or derivatives thereof.

[0054] The term "functional nucleotide analog" as used herein refers to a modified version of a canonical nucleotide A, G, C, U or T that (a) retains the base-pairing properties of the corresponding canonical nucleotide, and (b) contains at least one chemical modification to (i) the nucleobase, (ii) the sugar group, (iii) the phosphate group, or (iv) any combinations of (i) to (iii), of the corresponding natural nucleotide. As used herein, base pairing encompasses not only the canonical Watson-Crick adenine-thymine, adenine-uracil, or guanine-cytosine base pairs, but also base pairs formed between canonical nucleotides and functional nucleotide analogs or between a pair of functional nucleotide analogs, wherein the arrangement of hydrogen bond donors and hydrogen bond acceptors permits hydrogen bonding between a modified nucleobase and a canonical nucleobase or between two complementary modified nucleobase structures. For example, a functional analog of guanosine (G) retains the ability to base-pair with cytosine (C) or a functional analog of cytosine. One example of such non-canonical base pairing is the base pairing between the modified nucleotide inosine and adenine, cytosine, or uracil. As described herein, a functional nucleotide analog can be either naturally occurring or non-naturally occurring.

Accordingly, a nucleic acid molecule containing a functional nucleotide analog can have at least one modified nucleobase, sugar group and/or internucleoside linkage. Exemplary chemical modifications to the nucleobases, sugar groups, or internucleoside linkages of a nucleic acid molecule are provided herein.

[0055] The terms "translational enhancer element," "TEE" and "translational enhancers" as used herein refers to an region in a nucleic acid molecule that functions to promotes translation of a coding sequence of the nucleic acid into a protein or peptide product, such as via cap-dependent or cap-independent translation. A TEE typically locates in the UTR region of a nucleic acid molecule (*e.g.*, mRNA) and enhance the translational level of a coding sequence located either upstream or downstream. For example, a TEE in a 5'-UTR of a nucleic acid molecule can locate between the promoter and the starting codon of the nucleic acid molecule. Various TEE sequences are known in the art (Wellensiek *et al*. Genome-wide profiling of human cap-independent translation-enhancing elements, *Nature Methods*, 2013 Aug; 10(8): 747–750; Chappell *et al.* PNAS June 29, 2004 101 (26) 9590-9594). Some TEEs are known to be conserved across multiple species (Pánek *et al. Nucleic Acids Research*, Volume 41, Issue 16, 1 September 2013, Pages 7625–7634).

[0056] As used herein, the term "stem-loop sequence" refers to a single-stranded polynucleotide sequence having at least two regions that are complementary or substantially complementary to each other when read in opposite directions, and thus capable of base-pairing with each other to form at least one double helix and an unpaired loop. The resulting structure is known as a stem-loop structure, a hairpin, or a hairpin loop, which is a secondary structure found in many RNA molecules.

[0057] The term "peptide" as used herein refers to a polymer containing between two and fifty (2-50) amino acid residues linked by one or more covalent peptide bond(s). The terms apply to naturally occurring amino acid polymers as well as amino acid polymers in which one or more amino acid residues is a non-naturally occurring amino acid (*e.g.*, an amino acid analog or non-natural amino acid).

[0058] The terms "polypeptide" and "protein" are used interchangeably herein to refer to a polymer of greater than fifty (50) amino acid residues linked by covalent peptide bonds. That is, a description directed to a polypeptide applies equally to a description of a protein, and *vice versa*. The terms apply to naturally occurring amino acid polymers as well as amino acid polymers in which one or more amino acid residues is a non-naturally occurring amino

acid (*e.g.*, an amino acid analog). As used herein, the terms encompass amino acid chains of any length, including full length proteins (*e.g.*, antigens).

[0059] The term "antigen" refers to a substance that can be recognized by the immune system of a subject (including by the adaptive immune system), and is capable of triggering an immune response after the subject is contacted with the antigen (including an antigen-specific immune response). In certain embodiments, the antigen is a protein associated with a diseased cell, such as a cell infected by a pathogen or a neoplastic cell (*e.g.*, tumor associated antigen (TAA)).

[0060] In the context of a peptide or polypeptide, the term "fragment" as used herein refers to a peptide or polypeptide that comprises less than the full length amino acid sequence. Such a fragment may arise, for example, from a truncation at the amino terminus, a truncation at the carboxy terminus, and/or an internal deletion of a residue(s) from the amino acid sequence. Fragments may, for example, result from alternative RNA splicing or from *in vivo* protease activity. In certain embodiments, fragments refers to polypeptides comprising an amino acid sequence of at least 5 contiguous amino acid residues, at least 10 contiguous amino acid residues, at least 15 contiguous amino acid residues, at least 20 contiguous amino acid residues, at least 25 contiguous amino acid residues, at least 30 contiguous amino acid residues, at least 40 contiguous amino acid residues, at least 50 contiguous amino acid residues, at least 60 contiguous amino residues, at least 70 contiguous amino acid residues, at least 80 contiguous amino acid residues, at least 90 contiguous amino acid residues, at least contiguous 100 amino acid residues, at least 125 contiguous amino acid residues, at least 150 contiguous amino acid residues, at least 175 contiguous amino acid residues, at least 200 contiguous amino acid residues, at least 250, at least 300, at least 350, at least 400, at least 450, at least 500, at least 550, at least 600, at least 650, at least 700, at least 750, at least 800, at least 850, at least 900, or at least 950 contiguous amino acid residues of the amino acid sequence of a polypeptide. In a specific embodiment, a fragment of a polypeptide retains at least 1, at least 2, at least 3, or more functions of the polypeptide.

[0061] An "epitope" is the site on the surface of an antigen molecule to which a single antibody molecule binds, such as a localized region on the surface of an antigen that is capable of being bound to one or more antigen binding regions of an antibody, and that has antigenic or immunogenic activity in an animal, such as a mammal (*e.g.*, a human), that is capable of eliciting an immune response. An epitope having immunogenic activity is a portion of a polypeptide that elicits an antibody response in an animal. An epitope having

antigenic activity is a portion of a polypeptide to which an antibody binds as determined by any method well known in the art, including, for example, by an immunoassay. Antigenic epitopes need not necessarily be immunogenic. Epitopes often consist of chemically active surface groupings of molecules such as amino acids or sugar side chains and have specific three dimensional structural characteristics as well as specific charge characteristics. Antibody epitopes may be linear epitopes or conformational epitopes. Linear epitopes are formed by a continuous sequence of amino acids in a protein. Conformational epitopes are formed of amino acids that are discontinuous in the protein sequence, but which are brought together upon folding of the protein into its three-dimensional structure. Induced epitopes are formed when the three dimensional structure of the protein is in an altered conformation, such as following activation or binding of another protein or ligand. In certain embodiments, an epitope is a three-dimensional surface feature of a polypeptide. In other embodiments, an epitope is linear feature of a polypeptide. Generally an antigen has several or many different epitopes and may react with many different antibodies.

[0062] The term "genetic vaccine" as used herein refers to a therapeutic or prophylactic composition comprising at least one nucleic acid molecule encoding an antigen associated with a target disease (*e.g.*, an infectious disease or a neoplastic disease). Administration of the vaccine to a subject ("vaccination") allows for the production of the encoded peptide or protein, thereby eliciting an immune response against the target disease in the subject. In certain embodiments, the immune response comprises adaptive immune response, such as the production of antibodies against the encoded antigen, and/or activation and proliferations of immune cells capable of specifically eliminating diseased cells expressing the antigen. In certain embodiments, the immune response further comprises innate immune response. According to the present disclosure, a vaccine can be administered to a subject either before or after the onset of clinical symptoms of the target disease. In some embodiments, vaccination of a healthy or asymptomatic subject renders the vaccinated subject immune or less susceptible to the development of the target disease. In some embodiments, vaccination of a subject showing symptoms of the disease improves the condition of, or treats, the disease in the vaccinated subject.

[0063] The terms "innate immune response" and "innate immunity" are recognized in the art, and refer to non-specific defense mechanism a body's immune system initiates upon recognition of pathogen-associated molecular patterns, which involves different forms of cellular activities, including cytokine production and cell death through various pathways.

As used herein, innate immune responses include, without limitation, increased production of inflammation cytokines (*e.g.*, type I interferon or IL-10 production), activation of the NFκB pathway, increased proliferation, maturation, differentiation and/or survival of immune cells, and in some cases, induction of cell apoptosis. Activation of the innate immunity can be detected using methods known in the art, such as measuring the (NF)-κB activation.

[0064] The terms "adaptive immune response" and "adaptive immunity" are recognized in the art, and refer to antigen-specific defense mechanism a body's immune system initiates upon recognition of a specific antigen, which include both humoral response and cell-mediated responses. As used herein, adaptive immune responses include cellular responses that is triggered and/or augmented by a vaccine composition, such as a genetic composition described herein. In some embodiments, the vaccine composition comprises an antigen that is the target of the antigen-specific adaptive immune response. In other embodiments, the vaccine composition, upon administration, allows the production in an immunized subject of an antigen that is the target of the antigen-specific adaptive immune response. Activation of an adaptive immune response can be detected using methods known in the art, such as measuring the antigen-specific antibody production, or the level of antigen-specific cell-mediated cytotoxicity.

[0065] The term "antibody" is intended to include a polypeptide product of B cells within the immunoglobulin class of polypeptides that is able to bind to a specific molecular antigen and is composed of two identical pairs of polypeptide chains, wherein each pair has one heavy chain (about 50-70 kDa) and one light chain (about 25 kDa), each amino-terminal portion of each chain includes a variable region of about 100 to about 130 or more amino acids, and each carboxy-terminal portion of each chain includes a constant region. *See, e.g.*, *Antibody Engineering* (Borrebaeck ed., 2d ed. 1995); and Kuby, *Immunology* (3d ed. 1997). In specific embodiments, the specific molecular antigen can be bound by an antibody provided herein, including a polypeptide, a fragment or an epitope thereof. Antibodies also include, but are not limited to, synthetic antibodies, recombinantly produced antibodies, camelized antibodies, intrabodies, anti-idiotypic (anti-Id) antibodies, and functional fragments of any of the above, which refers to a portion of an antibody heavy or light chain polypeptide that retains some or all of the binding activity of the antibody from which the fragment was derived. Non-limiting examples of functional fragments include single-chain Fvs (scFv) (*e.g.*, including monospecific, bispecific, *etc.*), Fab fragments, F(ab') fragments, $F(ab)_2$ fragments, $F(ab')_2$ fragments, disulfide-linked Fvs (dsFv), Fd fragments, Fv fragments,

diabody, triabody, tetrabody, and minibody. In particular, antibodies provided herein include immunoglobulin molecules and immunologically active portions of immunoglobulin molecules, for example, antigen-binding domains or molecules that contain an antigen-binding site (*e.g.*, one or more CDRs of an antibody). Such antibody fragments can be found in, for example, Harlow and Lane, *Antibodies: A Laboratory Manual* (1989); *Mol. Biology and Biotechnology: A Comprehensive Desk Reference* (Myers ed., 1995); Huston *et al.*, 1993, Cell Biophysics 22:189-224; Plückthun and Skerra, 1989, Meth. Enzymol. 178:497-515; and Day, *Advanced Immunochemistry* (2d ed. 1990). The antibodies provided herein can be of any class (*e.g.*, IgG, IgE, IgM, IgD, and IgA) or any subclass (*e.g.*, IgG1, IgG2, IgG3, IgG4, IgA1, and IgA2) of immunoglobulin molecule.

[0066] The term "administer" or "administration" refers to the act of injecting or otherwise physically delivering a substance as it exists outside the body (*e.g.*, a lipid nanoparticle composition as described herein) into a patient, such as by mucosal, intradermal, intravenous, intramuscular delivery, and/or any other method of physical delivery described herein or known in the art. When a disease, disorder, condition, or a symptom thereof, is being treated, administration of the substance typically occurs after the onset of the disease, disorder, condition, or symptoms thereof. When a disease, disorder, condition, or symptoms thereof, are being prevented, administration of the substance typically occurs before the onset of the disease, disorder, condition, or symptoms thereof.

[0067] "Chronic" administration refers to administration of the agent(s) in a continuous mode (*e.g.*, for a period of time such as days, weeks, months, or years) as opposed to an acute mode, so as to maintain the initial therapeutic effect (activity) for an extended period of time. "Intermittent" administration is treatment that is not consecutively done without interruption, but rather is cyclic in nature.

[0068] The term "targeted delivery" or the verb form "target" as used herein refers to the process that promotes the arrival of a delivered agent (such as a therapeutic payload molecule in a lipid nanoparticle composition as described herein) at a specific organ, tissue, cell and/or intracellular compartment (referred to as the targeted location) more than any other organ, tissue, cell or intracellular compartment (referred to as the non-target location). Targeted delivery can be detected using methods known in the art, for example, by comparing the concentration of the delivered agent in a targeted cell population with the concentration of the delivered agent at a non-target cell population after systemic administration. In certain

embodiments, targeted delivery results in at least 2 fold higher concentration at a targeted location as compared to a non-target location.

[0069] An "effective amount" is generally an amount sufficient to reduce the severity and/or frequency of symptoms, eliminate the symptoms and/or underlying cause, prevent the occurrence of symptoms and/or their underlying cause, and/or improve or remediate the damage that results from or is associated with a disease, disorder, or condition, including, for example, infection and neoplasia. In some embodiments, the effective amount is a therapeutically effective amount or a prophylactically effective amount.

[0070] The term "therapeutically effective amount" as used herein refers to the amount of an agent (*e.g.*, a vaccine composition) that is sufficient to reduce and/or ameliorate the severity and/or duration of a given disease, disorder, or condition, and/or a symptom related thereto (*e.g.*, an infectious disease such as caused by viral infection, or a neoplastic disease such as cancer). A "therapeutically effective amount" of a substance/molecule/agent of the present disclosure (*e.g.*, the lipid nanoparticle composition as described herein) may vary according to factors such as the disease state, age, sex, and weight of the individual, and the ability of the substance/molecule/agent to elicit a desired response in the individual. A therapeutically effective amount encompasses an amount in which any toxic or detrimental effects of the substance/molecule/agent are outweighed by the therapeutically beneficial effects. In certain embodiments, the term "therapeutically effective amount" refers to an amount of a lipid nanoparticle composition as described herein or a therapeutic or prophylactic agent contained therein (*e.g.*, a therapeutic mRNA) effective to "treat" a disease, disorder, or condition, in a subject or mammal.

[0071] A "prophylactically effective amount" is an amount of a pharmaceutical composition that, when administered to a subject, will have the intended prophylactic effect, *e.g.*, preventing, delaying, or reducing the likelihood of the onset (or reoccurrence) of a disease, disorder, condition, or associated symptom(s) (*e.g.*, an infectious disease such as caused by viral infection, or a neoplastic disease such as cancer). Typically, but not necessarily, since a prophylactic dose is used in subjects prior to or at an earlier stage of a disease, disorder, or condition, a prophylactically effective amount may be less than a therapeutically effective amount. The full therapeutic or prophylactic effect does not necessarily occur by administration of one dose, and may occur only after administration of a series of doses. Thus, a therapeutically or prophylactically effective amount may be administered in one or more administrations.

[0072] As used herein and unless otherwise specified, the terms "treat", "treating", and "treatment" refer to an alleviation, in whole or in part, of a disorder, disease or condition, or one or more of the symptoms associated with a disorder, disease, or condition, or slowing or halting of further progression or worsening of those symptoms, or alleviating or eradicating the cause(s) of the disorder, disease, or condition itself.

[0073] As used herein and unless otherwise specified, the terms "prevent," "preventing," and "prevention" refer to reducing the likelihood of the onset (or recurrence) of a disease, disorder, condition, or associated symptom(s) (*e.g.*, an infectious disease such as caused by viral infection, or a neoplastic disease such as cancer).

[0074] As used herein and unless otherwise specified, the terms "manage," "managing," and "management" refer to the beneficial effects that a subject derives from a therapy (*e.g.*, a prophylactic or therapeutic agent), which does not result in a cure of the disease. In certain embodiments, a subject is administered one or more therapies (*e.g.*, prophylactic or therapeutic agents, such as a lipid nanoparticle composition as described herein) to "manage" an infectious or neoplastic disease, one or more symptoms thereof, so as to prevent the progression or worsening of the disease.

[0075] The term "prophylactic agent" refers to any agent that can totally or partially inhibit the development, recurrence, onset, or spread of disease and/or symptom related thereto in a subject.

[0076] The term "therapeutic agent" refers to any agent that can be used in treating, preventing, or alleviating a disease, disorder, or condition, including in the treatment, prevention, or alleviation of one or more symptoms of a disease, disorder, or condition and/or a symptom related thereto.

[0077] The term "therapy" refers to any protocol, method, and/or agent that can be used in the prevention, management, treatment, and/or amelioration of a disease, disorder, or condition. In certain embodiments, the terms "therapies" and "therapy" refer to a biological therapy, supportive therapy, and/or other therapies useful in the prevention, management, treatment, and/or amelioration of a disease, disorder, or condition, known to one of skill in the art such as medical personnel.

[0078] As used herein, a "prophylactically effective serum titer" is the serum titer of an antibody in a subject (*e.g.,* a human), that totally or partially inhibits the development,

recurrence, onset, or spread of a disease, disorder, or condition, and/or symptom related thereto in the subject.

[0079] In certain embodiments, a "therapeutically effective serum titer" is the serum titer of an antibody in a subject (*e.g.,* a human), that reduces the severity, the duration, and/or the symptoms associated with a disease, disorder, or condition, in the subject.

[0080] The term "serum titer" refers to an average serum titer in a subject from multiple samples (*e.g.*, at multiple time points) or in a population of at least 10, at least 20, at least 40 subjects, up to about 100, 1000, or more.

[0081] The term "side effects" encompasses unwanted and/or adverse effects of a therapy (*e.g.*, a prophylactic or therapeutic agent). Unwanted effects are not necessarily adverse. An adverse effect from a therapy (*e.g.*, a prophylactic or therapeutic agent) might be harmful, uncomfortable, or risky. Examples of side effects include, diarrhea, cough, gastroenteritis, wheezing, nausea, vomiting, anorexia, abdominal cramping, fever, pain, loss of body weight, dehydration, alopecia, dyspenea, insomnia, dizziness, mucositis, nerve and muscle effects, fatigue, dry mouth, loss of appetite, rashes or swellings at the site of administration, flu-like symptoms such as fever, chills, and fatigue, digestive tract problems, and allergic reactions. Additional undesired effects experienced by patients are numerous and known in the art. Many are described in *Physician's Desk Reference* (68th ed. 2014).

[0082] The terms "subject" and "patient" may be used interchangeably. As used herein, in certain embodiments, a subject is a mammal, such as a non-primate (*e.g.*, cow, pig, horse, cat, dog, rat, *etc.*) or a primate (*e.g.*, monkey and human). In specific embodiments, the subject is a human. In one embodiment, the subject is a mammal (*e.g.*, a human) having an infectious disease or neoplastic disease. In another embodiment, the subject is a mammal (*e.g.*, a human) at risk of developing an infectious disease or neoplastic disease.

[0083] The term "detectable probe" refers to a composition that provides a detectable signal. The term includes, without limitation, any fluorophore, chromophore, radiolabel, enzyme, antibody or antibody fragment, and the like, that provide a detectable signal via its activity.

[0084] The term "detectable agent" refers to a substance that can be used to ascertain the existence or presence of a desired molecule, such as an antigen encoded by an mRNA molecule as described herein, in a sample or subject. A detectable agent can be a substance

that is capable of being visualized or a substance that is otherwise able to be determined and/or measured (*e.g.*, by quantitation).

[0085] "Substantially all" refers to at least about 60%, at least about 65%, at least about 70%, at least about 75%, at least about 80%, at least about 85%, at least about 90%, at least about 95%, at least about 98%, at least about 99%, or about 100%.

[0086] As used herein, and unless otherwise indicated, the term "about" or "approximately" means an acceptable error for a particular value as determined by one of ordinary skill in the art, which depends in part on how the value is measured or determined. In certain embodiments, the term "about" or "approximately" means within 1, 2, 3, or 4 standard deviations. In certain embodiments, the term "about" or "approximately" means within 20%, 15%, 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, 1%, 0.5%, 0.05%, or less of a given value or range.

[0087] The singular terms "a," "an," and "the" as used herein include the plural reference unless the context clearly indicates otherwise.

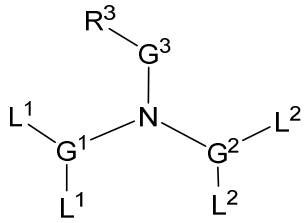
[0088] All publications, patent applications, accession numbers, and other references cited in this specification are herein incorporated by reference in their entirety as if each individual publication or patent application were specifically and individually indicated to be incorporated by reference. The publications discussed herein are provided solely for their disclosure prior to the filing date of the present application. Nothing herein is to be construed as an admission that the present invention is not entitled to antedate such publication by virtue of prior invention. Further, the dates of publication provided can be different from the actual publication dates which can need to be independently confirmed.

[0089] A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, the descriptions in the Experimental section and examples are intended to illustrate but not limit the scope of invention described in the claims.

5.3 *Lipid Compounds*

[0090] Unless otherwise specified, the descriptions provided herein apply to all the formulas provided herein (*e.g.*, Formula (I) and Formula (II), including their sub-formulas), to the extent that they are applicable.

[0091] In one embodiment, provided herein is a compound of Formula (I):



(I),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof, wherein:

G^1 and G^2 are each independently C_2-C_{25} alkylene or C_2-C_{25} alkenylene, wherein one or more -CH_2- in G^1 and G^2 is optionally replaced by -O-, -C(=O)O-, or -OC(=O)-;

each L^1 is independently –OC(=O)R^1, -C(=O)OR^1, -OC(=O)OR^1, -C(=O)R^1, -OR^1, -S(O)$_x$$R^1$, -S-S$R^1$, -C(=O)S$R^1$, -SC(=O)$R^1$, -N$R^a$C(=O)$R^1$, -C(=O)N$R^b$$R^c$, -N$R^a$C(=O)N$R^b$$R^c$, -OC(=O)N$R^b$$R^c$, -N$R^a$C(=O)O$R^1$, -SC(=S)$R^1$, -C(=S)S$R^1$, -C(=S)$R^1$, -CH(OH)$R^1$, -P(=O)(O$R^b$)(O$R^c$), -N$R^a$P(=O)(O$R^b$)(O$R^c$);

each L^2 is independently –OC(=O)R^2, -C(=O)OR^2, -OC(=O)OR^2, -C(=O)R^2, -OR^2, -S(O)$_x$$R^2$, -S-S$R^2$, -C(=O)S$R^2$, -SC(=O)$R^2$, -N$R^d$C(=O)$R^2$, -C(=O)N$R^e$$R^f$, -N$R^d$C(=O)N$R^e$$R^f$, -OC(=O)N$R^e$$R^f$, -N$R^d$C(=O)O$R^2$, -SC(=S)$R^2$, -C(=S)S$R^2$, -C(=S)$R^2$, -CH(OH)$R^2$, -P(=O)(O$R^e$)(O$R^f$), -N$R^d$P(=O)(O$R^e$)(O$R^f$);

R^1 and R^2 are each independently C_6-C_{24} alkyl or C_6-C_{24} alkenyl, wherein one or more -CH_2- in R^1 and R^2 is optionally replaced by -S-S-;

R^a, R^b, R^d, and R^e are each independently H, C_1-C_{24} alkyl, or C_2-C_{24} alkenyl;

R^c and R^f are each independently C_1-C_{24} alkyl or C_2-C_{24} alkenyl, wherein one or more -CH_2- in R^c and R^f is optionally replaced by -S-S;

G^3 is C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein part or all of alkylene or alkenylene is optionally replaced by a C_3-C_8 cycloalkylene or C_3-C_8 cycloalkenylene;

R^3 is -N(R^4)R^5, -OR^6, or -SR^6;

R^4 is C_1-C_{12} alkyl, C_2-C_{12} alkenyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

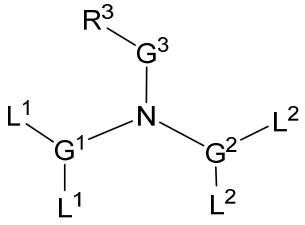
R^5 is H, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

R^6 is hydrogen, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, or C_6-C_{10} aryl;

x is 0, 1, or 2; and

wherein each alkyl, alkenyl, cycloalkyl, cycloalkenyl, heterocycloalkyl, aryl, alkylene, alkenylene, cycloalkylene, and cycloalkenylene is independently optionally substituted.

[0092] In one embodiment, provided herein is a compound of Formula (I):



(I),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof, wherein:

G^1 and G^2 are each independently C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein one or more -CH_2- in G^1 and G^2 is optionally replaced by -O-, -C(=O)O-, or -OC(=O)-;

each L^1 is independently –OC(=O)R^1, -C(=O)OR^1, -OC(=O)OR^1, -C(=O)R^1, -OR^1, -S(O)$_x$$R^1$, -S-S$R^1$, -C(=O)S$R^1$, -SC(=O)$R^1$, -N$R^a$C(=O)$R^1$, -C(=O)N$R^b$$R^c$, -N$R^a$C(=O)N$R^b$$R^c$, -OC(=O)N$R^b$$R^c$, -N$R^a$C(=O)O$R^1$, -SC(=S)$R^1$, -C(=S)S$R^1$, -C(=S)$R^1$, -CH(OH)$R^1$, -P(=O)(O$R^b$)(O$R^c$), -N$R^a$P(=O)(O$R^b$)(O$R^c$);

each L^2 is independently –OC(=O)R^2, -C(=O)OR^2, -OC(=O)OR^2, -C(=O)R^2, -OR^2, -S(O)$_x$$R^2$, -S-S$R^2$, -C(=O)S$R^2$, -SC(=O)$R^2$, -N$R^d$C(=O)$R^2$, -C(=O)N$R^e$$R^f$, -N$R^d$C(=O)N$R^e$$R^f$, -OC(=O)N$R^e$$R^f$, -N$R^d$C(=O)O$R^2$, -SC(=S)$R^2$, -C(=S)S$R^2$, -C(=S)$R^2$, -CH(OH)$R^2$, -P(=O)(O$R^e$)(O$R^f$), -N$R^d$P(=O)(O$R^e$)(O$R^f$);

R^1 and R^2 are each independently C_6-C_{24} alkyl or C_6-C_{24} alkenyl;

R^a, R^b, R^d, and R^e are each independently H, C_1-C_{24} alkyl, or C_2-C_{24} alkenyl;

R^c and R^f are each independently C_1-C_{24} alkyl or C_2-C_{24} alkenyl;

G^3 is C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein part or all of alkylene or alkenylene is optionally replaced by a C_3-C_8 cycloalkylene or C_3-C_8 cycloalkenylene;

R^3 is -N(R^4)R^5, -OR^6, or -SR^6;

R^4 is C_1-C_{12} alkyl, C_2-C_{12} alkenyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

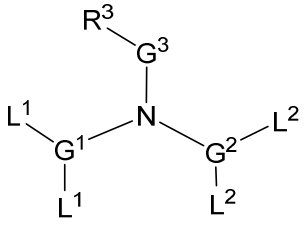
R^5 is H, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

R^6 is hydrogen, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, or C_6-C_{10} aryl;

x is 0, 1, or 2; and

wherein each alkyl, alkenyl, cycloalkyl, cycloalkenyl, heterocycloalkyl, aryl, alkylene, alkenylene, cycloalkylene, and cycloalkenylene is independently optionally substituted.

[0093] In one embodiment, provided herein is a compound of Formula (I):



(I),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof, wherein:

G^1 and G^2 are each independently C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein one or more -CH_2- in G^1 and G^2 is optionally replaced by -O-, -C(=O)O-, or -OC(=O)-;

each L^1 is independently –OC(=O)R^1, -C(=O)OR^1, -OC(=O)OR^1, -C(=O)R^1, -OR^1, -S(O)$_x$$R^1$, -S-S$R^1$, -C(=O)S$R^1$, -SC(=O)$R^1$, -N$R^a$C(=O)$R^1$, -C(=O)N$R^b$$R^c$, -N$R^a$C(=O)N$R^b$$R^c$, -OC(=O)N$R^b$$R^c$, -N$R^a$C(=O)O$R^1$, -SC(=S)$R^1$, -C(=S)S$R^1$, -C(=S)$R^1$, -CH(OH)$R^1$, -P(=O)(O$R^b$)(O$R^c$), -N$R^a$P(=O)(O$R^b$)(O$R^c$);

each L^2 is independently –OC(=O)R^2, -C(=O)OR^2, -OC(=O)OR^2, -C(=O)R^2, -OR^2, -S(O)$_x$$R^2$, -S-S$R^2$, -C(=O)S$R^2$, -SC(=O)$R^2$, -N$R^d$C(=O)$R^2$, -C(=O)N$R^e$$R^f$, -N$R^d$C(=O)N$R^e$$R^f$, -OC(=O)N$R^e$$R^f$, -N$R^d$C(=O)O$R^2$, -SC(=S)$R^2$, -C(=S)S$R^2$, -C(=S)$R^2$, -CH(OH)$R^2$, -P(=O)(O$R^e$)(O$R^f$), -N$R^d$P(=O)(O$R^e$)(O$R^f$);

R^1 and R^2 are each independently C_6-C_{24} alkyl or C_6-C_{24} alkenyl;

R^a, R^b, R^d, and R^e are each independently H, C_1-C_{24} alkyl, or C_2-C_{24} alkenyl;

R^c and R^f are each independently C_1-C_{24} alkyl or C_2-C_{24} alkenyl;

G^3 is C_2-C_{24} alkylene, C_2-C_{24} alkenylene, C_3-C_8 cycloalkylene, or C_3-C_8 cycloalkenylene;

R^3 is -N(R^4)R^5 or -OR^6;

R^4 is C_1-C_{12} alkyl, C_2-C_{12} alkenyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

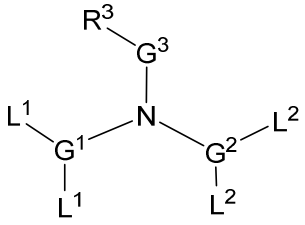
R^5 is hydrogen, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

R^6 is hydrogen, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, or C_6-C_{10} aryl;

x is 0, 1, or 2; and

wherein each alkyl, alkenyl, cycloalkyl, cycloalkenyl, heterocycloalkyl, aryl, alkylene, alkenylene, cycloalkylene, and cycloalkenylene is independently optionally substituted.

[0094] In one embodiment, provided herein is a compound of Formula (I):



(I),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof, wherein:

G^1 and G^2 are each independently C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein one or more -CH_2- in G^1 and G^2 is optionally replaced by -O-, -C(=O)O-, or -OC(=O)-;

each L^1 is independently –OC(=O)R^1, -C(=O)OR^1, -OC(=O)OR^1, -C(=O)R^1, -OR^1, -S(O)$_x$$R^1$, -S-S$R^1$, -C(=O)S$R^1$, -SC(=O)$R^1$, -N$R^a$C(=O)$R^1$, -C(=O)N$R^b$$R^c$, -N$R^a$C(=O)N$R^b$$R^c$, -OC(=O)N$R^b$$R^c$, -N$R^a$C(=O)O$R^1$, -SC(=S)$R^1$, -C(=S)S$R^1$, -C(=S)$R^1$, -CH(OH)$R^1$, -P(=O)(O$R^b$)(O$R^c$), -N$R^a$P(=O)(O$R^b$)(O$R^c$);

each L^2 is independently –OC(=O)R^2, -C(=O)OR^2, -OC(=O)OR^2, -C(=O)R^2, -OR^2, -S(O)$_x$$R^2$, -S-S$R^2$, -C(=O)S$R^2$, -SC(=O)$R^2$, -N$R^d$C(=O)$R^2$, -C(=O)N$R^e$$R^f$, -N$R^d$C(=O)N$R^e$$R^f$, -OC(=O)N$R^e$$R^f$, -N$R^d$C(=O)O$R^2$, -SC(=S)$R^2$, -C(=S)S$R^2$, -C(=S)$R^2$, -CH(OH)$R^2$, -P(=O)(O$R^e$)(O$R^f$), -N$R^d$P(=O)(O$R^e$)(O$R^f$);

R^1 and R^2 are each independently C_6-C_{24} alkyl or C_6-C_{24} alkenyl;

R^a, R^b, R^d, and R^e are each independently H, C_1-C_{24} alkyl, or C_2-C_{24} alkenyl;

R^c and R^f are each independently C_1-C_{24} alkyl or C_2-C_{24} alkenyl;

G^3 is C_2-C_{12} alkylene, C_2-C_{12} alkenylene, C_3-C_8 cycloalkylene, or C_3-C_8 cycloalkenylene;

R^3 is -N(R^4)R^5 or -OR^6;

R^4 is C_1-C_{12} alkyl, C_2-C_{12} alkenyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

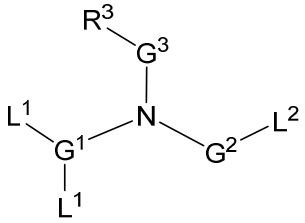
R^5 is H, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

R^6 is hydrogen, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, or C_6-C_{10} aryl;

x is 0, 1, or 2; and

wherein each alkyl, alkenyl, cycloalkyl, cycloalkenyl, heterocycloalkyl, aryl, alkylene, alkenylene, cycloalkylene, and cycloalkenylene is independently optionally substituted.

[0095] In one embodiment, provided herein is a compound of Formula (II):



(II),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof, wherein:

G^1 and G^2 are each independently C_2-C_{25} alkylene or C_2-C_{25} alkenylene, wherein one or more -CH_2- in G^1 and G^2 is optionally replaced by -O-, -C(=O)O-, or -OC(=O)-;

each L^1 is independently –OC(=O)R^1, -C(=O)OR^1, -OC(=O)OR^1, -C(=O)R^1, -OR^1, -S(O)$_x$$R^1$, -S-S$R^1$, -C(=O)S$R^1$, -SC(=O)$R^1$, -N$R^a$C(=O)$R^1$, -C(=O)N$R^b$$R^c$, -N$R^a$C(=O)N$R^b$$R^c$, -OC(=O)N$R^b$$R^c$, -N$R^a$C(=O)O$R^1$, -SC(=S)$R^1$, -C(=S)S$R^1$, -C(=S)$R^1$, -CH(OH)$R^1$, -P(=O)(O$R^b$)(O$R^c$), -N$R^a$P(=O)(O$R^b$)(O$R^c$);

each L^2 is independently –OC(=O)R^2, -C(=O)OR^2, -OC(=O)OR^2, -C(=O)R^2, -OR^2, -S(O)$_x$$R^2$, -S-S$R^2$, -C(=O)S$R^2$, -SC(=O)$R^2$, -N$R^d$C(=O)$R^2$, -C(=O)N$R^e$$R^f$, -N$R^d$C(=O)N$R^e$$R^f$, -OC(=O)N$R^e$$R^f$, -N$R^d$C(=O)O$R^2$, -SC(=S)$R^2$, -C(=S)S$R^2$, -C(=S)$R^2$, -CH(OH)$R^2$, -P(=O)(O$R^e$)(O$R^f$), -N$R^d$P(=O)(O$R^e$)(O$R^f$);

R^1 and R^2 are each independently C_6-C_{24} alkyl or C_6-C_{24} alkenyl, wherein one or more -CH_2- in R^1 and R^2 is optionally replaced by -S-S-;

R^a, R^b, R^d, and R^e are each independently H, C_1-C_{24} alkyl, or C_2-C_{24} alkenyl;

R^c and R^f are each independently C_1-C_{24} alkyl or C_2-C_{24} alkenyl, wherein one or more -CH_2- in R^c and R^f is optionally replaced by -S-S-;

G^3 is C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein part or all of alkylene or alkenylene is optionally replaced by a C_3-C_8 cycloalkylene or C_3-C_8 cycloalkenylene;

R^3 is -N(R^4)R^5, -OR^6, or -SR^6;

R^4 is C_1-C_{12} alkyl, C_2-C_{12} alkenyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

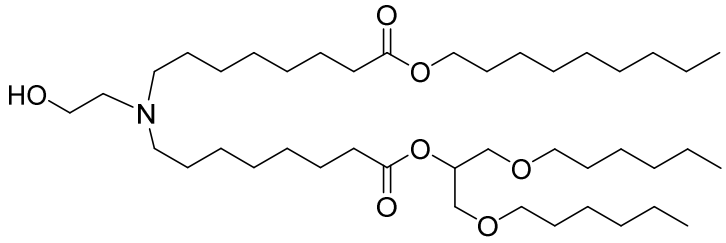
R^5 is H, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

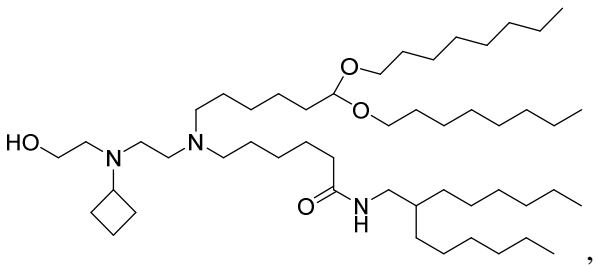
R^6 is hydrogen, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, or C_6-C_{10} aryl;

x is 0, 1, or 2; and

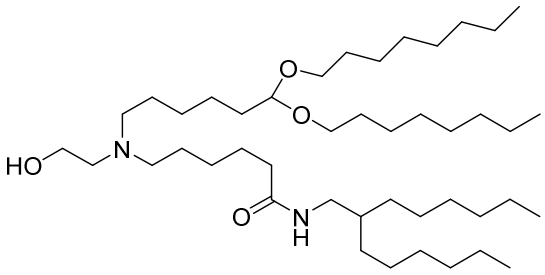
wherein each alkyl, alkenyl, cycloalkyl, cycloalkenyl, heterocycloalkyl, aryl, alkylene, alkenylene, cycloalkylene, and cycloalkenylene is independently optionally substituted;

provided that the compound is not:



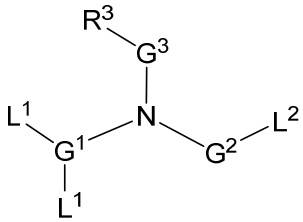


, or



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[0096] In one embodiment, provided herein is a compound of Formula (II):



(II),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof, wherein:

G^1 and G^2 are each independently C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein one or more -CH_2- in G^1 and G^2 is optionally replaced by -O-, -C(=O)O-, or -OC(=O)-;

each L^1 is independently –$OC(=O)R^1$, -$C(=O)OR^1$, -$OC(=O)OR^1$, -$C(=O)R^1$, -OR^1, -$S(O)_xR^1$, -S-SR^1, -$C(=O)SR^1$, -$SC(=O)R^1$, -$NR^aC(=O)R^1$, -$C(=O)NR^bR^c$, -$NR^aC(=O)NR^bR^c$, -$OC(=O)NR^bR^c$, -$NR^aC(=O)OR^1$, -$SC(=S)R^1$, -$C(=S)SR^1$, -$C(=S)R^1$, -$CH(OH)R^1$, -$P(=O)(OR^b)(OR^c)$, -$NR^aP(=O)(OR^b)(OR^c)$;

each L^2 is independently –$OC(=O)R^2$, -$C(=O)OR^2$, -$OC(=O)OR^2$, -$C(=O)R^2$, -OR^2, -$S(O)_xR^2$, -S-SR^2, -$C(=O)SR^2$, -$SC(=O)R^2$, -$NR^dC(=O)R^2$, -$C(=O)NR^eR^f$, -$NR^dC(=O)NR^eR^f$, -$OC(=O)NR^eR^f$, -$NR^dC(=O)OR^2$, -$SC(=S)R^2$, -$C(=S)SR^2$, -$C(=S)R^2$, -$CH(OH)R^2$, -$P(=O)(OR^e)(OR^f)$, -$NR^dP(=O)(OR^e)(OR^f)$;

R^1 and R^2 are each independently C_6-C_{24} alkyl or C_6-C_{24} alkenyl;

R^a, R^b, R^d, and R^e are each independently H, C_1-C_{24} alkyl, or C_2-C_{24} alkenyl;

R^c and R^f are each independently C_1-C_{24} alkyl or C_2-C_{24} alkenyl;

G^3 is C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein part or all of alkylene or alkenylene is optionally replaced by a C_3-C_8 cycloalkylene or C_3-C_8 cycloalkenylene;

R^3 is $-N(R^4)R^5$, $-OR^6$, or $-SR^6$;

R^4 is C_1-C_{12} alkyl, C_2-C_{12} alkenyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

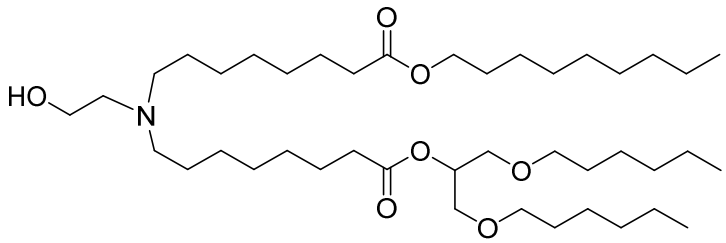
R^5 is H, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

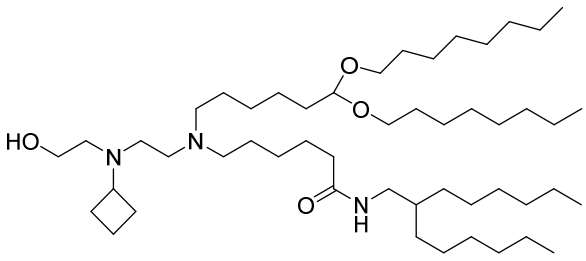
R^6 is hydrogen, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, or C_6-C_{10} aryl;

x is 0, 1, or 2; and

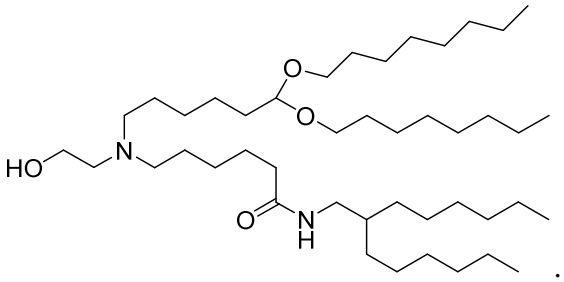
wherein each alkyl, alkenyl, cycloalkyl, cycloalkenyl, heterocycloalkyl, aryl, alkylene, alkenylene, cycloalkylene, and cycloalkenylene is independently optionally substituted;

provided that the compound is not:



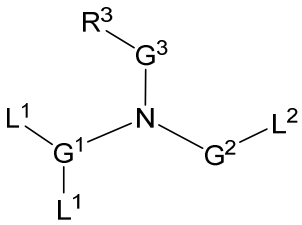


, or



.

[0097] In one embodiment, provided herein is a compound of Formula (II):



(II),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof, wherein:

G^1 and G^2 are each independently C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein one or more -CH_2- in G^1 and G^2 is optionally replaced by -O-, -C(=O)O-, or -OC(=O)-;

each L^1 is independently –OC(=O)R^1, -C(=O)OR^1, -OC(=O)OR^1, -C(=O)R^1, -OR^1, -S(O)$_x$$R^1$, -S-S$R^1$, -C(=O)S$R^1$, -SC(=O)$R^1$, -N$R^a$C(=O)$R^1$, -C(=O)N$R^b$$R^c$, -N$R^a$C(=O)N$R^b$$R^c$, -OC(=O)N$R^b$$R^c$, -N$R^a$C(=O)O$R^1$, -SC(=S)$R^1$, -C(=S)S$R^1$, -C(=S)$R^1$, -CH(OH)$R^1$, -P(=O)(O$R^b$)(O$R^c$), -N$R^a$P(=O)(O$R^b$)(O$R^c$);

each L^2 is independently –OC(=O)R^2, -C(=O)OR^2, -OC(=O)OR^2, -C(=O)R^2, -OR^2, -S(O)$_x$$R^2$, -S-S$R^2$, -C(=O)S$R^2$, -SC(=O)$R^2$, -N$R^d$C(=O)$R^2$, -C(=O)N$R^e$$R^f$, -N$R^d$C(=O)N$R^e$$R^f$, -OC(=O)N$R^e$$R^f$, -N$R^d$C(=O)O$R^2$, -SC(=S)$R^2$, -C(=S)S$R^2$, -C(=S)$R^2$, -CH(OH)$R^2$, -P(=O)(O$R^e$)(O$R^f$), -N$R^d$P(=O)(O$R^e$)(O$R^f$);

R^1 and R^2 are each independently C_6-C_{24} alkyl or C_6-C_{24} alkenyl;

R^a, R^b, R^d, and R^e are each independently H, C_1-C_{24} alkyl, or C_2-C_{24} alkenyl;

R^c and R^f are each independently C_1-C_{24} alkyl or C_2-C_{24} alkenyl;

G^3 is C_2-C_{24} alkylene, C_2-C_{24} alkenylene, C_3-C_8 cycloalkylene, or C_3-C_8 cycloalkenylene;

R^3 is -N(R^4)R^5 or -OR^6;

R^4 is C_1-C_{12} alkyl, C_2-C_{12} alkenyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

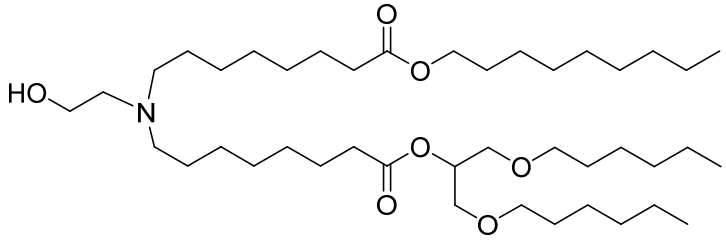
R^5 is hydrogen, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

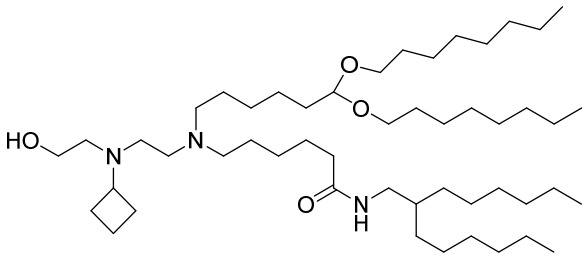
R^6 is hydrogen, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, or C_6-C_{10} aryl;

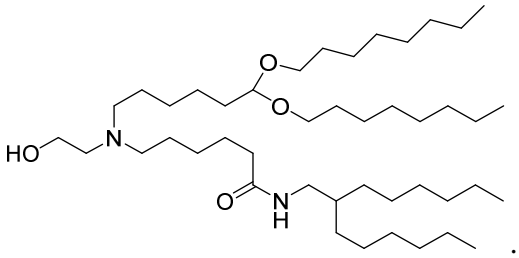
x is 0, 1, or 2; and

wherein each alkyl, alkenyl, cycloalkyl, cycloalkenyl, heterocycloalkyl, aryl, alkylene, alkenylene, cycloalkylene, and cycloalkenylene is independently optionally substituted;

provided that the compound is not:

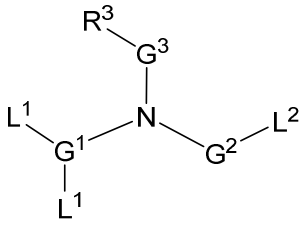




, or


.

[0098] In one embodiment, provided herein is a compound of Formula (II):



(II),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof, wherein:

G^1 and G^2 are each independently C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein one or more -CH_2- in G^1 and G^2 is optionally replaced by -O-, -C(=O)O-, or -OC(=O)-;

each L^1 is independently –OC(=O)R^1, -C(=O)OR^1, -OC(=O)OR^1, -C(=O)R^1, -OR^1, -S(O)$_x$$R^1$, -S-S$R^1$, -C(=O)S$R^1$, -SC(=O)$R^1$, -N$R^a$C(=O)$R^1$, -C(=O)N$R^b$$R^c$, -N$R^a$C(=O)N$R^b$$R^c$, -OC(=O)N$R^b$$R^c$, -N$R^a$C(=O)O$R^1$, -SC(=S)$R^1$, -C(=S)S$R^1$, -C(=S)$R^1$, -CH(OH)$R^1$, -P(=O)(O$R^b$)(O$R^c$), -N$R^a$P(=O)(O$R^b$)(O$R^c$);

each L^2 is independently –OC(=O)R^2, -C(=O)OR^2, -OC(=O)OR^2, -C(=O)R^2, -OR^2, -S(O)$_x$$R^2$, -S-S$R^2$, -C(=O)S$R^2$, -SC(=O)$R^2$, -N$R^d$C(=O)$R^2$, -C(=O)N$R^e$$R^f$, -N$R^d$C(=O)N$R^e$$R^f$, -OC(=O)N$R^e$$R^f$, -N$R^d$C(=O)O$R^2$, -SC(=S)$R^2$, -C(=S)S$R^2$, -C(=S)$R^2$, -CH(OH)$R^2$, -P(=O)(O$R^e$)(O$R^f$), -N$R^d$P(=O)(O$R^e$)(O$R^f$);

R^1 and R^2 are each independently C_6-C_{24} alkyl or C_6-C_{24} alkenyl;

R^a, R^b, R^d, and R^e are each independently H, C_1-C_{24} alkyl, or C_2-C_{24} alkenyl;

R^c and R^f are each independently C_1-C_{24} alkyl or C_2-C_{24} alkenyl;

G^3 is C_2-C_{12} alkylene, C_2-C_{12} alkenylene, C_3-C_8 cycloalkylene, or C_3-C_8 cycloalkenylene;

R^3 is -N(R^4)R^5 or -OR^6;

R^4 is C_1-C_{12} alkyl, C_2-C_{12} alkenyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

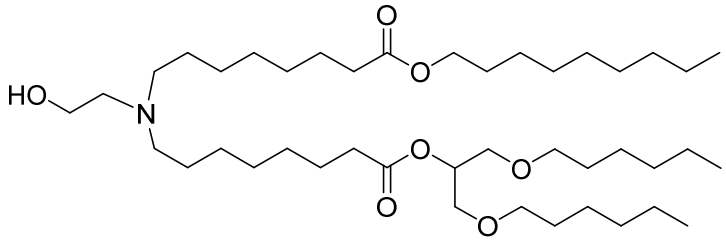
R^5 is H, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

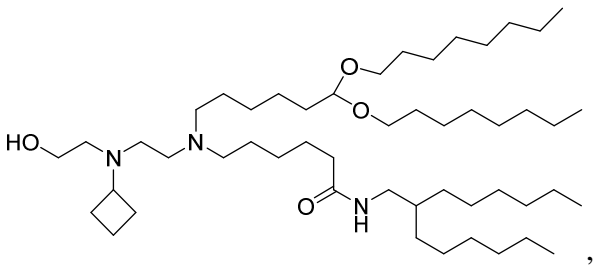
R^6 is hydrogen, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, or C_6-C_{10} aryl;

x is 0, 1, or 2; and

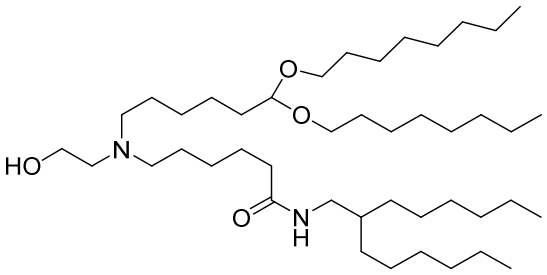
wherein each alkyl, alkenyl, cycloalkyl, cycloalkenyl, heterocycloalkyl, aryl, alkylene, alkenylene, cycloalkylene, and cycloalkenylene is independently optionally substituted;

provided that the compound is not:



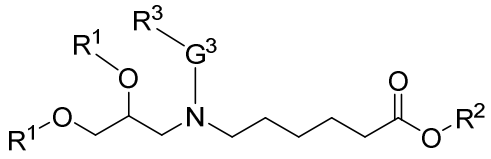


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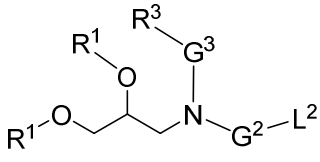


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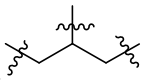
[0099] In one embodiment, provided that the compound is not a compound of the formula



. In one embodiment, provided that the compound is not a compound of the formula



. In one embodiment, provided that G^1 is not



.

[00100] In one embodiment, G^3 is C_2-C_{12} alkylene. In one embodiment, G^3 is C_2-C_8 alkylene. In one embodiment, G^3 is C_2-C_6 alkylene. In one embodiment, G^3 is C_2-C_4 alkylene. In one embodiment, G^3 is C_2 alkylene. In one embodiment, G^3 is C_3 alkylene. In one embodiment, G^3 is C_4 alkylene. In one embodiment, G^3 is C_5 alkylene. In one embodiment, G^3 is C_6 alkylene. In one embodiment, G^3 is $-CH_2CH_2-$.

[00101] In one embodiment, G^3 is C_2-C_{12} alkenylene. In one embodiment, G^3 is C_2-C_8 alkenylene. In one embodiment, G^3 is C_2-C_6 alkenylene. In one embodiment, G^3 is C_2-C_4 alkenylene. In one embodiment, G^3 is C_2 alkenylene. In one embodiment, G^3 is C_3

alkenylene. In one embodiment, G^3 is C_4 alkenylene. In one embodiment, G^3 is C_5 alkenylene. In one embodiment, G^3 is C_6 alkenylene.

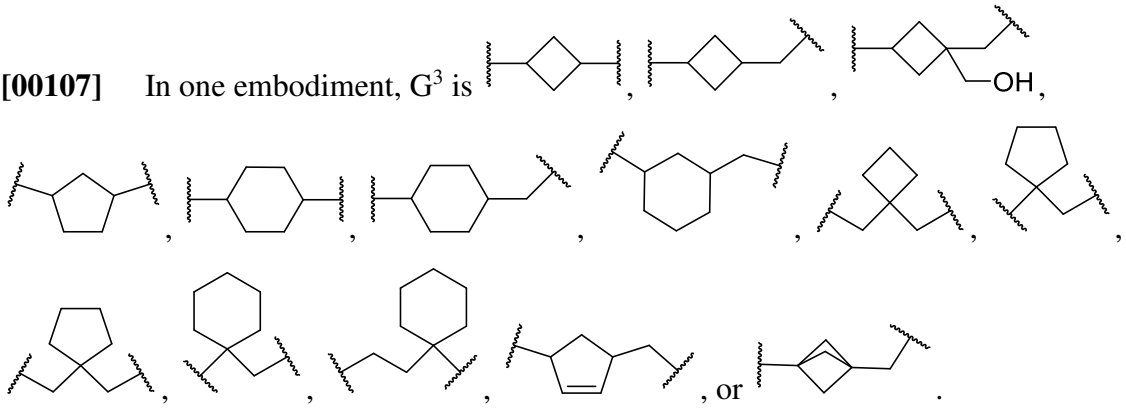
[00102] In one embodiment, G^3 is C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein part or all of alkylene or alkenylene is replaced by a C_3-C_8 cycloalkylene. In one embodiment, G^3 is (C_0-C_2 alkylene)-(C_3-C_8 cycloalkylene)-(C_0-C_2 alkylene). In one embodiment, G^3 is (C_1-C_2 alkylene)-(C_3-C_8 cycloalkylene)-(C_1-C_2 alkylene). In one embodiment, G^3 is (C_1-C_2 alkylene)-(C_3-C_8 cycloalkylene). In one embodiment, G^3 is (C_3-C_8 cycloalkylene)-(C_1-C_2 alkylene). In one embodiment, G^3 is C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein all of alkylene or alkenylene is replaced by C_3-C_8 cycloalkylene, *i.e.*, G^3 is C_3-C_8 cycloalkylene.

[00103] The cycloalkylene moiety in G^3 can be monocyclic or multicyclic (*e.g.*, fused, spiro, or bridged rings). In one embodiment, the cycloalkylene moiety is cyclopropylene. In one embodiment, the cycloalkylene moiety is cyclobutylene. In one embodiment, the cycloalkylene moiety is cyclopentylene. In one embodiment, the cycloalkylene moiety is cyclohexylene. In one embodiment, the cycloalkylene moiety is cycloheptylene. In one embodiment, the cycloalkylene moiety is cyclooctylene.

