

METHODS AND COMPOSITIONS FOR DENDRITIC CELL TARGETING VACCINES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority of U.S. Provisional Patent Applications No. 63/458,102, filed on April 8, 2023, U.S. Provisional Patent Applications No. 63/587,231, filed on October 2, 2023, U.S. Provisional Patent Applications No. 63/588,932, filed on October 9, 2023, U.S. Provisional Patent Applications No. 63/549,343, filed on February 2, 2024, U.S. Provisional Patent Applications No. 63/575,093, filed on April 5, 2024, and PCT patent publication, filed on April 8, 2024, titled “METHODS AND COMPOSITIONS FOR DENDRITIC CELL TARGETING NANO-DELIVERY.” The entireties of the aforementioned applications are incorporated herein by reference.

SEQUENCE LISTING

[0002] The instant application contains a Sequence Listing, which has been submitted electronically in ASCII XML format under Rule ST.26 and is hereby incorporated by reference in its entirety. Said ASCII copy, created on April 5, 2024, is named A1000-01100PCT-3_20240405_SeqListing.xml and is 168 bytes in size.

FIELD

[0003] The instant disclosure relates to novel vaccine formulations for targeted nano-delivery. Specifically, the disclosure relates to compositions and methods directed to novel bi-functional nanoparticle vaccine formulations capable of selectively delivering a payload to a desired region in a tissue or a specific cell type, including dendritic cells.

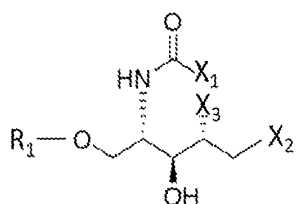
BACKGROUND OF THE INVENTION

[0004] Localized delivery via nanotechnology has been widely used in scientific, industrial, and clinical applications. It has increasingly become a promising way for drug delivery, providing advantages including improving solubility and penetration of drug molecules. In recent examples of the mRNA vaccines developed against COVID-19 viruses, in view of mRNA molecules' instability and need for low-temperature storage (e.g., -70°C), lipid nanoparticles (LNP) were developed to encapsulate and stabilize mRNA molecules both in transit and once injected into the human body. The lipid nanoparticles are usually composed of several types of lipids. The ratio of those lipids requires fine-tuning, and the

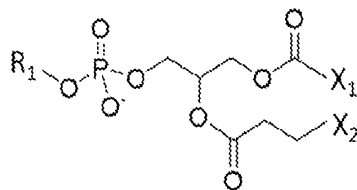
manufacturing of the lipid nanoparticles can be costly, and most importantly, the lipid nanoparticles generally cannot deliver the mRNA molecules with much localized selectivity. Therefore, there is an unmet need for novel vaccine nanoparticle formulations with selective delivery functionality.

BRIEF SUMMARY OF THE INVENTION

[0005] One aspect of the present disclosure is directed to a bi-functional compound for forming a lipid nanoparticle suitable for pharmaceutical vaccine formulation. The component comprises the formula:



Formula 1; or



Formula 2;

wherein R_1 comprises a substituted or non-substituted glycosyl group;

wherein X_1 and X_2 are each independently hydrogen, C_{1-30} alkyl, C_{1-30} alkenyl, C_{1-30} alkynyl, aryl, aryloxy, or a substituted version thereof, or

$-(CH_2)_nX_4$, n is 0 to 30, and X_4 is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X_4 is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N, or a combination thereof; and

wherein X_3 is hydrogen, C_{1-6} alkyl, or hydroxyl.

[0006] One aspect of the present disclosure is directed to a formulation for forming a lipid nanoparticle, comprising the compound of the present disclosure, wherein the compound comprises 1 to 10 mol% of the composition.

[0007] One aspect of the present disclosure is directed to a dendritic cell targeting vaccine comprising a lipid nanoparticle and/or a lipid nanoparticle formulation. The lipid nanoparticle and/or a lipid nanoparticle formulation comprises a membrane defining an inner space, wherein the membrane is formed with a plurality of lipid components comprising the compound of the present disclosure.

[0008] One aspect of the present disclosure is directed to a bi-functional targeting nanocarrier vaccine composition/formulation, which comprises the lipid nanoparticle of the present disclosure.

[0009] One aspect of the present disclosure is directed to a kit and/or a reagent mixture for preparing a lipid nanoparticle, comprising a first reagent, comprising the compound of the present disclosure; and a second reagent, comprising an ionizable lipid, a helper lipid, or a mixture thereof.

[0010] One aspect of the present disclosure is directed to a method of targeted immunogenic payload delivery in a subject in need thereof, comprising administering to the subject an effective amount of the targeting lipid nanoparticle of the present disclosure in a pharmaceutically acceptable vaccine formulation, wherein the payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof, and the payload is encapsulated by the lipid nanoparticle.

[0011] One aspect of the present disclosure is directed to a method of preventing or treating a disease in a subject in need thereof, comprising administering to the subject an effective amount of the targeting lipid nanoparticle of the present disclosure in a pharmaceutically acceptable vaccine formulation, wherein the payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof, and the payload is encapsulated within the lipid nanoparticle; and wherein the payload is an immunogenic/therapeutic agent or derivatives an immunogenic/therapeutic agent.

[0012] One aspect of the present disclosure is directed to a method of boosting an adaptive immune response, comprising administering to the subject an effective amount of the targeting lipid nanoparticle of the present disclosure in a pharmaceutically acceptable vaccine formulation, wherein the payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof, and the payload is encapsulated within the lipid nanoparticle; and wherein the payload is immunogenic or derivatives of an immunogenic biomolecule.

[0013] In certain embodiments of the bi-functional molecule and vaccine formulations thereof, Formula 1 can be structural and/or functional analogs/mimetics with cell-targeting functionalities, and Formula 2 can be structural/functional analogs/mimetics with lipid membrane insertion/anchoring functionalities.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 provides a graphic representation of the FACS analysis results demonstrating the efficacy of the exemplary inventive embodiments. The experiments demonstrated the uptake of the novel nano-delivery formulations targeting BDMCs, according to embodiments of the present disclosure, compared to traditional LNPs. The FITC+ values shown in the figures are fluorescent intensities in arbitrary units (A.U.).

[0015] FIG. 2 provides a graphic representation of the FACS analysis results demonstrating the efficacy of the exemplary novel dendritic cell targeting formulations of the present disclosure. The experiments showed the uptake of the exemplary novel dendritic targeting formulations, according to embodiments of the present disclosure, targeting dendritic cells (DC), B cells, and T cells, compared with conventional LNPs. The FITC+ values shown in the figures are fluorescent intensities in arbitrary units (A.U.).

[0016] FIG. 3 provides a graphic representation showing the FACS analysis results demonstrating the efficacy of the exemplary novel dendritic targeting formulations of the present disclosure. The experiments showed the uptake of the dendritic cell targeting formulations, according to embodiments of the present disclosure targeting BDMCs, compared with conventional LNPs. The FITC+ values shown in the figures are fluorescent intensities in arbitrary units (A.U.). 22-LNP represents the targeting formulation made using compound 22 of the present disclosure, and the percentage in parentheses indicates the molar ratio of compound 22. Likewise, 23-LNP represents the targeting formulation made using compound 23 of the present disclosure, and the percentage in parentheses indicates the molar ratio of compound 23. The negative control was an LNP without using the present disclosure's novel targeting compound/formulation (i.e., "traditional LNP" as described herein).

[0017] FIG. 4 provides a graphic representation showing the FACS analysis results demonstrating the efficacy of the exemplary novel dendritic cell targeting formulations of the present disclosure. The experiments showed the transfection of the targeting formulations targeting BDMCs compared with LNPs without the compound of the present disclosure. The FITC+ values shown in the figures are fluorescent intensities in arbitrary units (A.U.). 22-LNP represents the targeting formulation made using compound 22 of the present disclosure, and the percentage in parentheses indicates the molar ratio of compound 22. Likewise, 23-LNP represents the targeting formulation made using compound 23 of the present disclosure, and the percentage in parentheses indicates the molar ratio of compound 23. The negative

control was an LNP formed without using the present disclosure's novel targeting compound/formulation (i.e., "traditional LNP" as described herein).

[0018] FIG. 5 provides a graphic representation demonstrating the targeting efficacy and specificity of the exemplary formulation based on the distribution of the targeting LNPs in an animal model. The LNPs carried an mRNA configured to encode a luciferase in the targeted cells of the tested animals. The assay would generate detectable luminescence if the LNPs successfully transfect cells and the cells express the luciferase. The results clearly showed tissue-specific targeting of spleen and lymph tissue by the exemplary targeting formulation, thereby providing supporting evidence of immune cell (e.g., dendritic cell) specificity.

[0019] FIG. 6 shows the ^1H NMR spectrum of compound 12 of the present disclosure.

[0020] FIG. 7 shows the ^{13}C NMR spectrum of compound 12 of the present disclosure.

[0021] FIG. 8 presents bar charts showing the IFN γ (A) and IL-4 (B) induction by the exemplary targeting LNPs formulation according to an embodiment of the present disclosure *in vivo*. The sera were collected from experimental animals 2 hours, 24 hours, and 48 hours after administration.

[0022] FIG. 9 shows a graphic representation demonstrating the neutralization inhibitory effects of the exemplary LNPs of the present disclosure compared to control LNPs. The neutralization inhibition was evaluated against different dilution factors to show the difference between samples.

[0023] FIG. 10 provides a bar chart demonstrating that the exemplary LNPs according to the present disclosure, carrying mRNA encoding wide-type spike protein, were able to invoke IgG production *in vivo* against wild-type virus and Delta and Omicron strains thereof.

[0024] FIG. 11 shows a comparative bar chart demonstrating the IgG titer (A) and neutralization ability (B) induced respectively by commercially available LNPs vs. LNP formulation formulated based on, and/or constructed with, exemplary compounds according to embodiments of the present disclosure. Both LNPs carried mRNA encoding a wide-type spike protein.

[0025] FIG. 12 shows the LCMS spectrum of compound 21 of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0026] Nanoparticles have been widely used in various applications. Among them, **lipid nanoparticles (e.g., liposomes)** are the most well-established delivery systems for medicines due to their

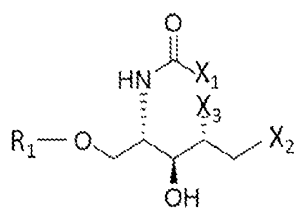
biocompatibility and biodegradability. A typical liposome has a bilayer structure formed by phospholipids due to their amphipathic properties. The bilayer structure (i.e., a bilayer membrane) encloses an inner space, which can encapsulate hydrophilic molecules, while the bilayer structure itself can carry hydrophobic molecules. Lipid nanoparticles (LNP) are also the most studied vehicles for delivering nucleic acids, such as RNA. By encapsulation, LNPs protect nucleic acids from extracellular nucleases, thus allowing for safe delivery to cells.

[0027] LNPs commonly have four kinds of lipid components in desired ratios: (i) helper lipid to encapsulate cargo, (ii) ionizable lipid to enhance endosomal escape and delivery, (iii) cholesterol to promote stability, and (iv) lipid-anchored polyethylene glycol (PEG-lipid) to reduce immune system recognition and improve biodistribution. Cholesterol and PEG-lipid can also be categorized as helper lipids. The properties of a liposome can be adjusted by selecting desired lipid components or ratios thereof. Without wishing to be bound by theories, targeting moieties can also be conjugated with the lipid components to provide selective delivery.