[00104] In one embodiment, G^3 is C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein part or all of alkylene or alkenylene is replaced by a C_3-C_8 cycloalkenylene. In one embodiment, G^3 is (C_0-C_2 alkylene)-(C_3-C_8 cycloalkenylene)-(C_0-C_2 alkylene). In one embodiment, G^3 is (C_1-C_2 alkylene)-(C_3-C_8 cycloalkenylene)-(C_1-C_2 alkylene). In one embodiment, G^3 is (C_1-C_2 alkylene)-(C_3-C_8 cycloalkenylene). In one embodiment, G^3 is (C_3-C_8 cycloalkenylene)-(C_1-C_2 alkylene). In one embodiment, G^3 is C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein all of alkylene or alkenylene is replaced by C_3-C_8 cycloalkenylene, *i.e.*, G^3 is C_3-C_8 cycloalkenylene.

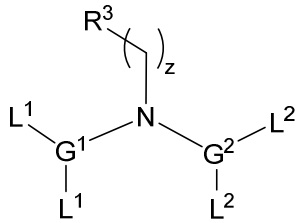
[00105] The cycloalkenylene moiety in G^3 can be monocyclic or multicyclic (*e.g.*, fused, spiro, or bridged rings). In one embodiment, the cycloalkenylene moiety is cyclopropenylene. In one embodiment, the cycloalkenylene moiety is cyclobutenylene. In one embodiment, the cycloalkenylene moiety is cyclopentenylene. In one embodiment, the cycloalkenylene moiety is cyclohexenylene. In one embodiment, the cycloalkenylene moiety is cycloheptenylene. In one embodiment, the cycloalkenylene moiety is cyclooctenylene.

[00106] In one embodiment, G^3 is unsubstituted. In one embodiment, G^3 is substituted with one or more C_1-C_6 alkyl. In one embodiment, G^3 is substituted with two C_1-C_6 alkyl. In one embodiment, the C_1-C_6 alkyl is optionally substituted with a hydroxy.

[00107] In one embodiment, G^3 is .

[00108] Unless otherwise specified, the direction of the G^3 groups provided herein from left to right is from nitrogen atom to R^3 group. The point of attachment on the left side is to the nitrogen atom, and the point of attachment on the right side is to the R^3 group. In one embodiment, the two points of attachment are on the same atom of G^3. In one embodiment, the two points of attachment are on different atoms of G^3. In one embodiment, the cycloalkylene or cycloalkenylene moiety in G^3 has cis-configuration with regard to the two points of attachment. In one embodiment, the cycloalkylene or cycloalkenylene moiety in G^3 has trans-configuration with regard to the two points of attachment.

[00109] In one embodiment, the compound is a compound of Formula (III):

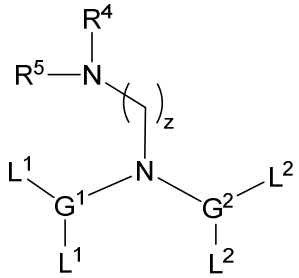


(III),

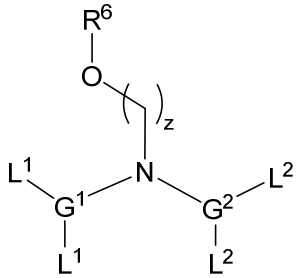
wherein z is an integer from 2 to 12,

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

[00110] In one embodiment, the compound is a compound of Formula (III-A) or (III-B):



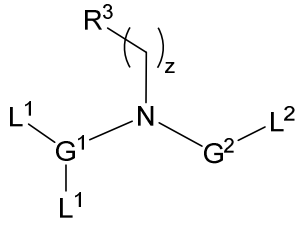
(III-A) or



(III-B),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

[00111] In one embodiment, the compound is a compound of Formula (IV):

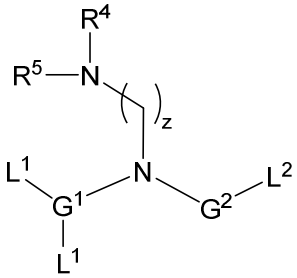


(IV),

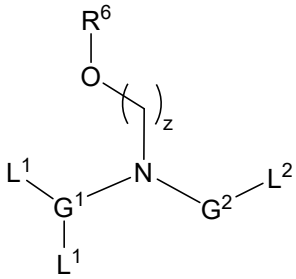
wherein z is an integer from 2 to 12,

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

[00112] In one embodiment, the compound is a compound of Formula (IV-A) or (IV-B):



(IV-A) or



(IV-B),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

[00113] In one embodiment, z is an integer from 2 to 12. In one embodiment, z is an integer from 2 to 8. In one embodiment, z is an integer from 2 to 6. In one embodiment, z is an integer from 2 to 4. In one embodiment, z is 2. In one embodiment, z is 3. In one embodiment, z is 4. In one embodiment, z is 5. In one embodiment, z is 6.

[00114] In one embodiment, G^1 is C_2-C_{25} alkylene. In one embodiment, G^1 is C_2-C_{20} alkylene. In one embodiment, G^1 is C_2-C_{16} alkylene. In one embodiment, G^1 is C_2-C_{14} alkylene. In one embodiment, G^1 is C_2-C_{12} alkylene. In one embodiment, G^1 is C_4-C_8 alkylene. In one embodiment, G^1 is C_4-C_{10} alkylene. In one embodiment, G^1 is C_5-C_7 alkylene. In one embodiment, G^1 is C_2 alkylene. In one embodiment, G^1 is C_3 alkylene. In one embodiment, G^1 is C_4 alkylene. In one embodiment, G^1 is C_5 alkylene. In one embodiment, G^1 is C_6 alkylene. In one embodiment, G^1 is C_7 alkylene. In one embodiment, G^1 is C_{12} alkylene. In one embodiment, G^1 is C_{14} alkylene. In one embodiment, G^1 is C_{16} alkylene. In one embodiment, G^1 is C_{18} alkylene. In one embodiment, G^1 is C_{20} alkylene. In one embodiment, G^1 is C_{22} alkylene. In one embodiment, G^1 is C_{24} alkylene. In one embodiment, G^1 is C_2-C_{14} alkenylene. In one embodiment, G^1 is C_2-C_{12} alkenylene.

In one embodiment, G^1 is C_4-C_8 alkenylene. In one embodiment, G^1 is C_5-C_7 alkenylene. In one embodiment, G^1 is C_5 alkenylene. In one embodiment, G^1 is C_7 alkenylene. In one embodiment, G^1 is C_{10} alkenylene. In one embodiment, G^1 is straight. In one embodiment, G^1 is branched. In one embodiment, G^1 is divalent. In one embodiment, G^1 is trivalent.

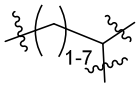
[00115] In one embodiment, G^2 is a bond. In one embodiment, G^2 is C_2-C_{25} alkylene. In one embodiment, G^2 is C_2-C_{20} alkylene. In one embodiment, G^2 is C_2-C_{16} alkylene. In one embodiment, G^2 is C_2-C_{14} alkylene. In one embodiment, G^2 is C_2-C_{12} alkylene. In one embodiment, G^2 is C_4-C_{10} alkylene. In one embodiment, G^2 is C_4-C_8 alkylene. In one embodiment, G^2 is C_5-C_7 alkylene. In one embodiment, G^2 is C_2 alkylene. In one embodiment, G^2 is C_3 alkylene. In one embodiment, G^2 is C_4 alkylene. In one embodiment, G^2 is C_5 alkylene. In one embodiment, G^2 is C_6 alkylene. In one embodiment, G^2 is C_7 alkylene. In one embodiment, G^2 is C_{12} alkylene. . In one embodiment, G^2 is C_{14} alkylene. In one embodiment, G^2 is C_{16} alkylene. In one embodiment, G^2 is C_{18} alkylene. In one embodiment, G^2 is C_{20} alkylene. In one embodiment, G^2 is C_{22} alkylene. In one embodiment, G^2 is C_{24} alkylene. In one embodiment, G^2 is C_2-C_{14} alkenylene. In one embodiment, G^2 is C_2-C_{12} alkenylene. In one embodiment, G^2 is C_4-C_8 alkenylene. In one embodiment, G^2 is C_5-C_7 alkenylene. In one embodiment, G^2 is C_5 alkenylene. In one embodiment, G^2 is C_7 alkenylene. In one embodiment, G^2 is C_{10} alkenylene. In one embodiment, G^2 is straight. In one embodiment, G^2 is branched. In one embodiment, G^2 is divalent. In one embodiment, G^2 is trivalent.

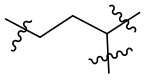
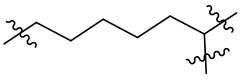
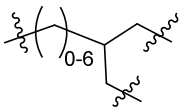
[00116] In one embodiment, G^1 and G^2 are each independently C_2-C_{25} alkylene. In one embodiment, G^1 and G^2 are each independently C_2-C_{20} alkylene. In one embodiment, G^1 and G^2 are each independently C_2-C_{16} alkylene. In one embodiment, G^1 and G^2 are each independently C_2-C_{12} alkylene. In one embodiment, G^1 and G^2 are each independently C_4 alkylene. In one embodiment, G^1 and G^2 are each independently C_5 alkylene. In one embodiment, G^1 and G^2 are each independently C_7 alkylene. In one embodiment, G^1 and G^2 are each independently C_{10} alkylene. In one embodiment, G^1 and G^2 are each independently C_{12} alkylene. In one embodiment, G^1 and G^2 are each independently C_{14} alkylene. In one embodiment, G^1 and G^2 are each independently C_{16} alkylene. In one embodiment, G^1 and G^2 are each independently C_{18} alkylene. In one embodiment, G^1 and G^2 are each independently C_{20} alkylene. In one embodiment, G^1 and G^2 are each independently C_{22} alkylene. In one embodiment, G^1 and G^2 are each independently C_{24} alkylene.

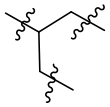
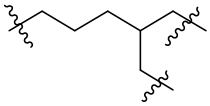
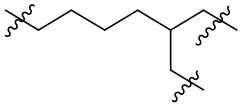
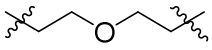
[00117] In one embodiment, one or more -CH_2- in G^1 is replaced by -O-. In one embodiment, one or more non-terminal -CH_2- in G^1 is replaced by -O-. In one embodiment, one non-terminal -CH_2- in G^1 is replaced by -O-. In one embodiment, G^1 is (C_2-C_{12} alkylene)-O-(C_2-C_{12} alkylene). In one embodiment, G^1 is (C_2-C_5 alkylene)-O-(C_2-C_6 alkylene).

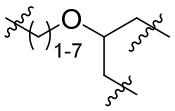
[00118] In one embodiment, one or more -CH_2- in G^1 is replaced by -C(=O)O-. In one embodiment, one or more non-terminal -CH_2- in G^1 is replaced by -C(=O)O-. In one embodiment, one non-terminal -CH_2- in G^1 is replaced by -C(=O)O-. In one embodiment, G^1 is (C_2-C_{12} alkylene)-C(=O)O-(C_2-C_{12} alkylene). In one embodiment, G^1 is (C_2-C_5 alkylene)-C(=O)O-(C_2-C_6 alkylene).

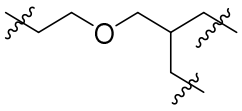
[00119] In one embodiment, one or more -CH_2- in G^1 is replaced by -OC(=O)-. In one embodiment, one or more non-terminal -CH_2- in G^1 is replaced by -OC(=O)-. In one embodiment, one non-terminal -CH_2- in G^1 is replaced by -OC(=O)-. In one embodiment, G^1 is (C_2-C_{12} alkylene)-OC(=O)-(C_2-C_{12} alkylene). In one embodiment, G^1 is (C_2-C_5 alkylene)-OC(=O)-(C_2-C_6 alkylene).

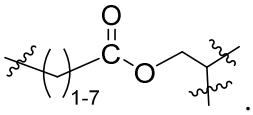
[00120] In one embodiment, G^1 is 

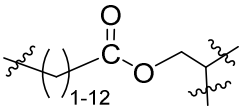
. In one embodiment, G^1 is . In one embodiment, G^1 is . In one embodiment, G^1 is 

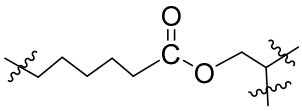
. In one embodiment, G^1 is . In one embodiment, G^1 is . In one embodiment, G^1 is . In one embodiment, G^1 is 

. In one embodiment, G^1 is 

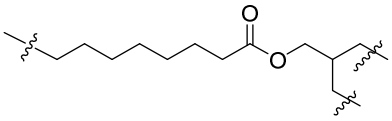
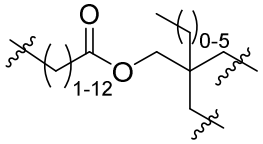
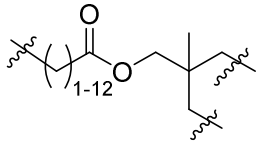
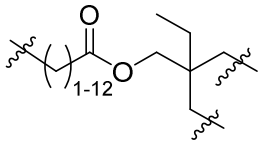
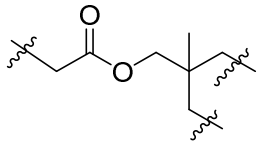
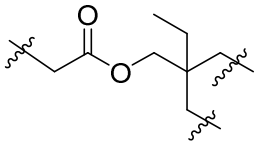
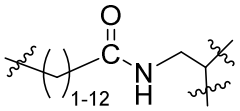
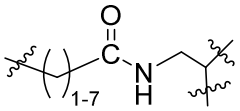
. In one embodiment, G^1 is 

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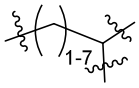
In one embodiment, G^1 is  . In one embodiment, G^1 is . In one embodiment, G^1 is . In one embodiment, G^1 is . In one embodiment, G^1 is . In one embodiment, G^1 is . In one embodiment, G^1 is .

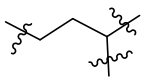
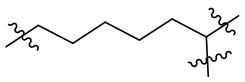
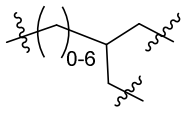
[00121] Unless otherwise specified, the direction of the G^1 groups provided herein from left to right is from nitrogen atom to L^1 group(s). The point of attachment on the left side is to the nitrogen atom, and the point(s) of attachment on the right side is to the L^1 group(s).

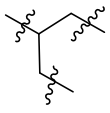
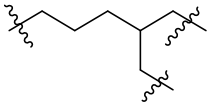
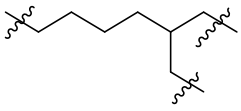
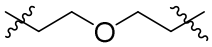
[00122] In one embodiment, one or more -CH_2- in G^2 is replaced by -O-. In one embodiment, one or more non-terminal -CH_2- in G^2 is replaced by -O-. In one embodiment, one non-terminal -CH_2- in G^2 is replaced by -O-. In one embodiment, G^2 is (C_2-C_{12} alkylene)-O-(C_2-C_{12} alkylene). In one embodiment, G^2 is (C_2-C_5 alkylene)-O-(C_2-C_6 alkylene).

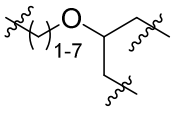
[00123] In one embodiment, one or more -CH_2- in G^2 is replaced by -C(=O)O-. In one embodiment, one or more non-terminal -CH_2- in G^2 is replaced by -C(=O)O-. In one embodiment, one non-terminal -CH_2- in G^2 is replaced by -C(=O)O-. In one embodiment, G^2 is (C_2-C_{12} alkylene)-C(=O)O-(C_2-C_{12} alkylene). In one embodiment, G^2 is (C_2-C_5 alkylene)-C(=O)O-(C_2-C_6 alkylene).

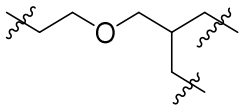
[00124] In one embodiment, one or more -CH_2- in G^2 is replaced by -OC(=O)-. In one embodiment, one or more non-terminal -CH_2- in G^2 is replaced by -OC(=O)-. In one embodiment, one non-terminal -CH_2- in G^2 is replaced by -OC(=O)-. In one embodiment, G^2 is (C_2-C_{12} alkylene)-OC(=O)-(C_2-C_{12} alkylene). In one embodiment, G^2 is (C_2-C_5 alkylene)-OC(=O)-(C_2-C_6 alkylene).

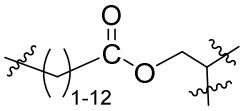
[00125] In one embodiment, G^2 is 

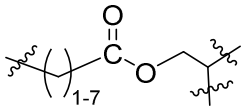
. In one embodiment, G^2 is . In one embodiment, G^2 is . In one embodiment, G^2 is 

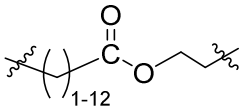
. In one embodiment, G^2 is . In one embodiment, G^2 is . In one embodiment, G^2 is . In one embodiment, G^2 is 

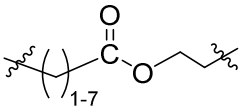
. In one embodiment, G^2 is 

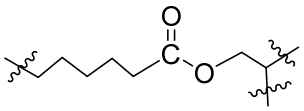
. In one embodiment, G^2 is 

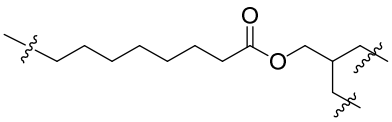
. In one embodiment, G^2 is 

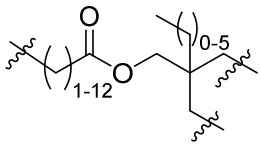
. In one embodiment, G^2 is 

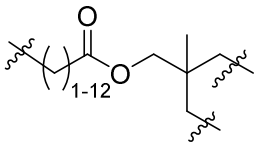
. In one embodiment, G^2 is 

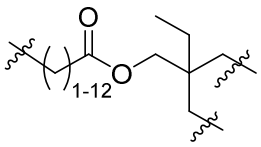
. In one embodiment, G^2 is 

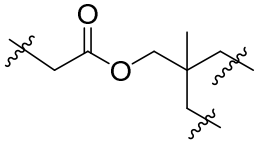
. In one embodiment, G^2 is 

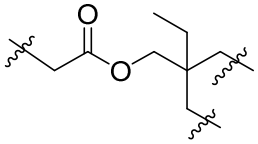
. In one embodiment, G^2 is 

. In one embodiment, G^2 is 

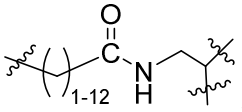
. In one embodiment, G^2 is 

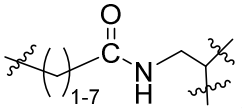
. In one embodiment, G^2 is 

. In one embodiment, G^2 is 

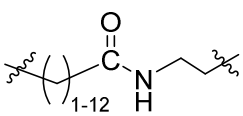
. In one embodiment, G^2 is 

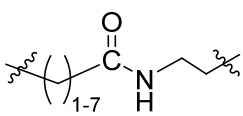
.

In one embodiment, G^2 is 

. In one embodiment, G^2 is 

.

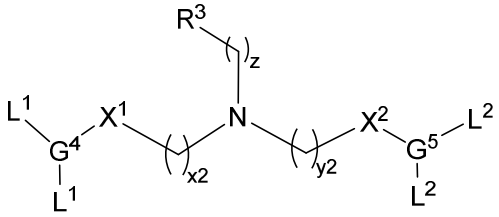
In one embodiment, G^2 is 

. In one embodiment, G^2 is 

.

[00126] Unless otherwise specified, the direction of the G^2 groups provided herein from left to right is from nitrogen atom to L^2 group(s). The point of attachment on the left side is to the nitrogen atom, and the point(s) of attachment on the right side is to the L^2 group(s).

[00127] In one embodiment, the compound is a compound of Formula (V):



(V),

wherein X^1 and X^2 are each independently a bond, -O-, -C(=O)O-, or –OC(=O)-;

z is an integer from 2 to 12;

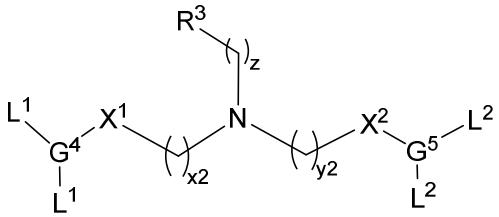
x2 is an integer from 2 to 5 when X^1 is -O-, -C(=O)O-, or –OC(=O)-, and x2 is an integer from 2 to 6 when X^1 is a bond;

y2 is an integer from 2 to 5 when X^2 is -O-, -C(=O)O-, or –OC(=O)-, and y2 is an integer from 2 to 6 when X^2 is a bond;

G^4 and G^5 are each independently C_2-C_6 alkylene;

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

[00128] In one embodiment, the compound is a compound of Formula (V):



(V),

wherein X^1 and X^2 are each independently a bond, -O-, -C(=O)O-, or –OC(=O)-;

z is an integer from 2 to 12;

x2 is an integer from 2 to 12 when X^1 is -O-, -C(=O)O-, or –OC(=O)-, and x2 is an integer from 2 to 13 when X^1 is a bond;

y2 is an integer from 2 to 12 when X^2 is -O-, -C(=O)O-, or –OC(=O)-, and y2 is an integer from 2 to 13 when X^2 is a bond;

G^4 and G^5 are each independently C_2-C_{12} alkylene;

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

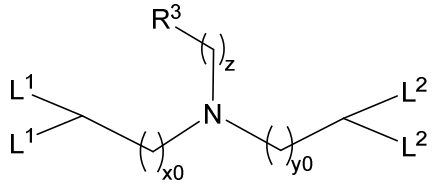
[00129] In one embodiment, z is an integer from 2 to 12. In one embodiment, z is an integer from 2 to 8. In one embodiment, z is an integer from 2 to 6. In one embodiment, z is an integer from 2 to 4. In one embodiment, z is 2. In one embodiment, z is 3. In one embodiment, z is 4. In one embodiment, z is 5. In one embodiment, z is 6.

[00130] In one embodiment, x2 is an integer from 2 to 12. In one embodiment, x2 is an integer from 2 to 8. In one embodiment, x2 is an integer from 2 to 6. In one embodiment, x2 is an integer from 2 to 4. In one embodiment, x2 is 2. In one embodiment, x2 is 3. In one embodiment, x2 is 4. In one embodiment, x2 is 5. In one embodiment, x2 is 6. In one embodiment, x2 is 7.

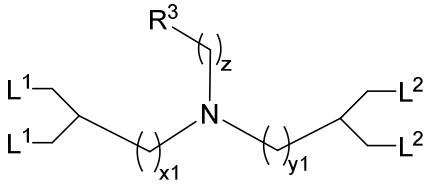
[00131] In one embodiment, y2 is an integer from 2 to 12. In one embodiment, y2 is an integer from 2 to 8. In one embodiment, y2 is an integer from 2 to 6. In one embodiment, y2 is an integer from 2 to 4. In one embodiment, y2 is 2. In one embodiment, y2 is 3. In one embodiment, y2 is 4. In one embodiment, y2 is 5. In one embodiment, y2 is 6. In one embodiment, y2 is 7.

[00132] In one embodiment, x2 and y2 are independently an integer from 2 to 12. In one embodiment, x2 and y2 are independently an integer from 2 to 8. In one embodiment, x2 and y2 are independently an integer from 2 to 6. In one embodiment, x2 and y2 are independently an integer from 2 to 4. In one embodiment, x2 and y2 are both 2. In one embodiment, x2 and y2 are both 3. In one embodiment, x2 and y2 are both 4. In one embodiment, x2 and y2 are both 5. In one embodiment, x2 and y2 are both 6. In one embodiment, x2 and y2 are both 7.

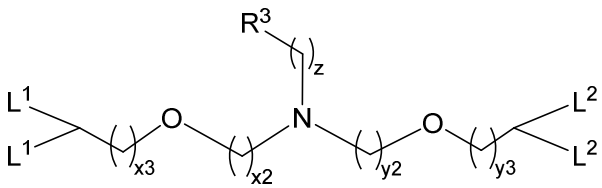
[00133] In one embodiment, the compound is a compound of Formula (V-A), (V-B), (V-C), (V-D), (V-E), or (V-F):



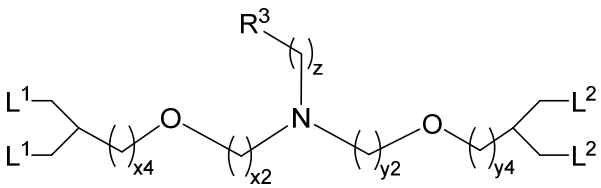
(V-A),



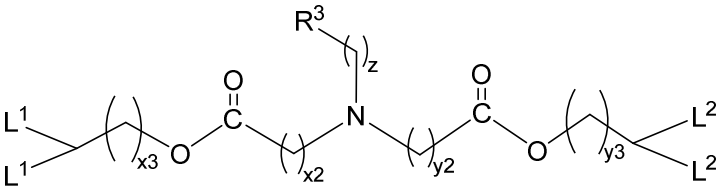
(V-B),



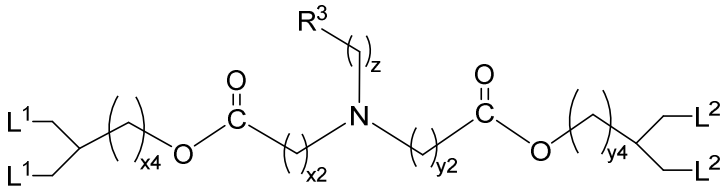
(V-C),



(V-D),



(V-E),



(V-F),

wherein z is an integer from 2 to 12,

x0 is an integer from 1 to 11;

y0 is an integer from 1 to 11;

x1 is an integer from 0 to 9;

y1 is an integer from 0 to 9;

x2 is an integer from 2 to 5;

x3 is an integer from 1 to 5;

x4 is an integer from 0 to 3;

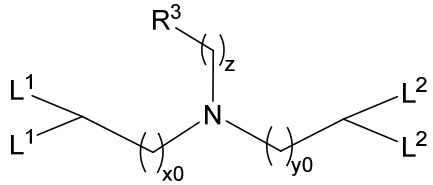
y2 is an integer from 2 to 5;

y3 is an integer from 1 to 5; and

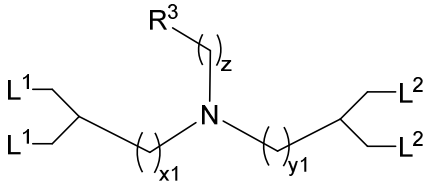
y4 is an integer from 0 to 3;

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

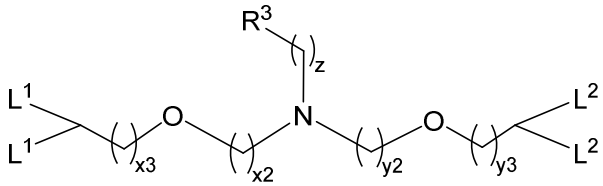
[00134] In one embodiment, the compound is a compound of Formula (V-A), (V-B), (V-C), (V-D), (V-E), (V-F), or (V-G):



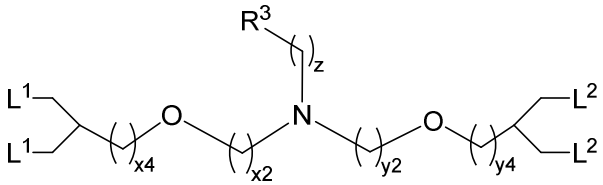
(V-A),



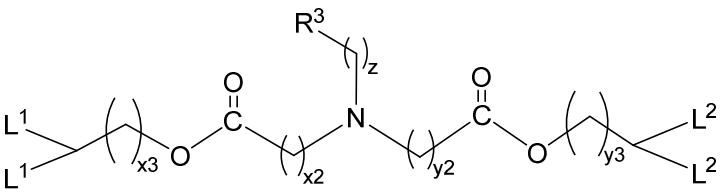
(V-B),



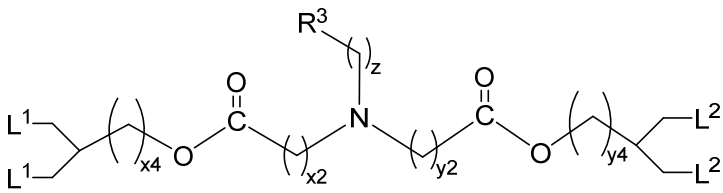
(V-C),



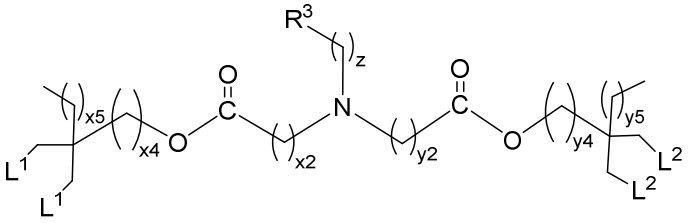
(V-D),



(V-E),



(V-F), or



(V-G),

wherein z is an integer from 2 to 12,

x0 is an integer from 1 to 11;

y0 is an integer from 1 to 11;

x1 is an integer from 0 to 9;

y1 is an integer from 0 to 9;

x2 is an integer from 2 to 12;

x3 is an integer from 1 to 5;

x4 is an integer from 0 to 3;

x5 is an integer from 0 to 5;

y2 is an integer from 2 to 12;

y3 is an integer from 1 to 5;

y4 is an integer from 0 to 3; and

y5 is an integer from 0 to 5;

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

[00135] In one embodiment, x0 is an integer from 2 to 10. In one embodiment, x0 is an integer from 2 to 8. In one embodiment, x0 is an integer from 2 to 6. In one embodiment, x0 is an integer from 4 to 6. In one embodiment, x0 is 2. In one embodiment, x0 is 3. In one embodiment, x0 is 4. In one embodiment, x0 is 5. In one embodiment, x0 is 6.

[00136] In one embodiment, y0 is an integer from 2 to 10. In one embodiment, y0 is an integer from 2 to 8. In one embodiment, y0 is an integer from 2 to 6. In one embodiment, y0 is an integer from 4 to 6. In one embodiment, y0 is 2. In one embodiment, y0 is 3. In one embodiment, y0 is 4. In one embodiment, y0 is 5. In one embodiment, y0 is 6.

[00137] In one embodiment, x0 and y0 are independently an integer from 2 to 10. In one embodiment, x0 and y0 are independently an integer from 2 to 8. In one embodiment, x0 and y0 are independently an integer from 2 to 6. In one embodiment, x0 and y0 are independently an integer from 4 to 6. In one embodiment, x0 and y0 are both 4. In one embodiment, x0 and y0 are both 5.

[00138] In one embodiment, x1 is an integer from 0 to 9. In one embodiment, x1 is an integer from 2 to 8. In one embodiment, x1 is an integer from 2 to 6. In one embodiment, x1 is an integer from 4 to 6. In one embodiment, x1 is 2. In one embodiment, x1 is 3. In one embodiment, x1 is 4. In one embodiment, x1 is 5. In one embodiment, x1 is 6.

[00139] In one embodiment, y1 is an integer from 0 to 9. In one embodiment, y1 is an integer from 2 to 8. In one embodiment, y1 is an integer from 2 to 6. In one embodiment, y1 is an integer from 4 to 6. In one embodiment, y1 is 2. In one embodiment, y1 is 3. In one embodiment, y1 is 4. In one embodiment, y1 is 5. In one embodiment, y1 is 6.

[00140] In one embodiment, x1 and y1 are independently an integer from 0 to 9. In one embodiment, x1 and y1 are independently an integer from 2 to 8. In one embodiment, x1 and y1 are independently an integer from 2 to 6. In one embodiment, x1 and y1 are independently an integer from 4 to 6. In one embodiment, x1 and y1 are both 4. In one embodiment, x1 and y1 are both 5.

[00141] In one embodiment, x2 is an integer from 2 to 12. In one embodiment, x2 is an integer from 2 to 7. In one embodiment, x2 is an integer from 2 to 5. In one embodiment, x2 is an integer from 2 to 4. In one embodiment, x2 is 2. In one embodiment, x2 is 3. In one embodiment, x2 is 4. In one embodiment, x2 is 5. In one embodiment, x2 is 7. In one embodiment, x2 is 12.

[00142] In one embodiment, y2 is an integer from 2 to 12. In one embodiment, y2 is an integer from 2 to 7. In one embodiment, y2 is an integer from 2 to 5. In one embodiment, y2 is an integer from 2 to 4. In one embodiment, y2 is 2. In one embodiment, y2 is 3. In one embodiment, y2 is 4. In one embodiment, y2 is 5. In one embodiment, y2 is 7. In one embodiment, y2 is 12.

[00143] In one embodiment, x2 and y2 are independently an integer from 2 to 12. In one embodiment, x2 and y2 are independently an integer from 2 to 7. In one embodiment, x2 and y2 are independently an integer from 2 to 5. In one embodiment, x2 and y2 are independently an integer from 2 to 4. In one embodiment, x2 and y2 are both 2. In one embodiment, x2 and y2 are both 3. In one embodiment, x2 and y2 are both 4. In one embodiment, x2 and y2 are both 5. In one embodiment, x2 and y2 are both 7. In one embodiment, x2 and y2 are both 12.

[00144] In one embodiment, x3 is an integer from 1 to 5. In one embodiment, x3 is 1. In one embodiment, x3 is 2. In one embodiment, x3 is 3. In one embodiment, x3 is 4. In one embodiment, x3 is 5.

[00145] In one embodiment, y3 is an integer from 1 to 5. In one embodiment, y3 is 1. In one embodiment, y3 is 2. In one embodiment, y3 is 3. In one embodiment, y3 is 4. In one embodiment, y3 is 5.

[00146] In one embodiment, x3 and y3 are independently an integer from 1 to 5. In one embodiment, x3 and y3 are both 1. In one embodiment, x3 and y3 are both 2. In one embodiment, x3 and y3 are both 3. In one embodiment, x3 and y3 are both 4. In one embodiment, x3 and y3 are both 5.

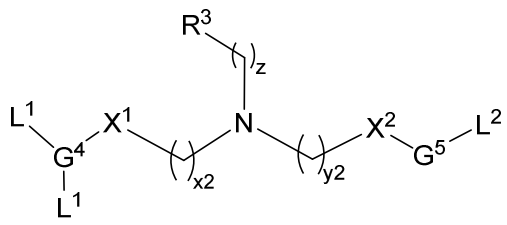
[00147] In one embodiment, x4 is an integer from 0 to 3. In one embodiment, x4 is 0. In one embodiment, x4 is 1. In one embodiment, x4 is 2. In one embodiment, x4 is 3.

[00148] In one embodiment, y4 is an integer from 0 to 3. In one embodiment, y4 is 0. In one embodiment, y4 is 1. In one embodiment, y4 is 2. In one embodiment, y4 is 3.

[00149] In one embodiment, x4 and y4 are independently an integer from 0 to 3. In one embodiment, x4 and y4 are both 0. In one embodiment, x4 and y4 are both 1. In one embodiment, x4 and y4 are both 2. In one embodiment, x4 and y4 are both 3.

[00150] In one embodiment, x5 is an integer from 0 to 5. In one embodiment, x5 is 0. In one embodiment, x5 is 1. In one embodiment, x5 is 2. In one embodiment, x5 is 3. In one embodiment, x5 is 4. In one embodiment, x5 is 5. In one embodiment, y5 is an integer from 0 to 5. In one embodiment, y5 is 0. In one embodiment, y5 is 1. In one embodiment, y5 is 2. In one embodiment, y5 is 3. In one embodiment, y5 is 4. In one embodiment, y5 is 5. In one embodiment, x4 and y4 are independently an integer from 0 to 5. In one embodiment, x5 and y5 are both 0. In one embodiment, x5 and y5 are both 1. In one embodiment, x5 and y5 are both 2. In one embodiment, x5 and y5 are both 3. In one embodiment, x5 and y5 are both 4. In one embodiment, x5 and y5 are both 5.

[00151] In one embodiment, the compound is a compound of Formula (VI):



(VI),

wherein X^1 and X^2 are each independently a bond, -O-, -C(=O)O-, or –OC(=O)-;

z is an integer from 2 to 12;

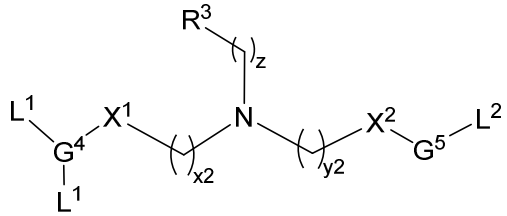
x2 is an integer from 2 to 5 when X^1 is -O-, -C(=O)O-, or –OC(=O)-, and x2 is an integer from 2 to 6 when X^1 is a bond;

y2 is an integer from 2 to 5 when X^2 is -O-, -C(=O)O-, or –OC(=O)-, and y2 is an integer from 2 to 6 when X^2 is a bond;

G^4 and G^5 are each independently C_2-C_6 alkylene;

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

[00152] In one embodiment, the compound is a compound of Formula (VI):



(VI),

wherein X^1 and X^2 are each independently a bond, -O-, -C(=O)O-, or –OC(=O)-;

z is an integer from 2 to 12;

x2 is an integer from 2 to 12 when X^1 is -O-, -C(=O)O-, or –OC(=O)-, and x2 is an integer from 2 to 13 when X^1 is a bond;

y2 is an integer from 2 to 12 when X^2 is -O-, -C(=O)O-, or –OC(=O)-, and y2 is an integer from 2 to 13 when X^2 is a bond;

G^4 and G^5 are each independently C_2-C_{12} alkylene;

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

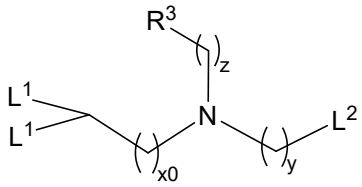
[00153] In one embodiment, z is an integer from 2 to 12. In one embodiment, z is an integer from 2 to 8. In one embodiment, z is an integer from 2 to 6. In one embodiment, z is an integer from 2 to 4. In one embodiment, z is 2. In one embodiment, z is 3. In one embodiment, z is 4. In one embodiment, z is 5. In one embodiment, z is 6.

[00154] In one embodiment, x2 is an integer from 2 to 12. In one embodiment, x2 is an integer from 2 to 8. In one embodiment, x2 is an integer from 2 to 6. In one embodiment, x2 is an integer from 2 to 4. In one embodiment, x2 is 2. In one embodiment, x2 is 3. In one embodiment, x2 is 4. In one embodiment, x2 is 5. In one embodiment, x2 is 6. In one embodiment, x2 is 7. In one embodiment, x2 is 12.

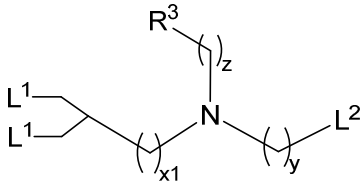
[00155] In one embodiment, y2 is an integer from 2 to 12. In one embodiment, y2 is an integer from 2 to 8. In one embodiment, y2 is an integer from 2 to 6. In one embodiment, y2 is an integer from 2 to 4. In one embodiment, y2 is 2. In one embodiment, y2 is 3. In one embodiment, y2 is 4. In one embodiment, y2 is 5. In one embodiment, y2 is 6. In one embodiment, y2 is 7. In one embodiment, y2 is 12.

[00156] In one embodiment, x2 and y2 are independently an integer from 2 to 12. In one embodiment, x2 and y2 are independently an integer from 2 to 8. In one embodiment, x2 and y2 are independently an integer from 2 to 6. In one embodiment, x2 and y2 are independently an integer from 2 to 4. In one embodiment, x2 and y2 are both 2. In one embodiment, x2 and y2 are both 3. In one embodiment, x2 and y2 are both 4. In one embodiment, x2 and y2 are both 5. In one embodiment, x2 and y2 are both 6. In one embodiment, x2 and y2 are both 7. In one embodiment, x2 and y2 are both 12.

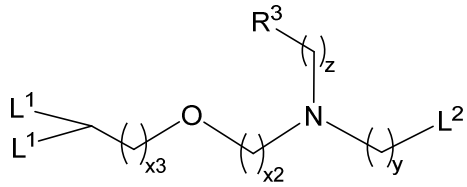
[00157] In one embodiment, the compound is a compound of Formula (VI-A), (VI-B), (VI-C), (VI-D), (VI-E), or (VI-F):



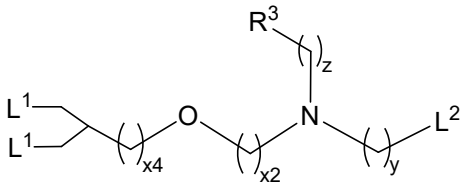
(VI-A),



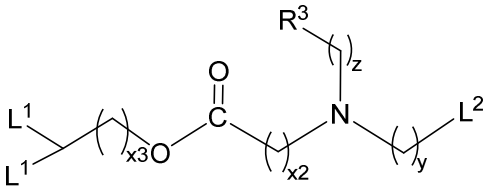
(VI-B),



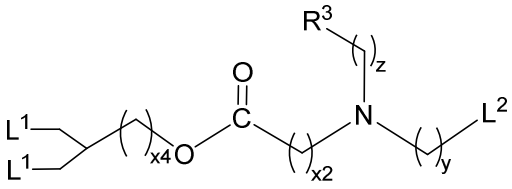
(VI-C),



(VI-D),



(VI-E), or



(VI-F),

wherein z is an integer from 2 to 12;

y is an integer from 2 to 12;

x0 is an integer from 1 to 11;

x1 is an integer from 0 to 9;

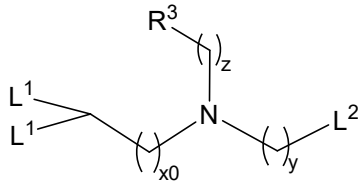
x2 is an integer from 2 to 5;

x3 is an integer from 1 to 5; and

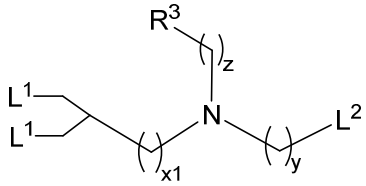
x4 is an integer from 0 to 3

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

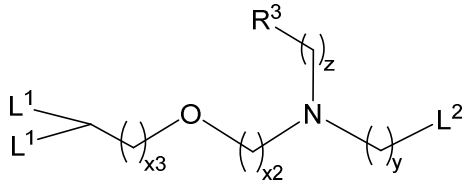
[00158] In one embodiment, the compound is a compound of Formula (VI-A), (VI-B), (VI-C), (VI-D), (VI-E), (VI-F) or (VI-G):



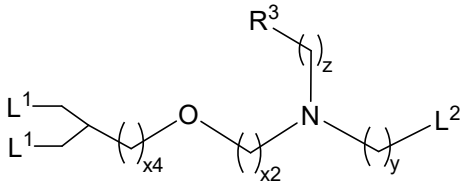
(VI-A),



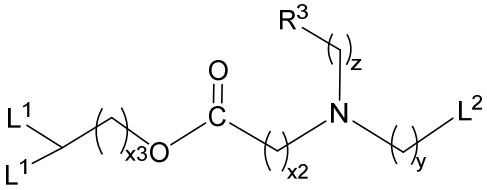
(VI-B),



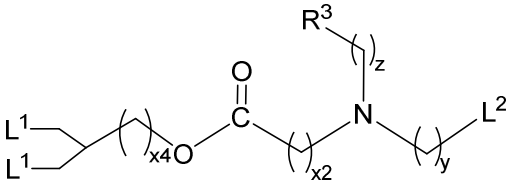
(VI-C),



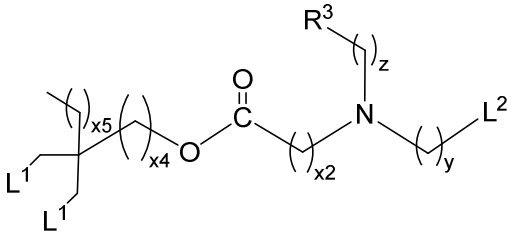
(VI-D),



(VI-E),



(VI-F), or



(VI-G)

wherein z is an integer from 2 to 12;

y is an integer from 2 to 12;

x0 is an integer from 1 to 11;

x1 is an integer from 0 to 9;

x2 is an integer from 2 to 12;

x3 is an integer from 1 to 5;

x4 is an integer from 0 to 3; and

x5 is an integer from 0 to 5;

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

[00159] In one embodiment, x0 is an integer from 2 to 10. In one embodiment, x0 is an integer from 2 to 8. In one embodiment, x0 is an integer from 2 to 6. In one embodiment, x0 is an integer from 4 to 6. In one embodiment, x0 is 2. In one embodiment, x0 is 3. In one embodiment, x0 is 4. In one embodiment, x0 is 5. In one embodiment, x0 is 6.

[00160] In one embodiment, x1 is an integer from 0 to 9. In one embodiment, x1 is an integer from 2 to 8. In one embodiment, x1 is an integer from 2 to 6. In one embodiment, x1 is an integer from 4 to 6. In one embodiment, x1 is 2. In one embodiment, x1 is 3. In one embodiment, x1 is 4. In one embodiment, x1 is 5. In one embodiment, x1 is 6.

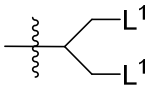
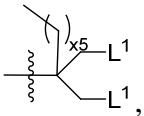
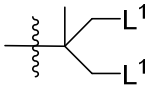
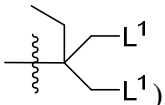
[00161] In one embodiment, x2 is an integer from 2 to 12. In one embodiment, x2 is an integer from 2 to 7. In one embodiment, x2 is an integer from 2 to 5. In one embodiment, x2 is an integer from 2 to 4. In one embodiment, x2 is 2. In one embodiment, x2 is 3. In one embodiment, x2 is 4. In one embodiment, x2 is 5. In one embodiment, x2 is 8. In one embodiment, x2 is 12.

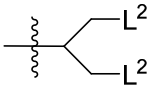
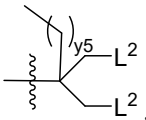
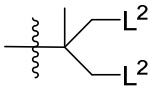
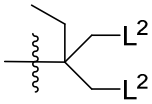
[00162] In one embodiment, x3 is an integer from 1 to 5. In one embodiment, x3 is 1. In one embodiment, x3 is 2. In one embodiment, x3 is 3. In one embodiment, x3 is 4. In one embodiment, x3 is 5.

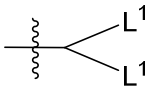
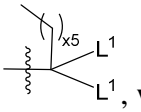
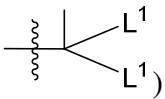
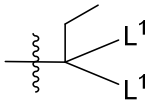
[00163] In one embodiment, x4 is an integer from 0 to 3. In one embodiment, x4 is 0. In one embodiment, x4 is 1. In one embodiment, x4 is 2. In one embodiment, x4 is 3.

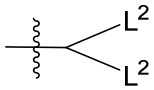
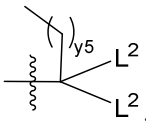
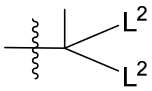
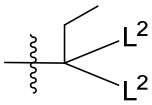
[00164] In one embodiment, x5 is 0. In one embodiment, x5 is 1. In one embodiment, x5 is 2. In one embodiment, x5 is 3. In one embodiment, x5 is 4. In one embodiment, x5 is 5.

[00165] In one embodiment, y is an integer from 2 to 10. In one embodiment, y is an integer from 2 to 8. In one embodiment, y is an integer from 2 to 6. In one embodiment, y is 2. In one embodiment, y is 3. In one embodiment, y is 4. In one embodiment, y is 5. In one embodiment, y is 6.

[00166] In one embodiment of Formula (V-B), (V-D), (V-F), (VI-B), (VI-D), or (VI-F), the  moiety is replaced by , wherein x5 is 0 or 5. In one embodiment, x5 is 0 (*i.e.*, replaced by ). In one embodiment, x5 is 1 (*i.e.*, replaced by ).

[00167] In one embodiment of Formula (V-B), (V-D), or (V-F), the  moiety is replaced by , wherein y5 is 0 or 5. In one embodiment, y5 is 0 (*i.e.*, replaced by ). In one embodiment, y5 is 1 (*i.e.*, replaced by ).

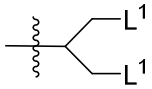
[00168] In one embodiment of Formula (V-A), (V-C), (V-E), (VI-A), (VI-C), or (VI-E), the  moiety is replaced by , wherein x5 is 0 or 5. In one embodiment, x5 is 0 (*i.e.*, ). In one embodiment, x5 is 1 (*i.e.*, replaced by ).

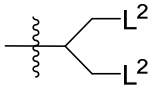
[00169] In one embodiment of Formula (V-A), (V-C), or (V-E), the  moiety is replaced by , wherein y5 is 0 or 5. In one embodiment, y5 is 0 (*i.e.*, replaced by ). In one embodiment, y5 is 1 (*i.e.*, replaced by ).

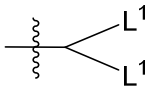
[00170] In one embodiment, L^1 is $–OR^1$, $–OC(=O)R^1$, $-C(=O)OR^1$, $-NR^aC(=O)R^1$, or $-C(=O)NR^bR^c$. In one embodiment, L^2 is $–OR^2$, $–OC(=O)R^2$, $-C(=O)OR^2$, $-NR^dC(=O)R^2$, or $-C(=O)NR^eR^f$. In one embodiment, each L_1 are independently $–OR^1$ or $–OC(=O)R^1$ and each L_2 are independently $–OR^2$ or $–OC(=O)R^2$.

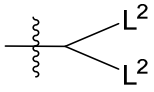
[00171] In one embodiment, where there are two L^1, each L^1 is independently $–OR^1$. In one embodiment, where there are two L^1, each L^1 is independently $–OC(=O)R^1$. In one

embodiment, where there are two L^2, each L^2 is independently $–OR^2$. In one embodiment, where there are two L^2, each L^2 is independently $–OC(=O)R^2$. In one embodiment, R^1 or R^2 are independently straight C_6-C_{10} alkyl. In one embodiment, R^1 or R^2 are both straight C_7 alkyl. In one embodiment, R^1 or R^2 are both straight C_8 alkyl. In one embodiment, R^1 or R^2 are both 2-(octyldisulfaneyl)ethyl. In one embodiment, R^1 or R^2 are independently $-R^7-CH(R^8)(R^9)$, wherein R^7 is C_0-C_5 alkylene, and R^8 and R^9 are independently C_2-C_{10} alkyl or C_2-C_{10} alkenyl. In one embodiment, R^1 or R^2 are independently $-R^7-CH(R^8)(R^9)$, wherein R^7 is C_0-C_1 alkylene, and R^8 and R^9 are independently C_4-C_8 alkyl. In one embodiment, R^1 or R^2 is $-R^{14}-S-S-R^{15}$, wherein R^{14} is C_2-C_{10} alkylene, and R^{15} is C_2-C_{10} alkyl. In one embodiment, R^1 or R^2 is $-CH_2CH_2-S-S-R^{16}$, wherein R^{16} is C_2-C_{18} alkyl. In one embodiment, R^{16} is C_4-C_{16} alkyl. In one embodiment, R^{16} is C_6-C_{12} alkyl. In one embodiment, R^{16} is C_8 alkyl. In one embodiment, R^{16} is a straight C_8 alkyl.

[00172] In one embodiment, when there is only one L^2, L^2 is $-C(=O)OR^2$. In one embodiment, when there is only one L^2, L^2 is $-OC(=O)R^2$. In another embodiment, when there is only one L^2, L^2 is $-C(=O)NR^eR^f$. In one embodiment, R^2 or R^f is $-R^7-CH(R^8)(R^9)$, wherein R^7 is C_0-C_1 alkylene, and R^8 and R^9 are independently C_4-C_8 alkyl. In one embodiment, R^2 or R^f is C_{10}-C_{18} alkyl. In one embodiment, R^2 or R^f is C_{18} alkyl. In one embodiment, R^2 or R^f is 2-(octyldisulfaneyl)ethyl. In one embodiment, R^2 or R^f is C_{10}-C_{18} alkenyl. In one embodiment, R^2 or R^f is C_{15} alkyl. In one embodiment, R^2 or R^f is C_{17} alkenyl. In one embodiment, R^2 or R^f is $-R^{14}-S-S-R^{15}$, wherein R^{14} is C_2-C_{10} alkylene, and R^{15} is C_2-C_{10} alkyl. In one embodiment, R^2 or R^f is $-CH_2CH_2-S-S-R^{16}$, wherein R^{16} is C_2-C_{18} alkyl. In one embodiment, R^{16} is C_4-C_{16} alkyl. In one embodiment, R^{16} is C_6-C_{12} alkyl. In one embodiment, R^{16} is C_8 alkyl. In one embodiment, R^{16} is a straight C_8 alkyl. In one particularly embodiment of any one of Formulas (V-A) to (V-F) and (VI-A) to (VI-F), when there is a  moiety, each L^1 is independently $–OC(=O)R^1$. In one embodiment, each R^1 is independently straight C_7-C_{10} alkyl. In one embodiment, one or more $-CH_2-$ in the alkyl is optionally replaced by -S-S-.

[00173] In one particularly embodiment of any one of Formulas (V-A) to (V-F) and (VI-A) to (VI-F), when there is a  moiety, each L^2 is independently $–OC(=O)R^2$. In one embodiment, each R^2 is independently straight C_7-C_{10} alkyl. In one embodiment, one or more $-CH_2-$ in the alkyl is optionally replaced by -S-S-.

[00174] In one particularly embodiment of any one of Formulas (V-A) to (V-F) and (VI-A) to (VI-F), when there is a  moiety, each L^1 is independently $-OR^1$. In another embodiment, each L^1 is independently $-OC(=O)R^1$. In one embodiment, each R^1 is independently straight C_7-C_{10} alkyl.

[00175] In one particularly embodiment of any one of Formulas (V-A) to (V-F) and (VI-A) to (VI-F), when there is a  moiety, each L^2 is independently $-OR^2$. In another embodiment, each L^2 is independently $-OC(=O)R^2$. In one embodiment, each R^2 is independently straight C_7-C_{10} alkyl.

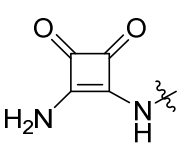
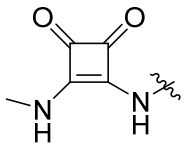
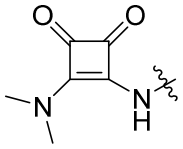
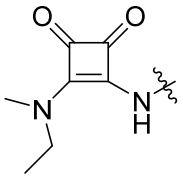
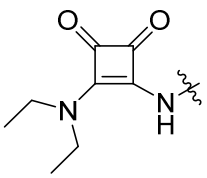
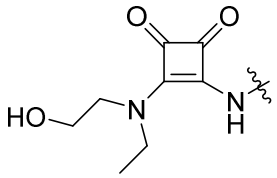
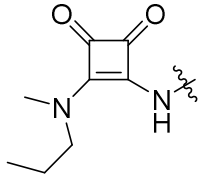
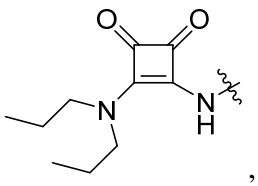
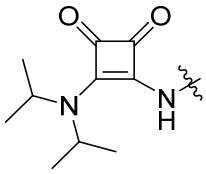
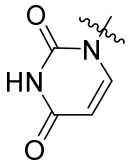
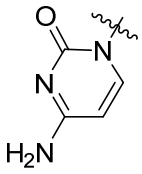
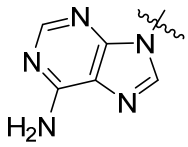
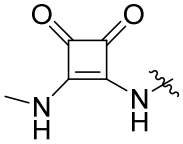
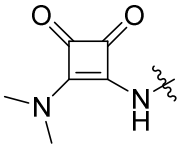
[00176] In one embodiment, R^3 is $-N(R^4)R^5$.

[00177] In one embodiment, R^4 is C_1-C_{12} alkyl. In one embodiment, R^4 is C_1-C_8 alkyl. In one embodiment, R^4 is C_1-C_6 alkyl. In one embodiment, R^4 is C_1-C_4 alkyl. In one embodiment, R^4 is methyl. In one embodiment, R^4 is ethyl. In one embodiment, R^4 is n-propyl. In one embodiment, R^4 is isopropyl. In one embodiment, R^4 is n-butyl. In one embodiment, R^4 is n-pentyl. In one embodiment, R^4 is n-hexyl. In one embodiment, R^4 is n-octyl. In one embodiment, R^4 is n-nonyl.

[00178] In one embodiment, R^4 is C_2-C_{12} alkenyl. In one embodiment, R^4 is C_2-C_8 alkenyl. In one embodiment, R^4 is C_2-C_6 alkenyl. In one embodiment, R^4 is C_2-C_4 alkenyl. In one embodiment, the alkenyl is straight alkenyl. In one embodiment, the alkenyl is branched alkenyl. In one embodiment, R^4 is ethenyl. In one embodiment, R^4 is allyl.

[00179] In one embodiment, R^4 is C_3-C_8 cycloalkyl. In one embodiment, R^4 is cyclopropyl. In one embodiment, R^4 is cyclobutyl. In one embodiment, R^4 is cyclopentyl. In one embodiment, R^4 is cyclohexyl. In one embodiment, R^4 is cycloheptyl.

[00180] In one embodiment, R^4 is C_3-C_8 cycloalkenyl. In one embodiment, R^4 is cyclopropenyl. In one embodiment, R^4 is cyclobutenyl. In one embodiment, R^4 is cyclopentenyl. In one embodiment, R^4 is cyclohexenyl. In one embodiment, R^4 is cycloheptenyl. In one embodiment, R^4 is cyclooctenyl. In one embodiment, the cycloalkenyl is substituted with one or more of hydroxyl, oxo, $-NH_2$, $-NH(C_1$-C_6 alkyl), or $-N(C_1$-C_6 alkyl$)_2$. In one embodiment, the C_1-C_6 alkyl is substituted with a hydroxy.

[00181] In one embodiment, R^3 is , , , , , , , , , , , or . In one embodiment, R^3 is . In one embodiment, R^3 is .

[00182] In one embodiment, R^4 is C_6-C_{10} aryl. In one embodiment, R^4 is phenyl.

[00183] In one embodiment, R^4 is 4- to 8-membered heterocycloalkyl. In one embodiment, R^4 is oxetanyl. In one embodiment, R^4 is tetrahydrofuranyl. In one embodiment, R^4 is tetrahydropyranyl. In one embodiment, R^4 is tetrahydrothiopyranyl. In one embodiment, R^4 is N-methylpiperidinyl.

[00184] In one embodiment, R^4 is unsubstituted.

[00185] In one embodiment, R^4 is substituted with one or more substituents selected from the group consisting of oxo, $–OR^g$, $-NR^gC(=O)R^h$, $-C(=O)NR^gR^h$, $-C(=O)R^h$, $-OC(=O)R^h$, $-C(=O)OR^h$, $–O-R^i-OH$, and $-N(R^{10})R^{11}$, wherein:

R^g is at each occurrence independently H or C_1-C_6 alkyl;

R^h is at each occurrence independently C_1-C_6 alkyl;

R^i is at each occurrence independently C_1-C_6 alkylene;

R^{10} is hydrogen or C_1-C_6 alkyl;

R^{11} is C_1-C_6 alkyl, C_3-C_8 cycloalkyl, or C_3-C_8 cycloalkenyl;

or R^{10} and R^{11} together with the nitrogen to which they are attached form a cyclic moiety;

and R^{11} or the cyclic moiety is optionally substituted with one or more of hydroxyl, oxo, $-NH_2$, $-NH(C_1$-C_6 alkyl), or $–N(C_1$-C_6 alkyl$)_2$.

[00186] In one embodiment, R^4 is substituted with one or more hydroxyl. In one embodiment, R^4 is substituted with one hydroxyl.

[00187] In one embodiment, R^4 is a substituted C_1-C_{12} alkyl. In one embodiment, R^4 is -$(CH_2)_pQ$, -$(CH_2)_pCHQR$, -CHQR, or -$CQ(R)_2$, wherein Q is C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_3-C_8 cycloalkynyl, 4- to 8-membered heterocyclyl, C_6-C_{10} aryl, 5- to 10-membered heteroaryl, -OR, -$O(CH_2)_pN(R)_2$, -C(O)OR, -OC(O)R, -CX_3, -CX_2H, -CXH_2, -CN, -$N(R)_2$, -$C(O)N(R)_2$, -N(R)C(O)R, -$N(R)S(O)_2R$, -$N(R)C(O)N(R)_2$, -$N(R)C(S)N(R)_2$, -$N(R)R^{22}$, -$O(CH_2)_pOR$, -$N(R)C(=NR^{23})N(R)_2$, -$N(R)C(=CHR^{23})N(R)_2$, -$OC(O)N(R)_2$, -N(R)C(O)OR, -N(OR)C(O)R, -$N(OR)S(O)_2R$, -N(OR)C(O)OR, -$N(OR)C(O)N(R)_2$, -$N(OR)C(S)N(R)_2$, -$N(OR)C(=NR^{23})N(R)_2$, -$N(OR)C(=CHR^{23})N(R)_2$, -$C(=NR^{23})N(R)_2$, -$C(=NR^{23})R$, -C(O)N(R)OR, or -$C(R)N(R)_2C(O)OR$, and each p is independently 1, 2, 3, 4, or 5;
R^{22} is C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_3-C_8 cycloalkynyl, 4- to 8-membered heterocyclyl, C_6-C_{10} aryl, or 5- to 10-membered heteroaryl;
R^{23} is H, -CN, -NO_2, C_1-C_6 alkyl, -OR, -$S(O)_2R$, -$S(O)_2N(R)_2$, C_2-C_6 alkenyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_3-C_8 cycloalkynyl, 4- to 8-membered heterocyclyl, C_6-C_{10} aryl, or 5- to 10-membered heteroaryl;
each R is independently H, C_1-C_3 alkyl, or C_2-C_3 alkenyl; or two R in a $N(R)_2$ moiety together with the nitrogen to which they are attached form a cyclic moiety; and
each X is independently F, CI, Br, or I.

[00188] In one embodiment, R^4 is –CH_2CH_2OH. In one embodiment, R^4 is –$CH_2CH_2CH_2OH$. In one embodiment, R^4 is –$CH_2CH_2CH_2CH_2OH$. In one embodiment, R^4 is –$CH_2CH_2OCH_2CH_2OH$.

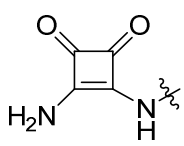
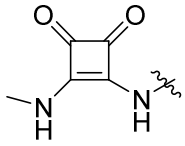
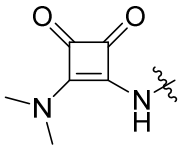
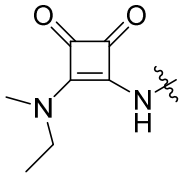
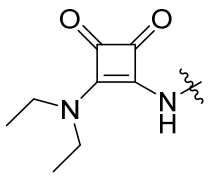
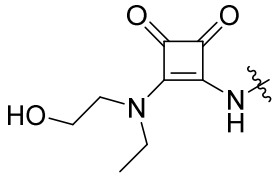
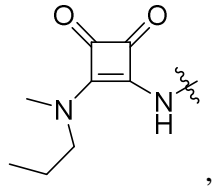
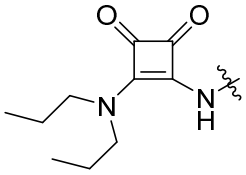
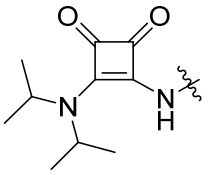
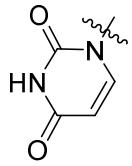
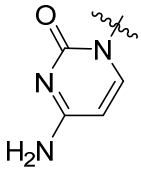
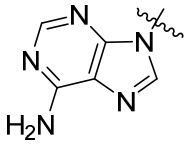
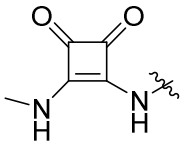
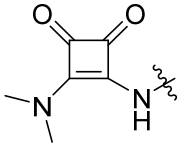
[00189] In one embodiment, R^4 is substituted with one or more -$N(R^{10})R^{11}$. In one embodiment, R^4 is substituted with one -$N(R^{10})R^{11}$.

[00190] In one embodiment, R^{10} is hydrogen.

[00191] In one embodiment, R^{11} is C_3-C_8 cycloalkenyl. In one embodiment, R^{11} is cyclobutenyl. In one embodiment, R^{11} is substituted with one or more of oxo, -NH_2, -$NH(C_1$-C_6 alkyl), or –$N(C_1$-C_6 alkyl$)_2$.

[00192] In one embodiment, R^{10} and R^{11} together with the nitrogen to which they are attached form a cyclic moiety. In one embodiment, the cyclic moiety is a 5- to 10-membered heteroaryl. In one embodiment, the cyclic moiety is pyrimidin-1-yl. In one embodiment, the

cyclic moiety is purin-9-yl. In one embodiment, the cyclic moiety is substituted with one or more of oxo, -NH_2, -NH(C_1-C_6 alkyl), or –N(C_1-C_6 alkyl)$_2$. In one embodiment, the C_1-C_6 alkyl is substituted with a hydroxy.

[00193] In one embodiment, R^4 is substituted with , , , , , , , , , , , or . In one embodiment, R^4 is substituted with . In one embodiment, R^4 is substituted with .

[00194] In one embodiment, R^5 is hydrogen. In one embodiment, R^5 is C_1-C_{12} alkyl. In one embodiment, R^5 is C_1-C_8 alkyl. In one embodiment, R^5 is C_1-C_6 alkyl. In one embodiment, R^5 is C_1-C_4 alkyl. In one embodiment, R^5 is methyl. In one embodiment, R^5 is ethyl. In one embodiment, R^5 is n-propyl. In one embodiment, R^5 is isopropyl. In one embodiment, R^5 is n-butyl. In one embodiment, R^5 is n-pentyl. In one embodiment, R^5 is n-hexyl. In one embodiment, R^5 is n-octyl. In one embodiment, R^5 is n-nonyl.

[00195] In one embodiment, R^5 is C_3-C_8 cycloalkyl. In one embodiment, R^5 is cyclopropyl. In one embodiment, R^5 is cyclobutyl. In one embodiment, R^5 is cyclopentyl. In one embodiment, R^5 is cyclohexyl. In one embodiment, R^5 is cycloheptyl. In one embodiment, R^5 is cyclooctyl.

[00196] In one embodiment, R^5 is C_3-C_8 cycloalkenyl. In one embodiment, R^5 is cyclopropenyl. In one embodiment, R^5 is cyclobutenyl. In one embodiment, R^5 is

cyclopentenyl. In one embodiment, R^5 is cyclohexenyl. In one embodiment, R^5 is cycloheptenyl. In one embodiment, R^5 is cyclooctenyl.

[00197] In one embodiment, R^5 is C_6-C_{10} aryl. In one embodiment, R^5 is phenyl.

[00198] In one embodiment, the R^5 is 4- to 8-membered heterocycloalkyl. In one embodiment, the R^5 is oxetanyl. In one embodiment, the R^5 is tetrahydrofuranyl. In one embodiment, the R^5 is tetrahydropyranyl. In one embodiment, the R^5 is tetrahydrothiopyranyl.

[00199] In one embodiment, R^5 is unsubstituted.

[00200] In one embodiment, R^5 is substituted with one or more substituents selected from the group consisting of oxo, $–OR^g$, $-NR^gC(=O)R^h$, $-C(=O)NR^gR^h$, $-C(=O)R^h$, $-OC(=O)R^h$, $-C(=O)OR^h$, $–O-R^i-OH$, and $-N(R^{10})R^{11}$, wherein:

R^g is at each occurrence independently H or C_1-C_6 alkyl;

R^h is at each occurrence independently C_1-C_6 alkyl;

R^i is at each occurrence independently C_1-C_6 alkylene;

R^{10} is hydrogen or C_1-C_6 alkyl;

R^{11} is C_1-C_6 alkyl, C_3-C_8 cycloalkyl, or C_3-C_8 cycloalkenyl;

or R^{10} and R^{11} together with the nitrogen to which they are attached form a cyclic moiety;

and R^{11} or the cyclic moiety is optionally substituted with one or more of hydroxyl, oxo, $-NH_2$, $-NH(C_1$-C_6 alkyl), or $–N(C_1$-C_6 alkyl$)_2$.

[00201] In one embodiment, R^5 is substituted with one or more hydroxyl or $-N(R^{10})R^{11}$.

[00202] In one embodiment, R^5 is substituted with one or more hydroxyl. In one embodiment, R^5 is substituted with one hydroxyl.

[00203] In one embodiment, R^5 is substituted with one or more $-N(R^{10})R^{11}$. In one embodiment, R^5 is substituted with one $-N(R^{10})R^{11}$.

[00204] In one embodiment, R^{10} is hydrogen.

[00205] In one embodiment, R^{11} is C_3-C_8 cycloalkenyl. In one embodiment, R^{11} is cyclobutenyl. In one embodiment, R^{11} is substituted with one or more of oxo, $-NH_2$, $-NH(C_1$-C_6 alkyl), or $–N(C_1$-C_6 alkyl$)_2$.

[00206] In one embodiment, R^{10} and R^{11} together with the nitrogen to which they are attached form a cyclic moiety. In one embodiment, the cyclic moiety is a 5- to 10-membered

heteroaryl. In one embodiment, the cyclic moiety is pyrimidin-1-yl. In one embodiment, the cyclic moiety is purin-9-yl. In one embodiment, the cyclic moiety is substituted with one or more of oxo, $-NH_2$, $-NH(C_1\text{-}C_6$ alkyl), or $-N(C_1\text{-}C_6$ alkyl)$_2$.

[00207] In one embodiment, R^3 is $-OR^6$. In one embodiment, R^3 is $-SR^6$.

[00208] In one embodiment, R^6 is hydrogen (*i.e.*, R^3 is -OH, or R^3 is -SH). In one embodiment, R^6 is $C_1\text{-}C_{12}$ alkyl. In one embodiment, R^6 is $C_1\text{-}C_8$ alkyl. In one embodiment, R^6 is $C_1\text{-}C_6$ alkyl. In one embodiment, R^6 is $C_1\text{-}C_4$ alkyl. In one embodiment, R^6 is methyl. In one embodiment, R^6 is ethyl. In one embodiment, R^6 is $C_3\text{-}C_8$ cycloalkyl. In one embodiment, R^6 is $C_3\text{-}C_8$ cycloalkenyl. In one embodiment, R^6 is $C_6\text{-}C_{10}$ aryl. In one embodiment, R^6 is phenyl.

[00209] In one embodiment, R^6 is unsubstituted.

[00210] In one embodiment, R^6 is substituted.

[00211] In one embodiment, R^6 is substituted with one or more hydroxyl. In one embodiment, R^6 is substituted with one hydroxyl.

[00212] In one embodiment, R^1 is straight $C_6\text{-}C_{24}$ alkyl. In one embodiment, R^1 is straight $C_7\text{-}C_{15}$ alkyl. In one embodiment, R^1 is straight C_7 alkyl. In one embodiment, R^1 is straight C_8 alkyl. In one embodiment, R^1 is straight C_9 alkyl. In one embodiment, R^1 is straight C_{10} alkyl. In one embodiment, R^1 is straight C_{11} alkyl. In one embodiment, R^1 is straight C_{12} alkyl. In one embodiment, R^1 is straight C_{13} alkyl. In one embodiment, R^1 is straight C_{14} alkyl. In one embodiment, R^1 is straight C_{15} alkyl.

[00213] In one embodiment, R^1 is straight $C_6\text{-}C_{24}$ alkenyl. In one embodiment, R^1 is straight $C_7\text{-}C_{17}$ alkenyl. In one embodiment, R^1 is straight C_7 alkenyl. In one embodiment, R^1 is straight C_8 alkenyl. In one embodiment, R^1 is straight C_9 alkenyl. In one embodiment, R^1 is straight C_{10} alkenyl. In one embodiment, R^1 is straight C_{11} alkenyl. In one embodiment, R^1 is straight C_{12} alkenyl. In one embodiment, R^1 is straight C_{13} alkenyl. In one embodiment, R^1 is straight C_{14} alkenyl. In one embodiment, R^1 is straight C_{15} alkenyl. In one embodiment, R^1 is straight C_{16} alkenyl. In one embodiment, R^1 is straight C_{17} alkenyl.

[00214] In one embodiment, R^1 is branched $C_6\text{-}C_{24}$ alkyl. In one embodiment, R^1 is $-R^7\text{-}CH(R^8)(R^9)$, wherein R^7 is $C_0\text{-}C_5$ alkylene, and R^8 and R^9 are independently $C_2\text{-}C_{10}$ alkyl. In one embodiment, R^1 is $-R^7\text{-}CH(R^8)(R^9)$, wherein R^7 is $C_0\text{-}C_1$ alkylene, and R^8 and R^9 are independently $C_4\text{-}C_8$ alkyl.

[00215] In one embodiment, R^1 is branched C_6-C_{24} alkenyl. In one embodiment, R^1 is -R^7-$CH(R^8)(R^9)$, wherein R^7 is C_0-C_5 alkylene, and R^8 and R^9 are independently C_2-C_{10} alkenyl. In one embodiment, R^1 is -R^7-$CH(R^8)(R^9)$, wherein R^7 is C_0-C_1 alkylene, and R^8 and R^9 are independently C_6-C_{10} alkenyl.

[00216] In one embodiment, one or more -CH_2- in R^1 is replaced by -S-S-. In one embodiment, one -CH_2- in R^1 is replaced by -S-S-. In one embodiment, R^1 has one or more disulfide bond. In one embodiment, R^1 has one disulfide bond. In one embodiment, R^1 has two disulfide bonds. In one embodiment, R^1 is -R^{14}-S-S-R^{15}, wherein R^{14} is C_2-C_{10} alkylene, and R^{15} is C_2-C_{10} alkyl. In one embodiment, R^1 is -CH_2CH_2-S-S-R^{16}, wherein R^{16} is C_2-C_{18} alkyl. In one embodiment, R^{16} is C_4-C_{16} alkyl. In one embodiment, R^{16} is C_6-C_{12} alkyl. In one embodiment, R^{16} is C_8 alkyl. In one embodiment, R^{16} is a straight C_8 alkyl. In one embodiment, R^1 is 2-(octyldisulfaneyl)ethyl.

[00217] In one embodiment, R^2 is straight C_6-C_{24} alkyl. In one embodiment, R^2 is straight C_7-C_{15} alkyl. In one embodiment, R^2 is straight C_7 alkyl. In one embodiment, R^2 is straight C_8 alkyl. In one embodiment, R^2 is straight C_9 alkyl. In one embodiment, R^2 is straight C_{10} alkyl. In one embodiment, R^2 is straight C_{11} alkyl. In one embodiment, R^2 is straight C_{12} alkyl. In one embodiment, R^2 is straight C_{13} alkyl. In one embodiment, R^2 is straight C_{14} alkyl. In one embodiment, R^2 is straight C_{15} alkyl.

[00218] In one embodiment, R^2 is straight C_6-C_{24} alkenyl. In one embodiment, R^2 is straight C_7-C_{17} alkenyl. In one embodiment, R^2 is straight C_7 alkenyl. In one embodiment, R^2 is straight C_8 alkenyl. In one embodiment, R^2 is straight C_9 alkenyl. In one embodiment, R^2 is straight C_{10} alkenyl. In one embodiment, R^2 is straight C_{11} alkenyl. In one embodiment, R^2 is straight C_{12} alkenyl. In one embodiment, R^2 is straight C_{13} alkenyl. In one embodiment, R^2 is straight C_{14} alkenyl. In one embodiment, R^2 is straight C_{15} alkenyl. In one embodiment, R^2 is straight C_{16} alkenyl. In one embodiment, R^2 is straight C_{17} alkenyl.

[00219] In one embodiment, R^2 is branched C_6-C_{24} alkyl. In one embodiment, R^2 is -R^7-$CH(R^8)(R^9)$, wherein R^7 is C_0-C_5 alkylene, and R^8 and R^9 are independently C_2-C_{10} alkyl. In one embodiment, R^2 is -R^7-$CH(R^8)(R^9)$, wherein R^7 is C_0-C_1 alkylene, and R^8 and R^9 are independently C_4-C_8 alkyl.

[00220] In one embodiment, R^2 is branched C_6-C_{24} alkenyl. In one embodiment, R^2 is -R^7-$CH(R^8)(R^9)$, wherein R^7 is C_0-C_5 alkylene, and R^8 and R^9 are independently C_2-C_{10} alkenyl.

In one embodiment, R^2 is $-R^7-CH(R^8)(R^9)$, wherein R^7 is C_0-C_1 alkylene, and R^8 and R^9 are independently C_6-C_{10} alkenyl.

[00221] In one embodiment, one or more $-CH_2-$ in R^2 is replaced by -S-S-. In one embodiment, one $-CH_2-$ in R^2 is replaced by -S-S-. In one embodiment, R^2 has one or more disulfide bond. In one embodiment, R^2 has one disulfide bond. In one embodiment, R^2 has two disulfide bonds. In one embodiment, R^2 is $-R^{14}-S-S-R^{15}$, wherein R^{14} is C_2-C_{10} alkylene, and R^{15} is C_2-C_{10} alkyl. In one embodiment, R^2 is $-CH_2CH_2-S-S-R^{16}$, wherein R^{16} is C_2-C_{18} alkyl. In one embodiment, R^{16} is C_4-C_{16} alkyl. In one embodiment, R^{16} is C_6-C_{12} alkyl. In one embodiment, R^{16} is C_8 alkyl. In one embodiment, R^{16} is a straight C_8 alkyl. In one embodiment, R^2 is 2-(octyldisulfaneyl)ethyl.

[00222] In one embodiment, R^c is straight C_6-C_{24} alkyl. In one embodiment, R^c is straight C_7-C_{15} alkyl. In one embodiment, R^c is straight C_7 alkyl. In one embodiment, R^c is straight C_8 alkyl. In one embodiment, R^c is straight C_9 alkyl. In one embodiment, R^c is straight C_{10} alkyl. In one embodiment, R^c is straight C_{11} alkyl. In one embodiment, R^c is straight C_{12} alkyl. In one embodiment, R^c is straight C_{13} alkyl. In one embodiment, R^c is straight C_{14} alkyl. In one embodiment, R^c is straight C_{15} alkyl.

[00223] In one embodiment, R^c is straight C_6-C_{24} alkenyl. In one embodiment, R^c is straight C_7-C_{17} alkenyl. In one embodiment, R^c is straight C_7 alkenyl. In one embodiment, R^c is straight C_8 alkenyl. In one embodiment, R^c is straight C_9 alkenyl. In one embodiment, R^c is straight C_{10} alkenyl. In one embodiment, R^c is straight C_{11} alkenyl. In one embodiment, R^c is straight C_{12} alkenyl. In one embodiment, R^c is straight C_{13} alkenyl. In one embodiment, R^c is straight C_{14} alkenyl. In one embodiment, R^c is straight C_{15} alkenyl. In one embodiment, R^c is straight C_{16} alkenyl. In one embodiment, R^c is straight C_{17} alkenyl.

[00224] In one embodiment, R^c is branched C_6-C_{24} alkyl. In one embodiment, R^c is $-R^7-CH(R^8)(R^9)$, wherein R^7 is C_0-C_5 alkylene, and R^8 and R^9 are independently C_2-C_{10} alkyl. In one embodiment, R^c is $-R^7-CH(R^8)(R^9)$, wherein R^7 is C_0-C_1 alkylene, and R^8 and R^9 are independently C_4-C_8 alkyl.

[00225] In one embodiment, R^c is branched C_6-C_{24} alkenyl. In one embodiment, R^c is $-R^7-CH(R^8)(R^9)$, wherein R^7 is C_0-C_5 alkylene, and R^8 and R^9 are independently C_2-C_{10} alkenyl. In one embodiment, R^c is $-R^7-CH(R^8)(R^9)$, wherein R^7 is C_0-C_1 alkylene, and R^8 and R^9 are independently C_6-C_{10} alkenyl.

[00226] In one embodiment, one or more -CH_2- in R^c is replaced by -S-S-. In one embodiment, one -CH_2- in R^c is replaced by -S-S-. In one embodiment, R^c has one or more disulfide bond. In one embodiment, R^c has one disulfide bond. In one embodiment, R^c has two disulfide bonds. In one embodiment, R^c is -R^{14}-S-S-R^{15}, wherein R^{14} is C_2-C_{10} alkylene, and R^{15} is C_2-C_{10} alkyl. In one embodiment, R^c is -CH_2CH_2-S-S-R^{16}, wherein R^{16} is C_2-C_{18} alkyl. In one embodiment, R^{16} is C_4-C_{16} alkyl. In one embodiment, R^{16} is C_6-C_{12} alkyl. In one embodiment, R^{16} is C_8 alkyl. In one embodiment, R^{16} is a straight C_8 alkyl. In one embodiment, R^c is 2-(octyldisulfaneyl)ethyl.

[00227] In one embodiment, R^f is straight C_6-C_{24} alkyl. In one embodiment, R^f is straight C_7-C_{15} alkyl. In one embodiment, R^f is straight C_7 alkyl. In one embodiment, R^f is straight C_8 alkyl. In one embodiment, R^f is straight C_9 alkyl. In one embodiment, R^f is straight C_{10} alkyl. In one embodiment, R^f is straight C_{11} alkyl. In one embodiment, R^f is straight C_{12} alkyl. In one embodiment, R^f is straight C_{13} alkyl. In one embodiment, R^f is straight C_{14} alkyl. In one embodiment, R^f is straight C_{15} alkyl.

[00228] In one embodiment, R^f is straight C_6-C_{24} alkenyl. In one embodiment, R^f is straight C_7-C_{17} alkenyl. In one embodiment, R^f is straight C_7 alkenyl. In one embodiment, R^f is straight C_8 alkenyl. In one embodiment, R^f is straight C_9 alkenyl. In one embodiment, R^f is straight C_{10} alkenyl. In one embodiment, R^f is straight C_{11} alkenyl. In one embodiment, R^f is straight C_{12} alkenyl. In one embodiment, R^f is straight C_{13} alkenyl. In one embodiment, R^f is straight C_{14} alkenyl. In one embodiment, R^f is straight C_{15} alkenyl. In one embodiment, R^f is straight C_{16} alkenyl. In one embodiment, R^f is straight C_{17} alkenyl.

[00229] In one embodiment, R^f is branched C_6-C_{24} alkyl. In one embodiment, R^f is -R^7-$CH(R^8)(R^9)$, wherein R^7 is C_0-C_5 alkylene, and R^8 and R^9 are independently C_2-C_{10} alkyl. In one embodiment, R^f is -R^7-$CH(R^8)(R^9)$, wherein R^7 is C_0-C_1 alkylene, and R^8 and R^9 are independently C_4-C_8 alkyl.

[00230] In one embodiment, R^f is branched C_6-C_{24} alkenyl. In one embodiment, R^f is -R^7-$CH(R^8)(R^9)$, wherein R^7 is C_0-C_5 alkylene, and R^8 and R^9 are independently C_2-C_{10} alkenyl. In one embodiment, R^f is -R^7-$CH(R^8)(R^9)$, wherein R^7 is C_0-C_1 alkylene, and R^8 and R^9 are independently C_6-C_{10} alkenyl.

[00231] In one embodiment, one or more -CH_2- in R^f is replaced by -S-S-. In one embodiment, one -CH_2- in R^f is replaced by -S-S-. In one embodiment, R^f has one or more disulfide bond. In one embodiment, R^f has one disulfide bond. In one embodiment, R^f has

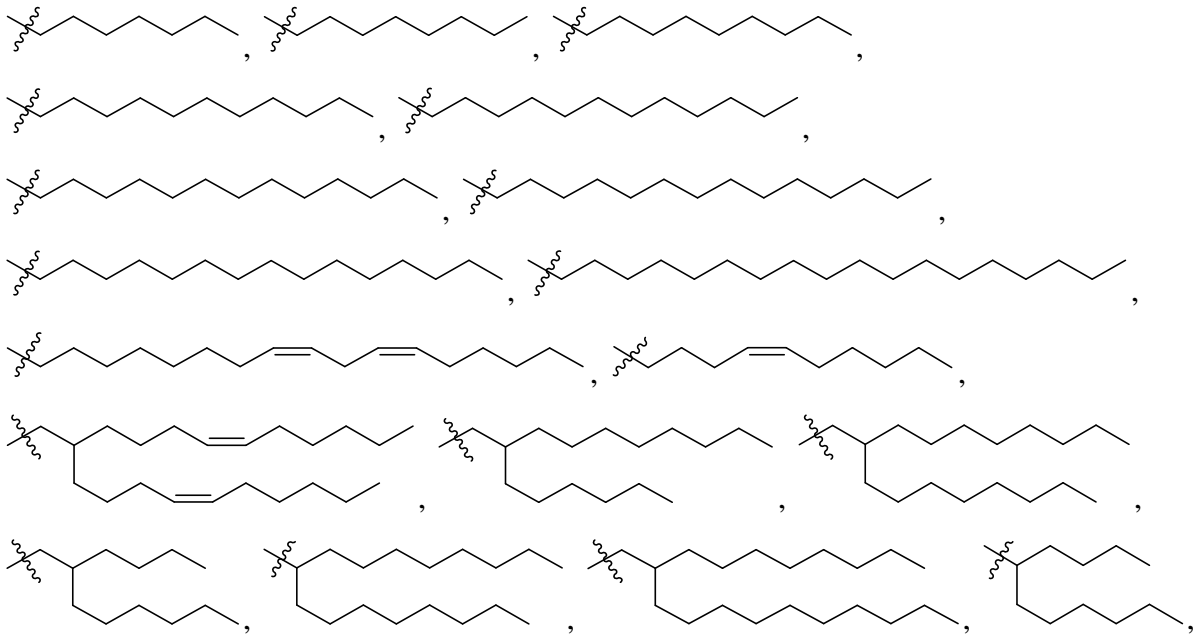
two disulfide bonds. In one embodiment, R^f is $-R^{14}$-S-S-R^{15}, wherein R^{14} is C_2-C_{10} alkylene, and R^{15} is C_2-C_{10} alkyl. In one embodiment, R^f is $-CH_2CH_2$-S-S-R^{16}, wherein R^{16} is C_2-C_{18} alkyl. In one embodiment, R^{16} is C_4-C_{16} alkyl. In one embodiment, R^{16} is C_6-C_{12} alkyl. In one embodiment, R^{16} is C_8 alkyl. In one embodiment, R^{16} is a straight C_8 alkyl. In one embodiment, R^f is 2-(octyldisulfaneyl)ethyl.

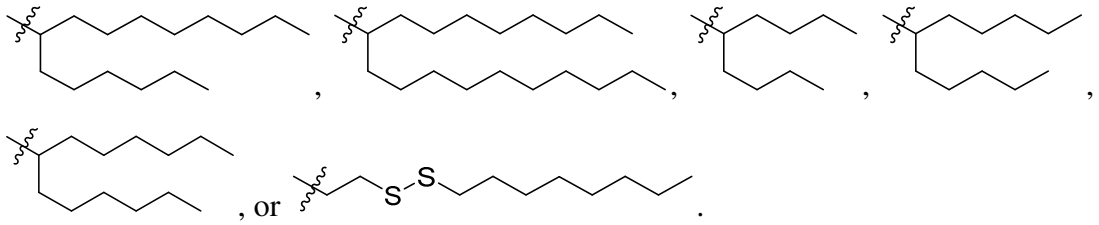
[00232] In one embodiment, R^1, R^2, R^c, and R^f are each independently straight C_6-C_{18} alkyl, straight C_6-C_{18} alkenyl, or $-R^7$-$CH(R^8)(R^9)$, wherein R^7 is C_0-C_5 alkylene, and R^8 and R^9 are independently C_2-C_{10} alkyl or C_2-C_{10} alkenyl.

[00233] In one embodiment, R^1, R^2, R^c, and R^f are each independently straight C_7-C_{15} alkyl, straight C_7-C_{15} alkenyl, or $-R^7$-$CH(R^8)(R^9)$, wherein R^7 is C_0-C_1 alkylene, and R^8 and R^9 are independently C_4-C_8 alkyl or C_6-C_{10} alkenyl.

[00234] In one embodiment, R^1, R^2, R^c, and R^f each independently contain two or more Sulphur atoms. In one embodiment, R^1, R^2, R^c, and R^f each independently contain two Sulphur atoms. In one embodiment, R^1, R^2, R^c, and R^f each independently contain one or more disulfide bond. In one embodiment, R^1, R^2, R^c, and R^f each independently contain one disulfide bond. In one embodiment, R^1, R^2, R^c, and R^f each independently contain two disulfide bonds.

[00235] In one embodiment, R^1, R^2, R^c, and R^f are each independently one of the following structures:

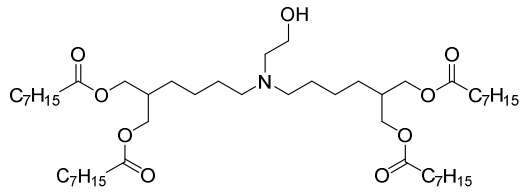
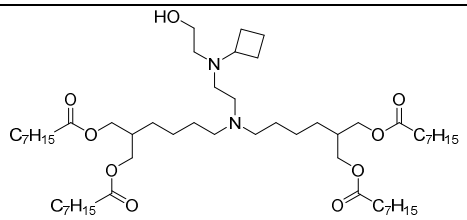
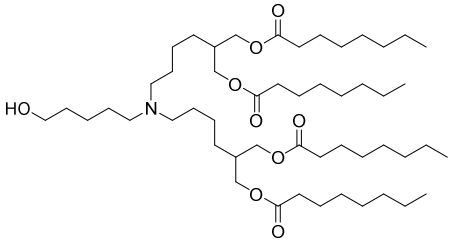
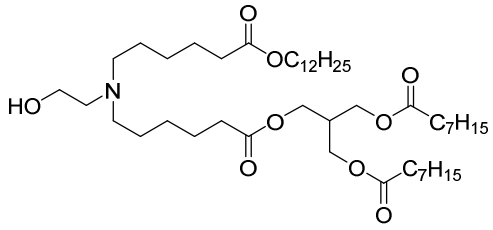
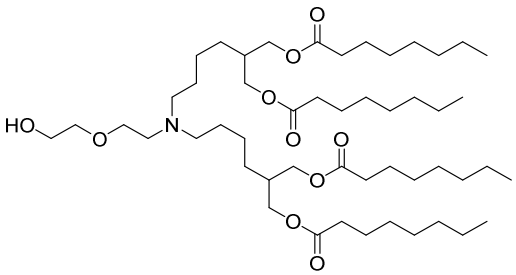
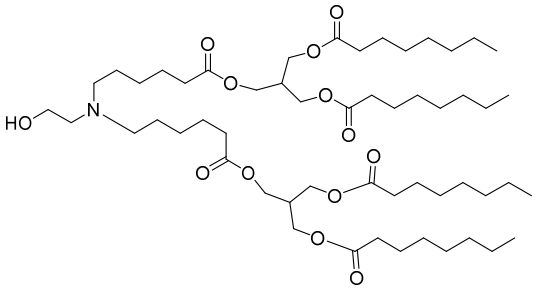


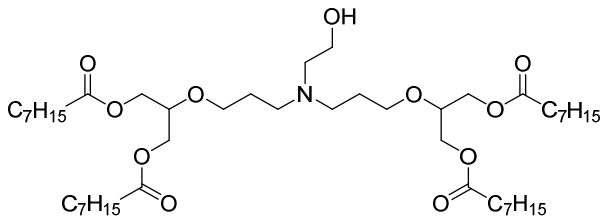
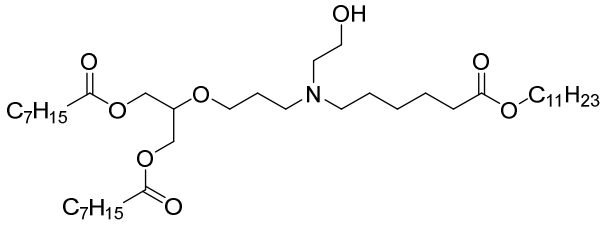
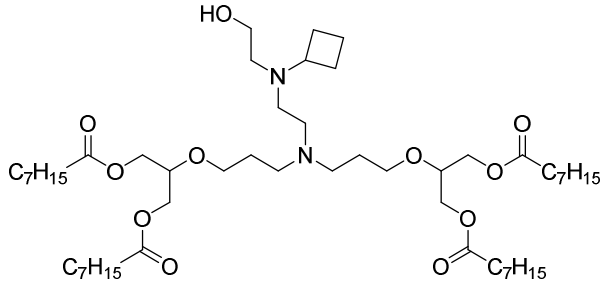
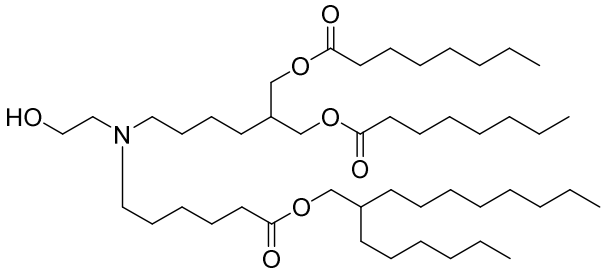
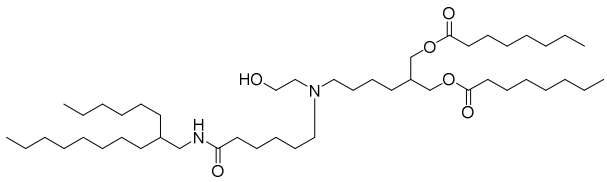
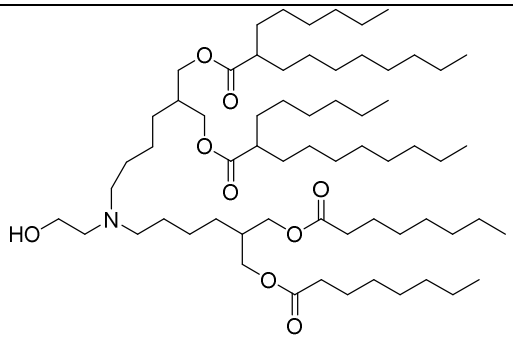
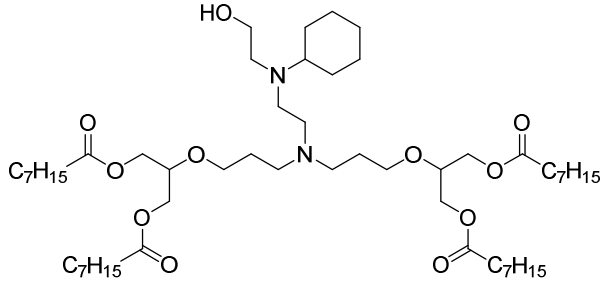
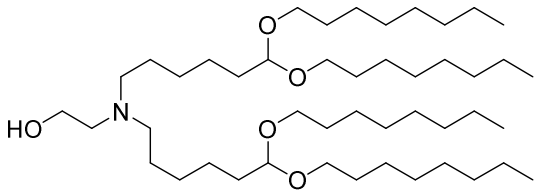
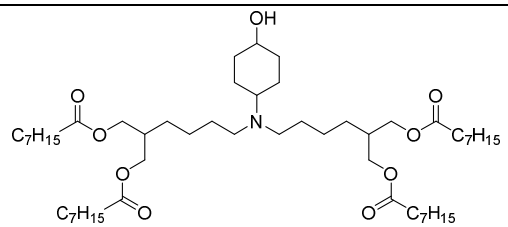
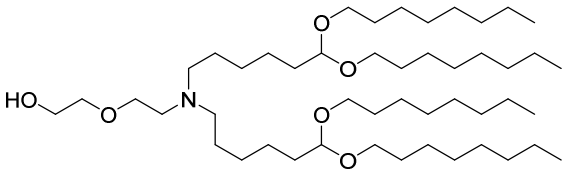
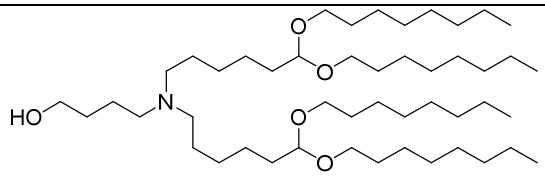
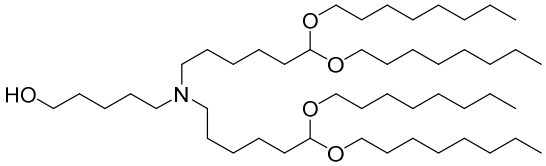


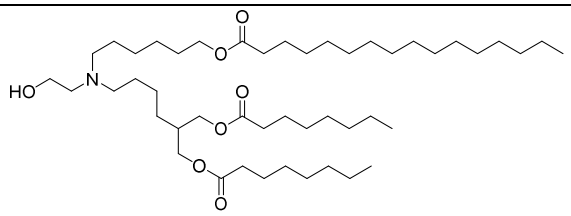
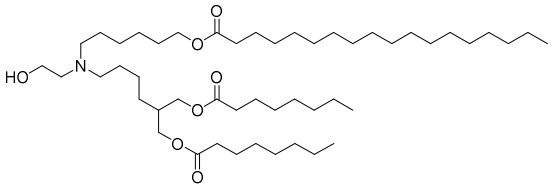
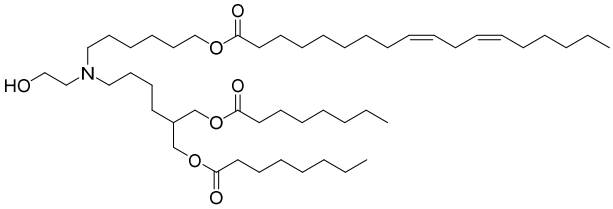
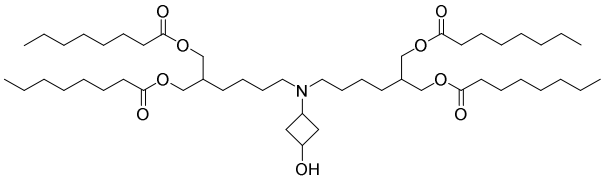
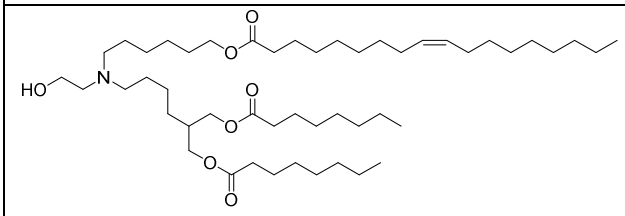
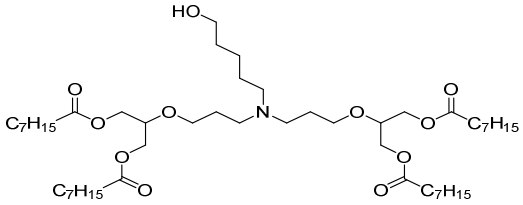
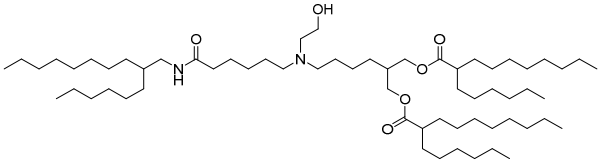
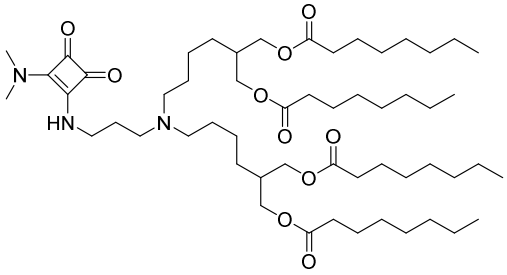
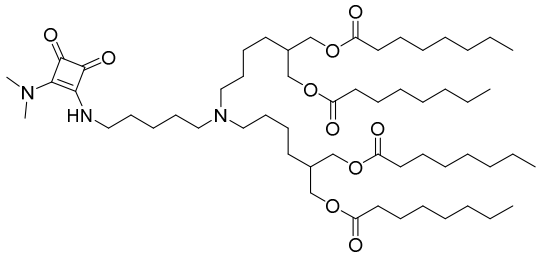
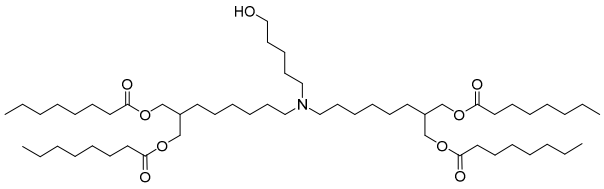
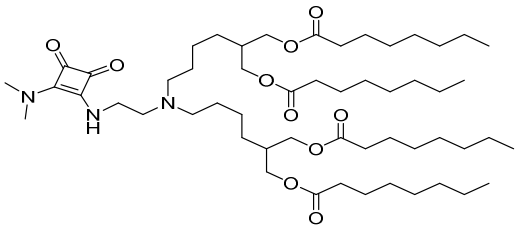
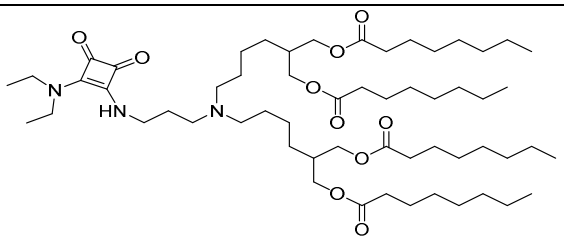
[00236] In one embodiment, R^a is H. In one embodiment, R^d is H. In one embodiment, R^a, R^b, R^d, and R^e are each independently H. In one embodiment, R^b is C_1-C_{24} alkyl. In one embodiment, R^b is C_1-C_{12} alkyl. In one embodiment, R^b is C_2-C_{24} alkenyl. In one embodiment, R^b is C_2-C_{12} alkenyl. In one embodiment, R^e is C_1-C_{24} alkyl. In one embodiment, R^e is C_1-C_{12} alkyl. In one embodiment, R^e is C_2-C_{24} alkenyl. In one embodiment, R^e is C_2-C_{12} alkenyl.

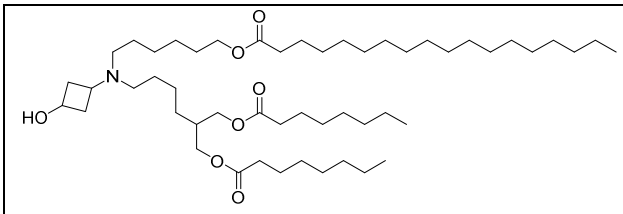
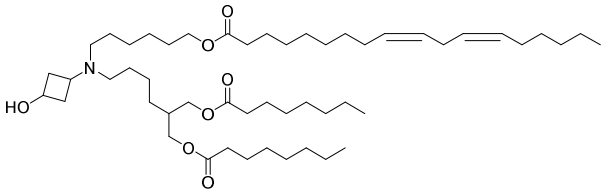
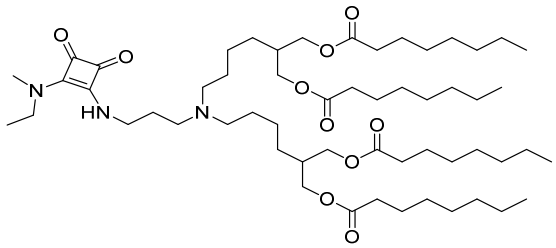
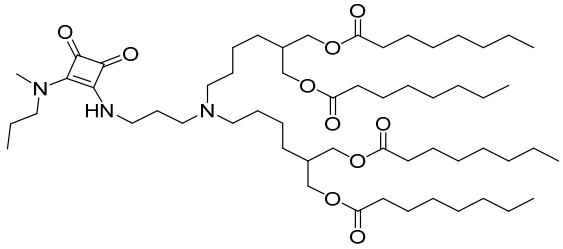
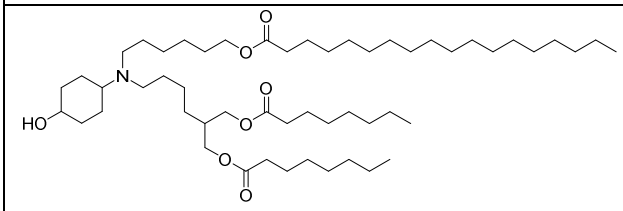
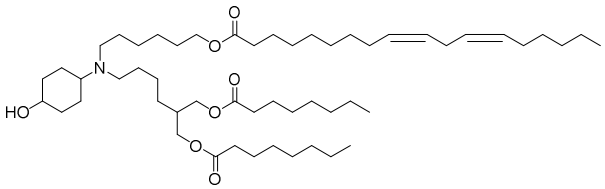
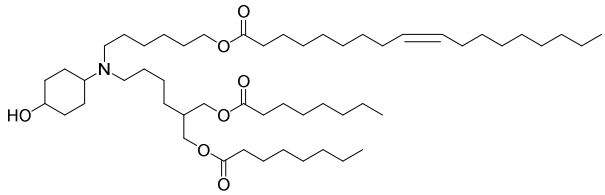
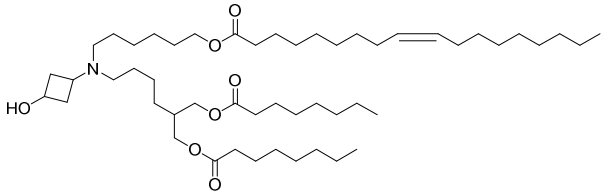
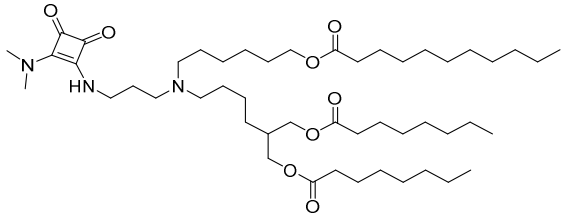
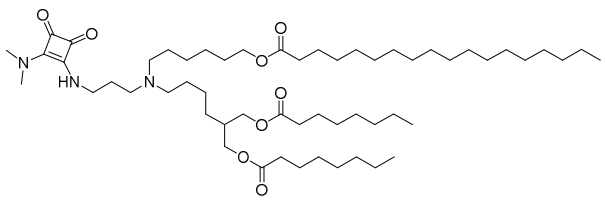
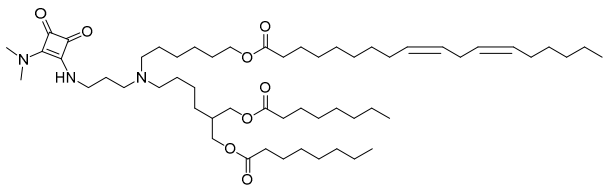
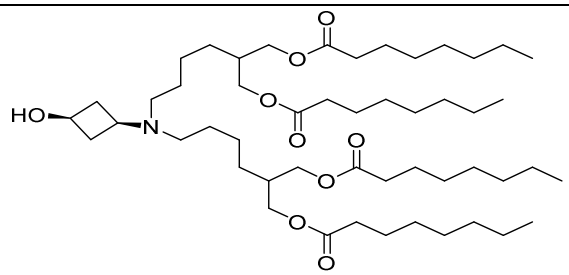
[00237] In one embodiment, the compound is a compound in Table 1, or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

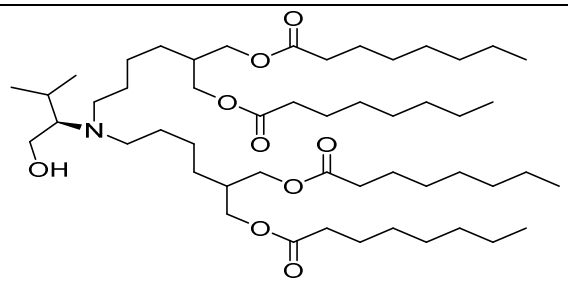
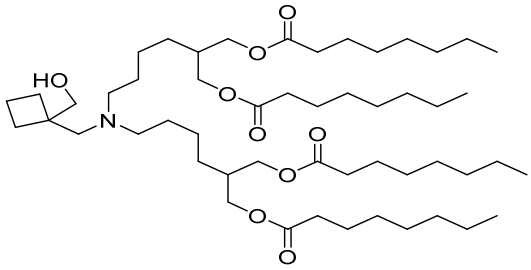
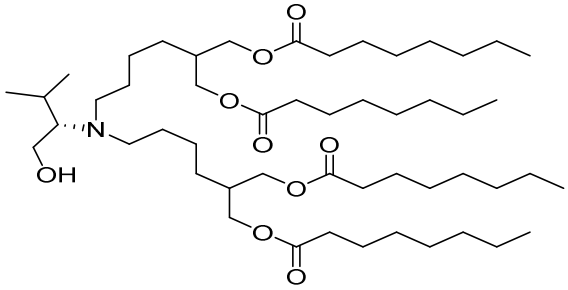
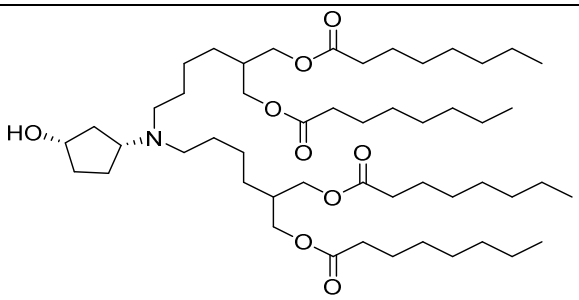
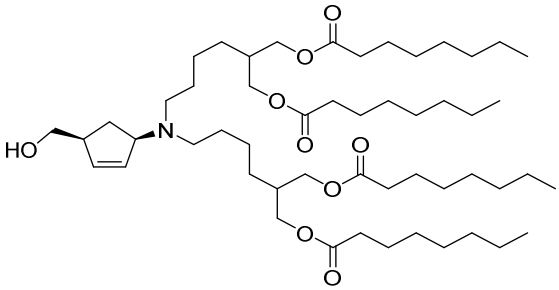
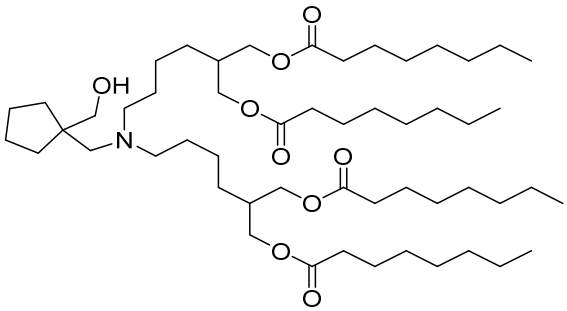
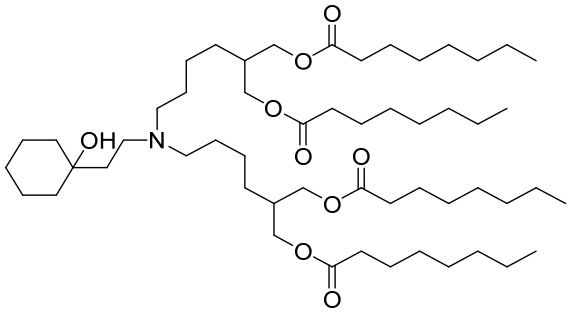
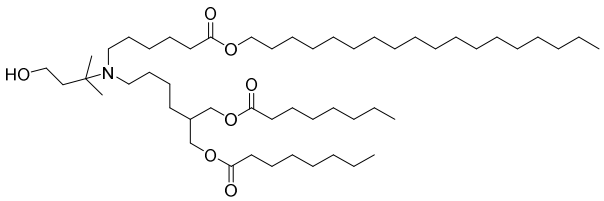
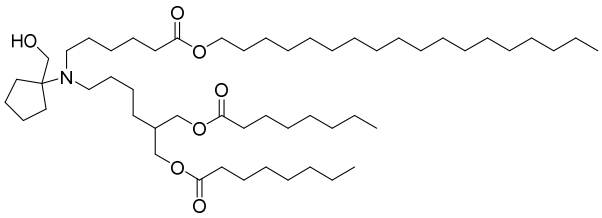
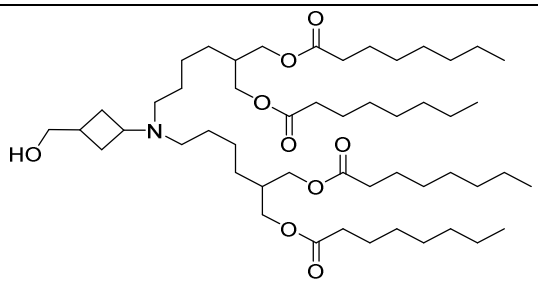
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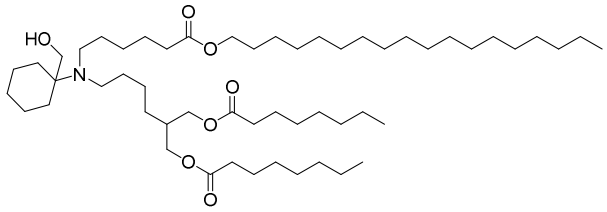
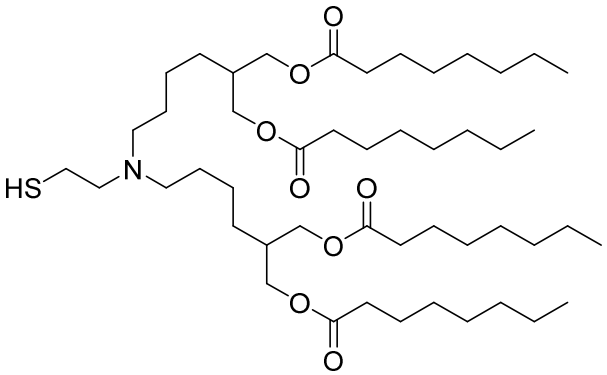
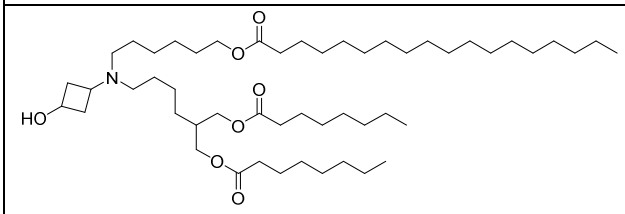
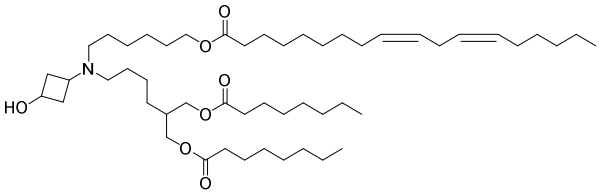
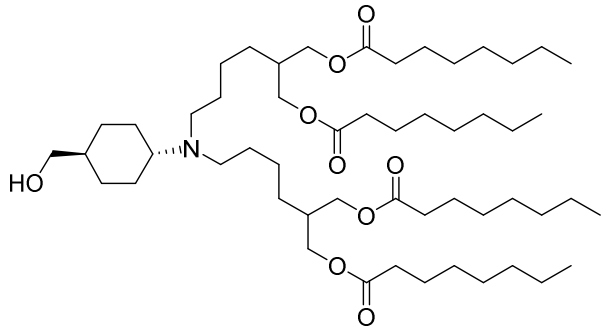
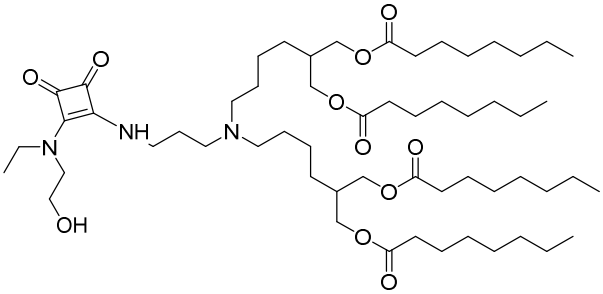
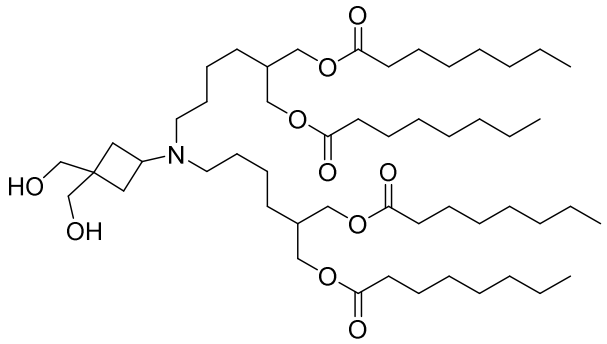
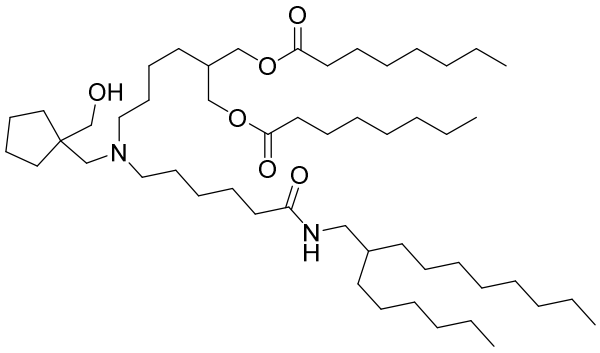
 Compound 1	 Compound 2
 Compound 3	 Compound 4
 Compound 5	 Compound 6