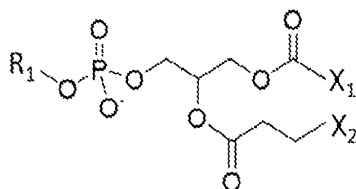
[0028] **TARGETING LIPID COMPOUND**

[0029] One aspect of the present disclosure provides a compound for forming a lipid nanoparticle (LNP) formulation suitable for specific cell targeting. In certain embodiments, the compound is a bi-functional compound containing a glycan-based cell targeting moiety and a lipid moiety, which can be incorporated into a lipid bi-layer such as an LNP. In some embodiments, the bi-functional compound is designed to have a targeting moiety configured to provide selective delivery functionalities as part of the bi-functional molecule and to have an exemplary lipid tail moiety capable of being incorporated into the lipid bilayer membrane of an exemplary formulation, including a lipid nanoparticle. The compound of the present disclosure can have a dual-tail structure, which comprises two extended structures (e.g., X_1 and X_2 group below). At least one of the two extended structures is configured to be incorporated into a bilayer membrane of the formed lipid nanoparticle. The term “incorporated into a bilayer” herein describes that at least a portion of the extended structure is incorporated into the bilayer. In some embodiments, the entire extended structure is incorporated into the bilayer, but the term is not limited to the scenario.

[0030] In one exemplary aspect, the compound of the present disclosure comprises:



Formula 1; or



Formula 2;

wherein R_1 comprises a substituted or non-substituted glycosyl group; wherein X_1 and X_2 are each independently hydrogen, alkyl, alkenyl, alkynyl, aryloxy, or a substituted version thereof, or $-(CH_2)_nX_4$, n is 0 to 50, and X_4 is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X_4 is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N; and wherein X_3 is hydrogen, C_{1-6} alkyl, or hydroxyl.

[0031] ***R₁ group***

[0032] ***Targeting Functionality.*** In certain embodiments, the R_1 group is configured to provide selective delivery or targeted delivery functionality for the exemplary LNP formulation formed by the component of the present disclosure. In some embodiments, the R_1 group is configured to target an antigen-presenting cell (e.g., a dendritic cell). In some embodiments, the target cell can be other types of immune cells. In yet some other embodiments, the target can be any biological cells where the payload is designed. In certain embodiments, the R_1 group is designed to have a targeting moiety, which can be a ligand of a receptor on a target cell. For example, the R_1 group might be configured to target the DC-SIGN of a dendritic cell.

[0033] Without wishing to be bound by theory, it is believed that mannoside and fucoside can bind a dendritic cell (e.g., via binding to DC-SIGN) with specificity. Therefore, in some embodiments, the R_1 group comprises a mannoside, fucoside, or both as the targeting moiety. The mannoside and/or the fucoside can be a terminal mannose or a terminal fucoside of the R_1 group, which might provide better chances to interact with a dendritic cell.

[0034] In some other embodiments, the R_1 group is configured to target Siglec-1, so the glycosyl group can comprise 9-N-(4H-thieno[3,2-c]chromene-2-carbamoyl)-Neu5Ac- α 2,3-Gal-GlcNAc. In some embodiments, the R_1 group is configured to target Siglec-2, and the glycosyl group can comprise 9-Biphenyl Neu5Ac- α 2,6-Gal-GlcNAc. In some embodiments, the R_1 group is configured to target Siglec-5/E, and the glycosyl group can comprise Neu5Ac- α 2,3-Gal-GlcNAc.

[0035] In some embodiments, the R_1 group comprises a formula of R_2-R_A , wherein R_2 is the substituted or non-substituted glycosyl group, and R_A is an attachment group, and wherein the attachment group is an aryl, an alkyl, an amide, an alkyl amide, a combination thereof, or a covalent bond. In some embodiments, the aryl comprises 0 to 3 substituents (e.g., 1 to 3 substituents), wherein the substituent of the aryl is C_{1-6} alkyl, halide, or C_{1-6} alkyl halide. In some embodiments, the attachment group is configured to provide structural flexibilities and/or facilitate the binding between the targeting moiety and the target. In certain embodiments, R_2 is conjugated covalently to R_A at a carbon of the glycosyl group, resulting in an O-glycosylation.

[0036] *Binding in acidic conditions.* In some embodiments, the binding between the glycosyl group of R_1 and a target is Ca^{2+} -correlated, and the calcium coordination might decrease at a low pH environment, resulting in lower binding affinity. Therefore, to provide a better binding affinity under acidic conditions, the attachment group can comprise an aryl group. Without wishing to be bound by any theories, the aryl group may engage in the CH- π and hydrophobic interactions that enhance the binding under acidic conditions. The aryl group can be an unsubstituted benzene or a benzene substituted with a halide or an alkyl halide (e.g., a CF_3). In some embodiments, the aryl group is coupled with the targeting moiety. For example, the R_1 group can comprise an O-aryl mannoside.

[0037] *Spacer.* In some embodiments, the attachment group of R_1 comprises a spacer. The spacer is configured to provide structural flexibility to R_1 . Without wishing to be bound by theories, the flexibility allows the glycosyl group of R_1 to move during the interaction between the targeting moiety and the target, thereby facilitating the binding between them.

[0038] In certain embodiments, a preferred spacer is biocompatible. In some embodiments, the initiator spacer comprises a saturated carbon moiety, a polyethylene glycol (PEG) moiety, or a combination thereof. For example, the spacer can be a polyethylene glycol (PEG) moiety, formed by 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 18, 20, 24, 30, 36, 40, 48, 50, 55, 60, 65, or 72 (OCH_2CH_2) subunits, or any ranges defined by the foregoing endpoints, such as 2 to 72, 2 to 60, 2 to 48, 2 to 36, 2 to 24, 2 to 18, 2 to 15, 2 to 10, 4 to 72, 4 to 60, 4 to 48, 4 to 36, 4 to 24, 4 to 18, 4 to 15, 4 to 10, 8 to 72, 8 to 60, 8 to 48, 8 to

36, 8 to 24, 8 to 18, 8 to 15, or 8 to 10 (OCH₂CH₂) subunits. In some embodiments, the PEG moiety can be a linear, branched, or star structure.

[0039] *Structural configuration.* In certain embodiments, the glycosyl group can be a linear structure or a branched structure. In some embodiments, the glycosyl group might have a plurality of targeting moieties, for example, 2, 3, 4, 5, 6, 7, 8, 9, or 10 targeting moieties. The plurality of targeting moieties can be arranged in a linear, branched, or star configuration. For example, the glycosyl group might comprise a mono-mannoside, a di-mannoside, or a tri-mannoside, and when the glycosyl group comprises a tri-mannoside, the tri-mannoside can be a linear form or a branched structure, such as a α -1,3- α -1,6-trimannoside. In certain embodiments, it is noticed that a branched configuration (e.g., a tri-mannoside glycan head) shows superior binding affinity to its target receptor.

[0040] In some embodiments, the R₁ group is a substituted glycosyl group. The glycosyl group might comprise 1 to 6 substituents, and each substituent can be C₁₋₆ alkyl, C₁₋₆ alkenyl, halogen, C₁₋₆ alkyl halide, C₁₋₆ alkoxy, amine, nitro, C₁₋₆ alkyl amine, amide, azido, aryl, cycloalkyl, heterocycloalkyl, sulfite, or a substituted version thereof, or a combination thereof. In certain embodiments, the substituent is conjugated to a carbon of the glycosyl group directly or is conjugated to the carbon via an O-yl conjugation (e.g., by replacing the hydrogen of the hydroxyl group on the carbon).

[0041] In certain embodiments, the substituent of the glycosyl group is selected from the group consisting of aryl, 5-membered cycloalkyl, 6-membered cycloalkyl, 5-membered heterocycloalkyl, and 6-membered heterocycloalkyl, and a substituted version thereof, which comprises 1 to 6 substituents selected from the group consisting of C₁₋₆ alkyl, halogen, C₁₋₆ alkyl halide, C₁₋₆ alkoxy, amine, nitro, C₁₋₆ alkyl amine, azido, amide, carboxyl, hydroxyl, aryl, cycloalkyl, heterocycloalkyl, or a substituted version thereof, or a combination thereof. In some embodiments, the heterocycloalkyl comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N.

[0042] In some embodiments, the substituent of the glycosyl group is a substituted or non-substituted aryl, for example, a substituted or non-substituted phenyl group. In certain embodiments, the aryl is substituted with 1 to 6 substituents, each is independently selected from the group consisting of C₁₋₆ alkyl, halogen, C₁₋₆ alkyl halide, C₁₋₆ alkoxy, amine, nitro, C₁₋₆ alkyl amine, azido, amide, carboxyl, hydroxyl, aryl, cycloalkyl, heterocycloalkyl, or a substituted version thereof, or a combination thereof. In certain embodiments, the substituent of the glycosyl group is a phenyl (benzene ring) substituted with OH, CH₃, NH₂, CF₃, OCH₃, F, Br, Cl, NO₂, N₃, or a combination thereof. For example, the substituted benzene ring can be a phenol group.

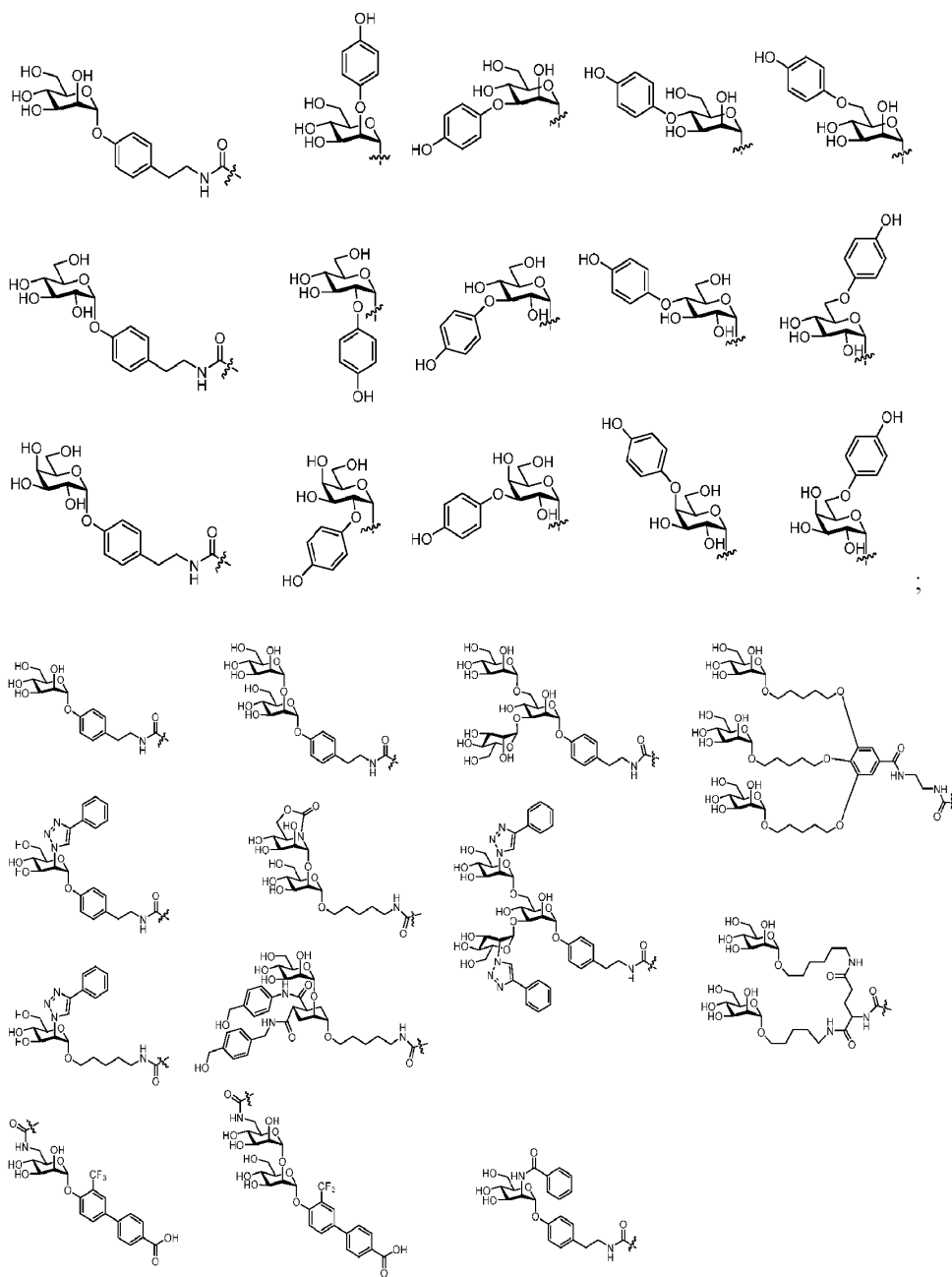
[0043] In some embodiments, the R₁ group is a mono-mannoside substituted with 1 to 6 substituents, and each substituent can be C₁₋₆ alkyl, C₁₋₆ alkenyl, halogen, C₁₋₆ alkyl halide, amine, C₁₋₆ alkyl amine, amide, aryl, cycloalkyl, heterocycloalkyl, sulfite, or a substituted version thereof, or a combination thereof. In certain embodiments, the R₁ group is a mono-mannoside substituted with a first substitute and a second substitute; each of the first substitute and the second substitute is independently selected from a group consisting of C₁₋₆ alkyl, C₁₋₆ alkenyl, halogen, C₁₋₆ alkyl halide, amine, C₁₋₆ alkyl amine, amide, aryl, cycloalkyl, heterocycloalkyl, and sulfite.