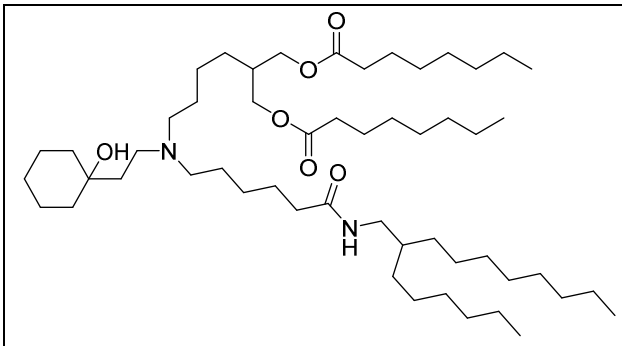
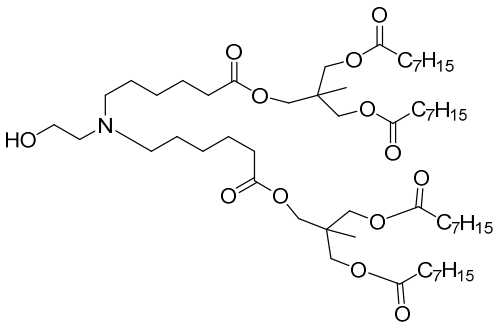
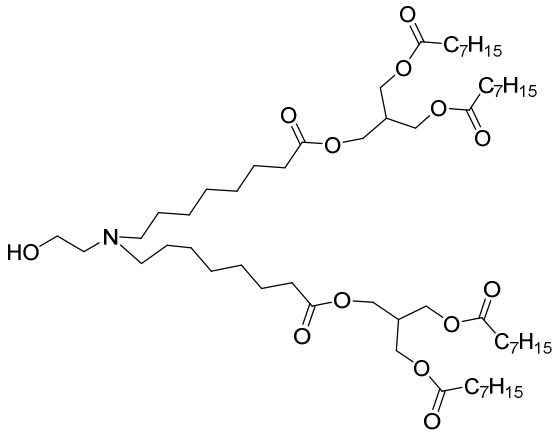
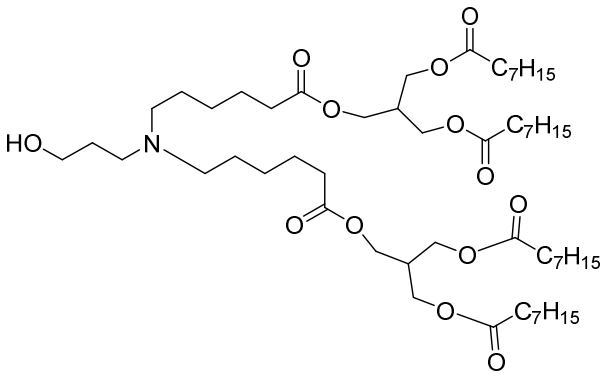
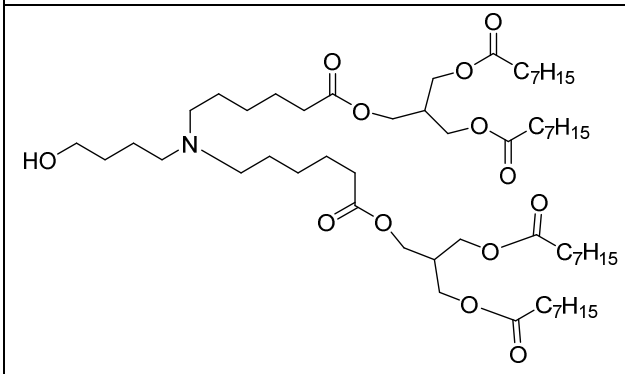
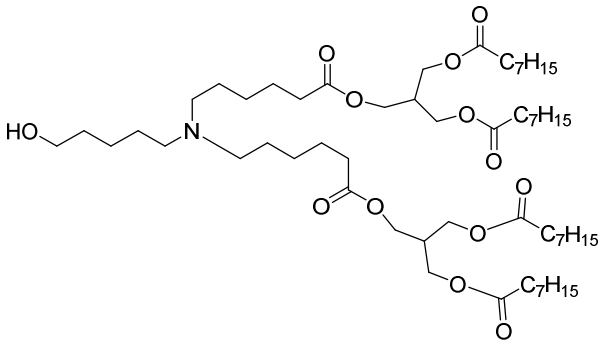
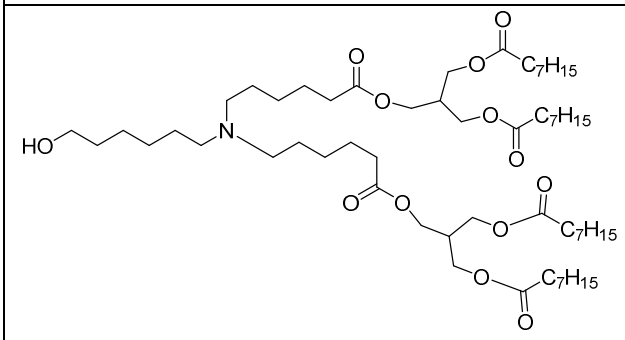
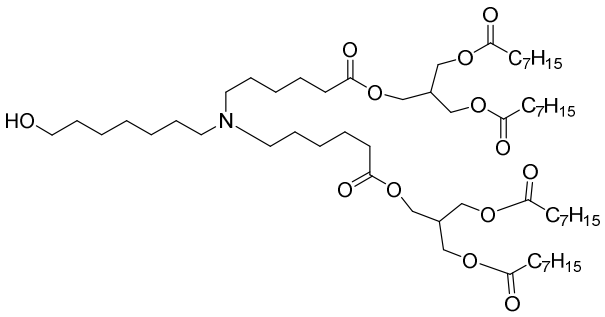
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 Compound 18	 Compound 19

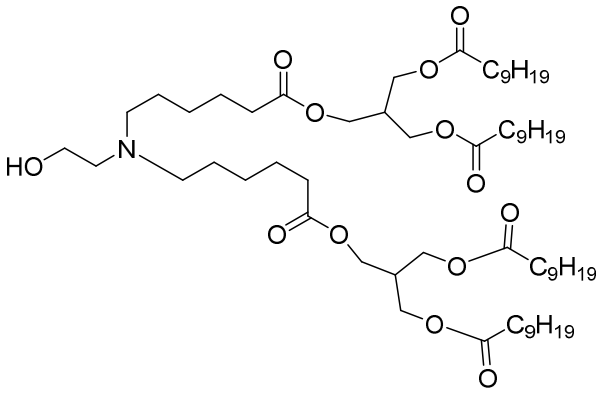
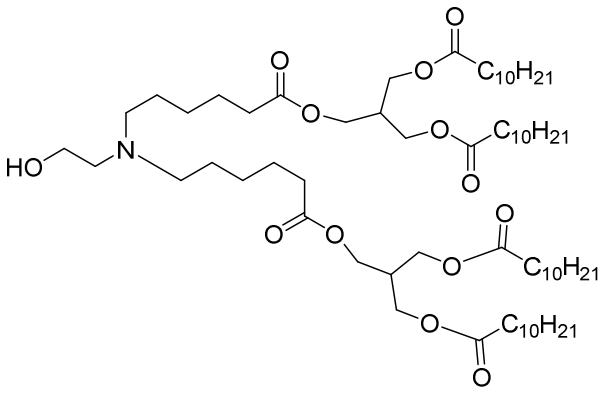
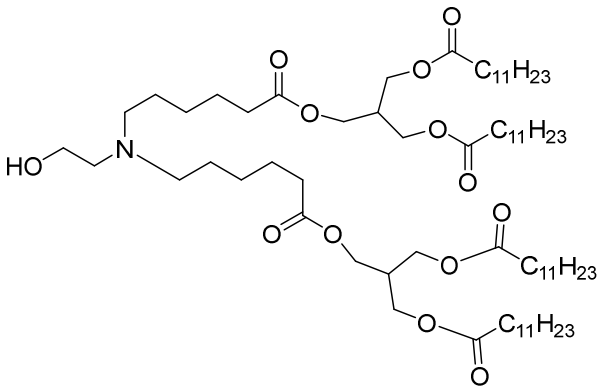
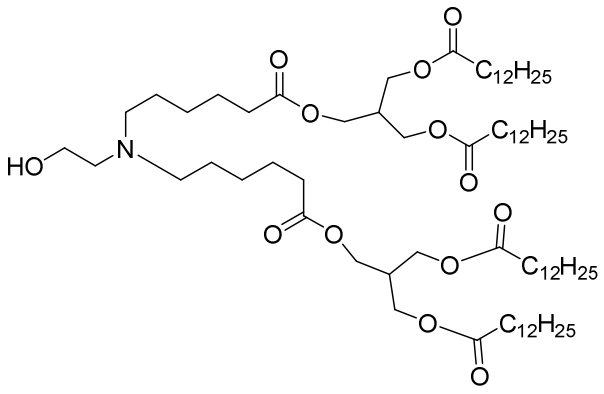
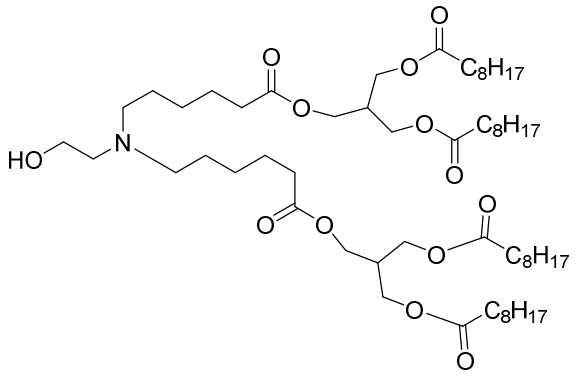
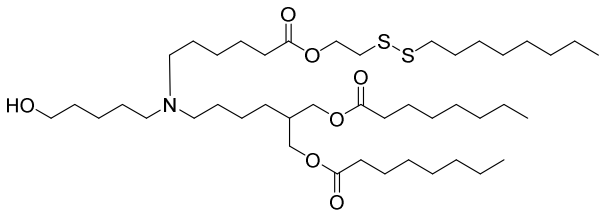
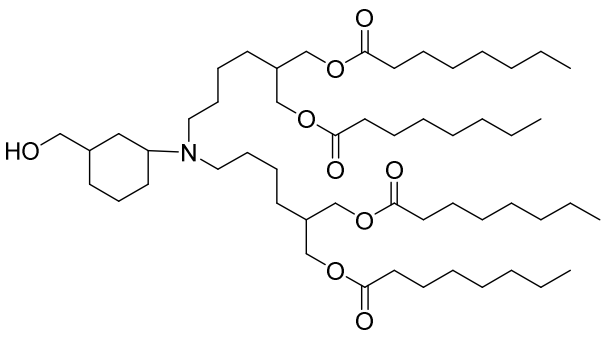
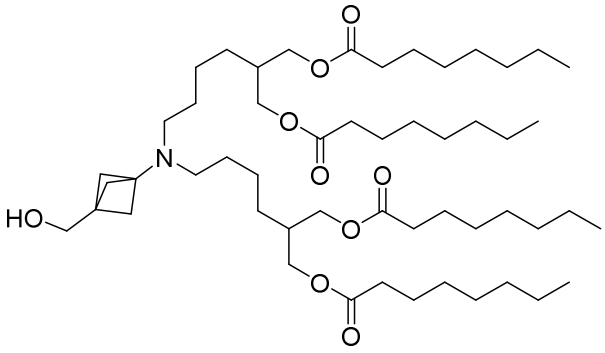
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 Compound 30	 Compound 31

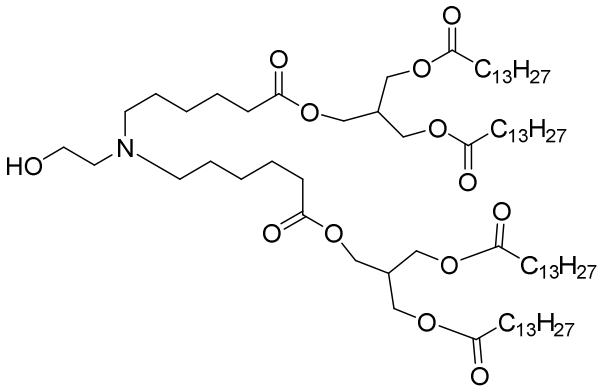
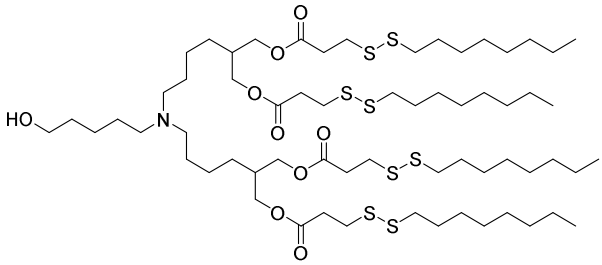
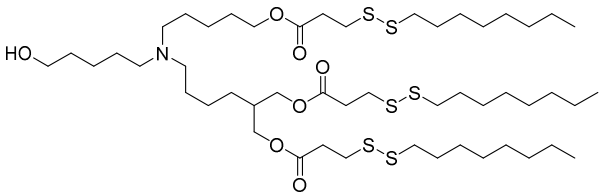
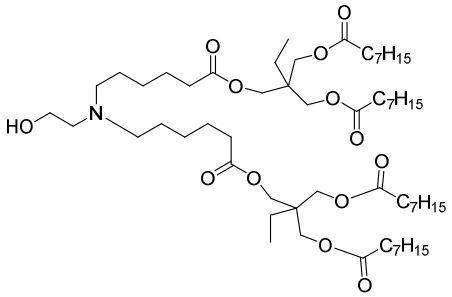
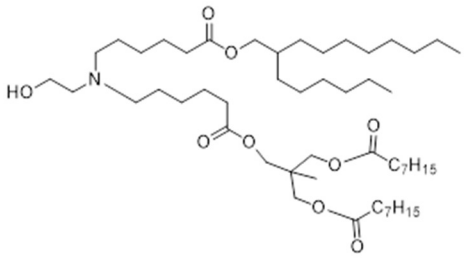
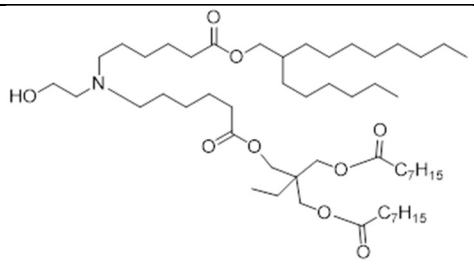
 Compound 32	 Compound 33
 Compound 34	 Compound 35
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 Compound 40	 Compound 41
 Compound 42	 Compound 43

 Compound 44	 Compound 45
 Compound 46	 Compound 47
 Compound 48	 Compound 49
 Compound 50	 Compound 51
 Compound 52	 Compound 54

 Compound 55	 Compound 56
 Compound 57	 Compound 58
 Compound 59	 Compound 60
 Compound 61	 Compound 62

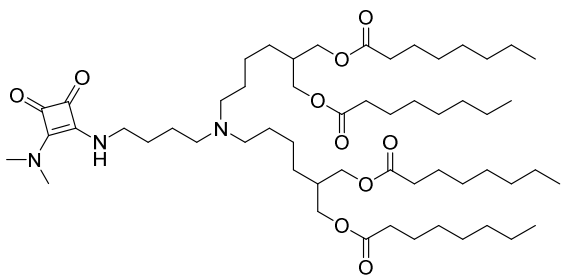
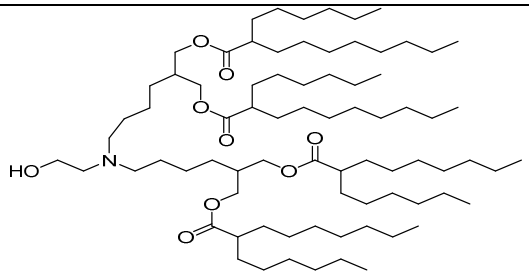
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 Compound 67	 Compound 68
 Compound 69	 Compound 70

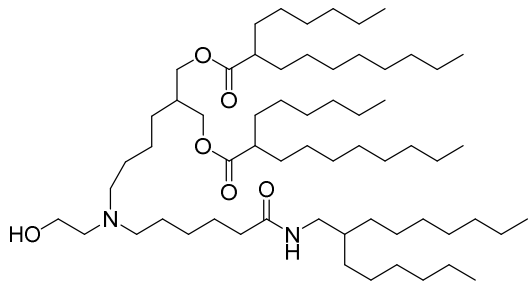
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 Compound 77	 Compound 78

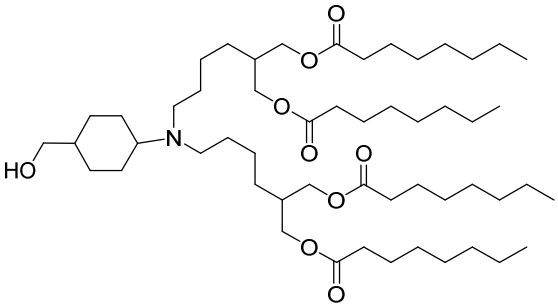
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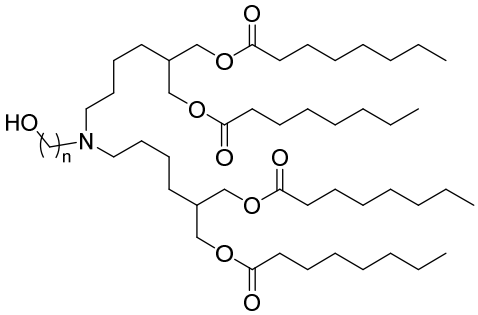
[00238] In one embodiment, the compound is a compound in Table 1A or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

Table 1A

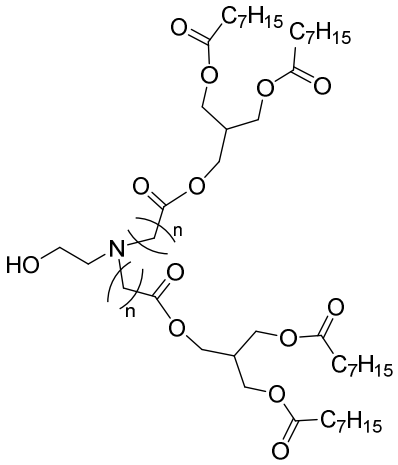
	







(n is 1 to 12)



(n is 1 to 12)

[00239] It is understood that any embodiment of the compounds provided herein, as set forth above, and any specific substituent and/or variable in the compound provided herein, as set forth above, may be independently combined with other embodiments and/or substituents and/or variables of the compounds to form embodiments not specifically set forth above. In addition, in the event that a list of substituents and/or variables is listed for any particular group or variable, it is understood that each individual substituent and/or variable may be deleted from the particular embodiment and/or claim and that the remaining list of substituents and/or variables will be considered to be within the scope of embodiments provided herein.

[00240] It is understood that in the present description, combinations of substituents and/or variables of the depicted formulae are permissible only if such contributions result in stable compounds.

5.4 *Nanoparticle Compositions*

[00241] In one aspect, described herein are nanoparticle compositions comprising a lipid compound described herein. In particular embodiments, the nanoparticle composition comprises a compound according to Formulae (I) or (II) (and sub-formulas thereof) as described herein.

[00242] In some embodiments, the largest dimension of a nanoparticle composition provided herein is 1 μm or shorter (*e.g.*, ≤1 μm, ≤900 nm, ≤800 nm, ≤700 nm, ≤600 nm, ≤500 nm, ≤400 nm, ≤300 nm, ≤200 nm, ≤175 nm, ≤150 nm, ≤125 nm, ≤100 nm, ≤75 nm, ≤50 nm, or shorter), such as when measured by dynamic light scattering (DLS), transmission electron microscopy, scanning electron microscopy, or another method. In one embodiment, the lipid nanoparticle provided herein has at least one dimension that is in the range of from about 40 to about 200 nm. In one embodiment, the at least one dimension is in the range of from about 40 to about 100 nm.

[00243] Nanoparticle compositions that can be used in connection with the present disclosure include, for example, lipid nanoparticles (LNPs), nano liproprotein particles, liposomes, lipid vesicles, and lipoplexes. In some embodiments, nanoparticle compositions are vesicles including one or more lipid bilayers. In some embodiments, a nanoparticle composition includes two or more concentric bilayers separated by aqueous compartments. Lipid bilayers may be functionalized and/or crosslinked to one another. Lipid bilayers may include one or more ligands, proteins, or channels.

[00244] The characteristics of a nanoparticle composition may depend on the components thereof. For example, a nanoparticle composition including cholesterol as a structural lipid may have different characteristics than a nanoparticle composition that includes a different structural lipid. Similarly, the characteristics of a nanoparticle composition may depend on the absolute or relative amounts of its components. For instance, a nanoparticle composition including a higher molar fraction of a phospholipid may have different characteristics than a nanoparticle composition including a lower molar fraction of a phospholipid. Characteristics may also vary depending on the method and conditions of preparation of the nanoparticle composition.

[00245] Nanoparticle compositions may be characterized by a variety of methods. For example, microscopy (e.g., transmission electron microscopy or scanning electron microscopy) may be used to examine the morphology and size distribution of a nanoparticle composition. Dynamic light scattering or potentiometry (e.g., potentiometric titrations) may be used to measure zeta potentials. Dynamic light scattering may also be utilized to determine particle sizes. Instruments such as the Zetasizer Nano ZS (Malvem Instruments Ltd, Malvem, and Worcestershire, UK) may also be used to measure multiple characteristics of a nanoparticle composition, such as particle size, polydispersity index, and zeta potential.

[00246] Dh (size): The mean size of a nanoparticle composition may be between 10s of nm and 100s of nm. For example, the mean size may be from about 40 nm to about 150 nm, such as about 40 nm, 45 nm, 50 nm, 55 nm, 60 nm, 65 nm, 70 nm, 75 nm, 80 nm, 85 nm, 90 nm, 95 nm, 100 nm, 105 nm, 110 nm, 115 nm, 120 nm, 125 nm, 130 nm, 135 nm, 140 nm, 145 nm, or 150 nm. In some embodiments, the mean size of a nanoparticle composition may be from about 50 nm to about 100 nm, from about 50 nm to about 90 nm, from about 50 nm to about 80 nm, from about 50 nm to about 70 nm, from about 50 nm to about 60 nm, from about 60 nm to about 100 nm, from about 60 nm to about 90 nm, from about 60 nm to about 80 nm, from about 60 nm to about 70 nm, from about 70 nm to about 100 nm, from about 70 nm to about 90 nm, from about 70 nm to about 80 nm, from about 80 nm to about 100 nm, from about 80 nm to about 90 nm, or from about 90 nm to about 100 nm. In certain embodiments, the mean size of a nanoparticle composition may be from about 70 nm to about 100 nm. In some embodiments, the mean size may be about 80 nm. In other embodiments, the mean size may be about 100 nm.

[00247] PDI: A nanoparticle composition may be relatively homogenous. A polydispersity index may be used to indicate the homogeneity of a nanoparticle composition, e.g., the particle size distribution of the nanoparticle compositions. A small (e.g., less than 0.3) polydispersity index generally indicates a narrow particle size distribution. A nanoparticle composition may have a polydispersity index from about 0 to about 0.25, such as 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, 0.19, 0.20, 0.21, 0.22, 0.23, 0.24, or 0.25. In some embodiments, the polydispersity index of a nanoparticle composition may be from about 0.10 to about 0.20.

[00248] Encapsulation Efficiency: The efficiency of encapsulation of a therapeutic and/or prophylactic agent describes the amount of therapeutic and/or prophylactic agent that is encapsulated or otherwise associated with a nanoparticle composition after preparation, relative to the initial amount provided. The encapsulation efficiency is desirably high (e.g., close to 100 %). The encapsulation efficiency may be measured, for example, by comparing the amount of therapeutic and/or prophylactic agent in a solution containing the nanoparticle composition before and after breaking up the nanoparticle composition with one or more organic solvents or detergents. Fluorescence may be used to measure the amount of free therapeutic and/or prophylactic agent (e.g., RNA) in a solution. For the nanoparticle compositions described herein, the encapsulation efficiency of a therapeutic and/or prophylactic agent may be at least 50 %, for example 50 %, 55 %, 60 %, 65 %, 70 %, 75 %,

80 %, 85 %, 90 %, 91 %, 92 %, 93 %, 94 %, 95 %, 96 %, 97 %, 98 %, 99 %, or 100 %. In some embodiments, the encapsulation efficiency may be at least 80 %. In certain embodiments, the encapsulation efficiency may be at least 90 %.

[00249] Apparant pKa: The zeta potential of a nanoparticle composition may be used to indicate the electrokinetic potential of the composition. For example, the zeta potential may describe the surface charge of a nanoparticle composition. Nanoparticle compositions with relatively low charges, positive or negative, are generally desirable, as more highly charged species may interact undesirably with cells, tissues, and other elements in the body. In some embodiments, the zeta potential of a nanoparticle composition may be from about - 10 mV to about + 20 mV, from about - 10 mV to about + 15mV, from about - 10 mV to about + 10 mV, from about - 10 mV to about + 5 mV, from about - 10 mV to about 0 mV, from about - 10 mV to about - 5 mV, from about - 5 mV to about + 20 mV, from about - 5 mV to about + 15 mV, from about - 5 mV to about + 10 mV, from about - 5 mV to about + 5 mV, from about - 5 mV to about 0 mV, from about 0 mV to about + 20 mV, from about 0 mV to about + 15 mV, from about 0 mV to about + 10 mV, from about 0 mV to about + 5 mV, from about + 5 mV to about + 20 mV, from about + 5 mV to about + 15 mV, or from about + 5 mV to about + 10 mV.

[00250] In another embodiment, the self-replicating RNA may be formulated in a liposome. As a non-limiting example, the self-replicating RNA may be formulated in liposomes as described in International Publication No. WO20120067378, herein incorporated by reference in its entirety. In one aspect, the liposomes may comprise lipids which have a pKa value which may be advantageous for delivery of mRNA. In another aspect, the liposomes may have an essentially neutral Surface charge at physiological pH and may therefore be effective for immunization (see e.g., the liposomes described in International Publication No. WO20120067378, herein incorporated by reference in its entirety).

[00251] In some embodiments, nanoparticle compositions as described comprise a lipid component including at least one lipid, such as a compound according to one of Formulae (I) or (II) (and sub-formulas thereof) as described herein. For example, in some embodiments, a nanoparticle composition may include a lipid component including one of compounds provided herein. Nanoparticle compositions may also include one or more other lipid or non-lipid components as described below.

[00252] In one embodiment, a nanoparticle composition comprising a compound provided herein and an mRNA shows improved expression level of the mRNA (*e.g.*, as compared to standard cationic lipid compounds known in the art, *e.g.*, MC3). In one embodiment, after a nanoparticle composition comprising a compound provided herein is administered to a subject, the compound shows a rapid tissue clearance (*e.g.*, liver clearance).

5.4.1 *Cationic/Ionizable Lipids*

[00253] As described herein, in some embodiments, a nanoparticle composition provided herein comprises one or more charged or ionizable lipids in addition to a lipid according Formulae (I) or (II) (and sub-formulas thereof). Without being bound by the theory, it is contemplated that certain charged or zwitterionic lipid components of a nanoparticle composition resembles the lipid component in the cell membrane, thereby can improve cellular uptake of the nanoparticle. Exemplary charged or ionizable lipids that can form part of the present nanoparticle composition include but are not limited to 3-(didodecylamino)-N1,N1,4-tridodecyl-1-piperazineethanamine (KL10), N1-[2-(didodecylamino)ethyl]-N1,N4,N4-tridodecyl-1,4-piperazinediethanamine (KL22), 14,25-ditridecyl-15,18,21,24-tetraaza-octatriacontane (KL25), 1,2-dilinoleyloxy-N,N-dimethylaminopropane (DLinDMA), 2,2-dilinoleyl-4-dimethylaminomethyl-[1,3]-dioxolane (DLin-K-DMA), heptatriaconta-6,9,28,31-tetraen-19-yl 4-(dimethylamino)butanoate (DLin-MC3-DMA), 2,2-dilinoleyl-4-(2-dimethylaminoethyl)-[1,3]-dioxolane (DLin-KC2-DMA), 1,2-dioleyloxy-N,N-dimethylaminopropane (DODMA), 2-({8-[(3β)-cholest-5-en-3-yloxy]octyl}oxy)-N,N-dimethyl-3 [(9Z,12Z)-octadeca-9,12-dien-1-yloxy]propan-1-amine (Octyl-CLinDMA), (2R)-2-({8-[(3β)-cholest-5-en-3-yloxy]octyl}oxy)-N,N-dimethyl-3-[(9Z,12Z)-octadeca-9,12-dien-1-yloxy]propan-1-amine (Octyl-CLinDMA (2R)), (2S)-2-({8-[(3β)-cholest-5-en-3-yloxy]octyl}oxy)-N,N-dimethyl-3-[(9Z-,12Z)-octadeca-9,12-dien-1-yloxy]propan-1-amine (Octyl-CLinDMA (2S)), (12Z,15Z)-N,N-dimethyl-2-nonylhenicosa-12,15-den-1-amine, N,N-dimethyl-1-{(1S,2R)-2-octylcyclopropyl}heptadecan-8-amine. Additional exemplary charged or ionizable lipids that can form part of the present nanoparticle composition include the lipids (e.g., lipid 5) described in Sabnis et al. "A Novel Amino Lipid Series for mRNA Delivery: Improved Endosomal Escape and Sustained Pharmacology and Safety in Non-human Primates", Molecular Therapy Vol. 26 No 6, 2018, the entirety of which is incorporated herein by reference.

[00254] In some embodiments, suitable cationic lipids include N-[1-(2,3-dioleyloxy)propyl]-N,N,N-trimethylammonium chloride (DOTMA); N-[1-(2,3-

dioleoyloxy)propyl]-N,N,N-trimethylammonium chloride (DOTAP); 1,2-dioleoyl-sn-glycero-3-ethylphosphocholine (DOEPC); 1,2-dilauroyl-sn-glycero-3-ethylphosphocholine (DLEPC); 1,2-dimyristoyl-sn-glycero-3-ethylphosphocholine (DMEPC); 1,2-dimyristoleoyl-sn-glycero-3-ethylphosphocholine (14:1); N1-[2-((1S)-1-[(3-aminopropyl)amino]-4-[di(3-amino-propyl)amino]butylcarboxamido)ethyl]-3,4-di[oleyloxy]-benzamide (MVL5); dioctadecylamido-glycylspermine (DOGS); 3b-[N-(N',N'-dimethylaminoethyl)carbamoyl]cholesterol (DC-Chol); dioctadecyldimethylammonium bromide (DDAB); SAINT-2, N-methyl-4-(dioleyl)methylpyridinium; 1,2-dimyristyloxypropyl-3-dimethylhydroxyethylammonium bromide (DMRIE); 1,2-dioleoyl-3-dimethyl-hydroxyethyl ammonium bromide (DORIE); 1,2-dioleoyloxypropyl-3-dimethylhydroxyethyl ammonium chloride (DORI); di-alkylated amino acid ($DILA^2$) (*e.g.*, C18:1-norArg-C16); dioleyldimethylammonium chloride (DODAC); 1-palmitoyl-2-oleoyl-sn-glycero-3-ethylphosphocholine (POEPC); 1,2-dimyristoleoyl-sn-glycero-3-ethylphosphocholine (MOEPC); (R)-5-(dimethylamino)pentane-1,2-diyl dioleate hydrochloride (DODAPen-Cl); (R)-5-guanidinopentane-1,2-diyl dioleate hydrochloride (DOPen-G); and (R)-N,N,N-trimethyl-4,5-bis(oleoyloxy)pentan-1-aminium chloride (DOTAPen). Also suitable are cationic lipids with headgroups that are charged at physiological pH, such as primary amines (*e.g.*, DODAG N',N'-dioctadecyl-N-4,8-diaza-10-aminodecanoylglycine amide) and guanidinium head groups (*e.g.*, bis-guanidinium-spermidine-cholesterol (BGSC), bis-guanidiniumtren-cholesterol (BGTC), PONA, and (R)-5-guanidinopentane-1,2-diyl dioleate hydrochloride (DOPen-G)). Yet another suitable cationic lipid is (R)-5-(dimethylamino)pentane-1,2-diyl dioleate hydrochloride (DODAPen-Cl). In certain embodiments, the cationic lipid is a particular enantiomer or the racemic form, and includes the various salt forms of a cationic lipid as above (*e.g.*, chloride or sulfate). For example, in some embodiments, the cationic lipid is N-[1-(2,3-dioleoyloxy)propyl]-N,N,N-trimethylammonium chloride (DOTAP-Cl) or N-[1-(2,3-dioleoyloxy)propyl]-N,N,N-trimethylammonium sulfate (DOTAP-Sulfate). In some embodiments, the cationic lipid is an ionizable cationic lipid such as, *e.g.*, dioctadecyldimethylammonium bromide (DDAB); 1,2-dilinoleyloxy-3-dimethylaminopropane (DLinDMA); 2,2-dilinoleyl-4-(2dimethylaminoethyl)-[1,3]-dioxolane (DLin-KC2-DMA); heptatriaconta-6,9,28,31-tetraen-19-yl 4-(dimethylamino)butanoate (DLin-MC3-DMA); 1,2-dioleoyloxy-3-dimethylaminopropane (DODAP); 1,2-dioleyloxy-3-dimethylaminopropane (DODMA); and morpholinocholesterol (Mo-CHOL). In certain embodiments, a lipid nanoparticle includes a combination or two or more cationic lipids (*e.g.*, two or more cationic lipids as above).

[00255] Additionally, in some embodiments, the charged or ionizable lipid that can form part of the present nanoparticle composition is a lipid including a cyclic amine group. Additional cationic lipids that are suitable for the formulations and methods disclosed herein include those described in WO2015199952, WO2016176330, and WO2015011633, the entire contents of each of which are hereby incorporated by reference in their entireties.

5.4.2 *Polymer Conjugated Lipids*

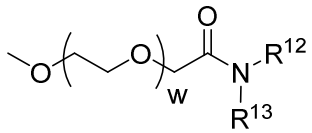
[00256] In some embodiments, the lipid component of a nanoparticle composition can include one or more polymer conjugated lipids, such as PEGylated lipids (PEG lipids). Without being bound by the theory, it is contemplated that a polymer conjugated lipid component in a nanoparticle composition can improve of colloidal stability and/or reduce protein absorption of the nanoparticles. Exemplary cationic lipids that can be used in connection with the present disclosure include but are not limited to PEG-modified phosphatidylethanolamines, PEG-modified phosphatidic acids, PEG-modified ceramides, PEG-modified dialkylamines, PEG-modified diacylglycerols, PEG-modified dialkylglycerols, and mixtures thereof. For example, a PEG lipid may be PEG-c-DOMG, PEG-DMG, PEG-DLPE, PEG-DMPE, PEG-DPPC, PEG-DSPE, Ceramide-PEG2000, or Chol-PEG2000.

[00257] In one embodiment, the polymer conjugated lipid is a pegylated lipid. For example, some embodiments include a pegylated diacylglycerol (PEG-DAG) such as 1-(monomethoxy-polyethyleneglycol)-2,3-dimyristoylglycerol (PEG-DMG), a pegylated phosphatidylethanoloamine (PEG-PE), a PEG succinate diacylglycerol (PEG-S-DAG) such as 4-O-(2',3'-di(tetradecanoyloxy)propyl-1-O-(ω-methoxy(polyethoxy)ethyl)butanedioate (PEG-S-DMG), a pegylated ceramide (PEG-cer), or a PEG dialkoxypropylcarbamate such as ω-methoxy(polyethoxy)ethyl-N-(2,3-di(tetradecanoxy)propyl)carbamate or 2,3-di(tetradecanoxy)propyl-N-(ω-methoxy(polyethoxy)ethyl)carbamate.

[00258] In one embodiment, the polymer conjugated lipid is present in a concentration ranging from 1.0 to 2.5 molar percent. In one embodiment, the polymer conjugated lipid is present in a concentration of about 1.7 molar percent. In one embodiment, the polymer conjugated lipid is present in a concentration of about 1.5 molar percent.

[00259] In one embodiment, the molar ratio of cationic lipid to the polymer conjugated lipid ranges from about 35:1 to about 25:1. In one embodiment, the molar ratio of cationic lipid to polymer conjugated lipid ranges from about 100:1 to about 20:1.

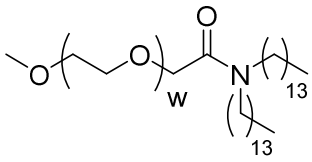
[00260] In one embodiment, the pegylated lipid has the following Formula:



or a pharmaceutically acceptable salt, tautomer or stereoisomer thereof, wherein:
R^{12} and R^{13} are each independently a straight or branched, saturated or unsaturated alkyl chain containing from 10 to 30 carbon atoms, wherein the alkyl chain is optionally interrupted by one or more ester bonds; and
w has a mean value ranging from 30 to 60.

[00261] In one embodiment, R^{12} and R^{13} are each independently straight, saturated alkyl chains containing from 12 to 16 carbon atoms. In other embodiments, the average w ranges from 42 to 55, for example, the average w is 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54 or 55. In some specific embodiments, the average w is about 49.

[00262] In one embodiment, the pegylated lipid has the following Formula:



wherein the average w is about 49.

5.4.3 *Structural Lipids*

[00263] In some embodiments, the lipid component of a nanoparticle composition can include one or more structural lipids. Without being bound by the theory, it is contemplated that structural lipids can stabilize the amphiphilic structure of a nanoparticle, such as but not limited to the lipid bilayer structure of a nanoparticle. Exemplary structural lipids that can be used in connection with the present disclosure include but are not limited to cholesterol, fecosterol, sitosterol, ergosterol, campesterol, stigmasterol, brassicasterol, tomatidine, tomatine, ursolic acid, alpha-tocopherol, and mixtures thereof. In certain embodiments, the structural lipid is cholesterol. In some embodiments, the structural lipid includes cholesterol and a corticosteroid (such as prednisolone, dexamethasone, prednisone, and hydrocortisone), or a combination thereof.

[00264] In one embodiment, the lipid nanoparticles provided herein comprise a steroid or steroid analogue. In one embodiment, the steroid or steroid analogue is cholesterol. In one embodiment, the steroid is present in a concentration ranging from 39 to 49 molar percent, 40

to 46 molar percent, from 40 to 44 molar percent, from 40 to 42 molar percent, from 42 to 44 molar percent, or from 44 to 46 molar percent. In one embodiment, the steroid is present in a concentration of 40, 41, 42, 43, 44, 45, or 46 molar percent.

[00265] In one embodiment, the molar ratio of cationic lipid to the steroid ranges from 1.0:0.9 to 1.0:1.2, or from 1.0:1.0 to 1.0:1.2. In one embodiment, the molar ratio of cationic lipid to cholesterol ranges from about 5:1 to 1:1. In one embodiment, the steroid is present in a concentration ranging from 32 to 40 mol percent of the steroid.

5.4.4 *Phospholipids*

[00266] In some embodiments, the lipid component of a nanoparticle composition can include one or more phospholipids, such as one or more (poly)unsaturated lipids. Without being bound by the theory, it is contemplated that phospholipids may assemble into one or more lipid bilayers structures. Exemplary phospholipids that can form part of the present nanoparticle composition include but are not limited to 1,2-distearoyl-sn-glycero-3-phosphocholine (DSPC), 1,2-dioleoyl-sn-glycero-3-phosphoethanolamine (DOPE), 1,2-dilinoleoyl-sn-glycero-3-phosphocholine (DLPC), 1,2-dimyristoyl-sn-glycero-phosphocholine (DMPC), 1,2-dioleoyl-sn-glycero-3-phosphocholine (DOPC), 1,2-dipalmitoyl-sn-glycero-3-phosphocholine (DPPC), 1,2-diundecanoyl-sn-glycero-phosphocholine (DUPC), 1-palmitoyl-2-oleoyl-sn-glycero-3-phosphocholine (POPC), 1,2-di-O-octadecenyl-sn-glycero-3-phosphocholine (18:0 Diether PC), 1-oleoyl-2-cholesterylhemisuccinoyl-sn-glycero-3-phosphocholine (OChemsPC), 1-hexadecyl-sn-glycero-3-phosphocholine (C16 Lyso PC), 1,2-dilinolenoyl-sn-glycero-3-phosphocholine, 1,2-diarachidonoyl-sn-glycero-3-phosphocholine, 1,2-didocosahexaenoyl-sn-glycero-3-phosphocholine, 1,2-diphytanoyl-sn-glycero-3-phosphoethanolamine (ME 16.0 PE), 1,2-distearoyl-sn-glycero-3-phosphoethanolamine, 1,2-dilinoleoyl-sn-glycero-3-phosphoethanolamine, 1,2-dilinolenoyl-sn-glycero-3-phosphoethanolamine, 1,2-diarachidonoyl-sn-glycero-3-phosphoethanolamine, 1,2-didocosahexaenoyl-sn-glycero-3-phosphoethanolamine, 1,2-dioleoyl-sn-glycero-3-phospho-rac-(1-glycerol) sodium salt (DOPG), and sphingomyelin. In certain embodiments, a nanoparticle composition includes DSPC. In certain embodiments, a nanoparticle composition includes DOPE. In some embodiments, a nanoparticle composition includes both DSPC and DOPE.

[00267] Additional exemplary neutral lipids include, for example, dipalmitoylphosphatidylglycerol (DPPG), palmitoyloleoyl-phosphatidylethanolamine (POPE)

and dioleoyl-phosphatidylethanolamine 4-(N-maleimidomethyl)-cyclohexane-1carboxylate (DOPE-mal), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidylethanolamine (DSPE), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1-trans PE, 1-stearioyl-2-oleoylphosphatidyethanol amine (SOPE), and 1,2-dielaidoyl-sn-glycero-3-phophoethanolamine (transDOPE). In one embodiment, the neutral lipid is 1,2-distearoyl-sn-glycero-3phosphocholine (DSPC). In one embodiment, the neutral lipid is selected from DSPC, DPPC, DMPC, DOPC, POPC, DOPE and SM.

[00268] In one embodiment, the neutral lipid is phosphatidylcholine (PC), phosphatidylethanolamine (PE) phosphatidylserine (PS), phosphatidic acid (PA), or phosphatidylglycerol (PG).

[00269] Additionally phospholipids that can form part of the present nanoparticle composition also include those described in WO2017/112865, the entire content of which is hereby incorporated by reference in its entirety.

5.4.5 *Therapeutic Payload*

[00270] According to the present disclosure, nanoparticle compositions as described herein can further comprise one or more therapeutic and/or prophylactic agents. These therapeutic and/or prophylactic agents are sometimes referred to as a "therapeutic payload" or "payload" in the present disclosure. In some embodiments, the therapeutic payload can be administered *in vivo* or *in vitro* using the nanoparticles as a delivery vehicle.

[00271] In some embodiments, the nanoparticle composition comprises, as the therapeutic payload, a small molecule compound (*e.g.*, a small molecule drug) such as antineoplastic agents (*e.g.*, vincristine, doxorubicin, mitoxantrone, camptothecin, cisplatin, bleomycin, cyclophosphamide, methotrexate, and streptozotocin), antitumor agents (e.g., actinomycin D, vincristine, vinblastine, cytosine arabinoside, anthracyclines, alkylating agents, platinum compounds, antimetabolites, and nucleoside analogs, such as methotrexate and purine and pyrimidine analogs), anti-infective agents, local anesthetics (e.g., dibucaine and chlorpromazine), beta-adrenergic blockers (e.g., propranolol, timolol, and labetalol), antihypertensive agents (e.g., clonidine and hydralazine), anti-depressants (e.g., imipramine, amitriptyline, and doxepin), anti-convulsants (e.g., phenytoin), antihistamines (e.g., diphenhydramine, chlorpheniramine, and promethazine), antibiotic/antibacterial agents (e.g., gentamycin, ciprofloxacin, and cefoxitin), antifungal agents (e.g., miconazole, terconazole,

econazole, isoconazole, butaconazole, clotrimazole, itraconazole, nystatin, naftifine, and amphotericin B), antiparasitic agents, hormones, hormone antagonists, immunomodulators, neurotransmitter antagonists, antiglaucoma agents, vitamins, narcotics, and imaging agents.

[00272] In some embodiments, the therapeutic payload comprises a cytotoxin, a radioactive ion, a chemotherapeutic, a vaccine, a compound that elicits an immune response, and/or another therapeutic and/or prophylactic agent. A cytotoxin or cytotoxic agent includes any agent that may be detrimental to cells. Examples include, but are not limited to, taxol, cytochalasin B, gramicidin D, ethidium bromide, emetine, mitomycin, etoposide, teniposide, vincristine, vinblastine, colchicine, doxorubicin, daunorubicin, dihydroxyanthracinedione, mitoxantrone, mithramycin, actinomycin D, 1-dehydrotestosterone, glucocorticoids, procaine, tetracaine, lidocaine, propranolol, puromycin, maytansinoids, e.g., maytansinol, rachelmycin (CC-1065), and analogs or homologs thereof. Radioactive ions include, but are not limited to iodine (e.g., iodine 125 or iodine 131), strontium 89, phosphorous, palladium, cesium, iridium, phosphate, cobalt, yttrium 90, samarium 153, and praseodymium.

[00273] In other embodiments, the therapeutic payload of the present nanoparticle composition can include, but is not limited to, therapeutic and/or prophylactic agents such as antimetabolites (e.g., methotrexate, 6-mercaptopurine, 6-thioguanine, cytarabine, 5-fluorouracil, dacarbazine), alkylating agents (e.g., mechlorethamine, thiotepa chlorambucil, rachelmycin (CC-1065), melphalan, carmustine (BSNU), lomustine (CCNU), cyclophosphamide, busulfan, dibromomannitol, streptozotocin, mitomycin C, and cis-dichlorodiamine platinum (II) (DDP) cisplatin), anthracyclines (e.g., daunorubicin (formerly daunomycin) and doxorubicin), antibiotics (e.g., dactinomycin (formerly actinomycin), bleomycin, mithramycin, and anthramycin (AMC)), and anti-mitotic agents (e.g., vincristine, vinblastine, taxol and maytansinoids).

[00274] In some embodiments, the nanoparticle composition comprises, as the therapeutic payload, a biological molecule such as peptides and polypeptides. The biological molecules forming part of the present nanoparticle composition can be either of a natural source or synthetic. For example, in some embodiments, the therapeutic payload of the present nanoparticle composition can include, but is not limited to gentamycin, amikacin, insulin, erythropoietin (EPO), granulocyte-colony stimulating factor (G-CSF), granulocyte-macrophage colony stimulating factor (GM-CSF), Factor VIR, luteinizing hormone-releasing hormone (LHRH) analogs, interferons, heparin, Hepatitis B surface antigen, typhoid vaccine, cholera vaccine, and peptides and polypeptides.

5.4.5.1 *Nucleic Acids*

[00275] In some embodiments, the present nanoparticle composition comprises one or more nucleic acid molecules (*e.g.*, DNA or RNA molecules) as the therapeutic payload. Exemplary forms of nucleic acid molecules that can be included in the present nanoparticle composition as therapeutic payload include, but are not limited to, one or more of deoxyribonucleic acid (DNA), ribonucleic acid (RNA) including messenger mRNA (mRNA), hybrids thereof, RNAi-inducing agents, RNAi agents, siRNAs, shRNAs, miRNAs, antisense RNAs, ribozymes, catalytic DNA, RNAs that induce triple helix formation, aptamers, vectors, *etc*. In certain embodiments, the therapeutic payload comprises an RNA. RNA molecules that can be included in the present nanoparticle composition as the therapeutic payload include, but are not limited to, shortmers, agomirs, antagomirs, antisense, ribozymes, small interfering RNA (siRNA), asymmetrical interfering RNA (aiRNA), microRNA (miRNA), Dicer-substrate RNA (dsRNA), small hairpin RNA (shRNA), transfer RNA (tRNA), messenger RNA (mRNA), and other forms of RNA molecules known in the art. In particular embodiments, the RNA is an mRNA.

[00276] In other embodiments, the nanoparticle composition comprises a siRNA molecule as the therapeutic payload. Particularly, in some embodiments, the siRNA molecule is capable of selectively interfering with and downregulate the expression of a gene of interest. For example, in some embodiments, the siRNA payload selectively silence a gene associated with a particular disease, disorder, or condition upon administration to a subject in need thereof of a nanoparticle composition including the siRNA. In some embodiments, the siRNA molecule comprises a sequence that is complementary to an mRNA sequence encoding a protein product of interest. In some embodiments, the siRNA molecule is an immunomodulatory siRNA.

[00277] In some embodiments, the nanoparticle composition comprises a shRNA molecule or a vector encoding the shRNA molecule as the therapeutic payload. Particularly, in some embodiments, the therapeutic payload, upon administering to a target cell, produces shRNA inside the target cell. Constructs and mechanisms relating to shRNA are well known in the relevant arts.

[00278] In some embodiments, the nanoparticle composition comprises an mRNA molecule as the therapeutic payload. Particularly, in some embodiments, the mRNA molecule encodes a polypeptide of interest, including any naturally or non-naturally

occurring or otherwise modified polypeptide. A polypeptide encoded by an mRNA may be of any size and may have any secondary structure or activity. In some embodiments, the polypeptide encoded by an mRNA payload can have a therapeutic effect when expressed in a cell.

[00279] In some embodiment, a nucleic acid molecule of the present disclosure comprises an mRNA molecule. In specific embodiments, the nucleic acid molecule comprises at least one coding region encoding a peptide or polypeptide of interest (*e.g.*, an open reading frame (ORF)). In some embodiments, the nucleic acid molecule further comprises at least one untranslated region (UTR). In particular embodiments, the untranslated region (UTR) is located upstream (to the 5'-end) of the coding region, and is referred to herein as the 5'-UTR. In particular embodiments, the untranslated region (UTR) is located downstream (to the 3'-end) of the coding region, and is referred to herein as the 3'-UTR. In particular embodiments, the nucleic acid molecule comprises both a 5'-UTR and a 3'-UTR. In some embodiments, the 5'-UTR comprises a 5'-Cap structure. In some embodiments, the nucleic acid molecule comprises a Kozak sequence (*e.g.*, in the 5'-UTR). In some embodiments, the nucleic acid molecule comprises a poly-A region (*e.g.*, in the 3'-UTR). In some embodiments, the nucleic acid molecule comprises a polyadenylation signal (*e.g.*, in the 3'-UTR). In some embodiments, the nucleic acid molecule comprises stabilizing region (*e.g.*, in the 3'-UTR). In some embodiments, the nucleic acid molecule comprises a secondary structure. In some embodiments, the secondary structure is a stem-loop. In some embodiments, the nucleic acid molecule comprises a stem-loop sequence (*e.g.*, in the 5'-UTR and/or the 3'-UTR). In some embodiments, the nucleic acid molecule comprises one or more intronic regions capable of being excised during splicing. In a specific embodiment, the nucleic acid molecule comprises one or more region selected from a 5'-UTR, and a coding region. In a specific embodiment, the nucleic acid molecule comprises one or more region selected from a coding region and a 3'-UTR. In a specific embodiment, the nucleic acid molecule comprises one or more region selected from a 5'-UTR, a coding region, and a 3'-UTR.

Coding Region

[00280] In some embodiments, the nucleic acid molecule of the present disclosure comprises at least one coding region. In some embodiments, the coding region is an open reading frame (ORF) that encodes for a single peptide or protein. In some embodiments, the coding region comprises at least two ORFs, each encoding a peptide or protein. In those

embodiments where the coding region comprises more than one ORFs, the encoded peptides and/or proteins can be the same as or different from each other. In some embodiments, the multiple ORFs in a coding region are separated by non-coding sequences. In specific embodiments, a non-coding sequence separating two ORFs comprises an internal ribosome entry sites (IRES).