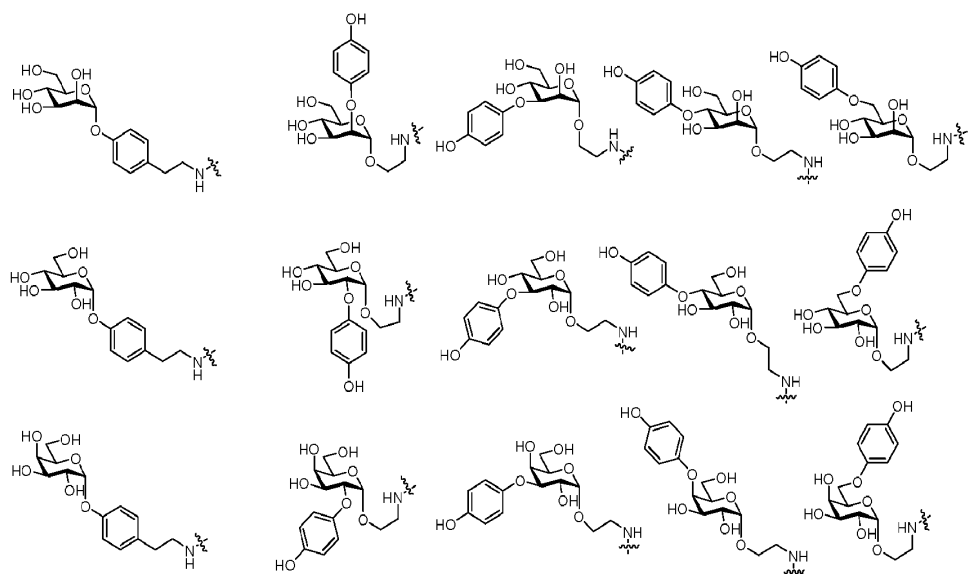
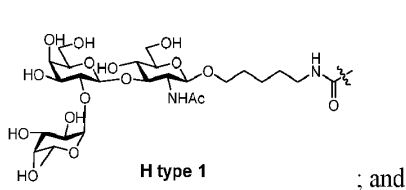
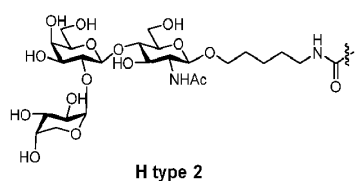
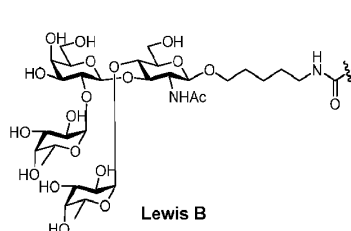
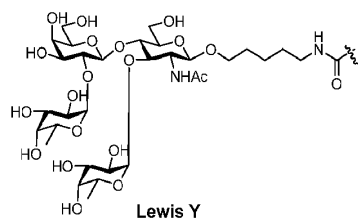
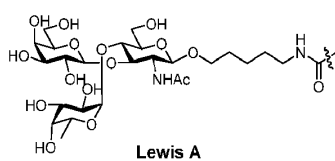
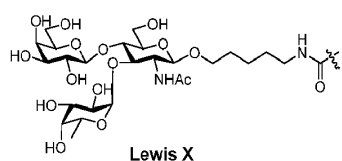
[0044] In some embodiments, the R₁ group comprises a first mannoside and a second mannoside. Each of the first mannoside and the second mannoside is independently substituted with 1 to 6 substituents, and each substituent can be C₁₋₆ alkyl, C₁₋₆ alkenyl, halogen, C₁₋₆ alkyl halide, amine, C₁₋₆ alkyl amine, amide, aryl, cycloalkyl, heterocycloalkyl, sulfite, or a substituted version thereof, or a combination thereof.

[0045] *Binding affinity.* In some embodiments, the binding affinity between the glycosyl group of R₁ and a target can be defined by a dissociation constant (K_D). In some embodiments, the K_D at pH 7.4 can be 5, 10, 15, 20, 30, 40, 50, 75, 100, 125, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 3000, 3250, 3500, 3750, 4000, 4250, 4500, 4750, 5000, 5250, 5500, 5750, 6000, 6250, 6500, 6750, 7000, 7250, 7500, 7750, or 8000 nM, or any range defined by the foregoing endpoints, such as, 5 to 8000, 5 to 7000, 5 to 6000, 5 to 5000, 5 to 4000, 5 to 3000, 5 to 2500, 5 to 2000, 5 to 1500, 5 to 1250, 5 to 1000, 5 to 900, 5 to 800, 5 to 700, 5 to 600, 5 to 500, 5 to 400, 5 to 300, 5 to 200, 5 to 150, 5 to 100, 5 to 75, 5 to 50, 5 to 30, 5 to 20, 10 to 8000, 10 to 7000, 10 to 6000, 10 to 5000, 10 to 4000, 10 to 3000, 10 to 2500, 10 to 2000, 10 to 1500, 10 to 1250, 10 to 1000, 10 to 900, 10 to 800, 10 to 700, 10 to 600, 10 to 500, 10 to 400, 10 to 300, 10 to 200, 10 to 150, 10 to 100, 10 to 75, 10 to 50, 10 to 30, or 10 to 20 nM.

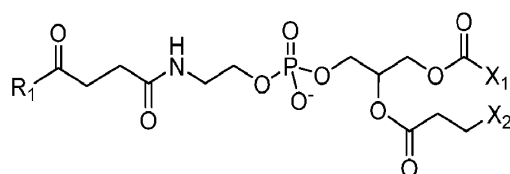
[0046] In some other embodiments, the K_D at pH 5 can be 1, 2, 3, 4, 5, 10, 15, 20, 30, 40, 50, 75, 100, 125, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 1000, 1250, 1500, 1750, or 2000 nM, or any range defined by the foregoing endpoints, such as, 1 to 2000, 1 to 1500, 1 to 1000, 1 to 900, 1 to 800, 1 to 750, 1 to 700, 1 to 650, 1 to 600, 1 to 550, 1 to 500, 1 to 450, 1 to 400, 1 to 350, 1 to 300, 1 to 250, 1 to 200, 1 to 150, 1 to 100, 1 to 75, 1 to 50, 1 to 40, 1 to 30, 1 to 20, 1 to 10, or to 5, 5 to 2000, 5 to 1500, 5 to 1000, 5 to 900, 5 to 800, 5 to 750, 5 to 700, 5 to 650, 5 to 600, 5 to 550, 5 to 500, 5 to 450, 5 to 400, 5 to 350, 5 to 300, 5 to 250, 5 to 200, 5 to 150, 5 to 100, 5 to 75, 5 to 50, 5 to 40, 5 to 30, 5 to 20, 5 to 10 nM.

[0047] *Examples.* In some embodiments, the R₁ group is selected from the group consisting of (each structure shown below is independent from one another despite whether it is separated using a semicolon with an adjacent structure):



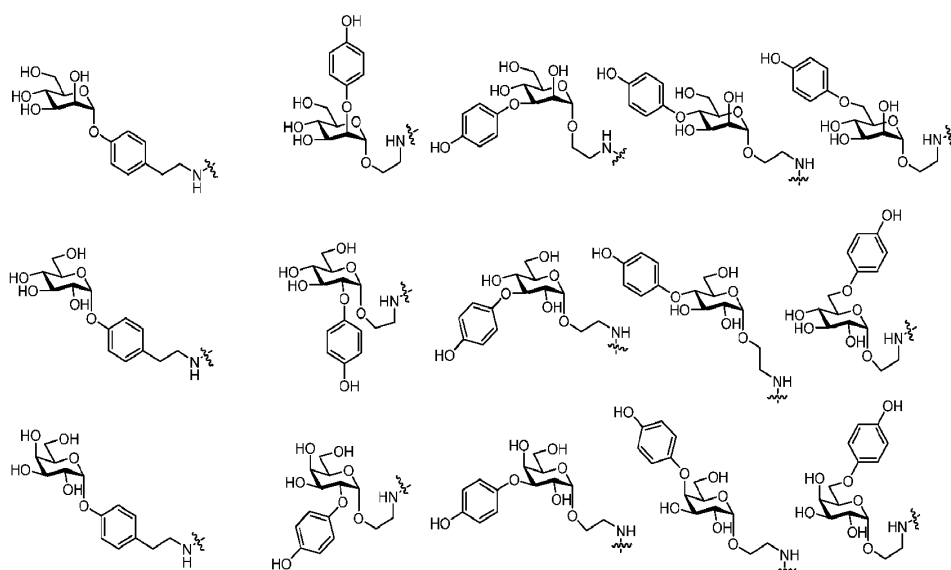


[0048] In some embodiments, the compound of the present disclosure has the structure shown in Formula 3:



Formula 3; and

wherein the R_1 group is selected from the group consisting of (each structure shown below is independent from one another despite whether it is separated using a semicolon with an adjacent structure):



[0049] X_1 and X_2

[0050] The X_1 and X_2 are each independently hydrogen, C_{1-30} alkyl, C_{1-30} alkenyl, C_{1-30} alkynyl, aryl, aryloxy, or a substituted version thereof, or $-(CH_2)_nX_4$, n is 0 to 30, and X_4 is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X_4 is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N, or a combination thereof. Without wishing to be bound by theories, at least one of the X_1 and X_2 groups is designed to provide the compound of the present disclosure with desired hydrophobicity.

[0051] In some embodiments, at least one of the X_1 and X_2 comprises a saturated hydrocarbon chain, which comprises at least 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 24, 26, 28, or 30 carbons, or any range of carbons defined by the foregoing endpoints, such as 2 to 30, 2 to 28, 2

to 26, 2 to 24, 2 to 20, 2 to 18, 2 to 15, 2 to 12, 2 to 10, 2 to 8, 2 to 6, 2 to 4, 3 to 30, 3 to 28, 3 to 26, 3 to 24, 3 to 20, 3 to 18, 3 to 15, 3 to 14, 3 to 13, 3 to 12, 3 to 11, 3 to 10, 3 to 9, 3 to 8, 3 to 7, 3 to 6, 3 to 5, 4 to 30, 4 to 28, 4 to 26, 4 to 24, 4 to 20, 4 to 18, 4 to 15, 4 to 14, 4 to 13, 4 to 12, 4 to 11, 4 to 10, 4 to 9, 4 to 8, 4 to 7, 4 to 6, 6 to 15, 6 to 14, 6 to 13, 6 to 12, 6 to 11, 6 to 10, 6 to 9, 6 to 8, 10 to 30, 10 to 20, 15 to 30, 15 to 28, 15 to 26, or 15 to 20 carbons.