[00281] Without being bound by the theory, it is contemplated that an internal ribosome entry sites (IRES) can act as the sole ribosome binding site, or serve as one of multiple ribosome binding sites of an mRNA. An mRNA molecule containing more than one functional ribosome binding site can encode several peptides or polypeptides that are translated independently by the ribosomes (*e.g.*, multicistronic mRNA). Accordingly, in some embodiments, the nucleic acid molecule of the present disclosure (*e.g.*, mRNA) comprises one or more internal ribosome entry sites (IRES). Examples of IRES sequences that can be used in connection with the present disclosure include, without limitation, those from picomaviruses (e.g., FMDV), pest viruses (CFFV), polio viruses (PV), encephalomyocarditis viruses (ECMV), foot-and-mouth disease viruses (FMDV), hepatitis C viruses (HCV), classical swine fever viruses (CSFV), murine leukemia virus (MLV), simian immune deficiency viruses (SIV) or cricket paralysis viruses (CrPV).

[00282] In various embodiments, the nucleic acid molecule of the present disclose encodes for at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more than 10 peptides or proteins. Peptides and proteins encoded by a nucleic acid molecule can be the same or different. In some embodiments, the nucleic acid molecule of the present disclosure encodes a dipeptide (*e.g.*, camosine and anserine). In some embodiments, the nucleic acid molecule encodes a tripeptide. In some embodiments, the nucleic acid molecule encodes a tetrapeptide. In some embodiments, the nucleic acid molecule encodes a pentapeptide. In some embodiments, the nucleic acid molecule encodes a hexapeptide. In some embodiments, the nucleic acid molecule encodes a heptapeptide. In some embodiments, the nucleic acid molecule encodes an octapeptide. In some embodiments, the nucleic acid molecule encodes a nonapeptide. In some embodiments, the nucleic acid molecule encodes a decapeptide. In some embodiments, the nucleic acid molecule encodes a peptide or polypeptide that has at least about 15 amino acids. In some embodiments, the nucleic acid molecule encodes a peptide or polypeptide that has at least about 50 amino acids. In some embodiments, the nucleic acid molecule encodes a peptide or polypeptide that has at least about 100 amino acids. In some embodiments, the nucleic acid molecule encodes a peptide or polypeptide that has at least about 150 amino

acids. In some embodiments, the nucleic acid molecule encodes a peptide or polypeptide that has at least about 300 amino acids. In some embodiments, the nucleic acid molecule encodes a peptide or polypeptide that has at least about 500 amino acids. In some embodiments, the nucleic acid molecule encodes a peptide or polypeptide that has at least about 1000 amino acids.

[00283] In some embodiments, the nucleic acid molecule of the present disclosure is at least about 30 nucleotides (nt) in length. In some embodiments, the nucleic acid molecule is at least about 35 nt in length. In some embodiments, the nucleic acid molecule is at least about 40 nt in length. In some embodiments, the nucleic acid molecule is at least about 45 nt in length. In some embodiments the nucleic acid molecule is at least about 50 nt in length. In some embodiments, the nucleic acid molecule is at least about 55 nt in length. In some embodiments, the nucleic acid molecule is at least about 60 nt in length. In some embodiments, the nucleic acid molecule is at least about 65 nt in length. In some embodiments, the nucleic acid molecule is at least about 70 nt in length. In some embodiments, the nucleic acid molecule is at least about 75 nt in length. In some embodiments, the nucleic acid molecule is at least about 80 nt in length. In some embodiments the nucleic acid molecule is at least about 85 nt in length. In some embodiments, the nucleic acid molecule is at least about 90 nt in length. In some embodiments, the nucleic acid molecule is at least about 95 nt in length. In some embodiments, the nucleic acid molecule is at least about 100 nt in length. In some embodiments, the nucleic acid molecule is at least about 120 nt in length. In some embodiments, the nucleic acid molecule is at least about 140 nt in length. In some embodiments, the nucleic acid molecule is at least about 160 nt in length. In some embodiments, the nucleic acid molecule is at least about 180 nt in length. In some embodiments, the nucleic acid molecule is at least about 200 nt in length. In some embodiments, the nucleic acid molecule is at least about 250 nt in length. In some embodiments, the nucleic acid molecule is at least about 300 nt in length. In some embodiments, the nucleic acid molecule is at least about 400 nt in length. In some embodiments, the nucleic acid molecule is at least about 500 nt in length. In some embodiments, the nucleic acid molecule is at least about 600 nt in length. In some embodiments, the nucleic acid molecule is at least about 700 nt in length. In some embodiments, the nucleic acid molecule is at least about 800 nt in length. In some embodiments, the nucleic acid molecule is at least about 900 nt in length. In some

embodiments, the nucleic acid molecule is at least about 1000 nt in length. In some embodiments, the nucleic acid molecule is at least about 1100 nt in length. In some embodiments, the nucleic acid molecule is at least about 1200 nt in length. In some embodiments, the nucleic acid molecule is at least about 1300 nt in length. In some embodiments, the nucleic acid molecule is at least about 1400 nt in length. In some embodiments, the nucleic acid molecule is at least about 1500 nt in length. In some embodiments, the nucleic acid molecule is at least about 1600 nt in length. In some embodiments, the nucleic acid molecule is at least about 1700 nt in length. In some embodiments, the nucleic acid molecule is at least about 1800 nt in length. In some embodiments, the nucleic acid molecule is at least about 1900 nt in length. In some embodiments, the nucleic acid molecule is at least about 2000 nt in length. In some embodiments, the nucleic acid molecule is at least about 2500 nt in length. In some embodiments, the nucleic acid molecule is at least about 3000 nt in length. In some embodiments, the nucleic acid molecule is at least about 3500 nt in length. In some embodiments, the nucleic acid molecule is at least about 4000 nt in length. In some embodiments, the nucleic acid molecule is at least about 4500 nt in length. In some embodiments, the nucleic acid molecule is at least about 5000 nt in length.

[00284] In specific embodiments, the therapeutic payload comprises a vaccine composition (*e.g.*, a genetic vaccine) as described herein. In some embodiments, the therapeutic payload comprises a compound capable of eliciting immunity against one or more target conditions or disease. In some embodiments, the target condition is related to or caused by infection by a pathogen, such as a coronavirus (*e.g.* 2019-nCoV), influenza, measles, human papillomavirus (HPV), rabies, meningitis, whooping cough, tetanus, plague, hepatitis, and tuberculosis. In some embodiments, the therapeutic payload comprises a nucleic acid sequence (*e.g.*, mRNA) encoding a pathogenic protein characteristic for the pathogen, or an antigenic fragment or epitope thereof. The vaccine, upon administration to a vaccinated subject, allows for expression of the encoded pathogenic protein (or the antigenic fragment or epitope thereof), thereby eliciting immunity in the subject against the pathogen.

[00285] In some embodiments, the target condition is related to or caused by neoplastic growth of cells, such as a cancer. In some embodiments, the therapeutic payload comprises a nucleic acid sequence (*e.g.*, mRNA) encoding a tumor associated antigen (TAA) characteristic for the cancer, or an antigenic fragment or epitope thereof. The vaccine, upon administration to a vaccinated subject, allows for expression of the encoded TAA (or the

antigenic fragment or epitope thereof), thereby eliciting immunity in the subject against the neoplastic cells expressing the TAA.

5'-Cap Structure

[00286] Without being bound by the theory, it is contemplated that, a 5'-cap structure of a polynucleotide is involved in nuclear export and increasing polynucleotide stability and binds the mRNA Cap Binding Protein (CBP), which is responsible for polynucleotide stability in the cell and translation competency through the association of CBP with poly-A binding protein to form the mature cyclic mRNA species. The 5'-cap structure further assists the removal of 5'-proximal introns removal during mRNA splicing. Accordingly, in some embodiments, the nucleic acid molecules of the present disclosure comprise a 5'-cap structure.

[00287] Nucleic acid molecules may be 5'-end capped by the endogenous transcription machinery of a cell to generate a 5'-ppp-5'-triphosphate linkage between a terminal guanosine cap residue and the 5'-terminal transcribed sense nucleotide of the polynucleotide. This 5'-guanylate cap may then be methylated to generate an N7-methyl-guanylate residue. The ribose sugars of the terminal and/or anteterminal transcribed nucleotides of the 5' end of the polynucleotide may optionally also be 2'-O-methylated. 5'-decapping through hydrolysis and cleavage of the guanylate cap structure may target a nucleic acid molecule, such as an mRNA molecule, for degradation.

[00288] In some embodiments, the nucleic acid molecules of the present disclosure comprise one or more alterations to the natural 5'-cap structure generated by the endogenous process. Without being bound by the theory, a modification on the 5'-cap may increase the stability of polynucleotide, increase the half-life of the polynucleotide, and could increase the polynucleotide translational efficiency.

[00289] Exemplary alterations to the natural 5'-Cap structure include generation of a non-hydrolyzable cap structure preventing decapping and thus increasing polynucleotide half-life. In some embodiments, because cap structure hydrolysis requires cleavage of 5'-ppp-5' phosphorodiester linkages, in some embodiments, modified nucleotides may be used during the capping reaction. For example, in some embodiments, a Vaccinia Capping Enzyme from New England Biolabs (Ipswich, Mass.) may be used with α-thio-guanosine nucleotides according to the manufacturer's instructions to create a phosphorothioate linkage in the 5'-

ppp-5' cap. Additional modified guanosine nucleotides may be used, such as α-methyl-phosphonate and seleno-phosphate nucleotides.

[00290] Additional exemplary alterations to the natural 5'-Cap structure also include modification at the 2'- and/or 3'-position of a capped guanosine triphosphate (GTP), a replacement of the sugar ring oxygen (that produced the carbocyclic ring) with a methylene moiety (CH_2), a modification at the triphosphate bridge moiety of the cap structure, or a modification at the nucleobase (G) moiety.

[00291] Additional exemplary alterations to the natural 5'-cap structure include, but are not limited to, 2'-O-methylation of the ribose sugars of 5'-terminal and/or 5'-anteterminal nucleotides of the polynucleotide (as mentioned above) on the 2'-hydroxy group of the sugar. Multiple distinct 5'-cap structures can be used to generate the 5'-cap of a polynucleotide, such as an mRNA molecule. Additional exemplary 5'-Cap structures that can be used in connection with the present disclosure further include those described in International Patent Publication Nos. WO2008127688, WO 2008016473, and WO 2011015347, the entire contents of each of which are incorporated herein by reference.

[00292] In various embodiments, 5'-terminal caps can include cap analogs. Cap analogs, which herein are also referred to as synthetic cap analogs, chemical caps, chemical cap analogs, or structural or functional cap analogs, differ from natural (*i.e.*, endogenous, wild-type, or physiological) 5'-caps in their chemical structure, while retaining cap function. Cap analogs may be chemically (*i.e.*, non-enzymatically) or enzymatically synthesized and/linked to a polynucleotide.

[00293] For example, the Anti-Reverse Cap Analog (ARCA) cap contains two guanosines linked by a 5'-5'-triphosphate group, wherein one guanosine contains an N7-methyl group as well as a 3'-O-methyl group (*i.e.*, N7,3'-O-dimethyl-guanosine-5'-triphosphate-5'-guanosine, m^7G-3'mppp-G, which may equivalently be designated 3' O-Me-m7G(5')ppp(5')G). The 3'-O atom of the other, unaltered, guanosine becomes linked to the 5'-terminal nucleotide of the capped polynucleotide (*e.g.*, an mRNA). The N7- and 3'-O-methlyated guanosine provides the terminal moiety of the capped polynucleotide (*e.g.*, mRNA). Another exemplary cap structure is mCAP, which is similar to ARCA but has a 2'-O-methyl group on guanosine (*i.e.*, N7,2'-O-dimethyl-guanosine-5'-triphosphate-5'-guanosine, m_7Gm-ppp-G).

[00294] In some embodiments, a cap analog can be a dinucleotide cap analog. As a non-limiting example, the dinucleotide cap analog may be modified at different phosphate

positions with a boranophosphate group or a phophoroselenoate group such as the dinucleotide cap analogs described in U.S. Patent No.: 8,519,110, the entire content of which is herein incorporated by reference in its entirety.

[00295] In some embodiments, a cap analog can be a N7-(4-chlorophenoxyethyl) substituted dinucleotide cap analog known in the art and/or described herein. Non-limiting examples of N7-(4-chlorophenoxyethyl) substituted dinucleotide cap analogs include a N7-(4-chlorophenoxyethyl)-G(5')ppp(5')G and a N7-(4-chlorophenoxyethyl)-m3'-OG(5')ppp(5')G cap analog (see, *e.g.*, the various cap analogs and the methods of synthesizing cap analogs described in Kore *et al*. Bioorganic & Medicinal Chemistry 2013 21:4570-4574; the entire content of which is herein incorporated by reference). In other embodiments, a cap analog useful in connection with the nucleic acid molecules of the present disclosure is a 4-chloro/bromophenoxyethyl analog.

[00296] In various embodiments, a cap analog can include a guanosine analog. Useful guanosine analogs include but are not limited to inosine, N1-methyl-guanosine, 2'-fluoro-guanosine, 7-deaza-guanosine, 8-oxo-guanosine, 2-amino-guanosine, LNA-guanosine, and 2-azido-guanosine.

[00297] Without being bound by the theory, it is contemplated that while cap analogs allow for the concomitant capping of a polynucleotide in an *in vitro* transcription reaction, up to 20% of transcripts remain uncapped. This, as well as the structural differences of a cap analog from the natural 5'-cap structures of polynucleotides produced by the endogenous transcription machinery of a cell, may lead to reduced translational competency and reduced cellular stability.

[00298] Accordingly, in some embodiments, a nucleic acid molecule of the present disclosure can also be capped post-transcriptionally, using enzymes, in order to generate more authentic 5'-cap structures. As used herein, the phrase "more authentic" refers to a feature that closely mirrors or mimics, either structurally or functionally, an endogenous or wild type feature. That is, a "more authentic" feature is better representative of an endogenous, wild-type, natural or physiological cellular function, and/or structure as compared to synthetic features or analogs of the prior art, or which outperforms the corresponding endogenous, wild-type, natural, or physiological feature in one or more respects. Non-limiting examples of more authentic 5'-cap structures useful in connection with the nucleic acid molecules of the present disclosure are those which, among other things,

have enhanced binding of cap binding proteins, increased half-life, reduced susceptibility to 5'-endonucleases, and/or reduced 5'-decapping, as compared to synthetic 5'-cap structures known in the art (or to a wild-type, natural or physiological 5'-cap structure). For example, in some embodiments, recombinant Vaccinia Virus Capping Enzyme and recombinant 2'-O-methyltransferase enzyme can create a canonical 5'-5'-triphosphate linkage between the 5'-terminal nucleotide of a polynucleotide and a guanosine cap nucleotide wherein the cap guanosine contains an N7-methylation and the 5'-terminal nucleotide of the polynucleotide contains a 2'-O-methyl. Such a structure is termed the Cap1 structure. This cap results in a higher translational-competency, cellular stability, and a reduced activation of cellular pro-inflammatory cytokines, as compared, *e.g.*, to other 5'cap analog structures known in the art. Other exemplary cap structures include 7mG(5')ppp(5')N,pN2p (Cap 0), 7mG(5')ppp(5')NlmpNp (Cap 1), 7mG(5')-ppp(5')NlmpN2mp (Cap 2), and m(7)Gpppm(3)(6,6,2')Apm(2')Apm(2')Cpm(2)(3,2')Up (Cap 4).

[00299] Without being bound by the theory, it is contemplated that the nucleic acid molecules of the present disclosure can be capped post-transcriptionally, and because this process is more efficient, nearly 100% of the nucleic acid molecules may be capped.

Untranslated Regions (UTRs)

[00300] In some embodiments, the nucleic acid molecules of the present disclosure comprise one or more untranslated regions (UTRs). In some embodiments, an UTR is positioned upstream to a coding region in the nucleic acid molecule, and is termed 5'-UTR. In some embodiments, an UTR is positioned downstream to a coding region in the nucleic acid molecule, and is termed 3'-UTR. The sequence of an UTR can be homologous or heterologous to the sequence of the coding region found in a nucleic acid molecule. Multiple UTRs can be included in a nucleic acid molecule and can be of the same or different sequences, and/or genetic origin. According to the present disclosure, any portion of UTRs in a nucleic acid molecule (including none) can be codon optimized and any may independently contain one or more different structural or chemical modification, before and/or after codon optimization.

[00301] In some embodiments, a nucleic acid molecule of the present disclosure (*e.g.*, mRNA) comprises UTRs and coding regions that are homologous with respect to each other. In other embodiments, a nucleic acid molecule of the present disclosure (*e.g.*, mRNA) comprises UTRs and coding regions that are heterogeneous with respect to each other. In

some embodiments, to monitor the activity of a UTR sequence, a nucleic acid molecule comprising the UTR and a coding sequence of a detectable probe can be administered *in vitro* (*e.g.*, cell or tissue culture) or *in vivo* (*e.g.*, to a subject), and an effect of the UTR sequence (*e.g.*, modulation on the expression level, cellular localization of the encoded product, or half-life of the encoded product) can be measured using methods known in the art.

[00302] In some embodiments, the UTR of a nucleic acid molecule of the present disclosure (*e.g.*, mRNA) comprises at least one translation enhancer element (TEE) that functions to increase the amount of polypeptide or protein produced from the nucleic acid molecule. In some embodiments, the TEE is located in the 5'-UTR of the nucleic acid molecule. In other embodiments, the TEE is located at the 3'-UTR of the nucleic acid molecule. In yet other embodiments, at least two TEE are located at the 5'-UTR and 3'-UTR of the nucleic acid molecule respectively. In some embodiments, a nucleic acid molecule of the present disclosure (*e.g.*, mRNA) can comprise one or more copies of a TEE sequence or comprise more than one different TEE sequences. In some embodiments, different TEE sequences that are present in a nucleic acid molecule of the present disclosure can be homologues or heterologous with respect to one another.

[00303] Various TEE sequences that are known in the art and can be used in connection with the present disclosure. For example, in some embodiments, the TEE can be an internal ribosome entry site (IRES), HCV-IRES or an IRES element. Chappell *et al. Proc. Natl. Acad. Sci.* USA 101:9590-9594, 2004; Zhou *et al*. *Proc. Natl. Acad. Sci.* 102:6273-6278, 2005. Additional internal ribosome entry site (IRES) that can be used in connection with the present disclosure include but are not limited to those described in U.S. Patent No. 7,468,275, U.S. Patent Publication No. 2007/0048776 and U.S. Patent Publication No. 2011/0124100 and International Patent Publication No. WO2007/025008 and International Patent Publication No. WO2001/055369, the content of each of which is enclosed herein by reference in its entirety. In some embodiments, the TEE can be those described in Supplemental Table 1 and in Supplemental Table 2 of Wellensiek *et al* Genome-wide profiling of human cap-independent translation-enhancing elements, *Nature Methods*, 2013 Aug; 10(8): 747–750; the content of which is incorporated by reference in its entirety.

[00304] Additional exemplary TEEs that can be used in connection with the present disclosure include but are not limited to the TEE sequences disclosed in U.S. Patent No. 6,310,197, U.S. Patent No. 6,849,405, U.S. Patent No. 7,456,273, U.S. Patent No. 7,183,395, U.S. Patent Publication No. 2009/0226470, U.S. Patent Publication No. 2013/0177581, U.S.

Patent Publication No. 2007/0048776, U.S. Patent Publication No. 2011/0124100, U.S. Patent Publication No. 2009/0093049, International Patent Publication No. WO2009/075886, International Patent Publication No. WO2012/009644, and International Patent Publication No. WO1999/024595, International Patent Publication No.WO2007/025008, International Patent Publication No.WO2001/055371, European Patent No. 2610341, European Patent No. 2610340, the content of each of which is enclosed herein by reference in its entirety.

[00305] In various embodiments, a nucleic acid molecule of the present disclosure (*e.g.*, mRNA) comprises at least one UTR that comprises at least 1, at least 2, at least 3, at least 4, at least 5, at least 6, at least 7, at least 8, at least 9, at least 10, at least 11, at least 12, at least 13, at least 14, at least 15, at least 16, at least 17, at least 18 at least 19, at least 20, at least 21, at least 22, at least 23, at least 24, at least 25, at least 30, at least 35, at least 40, at least 45, at least 50, at least 55 or more than 60 TEE sequences. In some embodiments, the TEE sequences in the UTR of a nucleic acid molecule are copies of the same TEE sequence. In other embodiments, at least two TEE sequences in the UTR of a nucleic acid molecule are of different TEE sequences. In some embodiments, multiple different TEE sequences are arranged in one or more repeating patterns in the UTR region of a nucleic acid molecule. For illustrating purpose only, a repeating pattern can be, for example, ABABAB, AABBAABBAABB, ABCABCABC, or the like, where in these exemplary patterns, each capitalized letter (A, B, or C) represents a different TEE sequence. In some embodiments, at least two TEE sequences are consecutive with one another (*i.e.*, no spacer sequence in between) in a UTR of a nucleic acid molecule. In other embodiments, at least two TEE sequences are separated by a spacer sequence. In some embodiments, a UTR can comprise a TEE sequence-spacer sequence module that is repeated at least once, at least twice, at least 3 times, at least 4 times, at least 5 times, at least 6 times, at least 7 times, at least 8 times, at least 9 times, or more than 9 times in the UTR. In any of the embodiments described in this paragraph, the UTR can be a 5'-UTR, a 3'-UTR or both 5'-UTR and 3'-UTR of a nucleic acid molecule.

[00306] In some embodiments, the UTR of a nucleic acid molecule of the present disclosure (*e.g.*, mRNA) comprises at least one translation suppressing element that functions to decrease the amount of polypeptide or protein produced from the nucleic acid molecule. In some embodiments, the UTR of the nucleic acid molecule comprises one or more miR sequences or fragment thereof (*e.g.*, miR seed sequences) that are recognized by one or more microRNA. In some embodiments, the UTR of the nucleic acid molecule comprises one or

more stem-loop structure that downregulates translational activity of the nucleic acid molecule. Other mechanisms for suppressing translational activities associated with a nucleic acid molecules are known in the art. In any of the embodiments described in this paragraph, the UTR can be a 5'-UTR, a 3'-UTR or both 5'-UTR and 3'-UTR of a nucleic acid molecule.

The Polyadenylation (Poly-A) Regions

[00307] During natural RNA processing, a long chain of adenosine nucleotides (poly-A region) is normally added to messenger RNA (mRNA) molecules to increase the stability of the molecule. Immediately after transcription, the 3'-end of the transcript is cleaved to free a 3'-hydroxy. Then poly-A polymerase adds a chain of adenosine nucleotides to the RNA. The process, called polyadenylation, adds a poly-A region that is between 100 and 250 residues long. Without being bound by the theory, it is contemplated that a poly-A region can confer various advantages to the nucleic acid molecule of the present disclosure.

[00308] Accordingly, in some embodiments, a nucleic acid molecule of the present disclosure (*e.g.*, an mRNA) comprises a polyadenylation signal. In some embodiments, a nucleic acid molecule of the present disclosure (*e.g.*, an mRNA) comprises one or more polyadenylation (poly-A) regions. In some embodiments, a poly-A region is composed entirely of adenine nucleotides or functional analogs thereof. In some embodiments, the nucleic acid molecule comprises at least one poly-A region at its 3'-end. In some embodiments, the nucleic acid molecule comprises at least one poly-A region at its 5'-end. In some embodiments, the nucleic acid molecule comprises at least one poly-A region at its 5'-end and at least one poly-A region at its 3'-end.

[00309] According to the present disclosure, the poly-A region can have varied lengths in different embodiments. Particularly, in some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 30 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 35 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 40 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 45 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 50 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 55 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure

is at least 60 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 65 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 70 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 75 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 80 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 85 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 90 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 95 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 100 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 110 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 120 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 130 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 140 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 150 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 160 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 170 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 180 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 190 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 200 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 225 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 250 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 275 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 300 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 350 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present

disclosure is at least 400 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 450 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 500 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 600 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 700 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 800 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 900 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 1000 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 1100 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 1200 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 1300 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 1400 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 1500 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 1600 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 1700 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 1800 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 1900 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 2000 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 2250 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 2500 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 2750 nucleotides in length. In some embodiments, the poly-A region of a nucleic acid molecule of the present disclosure is at least 3000 nucleotides in length.

[00310] In some embodiments, length of a poly-A region in a nucleic acid molecule can be selected based on the overall length of the nucleic acid molecule, or a portion thereof (such as the length of the coding region or the length of an open reading frame of the nucleic acid molecule, *etc.*). For example, in some embodiments, the poly-A region accounts for about 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95% or more of the total length of nucleic acid molecule containing the poly-A region.

[00311] Without being bound by the theory, it is contemplated that certain RNA-binding proteins can bind to the poly-A region located at the 3'-end of an mRNA molecule. These poly-A binding proteins (PABP) can modulate mRNA expression, such as interacting with translation initiation machinery in a cell and/or protecting the 3'-poly-A tails from degradation. Accordingly, in some embodiments, in some embodiments, the nucleic acid molecule of the present disclosure (*e.g.*, mRNA) comprises at least one binding site for poly-A binding protein (PABP). In other embodiments, the nucleic acid molecule is conjugated or complex with a PABP before loaded into a delivery vehicle (*e.g.*, lipid nanoparticles).

[00312] In some embodiments, the nucleic acid molecule of the present disclosure (*e.g.*, mRNA) comprises a poly-A-G Quartet. The G-quartet is a cyclic hydrogen bonded array of four guanosine nucleotides that can be formed by G-rich sequences in both DNA and RNA. In this embodiment, the G-quartet is incorporated at the end of the poly-A region. The resultant polynucleotides (*e.g.*, mRNA) may be assayed for stability, protein production and other parameters including half-life at various time points. It has been discovered that the polyA-G quartet structure results in protein production equivalent to at least 75% of that seen using a poly-A region of 120 nucleotides alone.

[00313] In some embodiments, the nucleic acid molecule of the present disclosure (*e.g.*, mRNA) may include a poly-A region and may be stabilized by the addition of a 3'-stabilizing region. In some embodiments, the 3'-stabilizing region which may be used to stabilize a nucleic acid molecule (*e.g.*, mRNA) including the poly-A or poly-A-G Quartet structures as described in International Patent Publication No. WO2013/103659, the content of which is incorporated herein by reference in its entirety.

[00314] In other embodiments, the 3'-stabilizing region which may be used in connection with the nucleic acid molecules of the present disclosure include a chain termination nucleoside such as but is not limited to 3'-deoxyadenosine (cordycepin), 3'-deoxyuridine, 3'-

deoxycytosine, 3'-deoxyguanosine, 3'-deoxythymine, 2',3'-dideoxynucleosides, such as 2',3'-dideoxyadenosine, 2',3'-dideoxyuridine, 2',3'-dideoxycytosine, 2',3'-dideoxyguanosine, 2',3'-dideoxythymine, a 2'-deoxynucleoside, or an O-methylnucleoside, 3'-deoxynucleoside, 2',3'-dideoxynucleoside 3'-O-methylnucleosides, 3'-O-ethylnucleosides, 3'-arabinosides, and other alternative nucleosides known in the art and/or described herein.

Secondary Structure

[00315] Without being bound by the theory, it is contemplated that a stem-loop structure can direct RNA folding, protect structural stability of a nucleic acid molecule (*e.g.*, mRNA), provide recognition sites for RNA binding proteins, and serve as a substrate for enzymatic reactions. For example, the incorporation of a miR sequence and/or a TEE sequence changes the shape of the stem loop region which may increase and/or decrease translation (Kedde *et al*. A Pumilio-induced RNA structure switch in p27-3'UTR controls miR-221 and miR-222 accessibility. *Nat Cell Biol.*, 2010 Oct; 12(10):1014-20, the content of which is herein incorporated by reference in its entirety).

[00316] Accordingly, in some embodiments, the nucleic acid molecules as described herein (*e.g.*, mRNA) or a portion thereof may assume a stem-loop structure, such as but is not limited to a histone stem loop. In some embodiments, the stem-loop structure is formed from a stem-loop sequence that is about 25 or about 26 nucleotides in length such as, but not limited to, those as described in International Patent Publication No. WO2013/103659, the content of which is incorporated herein by reference in its entirety. Additional examples of stem-loop sequences include those described in International Patent Publication No. WO2012/019780 and International Patent Publication No. WO201502667, the contents of which are incorporated herein by reference. In some embodiments, the step-loop sequence comprises a TEE as described herein. In some embodiments, the step-loop sequence comprises a miR sequence as described herein. In specific embodiments, the stem loop sequence may include a miR-122 seed sequence. In specific embodiments, the nucleic acid molecule comprises the two stem-loop sequence described in International Patent Publication No. WO2021204175, the entirety of which is incorporated herein by reference.

[00317] In some embodiments, the nucleic acid molecule of the present disclosure (*e.g.*, mRNA) comprises a stem-loop sequence located upstream (to the 5'-end) of the coding region in a nucleic acid molecule. In some embodiments, the stem-loop sequence is located

within the 5'-UTR of the nucleic acid molecule. In some embodiments, the nucleic acid molecule of the present disclosure (*e.g.*, mRNA) comprises a stem-loop sequence located downstream (to the 3'-end) of the coding region in a nucleic acid molecule. In some embodiments, the stem-loop sequence is located within the 3'-UTR of the nucleic acid molecule. In some cases, a nucleic acid molecule can contain more than one stem-loop sequences. In some embodiment, the nucleic acid molecule comprises at least one stem-loop sequence in the 5'-UTR, and at least one stem-loop sequence in the 3'-UTR.

[00318] In some embodiments, a nucleic acid molecule comprising a stem-loop structure further comprises a stabilization region. In some embodiment, the stabilization region comprises at least one chain terminating nucleoside that functions to slow down degradation and thus increases the half-life of the nucleic acid molecule. Exemplary chain terminating nucleoside that can be used in connection with the present disclosure include but are not limited to 3'-deoxyadenosine (cordycepin), 3'-deoxyuridine, 3'-deoxycytosine, 3'-deoxyguanosine, 3'-deoxythymine, 2',3'-dideoxynucleosides, such as 2',3'-dideoxyadenosine, 2',3'-dideoxyuridine, 2',3'-dideoxycytosine, 2',3'-dideoxyguanosine, 2',3'-dideoxythymine, a 2'-deoxynucleoside, or an O-methylnucleoside, 3'-deoxynucleoside, 2',3'-dideoxynucleoside 3'-O-methylnucleosides, 3'-O-ethylnucleosides, 3'-arabinosides, and other alternative nucleosides known in the art and/or described herein. In other embodiments, a stem-loop structure may be stabilized by an alteration to the 3'-region of the polynucleotide that can prevent and/or inhibit the addition of oligio(U) (International Patent Publication No. WO2013/103659, incorporated herein by reference in its entirety).

[00319] In some embodiments, a nucleic acid molecule of the present disclosure comprises at least one stem-loop sequence and a poly-A region or polyadenylation signal. Non-limiting examples of polynucleotide sequences comprising at least one stem-loop sequence and a poly-A region or a polyadenylation signal include those described in International Patent Publication No. WO2013/120497, International Patent Publication No. WO2013/120629, International Patent Publication No. WO2013/120500, International Patent Publication No. WO2013/120627, International Patent Publication No. WO2013/120498, International Patent Publication No. WO2013/120626, International Patent Publication No. WO2013/120499 and International Patent Publication No. WO2013/120628, the content of each of which is incorporated herein by reference in its entirety.

[00320] In some embodiments, the nucleic acid molecule comprising a stem-loop sequence and a poly-A region or a polyadenylation signal can encode for a pathogen antigen

or fragment thereof such as the polynucleotide sequences described in International Patent Publication No. WO2013/120499 and International Patent Publication No. WO2013/120628, the content of each of which is incorporated herein by reference in its entirety.

[00321] In some embodiments, the nucleic acid molecule comprising a stem-loop sequence and a poly-A region or a polyadenylation signal can encode for a therapeutic protein such as the polynucleotide sequences described in International Patent Publication No. WO2013/120497 and International Patent Publication No. WO2013/120629, the content of each of which is incorporated herein by reference in its entirety.

[00322] In some embodiments, the nucleic acid molecule comprising a stem-loop sequence and a poly-A region or a polyadenylation signal can encode for a tumor antigen or fragment thereof such as the polynucleotide sequences described in International Patent Publication No. WO2013/120500 and International Patent Publication No.WO2013/120627, the content of each of which is incorporated herein by reference in its entirety.

[00323] In some embodiments, the nucleic acid molecule comprising a stem-loop sequence and a poly-A region or a polyadenylation signal can code for an allergenic antigen or an autoimmune self-antigen such as the polynucleotide sequences described in International Patent Publication No. WO2013/120498 and International Patent Publication No. WO2013/120626, the content of each of which is incorporated herein by reference in its entirety.

Functional nucleotide analogs

[00324] In some embodiments, a payload nucleic acid molecule described herein contains only canonical nucleotides selected from A (adenosine), G (guanosine), C (cytosine), U (uridine), and T (thymidine). Without being bound by the theory, it is contemplated that certain functional nucleotide analogs can confer useful properties to a nucleic acid molecule. Examples of such as useful properties in the context of the present disclosure include but are not limited to increased stability of the nucleic acid molecule, reduced immunogenicity of the nucleic acid molecule in inducing innate immune responses, enhanced production of protein encoded by the nucleic acid molecule, increased intracellular delivery and/or retention of the nucleic acid molecule, and/or reduced cellular toxicity of the nucleic acid molecule, *etc.*

[00325] Accordingly, in some embodiments, a payload nucleic acid molecule comprises at least one functional nucleotide analog as described herein. In some embodiments, the functional nucleotide analog contains at least one chemical modification to the nucleobase,

the sugar group and/or the phosphate group. Accordingly, a payload nucleic acid molecule comprising at least one functional nucleotide analog contains at least one chemical modification to the nucleobases, the sugar groups, and/or the internucleoside linkage. Exemplary chemical modifications to the nucleobases, sugar groups, or internucleoside linkages of a nucleic acid molecule are provided herein.

[00326] As described herein, ranging from 0% to 100% of all nucleotides in a payload nucleic acid molecule can be functional nucleotide analogs as described herein. For example, in various embodiments, from about 1% to about 20%, from about 1% to about 25%, from about 1% to about 50%, from about 1% to about 60%, from about 1% to about 70%, from about 1% to about 80%, from about 1% to about 90%, from about 1% to about 95%, from about 10% to about 20%, from about 10% to about 25%, from about 10% to about 50%, from about 10% to about 60%, from about 10% to about 70%, from about 10% to about 80%, from about 10% to about 90%, from about 10% to about 95%, from about 10% to about 100%, from about 20% to about 25%, from about 20% to about 50%, from about 20% to about 60%, from about 20% to about 70%, from about 20% to about 80%, from about 20% to about 90%, from about 20% to about 95%, from about 20% to about 100%, from about 50% to about 60%, from about 50% to about 70%, from about 50% to about 80%, from about 50% to about 90%, from about 50% to about 95%, from about 50% to about 100%, from about 70% to about 80%, from about 70% to about 90%, from about 70% to about 95%, from about 70% to about 100%, from about 80% to about 90%, from about 80% to about 95%, from about 80% to about 100%, from about 90% to about 95%, from about 90% to about 100%, or from about 95% to about 100% of all nucleotides in a nucleic acid molecule are functional nucleotide analogs described herein. In any of these embodiments, a functional nucleotide analog can be present at any position(s) of a nucleic acid molecule, including the 5'- terminus, 3'- terminus, and/or one or more internal positions. In some embodiments, a single nucleic acid molecule can contain different sugar modifications, different nucleobase modifications, and/or different types internucleoside linkages (*e.g.*, backbone structures).

[00327] As described herein, ranging from 0% to 100% of all nucleotides of a kind (*e.g.*, all purine-containing nucleotides as a kind, or all pyrimidine-containing nucleotides as a kind, or all A, G, C, T or U as a kind) in a payload nucleic acid molecule can be functional nucleotide analogs as described herein. For example, in various embodiments, from about 1% to about 20%, from about 1% to about 25%, from about 1% to about 50%, from about 1% to about 60%, from about 1% to about 70%, from about 1% to about 80%, from about 1% to

about 90%, from about 1% to about 95%, from about 10% to about 20%, from about 10% to about 25%, from about 10% to about 50%, from about 10% to about 60%, from about 10% to about 70%, from about 10% to about 80%, from about 10% to about 90%, from about 10% to about 95%, from about 10% to about 100%, from about 20% to about 25%, from about 20% to about 50%, from about 20% to about 60%, from about 20% to about 70%, from about 20% to about 80%, from about 20% to about 90%, from about 20% to about 95%, from about 20% to about 100%, from about 50% to about 60%, from about 50% to about 70%, from about 50% to about 80%, from about 50% to about 90%, from about 50% to about 95%, from about 50% to about 100%, from about 70% to about 80%, from about 70% to about 90%, from about 70% to about 95%, from about 70% to about 100%, from about 80% to about 90%, from about 80% to about 95%, from about 80% to about 100%, from about 90% to about 95%, from about 90% to about 100%, or from about 95% to about 100% of a kind of nucleotides in a nucleic acid molecule are functional nucleotide analogs described herein. In any of these embodiments, a functional nucleotide analog can be present at any position(s) of a nucleic acid molecule, including the 5'- terminus, 3'- terminus, and/or one or more internal positions. In some embodiments, a single nucleic acid molecule can contain different sugar modifications, different nucleobase modifications, and/or different types internucleoside linkages (*e.g.*, backbone structures).

Modification to Nucleobases

[00328] In some embodiments, a functional nucleotide analog contains a non-canonical nucleobase. In some embodiments, canonical nucleobases (*e.g.*, adenine, guanine, uracil, thymine, and cytosine) in a nucleotide can be modified or replaced to provide one or more functional analogs of the nucleotide. Exemplary modification to nucleobases include but are not limited to one or more substitutions or modifications including but not limited to alkyl, aryl, halo, oxo, hydroxyl, alkyloxy, and/or thio substitutions; one or more fused or open rings, oxidation, and/or reduction.

[00329] In some embodiments, the non-canonical nucleobase is a modified uracil. Exemplary nucleobases and nucleosides having an modified uracil include pseudouridine (ψ), pyridin-4-one ribonucleoside, 5-aza-uracil, 6-aza-uracil, 2-thio-5-aza-uracil, 2-thio-uracil (s^2U), 4-thio-uracil (s^4U), 4-thio-pseudouridine, 2-thio-pseudouridine, 5-hydroxy-uracil (ho^5U), 5-aminoallyl-uracil, 5-halo-uracil (e.g., 5-iodo-uracil or 5-bromo-uracil), 3-methyl-uracil (m^3U), 5-methoxy-uracil (mo^5U), uracil 5-oxyacetic acid (cmo^5U), uracil 5-oxyacetic acid methyl ester ($mcmo^5U$), 5-carboxymethyl-uracil (cm^5U), 1-carboxymethyl-

pseudouridine, 5-carboxyhydroxymethyl-uracil (chm^5U), 5-carboxyhydroxymethyl-uracil methyl ester ($mchm^5U$), 5-methoxycarbonylmethyl-uracil (mcm^5U), 5-methoxycarbonylmethyl-2-thio-uracil (mcm^5s^2U), 5-aminomethyl-2-thio-uracil (nm^5s^2U), 5-methylaminomethyl-uracil (mnm^5U), 5-methylaminomethyl-2-thio-uracil (mnm^5s^2U), 5-methylaminomethyl-2-seleno-uracil (mnm^5se^2U), 5-carbamoylmethyl-uracil (ncm^5U), 5-carboxymethylaminomethyl-uracil ($cmnm^5U$), 5-carboxymethylaminomethyl-2-thio-uracil ($cmnm^5s^2U$), 5-propynyl-uracil, 1-propynyl-pseudouracil, 5-taurinomethyl-uracil (τm^5U), 1-taurinomethyl-pseudouridine, 5-taurinomethyl-2-thio-uracil($\tau m^5 5s^2U$), 1-taurinomethyl-4-thio-pseudouridine, 5-methyl-uracil (m^5U, i.e., having the nucleobase deoxythymine), 1-methyl-pseudouridine ($m^1\psi$), 1-ethyl-pseudouridine ($Et^1\psi$), 5-methyl-2-thio-uracil (m^5s^2U), 1-methyl-4-thio-pseudouridine ($m^1s^4\psi$), 4-thio-1-methyl-pseudouridine, 3-methyl-pseudouridine ($m^3\psi$), 2-thio-1-methyl-pseudouridine, 1-methyl-1-deaza-pseudouridine, 2-thio-1-methyl-1-deaza-pseudouridine, dihydrouracil (D), dihydropseudouridine, 5,6-dihydrouracil, 5-methyl-dihydrouracil (m^5D), 2-thio-dihydrouracil, 2-thio-dihydropseudouridine, 2-methoxy-uracil, 2-methoxy-4-thio-uracil, 4-methoxy-pseudouridine, 4-methoxy-2-thio-pseudouridine, N1-methyl-pseudouridine, 3-(3-amino-3-carboxypropyl)uracil (acp^3U), 1-methyl-3-(3-amino-3-carboxypropyl)pseudouridine ($acp^3\psi$), 5-(isopentenylaminomethyl)uracil (m^5U), 5-(isopentenylaminomethyl)-2-thio-uracil (m^5s^2U), 5,2'-O-dimethyl-uridine (m^5Um), 2-thio-2'-O-methyl-uridine (s^2Um), 5-methoxycarbonylmethyl-2'-O-methyl-uridine (mcm^5Um), 5-carbamoylmethyl-2'-O-methyl-uridine (ncm^5Um), 5-carboxymethylaminomethyl-2'-O-methyl-uridine ($cmnm^5Um$), 3,2'-O-dimethyl-uridine (m^3Um), and 5-(isopentenylaminomethyl)-2'-O-methyl-uridine (inm^5Um), 1-thio-uracil, deoxythymidine, 5-(2-carbomethoxyvinyl)-uracil, 5-(carbamoylhydroxymethyl)-uracil, 5-carbamoylmethyl-2-thio-uracil, 5-carboxymethyl-2-thio-uracil, 5-cyanomethyl-uracil, 5-methoxy-2-thio-uracil, and 5-[3-(1-E-propenylamino)]uracil.

[00330] In some embodiments, the non-canonical nucleobase is a modified cytosine. Exemplary nucleobases and nucleosides having a modified cytosine include 5-aza-cytosine, 6-aza-cytosine, pseudoisocytidine, 3-methyl-cytosine (m3C), N4-acetyl-cytosine (ac4C), 5-formyl-cytosine (f5C), N4-methyl-cytosine (m4C), 5-methyl-cytosine (m5C), 5-halo-cytosine (*e.g.*, 5-iodo-cytosine), 5-hydroxymethyl-cytosine (hm5C), 1-methyl-pseudoisocytidine, pyrrolo-cytosine, pyrrolo-pseudoisocytidine, 2-thio-cytosine (s2C), 2-thio-5-methyl-cytosine, 4-thio-pseudoisocytidine, 4-thio-1-methyl-pseudoisocytidine, 4-thio-1-methyl-1-deaza-

pseudoisocytidine, 1-methyl-1-deaza-pseudoisocytidine, zebularine, 5-aza-zebularine, 5-methyl-zebularine, 5-aza-2-thio-zebularine, 2-thio-zebularine, 2-methoxy-cytosine, 2-methoxy-5-methyl-cytosine, 4-methoxy-pseudoisocytidine, 4-methoxy-1-methyl-pseudoisocytidine, lysidine (k2C), 5,2'-O-dimethyl-cytidine (m5Cm), N4-acetyl-2'-O-methyl-cytidine (ac4Cm), N4,2'-O-dimethyl-cytidine (m4Cm), 5-formyl-2'-O-methyl-cytidine (fSCm), N4,N4,2'-O-trimethyl-cytidine (m42Cm), 1-thio-cytosine, 5-hydroxy-cytosine, 5-(3-azidopropyl)-cytosine, and 5-(2-azidoethyl)-cytosine.

[00331] In some embodiments, the non-canonical nucleobase is a modified adenine. Exemplary nucleobases and nucleosides having an alternative adenine include 2-amino-purine, 2,6-diaminopurine, 2-amino-6-halo-purine (e.g., 2-amino-6-chloro-purine), 6-halo-purine (e.g., 6-chloro-purine), 2-amino-6-methyl-purine, 8-azido-adenine, 7-deaza-adenine, 7-deaza-8-aza-adenine, 7-deaza-2-amino-purine, 7-deaza-8-aza-2-amino-purine, 7-deaza-2,6-diaminopurine, 7-deaza-8-aza-2,6-diaminopurine, 1-methyl-adenine (m1A), 2-methyl-adenine (m2A), N6-methyl-adenine (m6A), 2-methylthio-N6-methyl-adenine (ms2m6A), N6-isopentenyl-adenine (i6A), 2-methylthio-N6-isopentenyl-adenine (ms2i6A), N6-(cis-hydroxyisopentenyl)adenine (io6A), 2-methylthio-N6-(cis-hydroxyisopentenyl)adenine (ms2io6A), N6-glycinylcarbamoyl-adenine (g6A), N6-threonylcarbamoyl-adenine (t6A), N6-methyl-N6-threonylcarbamoyl-adenine (m6t6A), 2-methylthio-N6-threonylcarbamoyl-adenine (ms2g6A), N6,N6-dimethyl-adenine (m62A), N6-hydroxynorvalylcarbamoyl-adenine (hn6A), 2-methylthio-N6-hydroxynorvalylcarbamoyl-adenine (ms2hn6A), N6-acetyl-adenine (ac6A), 7-methyl-adenine, 2-methylthio-adenine, 2-methoxy-adenine, N6,2'-O-dimethyl-adenosine (m6Am), N6,N6,2'-O-trimethyl-adenosine (m62Am), 1,2'-O-dimethyl-adenosine (m1Am), 2-amino-N6-methyl-purine, 1-thio-adenine, 8-azido-adenine, N6-(19-amino-pentaoxanonadecyl)-adenine, 2,8-dimethyl-adenine, N6-formyl-adenine, and N6-hydroxymethyl-adenine.

[00332] In some embodiments, the non-canonical nucleobase is a modified guanine. Exemplary nucleobases and nucleosides having a modified guanine include inosine (I), 1-methyl-inosine (m1I), wyosine (imG), methylwyosine (mimG), 4-demethyl-wyosine (imG-14), isowyosine (imG2), wybutosine (yW), peroxywybutosine (o2yW), hydroxywybutosine (OHyW), undermodified hydroxywybutosine (OHyW*), 7-deaza-guanine, queuosine (Q), epoxyqueuosine (oQ), galactosyl-queuosine (galQ), mannosyl-queuosine (manQ), 7-cyano-7-deaza-guanine (preQO), 7-aminomethyl-7-deaza-guanine (preQ1), archaeosine (G+), 7-deaza-8-aza-guanine, 6-thio-guanine, 6-thio-7-deaza-guanine, 6-thio-7-deaza-8-aza-guanine,

7-methyl-guanine (m7G), 6-thio-7-methyl-guanine, 7-methyl-inosine, 6-methoxy-guanine, 1-methyl-guanine (m1G), N2-methyl-guanine (m2G), N2,N2-dimethyl-guanine (m22G), N2,7-dimethyl-guanine (m2,7G), N2, N2,7-dimethyl-guanine (m2,2,7G), 8-oxo-guanine, 7-methyl-8-oxo-guanine, 1-methyl-6-thio-guanine, N2-methyl-6-thio-guanine, N2,N2-dimethyl-6-thio-guanine, N2-methyl-2'-O-methyl-guanosine (m2Gm), N2,N2-dimethyl-2'-O-methyl-guanosine (m22Gm), 1-methyl-2'-O-methyl-guanosine (m1Gm), N2,7-dimethyl-2'-O-methyl-guanosine (m2,7Gm), 2'-O-methyl-inosine (Im), 1,2'-O-dimethyl-inosine (m1Im), 1-thio-guanine, and O-6-methyl-guanine.

[00333] In some embodiments, the non-canonical nucleobase of a functional nucleotide analog can be independently a purine, a pyrimidine, a purine or pyrimidine analog. For example, in some embodiments, the non-canonical nucleobase can be modified adenine, cytosine, guanine, uracil, or hypoxanthine. In other embodiments, the non-canonical nucleobase can also include, for example, naturally-occurring and synthetic derivatives of a base, including pyrazolo[3,4-d]pyrimidines, 5-methylcytosine (5-me-C), 5-hydroxymethyl cytosine, xanthine, hypoxanthine, 2-aminoadenine, 6-methyl and other alkyl derivatives of adenine and guanine, 2-propyl and other alkyl derivatives of adenine and guanine, 2-thiouracil, 2-thiothymine and 2-thiocytosine, 5-propynyl uracil and cytosine, 6-azo uracil, cytosine and thymine, 5-uracil (pseudouracil), 4-thiouracil, 8-halo (e.g., 8-bromo), 8-amino, 8-thiol, 8-thioalkyl, 8-hydroxy 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, deazaguanine, 7-deazaguanine, 3-deazaguanine, deazaadenine, 7-deazaadenine, 3-deazaadenine, pyrazolo[3,4-d]pyrimidine, imidazo[1,5-a]1,3,5 triazinones, 9-deazapurines, imidazo[4,5-d]pyrazines, thiazolo[4,5-d]pyrimidines, pyrazin-2-ones, 1,2,4-triazine, pyridazine; or 1,3,5 triazine.

Modification to the Sugar

[00334] In some embodiments, a functional nucleotide analog contains a non-canonical sugar group. In various embodiments, the non-canonical sugar group can be a 5-carbon or 6-carbon sugar (such as pentose, ribose, arabinose, xylose, glucose, galactose, or a deoxy derivative thereof) with one or more substitutions, such as a halo group, a hydroxy group, a thiol group, an alkyl group, an alkoxy group, an alkenyloxy group, an alkynyloxy group, an cycloalkyl group, an aminoalkoxy group, an alkoxyalkoxy group, an hydroxyalkoxy group, an amino group, an azido group, an aryl group, an aminoalkyl group, an aminoalkenyl group, an aminoalkynyl group, etc.

[00335] Generally, RNA molecules contains the ribose sugar group, which is a 5-membered ring having an oxygen. Exemplary, non-limiting alternative nucleotides include replacement of the oxygen in ribose (*e.g.*, with S, Se, or alkylene, such as methylene or ethylene); addition of a double bond (e.g., to replace ribose with cyclopentenyl or cyclohexenyl); ring contraction of ribose (e.g., to form a 4-membered ring of cyclobutane or oxetane); ring expansion of ribose (*e.g.*, to form a 6- or 7-membered ring having an additional carbon or heteroatom, such as for anhydrohexitol, altritol, mannitol, cyclohexanyl, cyclohexenyl, and morpholino (that also has a phosphoramidate backbone)); multicyclic forms (*e.g.*, tricyclo and "unlocked" forms, such as glycol nucleic acid (GNA) (*e.g.*, R-GNA or S-GNA, where ribose is replaced by glycol units attached to phosphodiester bonds), threose nucleic acid (TNA, where ribose is replace with α-L-threofuranosyl-(3'→2')), and peptide nucleic acid (PNA, where 2-amino-ethyl-glycine linkages replace the ribose and phosphodiester backbone).

[00336] In some embodiments, the sugar group contains one or more carbons that possess the opposite stereochemical configuration of the corresponding carbon in ribose. Thus, a nucleic acid molecule can include nucleotides containing, *e.g.*, arabinose or L-ribose, as the sugar. In some embodiments, the nucleic acid molecule includes at least one nucleoside wherein the sugar is L-ribose, 2'-O-methyl-ribose, 2'-fluoro-ribose, arabinose, hexitol, an LNA, or a PNA.

Modifications to the Internucleoside Linkage

[00337] In some embodiments, the payload nucleic acid molecule of the present disclosure can contain one or more modified internucleoside linkage (*e.g.*, phosphate backbone). Backbone phosphate groups can be altered by replacing one or more of the oxygen atoms with a different substituent.

[00338] In some embodiments, the functional nucleotide analogs can include the replacement of an unaltered phosphate moiety with another internucleoside linkage as described herein. Examples of alternative phosphate groups include, but are not limited to, phosphorothioate, phosphoroselenates, boranophosphates, boranophosphate esters, hydrogen phosphonates, phosphoramidates, phosphorodiamidates, alkyl or aryl phosphonates, and phosphotriesters. Phosphorodithioates have both non-linking oxygens replaced by sulfur. The phosphate linker can also be altered by the replacement of a linking oxygen with nitrogen

(bridged phosphoramidates), sulfur (bridged phosphorothioates), and carbon (bridged methylene-phosphonates).

[00339] The alternative nucleosides and nucleotides can include the replacement of one or more of the non-bridging oxygens with a borane moiety (BH_3), sulfur (thio), methyl, ethyl, and/or methoxy. As a non-limiting example, two non-bridging oxygens at the same position (*e.g.,* the alpha (α), beta (β) or gamma (γ) position) can be replaced with a sulfur (thio) and a methoxy. The replacement of one or more of the oxygen atoms at the position of the phosphate moiety (*e.g.*, α-thio phosphate) is provided to confer stability (such as against exonucleases and endonucleases) to RNA and DNA through the unnatural phosphorothioate backbone linkages. Phosphorothioate DNA and RNA have increased nuclease resistance and subsequently a longer half-life in a cellular environment.

[00340] Other internucleoside linkages that may be employed according to the present disclosure, including internucleoside linkages which do not contain a phosphorous atom, are described herein.

[00341] Additional examples of nucleic acid molecules (*e.g.*, mRNA), compositions, formulations and/or methods associated therewith that can be used in connection with the present disclosure further include those described in WO2002/098443, WO2003/051401, WO2008/052770, WO2009127230, WO2006122828, WO2008/083949, WO2010088927, WO2010/037539, WO2004/004743, WO2005/016376, WO2006/024518, WO2007/095976, WO2008/014979, WO2008/077592, WO2009/030481, WO2009/095226, WO2011069586, WO2011026641, WO2011/144358, WO2012019780, WO2012013326, WO2012089338, WO2012113513, WO2012116811, WO2012116810, WO2013113502, WO2013113501, WO2013113736, WO2013143698, WO2013143699, WO2013143700, WO2013/120626, WO2013120627, WO2013120628, WO2013120629, WO2013174409, WO2014127917, WO2015/024669, WO2015/024668, WO2015/024667, WO2015/024665, WO2015/024666, WO2015/024664, WO2015101415, WO2015101414, WO2015024667, WO2015062738, WO2015101416, the content of each of which is incorporated herein in its entirety.

5.5 *Formulation*

[00342] According to the present disclosure, nanoparticle compositions described herein can include at least one lipid component and one or more additional components, such as a therapeutic and/or prophylactic agent. A nanoparticle composition may be designed for one or more specific applications or targets. The elements of a nanoparticle composition may be

selected based on a particular application or target, and/or based on the efficacy, toxicity, expense, ease of use, availability, or other feature of one or more elements. Similarly, the particular formulation of a nanoparticle composition may be selected for a particular application or target according to, for example, the efficacy and toxicity of particular combinations of elements.

[00343] The lipid component of a nanoparticle composition may include, for example, a lipid according to one of formulae (I) or (II) (and sub-formulas thereof) described herein, a phospholipid (such as an unsaturated lipid, e.g., DOPE or DSPC), a PEG lipid, and a structural lipid. The elements of the lipid component may be provided in specific fractions.

[00344] In one embodiment, provided herein is a nanoparticle compositions comprising a cationic or ionizable lipid compound provided herein, a therapeutic agent, and one or more excipients. In one embodiment, cationic or ionizable lipid compound comprises a compound according to one of Formulae (I) or (II) (and sub-formulas thereof) as described herein, and optionally one or more additional ionizable lipid compounds. In one embodiment, the one or more excipients are selected from neutral lipids, steroids, and polymer conjugated lipids. In one embodiment, the therapeutic agent is encapsulated within or associated with the lipid nanoparticle.

[00345] In one embodiment, provided herein is a nanoparticle composition (lipid nanoparticle) comprising:

i) between 40 and 50 mol percent of a cationic lipid;

ii) a neutral lipid;

iii) a steroid;

iv) a polymer conjugated lipid; and

v) a therapeutic agent.