[0052] In some embodiments, X_1 and X_2 are each independently hydrogen, C_{4-30} alkyl, C_{4-30} alkenyl, C_{4-30} alkynyl, aryl, aryloxy, or a substituted version thereof, or $-(CH_2)_nX_4$, n is 4 to 30, and X_4 is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X_4 is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N, or a combination thereof.

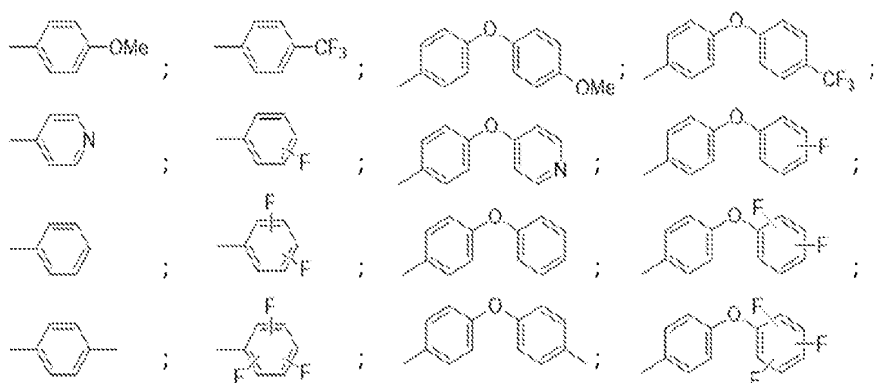
[0053] In some embodiments, X_1 and X_2 are each independently hydrogen, C_{8-30} alkyl, C_{8-30} alkenyl, C_{8-30} alkynyl, aryl, aryloxy, or a substituted version thereof, or $-(CH_2)_nX_4$, n is 8 to 30, and X_4 is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X_4 is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N, or a combination thereof.

[0054] In some embodiments, when one of X_1 and X_2 is hydrogen, the other one is not hydrogen. In some embodiments, when one of X_1 and X_2 is hydrogen, the other one comprises a saturated hydrocarbon chain, comprising at least 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 24, 26, 28, or 30 carbons, or any range of carbons defined by the foregoing endpoints, such as 2 to 30, 2 to 28, 2 to 26, 2 to 24, 2 to 20, 2 to 18, 2 to 15, 2 to 12, 2 to 10, 2 to 8, 2 to 6, 2 to 4, 3 to 30, 3 to 28, 3 to 26, 3 to 24, 3 to 20, 3 to 18, 3 to 15, 3 to 14, 3 to 13, 3 to 12, 3 to 11, 3 to 10, 3 to 9, 3 to 8, 3 to 7, 3 to 6, 3 to 5, 4 to 30, 4 to 28, 4 to 26, 4 to 24, 4 to 20, 4 to 18, 4 to 15, 4 to 14, 4 to 13, 4 to 12, 4 to 11, 4 to 10, 4 to 9, 4 to 8, 4 to 7, 4 to 6, 6 to 15, 6 to 14, 6 to 13, 6 to 12, 6 to 11, 6 to 10, 6 to 9, 6 to 8, 10 to 30, 10 to 20, 15 to 30, 15 to 28, 15 to 26, or 15 to 20 carbons. In some embodiments, one of X_1 and X_2 is C_{15-30} alkyl, and the other is $-(CH_2)_nX_4$, as defined above.

[0055] In some embodiments, X_4 is an aryl, aryloxy, heterocyclic group, cycloalkyl, heterocycloalkyl, or a combination thereof, and wherein X_4 comprises 0 to 6 substituents, selected from the group consisting of C_{1-6} alkyl, halogen, C_{1-6} alkyl halogen, and C_{1-6} alkoxy. In certain embodiments, X_4 comprises 1 to 3 substituents. The substituent can be, but is not limited to, CH_3 , CF_3 , F, or OCH_3 .

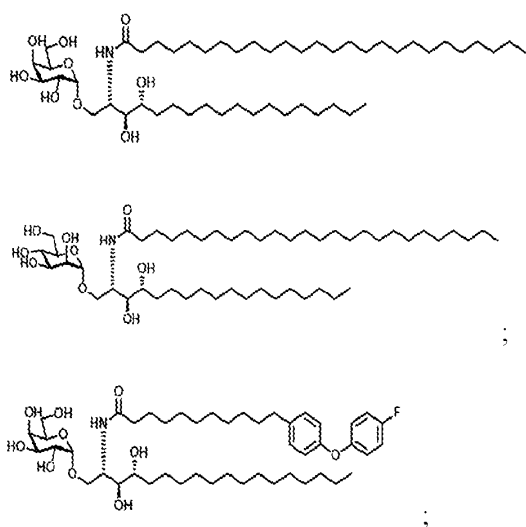
[0056] In some embodiments, X_4 is $-R_3-O-R_4$, wherein R_3 and R_4 are each independently aryl, heterocyclic group, cycloalkyl, heterocycloalkyl, each comprising 0 to 6 substituents selected from the group consisting of C_{1-6} alkyl, halogen, C_{1-6} alkyl halogen, and C_{1-6} alkoxy.

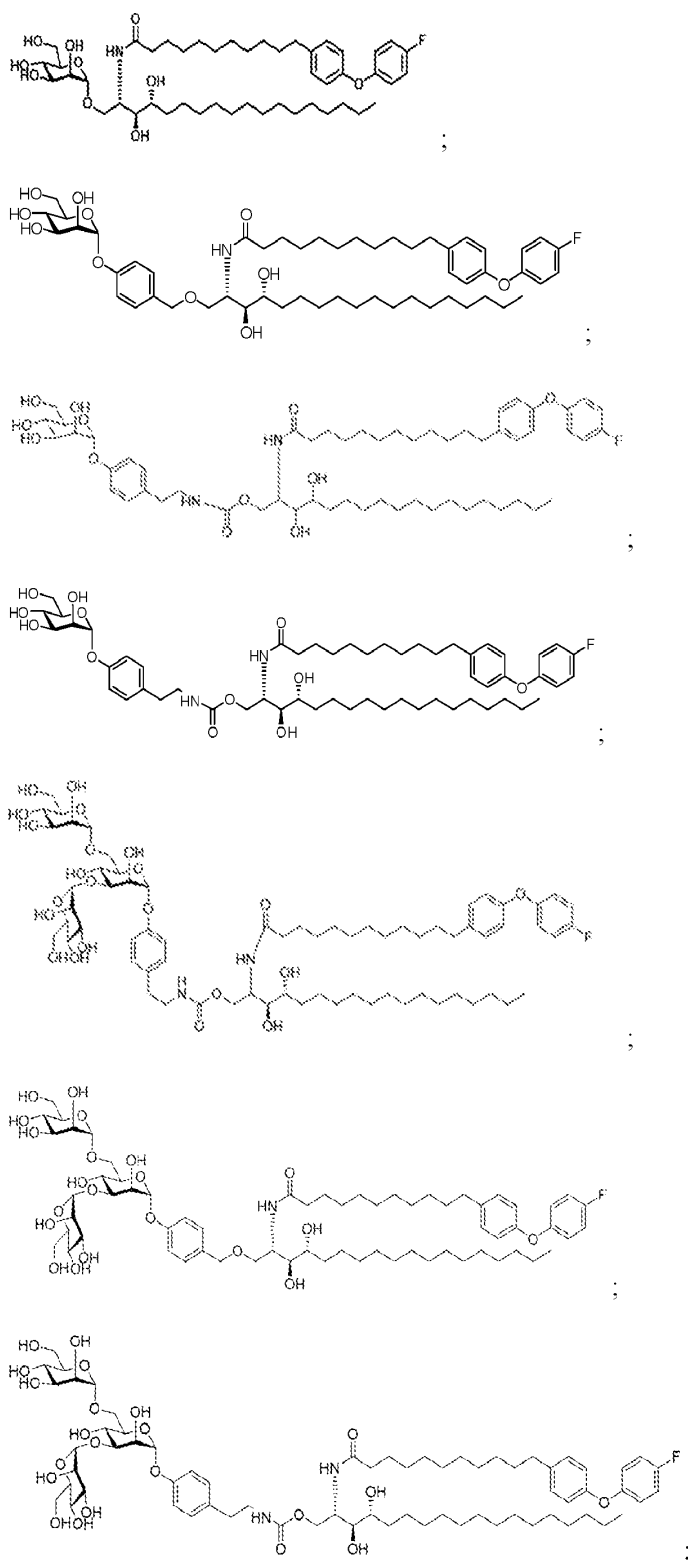
[0057] In certain embodiments, X_4 is selected from the group consisting of:

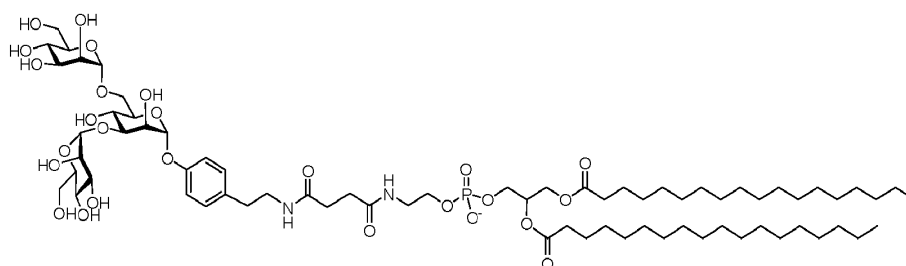
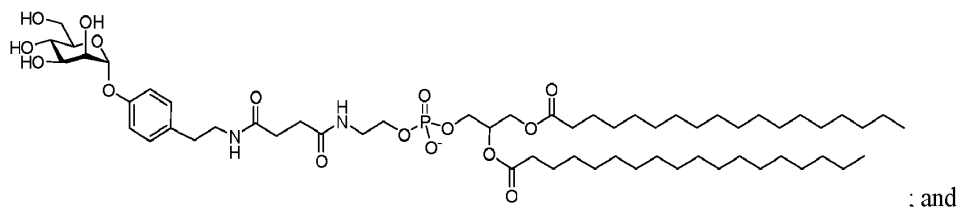
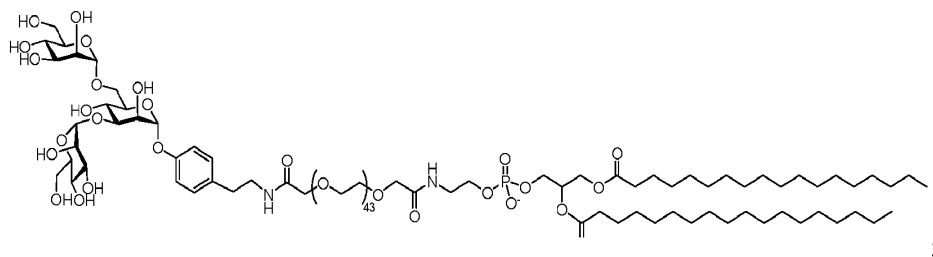
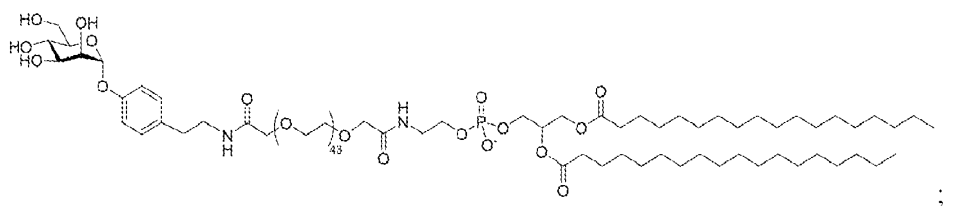


[0058] Exemplary Compound of the Present Disclosure

[0059] This section lists some exemplary structures of the compound of the present disclosure. However, the present disclosure is not limited to the exemplary structures listed below or in the specification. In some embodiments, the compound of the present disclosure does not comprise glycolipid C34 or α -galactosylceramide (α -GalCer).