[00346] As used herein, "mol percent" refers to a component's molar percentage relative to total mols of all lipid components in the LNP (i.e., total mols of cationic lipid(s), the neutral lipid, the steroid and the polymer conjugated lipid).

[00347] In one embodiment, the lipid nanoparticle comprises from 41 to 49 mol percent, from 41 to 48 mol percent, from 42 to 48 mol percent, from 43 to 48 mol percent, from 44 to 48 mol percent, from 45 to 48 mol percent, from 46 to 48 mol percent, or from 47.2 to 47.8 mol percent of the cationic lipid. In one embodiment, the lipid nanoparticle comprises about

47.0, 47.1, 47.2, 47.3, 47.4, 47.5, 47.6, 47.7, 47.8, 47.9 or 48.0 mol percent of the cationic lipid.

[00348] In one embodiment, the neutral lipid is present in a concentration ranging from 5 to 15 mol percent, 7 to 13 mol percent, or 9 to 11 mol percent. In one embodiment, the neutral lipid is present in a concentration of about 9.5, 10 or 10.5 mol percent. In one embodiment, the molar ratio of the cationic lipid to the neutral lipid ranges from about 4.1:1.0 to about 4.9:1.0, from about 4.5:1.0 to about 4.8:1.0, or from about 4.7:1.0 to 4.8:1.0.

[00349] In one embodiment, the steroid is present in a concentration ranging from 39 to 49 molar percent, 40 to 46 molar percent, from 40 to 44 molar percent, from 40 to 42 molar percent, from 42 to 44 molar percent, or from 44 to 46 molar percent. In one embodiment, the steroid is present in a concentration of 40, 41, 42, 43, 44, 45, or 46 molar percent. In one embodiment, the molar ratio of cationic lipid to the steroid ranges from 1.0:0.9 to 1.0:1.2, or from 1.0:1.0 to 1.0:1.2. In one embodiment, the steroid is cholesterol.

[00350] In one embodiment, the therapeutic agent to lipid ratio in the LNP (i.e., N/P, were N represents the moles of cationic lipid and P represents the moles of phosphate present as part of the nucleic acid backbone) range from 2:1 to 30:1, for example 3:1 to 22:1. In one embodiment, N/P ranges from 6:1 to 20:1 or 2:1 to 12:1. Exemplary N/P ranges include about 3:1. About 6:1, about 12:1 and about 22:1.

[00351] In one embodiment, provided herein is a lipid nanoparticle comprising:

i) a cationic lipid having an effective pKa greater than 6.0; ii) from 5 to 15 mol percent of a neutral lipid;

iii) from 1 to 15 mol percent of an anionic lipid;

iv) from 30 to 45 mol percent of a steroid;

v) a polymer conjugated lipid; and

vi) a therapeutic agent, or a pharmaceutically acceptable salt or prodrug thereof, wherein the mol percent is determined based on total mol of lipid present in the lipid nanoparticle.

[00352] In one embodiment, the cationic lipid can be any of a number of lipid species which carry a net positive charge at a selected pH, such as physiological pH. Exemplary cationic lipids are described herein below. In one embodiment, the cationic lipid has a pKa greater than 6.25. In one embodiment, the cationic lipid has a pKa greater than 6.5. In one embodiment, the cationic lipid has a pKa greater than 6.1, greater than 6.2, greater than 6.3,

greater than 6.35, greater than 6.4, greater than 6.45, greater than 6.55, greater than 6.6, greater than 6.65, or greater than 6.7.

[00353] In one embodiment, the lipid nanoparticle comprises from 40 to 45 mol percent of the cationic lipid. In one embodiment, the lipid nanoparticle comprises from 45 to 50 mole percent of the cationic lipid.

[00354] In one embodiment, the molar ratio of the cationic lipid to the neutral lipid ranges from about 2:1 to about 8:1. In one embodiment, the lipid nanoparticle comprises from 5 to 10 mol percent of the neutral lipid.

[00355] Exemplary anionic lipids include, but are not limited to, phosphatidylglycerol, dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG) or 1,2-distearoyl-sn-glycero-3-phospho-(1'-rac-glycerol) (DSPG).

[00356] In one embodiment, the lipid nanoparticle comprises from 1 to 10 mole percent of the anionic lipid. In one embodiment, the lipid nanoparticle comprises from 1 to 5 mole percent of the anionic lipid. In one embodiment, the lipid nanoparticle comprises from 1 to 9 mole percent, from 1 to 8 mole percent, from 1 to 7 mole percent, or from 1 to 6 mole percent of the anionic lipid. In one embodiment, the mol ratio of anionic lipid to neutral lipid ranges from 1:1 to 1:10.

[00357] In one embodiment, the steroid cholesterol. In one embodiment, the molar ratio of the cationic lipid to cholesterol ranges from about 5:1 to 1:1. In one embodiment, the lipid nanoparticle comprises from 32 to 40 mol percent of the steroid.

[00358] In one embodiment, the sum of the mol percent of neutral lipid and mol percent of anionic lipid ranges from 5 to 15 mol percent. In one embodiment, wherein the sum of the mol percent of neutral lipid and mol percent of anionic lipid ranges from 7 to 12 mol percent.

[00359] In one embodiment, the mol ratio of anionic lipid to neutral lipid ranges from 1:1 to 1:10. In one embodiment, the sum of the mol percent of neutral lipid and mol percent steroid ranges from 35 to 45 mol percent.

[00360] In one embodiment, the lipid nanoparticle comprises:

i) from 45 to 55 mol percent of the cationic lipid;

ii) from 5 to 10 mol percent of the neutral lipid;

iii) from 1 to 5 mol percent of the anionic lipid; and

iv) from 32 to 40 mol percent of the steroid.

[00361] In one embodiment, the lipid nanoparticle comprises from 1.0 to 2.5 mol percent of the conjugated lipid. In one embodiment, the polymer conjugated lipid is present in a concentration of about 1.5 mol percent.

[00362] In one embodiment, the neutral lipid is present in a concentration ranging from 5 to 15 mol percent, 7 to 13 mol percent, or 9 to 11 mol percent. In one embodiment, the neutral lipid is present in a concentration of about 9.5, 10 or 10.5 mol percent. In one embodiment, the molar ratio of the cationic lipid to the neutral lipid ranges from about 4.1:1.0 to about 4.9:1.0, from about 4.5:1.0 to about 4.8:1.0, or from about 4.7:1.0 to 4.8:1.0.

[00363] In one embodiment, the steroid is cholesterol. In some embodiments, the steroid is present in a concentration ranging from 39 to 49 molar percent, 40 to 46 molar percent, from 40 to 44 molar percent, from 40 to 42 molar percent, from 42 to 44 molar percent, or from 44 to 46 molar percent. In one embodiment, the steroid is present in a concentration of 40, 41, 42, 43, 44, 45, or 46 molar percent. In certain embodiments, the molar ratio of cationic lipid to the steroid ranges from 1.0:0.9 to 1.0:1.2, or from 1.0:1.0 to 1.0:1.2.

[00364] In one embodiment, the molar ratio of cationic lipid to steroid ranges from 5:1 to 1:1.

[00365] In one embodiment, the lipid nanoparticle comprises from 1.0 to 2.5 mol percent of the conjugated lipid. In one embodiment, the polymer conjugated lipid is present in a concentration of about 1.5 mol percent.

[00366] In one embodiment, the molar ratio of cationic lipid to polymer conjugated lipid ranges from about 100:1 to about 20:1. In one embodiment, the molar ratio of cationic lipid to the polymer conjugated lipid ranges from about 35:1 to about 25:1.

[00367] In one embodiment, the lipid nanoparticle has a mean diameter ranging from 50 nm to 100 nm, or from 60 nm to 85 nm.

[00368] In one embodiment, the composition comprises a cationic lipid provided herein, DSPC, cholesterol, and PEG-lipid, and mRNA. In one embodiment, the a cationic lipid provided herein, DSPC, cholesterol, and PEG-lipid are at a molar ratio of about 50:10:38.5:1.5.

[00369] Nanoparticle compositions can be designed for one or more specific applications or targets. For example, a nanoparticle composition can be designed to deliver a therapeutic and/or prophylactic agent such as an RNA to a particular cell, tissue, organ, or system or

group thereof in a mammal's body. Physiochemical properties of nanoparticle compositions can be altered in order to increase selectivity for particular bodily targets. For instance, particle sizes can be adjusted based on the fenestration sizes of different organs. The therapeutic and/or prophylactic agent included in a nanoparticle composition can also be selected based on the desired delivery target or targets. For example, a therapeutic and/or prophylactic agent can be selected for a particular indication, condition, disease, or disorder and/or for delivery to a particular cell, tissue, organ, or system or group thereof (e.g., localized or specific delivery). In certain embodiments, a nanoparticle composition can include an mRNA encoding a polypeptide of interest capable of being translated within a cell to produce the polypeptide of interest. Such a composition can be designed to be specifically delivered to a particular organ. In certain embodiments, a composition can be designed to be specifically delivered to a mammalian liver.

[00370] The amount of a therapeutic and/or prophylactic agent in a nanoparticle composition can depend on the size, composition, desired target and/or application, or other properties of the nanoparticle composition as well as on the properties of the therapeutic and/or prophylactic agent. For example, the amount of an RNA useful in a nanoparticle composition can depend on the size, sequence, and other characteristics of the RNA. The relative amounts of a therapeutic and/or prophylactic agent and other elements (*e.g.*, lipids) in a nanoparticle composition can also vary. In some embodiments, the wt/wt ratio of the lipid component to a therapeutic and/or prophylactic agent in a nanoparticle composition can be from about 5:1 to about 60:1, such as 5:1, 6:1, 7:1, 8:1, 9:1, 10:1, 11:1, 12:1, 13:1, 14:1, 15:1, 16:1, 17:1, 18:1, 19:1, 20:1, 25:1, 30:1, 35:1, 40:1, 45:1, 50:1, and 60:1. For example, the wt/wt ratio of the lipid component to a therapeutic and/or prophylactic agent can be from about 10:1 to about 40:1. In certain embodiments, the wt/wt ratio is about 20:1. The amount of a therapeutic and/or prophylactic agent in a nanoparticle composition can, for example, be measured using absorption spectroscopy (e.g., ultraviolet-visible spectroscopy).

[00371] In some embodiments, a nanoparticle composition includes one or more RNAs, and the one or more RNAs, lipids, and amounts thereof can be selected to provide a specific N:P ratio. The N:P ratio of the composition refers to the molar ratio of nitrogen atoms in one or more lipids to the number of phosphate groups in an RNA. In some embodiments, a lower N:P ratio is selected. The one or more RNA, lipids, and amounts thereof can be selected to provide an N:P ratio from about 2:1 to about 30:1, such as 2:1, 3:1, 4:1, 5:1, 6:1, 7:1, 8:1, 9:1, 10:1, 12:1, 14:1, 16:1, 18:1, 20:1, 22:1, 24:1, 26:1, 28:1, or 30:1. In certain embodiments, the

N:P ratio can be from about 2:1 to about 8:1. In other embodiments, the N:P ratio is from about 5:1 to about 8:1. For example, the N:P ratio may be about 5.0:1, about 5.5:1, about 5.67:1, about 6.0:1, about 6.5:1, or about 7.0:1. For example, the N:P ratio may be about 5.67:1.

[00372] The physical properties of a nanoparticle composition can depend on the components thereof. For example, a nanoparticle composition including cholesterol as a structural lipid can have different characteristics compared to a nanoparticle composition that includes a different structural lipid. Similarly, the characteristics of a nanoparticle composition can depend on the absolute or relative amounts of its components. For instance, a nanoparticle composition including a higher molar fraction of a phospholipid may have different characteristics than a nanoparticle composition including a lower molar fraction of a phospholipid. Characteristics may also vary depending on the method and conditions of preparation of the nanoparticle composition.

[00373] Nanoparticle compositions may be characterized by a variety of methods. For example, microscopy (e.g., transmission electron microscopy or scanning electron microscopy) may be used to examine the morphology and size distribution of a nanoparticle composition. Dynamic light scattering or potentiometry (e.g., potentiometric titrations) may be used to measure zeta potentials. Dynamic light scattering may also be utilized to determine particle sizes. Instruments such as the Zetasizer Nano ZS (Malvem Instruments Ltd, Malvem, Worcestershire, UK) may also be used to measure multiple characteristics of a nanoparticle composition, such as particle size, polydispersity index, and zeta potential.

[00374] In various embodiments, the mean size of a nanoparticle composition can be between 10s of nm and 100s of nm. For example, the mean size can be from about 40 nm to about 150 nm, such as about 40 nm, 45 nm, 50 nm, 55 nm, 60 nm, 65 nm, 70 nm, 75 nm, 80 nm, 85 nm, 90 nm, 95 nm, 100 nm, 105 nm, 110 nm, 115 nm, 120 nm, 125 nm, 130 nm, 135 nm, 140 nm, 145 nm, or 150 nm. In some embodiments, the mean size of a nanoparticle composition can be from about 50 nm to about 100 nm, from about 50 nm to about 90 nm, from about 50 nm to about 80 nm, from about 50 nm to about 70 nm, from about 50 nm to about 60 nm, from about 60 nm to about 100 nm, from about 60 nm to about 90 nm, from about 60 nm to about 80 nm, from about 60 nm to about 70 nm, from about 70 nm to about 100 nm, from about 70 nm to about 90 nm, from about 70 nm to about 80 nm, from about 80 nm to about 100 nm, from about 80 nm to about 90 nm, or from about 90 nm to about 100 nm. In certain embodiments, the mean size of a nanoparticle composition can be from about

70 nm to about 100 nm. In some embodiments, the mean size can be about 80 nm. In other embodiments, the mean size can be about 100 nm.

[00375] A nanoparticle composition can be relatively homogenous. A polydispersity index can be used to indicate the homogeneity of a nanoparticle composition, *e.g.*, the particle size distribution of the nanoparticle compositions. A small (*e.g.*, less than 0.3) polydispersity index generally indicates a narrow particle size distribution. A nanoparticle composition can have a polydispersity index from about 0 to about 0.25, such as 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, 0.19, 0.20, 0.21, 0.22, 0.23, 0.24, or 0.25. In some embodiments, the polydispersity index of a nanoparticle composition can be from about 0.10 to about 0.20.

[00376] The zeta potential of a nanoparticle composition can be used to indicate the electrokinetic potential of the composition. For example, the zeta potential can describe the surface charge of a nanoparticle composition. Nanoparticle compositions with relatively low charges, positive or negative, are generally desirable, as more highly charged species can interact undesirably with cells, tissues, and other elements in the body. In some embodiments, the zeta potential of a nanoparticle composition can be from about -10 mV to about +20 mV, from about -10 mV to about +15 mV, from about -10 mV to about +10 mV, from about -10 mV to about +5 mV, from about -10 mV to about 0 mV, from about -10 mV to about -5 mV, from about -5 mV to about +20 mV, from about -5 mV to about +15 mV, from about -5 mV to about +10 mV, from about -5 mV to about +5 mV, from about -5 mV to about 0 mV, from about 0 mV to about +20 mV, from about 0 mV to about +15 mV, from about 0 mV to about +10 mV, from about 0 mV to about +5 mV, from about +5 mV to about +20 mV, from about +5 mV to about +15 mV, or from about +5 mV to about +10 mV.

[00377] The efficiency of encapsulation of a therapeutic and/or prophylactic agent describes the amount of therapeutic and/or prophylactic agent that is encapsulated or otherwise associated with a nanoparticle composition after preparation, relative to the initial amount provided. The encapsulation efficiency is desirably high (*e.g.*, close to 100%). The encapsulation efficiency can be measured, for example, by comparing the amount of therapeutic and/or prophylactic agent in a solution containing the nanoparticle composition before and after breaking up the nanoparticle composition with one or more organic solvents or detergents. Fluorescence can be used to measure the amount of free therapeutic and/or prophylactic agent (*e.g.,* RNA) in a solution. For the nanoparticle compositions described herein, the encapsulation efficiency of a therapeutic and/or prophylactic agent can be at least

50%, for example 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100%. In some embodiments, the encapsulation efficiency can be at least 80%. In certain embodiments, the encapsulation efficiency can be at least 90%.

[00378] A nanoparticle composition can optionally comprise one or more coatings. For example, a nanoparticle composition can be formulated in a capsule, film, or tablet having a coating. A capsule, film, or tablet including a composition described herein can have any useful size, tensile strength, hardness, or density.

5.6 *Pharmaceutical Compositions*

[00379] According to the present disclosure, nanoparticle compositions can be formulated in whole or in part as pharmaceutical compositions. Pharmaceutical compositions can include one or more nanoparticle compositions. For example, a pharmaceutical composition can include one or more nanoparticle compositions including one or more different therapeutic and/or prophylactic agents. Pharmaceutical compositions can further include one or more pharmaceutically acceptable excipients or accessory ingredients such as those described herein. General guidelines for the formulation and manufacture of pharmaceutical compositions and agents are available, for example, in Remington's The Science and Practice of Pharmacy, 21st Edition, A. R. Gennaro; Lippincott, Williams & Wilkins, Baltimore, Md., 2006. Conventional excipients and accessory ingredients can be used in any pharmaceutical composition, except insofar as any conventional excipient or accessory ingredient can be incompatible with one or more components of a nanoparticle composition. An excipient or accessory ingredient can be incompatible with a component of a nanoparticle composition if its combination with the component can result in any undesirable biological effect or otherwise deleterious effect.

[00380] In some embodiments, one or more excipients or accessory ingredients can make up greater than 50% of the total mass or volume of a pharmaceutical composition including a nanoparticle composition. For example, the one or more excipients or accessory ingredients can make up 50%, 60%, 70%, 80%, 90%, or more of a pharmaceutical composition. In some embodiments, a pharmaceutically acceptable excipient is at least 95%, at least 96%, at least 97%, at least 98%, at least 99%, or 100% pure. In some embodiments, an excipient is approved for use in humans and for veterinary use. In some embodiments, an excipient is approved by United States Food and Drug Administration. In some embodiments, an excipient is pharmaceutical grade. In some embodiments, an excipient meets the standards of

the United States Pharmacopoeia (USP), the European Pharmacopoeia (EP), the British Pharmacopoeia, and/or the International Pharmacopoeia.

[00381] Relative amounts of the one or more nanoparticle compositions, the one or more pharmaceutically acceptable excipients, and/or any additional ingredients in a pharmaceutical composition in accordance with the present disclosure will vary, depending upon the identity, size, and/or condition of the subject treated and further depending upon the route by which the composition is to be administered. By way of example, a pharmaceutical composition can comprise between 0.1% and 100% (wt/wt) of one or more nanoparticle compositions.

[00382] In certain embodiments, the nanoparticle compositions and/or pharmaceutical compositions of the disclosure are refrigerated or frozen for storage and/or shipment (e.g., being stored at a temperature of 4 °C or lower, such as a temperature between about -150 °C and about 0 °C or between about -80 °C and about -20 °C (*e.g.*, about -5 °C, -10 °C, -15 °C, -20 °C, -25 °C, -30 °C, -40 °C, -50 °C, -60 °C, -70 °C, -80 °C, -90 °C, -130 °C or -150 °C). For example, the pharmaceutical composition comprising a compound of any of Formulae (I) or (II) (and sub-formulas thereof) is a solution that is refrigerated for storage and/or shipment at, for example, about -20 °C, -30 °C, -40 °C, -50 °C, -60 °C, -70 °C, or -80 °C In certain embodiments, the disclosure also relates to a method of increasing stability of the nanoparticle compositions and/or pharmaceutical compositions comprising a compound of any of Formulae (I) or (II) (and sub-formulas thereof) by storing the nanoparticle compositions and/or pharmaceutical compositions at a temperature of 4 °C or lower, such as a temperature between about -150 °C and about 0 °C or between about -80 °C and about -20 °C, e.g., about -5 °C, -10 °C, -15 °C, -20 °C, -25 °C, -30 °C, -40 °C, -50 °C, -60 °C, -70 °C, -80 °C, -90 °C, -130 °C or -150 °C). For example, the nanoparticle compositions and/or pharmaceutical compositions disclosed herein are stable for about at least 1 week, at least 2 weeks, at least 3 weeks, at least 4 weeks, at least 5 weeks, at least 6 weeks, at least 1 month, at least 2 months, at least 4 months, at least 6 months, at least 8 months, at least 10 months, at least 12 months, at least 14 months, at least 16 months, at least 18 months, at least 20 months, at least 22 months, or at least 24 months, e.g., at a temperature of 4 °C or lower (e.g., between about 4 °C and -20 °C). In one embodiment, the formulation is stabilized for at least 4 weeks at about 4 °C In certain embodiments, the pharmaceutical composition of the disclosure comprises a nanoparticle composition disclosed herein and a pharmaceutically acceptable carrier selected from one or more of Tris, an acetate (e.g., sodium acetate), an citrate (e.g., sodium citrate), saline, PBS, and sucrose. In certain embodiments, the pharmaceutical

composition of the disclosure has a pH value between about 7 and 8 (e.g., 6.8, 6.9, 7.0, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9 or 8.0, or between 7.5 and 8 or between 7 and 7.8). For example, a pharmaceutical composition of the disclosure comprises a nanoparticle composition disclosed herein, Tris, saline and sucrose, and has a pH of about 7.5-8, which is suitable for storage and/or shipment at, for example, about -20 °C For example, a pharmaceutical composition of the disclosure comprises a nanoparticle composition disclosed herein and PBS and has a pH of about 7-7.8, suitable for storage and/or shipment at, for example, about 4 °C or lower. "Stability," "stabilized," and "stable" in the context of the present disclosure refers to the resistance of nanoparticle compositions and/or pharmaceutical compositions disclosed herein to chemical or physical changes (*e.g.,* degradation, particle size change, aggregation, change in encapsulation, *etc*.) under given manufacturing, preparation, transportation, storage and/or in-use conditions, e.g., when stress is applied such as shear force, freeze/thaw stress, *etc*.

[00383] Nanoparticle compositions and/or pharmaceutical compositions including one or more nanoparticle compositions can be administered to any patient or subject, including those patients or subjects that can benefit from a therapeutic effect provided by the delivery of a therapeutic and/or prophylactic agent to one or more particular cells, tissues, organs, or systems or groups thereof, such as the renal system. Although the descriptions provided herein of nanoparticle compositions and pharmaceutical compositions including nanoparticle compositions are principally directed to compositions which are suitable for administration to humans, it will be understood by the skilled artisan that such compositions are generally suitable for administration to any other mammal. Modification of compositions suitable for administration to humans in order to render the compositions suitable for administration to various animals is well understood, and the ordinarily skilled veterinary pharmacologist can design and/or perform such modification with merely ordinary, if any, experimentation. Subjects to which administration of the compositions is contemplated include, but are not limited to, humans, other primates, and other mammals, including commercially relevant mammals such as cattle, pigs, horses, sheep, cats, dogs, mice, and/or rats.

[00384] A pharmaceutical composition including one or more nanoparticle compositions can be prepared by any method known or hereafter developed in the art of pharmacology. In general, such preparatory methods include bringing the active ingredient into association with an excipient and/or one or more other accessory ingredients, and then, if desirable or

necessary, dividing, shaping, and/or packaging the product into a desired single- or multi-dose unit.

[00385] A pharmaceutical composition in accordance with the present disclosure can be prepared, packaged, and/or sold in bulk, as a single unit dose, and/or as a plurality of single unit doses. As used herein, a "unit dose" is discrete amount of the pharmaceutical composition comprising a predetermined amount of the active ingredient (*e.g.*, nanoparticle composition). The amount of the active ingredient is generally equal to the dosage of the active ingredient which would be administered to a subject and/or a convenient fraction of such a dosage such as, for example, one-half or one-third of such a dosage.

[00386] Pharmaceutical compositions can be prepared in a variety of forms suitable for a variety of routes and methods of administration. For example, pharmaceutical compositions can be prepared in liquid dosage forms (*e.g.*, emulsions, microemulsions, nanoemulsions, solutions, suspensions, syrups, and elixirs), injectable forms, solid dosage forms (e.g., capsules, tablets, pills, powders, and granules), dosage forms for topical and/or transdermal administration (e.g., ointments, pastes, creams, lotions, gels, powders, solutions, sprays, inhalants, and patches), suspensions, powders, and other forms.

[00387] Liquid dosage forms for oral and parenteral administration include, but are not limited to, pharmaceutically acceptable emulsions, microemulsions, nanoemulsions, solutions, suspensions, syrups, and/or elixirs. In addition to active ingredients, liquid dosage forms can comprise inert diluents commonly used in the art such as, for example, water or other solvents, solubilizing agents and emulsifiers such as ethyl alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, 1,3-butylene glycol, dimethylformamide, oils (in particular, cottonseed, groundnut, corn, germ, olive, castor, and sesame oils), glycerol, tetrahydrofurfuryl alcohol, polyethylene glycols and fatty acid esters of sorbitan, and mixtures thereof. Besides inert diluents, oral compositions can include additional therapeutic and/or prophylactic agents, additional agents such as wetting agents, emulsifying and suspending agents, sweetening, flavoring, and/or perfuming agents. In certain embodiments for parenteral administration, compositions are mixed with solubilizing agents such as Cremophor™, alcohols, oils, modified oils, glycols, polysorbates, cyclodextrins, polymers, and/or combinations thereof.

[00388] Injectable preparations, for example, sterile injectable aqueous or oleaginous suspensions can be formulated according to the known art using suitable dispersing agents,

wetting agents, and/or suspending agents. Sterile injectable preparations can be sterile injectable solutions, suspensions, and/or emulsions in nontoxic parenterally acceptable diluents and/or solvents, for example, as a solution in 1,3-butanediol. Among the acceptable vehicles and solvents that can be employed are water, Ringer's solution, U.S.P., and isotonic sodium chloride solution. Sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose any bland fixed oil can be employed including synthetic mono- or diglycerides. Fatty acids such as oleic acid can be used in the preparation of injectables.

[00389] Injectable formulations can be sterilized, for example, by filtration through a bacterial-retaining filter, and/or by incorporating sterilizing agents in the form of sterile solid compositions which can be dissolved or dispersed in sterile water or other sterile injectable medium prior to use.

[00390] The disclosure features methods of delivering a therapeutic and/or prophylactic agent to a mammalian cell or organ, producing a polypeptide of interest in a mammalian cell, and treating a disease or disorder in a mammal in need thereof comprising administering to a mammal and/or contacting a mammalian cell with a nanoparticle composition including a therapeutic and/or prophylactic agent.

6. EXAMPLES

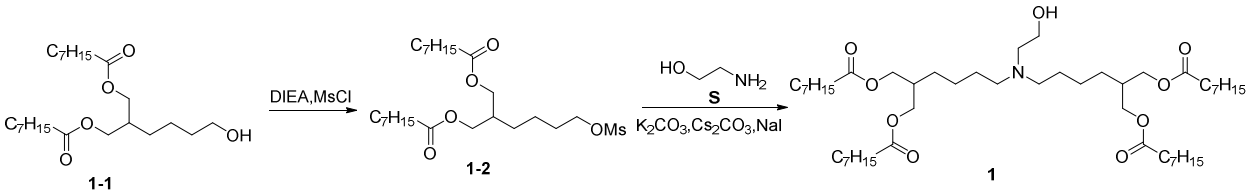
[00391] The examples in this section are offered by way of illustration, and not by way of limitation.

General Methods.

[00392] General preparative HPLC method: HPLC purification is carried out on a Waters 2767 equipped with a diode array detector (DAD) on an Inertsil Pre-C8 OBD column, generally with water containing 0.1% TFA as solvent A and acetonitrile as solvent B.

[00393] General LCMS method: LCMS analysis is conducted on a Shimadzu (LC-MS2020) System. Chromatography is performed on a SunFire C18, generally with water containing 0.1% formic acid as solvent A and acetonitrile containing 0.1% formic acid as solvent B.

6.1 Example 1: Preparation of Compound 1.



Step 1: Preparation of compound 1-2

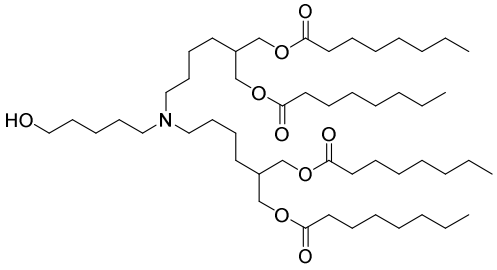
[00394] To a solution of compound 1-1 (1.0 g, 2.5 mmol, 1.0 eq.) and DIPEA (0.65 g, 4.99 mmol, 2.0 eq.) in DCM (30 mL) was added MsCl (350 mg, 3.0 mmol, 1.2 eq.). The mixture was stirred at room temperature for 2 hours. The mixture was poured into water and extracted with DCM. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated to give the title compound 1-2 (1.0 g, 84% yield) as yellow oil. It was used in the next step without further purification.

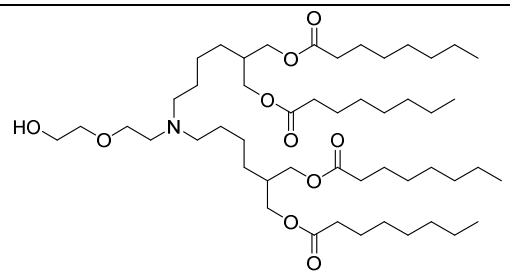
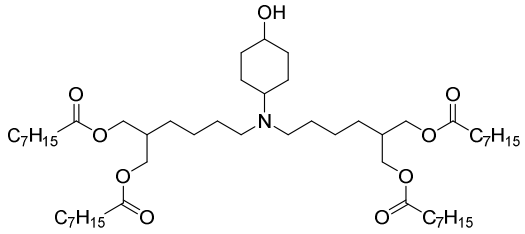
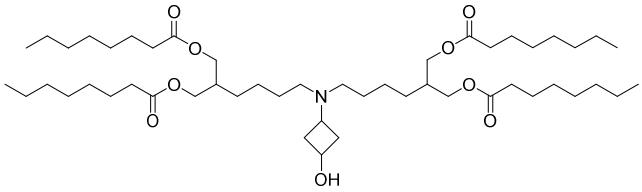
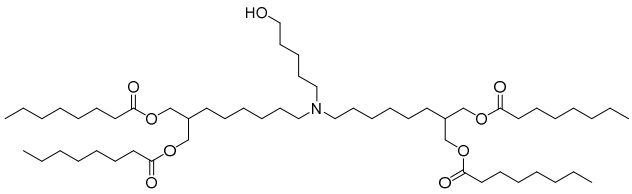
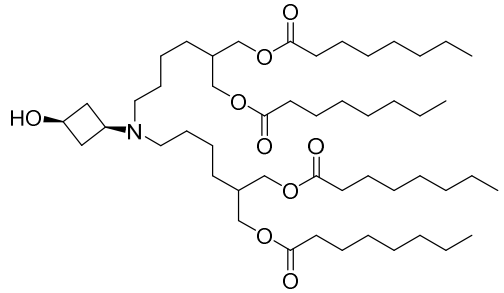
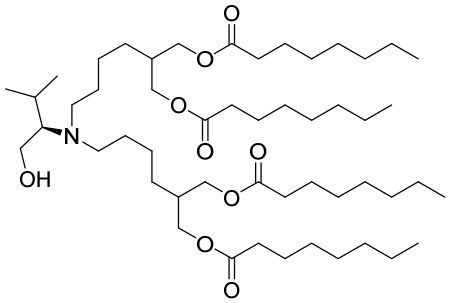
Step 2: Preparation of compound 1

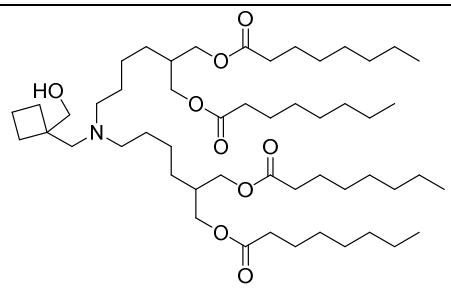
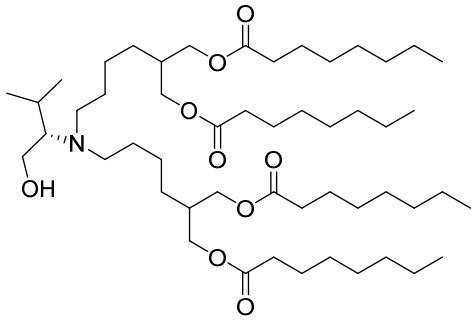
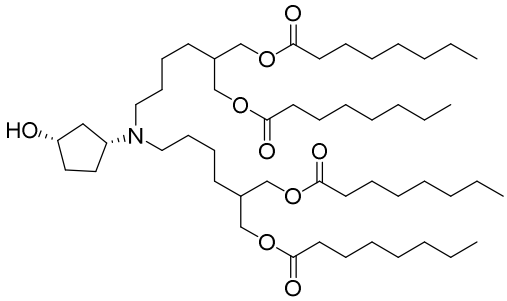
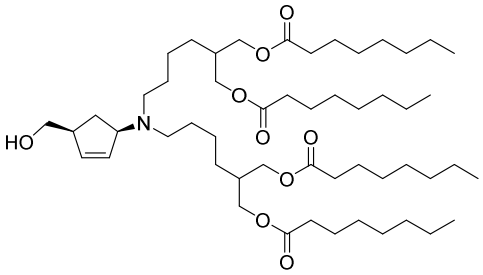
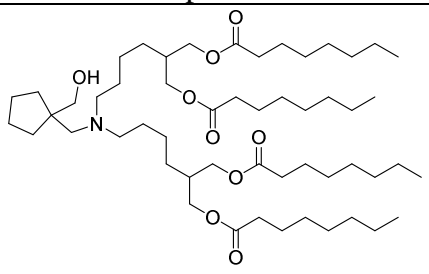
[00395] To a solution of compound 1-2 (1.0 g, 1.96 mmol, 3.0 eq.) and compound S (40 mg, 0.65 mmol, 1.0 eq.) in ACN (30 mL) were added K_2CO_3 (270 mg, 1.96 mmol, 3.0 eq.), Cs_2CO_3 (65 mg, 0.19 mmol, 0.3 eq.) and NaI (30 mg, 0.19 mmol, 0.3 eq.). The mixture was stirred at 80 ^oC for 10 hours. LCMS showed the reaction was complete. The mixture was concentrated and purified by prep-HPLC to give the title compound 1 (35 mg, 6% yield) as yellow oil.

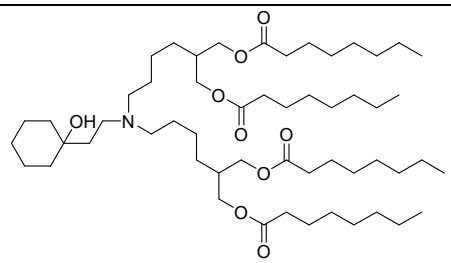
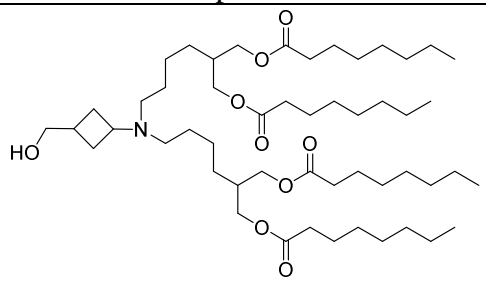
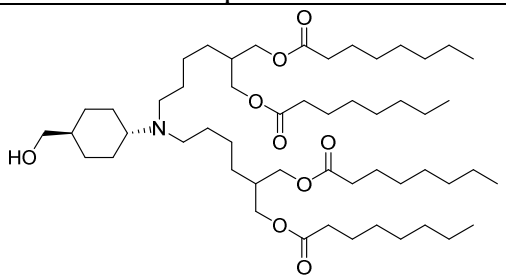
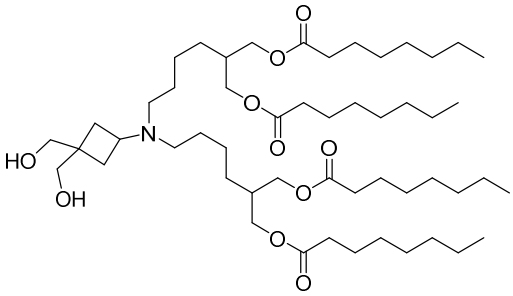
[00396] ^1H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.27-1.63 (m, 53H), 1.97-2.01 (m, 2H), 2.28-2.64 (m, 14H), 3.52-3.58 (m, 2H), 4.00-4.10 (m, 8H). LCMS: Rt: 1.080 min; MS m/z (ESI): 826.0 $[M+H]^+$.

[00397] The following compounds were prepared in analogous fashion as Compound 1, using corresponding starting material.

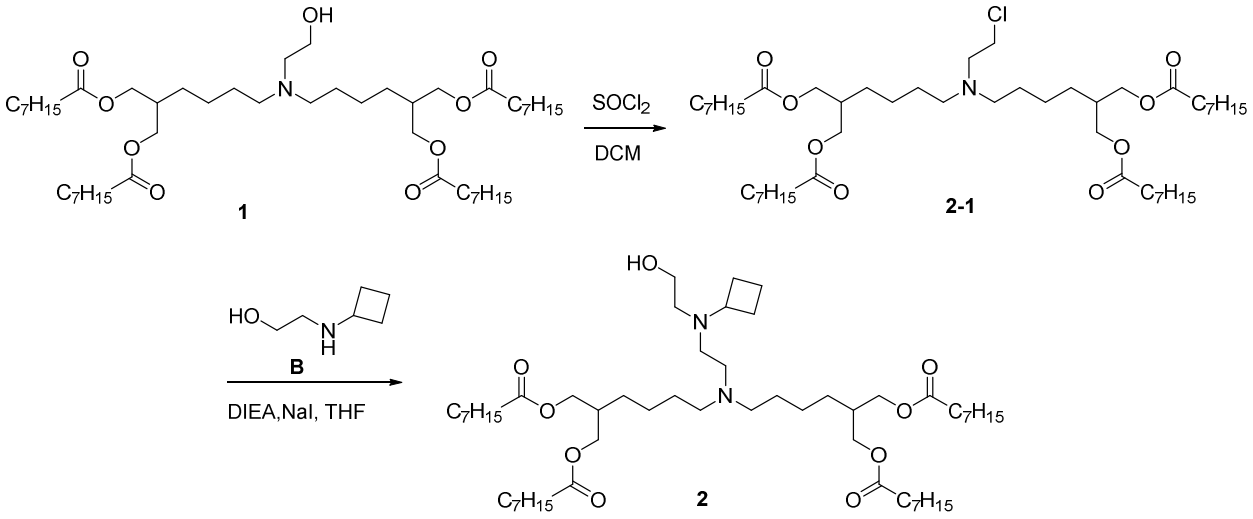
Compound	Characterization
 Compound 3	^1H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.32 (m, 30H), 1.35-1.44 (m, 12H), 1.57-1.66 (m, 17H), 1.95-2.01 (m, 2H), 2.28-2.40 (m, 14H), 3.63-3.66 (m, 2H), 4.00-4.11 (m, 8H). LCMS: Rt: 1.140 min; MS m/z (ESI): 868.1 $[M+H]^+$.

 Compound 5	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.25-1.35 (m, 40H), 1.44-1.51 (m, 4H), 1.59-1.63 (m, 8H), 1.95-1.99 (m, 3H), 2.28-2.32 (m, 8H), 2.44-2.47 (m, 4H), 2.60-2.63 (m, 2H), 3.59-3.70 (m, 6H), 4.00-4.10 (m, 8H). LCMS: Rt: 1.067 min; MS m/z (ESI): 870.6 $[M+H]^+$.
 Compound 16	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.89 (m, 12H), 1.28-1.32 (m, 43H), 1.37-1.41 (m, 12H), 1.57-1.63 (m, 8H), 1.97-2.32 (m, 10H), 2.89-3.20 (m, 3H), 3.99-4.04 (m, 1H), 4.06-4.10 (m, 8H). LCMS: Rt: 1.260 min; MS m/z (ESI): 880.9 $[M+H]^+$.
 Compound 23	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.30-1.43 (m, 41H), 1.60-1.78 (m, 14H), 1.95-2.03 (m, 2H), 2.28-2.40 (m, 12H), 2.48-2.61 (m, 3H), 3.92-4.11 (m, 9H). LCMS: Rt: 0.093 min; MS m/z (ESI): 852.6 $[M+H]^+$.
 Compound 29	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.47 (m, 55H), 1.57-1.63 (m, 12H), 1.98-1.99 (m, 2H), 2.28-2.38 (m, 14H), 3.62-3.66 (m, 2H), 4.00-4.10 (m, 8H). LCMS: Rt:1.250 min; MS m/z (ESI): 925.8 $[M+H]^+$.
 Compound 43	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.84-0.90 (m, 12H), 1.29-1.51 (m, 46H), 1.53-1.66 (m, 9H), 1.89-2.01 (m, 3H), 2.23-2.30 (m, 8H), 2.32-2.72 (m, 6H), 3.89-4.14 (m, 9H). LCMS: Rt: 1.115 min; MS m/z (ESI): 852.7 $[M+H]^+$.
 Compound 44	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.76-0.93 (m, 15H), 0.92-0.94 (m, 3H), 1.22-1.31 (m, 44H), 1.53-1.56 (m, 10H), 1.67-1.73 (m, 1H), 1.84-1.97 (m, 2H), 2.22-2.25 (m, 8H), 2.32-2.60 (m, 4H), 2.96-3.06(m, 1H), 3.43-3.54 (m, 1H), 3.94-4.03 (m, 8H). LCMS: Rt: 0.970min; MS m/z (ESI): 868.8 $[M+H]^+$.

 Compound 45	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.83-0.89 (m, 12H), 1.16-1.45 (m, 45H), 1.59-1.67 (m, 16H), 1.80-1.94 (m, 4H), 1.94-1.99 (m, 2H), 1.99-2.55 (m, 10H), 2.55-2.38 (m, 1H), 3.75-3.99 (m, 1H), 3.75-4.04 (m, 7H). LCMS: Rt:0.887 min; MS m/z (ESI): 880.8 $[M+H]^+$.
 Compound 46	^{1}H NMR (400 MHz, $CDCl_3$) δ: 4.10-3.96 (m, 8H), 3.71-3.49 (m, 2H), 3.14-3.03 (m, 1H), 2.65-2.49 (m, 2H), 2.32-2.28 (m, 8H), 2.06-1.98 (m, 2H), 1.89-1.86 (m, 1H), 1.66-1.52 (m, 12H), 1.31-1.28 (m, 42H), 0.89-0.86 (m, 18H). LCMS: Rt: 0.930 min; MS m/z (ESI): 868.8 $[M+H]^+$.
 Compound 47	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.27-1.50 (m, 45H), 1.60-1.88 (m, 14H), 1.94-2.02 (m, 2H), 2.28-2.32 (m, 8H), 2.45-2.60 (m, 4H), 3.01-3.12 (m, 1H), 4.00-4.09 (m, 8H), 4.21-4.26 (m, 1H). LCMS: Rt: 0.927 min; MS m/z (ESI): 866.8 $[M+H]^+$.
 Compound 48	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.27-1.53 (m, 45H), 1.58-1.68 (m, 9H), 1.92-2.02 (m, 2H), 2.07-2.18 (m, 1H), 2.28-2.32 (m, 8H), 2.42-2.62 (m, 4H), 2.81-2.90 (m, 1H), 3.47-3.64 (m, 3H), 4.00-4.10 (m, 8H), 5.83-5.99 (m, 2H). LCMS: Rt: 0.877 min; MS m/z (ESI): 878.8 $[M+H]^+$.
 Compound 49	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.37 (m, 43H), 1.46-1.50 (m, 4H), 1.58-1.63 (m, 14H), 1.96-2.01 (m, 2H), 2.28-2.32 (m, 8H), 2.38-2.48 (m, 4H), 2.56 (s, 2H), 3.47 (s, 2H), 3.98-4.10 (m, 8H). LCMS: Rt: 0.787 min; MS m/z (ESI): 894.8 $[M+H]^+$.

 Compound 50	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.83-0.90 (m, 12H), 1.16-1.46 (m, 51H), 1.57-1.69 (m, 15H), 1.94-2.01 (m, 2H), 2.02-2.32 (m, 11H), 2.38-2.42 (m, 2H), 3.99-4.10 (m, 8H). LCMS: Rt: 1.167 min; MS m/z (ESI): 908.8 $[M+H]^+$.
 Compound 54	1H NMR (400 MHz, $CDCl_3$) δ: 0.83-0.90 (m, 12H), 1.27-1.45 (m, 57H), 1.96-2.02 (m, 5H), 2.28-2.36 (m, 10H), 3.13-3.20 (m,1H), 3.67-3.70 (m, 2H), 3.99-4.11 (m, 8H). LCMS: Rt: 0.080 min; MS m/z (ESI): 866.6 $[M+H]^+$.
 Compound 59	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.98 (m, 12H), 1.22-1.38 (m, 48H), 1.58-1.99 (m, 16H), 2.28-2.40 (m, 13H), 3.44-3.46 (m, 2H), 4.00-4.10 (m, 8H). LCMS： Rt: 0.373 min; MS m/z (ESI): 894.8 $[M+H]^+$.
 Compound 61	H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.78 (m, 56H), 1.95-2.07 (m, 4H), 2.25-2.32 (m, 8H), 2.40-2.42 (m, 4H), 3.05-3.08 (m, 1H), 3.64-3.68 (m, 4H), 4.00-4.11 (m, 8H). LCMS: Rt: 0.347 min; MS m/z (ESI): 896.7 $[M+H]^+$.

6.2 Example 2: Preparation of Compound 2.



Step 1: Preparation of compound 2-1

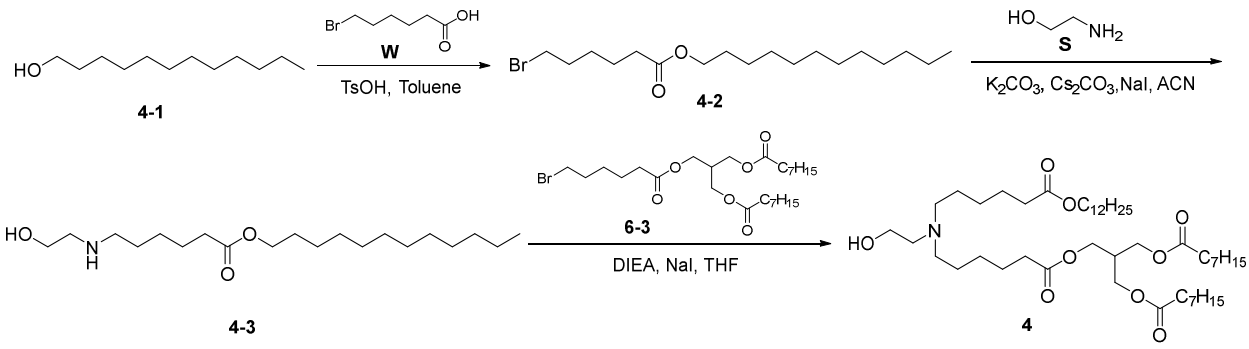
[00398] To a solution of compound 1 (250 mg, 0.3 mmol, 1.0 eq.) in DCM (10 mL) was added $SOCl_2$ (108 mg, 0.91 mmol, 3.0 eq.). The mixture was stirred at 35 °C for 10 hours. The mixture was concentrated to give the title compound 2-1 (255 mg, 100% yield) as yellow oil. LCMS: Rt: 0.613min; MS m/z (ESI): 843.9 $[M+H]^+$.

Step 2: Preparation of compound 2

[00399] To a solution of compound 2-1 (200 mg, 0.24 mmol, 1.0 eq.) and compound B (55 mg, 0.47 mmol, 2.0 eq.) in THF (10 mL) was added DIPEA (95 mg, 0.71 mmol, 3.0 eq.) and NaI (36 mg, 0.24 mmol, 1.0 eq.). The mixture was stirred at 70 °C for 10 hours. LCMS showed the reaction was completed. The mixture was concentrated and purified by prep-HPLC to give the title compound 2 (51 mg, 23% yield) as yellow oil.

[00400] ^1H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.67 (m, 54H), 1.88-2.01 (m, 7H), 2.28-2.56 (m, 18H), 3.16-3.20 (m, 1H), 3.52-3.54 (m, 2H), 4.00-4.10 (m, 8H). LCMS: Rt: 1.060 min; MS m/z (ESI): 923.0 $[M+H]^+$.

6.3 Example 3: Preparation of Compound 4.



Step 1: Preparation of compound 4-2

[00401] To a solution of compound 4-1 (900 mg, 4.45 mmol, 1.0 eq.), $TsOH.H_2O$ (423 mg, 2.23 mmol, 0.5 eq.) and compound W (931 mg, 4.77 mmol, 1.1 eq.) in toluene (30 mL) was stirred at 180 °C for 2 hours. The mixture was cooled to room temperature and concentrated. The residue was purified by column chromatography on silica gel (PE/EA = 100/1) to give the title compound 4-2 (1.43 g, 88.6% yield) as light yellow oil.

Step 2: Preparation of compound 4-3

[00402] To a solution of compound 4-2 (500 mg, 1.38 mmol, 1.0 eq.) and compound S (336 mg, 5.5 mmol, 4.0 eq.) in ACN (20 mL) were added K_2CO_3 (570 mg, 4.13 mmol, 3.0

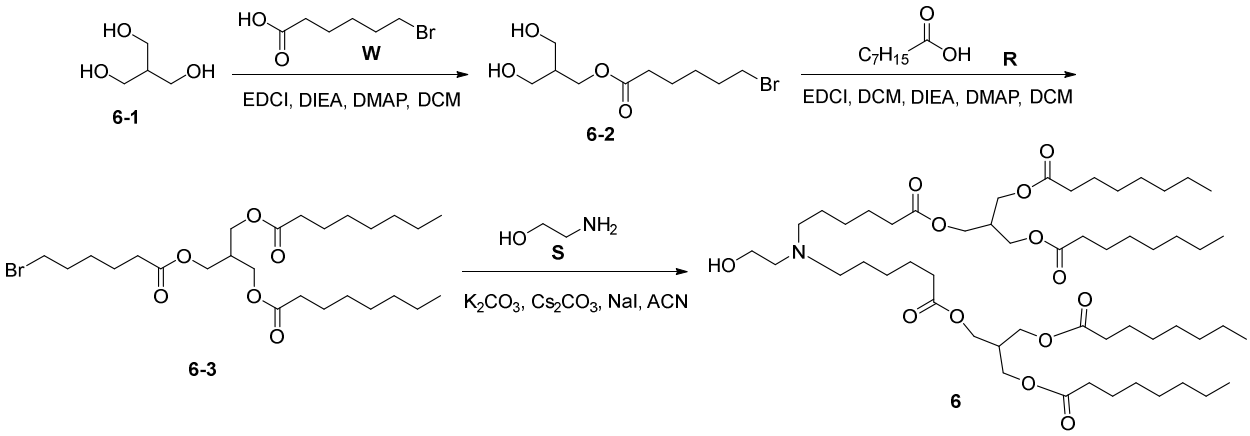
eq.), Cs_2CO_3 (13 mg, 0.04 mmol, 0.03 eq.) and NaI (103 mg, 0.69 mmol, 0.5 eq.). The mixture was stirred at 80 °C for 16 hours. The mixture was concentrated. The residue was purified by column chromatography on silica gel (MeOH/DCM = 1/10) to give the title compound 4-3 (265 mg, 56.0% yield) as light yellow oil. LCMS: Rt: 0.840 min; MS m/z (ESI): 344.1 $[M+H]^+$.

Step 3: Preparation of compound 4

[00403] To a solution of compound 4-3 (198 mg, 0.58 mmol, 1.0 eq.) and compound 6-3 (300 mg, 0.58mmol, 1.0 eq.) in THF (10 mL) were added DIPEA (223 mg, 1.73 mmol, 3.0 eq.) and NaI (43 mg, 0.29 mmol, 0.5 eq.). The mixture was stirred at 70 °C for 16 hours. LCMS show the reaction was completed. The mixture was concentrated and purified by prep HPLC to give the title compound 4 (27 mg, 5.91% yield) as colorless oil.

[00404] ^1H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 9H), 1.26-1.32 (m, 34H), 1.41-1.49 (m, 4H), 1.61-1.66 (m, 15H), 2.00-2.03 (m, 1H), 2.21-2.38 (m, 8H), 2.43-2.47 (m, 4H), 2.56-2.60 (m, 2H), 3.50-3.54 (m, 2H), 4.03-4.14 (m, 8H). LCMS: Rt: 1.030 min; MS m/z (ESI): 798.0 $[M+H]^+$.

6.4 Example 4: Preparation of Compound 6.



Step 1: Preparation of compound 6-2

[00405] To a solution of compound 6-1 (1.0 g, 9.43 mmol, 1.0 eq.) and compound W (1.6 g, 8.48 mmol, 0.9 eq.) in DCM (30 mL) were added EDCI (2.17 g, 11.31 mmol, 1.2 eq.), DIPEA (3.65 g, 28.28 mmol, 3.0 eq.) and DMAP (230 mg, 1.89 mmol, 0.2 eq.). The mixture was stirred at 35 °C for 16 hours. The mixture was poured into water and extracted with DCM. The combined organic layers were washed with brine, dried over Na_2SO_4 and

concentrated. The residue was purified by column chromatography on silica gel (PE/EA = 1/0-0/1) to give the title compound 6-2 (641 mg, 24.0 % yield) as colorless oil.

Step 2: Preparation of compound 6-3

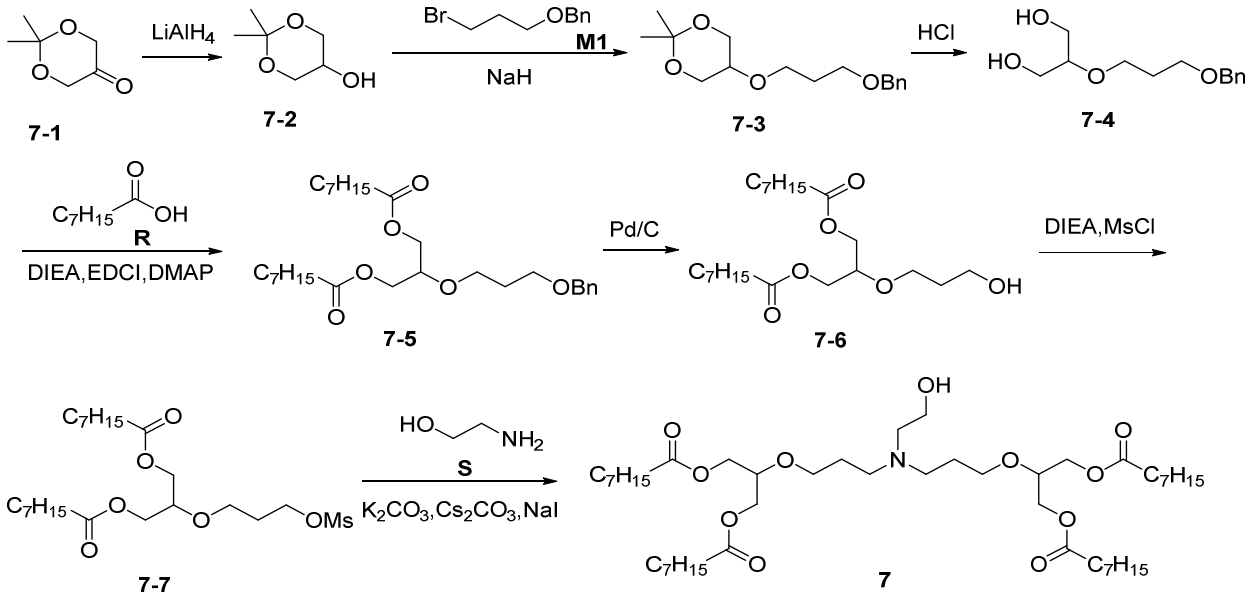
[00406] To a solution of compound 6-2 (641 mg, 2.26 mmol, 0.9 eq.) and compound R (815 mg, 5.65 mmol, 2.5 eq.) in DCM (10 mL) were added EDCI (1.03 g, 5.65 mmol, 2.5 eq.), DIPEA (1.5 g, 11.30 mmol, 5.0 eq.) and DMAP (83 mg, 0.68 mmol, 0.3 eq.). The mixture was stirred at 35 °C for 16 hours. The mixture was poured into water and extracted with DCM. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (PE/EA = 1/0-5/1) to give the title compound 6-3 (510 mg, 42.07 % yield) as colorless oil.