[0060] COMPOSITION FOR FORMING A LIPID NANOPARTICLE

[0061] Another aspect of the present disclosure is directed to a composition, which comprises the compound of the present disclosure. In some embodiments, the compound comprises 1 to 10 mol% of the composition. In certain embodiments, the compound comprises about 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 mol% of the composition, or any range of carbons defined by the foregoing endpoints, such as 1 to 10 mol%, 1 to 9 mol%, 1 to 8 mol%, 1 to 7 mol%, 1 to 6 mol%, 1 to 5 mol%, 1 to 4 mol%, 1 to 3 mol%, 1 to 2 mol%, 2 to 10 mol%, 2 to 9 mol%, 2 to 8 mol%, 2 to 7 mol%, 2 to 6 mol%, 2 to 5 mol%, 2 to 4 mol%, 2 to 3 mol%, 3 to 10 mol%, 3 to 9 mol%, 3 to 8 mol%, 3 to 7 mol%, 3 to 6 mol%, 3 to 5 mol%, 3 to 4 mol%, 4 to 10 mol%, 4 to 9 mol%, 4 to 8 mol%, 4 to 7 mol%, 4 to 6 mol%, 4 to 5 mol%, 5 to 10 mol%, 5 to 9 mol%, 5 to 8 mol%, 5 to 7 mol%, or 5 to 6 mol% of the composition.

[0062] In some embodiments, the composition might comprise a first compound of the present disclosure and a second compound of the present disclosure. In some embodiments, the composition might comprise more than one, two, or three compounds, each is independently according to the compound of the present disclosure. The first compound, the second compound, or anyone, or any two of the more than one, two, or three compounds can be designed to have the same targeting moiety of the R_1 group, different targeting moiety of the R_1 group targeting the same target, or different targeting moiety of the R_1 group targeting different targets.

[0063] In some embodiments, the composition is configured to form a lipid nanoparticle. The lipid nanoparticle formed is, in some embodiments, expected to perform targeting delivery contributed by the compound of the present disclosure. In some embodiments, the composition configured to form a lipid nanoparticle might further comprise an ionizable lipid, a helper lipid, or a mixture thereof. In some embodiments, the ionizable lipid comprises 30 to 60 mol% of the composition, the helper lipid comprises 5 to 60 mol% of the composition, and the rest percent is a carrier or a solvent.

[0064] In some embodiments, the composition further comprises a payload (i.e., a cargo), which is further discussed below. In certain embodiments, the payload is a first payload, and the composition further encapsulates a second payload. The first payload and the second payload can be the same or different.

[0065] ***Ionizable lipid.***

[0066] In some embodiments, the ionizable lipid would be positively charged at a low pH environment. This feature facilitates the encapsulation of charged molecules, such as nucleic acid (e.g., RNA molecules), and endosomal escape, which allows the release of the cargo/payload into the cytoplasm efficiently. In some embodiments, the ionizable lipid would be neutral at a physiological pH environment, thereby reducing potential toxic effects for a living organism. In some embodiments, the ionizable lipid comprises 30 to 60 mol% of the composition. In certain embodiments, the ionizable lipid comprises about 30, 35, 40, 45, 50, 55, or 60 mol% of the composition, or any range of carbons defined by the foregoing endpoints, such as 30 to 60 mol%, 30 to 55 mol%, 30 to 50 mol%, 30 to 45 mol%, 30 to 40 mol%, 30 to 35 mol%, 35 to 60 mol%, 35 to 55 mol%, 35 to 50 mol%, 35 to 45 mol%, 35 to 40 mol%, 40 to 60 mol%, 40 to 55 mol%, 40 to 50 mol%, 40 to 45 mol%, 45 to 60 mol%, 45 to 55 mol%, 45 to 50 mol%, or 50 to 60 mol% of the composition. In some embodiments, the ionizable lipid comprises but not limited to heptadecan-9-yl 8-[2-hydroxyethyl-(6-oxo-6-undecoxyhexyl)amino]octanoate (SM-102TM), (4-

hydroxybutyl)azanediy)bis(hexane-6,1-diyl)bis(2-hexyldecanoate) (ALC-0315TM, Pfizer), or a combination thereof.

[0067] *Helper lipid.*

[0068] A helper lipid is a lipid used to increase particle stability and fluidity of lipid nanoparticles. A helper lipid can be but is not limited to phosphatidylcholine, cholesterol or a derivative thereof, a polyethylene glycol-lipid (PEG-lipid), or a mixture thereof. Without wishing to be bound by theories, phosphatidylcholine can help increase the bilayer stability of the lipid nanoparticle and can reduce non-specific binding; cholesterol can fill the gaps between the lipid components forming the lipid nanoparticles and thereby enhancing particle stability by modulating membrane integrity and rigidity; PEGylated lipids (PEG lipids) can enhance colloidal stability and circulation time of lipid nanoparticles in vivo.

[0069] In some embodiments, the helper lipid comprises 5 to 60 mol% of the composition. In certain embodiments, the helper lipid comprises about 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, and 60 mol% of the composition, or any range of carbons defined by the foregoing endpoints, such as 5 to 60 mol%, 5 to 55 mol%, 5 to 50 mol%, 5 to 45 mol%, 5 to 40 mol%, 5 to 35 mol%, 5 to 30 mol%, 5 to 25 mol%, 5 to 20 mol%, 5 to 15 mol%, 5 to 10 mol%, 10 to 60 mol%, 10 to 55 mol%, 10 to 50 mol%, 10 to 45 mol%, 10 to 40 mol%, 10 to 35 mol%, 10 to 30 mol%, 10 to 25 mol%, 10 to 20 mol%, 10 to 15 mol%, 15 to 60 mol%, 15 to 55 mol%, 15 to 50 mol%, 15 to 45 mol%, 15 to 40 mol%, 15 to 35 mol%, 15 to 30 mol%, 15 to 25 mol%, 15 to 20 mol%, 20 to 60 mol%, 20 to 55 mol%, 20 to 50 mol%, 20 to 45 mol%, 20 to 40 mol%, 20 to 35 mol%, 20 to 30 mol%, 20 to 25 mol%, 25 to 60 mol%, 25 to 55 mol%, 25 to 50 mol%, 25 to 45 mol%, 25 to 40 mol%, 25 to 35 mol%, 25 to 30 mol%, 30 to 60 mol%, 30 to 55 mol%, 30 to 50 mol%, 30 to 45 mol%, 30 to 40 mol%, 30 to 35 mol%, 40 to 60 mol%, 40 to 55 mol%, 40 to 50 mol%, 40 to 45 mol%, 50 to 55 mol%, or 50 to 60 mol% of the composition.

[0070] *Phosphatidylcholine.* In some embodiments, the phosphatidylcholine comprises 5 to 10 mol% of the composition. In certain embodiments, the phosphatidylcholine comprises about 5, 6, 7, 8, 9, or 10 mol% of the composition, or any range of carbons defined by the foregoing endpoints, such as 5 to 10 mol%, 5 to 9 mol%, 5 to 8 mol%, 5 to 7 mol%, 5 to 6 mol%, 6 to 10 mol%, 6 to 9 mol%, 6 to 8 mol%, 6 to 7 mol%, 7 to 10 mol%, 7 to 9 mol%, 7 to 8 mol%, 8 to 10 mol%, 8 to 9 mol%, or 9 to 10 mol% of the composition. Examples of phosphatidylcholine include but are not limited to distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylethanolamine (DPOE), or a mixture thereof.

[0071] *Cholesterol*. In some embodiments, the cholesterol or a derivative thereof comprises 30 to 40 mol% of the composition. In certain embodiments, the cholesterol or a derivative thereof comprises about 30, 32, 34, 36, 38, or 40 mol% of the composition, or any range of carbons defined by the foregoing endpoints, such as 30 to 40 mol%, 30 to 38 mol%, 30 to 36 mol%, 30 to 34 mol%, 30 to 32 mol%, 32 to 40 mol%, 32 to 38 mol%, 32 to 36 mol%, 32 to 34 mol%, 34 to 40 mol%, 34 to 38 mol%, 34 to 36 mol%, 36 to 40 mol%, 36 to 38 mol%, or 38 to 40 mol% of the composition. Examples of the the cholesterol or a derivative thereof includes but are not limited to cholesterol, campesterol, beta-sitosterol, brassicasterol, ergosterol, dehydroergosterol, stigmasterol, fucosterol, DC-cholesterol HCl, OH-Chol, HAPC-Chol, MHAPC-Chol, DMHAPC-Chol, DMPAC-Chol, cholesteryl chloroformate, GL67, cholesteryl myristate, cholesteryl oleate, cholesteryl nervonate, LC10, cholesteryl hemisuccinate, (3 β ,5 β)-3-hydroxycholesterol-24-oic acid, alkyne cholesterol, 27-alkyne cholesterol, E-cholesterol alkyne, trifluoroacetate salt (Dios-Arg, 2H-Cho-Arg, or Cho-Arg), or a mixture thereof.

[0072] *PEG-lipid*. In some embodiments, the PEG-lipid comprises 1 to 10 mol% of the composition. In certain embodiments, the PEG-lipid comprises about 1, 2, 4, 6, 8, or 10 mol% of the composition, or any range of carbons defined by the foregoing endpoints, such as 1 to 10 mol%, 1 to 8 mol%, 1 to 6 mol%, 1 to 4 mol%, 1 to 2 mol%, 2 to 10 mol%, 2 to 8 mol%, 2 to 6 mol%, 2 to 4 mol%, 4 to 10 mol%, 4 to 8 mol%, 4 to 6 mol%, 6 to 10 mol%, 6 to 8 mol%, or 8 to 10 mol% of the composition. Examples of the PEG-lipid include but are not limited to DMG-PEG, DSG-PEG, mPEG-DPPE, DOPE-PEG, mPEG-DMPE, mPEG-DOPE, DSPE-PEG-amine, DSPE-PEG, mPEG-DSPE, PEG PE, m-PEG-Pentacosadiynoic acid, bromoacetamido-PEG, amine-PEG, azide-PEG, or a mixture thereof. In some embodiments, the function of a PEG-lipid in the composition/lipid nanoparticle can be provided by the compound of the present disclosure, especially by embodiments of the present disclosure where the attachment group of R₁ comprises a PEG moiety. In those circumstances, the composition does not need to comprise a PEG-lipid.

[0073] *Examples*. The table below lists some exemplary compositions according to the present disclosure. However, the present disclosure is not limited to the exemplary compositions or those described in the specification.