Step 3: Preparation of compound 6

[00407] To a solution of compound 6-3 (501 mg, 0.94 mmol, 1.0 eq.) in ACN (10 mL) were added compound S (23 mg, 0.37 mmol, 0.4 eq.), K_2CO_3 (387 mg, 0.81mmol, 3.0 eq.), Cs_2CO_3 (9 mg, 0.03 mmo, 0.03 eq.), and NaI (70 mg, 0.47 mmol, 0.5 eq.) at room temperature. The mixture was stirred overnight at 70 °C. The mixture was washed with water, brine, the organic layers was concentrated and purified by prep-HPLC to give the title compound 6 (112 mg, 12.34% yield) as colorless oil.

[00408] ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.32 (m, 42H), 1.42-1.47 (m, 4H), 1.62-1.65 (m, 6H), 1.97-2.01 (m, 1H), 2.29-2.48 (m, 18H), 2.53-2.58 (m, 2H), 3.50-3.54 (m, 2H), 4.12-4.14 (m, 12H). LCMS: Rt: 1.055 min; MS m/z (ESI): 970.8 $[M+H]^+$.

6.5 Example 5: Preparation of Compound 7.



Step 1: Preparation of compound 7-2

[00409] To a suspension of compound 7-1 (9.0 g, 69.15 mmol, 1.0 eq.) in THF (300 mL) was added $LiAlH_4$ (2.62 g, 69.15 mmol, 1.0 eq.). The resulting mixture was stirred at RT for 2 hours. The mixture was poured into water and extracted with EA. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (PE/EA = 1/1) to give the title compound 7-2 (6.0 g, 65% yield) as yellow oil.

Step2: Preparation of compound 7-3

[00410] To a suspension of compound 7-2 (6.0 g, 45.4 mmol, 1.0 eq.) in THF (300 mL) was added NaH (3.63 g, 90.8 mmol, 2.0 eq.). The resulting mixture was stirred at RT for 10 hours. Then, the compound M1 (20.8 g, 90.8 mmol, 2.0 eq.) was added dropwise and the resulting mixture was stirred at 60 ^oC for 10 hours. After cooling to room temperature, the mixture was poured into water and extracted with EA. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated. The residue was purified by column chromatography on silica gel (PE/EA = 4/1) to give the title compound 7-3 (3.0 g, 23% yield) as yellow oil.

Step 3: Preparation of compound 7-4

[00411] To a solution of compound 7-3 (3.0 g, 10.7 mmol, 1.0 eq.) in THF (20 mL) was added HCl (aq) (20 mL, 60 mmol, 5.6 eq.). The mixture was stirred at RT for 3 hours. The mixture was poured into water and extracted with EtOAc. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated to give the title compound 7-4 (2.2 g, 86% yield) as yellow oil.

Step 4: Preparation of compound 7-5

[00412] To a solution of compound 7-4 (2.2g, 9.16 mmol, 1.0 eq.) and compound R (3.96 g, 27.47 mmol, 3.0 eq.) in DCM (150 mL) was added DIEA (5.92 g, 45.783 mmol, 5.0 eq.), EDCI (5.27 g, 27.47 mmol, 3.0 eq.) and DMAP (1.12 g, 9.16 mmol, 1.0 eq.). The mixture was stirred at 45 ^oC for 10 hours. The reaction mixture was concentrated and purified by column chromatography on silica gel (PE/EA = 10:1) to give the title compound 7-5 (4.0 g, 88% yield) as colorless oil.

Step 5: Preparation of compound 7-6

[00413] To a solution of compound 7-5 (3.8 g, 7.71 mmol, 1.0 eq.) in EtOAc (150 mL) was added Pd/C (1.0 g). The mixture was stirred at room temperature under H_2 for 2 hours. The mixture was filtered through a pad of Celite and washed with MeOH. The filtration was concentrated to give the title compound 7-6 (5.1 g, 58% yield) as yellow oil.

Step 6: Preparation of compound 7-7

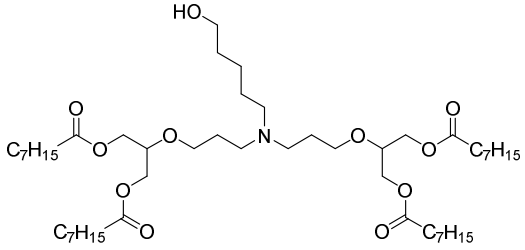
[00414] To a solution of compound 7-6 (2.0 g, 4.97 mmol, 1.0 eq.) and DIPEA (1.28 g, 9.94 mmol, 2.0 eq.) in DCM (50 mL) was added MsCl (680 mg, 5.96 mmol, 1.2 eq.). The mixture was stirred at room temperature for 2 hours. The mixture was poured into water and extracted with DCM. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated to give the title compound 7-7 (2.39 g, 100% yield) as yellow oil. It was used in the next step without further purification.

Step 7: Preparation of compound 7

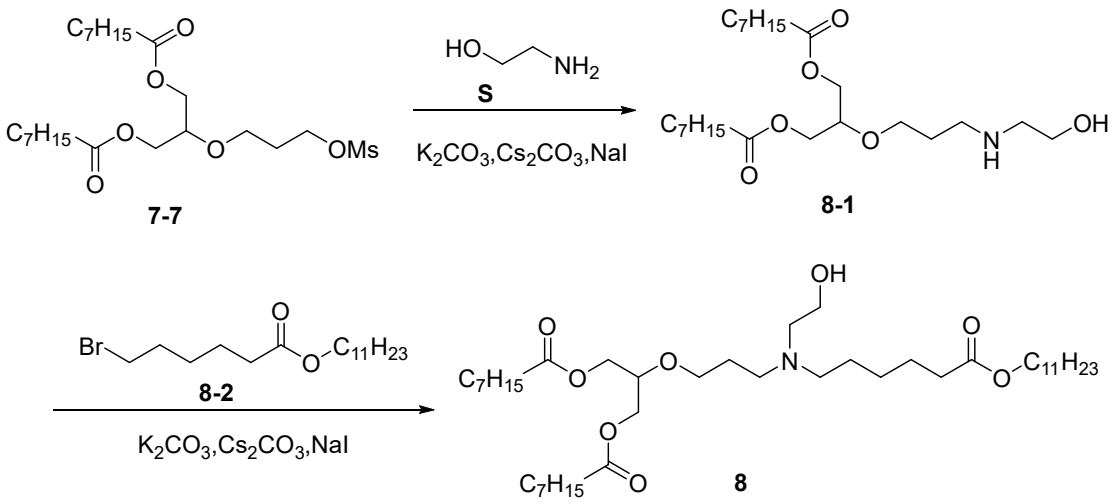
[00415] To a solution of compound 7-7 (2.36 g, 4.91 mmol, 3.0 eq.) and compound S (100 mg, 1.64 mmol, 1.0 eq.) in ACN (30 mL) were added K_2CO_3 (680 mg, 4.91 mmol, 3.0 eq.), Cs_2CO_3 (160 mg, 0.49 mmol, 0.3 eq.) and NaI (75 mg, 0.49 mmol, 0.3 eq.). The mixture was stirred at 80 ^oC for 10 hours. LCMS showed the reaction was completed. The reaction mixture was concentrated and purified by column chromatography on silica gel (DCM/MeOH = 20/1) to give the title compound 7 (600 mg, 48% yield) as yellow oil. LCMS: Rt: 1.087 min; MS m/z (ESI): 830.6 $[M+H]^+$. Then the compound 7 (150 mg) was purified by prep-HPLC to give the target product as yellow oil (13 mg, yield: 9 %).

[00416] ^1H NMR (400 MHz, $CDCl_3$) δ: 0.77-0.83 (m, 12H), 1.21-1.36 (m, 33H), 1.51-1.71 (m, 14H), 2.24-2.27 (m, 8H), 2.54-2.56 (m, 4H), 3.53-3.63 (m, 8H), , 4.01-4.15 (m, 8H). LCMS: Rt: 0.970 min; MS m/z (ESI): 830.6 $[M+H]^+$.

[00417] The following compounds were prepared in analogous fashion as Compound 7, using corresponding starting material.

Compound	Characterization
 Compound 25	^1H NMR (400 MHz, $CDCl_3$) δ: 0.79-0.83 (m, 12H), 1.21-1.68 (m, 52H), 2.24-2.48 (m, 13H), 3.53-3.60 (m, 8H), , 4.02-4.12 (m, 8H). LCMS: Rt:0.850 min; MS m/z (ESI): 872.7 $[M+H]^+$.

6.6 Example 6: Preparation of Compound 8.



Step 1: Preparation of compound 8-1

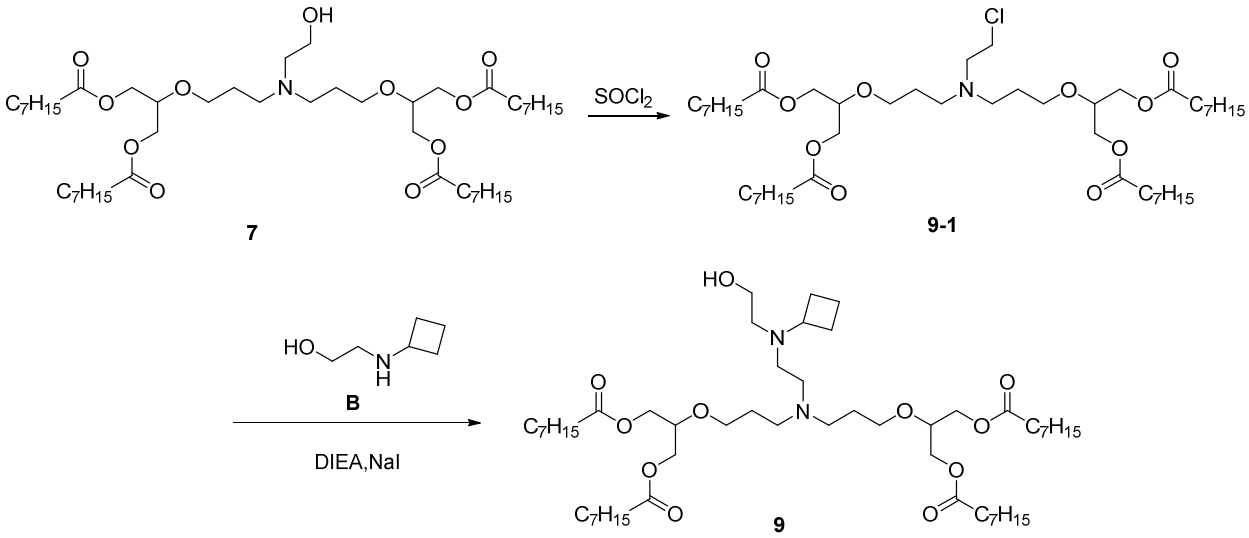
[00418] To a solution of compound 7-7 (1.19 g, 2.48 mmol, 1.0 eq.) and compound S (450 mg, 7.43 mmol, 3.0 eq.) in ACN (30 mL) were added K_2CO_3 (1.03 g, 7.43 mmol, 3.0 eq.), Cs_2CO_3 (242 mg, 0.74 mmol, 0.3 eq.) and NaI (115 mg, 0.74 mmol, 0.3 eq.). The mixture was stirred at 80 °C for 10 hours. LCMS showed the reaction was complete. The reaction mixture was concentrated and purified by column chromatography on silica gel (DCM/MeOH = 20/1) to give the title compound 8-1 (650 mg, 59% yield) as yellow oil. LCMS: Rt: 0.787 min; MS m/z (ESI): 446.4 $[M+H]^+$.

Step 2: Preparation of compound 8

[00419] To a solution of compound 8-1 (300 mg, 0.67 mmol, 1.0 eq.) and compound 8-2 (240 mg, 0.67 mmol, 1.0 eq.) in ACN (10 mL) were added K_2CO_3 (280 mg, 2.20 mmol, 3.2 eq.), Cs_2CO_3 (70 mg, 0.22 mmol, 0.3 eq.) and NaI (30 mg, 0.22 mmol, 0.3 eq.). The mixture was stirred at 80 °C for 10 hours. LCMS showed the reaction was completed. The mixture was concentrated and purified by prep-HPLC to give the title compound 8 (30 mg, 14% yield) as yellow oil.

[00420] ^1H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 9H), 1.26-1.74 (m, 47H), 2.28-2.34 (m, 6H), 2.46-2.61 (m, 6H), 3.54-3.69 (m, 5H), 4.04-4.21 (m, 6H). LCMS: Rt: 0.967min; MS m/z (ESI): 714.5 $[M+H]^+$.

6.7 Example 7: Preparation of Compound 9.



Step 1: Preparation of compound 9-1

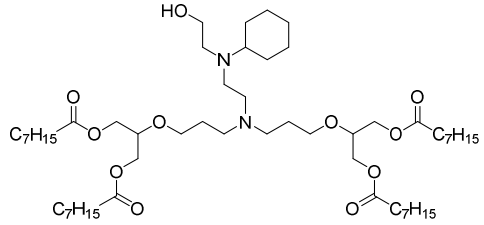
[00421] To a solution of compound 7 (250 mg, 0.3 mmol, 1.0 eq.) in DCM (10 mL) was added $SOCl_2$ (110 mg, 0.90 mmol, 3.0 eq.). The mixture was stirred at 35 ºC for 10 hours. The mixture was concentrated to give the title compound 9-1 (255 mg, 100% yield) as yellow oil. LCMS: Rt: 0.560min; MS m/z (ESI): 847.9 $[M+H]^+$.

Step 2: Preparation of compound 9

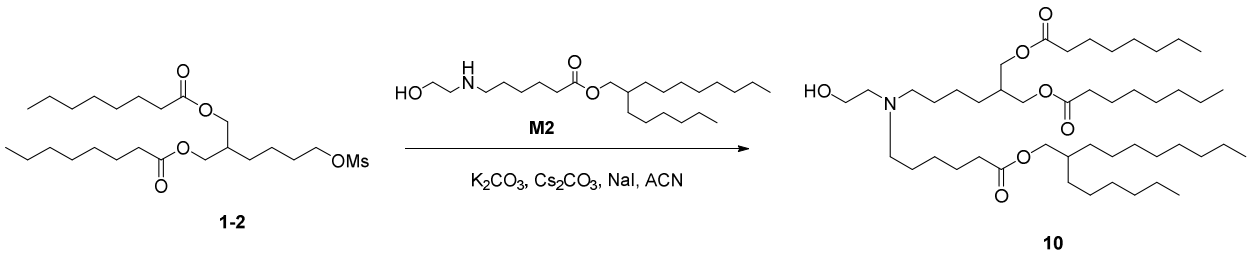
[00422] To a solution of compound 9-1 (200 mg, 0.23 mmol, 1.0 eq.) and compound B (55 mg, 0.47 mmol, 2.0 eq.) in THF (10 mL) were added DIPEA (95 mg, 0.71 mmol, 3.0 eq.) and NaI (36 mg, 0.23 mmol, 1.0 eq.). The mixture was stirred at 70 ºC for 10 hours. LCMS showed the reaction was completed. The mixture was concentrated and purified by prep-HPLC to give the title compound 9 (30 mg, 14% yield) as yellow oil.

[00423] ^1H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.30 (m, 33H), 1.58-2.01 (m, 18H), 2.30-2.54 (m, 18H), 3.10-3.19 (m, 1H), 3.52-3.68 (m, 8H), 4.09-4.20 (m, 8H). LCMS: Rt: 1.677 min; MS m/z (ESI): 927.7 $[M+H]^+$.

[00424] The following compounds were prepared in analogous fashion as Compound 9, using corresponding starting material.

Compound	Characterization
 Compound 14	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.30 (m, 40H), 1.58-1.80 (m, 16H), 2.30-2.60 (m, 18H), 3.58-3.68 (m, 8H), 4.08-4.20 (m, 8H). LCMS: Rt: 1.000 min; MS m/z (ESI): 955.7 $[M+H]^+$.

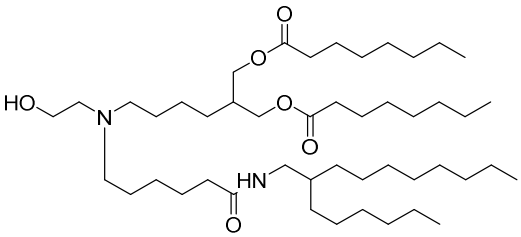
6.8 Example 8: Preparation of Compound 10.

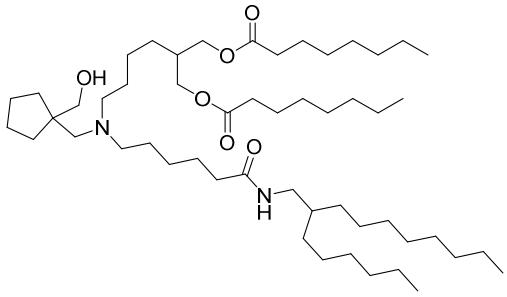
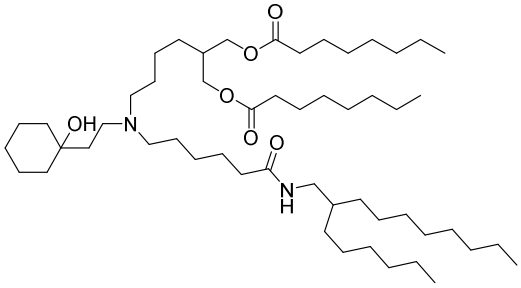


[00425] To a solution of compound 1-2 (310 mg, 0.65 mmol, 1.0 eq.) and compound M2 (260 mg, 0.65 mmol, 1.0 eq.) in ACN (10 mL) were added K_2CO_3 (269 mg, 1.95 mmol, 3.0 eq.), Cs_2CO_3 (65 mg, 0.20 mmol, 0.3 eq.) and NaI (30 mg, 0.20 mmol, 0.3 eq.). The mixture was stirred at 70 °C for 16 hours. LCMS show the reaction was completed. The mixture was poured into water and extracted with EA. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated. The residue was purified by prep-HPLC to give the title compound 10 (60 mg, 12% yield) as yellow oil.

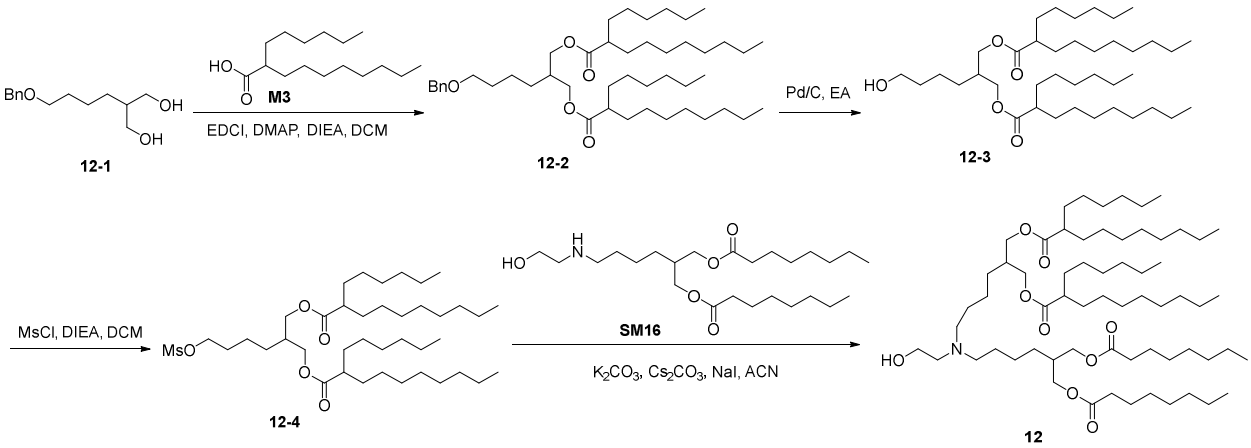
[00426] ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.26-1.41 (m, 48H), 1.51-1.72 (m, 11H), 1.94-2.03 (m, 1H), 2.29-2.32 (m, 6H), 2.41-2.91 (m, 5H), 3.51-3.76(m, 2H), 3.96-4.10 (m, 6H). LCMS: Rt: 1.327 min; MS m/z (ESI): 782.6 $[M+H]^+$.

[00427] The following compounds were prepared in analogous fashion as Compound 10, using corresponding starting material.

Compound	Characterization
 Compound 11	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.26-1.30 (m, 46H), 1.43-1.50 (m, 8H), 1.69-1.73 (m, 3H), 1.83-1.90 (m, 3H), 1.98-2.02 (m, 1H), 2.20-2.33 (m, 6H), 3.05-3.19 (m, 7H), 3.98-4.10 (m, 6H). LCMS: Rt: 1.205min; MS m/z (ESI): 781.7 $[M+H]^+$.

 Compound 62	^{1}H NMR (400 MHz, CDCl3) δ: 0.86-0.90 (m, 12H), 1.28-2.01 (m, 67H), 2.16-2.19 (m, 2H), 2.29-2.32 (m, 4H), 2.41-2.45 (m, 4H), 2.53-2.59 (m, 2H), 3.16-3.19 (m, 2H), 3.43-3.52 (m, 2H), 4.00-4.10 (m, 4H), 5.60-5.65 (m, 1H). LCMS: Rt:0.387 min; MS m/z (ESI): 849.8[M+H]$^+$.
 Compound 63	^{1}H NMR (400 MHz, CDCl3) δ: 0.86-0.90 (m, 12H), 1.28-1.65 (m, 70H), 1.94-2.02 (m, 1H), 2.15-2.19 (m, 2H), 2.28-2.45 (m, 8H), 2.63-2.68 (m, 2H), 3.16-3.19 (m, 2H), 4.00-4.10 (m, 4H), 5.53-5.62 (m, 1H). LCMS: Rt:1.120 min; MS m/z (ESI): 863.8[M+H]$^+$.

6.9 Example 9: Preparation of Compound 12.



Step 1: Preparation of compound 12-2

[00428] To a solution of compound 12-1 (3 g, 12.59 mmol, 1.0 eq.) and compound M3 (7.2 g, 26.44 mmol, 2.1 eq.) in DCM (70 mL) was added EDCI (7.2 g, 37.77 mmol, 3.0 eq.), DMAP (0.46 g, 3.777 mmol, 0.3 eq.), DIEA (8.1 g, 62.95 mmol, 5.0 eq.). The mixture was stirred at 55 ^{o}C for 16 hours. TLC showed the reaction was complete. The reaction mixture was concentrated and purified by column chromatography on silica gel to give the title compound 12-2 (5.3 g, 56.64% yield) as yellow oil.

Step 2: Preparation of compound 12-3

[00429] To a solution of compound 12-2 (5.3 g, 7.131 mmol, 1.0 eq.) in EA (100 mL) was added Pd/C (600 mg) and con.HCl (3 drops). The mixture was stirred at room temperature under H_2 for 16 hours. The mixture was filtered through a pad of Celite and washed with EA.

The filtration was concentrated and purified by column chromatography on silica gel (PE/EA = 3/1) to give the title compound 12-3 (3.7 g, 79.45% yield) as yellow oil.

Step 3: Preparation of compound 12-4

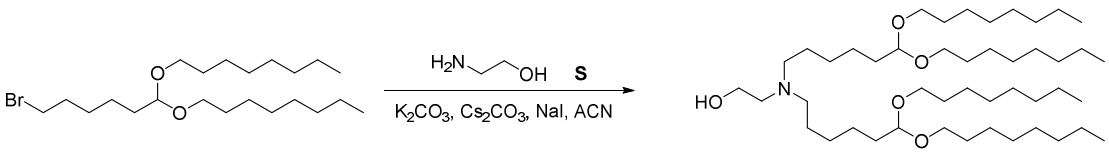
[00430] To a solution of compound 12-3 (3.7 g, 5.67 mmol, 1.0 eq.) and DIPEA (1.5 g, 11.3 mmol, 2.0 eq.) in DCM (50 mL) at 0 °C was added MsCl (0.78 g, 6.8 mmol, 1.2 eq.). The mixture was stirred still for 2 hours. The mixture was poured into water and extracted with DCM. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated to give the title compound 12-4 (4 g, 96%) as yellow oil.

Step 4: Preparation of compound 12

[00431] To a solution of compound 12-4 (300 mg, 0.41 mmol, 1.0 eq.) and compound SM16 (200 mg, 0.45 mmol, 1.1 eq.) in ACN (15 mL) were added K_2CO_3 (170 mg, 1.23 mmol, 3.0 eq.), Cs_2CO_3 (39 mg, 0.12 mmol, 0.3 eq.) and NaI (18 mg, 0.12 mmol, 0.3 eq.). The mixture was stirred at 80 °C for 16 hours. LCMS showed the reaction was completed. The reaction mixture was concentrated and purified by prep-HPLC to get the title compound 12 (130 mg, 30.18%) as yellow oil.

[00432] ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.89 (m, 18H), 1.25-1.35 (m, 53H), 1.41-1.48 (m, 8H), 1.56-1.61 (m, 20H), 1.95-2.01 (m, 2H), 2.28-2.35 (m, 6H), 2.43-2.46 (m, 4H), 2.56-2.58 (m, 2H), 3.51-3.54 (m, 2H), 4.00-4.10 (m, 8H). LCMS: Rt: 0.080 min; MS m/z (ESI): 1050.8 $[M+H]^+$.

6.10 Example 10: Preparation of Compound 15.

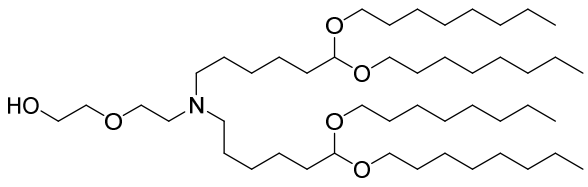
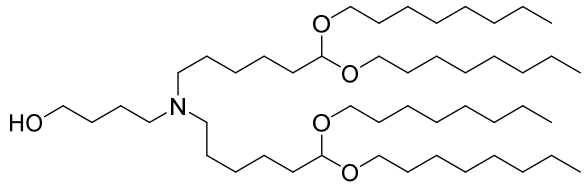
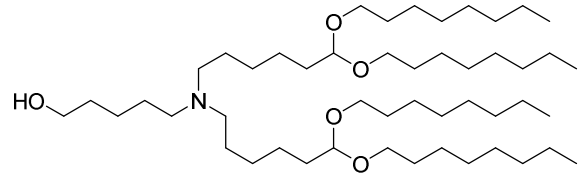


15-1 15

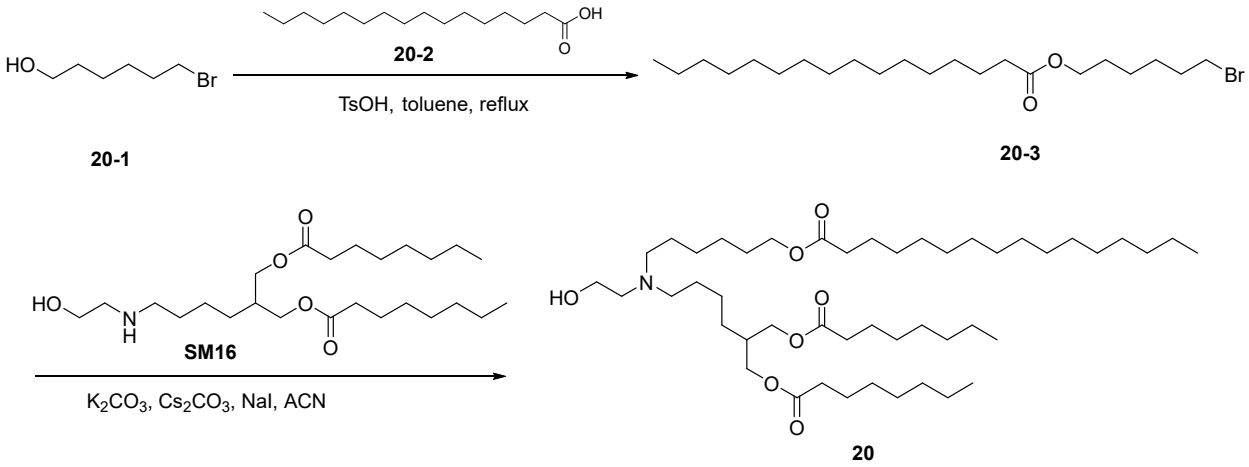
[00433] To a solution of compound 15-1 (600 mg, 1.47 mmol, 3.0 eq.) in ACN (10 mL) was added compound S (30 mg, 0.49 mmol, 1.0 eq.), K_2CO_3 (203 mg, 1.47 mmol, 3.0 eq.), Cs_2CO_3 (47 mg, 0.15 mmol, 0.3 eq.) and NaI (21 mg, 0.15 mmol, 0.3 eq.). The mixture was stirred at 80 °C for 10 hours. LCMS showed the reaction was completed. The mixture was poured into water and extracted with EA. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated. The residue was purified by prep-HPLC to give the title compound 15 (30 mg, 2.7% yield) as colorless oil.

[00434] ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.63 (m, 67H), 2.66-2.84 (m, 5H), 3.40-3.43 (m, 8H), 3.53-3.66 (m, 1H), 4.43-4.46 (m, 2H). LCMS: Rt: 1.590 min; MS m/z (ESI): 742.7 $[M+H]^+$.

[00435] The following compounds were prepared in analogous fashion as Compound 15, using corresponding starting material.

Compound	Characterization
 Compound 17	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.82-0.90 (m, 12H), 1.22-1.43 (m, 48H), 1.54-1.65 (m, 16H), 1.72-1.89 (m, 3H), 3.00-3.24 (m, 4H), 3.35-3.43 (m, 4H), 3.51-3.63 (m, 6H), 3.71-3.80 (m, 2H), 3.87-3.96 (m, 2H), 4.37-4.51(m, 2H). LCMS: Rt: 1.125 min; MS m/z (ESI): 786.7 $[M+H]^+$.
 Compound 18	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.82-0.90 (m, 12H), 1.18-1.43(m, 50H), 1.54-1.66 (m, 20H), 2.30-2.59 (m, 5H), 3.37-3.44 (m, 4H), 3.50-3.63(m, 6H), 4.43-4.48 (m, 2H). LCMS: Rt: 1.125 min; MS m/z (ESI): 770.7 $[M+H]^+$.
 Compound 19	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.89 (m, 12H), 1.27-1.38 (m, 46H), 1.54-1.59 (m, 24H), 1.60-1.75 (m, 6H), 2.89-2.97 (m, 4H), 3.41-3.54 (m, 8H), 3.56-4.43 (m, 1H). LCMS: Rt: 1.430 min; MS m/z (ESI): 784.7 $[M+H]^+$.

6.11 Example 11: Preparation of Compound 20.



Step 1: Preparation of compound 20-3

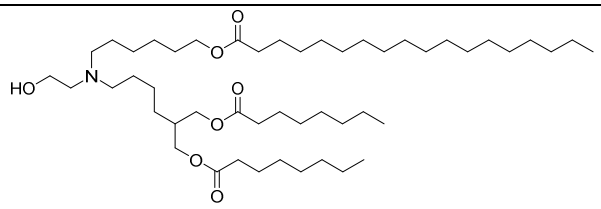
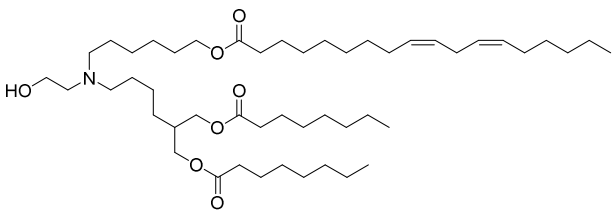
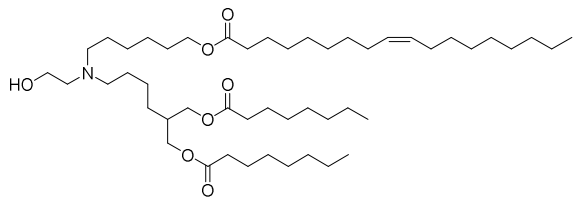
[00436] To a solution of compound 20-1 (10 g, 55.2 mmol, 1.0 eq.) and compound 20-2 (14.1 g, 55.2 mmol, 1.0 eq.) in toluene (100 mL) was added TsOH (2 g). The mixture was stirred at reflux for 2 hours with water separator. The mixture was concentrated and FCC to give the title compound (18 g, 77.73%) as colorless oil.

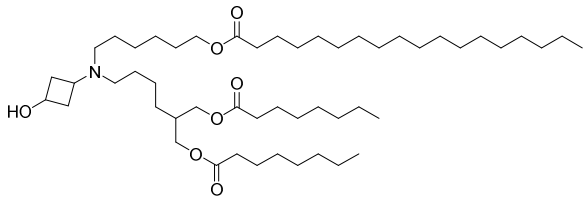
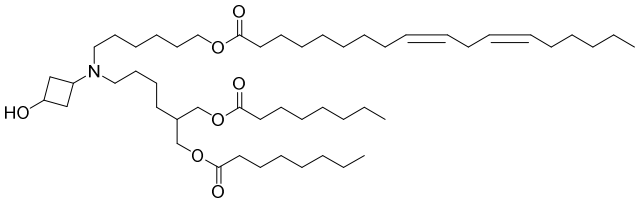
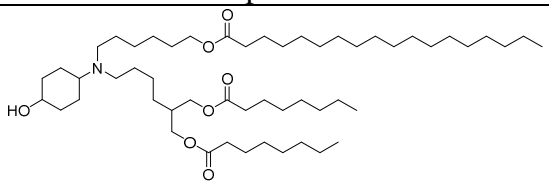
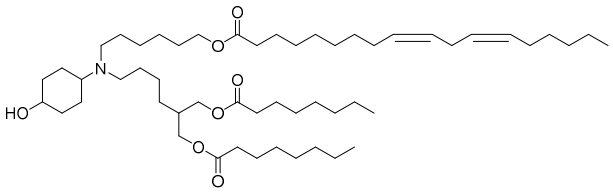
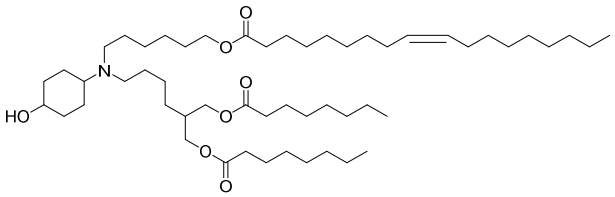
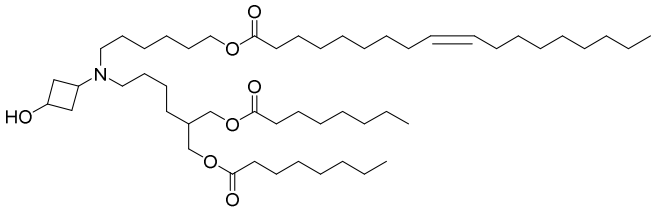
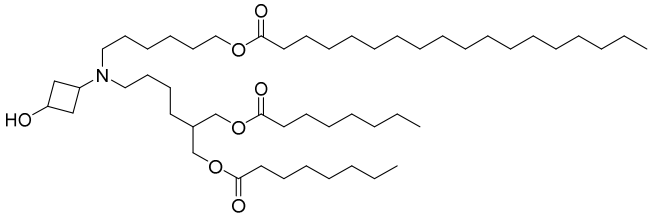
Step 2: Preparation of compound 20

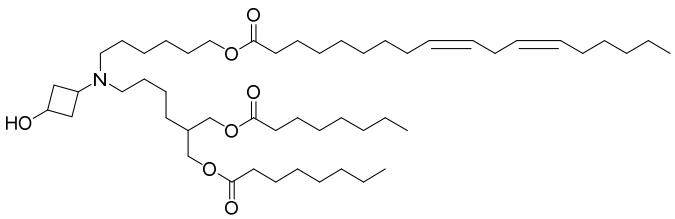
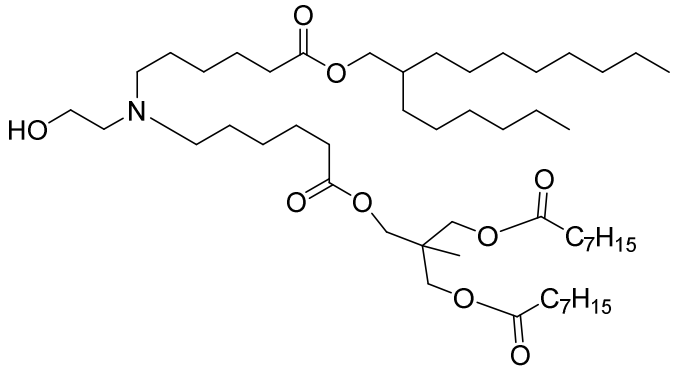
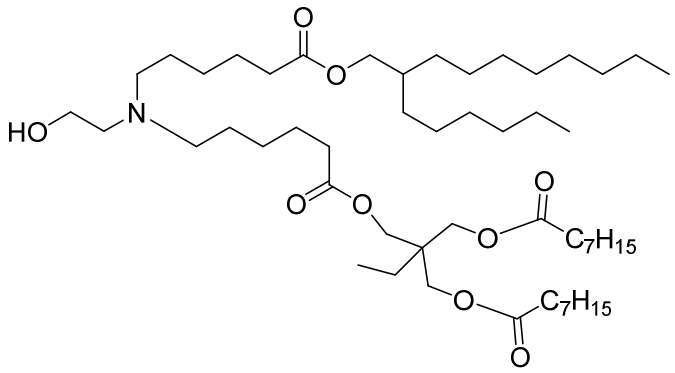
[00437] To a solution of compound 20-3 (570 mg, 1.35 mmol, 3.0 eq.) and compound SM16 (200 mg, 0.45 mmol, 1.0 eq.) in ACN (10 mL) was added K_2CO_3 (190 mg, 1.35 mmol, 3.0 eq.), Cs_2CO_3 (46 mg, 0.14 mmol, 0.3 eq.) and NaI (21 mg, 0.14 mmol, 0.3 eq.). The mixture was stirred at 80 ℃ for 16 hours. LCMS showed the reaction was complete. The reaction mixture was concentrated and purified by prep HPLC to get the title compound (80 mg, 22.73%) as yellow oil.

[00438] ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 9H), 1.25-1.36 (m, 48H), 1.41-1.48 (m, 5H), 1.60-1.62 (m, 8H), 1.97-2.00 (m, 1H), 2.27-2.32 (m, 6H), 2.43-2.46 (m, 4H), 2.56-2.59 (m, 2H), 3.52-3.54 (m, 2H), 4.01-4.10 (m, 6H). LCMS: Rt: 0.093 min; MS m/z (ESI): 782.6 $[M+H]^+$.

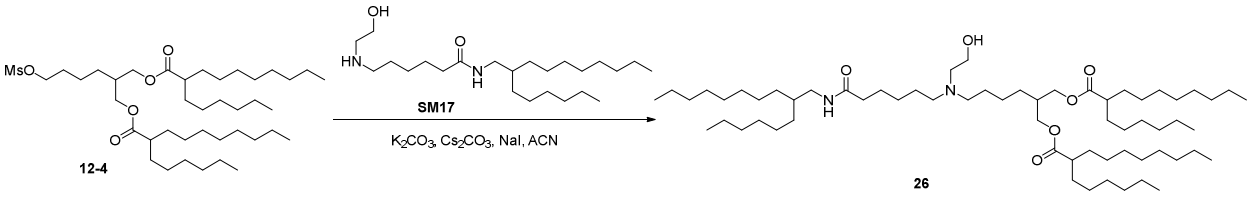
[00439] The following compounds were prepared in analogous fashion as Compound 20, using corresponding starting material.

Compound	Characterization
 Compound 21	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.88-0.99 (m, 9H), 1.28-1.30 (m, 44H), 1.42-1.56 (m, 8H), 1.59-1.63 (m, 12H), 1.64-1.90 (m, 4H), 2.27-2.33 (m, 6H), 3.03-3.23 (m, 4H), 4.03-4.07 (m, 8H). LCMS: Rt: 1.610 min; MS m/z (ESI): 810.6 $[M+H]^+$.
 Compound 22	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.91 (m, 9H), 1.29-1.36 (m, 38H), 1.41-1.48 (m, 4H), 1.60-1.62 (m, 9H), 1.95-2.07 (m, 5H), 2.27-2.32 (m, 6H), 2.43-2.46 (m, 4H), 2.56-2.59 (m, 2H), 2.75-2.79 (m, 2H), 3.51-3.54 (m, 2H), 4.01-4.10 (m, 6H), 5.30-5.42 (m, 4H). LCMS: Rt: 0.093 min; MS m/z (ESI): 806.6 $[M+H]^+$.
 Compound 24	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.89 (m, 9H), 1.27-1.39 (m, 42H), 1.59-1.67(m, 18H), 1.99-2.01 (m, 6H), 2.27-2.32 (m, 6H), 2.69-3.12 (m, 4H), 4.00-4.09 (m, 6H), 5.32-5.35 (m, 2H). LCMS: Rt: 1.100 min; MS m/z (ESI): 808.6 $[M+H]^+$.

 Compound 32	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 9H), 1.25-1.39 (m, 54H), 1.56-1.79 (m, 15H), 1.97-2.00 (m, 2H), 2.27-2.39 (m, 9H), 2.51-2.58 (m, 2H), 3.93-4.08 (m, 6H). LCMS: Rt:4.887 min; MS m/z (ESI): 836.9 $[M+H]^+$.
 Compound 33	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.91 (m, 9H), 1.28-1.39 (m, 44H), 1.60-1.63 (m, 10H), 1.74-1.80 (m, 1H), 1.96-2.07 (m, 5H), 2.27-2.40 (m, 9H), 2.52-2.62 (m, 2H) , 2.75-2.78 (m, 2H), 3.96-4.09 (m, 7H), 5.32-5.37 (m, 4H). LCMS: Rt:4.297min; MS m/z (ESI): 833.0 $[M+H]^+$.
 Compound 36	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.7-1.2 (m, 9H), 1.20-1.41 (m, 50H), 1.42-1.57 (m, 24H), 1.62-0.98 (m, 6H), 1.99-2.26 (m, 6H), 4.02-4.05 (m, 6H). LCMS: Rt: 5.527min; MS m/z (ESI):865.3 $[M+H]^+$.
 Compound 37	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.06-0.08 (m, 9H), 1.25-1.31 (m, 40H), 1.39-1.55 (m, 22H), 1.62-2.04 (m, 10H), 2.32-3.03 (m, 5H), 2.32-2.91 (m, 3H), 4.02-4.06 (m, 5H), 5.34-5.36 (m, 3H). LCMS: Rt:4.297 min; MS m/z (ESI):861.25 $[M+H]^+$.
 Compound 38	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.83-0.897 (m, 9H), 1.24-1.41 (m, 48H), 1.34-1.55 (m, 23H), 1.99-2.01 (m, 5H), 2.26-2.37 (m, 6H), 3.99-4.10 (m, 6H), 5.32-5.35 (m, 2H). LCMS: Rt: 5.187min; MS m/z (ESI): 863.25 $[M+H]^+$.
 Compound 39	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.897 (m, 9H), 1.26-1.39 (m, 44H), 1.60-1.63 (m, 12H), 1.71-1.75 (m, 3H), 2.00-2.02 (m, 5H), 2.26-2.32 (m, 6H), 2.35-2.38 (m, 4H), 2.50-2.60 (m, 3H), 4.03-4.08 (m, 7H), 5.32-5.37 (m, 2H). LCMS: Rt: 4.607min; MS m/z (ESI): 834.7 $[M+H]^+$.
 Compound 57	^{1}H NMR (400 MHz, CDCl3) δ: 0.86-0.90 (m, 9 H), 1.25-1.39 (m, 54 H), 1.56-1.79 (m, 15 H), 1.97-2.00 (m, 2 H), 2.27-2.39 (m, 9 H), 2.51-2.58 (m, 2 H), 3.93-4.08 (m, 6 H). LCMS: Rt: 4.887 min; MS m/z (ESI): 836.9$[M+H]^+$.

 Compound 58	^{1}H NMR (400 MHz, CDCl3) δ: 0.86-0.91 (m, 9 H), 1.28-1.39 (m, 44 H), 1.60-1.63 (m, 10 H), 1.74-1.80 (m, 1 H), 1.96-2.07 (m, 5 H), 2.27-2.40 (m, 9 H), 2.52-2.62 (m, 2 H) , 2.75-2.78 (m, 2 H), 3.96-4.09 (m, 7 H), 5.32-5.37 (m, 4 H). LCMS: Rt: 4.297min; MS m/z (ESI): 833.0[M+H]$^+$.
 Compound 83	**^{1}H NMR (400 MHz, CDCl3) δ：** 0.86-0.89 (m, 12H), 1.01 (s, 3H),1.26-1.31 (m, 46H), 1.41-1.55 (m, 4H), 1.59-1.65 (m, 9H), 2.29-2.34 (m, 8H), 2.41-2.67 (m, 5H), 3.50-3.61 (m, 2H), 3.96-4.05 (m, 8H). **LCMS：** Rt: 0.080 min; MS m/z (ESI): 868.6[M+H]$^+$
 Compound 84	**^{1}H NMR (400 MHz, CDCl3) δ：** 0.86-0.90(m, 15H), 1.27-1.45 (m, 45H), 1.46-1.49 (m, 6H), 1.59-1.61 (m, 9H), 2.28-2.33 (m, 8H), 2.43-2.46 (m, 4H), 2.47-2.57 (m, 2H), 3.52-3.54 (m, 2H), 3.96-4.01 (m, 8H). **LCMS：** Rt:0.960 min; MS m/z (ESI): 882.7[M+H]$^+$.

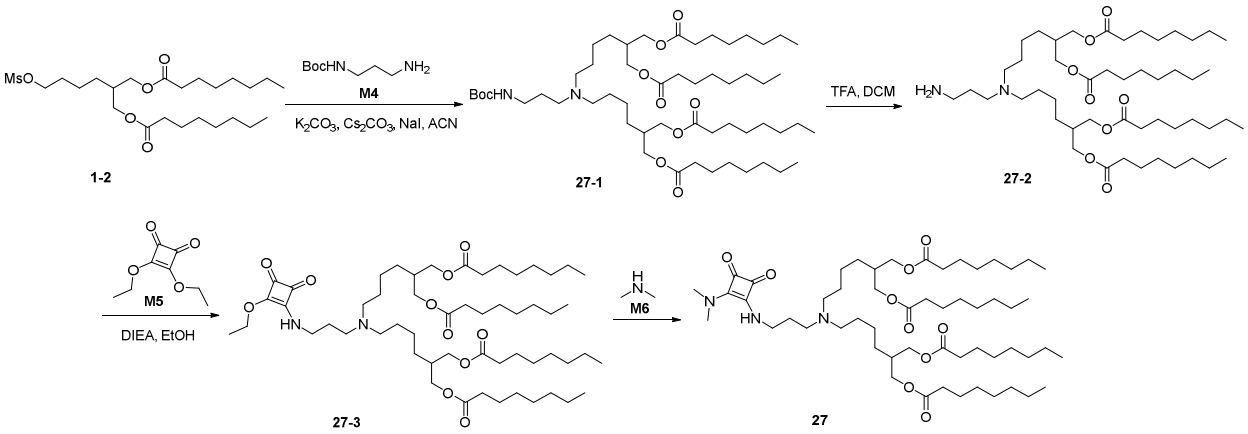
6.12 Example 12: Preparation of Compound 26.



[00440] To a solution of compound 12-4 (330 mg, 0.48 mmol, 1.0 eq.) and compound SM17 (190 mg, 0.48 mmol, 1.0 eq.) in ACN (10 mL) were added K_2CO_3 (200 mg, 1.44 mmol, 3.0 eq.), Cs_2CO_3 (46 mg, 0.14 mmol, 0.3 eq.) and NaI (21 mg, 0.14 mmol, 0.3 eq.). The mixture was stirred at 80 ℃ for 16 hours. LCMS showed the reaction was complete. The reaction mixture was concentrated and purified by prep HPLC to get the title compound (55 mg, 11.39%) as yellow oil.

[00441] ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.89 (m, 18H), 1.26-1.36 (m, 70H), 1.43-1.46 (m, 9H), 1.56-1.67 (m, 7H), 1.97-2.00 (m, 1H), 2.15-2.19 (m, 2H), 2.29-2.36 (m, 2H), 2.43-2.46 (m, 4H), 2.56-2.58 (m, 2H), 3.17-3.19 (m, 2H), 3.51-3.54 (m, 2H), 4.02-4.10 (m, 4H), 5.48 (s, 1H). LCMS: Rt: 0.093 min; MS m/z (ESI): 1005.9 $[M+H]^+$.

6.13 Example 13: Preparation of Compound 27.



Step 1: Preparation of compound 27-1

[00442] To a solution of compound 1-2 (1.3 g, 2.72 mmol, 3.0 eq.) and compound M4 (160 mg, 0.91 mmol, 1.0 eq.) in ACN (15 mL) was added K_2CO_3 (380 mg, 2.72 mmol, 3.0 eq.), Cs_2CO_3 (90 mg, 0.27 mmol, 0.3 eq.) and NaI (40 mg, 1.04 mmol, 0.3 eq.). The mixture was stirred at 80 °C for 16 hours. The reaction mixture was concentrated and purified by column chromatography on silica gel to give the title compound 27-1 (700 mg, 81.89% yield) as yellow oil.

Step 2: Preparation of compound 27-2

[00443] To a solution of compound 27-1 (700 mg, 0.75 mmol, 1.0 eq.) in DCM (10 mL) was added TFA (3 mL) at rt. The mixture was stirred for 16 hours. The mixture was concentrated to give the title compound 27-2 (700 mg, crude) as yellow oil.

Step 3: Preparation of compound 27-3

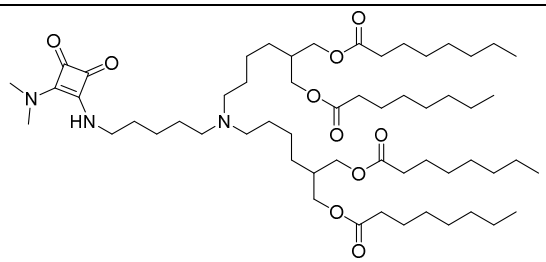
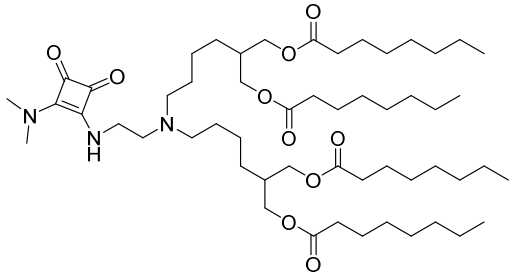
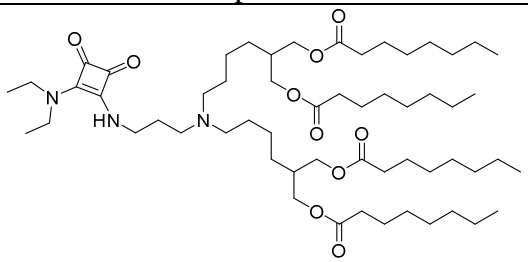
[00444] The mixture of compound 27-2 (700 mg, 0.75 mmol, 1.0 eq.) and compound M5 (640 mg, 3.75 mmol, 5.0 eq.) in EtOH (15 mL) was stirred for 16 hours at 40 °C. LCMS showed the reaction was complete. The mixture was used at the next step without workup. LCMS: Rt:0.827 min; MS m/z (ESI): 963.7 $[M+H]^+$.

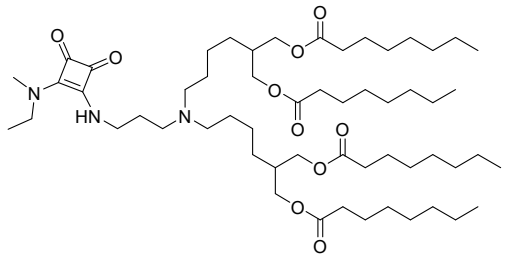
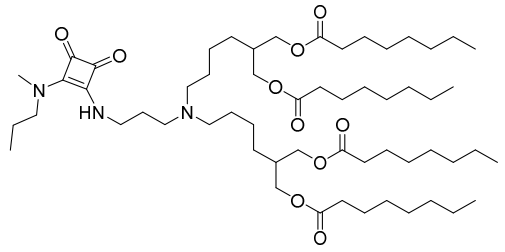
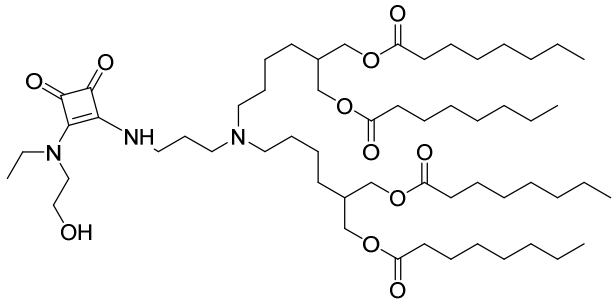
Step 4: Preparation of compound 27

[00445] To a stirred solution of compound 27-3 (700 mg, 0.75 mmol, 1.0 eq.) was added compound M6 (5 mL, 10 mmol, 13.0 eq.). The mixture was stirred at 40 ℃ for 16 hours. LCMS showed the reaction was complete. The reaction mixture was concentrated and purified by prep-HPLC to give the title compound 27 (120 mg, 18.36% yield) as yellow oil.

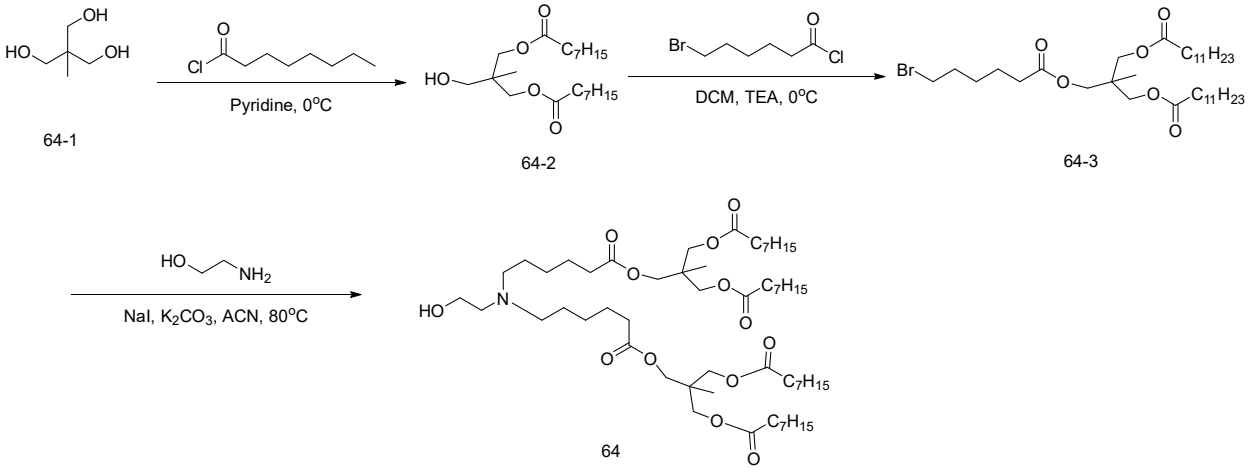
[00446] ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.42 (m, 42H), 1.59-1.74 (m, 12H), 1.95-2.00 (m, 2H), 2.29-2.32 (m, 8H), 2.41-2.44 (m, 4H), 2.59-2.61 (m, 2H), 3.21 (s, 6H), 3.86-3.90 (m, 2H), 4.00-4.11 (m, 8H), 7.44-7.46 (s, 1H). LCMS: Rt:0.093 min; MS m/z (ESI): 962.6 $[M+H]^+$.

[00447] The following compounds were prepared in analogous fashion as Compound 27, using corresponding starting material.