[0074] Table: Exemplary Embodiments of the Formulation of the Present Disclosure

Embodiments	L1: Ionizable lipid	L2: Phosphatidyl- choline	L3: Cholesterol	L4: PEG-Lipid	L5 the compound of the present disclosure
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C1 (control)	SM-102 50 mol%	DSPC 10 mol%	Cholesterol 38.5 mol%	DMG- PEG2000 1.5 mol%	none
C2-1	SM-102 45 mol%	DSPC 9 mol%	Cholesterol 34.65 mol%	DMG- PEG2000 1.35 mol%	Compound 22 10 mol%
C2-2	SM-102 45 mol%	DSPC 9 mol%	Cholesterol 34.65 mol%	DMG- PEG2000 1.35 mol%	Compound 23 10 mol%
C2-3	SM-102 45 mol%	DSPC 9 mol%	Cholesterol 34.65 mol%	DMG- PEG2000 1.35 mol%	Compound 24 10 mol%
C2-4	SM-102 45 mol%	DSPC 9 mol%	Cholesterol 34.65 mol%	DMG- PEG2000 1.35 mol%	Compound 25 10 mol%
C2-5	SM-102 45 mol%	DSPC 9 mol%	Cholesterol 34.65 mol%	DMG- PEG2000 1.35 mol%	Compound 22 + Compound 23 10 mol%
C2-6	SM-102 45 mol%	DSPC 9 mol%	Cholesterol 34.65 mol%	DMG- PEG2000 1.35 mol%	Compound 24 + Compound 25 10 mol%
C2-7	ALC-0315 45 mol%	DSPC 9 mol%	Cholesterol 34.65 mol%	DMG- PEG2000 1.35 mol%	Compound 22 10 mol%
C2-8	ALC-0315 45 mol%	DSPC 9 mol%	Cholesterol 34.65 mol%	DMG- PEG2000 1.35 mol%	Compound 24 10 mol%
C3-1	SM-102 47.5 mol%	DSPC 9.5 mol%	Cholesterol 36.5 mol%	DMG- PEG2000 1.5 mol%	Compound 22 5 mol%
C3-2	SM-102 47.5 mol%	DSPC 9.5 mol%	Cholesterol 36.5 mol%	DMG- PEG2000 1.5 mol%	Compound 23 5 mol%
C3-3	SM-102 47.5 mol%	DSPC 9.5 mol%	Cholesterol 36.5 mol%	DMG- PEG2000 1.5 mol%	Compound 24 5 mol%
C3-4	SM-102 47.5 mol%	DSPC 9.5 mol%	Cholesterol 36.5 mol%	DMG- PEG2000 1.5 mol%	Compound 25 5 mol%
C3-5	ALC-0315 47.5 mol%	DSPC 9.5 mol%	Cholesterol 36.5 mol%	DMG- PEG2000 1.5 mol%	Compound 22 5 mol%
C3-6	ALC-0315 47.5 mol%	DSPC 9.5 mol%	Cholesterol 36.5 mol%	DMG- PEG2000 1.5 mol%	Compound 24 5 mol%
C4-1	SM-102 40 mol%	DSPC 8 mol%	Cholesterol 30.5 mol%	DMG- PEG2000 1.5 mol%	Compound 22 20 mol%
C4-2	SM-102 40 mol%	DSPC 8 mol%	Cholesterol 30.5 mol%	DMG- PEG2000 1.5 mol%	Compound 23 20 mol%
C4-3	SM-102 40 mol%	DSPC 8 mol%	Cholesterol 30.5 mol%	DMG- PEG2000 1.5 mol%	Compound 24 20 mol%

C4-4	SM-102 40 mol%	DSPC 8 mol%	Cholesterol 30.5 mol%	DMG- PEG2000 1.5 mol%	Compound 25 20 mol%
C4-5	SM-102 40 mol%	DSPC 8 mol%	Cholesterol 30.5 mol%	DMG- PEG2000 1.5 mol%	Compound 22 + Compound 23 20 mol%
C4-6	SM-102 40 mol%	DSPC 8 mol%	Cholesterol 30.5 mol%	DMG- PEG2000 1.5 mol%	Compound 24 + Compound 25 20 mol%
C4-7	ALC-0315 40 mol%	DSPC 8 mol%	Cholesterol 30.5 mol%	DMG- PEG2000 1.5 mol%	Compound 22 20 mol%
C4-8	ALC-0315 40 mol%	DSPC 8 mol%	Cholesterol 30.5 mol%	DMG- PEG2000 1.5 mol%	Compound 23 20 mol%
C5-1	SM-102 45 mol%	DSPC 9 mol%	Cholesterol 34.5 mol%	DMG- PEG2000 1.5 mol%	Compound 22 10 mol%
C5-2	SM-102 45 mol%	DSPC 9 mol%	Cholesterol 34.5 mol%	DMG- PEG2000 1.5 mol%	Compound 23 10 mol%
C5-3	SM-102 45 mol%	DSPC 9 mol%	Cholesterol 34.5 mol%	DMG- PEG2000 1.5 mol%	Compound 24 10 mol%
C5-4	SM-102 45 mol%	DSPC 9 mol%	Cholesterol 34.5 mol%	DMG- PEG2000 1.5 mol%	Compound 25 10 mol%
C6-1	SM-102 50 mol%	DSPC 10 mol%	Cholesterol 38.5 mol%	DMG- PEG2000 1.5 mol%	Compound 22 10 mol%
C6-2	SM-102 50 mol%	DSPC 10 mol%	Cholesterol 38.5 mol%	DMG- PEG2000 1.5 mol%	Compound 23 10 mol%
C6-3	SM-102 50 mol%	DSPC 10 mol%	Cholesterol 38.5 mol%	DMG- PEG2000 1.5 mol%	Compound 24 10 mol%
C6-4	SM-102 50 mol%	DSPC 10 mol%	Cholesterol 38.5 mol%	DMG- PEG2000 1.5 mol%	Compound 25 10 mol%
C6-5	SM-102 50 mol%	DSPC 10 mol%	Cholesterol 38.5 mol%	DMG- PEG2000 1.5 mol%	Compound 22 + Compound 23 10 mol%
C6-6	SM-102 50 mol%	DSPC 10 mol%	Cholesterol 38.5 mol%	DMG- PEG2000 1.5 mol%	Compound 24 + Compound 25 10 mol%
C6-7	ALC-0315 50 mol%	DSPC 10 mol%	Cholesterol 38.5 mol%	DMG- PEG2000 1.5 mol%	Compound 24 10 mol%
C6-8	ALC-0315 50 mol%	DSPC 10 mol%	Cholesterol 38.5 mol%	DMG- PEG2000 1.5 mol%	Compound 25 10 mol%

[0075] LIPID NANOPARTICLE (LNP)

[0076] Another aspect of the present disclosure is related to a lipid nanoparticle (LNP). The lipid nanoparticle of the present disclosure comprises a membrane defining an inner space, wherein the membrane is formed with a plurality of lipid components comprising the compound of the present disclosure. The membrane of the lipid nanoparticle can be a bilayer structure, which can be a single bilayer structure or a multiple bilayer structure. In some embodiments, the plurality of lipid components can further comprise an ionizable lipid, a helper lipid, or a combination thereof. The ionizable lipid and the helper lipid can be those described above. Without wishing to be bound by theories, the membrane is formed via hydrophobic interaction between the plurality of the lipid components, while in some circumstances, there might be electrostatic interaction involved in the formation of the membrane.

[0077] In some embodiments, the plurality of lipid components does not comprise glycolipid C34 or α -galactosylceramide (α -GalCer). In some embodiments, the plurality of lipid compounds comprises glycolipid C34 or α -galactosylceramide (α -GalCer), and the glycolipid C34 or α -galactosylceramide (α -GalCer) comprises less than about 100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 25%, 20%, 15%, 10%, 5% molar ratio of the plurality of lipid compounds, or any range defined by the foregoing endpoints, such as 100% to 5%, 90% to 5%, 70% to 5%, 70% to 5%, 60% to 5%, 50% to 5%, 40% to 5%, 30% to 5%, 25% to 5%, 20% to 5%, 15% to 5%, 10% to 5%, 100% to 10%, 90% to 10%, 70% to 10%, 70% to 10%, 60% to 10%, 50% to 10%, 40% to 10%, 30% to 10%, 25% to 10%, 20% to 10%, or 15% to 10%.

[0078] In some embodiments, the plurality of lipid components of the LNP's membrane might comprise a first compound of the present disclosure and a second compound of the present disclosure. In some embodiments, the plurality of lipid components might comprise more than one, two, or three compounds, each is independently according to the compound of the present disclosure. The first compound, the second compound, or anyone, or any two of the more than one, two, or three compounds can be designed to have the same targeting moiety of the R₁ group, different targeting moiety of the R₁ group targeting the same target, or different targeting moiety of the R₁ group targeting different targets.

[0079] In some embodiments, the compound of the present disclosure comprises at least 0.1%, 0.5%, 1%, 2%, 3%, 4%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, or 70%, of the plurality of lipid components forming the membrane of the LNP, or any range defined by the foregoing endpoints, such as 0.1% to 70%, 0.1% to 60%, 0.1% to 50%, 0.1% to 40%, 0.1% to 35%, 0.1% to 30%, 0.1% to 25%, 0.1% to 20%, 0.1% to 15%, 0.1% to 10%, 0.1% to 5%, 0.1% to 4%, 0.1% to 3%, 0.1% to 2%, 0.1% to 1%, 0.1% to 0.5%, 0.5% to 70%, 0.5% to 60%, 0.5% to 50%, 0.5% to 40%, 0.5% to 35%, 0.5% to 30%, 0.5% to 25%, 0.5% to 20%, 0.5% to 15%, 0.5% to 10%, 0.5% to 5%, 0.5% to 4%, 0.5% to 3%, 0.5% to 2%, 0.5% to 1%, 1% to 70%, 1% to 60%, 1% to 50%, 1% to 40%, 1% to 35%, 1%

to 30%, 1% to 25%, 1% to 20%, 1% to 15%, 1% to 10%, 1% to 5%, 1% to 4%, 1% to 3%, 1% to 2%, 5% to 70%, 5% to 60%, 5% to 50%, 5% to 40%, 5% to 35%, 5% to 30%, 5% to 25%, 5% to 20%, 5% to 15%, 5% to 10%, 10% to 70%, 10% to 60%, 10% to 50%, 10% to 40%, 10% to 35%, 10% to 30%, 10% to 25%, 10% to 20%, 10 to 15%, 20% to 70%, 20% to 60%, 20% to 50%, 20% to 40%, 20% to 30%, 30% to 70%, 30% to 60%, 30% to 50%, 30% to 40%, 50% to 70%, 50% to 65%, 50% to 60%, 60% to 70%, or 60% to 65%,.

[0080] *Size of the LNP.*

[0081] In some embodiments, the LNP of the present disclosure has a diameter of 0.01, 0.05, 0.1, 0.15, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, or 5 microns, or any range defined by the foregoing endpoints, such as 0.00 to 5, 0.01 to 4, 0.00 to 3, 0.01 to 2, 0.01 to 1, 0.01 to 0.8, 0.01 to 0.6, 0.01 to 0.4, 0.01 to 0.2, 0.01 to 0.1, 0.01 to 0.05, 0.01 to 0.01, 0.05 to 5, 0.05 to 4, 0.05 to 3, 0.05 to 2, 0.05 to 1, 0.05 to 0.8, 0.05 to 0.6, 0.05 to 0.4, 0.05 to 0.2, 0.05 to 0.1, 0.1 to 5, 0.1 to 4, 0.1 to 3, 0.1 to 2, 0.1 to 1, 0.1 to 0.8, 0.1 to 0.6, 0.1 to 0.4, 0.1 to 0.2, 0.5 to 5, 0.5 to 4, 0.5 to 3, 0.5 to 2, 0.5 to 1, 0.5 to 0.8, 1 to 5, 1 to 4, 1 to 3, or 1 to 2 microns. The size of the LNP can be determined by using, but not limited to, Dynamic Light Scattering (DLS). In some embodiments, the LNP of the present disclosure has a polydispersity index (PDI) of about 0.01, 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, or 1, or any range defined by the foregoing endpoints, such as 0.01 to 1, 0.01 to 0.9, 0.01 to 0.8, 0.01 to 0.7, 0.01 to 0.6, 0.01 to 0.5, 0.01 to 0.4, 0.01 to 0.3, 0.01 to 0.2, 0.01 to 0.1, 0.01 to 0.05, 0.1 to 1, 0.1 to 0.9, 0.1 to 0.8, 0.1 to 0.7, 0.1 to 0.6, 0.1 to 0.5, 0.1 to 0.4, 0.1 to 0.3, or 0.1 to 0.2.

[0082] *Zeta potential and molecular weight.*

[0083] Without wishing to be bound by theories, the zeta potential and molecular weight of an LNP may affect the cellular uptake of the LNP. In some embodiments, the exemplary targeting LNP of the present disclosure comprises a zeta potential of about -50, -40, -30, -20, -15, -10, -5, 0, +5, +10, +15, +20, +30, +40, or +50, or any range defined by the foregoing endpoints, such as -50 to +50, -50 to +40, -50 to +30, -50 to +20, -50 to +15, -50 to +10, -50 to +5, -50 to -5, -50 to -10, -50 to -15, -50 to -20, -20 to +50, -20 to +40, -20 to +30, -20 to +20, -20 to +15, -20 to +10, -20 to +5, -20 to -5, -20 to -10, -20 to -15, -15 to +50, -15 to +40, -15 to +30, -15 to +20, -15 to +15, -15 to +10, -15 to +5, -15 to -5, -15 to -10, +5 to +50, +5 to +40, +5 to +30, +5 to +20, +5 to +15, or +5 to +10. In some embodiments, the exemplary targeting LNP of the present disclosure comprises a molecular weight of about 1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 15, 20, 25, 30, 35, 40, 45, 50 kDa, or any range defined by the foregoing endpoints, such as 1 to 50 kDa, 1 to 40 kDa, 1 to 30 kDa, 1 to 20 kDa, 1 to 15 kDa, 1 to 10 kDa, 1 to 5 kDa, 2 to 50 kDa, 2 to 40 kDa, 2 to

30 kDa, 2 to 20 kDa, 2 to 15 kDa, 2 to 10 kDa, 2 to 5 kDa, 5 to 50 kDa, 5 to 40 kDa, 5 to 30 kDa, 5 to 20 kDa, 5 to 15 kDa, 5 to 10 kDa, 8 to 50 kDa, 8 to 45 kDa, 8 to 40 kDa, 8 to 35 kDa, 8 to 30 kDa, 8 to 25 kDa, 8 to 20 kDa, 8 to 15 kDa, 8 to 10 kDa, 12 to 50 kDa, 12 to 45 kDa, 12 to 35 kDa, 12 to 25 kDa, 12 to 15 kDa, 25 to 50 kDa, 25 to 40 kDa, or 25 to 30 kDa.

[0084] **Payload**

[0085] In some embodiments, the membrane of the LNP defines an inner space configured to encapsulate or carry a payload (i.e., a cargo). As described herein, “encapsulate a payload” or “carry a payload” refers to the condition that the payload is retained within the LNP by the membrane thereof. The payload can be either contained within the inner space defined by the LNP or embedded within the membrane (e.g., embedded within the bilayer structure). The payload might be able to move freely within the inner space or be attached covalently or non-covalently to the membrane. The encapsulation can be substantial, complete, or partial and does not exclude the possibility that part of the payload might be exposed to the environment outside the LNP. In the embodiments of partial encapsulation, at least 1%, 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, or 95% of the payload is retained, enclosed, or surrounded by the membrane of the LNP. In some embodiments, the payload can be a biomolecule such as a nucleic acid, a compound, a polypeptide, a protein, a glycan head, or a combination thereof.

[0086] In some embodiments, the payload is a ribonucleic acid (RNA, e.g., an mRNA) or deoxyribonucleic acid (DNA, e.g., a double-strand DNA or a single-strand DNA), which, after being delivered by using the LNP of the present disclosure to a target cell, can encode a polypeptide or a protein *in vivo*. Nucleic acid, such as a mRNA molecule used in the present disclosure, can be prepared by *in vitro* transcription from a reference nucleic acid. The *in vitro* transcription can be performed as described in the PCT patent publication WO2014/152027, filed on March 13, 2014, which is incorporated by reference in its entirety.

[0087] In some embodiments, the polypeptide or the protein is immunogenic (e.g., antigenic) to an organism to which the exemplary targeting LNP is administered. In such embodiments, the targeting LNP of the present disclosure is used to encapsulate and carry an immunogenic protein or a nucleic acid configured to encode the immunogenic protein *in vivo*, such as an mRNA molecule in an RNA vaccine. The immunogenic protein can be a protein of a pathogen of viral (e.g., Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV, including SARS-CoV-2), influenza (flu), respiratory syncytial virus (RSV), EBV, DENGUE, VZV, HIV, ZIKA, or NIPAH), bacterial, or fungal origin. In some embodiments, an immunogenic protein can be a spike protein of a virus. In certain embodiments, the

spike protein can be of coronavirus (CoV) origin, such as SARS-CoV, MERS-CoV, and SARS-CoV-2. In some embodiments, examples of the coronavirus (CoV) described herein include but are not limited to, alpha-SARS-CoV2, beta-SARS-CoV2, gamma-SARS-CoV2, delta-SARS-CoV2, omicron-SARS-CoV2, and variants thereof.

[0088] In some embodiments, the payload is a nucleic acid, which can be a polynucleotide having an open reading frame configured to encode a polypeptide or protein *in vivo*. Such a polynucleotide might be modified with a 5' terminal cap, which is generated during an *in vitro*-transcription reaction using the following chemical RNA cap analogs: 3'-O-Me-m7G(5')ppp(5') G [the ARCA cap], G(5')ppp(5')A, G(5')ppp(5')G, m7G(5')ppp(5')A, or m7G(5')ppp(5')G (New England BioLabs, Ipswich, Mass.). A 5'-capping of a modified polynucleotide may be completed post-transcriptionally using a Vaccinia Virus Capping Enzyme to generate the "Cap 0" structure: m7G(5')ppp(5')G (New England BioLabs, Ipswich, Mass.). Cap 1 structure may be generated using both Vaccinia Virus Capping Enzyme and a 2'-O methyl-transferase to generate m7G(5')ppp(5')G-2'-O-methyl. Cap 2 structure may be generated from the Cap 1 structure followed by the 2'-O-methylation of the 5'-antepenultimate nucleotide using a 2'-O methyl-transferase. Cap 3 structure may be generated from the Cap 2 structure followed by the 2'-O-methylation of the 5'-preantepenultimate nucleotide using a 2'-O methyl-transferase. Enzymes may be derived from a recombinant source. After being transfected into mammalian cells, the modified polynucleotides have a stability of between 12-18 hours, or greater than 18 hours, e.g., 24, 36, 48, 60, 72, or greater than 72 hours.

[0089] In some embodiments, the nucleic acid might be modified. In some embodiments, the nucleic acid might have several (more than one) modifications, the same or different from each other. In some embodiments, the nucleic acid contains, in a particular region, one, two, or more (optionally different) nucleoside or nucleotide modifications. In some embodiments, a modified nucleic acid (e.g., a modified mRNA polynucleotide) exhibits reduced degradation in a cell or organism relative to unmodified ones. In some embodiments, a modified nucleic acid may exhibit reduced immunogenicity in an organism, respectively (e.g., a reduced innate response).

[0090] In some embodiments, the modification can comprise chemical modifications. In some embodiments, the modification can be naturally-occurring, non-naturally-occurring, or both. Some exemplary modifications useful in the present disclosure include but are not limited to, modifications of a sugar, a nucleobase, an internucleoside linkage (e.g., to a linking phosphate, to a phosphodiester linkage, or to the phosphodiester backbone), or a combination thereof. In some embodiments, the nucleic acid (e.g., RNA) used as a payload of the present disclosure can be codon optimized. For example, the nucleic

acid can be modified to enhance the G/C content thereof. The G/C content of a nucleic acid may influence the stability thereof. A nucleic acid having an increased amount of guanine (G) and/or cytosine (C) residues may be functionally more stable than those containing a large amount of adenine (A) and thymine (T) or uracil (U) nucleotides. For example, WO2002/098443 discloses a pharmaceutical composition containing an mRNA stabilized by sequence modifications in the translated region. Due to the degeneracy of the genetic code, the modifications work by substituting existing codons for those that promote greater RNA stability without changing the resulting amino acid.

[0091] In some embodiments, the nucleic acid might further comprise a sequence encoding a signal peptide. The signal peptide might comprise three regions: (1) an N-terminal region of differing length, which usually comprises positively charged amino acids, (2) a hydrophobic region, and (3) a short carboxy-terminal peptide region. In eukaryotes, the signal peptide of a nascent precursor protein (pre-protein) directs the ribosome to the rough endoplasmic reticulum (ER) membrane and initiates the transport of the growing peptide chain across it. A signal peptide usually is not responsible for the final destination of the mature protein, but it is not limited in the present disclosure. Signal peptides are usually cleaved from precursor proteins by an endoplasmic reticulum (ER)-resident signal peptidase. They might remain uncleaved and function as a membrane anchor. In some embodiments, a signal peptide might be designed to fuse with the polypeptide or protein to be encoded by the payload at its C-terminus or N-terminus.

[0092] In some embodiments, the payload can be a therapeutic or prophylactic reagent for treating or preventing a disease (e.g., cancer or an infectious disease). For example, the payload can be an anti-viral agent, including but not limited to ribavirin, penciclovir, nitazoxanide, nafamostat, chloroquine, remdesivir (GS-5734) and favipiravir (T-705), interferon, adefovir, tenofovir, acyclovir, brivudin, cidofovir, fomivirsen, foscarnet, ganciclovir, amantadine, rimantadine, zanamivir, remdesivir, molnupiravir, and paxlovid. In other examples, the payload can be an anti-cancer agent. In certain embodiments, the payload is a nucleic acid configured to encode a therapeutic or prophylactic reagent.

[0093] In some embodiments, the N/P ratio (positively-chargeable amine (nitrogen atom of the ionizable lipid, N = nitrogen) to negatively-charged nucleic acid phosphate (P) groups) of the exemplary targeting LNP encapsulating a nucleic acid is about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 35, 40, 45, or 50, or any range defined by the foregoing endpoints, include or exclude, such as 1 to 50, 1 to 40, 1 to 30, 1 to 20, 1 to 10, 1 to 5, 5 to 50, 5 to 40, 5 to 30, 5 to 20, 5 to 10, 10 to 50, 10 to 40, 10 to 30, 10 to 20, 8 to 40, 8 to 20, 8 to 12, 9 to 50, 9 to 30, or 9

to 15. In another embodiment, the exemplary targeting LNP encapsulating a mRNA has a nanoparticle/mRNA (N/P) ratio of about 10 or about 20.

[0094] In some embodiments where the payload of the LNP is a nucleic acid configured to encode a polypeptide or protein in a target cell, after uptake by the target cell, the LNP is configured to encode *in vivo* 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 35, 40, 45, or 50 copies of the polypeptide or protein, or any range defined by the foregoing endpoints, include or exclude, such as, 1 to 50, 1 to 40, 1 to 30, 1 to 20, 1 to 10, 1 to 5, 2 to 50, 2 to 40, 2 to 30, 2 to 20, 2 to 15, 2 to 10, 2 to 8, 2 to 6, 2 to 5, 2 to 4, 5 to 50, 5 to 40, 5 to 30, 5 to 20, 5 to 15, 5 to 10, 5 to 8, 4 to 50, 4 to 45, 4 to 35, 4 to 25, 4 to 15, 4 to 9, 4 to 6, 7 to 50, 7 to 45, 7 to 35, 7 to 25, 7 to 15, or 7 to 9 copies. In some embodiments, after uptake by the target cell, the LNP is configured to encode *in vivo* the polypeptide or protein continually and instantly until the nucleic acid (i.e., the payload) is deactivated *in vivo*.

[0095] ***Payload encoding low-sugar immunogenic peptide (Low sugar universal vaccine).***

Without wishing to be bound by theories, it is documented that removing glycan shields of an immunogenic peptide can expose glycan shield-masked epitopes of the peptide, thereby increasing the antigenic presentation and the corresponding immune responses induced by the immunogenic peptide.

[0096] Compared with the wild-type spike proteins such as Wuhan strains and delta strains (such as SEQ ID NOs: 2, 16, 18, and 20), the modified spike protein described herein comprises one or more amino acid deletions or additions at N-linked glycosylation sequons (N-X-S/T) to eliminate N-linked glycan sequons. Alternatively, the modified spike protein described herein comprises one or more amino acid substitutions of S/T to alanine (A) at O-linked glycosylation sites to eliminate O-linked glycosylation sites.