Compound	Characterization
 Compound 28	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.42 (m, 46H), 1.59-1.61 (m, 13H), 1.97-2.00 (m, 2H), 2.28-2.36 (m, 14H), 3.24 (s, 6H), 3.68-3.73 (m, 2H), 4.00-4.10 (m, 8H). LCMS: Rt:1.020 min; MS m/z (ESI): 990.7 $[M+H]^+$.
 Compound 30	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.79-0.83 (m, 12H), 1.07-1.41 (m, 46H), 1.51-1.58 (m, 11H), 1.86-1.93 (m, 2H), 2.19-2.25 (m, 8H), 2.34-2.44 (m, 2H), 2.53-2.62 (m, 1H), 3.06 -3.33 (m, 6H), 3.59-3.76 (m, 1H), 3.93-4.06 (m, 8H). LCMS: Rt: 1.165 min; MS m/z (ESI): 948.5 $[M+H]^+$.
 Compound 31	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.25-1.43 (m, 48H), 1.58-1.75 (m, 12H), 1.95-2.00 (m, 2H), 2.28-2.32 (m, 8H), 2.44 (s, 4H), 2.60 (s, 2H), 3.54 (s, 4H), 3.88-3.92 (m, 2H), 4.00-4.11 (m, 8H), 7.04 (s, 1H). LCMS: Rt: 0.080 min; MS m/z (ESI): 990.7 $[M+H]^+$.

 Compound 34	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.24-1.41 (m, 52H), 1.34-1.62 (m, 8H), 2.02-2.28 (m, 2H), 2.04-2.26 (m, 8H), 2.27-2.29 (m, 2H), 2.31-2.79 (m, 2H), 2.62-3.19 (m, 3H), 3.52-3.59 (m, 2H), 4.00-4.11 (m, 2H), 4.13-4.82 (m, 8H). LCMS: Rt: 1.090 min; MS m/z (ESI): 976.8 $[M+H]^+$.
 Compound 35	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 15H), 1.27-1.42 (m, 46H), 1.54-1.63 (m, 16H), 1.64-1.73 (m, 2H), 1.98-2.58 (m, 12H), 2.59-3.18 (m, 2H), 2.59-3.18 (m, 1H), 3.48-3.88 (m, 2H), 3.88-4.04 (m, 8H). LCMS: Rt: 1.200 min; MS m/z (ESI): 990.8 $[M+H]^+$.
 Compound 60	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.84-0.90 (m, 12H), 1.25-1.76 (m, 60H), 1.95-1.99 (m, 2H), 2.29-2.56 (m, 14H), 3.53-3.63 (m, 2H), 3.78-3.80 (m,4H), 4.00-4.11 (m, 8H), 7.01-7.26 (m,1H). LCMS: Rt: 1.100 min; MS m/z (ESI):1006.8 $[M+H]^+$.

6.14 Example 14: Preparation of Compound 64



Step 1: Preparation of compound 64-2

[00448] To a solution of 64-1 (1.0 g, 8.3 mmol, 1.0 eq) in pridine (10 mL) were added octanoyl chloride (2.97 g, 18.26 mmol, 2.2 eq). The mixture was stirred at 0°C for 1 hour. TLC showed the reaction was completed. The reaction mixture was poured into water and extracted with EA. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated. The residue was purified by silica gel column chromatography

(PE/EA=9/1) to give the title compound 64-2 (2.4 g, 77.77% yield) as yellow oil. ^{1}H NMR (400 MHz, CDCl3) δ: 0.80-0.85 (m, 6H), 0.90-0.95 (s, 3H), 1.20-1.40 (m, 16H), 1.50-1.72 (m, 4H), 2.25-2.38 (m, 4H), 2.40-2.65 (m, 1H), 3.31-3.41 (m, 2H), 3.90-4.10 (m, 4H).

Step 2: Preparation of compound 64-3

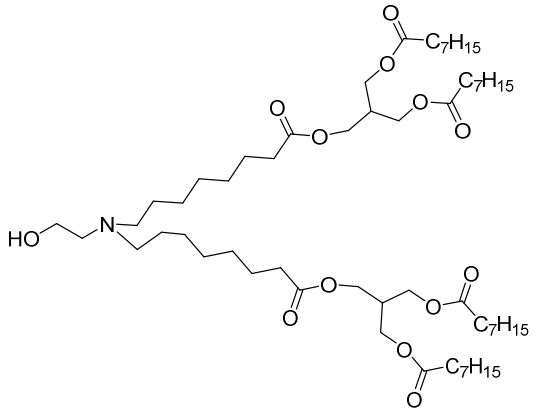
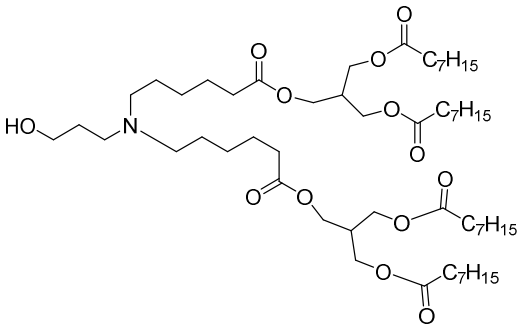
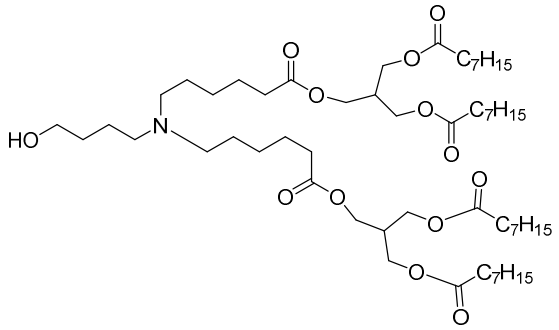
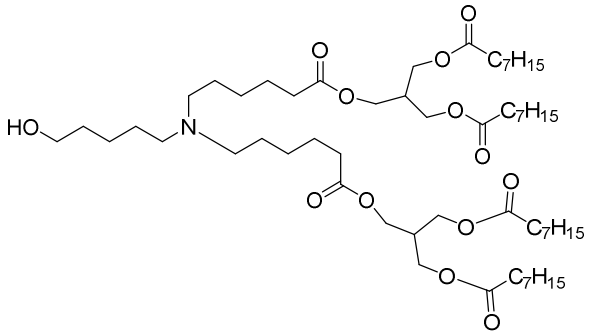
[00449] To a solution of 64-2 (1.0 g, 2.6 mmol, 1.0 eq) and TEA (0.4 g, 4.0 mmol, 1.5 eq) in DCM (50 mL) were added 6-bromohexanoyl chloride (0.85 g, 4.02 mmol, 1.5 eq). The mixture was stirred at 0 °C for 1 hour. TLC showed the reaction was completed. The reaction mixture was poured into water and extracted with EA. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated. The residue was purified by silica gel column chromatography (PE/EA=9/1) to give the title compound 64-3 (1.2 g, 83.91% yield) as yellow oil.

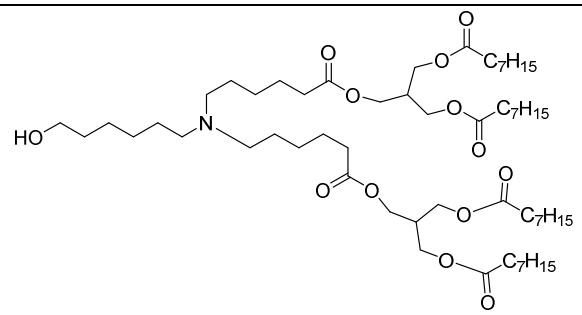
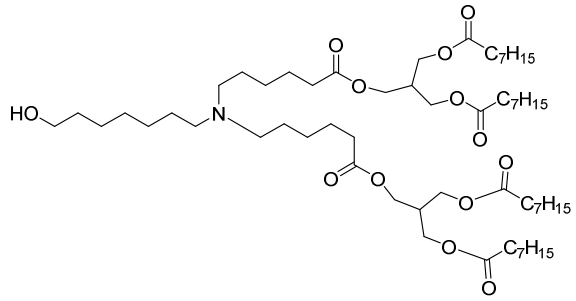
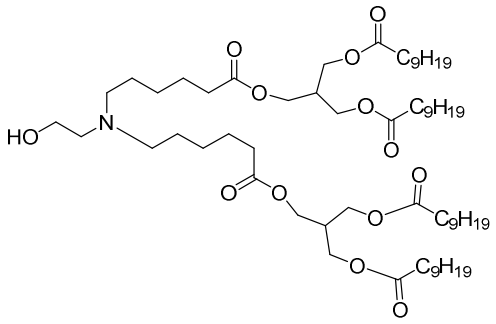
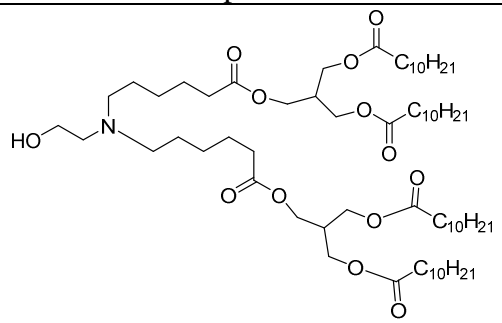
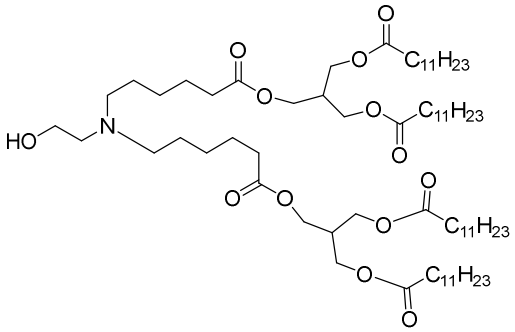
Step 3: Preparation of compound 64

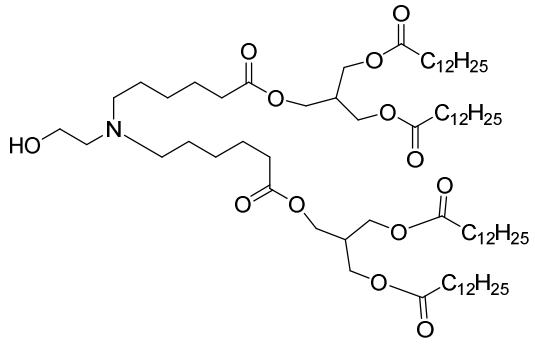
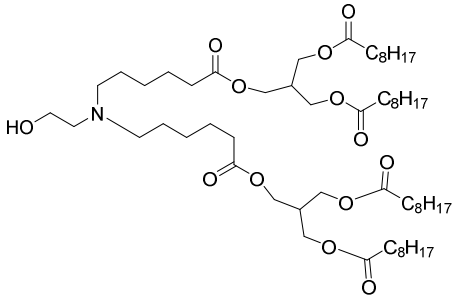
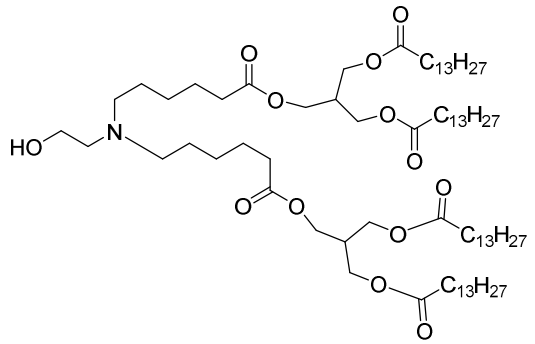
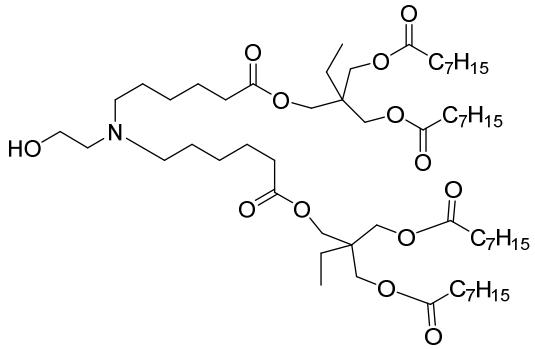
[00450] To a solution of 64-3 (462 mg, 0.84 mmol, 2.5 eq) and 2-aminoethanol (21 mg, 0.34 mmol, 1.0 eq) in ACN (20 mL) were added K_2CO_3 (116 mg, 0.84 mmol, 2.5 eq) and NaI (26 mg, 0.17 mmol, 0.5 eq). The reaction mixture was stirred at 80°C for 18 hours. LCMS showed the reaction was complete. The reaction mixture was poured into water and extracted with EA. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated. The residue was purified by pre-HPLC to give the title compound 64 (20 mg, 5.97% yield) as yellow oil.

[00451] ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.80-0.90 (m, 13H), 1.014 (s, 6H), 1.20-1.30 (m, 37H), 1.50-1.72 (m, 16H), 2.25-2.30 (m, 12H), 2.40-2.65 (m,4H), 3.61-3.64 (m, 2H), 3.90-4.10 (m, 12H). LCMS: Rt: 1.059 min; MS m/z (ESI): 998.8 $[M+H]^+$.

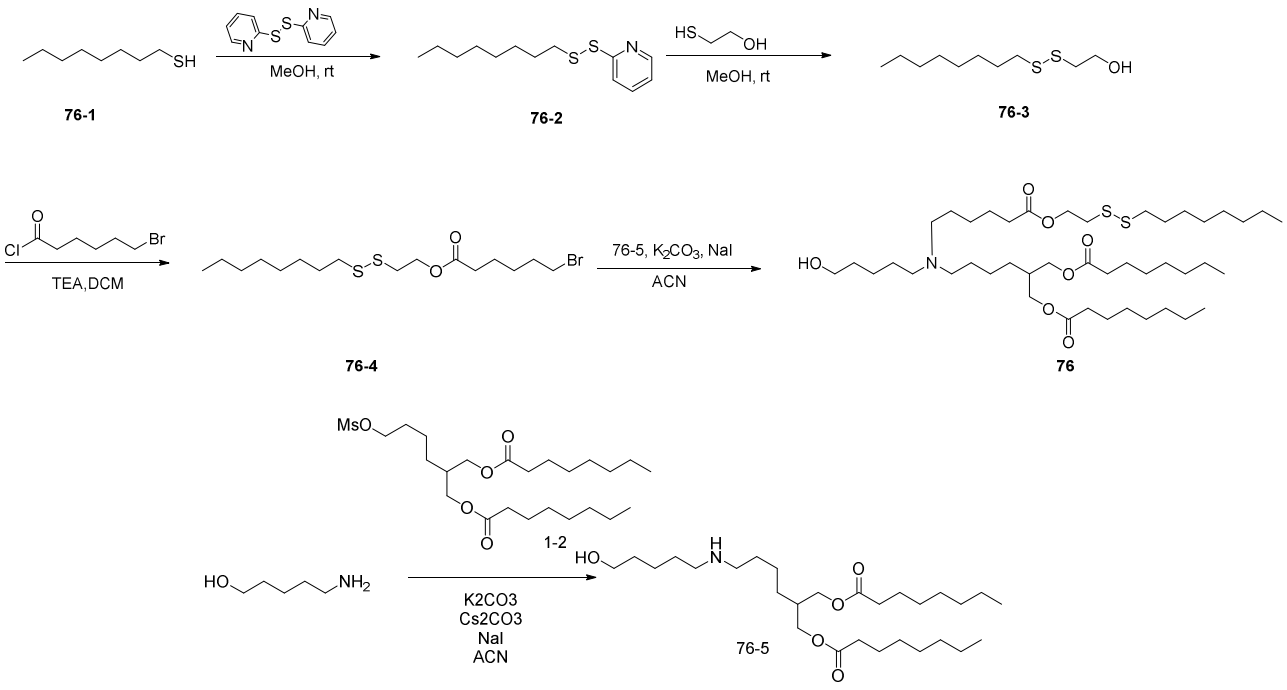
[00452] The following compounds were prepared in analogous fashion as Compound 64, using corresponding starting material.

Compound	Characterization
 Compound 65	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.30 (m, 45H), 1.38-1.45 (m, 4H), 1.57-1.63 (m, 12H), 2.28-2.46 (m,18H), 2.60 (m, 2H), 3.54 (m, 2H), 4.12-4.18 (m, 12H). LCMS: Rt: 0.080 min; MS m/z (ESI): 1026.7 $[M+H]^+$.
 Compound 66	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.35 (m, 37H), 1.45-1.52 (m, 4H), 1.57-1.69 (m, 14H), 2.28-2.44 (m,18H), 2.63-2.65 (m, 2H), 3.76-3.80 (m, 2H), 4.12-4.14 (m, 12H). LCMS: Rt: 0.080 min; MS m/z (ESI): 984.7 $[M+H]^+$.
 Compound 67	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.34(m, 44H), 1.48-1.66(m, 13H), 2.29-2.48(m, 20H), 3.51-3.59(m, 2H), 4.12-4.14(m, 12H). LCMS: Rt:0.870 min; MS m/z (ESI): 998.7 $[M+H]^+$.
 Compound 68	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.48(m, 45H), 1.59-1.65(m, 14H), 2.29-2.45(m, 20H), 3.61-3.67(m, 2H), 4.12-4.14(m, 12H). LCMS: Rt:0.880 min; MS m/z (ESI): 1012.7$[M+H]^+$.

 Compound 69	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.79-0.83 (m, 12H), 1.21-1.38 (m, 48H), 1.46-1.60 (m, 14H), 2.21-2.35 (m, 19H), 3.55-3.58 (m,2H), 4.05-4.07 (m, 12H). LCMS: Rt: 0.080 min; MS m/z (ESI): 1026.8 $[M+H]^+$.
 Compound 70	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.28-1.43 (m, 50H), 1.53-1.67 (m, 15H), 2.29-2.42 (m, 20H), 3.62-3.65 (m, 2H), 4.12-4.14 (m, 12H). LCMS: Rt: 0.413 min; MS m/z (ESI): 1054.8 $[M+H]^+$.
 Compound 71	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.83-0.90 (m, 12H), 1.26-1.34 (m, 51H), 1.44-1.48 (m, 5H), 1.59-1.65 (m, 13H), 2.28-2.47 (m,18H), 2.56-2.59 (m, 2H) ,3.51-3.55 (m, 2H) ,4.12-4.14 (m, 12H). LCMS: Rt: 0.080 min; MS m/z (ESI): 1082.9 $[M+H]^+$.
 Compound 72	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.26-1.28 (m, 64H), 1.59-1.67 (m, 16H), 2.28-2.32 (m, 15H), 2.34-2.42 (m, 4H), 4.12-4.14 (m, 12H). LCMS: Rt: 0.533 min; MS m/z (ESI): 1138.9$[M+H]^+$.
 Compound 73	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.80-0.88 (m, 12H), 1.19-1.30 (m, 72H), 1.40-1.52 (m, 4H), 1.50-1.65 (m, 13H), 2.31-2.41 (m, 12H), 2.44-2.46 (m,2H), 2.5-2.64 (m, 2H), 3.40-3.60 (m, 2H), 4.10-4.31 (m, 12H). LCMS: Rt: 0.067 min; MS m/z (ESI): 1194.9 $[M+H]^+$.

 Compound 74	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.26-1.59 (m, 78H), 1.61-1.65 (m, 15H), 2.29-2.64 (m, 20H), 3.51-3.59 (m, 2H), 4.12-4.14 (m, 12H). LCMS: Rt: 0.067 min; MS m/z (ESI): 1251.1 $[M+H]^+$.
 Compound 75	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 12H), 1.27-1.67 (m, 61H), 2.29-2.62 (m, 20H), 3.54-3.56 (m, 2H), 4.12-4.14 (m, 12H). LCMS: Rt:0.467 min; MS m/z (ESI): 1026.8 $[M+H]^+$.
 Compound 79	^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.79-0.82 (m, 12H), 1.11-1.29 (m, 91H), 1.47-1.62 (m, 17H), 2.21-2.25 (m, 12H), 4.05-4.06 (m, 12H), 4.26-4.35 (m, 1H), 4.58-4.67 (m, 2H). LCMS: Rt: 0.080 min; MS m/z (ESI): 1307.0 $[M+H]^+$.
 Compound 82	**^{1}H NMR (400 MHz, CDCl3) δ：** 0.86-0.90(m, 18H), 1.27-1.31 (m, 37H), 1.45-1.49 (m, 8H), 1.58-1.64 (m, 12H), 2.28-2.33 (m, 12H), 2.44-2.48 (m, 4H), 2.57-2.60 (m, 2H), 3.52-3.55 (m, 2H), 4.01(s, 12H)0 **LCMS：** Rt:0.400 min; MS m/z (ESI): 1026.7[M+H

6.15 Example 15: Preparation of Compound 76



Step 1: Preparation of compound 76-2

[00453] The mixture of 76-1 (2.7 g, 16.8 mmol, 1.0 eq), 1,2-di(pyridin-2-yl)disulfane (7.4 g, 33.7 mmol, 2.0 eq) in MeOH (50 ml) was stirred at RT for overnight. TLC showed 76-1 was consumed. The mixture was concentrated and the residue was diluted with DCM and washed with water and brine, dried and concentrated. The residue was purified by FCC to give the title product(3.2 g, 74.6% yield) as colorless oil.

Step 2: Preparation of compound 76-3

[00454] The mixture of 76-2 (3.1 g, 11.5 mmol, 1.0 eq), 2-mercaptoethanol (1.8 g, 23.0 mmol, 2.0 eq) in MeOH (50 ml) was stirred at RT for overnight. TLC showed 76-2 was consumed. The mixture was concentrated and the residue was diluted with DCM and washed with water and brine, dried and concentrated. The residue was purified by FCC to give the title product(2.3 g, 89.9% yield) as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.87-0.90 (m, 3H), 1.28-1.40 (m, 10H), 1.64-1.72 (m, 2H), 2.01 (s, 1H), 2.69-2.73 (m, 2H), 2.84-2.87 (m, 2H), 3.87-3.91 (m, 2H).

Step 3: Preparation of compound 76-4

[00455] The mixture of 76-3 (1.2 g, 5.4 mmol, 1.0 eq), TEA (1.1 g, 10.8 mmol, 2.0 eq) in DCM (30 ml) was added 6-bromohexanoyl chloride (1.4 g, 6.5 mmol, 1.2 eq) and stirred at RT for 2h. TLC showed 76-3 was consumed. The mixture diluted with DCM and washed

with water and brine, dried and concentrated. The residue was purified by FCC to give the title product (2.0 g, 94% yield) as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.87-0.90 (m, 3H), 1.25-1.40 (m, 12H), 1.47-1.54 (m, 2H), 1.67-1.72 (m, 4H), 1.85-1.92 (m, 2H), 2.33-2.37 (m, 2H), 2.68-2.72 (m, 2H), 2.88-2.92 (m, 2H), 3.39-3.43 (m, 2H), 4.32-4.35 (m, 2H).

Step 4: Preparation of compound 76-5

[00456] To a solution of 5-aminopentan-1-ol (7.76 g, 75.2 mmol, 3.0 eq) in ACN (50 mL) were added 1-2 (12 g, 25.06 mmol, 1.0 eq), K_2CO_3 (10.39 g, 75.2 mmol, 3.0 eq), Cs_2CO_3 (2.45 g, 7.52 mmol, 0.3 eq) and NaI (1.13g, 7.52 mmol, 0.3 eq). The mixture was stirred at 80 °C for 16 hours. TLC showed the reaction was complete. The mixture was poured into water and extracted with EA. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated. The crude product was purified by silica gel column chromatography (DCM/MeOH = 30/1) to give the title compound 76-5 (8.0 g, 22.3 % yield) as yellow oil.

Step 5: Preparation of compound 76

[00457] The mixture of 76-4 (300 mg, 0.8 mmol, 1.0 eq), 76-5 (364 mg, 0.8 mmol, 1.0 eq), K_2CO_3 (210 mg, 1.5 mmol, 2.0 eq) and NaI (60 mg, 0.4 mmol, 0.5 eq) in ACN (20 ml) was stirred at 80 °C for overnight. LCMS showed the title product. The mixture diluted with EA and washed with water and brine, dried and concentrated. The residue was purified by Pre-HPLC to give the title product (45 mg, 9.2% yield) as colorless oil.

[00458] ^{1}H NMR (400 MHz, $CDCl_3$) δ: 0.86-0.90 (m, 9H), 1.28-1.54 (m, 42H), 1.62-1.70 (m, 13H), 1.94-2.03 (m, 1H), 2.28-2.41 (m, 12H), 2.68-2.73 (m, 2H), 2.2.88-2.91 (m, 2H), 3.63-3.65 (m, 2H), 4.00-4.10 (m, 4H), 4.31-4.35 (m, 2H). LCMS: Rt:0.910 min; MS m/z (ESI): 804.6 $[M+H]^+$.

6.16 Example 16: Preparation and characterization of lipid nanoparticles

[00459] Briefly, a cationic lipid provided herein, DSPC, cholesterol, and PEG-lipid were solubilized in ethanol at a molar ratio of 50:10:38.5:1.5, and mRNA were diluted in 10 to 50 mM citrate buffer, pH = 4. The LNPs were prepared at a total lipid to mRNA weight ratio of approximately 10:1 to 30:1 by mixing the ethanolic lipid solution with the aqueous mRNA solution at a volume ratio of 1:3 using a microfluidic apparatus, total flow rate ranging from 9-30 mL/min. Ethanol were thereby removed and replaced by DPBS using dialysis. Finally, the lipid nanoparticles were filtered through a 0.2 μm sterile filter.

[00460] Lipid nanoparticle size were determined by dynamic light scattering using a Malvern Zetasizer Nano ZS (Malvern UK) using a 173º backscatter detection mode. The encapsulation efficiency of lipid nanoparticles were determined using a Quant-it Ribogreen RNA quantification assay kit (Thermo Fisher Scientific, UK) according to the manufacturer's instructions.

[00461] As reported in literature, the apparent pKa of LNP formulations correlates with the delivery efficiency of LNPs for nucleic acids *in vivo*. The apparent pKa of each formulation was determined using an assay based on fluorescence of 2-(p-toluidino)-6-napthalene sulfonic acid (TNS). LNP formulations comprising of cationic lipid / DSPC / cholesterol / DMG-PEG (50 /10 /38.5/1.5 mol %) in PBS were prepared as described above. TNS was prepared as a 300 µM stock solution in distilled water. LNP formulations were diluted to 0.1 mg/mL total lipid in 3 mL of buffered solutions containing 50 mM sodium citrate, 50 mM sodium phosphate, 50 mM sodium borate, and 30 mM sodium chloride where the pH ranged from 3 to 9. An aliquot of the TNS solution was added to give a final concentration of 0.1 mg/mL and following vortex mixing fluorescence intensity was measured at room temperature in a Molecular Devices Spectramax iD3 spectrometer using excitation and mission wavelengths of 325 nm and 435 nm. A sigmoidal best fit analysis was applied to the fluorescence data and the pKa value was measured as the pH giving rise to half – maximal fluorescent intensity.

6.17 Example 17: Animal Study 1

[00462] Lipid nanoparticles comprising compounds in the following table encapsulating human erythropoietin (hEPO) mRNA were systemically administered to 6-8 week old female ICR mice (Xipuer-Bikai, Shanghai) at 0.5 mg/kg dose by tail vein injection and mice blood were sampled at specific time points (e.g., 6 hours) post administration. In addition to the aforementioned tested groups, lipid nanoparticles comprising dilinoleylmethyl-4-dimethylaminobutyrate (DLin-MC3-DMA, usually abbreviated to MC3) encapsulating hEPO mRNA were similarly administered at the same dose to age and gender comparative groups of mice as a positive control.

[00463] Mice were euthanized by CO_2 overdoses after the last sampling time point. Serum were separated from total blood by centrifugation at 5000g for 10 minutes at 4 °C, snap-frozen and stored at -80 °C for analysis. ELISA assay were carried out using a commercial kit (DEP00, R&D systems) according to manufacturer's instructions.

[00464] Characteristics of tested lipid nanoparticles, including EPO expression levels over MC3 measured from the tested group are listed in the table below.

Table 2

Compound No.	Size (nm)	Polydispersity	Encapsulation efficiency	EPO expression over MC3	Apparent pKa
1	70.38	0.095	90.27%	A	
2	88.72	0.050	90.65%	A	
3	72.97	0.101	88.90%	A	6.726
4	95.73	0.120	87.94%	C	6.943
5	82.87	0.073	89.49%	A	
8	95.24	0.051	84.70%	C	6.992
9	111.6	0.046	87.29%	A	6.558
10	61.45	0.084	91.36%	B	6.624
11	59.17	0.082	85.63%	D	
12	56.95	0.053	87.61%	D	
14	91.43	0.049	82.84%	A	6.457
15	77.33	0.096	94.67%	C	6.219
16	68.14	0.021	90.78%	A	6.509
17	79.67	0.056	96.64%	C	6.189
18	62.64	0.057	93.58%	B	6.251
19	64.48	0.07	95.52%	B	6.216
20	72.72	0.078	91.22%	A	6.889
21	73.11	0.017	93.42%	B	6.962
22	79.16	0.051	89.98%	A	6.748
23	69.97	0.084	89.04%	A	6.601
24	70.66	0.07	90.29%	C	6.745
25	98.05	0.085	82.87%	B	6.418
26	55.11	0.01	85.33%	C	6.332
27	64.02	0.073	91.59%	A	6.404
28	68.48	0.077	89.90%	C	6.593
29	80.75	0.031	86.98%	A	6.513
31	72.36	0.073	88.17%	A	6.221
34	67.6	0.04761	89.70%	A	6.34
35	71.02	0.05652	89.19%	A	6.138
36	78.92	0.1156	85.90%	C	6.867
37	93.13	0.005279	88.34%	A	6.69
38	100.3	0.06385	87.69%	B	6.799
39	84.01	0.002	89.27%	C	6.801
40	66.72	0.1163	93.31%	N/A	

41	55.42	0.08791	95.98%	N/A	
42	77.38	0.0478	95.23%	C	6.657
43	64.77	0.057	89.21%	A	6.653
44	74.63	0.126	86.17%	N/A	
45	61.88	0.14	86.40%	N/A	
46	68.21	0.135	73.99%	N/A	
47	91.46	0.039	89.99%	A	6.767
48	92.53	0.027	84.12%	A	6.143
49	69.44	0.111	83.82%	N/A	
50	67.07	0.117	83.93%	N/A	
54	63.7	0.109	94.90%	B	6.679
59	168.4	0.066	72.86%	A	6.633
61	72.95	0.066	91.26%	C	7.32
62	71.06	0.031	88.45%	D	5.299
63	130.62	0.159	90.10%	C	6.297
64	83.57	0.094	94.94%	A	6.575
65	62.56	0.040	96.01%	A	6.338
66	113.3	0.010	95.46%	A	6.379
67	87.2	0.026	94.95%	A	6.705
68	100.16	0.010	94.91%	A	6.582
69	106.71	0.012	94.81%	B	6.271
70	67.7	0.037	95.70%	B	6.171
71	68.05	0.098	96.34%	A	6.599
72	72.07	0.111	96.28%	A	6.728
73	71.34	0.010	96.37%	C	6.536
74	66.23	0.012	94.82%	C	6.283
75	66.83	0.074	93.47%	A	6.703
82	69.37	0.010	95.75%	A	6.342
83	67.54	0.051	94.79%	A	6.547
84	72.82	0.022	94.81%	A	6.355

A: ≥ 2

B: ≥ 1 and < 2

C: ≥ 0.1 and < 1

D: < 0.1

6.18 Example 18: Animal Study 2

[00465] Lipid nanoparticles comprising compounds in the following table encapsulating mRNA encoding luciferase were systemically administered to 6-8 week old female Balb/c

mice (Charles River Lab, ZheJiang) at 0.25mg/kg dose by tail vein injection and mice blood were sampled at specific time points (*e.g.*, 6 hours) post administration. Optical imaging was performed using the IVIS Spectrum CT device (PerkinElmer Inc., Paris, France). The luminescence level was evaluated by an ROI applied to the injection site zone (Living Image software, PerkinElmer Inc., Paris, France). In addition to the aforementioned tested groups, lipid nanoparticles comprising dilinoleylmethyl-4-dimethylaminobutyrate (other names: DLin-MC3-DMA or MC3) encapsulating luciferase mRNA were similarly administered at the same dose to age and gender comparative groups of mice as a positive control.

[00466] Radiance of heart, liver, spleen, lung, kidney, brain and bone marrow were taken at 6 h after administration. The Dissected organs were placed on a black sheet and imaged with IVIS Spectrum CT (PerkinElmer, Hopkinton, MA). To quantify bioluminescence emission signal, identical regions of interest (ROI) were positioned to encircle each organ region, the imaging signal was quantitated as Total Flux [p/s]. The organ data of nanoparticle comprising Compound 76 is summarized in Table 4. As shown in Table 4, significant transduction and luciferase expression were observed in liver and spleen and the LNPs also demonstrated high absolute expression in the heart, spleen, lung, kidney, brain.

[00467] Characteristics of tested lipid nanoparticles, including luciferase expression levels over MC3 measured from the tested group are listed in the table below.

Table 3

Compound No.	Size (nm)	Polydispersity	Encapsulation efficiency	luciferase expression over MC3	Apparent pKa
57	86.07	0.026	90.36%	A	7.046
58	81.27	0.053	89.76%	A	6.948
60	73.37	0.011	93.20%	C	6.809
76	113.16	0.069	88.12%	B	6.762

A: ≥ 2

B: ≥ 1 and < 2

C: ≥ 0.1 and < 1

D: < 0.1

[00468] The bioluminescence emission data of the organs for nanoparticle comprising Compound 76 is summarized in the table below.

Table 4

Compound		Heart	Liver	spleen	Lung	Kidney	Brain	bone marrow
		Total Flux [p/s]						
76	ROI 1	3.97 E+06	1.40 E+09	6.70 E+08	5.18 E+06	1.06 E+07	4.60 E+06	2.09 E+06
	ROI 2	1.96 E+06	9.82 E+08	4.44 E+08	5.48 E+06	5.13 E+06	4.15 E+06	3.07 E+06
	ROI 3	2.41 E+06	1.38 E+09	2.89 E+08	4.33 E+06	8.54 E+06	5.13 E+06	2.94 E+06

6.19 Example 19: Lipid Clearance Study

[00469] LNPs were injected into mice via the tail vein (ICR female, IV, 0.5mg mRNA/kg), then mice were anesthetized under carbon dioxide at different time (*e.g.*, 6 h, 24 h, and 48 h) after administration and sacrificed via cardiac puncture. Liver tissue were collected immediately, and then washed by ice-cold saline. Liver samples were weighed and homogenized in ice water bath by adding pre-chilled 20% methanol-water (v/v) at 2~8 °C with the ratio of 1:5(w/v). The homogenized tissue samples were stored in -90 ~ -60 °C freezer prior to analysis.

[00470] Sample Processing. All liver tissue homogenate samples were allowed to thaw at room temperature. An aliquot of 50 µL of sample was added with 50 µL $MgCl_2$ (2M), then added with ACN which contains of Verapamil, 5 ng·mL^{-1} and Glibenclamide, 50 ng·mL^{-1} and Diclofenac, 200 ng·mL^{-1} and Tolbutamide, 200 ng·mL^{-1} for protein precipitation, then centrifuged at 13000 rpm for 8 min. Then 100 µL of supernatant was added with 100 µL water, then vortexed well. An aliquot of 5 µL of the mixture was injected into the LC-MS/MS system.

[00471] The results of MC3 and selected lipid compounds provided herein are listed in the table below.

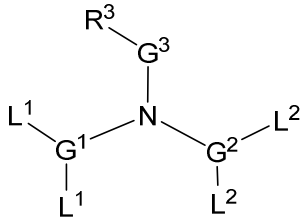
Table 5

Lipid	% Dose Remaining in Liver Tissue[a]		
	6 h	24 h	48 h
MC3	69.39%	61.63%	52.47%
5	2.646	0.098	0
8	1.274	0.068	0
9	1.071	0.089	0
10	0.981	0.19	0.038
11	3.1	0.537	0.139

[a] Percent of original lipid dose in mouse liver at different time after 0.5 mg/kg i.v. bolus dose mRNA

WHAT IS CLAIMED IS:

1. A compound of Formula (I):



(I),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof, wherein:

G^1 and G^2 are each independently C_2-C_{25} alkylene or C_2-C_{25} alkenylene, wherein one or more -CH_2- in G^1 and G^2 is optionally replaced by -O-, -C(=O)O-, or -OC(=O)-;

each L^1 is independently –OC(=O)R^1, -C(=O)OR^1, -OC(=O)OR^1, -C(=O)R^1, -OR^1, -S(O)$_x$$R^1$, -S-S$R^1$, -C(=O)S$R^1$, -SC(=O)$R^1$, -N$R^a$C(=O)$R^1$, -C(=O)N$R^b$$R^c$, -N$R^a$C(=O)N$R^b$$R^c$, -OC(=O)N$R^b$$R^c$, -N$R^a$C(=O)O$R^1$, -SC(=S)$R^1$, -C(=S)S$R^1$, -C(=S)$R^1$, -CH(OH)$R^1$, -P(=O)(O$R^b$)(O$R^c$), -N$R^a$P(=O)(O$R^b$)(O$R^c$);

each L^2 is independently –OC(=O)R^2, -C(=O)OR^2, -OC(=O)OR^2, -C(=O)R^2, -OR^2, -S(O)$_x$$R^2$, -S-S$R^2$, -C(=O)S$R^2$, -SC(=O)$R^2$, -N$R^d$C(=O)$R^2$, -C(=O)N$R^e$$R^f$, -N$R^d$C(=O)N$R^e$$R^f$, -OC(=O)N$R^e$$R^f$, -N$R^d$C(=O)O$R^2$, -SC(=S)$R^2$, -C(=S)S$R^2$, -C(=S)$R^2$, -CH(OH)$R^2$, -P(=O)(O$R^e$)(O$R^f$), -N$R^d$P(=O)(O$R^e$)(O$R^f$);

R^1 and R^2 are each independently C_6-C_{24} alkyl or C_6-C_{24} alkenyl, wherein one or more -CH_2- in R^1 and R^2 is optionally replaced by -S-S-;

R^a, R^b, R^d, and R^e are each independently H, C_1-C_{24} alkyl, or C_2-C_{24} alkenyl;

R^c and R^f are each independently C_1-C_{24} alkyl or C_2-C_{24} alkenyl, wherein one or more -CH_2- in R^c and R^f is optionally replaced by -S-S-;

G^3 is C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein part or all of alkylene or alkenylene is optionally replaced by a C_3-C_8 cycloalkylene or C_3-C_8 cycloalkenylene;

R^3 is -N(R^4)R^5, -OR^6, or -SR^6;

R^4 is C_1-C_{12} alkyl, C_2-C_{12} alkenyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

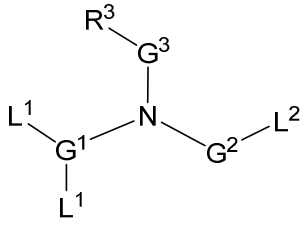
R^5 is H, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

R^6 is hydrogen, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, or C_6-C_{10} aryl;

x is 0, 1, or 2; and

wherein each alkyl, alkenyl, cycloalkyl, cycloalkenyl, heterocycloalkyl, aryl, alkylene, alkenylene, cycloalkylene, and cycloalkenylene is independently optionally substituted.

2. A compound of Formula (II):



(II),

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof, wherein:

G^1 and G^2 are each independently C_2-C_{25} alkylene or C_2-C_{25} alkenylene, wherein one or more -CH_2- in G^1 and G^2 is optionally replaced by -O-, -C(=O)O-, or -OC(=O)-;

each L^1 is independently –OC(=O)R^1, -C(=O)OR^1, -OC(=O)OR^1, -C(=O)R^1, -OR^1, -S(O)$_x$$R^1$, -S-S$R^1$, -C(=O)S$R^1$, -SC(=O)$R^1$, -N$R^a$C(=O)$R^1$, -C(=O)N$R^b$$R^c$, -N$R^a$C(=O)N$R^b$$R^c$, -OC(=O)N$R^b$$R^c$, -N$R^a$C(=O)O$R^1$, -SC(=S)$R^1$, -C(=S)S$R^1$, -C(=S)$R^1$, -CH(OH)$R^1$, -P(=O)(O$R^b$)(O$R^c$), -N$R^a$P(=O)(O$R^b$)(O$R^c$);

each L^2 is independently –OC(=O)R^2, -C(=O)OR^2, -OC(=O)OR^2, -C(=O)R^2, -OR^2, -S(O)$_x$$R^2$, -S-S$R^2$, -C(=O)S$R^2$, -SC(=O)$R^2$, -N$R^d$C(=O)$R^2$, -C(=O)N$R^e$$R^f$, -N$R^d$C(=O)N$R^e$$R^f$, -OC(=O)N$R^e$$R^f$, -N$R^d$C(=O)O$R^2$, -SC(=S)$R^2$, -C(=S)S$R^2$, -C(=S)$R^2$, -CH(OH)$R^2$, -P(=O)(O$R^e$)(O$R^f$), -N$R^d$P(=O)(O$R^e$)(O$R^f$);

R^1 and R^2 are each independently C_6-C_{24} alkyl or C_6-C_{24} alkenyl, wherein one or more -CH_2- in R^1 and R^2 is optionally replaced by -S-S-;

R^a, R^b, R^d, and R^e are each independently H, C_1-C_{24} alkyl, or C_2-C_{24} alkenyl;

R^c and R^f are each independently C_1-C_{24} alkyl or C_2-C_{24} alkenyl, wherein one or more -CH_2- in R^c and R^f is optionally replaced by -S-S-;

G^3 is C_2-C_{12} alkylene or C_2-C_{12} alkenylene, wherein part or all of alkylene or alkenylene is optionally replaced by a C_3-C_8 cycloalkylene or C_3-C_8 cycloalkenylene;

R^3 is -N(R^4)R^5, -OR^6, or -SR^6;

R^4 is C_1-C_{12} alkyl, C_2-C_{12} alkenyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

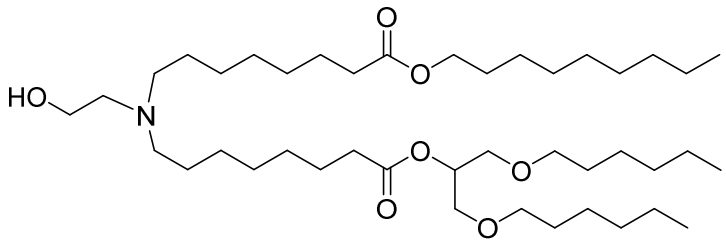
R^5 is H, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, C_6-C_{10} aryl, or 4- to 8-membered heterocycloalkyl;

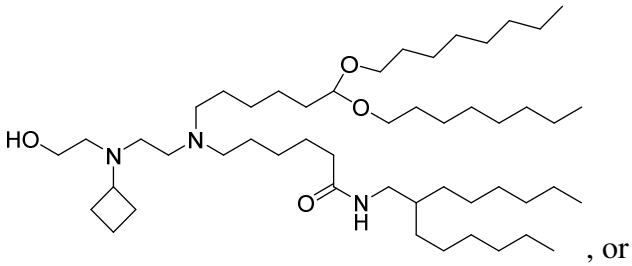
R^6 is hydrogen, C_1-C_{12} alkyl, C_3-C_8 cycloalkyl, C_3-C_8 cycloalkenyl, or C_6-C_{10} aryl;

x is 0, 1, or 2; and

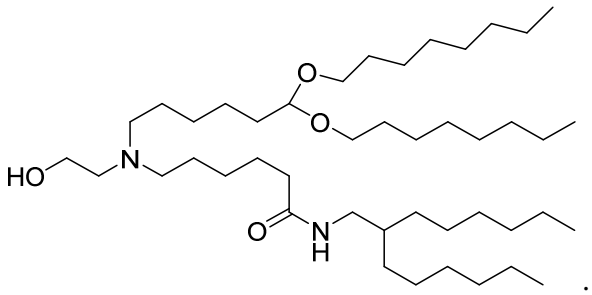
wherein each alkyl, alkenyl, cycloalkyl, cycloalkenyl, heterocycloalkyl, aryl, alkylene, alkenylene, cycloalkylene, and cycloalkenylene is independently optionally substituted;

provided that the compound is not:



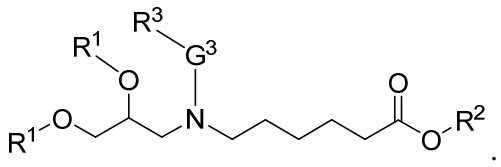


, or



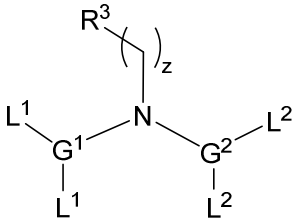
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3. The compound of claim 2, further provided that the compound is not

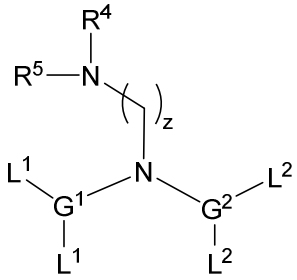


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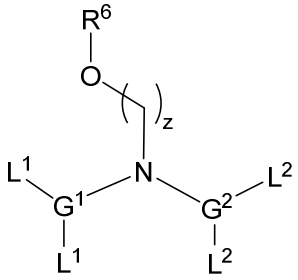
4. The compound of claim 1, which is a compound of Formula (III), (III-A), or (III-B):



(III),



(III-A), or

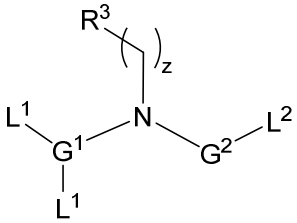


(III-B),

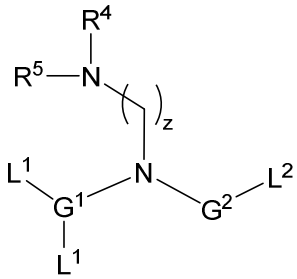
wherein z is an integer from 2 to 12,

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

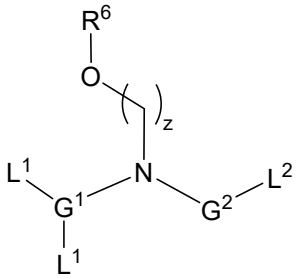
5. The compound of claim 2, which is a compound of Formula (IV), (IV-A), or (IV-B):



(IV),



(IV-A), or

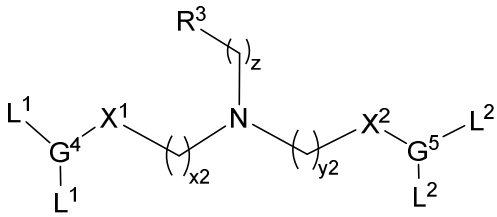


(IV-B),

wherein z is an integer from 2 to 12,

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

6. The compound of claim 1, which is a compound of Formula (V):



(V),

wherein X^1 and X^2 are each independently a bond, -O-, -C(=O)O-, or –OC(=O)-;

z is an integer from 2 to 12;

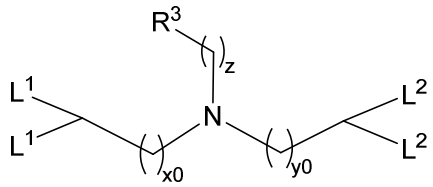
x2 is an integer from 2 to 12 when X^1 is -O-, -C(=O)O-, or –OC(=O)-, and x2 is an integer from 2 to 13 when X^1 is a bond;

y2 is an integer from 2 to 12 when X^2 is -O-, -C(=O)O-, or –OC(=O)-, and y2 is an integer from 2 to 13 when X^2 is a bond;

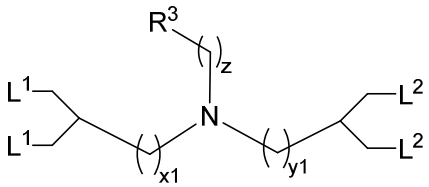
G^4 and G^5 are each independently C_2-C_{12} alkylene;

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

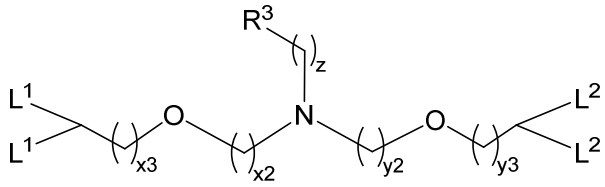
7. The compound of claim 12, wherein the compound is a compound of Formula (V-A), (V-B), (V-C), (V-D), (V-E), (V-F), or (V-G):



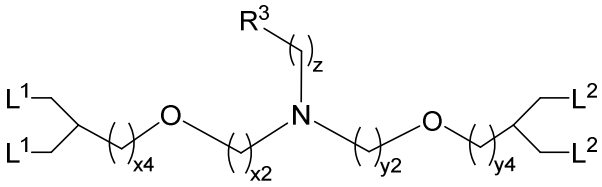
(V-A),



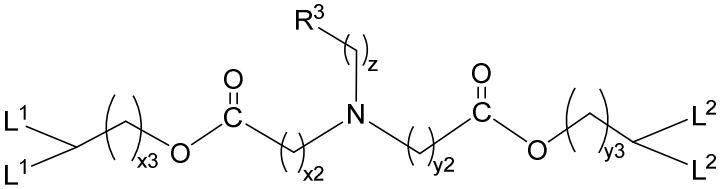
(V-B),



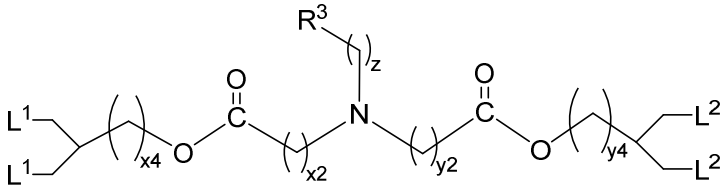
(V-C),



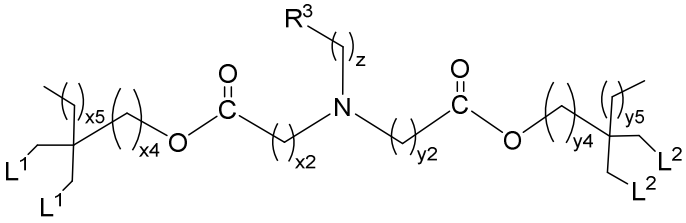
(V-D),



(V-E),



(V-F), or



(V-G),

wherein z is an integer from 2 to 12,

x0 is an integer from 1 to 11;

y0 is an integer from 1 to 11;

x1 is an integer from 0 to 9;

y1 is an integer from 0 to 9;

x2 is an integer from 2 to 12;

x3 is an integer from 1 to 5;

x4 is an integer from 0 to 3;

x5 is an integer from 0 to 5;

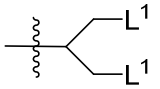
y2 is an integer from 2 to 12;

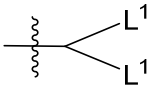
y3 is an integer from 1 to 5;

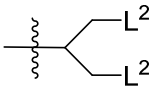
y4 is an integer from 0 to 3; and

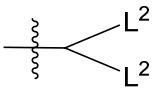
y5 is an integer from 0 to 5;

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

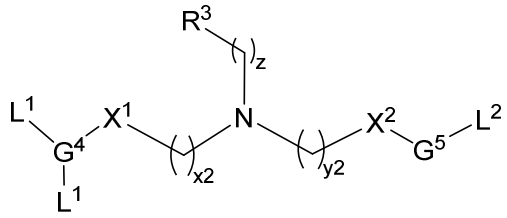
8. The compound of claim 7, wherein when there is a  moiety, each L^1 is independently $-OC(=O)R^1$;

when there is a  moiety, each L^1 is independently $-OR^1$;

when there is a  moiety, each L^2 is independently $-OC(=O)R^2$; or

when there is a  moiety, each L^2 is independently $-OR^2$.

9. The compound of claim 2, which is a compound of Formula (VI):



(VI),

wherein X^1 and X^2 are each independently a bond, -O-, -C(=O)O-, or –OC(=O)-;

z is an integer from 2 to 12;

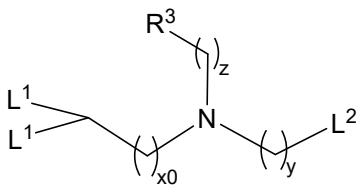
x2 is an integer from 2 to 12 when X^1 is -O-, -C(=O)O-, or –OC(=O)-, and x2 is an integer from 2 to 13 when X^1 is a bond;

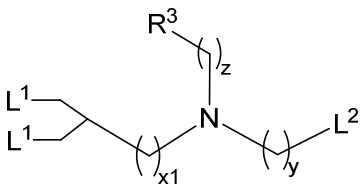
y2 is an integer from 2 to 12 when X^2 is -O-, -C(=O)O-, or –OC(=O)-, and y2 is an integer from 2 to 13 when X^2 is a bond;

G^4 and G^5 are each independently C_2-C_{12} alkylene;

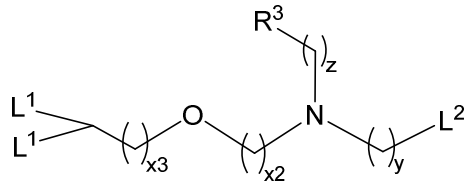
or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

10. The compound of claim 30, which is a compound of formula (VI-A), (VI-B), (VI-C), (VI-D), (VI-E), (VI-F), or (VI-G):

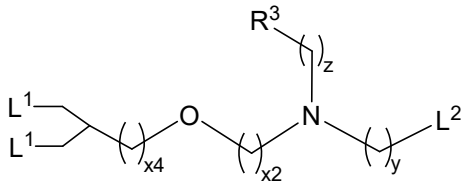




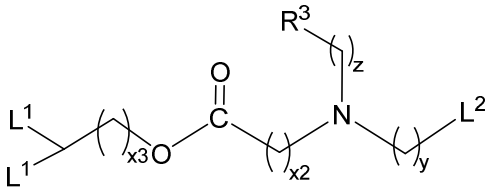
(VI-A),



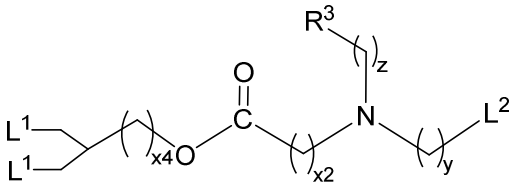
(VI-B),



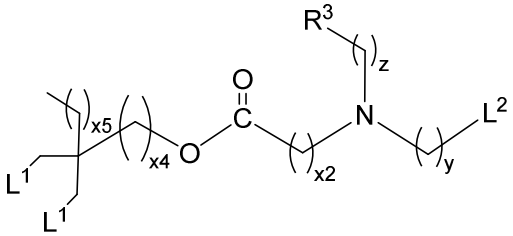
(VI-C),



(VI-D),



(VI-E),



(VI-F), or

(VI-G),

wherein z is an integer from 2 to 12;

y is an integer from 2 to 12;

x0 is an integer from 1 to 11;

x1 is an integer from 0 to 9;

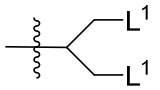
x2 is an integer from 2 to 12;

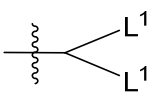
x3 is an integer from 1 to 5;

x4 is an integer from 0 to 3; and

x5 is an integer from 0 to 5;

or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

11. The compound of claim 10, wherein when there is a  moiety, each L^1 is independently $-OC(=O)R^1$; or

when there is a  moiety, each L^1 is independently $-OR^1$.

12. A compound in Table 1 or Table 1A, or a pharmaceutically acceptable salt, prodrug or stereoisomer thereof.

13. A composition comprising the compound of any one of claims 1 to 12, and a therapeutic or prophylactic agent.

14. A lipid nanoparticle comprising the compound of any one of claims 1 to 12, or the composition of claim 13.

15. A pharmaceutical composition comprising the compound of any one of claims 1 to 12, the composition of claim 13, or the lipid nanoparticle of claim 14, and a pharmaceutically acceptable excipient or diluent.

16. A method of delivering a therapeutic or prophylactic agent to a mammalian cell or organ, comprising contacting the mammalian cell or organ with the composition of claim 13, the lipid nanoparticle of claim 14 (wherein the lipid nanoparticle comprises the therapeutic or prophylactic agent), or the pharmaceutical composition of claim 15 (wherein the pharmaceutical composition comprises the therapeutic or prophylactic agent).