[0097] *In the first aspect*, the exemplary mRNA of a coronavirus spike protein can be used as an exemplary coronavirus vaccine, which has a mutation of one or more glycosites in the receptor binding domain (RBD), the subunit 1 (S1) or the subunit 2 (S2) domain, or a variant thereof. When said mRNA is suitably formulated in the targeting LNP formulation of the present disclosure, it can be effectively used for dendritic cell targeting delivery. The mutation of CoV or a variant thereof, as described herein, can be deletion, addition, or substitution. In some embodiments, a coronavirus spike protein mRNA has one or more mutations of the glycosites in RBD, S1, or S2 with one or more replacements of N to Q or S/T to A, or a combination thereof. The mutation of the N-glycosites is to change the putative sequon N-X-S/T to Q-X-S/T and/or change S/T of the O-glycosite to A. The glycosites with N to Q replacement include, but are not limited to, the following:

an S-(deg-RBD), which is an S protein with all 2 N-glycosites in RBD mutated from N to Q, and 2 O-glycosites mutated from S/T to A (such as SEQ ID NO: 4, 22, 24, or 26);

an S-(deg-S2), which is an S protein with all 9 glycosites in S2 mutated from N to Q (such as SEQ ID NO: 6, 28, 30, or 32);

an S-(deg-S2-1194), which is an S protein with 8 glycosites in S2 mutated from N to Q, except glycosite 1194 (such as SEQ ID NO: 8 or 34);

an S-(deg-RBD-801), which is an S protein with all 2 N-glycosites in RBD mutated from N to Q, and 2 O-glycosites mutated from S/T to A, and glycosite 801 mutated from N to Q (such as SEQ ID NO: 10 or 36));

an S-(deg-RBD-1194), which is an S protein with all 2 N-glycosites in RBD mutated from N to Q, and 2 O-glycosites mutated from S/T to A, and glycosite 1194 mutated from N to Q (such as SEQ ID NO: 12 or 38)); and

an S-(deg-RBD-122-165-234), which is an S protein with all 2 N-glycosites in RBD mutated from N to Q, and 2 O-glycosites mutated from S/T to A, and glycosite 122, 165, and 234 mutated from N to Q (such as SEQ ID NO: 14 or 40).

[0098] In a further embodiment, the mRNA or DNA for S-(deg-RBD) has the sequence of SEQ ID NO: 3, 21, 23, or 25, the mRNA or DNA for S-(deg-S2) has the sequence of SEQ ID NO: 5, 27, 29, or 31, the mRNA or DNA for S-(deg-S2-1194) has the sequence of SEQ ID NO: 7 or 33, the mRNA or DNA for S-(deg-RBD-801) has the sequence of SEQ ID NO: 9 or 35, the mRNA or DNA for S-(deg-RBD-1194) has the sequence of SEQ ID NO: 11 or 37, the mRNA or DNA for S-(deg-RBD-122-165-234) has the sequence of SEQ ID NO: 13 or 39.

[0099] The present disclosure also provides a linear DNA comprising a promoter, 5' untranslated region, 3' untranslated region, expression plasmid with or without S-2P, and poly(A) tail signal sequence, wherein the putative sequon N-X-S/T is changed to Q-X-S/T and the O-glycosite was changed from S/T to A on the expression plasmid. In one embodiment, the S-2P expression plasmid comprises the S gene of SARS-CoV-2 encoding the pre-fusion state of the S having proline substitutions of K968 and V969.

[0100] In certain embodiments, the cell targeting formulation of the present disclosure can contain exemplary immunogenic peptides with glycan shields removed, which further can include, but are not limited to, an immunogenic peptide, comprising at least one amino acid sequence selected from a group

consisting of: TESIVRFPNITNL (SEQ ID NO: 41), NITNLCPFGEVFNATR (SEQ ID NO: 42), LYNSASFSTFK (SEQ ID NO: 43), LDSKVGGNYN (SEQ ID NO: 44), KSNLKPFERDIST (SEQ ID NO: 45), KPFERDISTEIQAG (SEQ ID NO: 46), GPKKSTNLVKNKC (SEQ ID NO: 47), NCDVVIGIV[N]NTVY (SEQ ID NO: 48), PELDSFKEELDKYFK[N]HTS (SEQ ID NO: 49), VNIQKEIDRLNEVA (SEQ ID NO: 50), NL[N]ESLIDLQ (SEQ ID NO: 51) and LGKYEQYIKWP (SEQ ID NO: 52) or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95% or 90% identity to any of SEQ ID NOs: 41 to 52.

[0101] In some embodiments, the cell-targeting formulation payload comprises an RNA encoding a modified protein comprising (1) one or more amino acid substitutions of asparagine (N) to glutamine (Q) at N-linked glycosylation sequons (N-X-S/T), wherein X is any amino acid residue except proline, and S/T denotes a serine or threonine residue; and/or (2) one or more amino acid substitutions of S/T to alanine (A) at the O-glycosites. In certain embodiments, the payload comprises an RNA encoding an immunogenic peptide, which comprises at least one amino acid sequence selected from a group consisting of: TESIVRFPNITNL (SEQ ID NO: 41), NITNLCPFGEVFNATR (SEQ ID NO: 42), LYNSASFSTFK (SEQ ID NO: 43), LDSKVGGNYN (SEQ ID NO: 44), KSNLKPFERDIST (SEQ ID NO: 45), KPFERDISTEIQAG (SEQ ID NO: 46), GPKKSTNLVKNKC (SEQ ID NO: 47), NCDVVIGIV[N]NTVY (SEQ ID NO: 48), PELDSFKEELDKYFK[N]HTS (SEQ ID NO: 49), VNIQKEIDRLNEVA (SEQ ID NO: 50), NL[N]ESLIDLQ (SEQ ID NO: 51) and LGKYEQYIKWP (SEQ ID NO: 52) or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95% or 90% identity to any of SEQ ID NOs: 41 to 52.

[0102] In some embodiments, the cell targeting formulation payload is a nucleic acid comprising a nucleotide sequence set forth in SEQ ID NO: 01, SEQ ID NO: 3, SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 9, SEQ ID NO: 11, SEQ ID NO: 13, SEQ ID NO: 15, SEQ ID NO: 17, SEQ ID NO: 19, SEQ ID NO: 21, SEQ ID NO: 23, SEQ ID NO: 25, SEQ ID NO: 27, SEQ ID NO: 29, SEQ ID NO: 31, SEQ ID NO: 33, SEQ ID NO: 35, SEQ ID NO: 37, SEQ ID NO: 39, or at least about 99%, 98%, 97%, 96%, 95% or 90% identity thereto; or the payload is configured to encode a peptide comprising an amino acid sequence set forth in SEQ ID NO: 02, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 16, SEQ ID NO: 18, SEQ ID NO: 20, SEQ ID NO: 22, SEQ ID NO: 24, SEQ ID NO: 26, SEQ ID NO: 28, SEQ ID NO: 30, SEQ ID NO: 32, SEQ ID NO: 34, SEQ ID NO: 36, SEQ ID NO: 38, SEQ ID NO: 40, or at least about 99%, 98%, 97%, 96%, 95% or 90% identity thereto.

[0103] In the second aspect, exemplary immunogenic peptides with glycan shields removed include, but are not limited to, an immunogenic peptide, comprising at least one amino acid sequence selected from a group consisting of: SSANNCTFEYVSQ (SEQ ID NO: 58), TESIVRFPNITNL (SEQ ID NO: 59), KPFERDISTEIQAG (SEQ ID NO: 60), GPKKSTNLVKNKC (SEQ ID NO: 61), TEVPVAIHADQ (SEQ ID NO: 62), RVYSTGSNVFQTR (SEQ ID NO: 63), RRARSVASQS (SEQ ID NO: 64), DPSKPSKRSF (SEQ ID NO: 65), FIKQYGDCLGDI (SEQ ID NO: 66), ENQKLIANQFNS (SEQ ID NO: 67), GKIQDSLSSSTA (SEQ ID NO: 68), NCDVVIGIVNNTVY (SEQ ID NO: 69), PELDSFKEELDKYFKNHTS (SEQ ID NO: 70), TSPDVDLGDISGINA (SEQ ID NO: 71), VNIQKEIDRLNEVA (SEQ ID NO: 72), NLNESLIDLQ (SEQ ID NO: 73), and LGKYEQYIKWP (SEQ ID NO: 74).

[0104] In some embodiments, the cell-targeting formulation payload comprises an RNA encoding a modified protein comprising (1) one or more amino acid substitutions of asparagine (N) to glutamine (Q) at N-linked glycosylation sequons (N-X-S/T), wherein X is any amino acid residue except proline, and S/T denotes a serine or threonine residue; and/or (2) one or more amino acid substitutions of S/T to alanine (A) at the O-glycosites. In certain embodiments, the payload comprises an RNA encoding an immunogenic peptide, which comprises at least one amino acid sequence selected from a group consisting of: SSANNCTFEYVSQ (SEQ ID NO: 58), TESIVRFPNITNL (SEQ ID NO: 59), KPFERDISTEIQAG (SEQ ID NO: 60), GPKKSTNLVKNKC (SEQ ID NO: 61), TEVPVAIHADQ (SEQ ID NO: 62), RVYSTGSNVFQTR (SEQ ID NO: 63), RRARSVASQS (SEQ ID NO: 64), DPSKPSKRSF (SEQ ID NO: 65), FIKQYGDCLGDI (SEQ ID NO: 66), ENQKLIANQFNS (SEQ ID NO: 67), GKIQDSLSSSTA (SEQ ID NO: 68), NCDVVIGIVNNTVY (SEQ ID NO: 69), PELDSFKEELDKYFKNHTS (SEQ ID NO: 70), TSPDVDLGDISGINA (SEQ ID NO: 71), VNIQKEIDRLNEVA (SEQ ID NO: 72), NLNESLIDLQ (SEQ ID NO: 73), and LGKYEQYIKWP (SEQ ID NO: 74).

[0105] In some embodiments, the cell-targeting formulation payload is configured to encode a peptide comprising an amino acid sequence set forth in SEQ ID NO: 53, 54, 55, 56, or 57, or at least about 99%, 98%, 97%, 96%, 95% or 90% identity thereto.

[0106] As described herein, the exemplary Low Sugar Universal Vaccine (LSUV) is also described in WO2022/221835 (where the mRNA comprises a sequence selected from SEQ ID NO 1-52), WO2022/221837A2 (where the mRNA comprises a sequence selected from SEQ ID No 1-21) and US20200046826A1 (where the mRNA comprises a sequence selected from SEQ ID No 1-20), which are herein incorporated by reference in their entirety.

[0107] ***Kit for Preparing a Lipid Nanoparticle.***

[0108] One aspect of the present disclosure is directed to a kit/reagent mixture for preparing a targeting LNP formulation of the present disclosure. The kit comprises a first reagent and a second reagent, wherein the first reagent comprises the compound of the present disclosure, and the second reagent comprises an ionizable lipid, a helper lipid, or a mixture thereof. The ionizable lipid and the helper lipid can be those described herein. In some embodiments, the second reagent comprises the ionizable lipid, and in some embodiments, the kit further comprises a third reagent comprising the helper lipid. In some embodiments, the kit further comprises a fourth reagent comprising a payload, wherein the cell targeting payload can be as those described herein.

[0109] *Packaging.* All the components of the kit of the present disclosure can be packaged in a physical container, respectively. In some embodiments, the first reagent and the second reagent are contained in the same container; in other words, in a ready-to-use package. In some other embodiments, the first reagent and the second reagent are contained in separate containers, so a user can decide whether and when to mix the first reagent and the second reagent.

[0110] **COMPOSITIONS/FORMULATIONS**

[0111] One aspect of the present disclosure is directed to a pharmaceutically acceptable vaccine composition comprising the targeting LNP of the present disclosure. The LNP of the composition might encapsulate a payload and is configured to deliver the payload to a target region of an organism. The payload can be as described herein, comprising a nucleic acid, a compound, a peptide, a protein, a glycan head, or a combination thereof. In some embodiments, the payload can be an immunogenic protein or a nucleic acid configured to encode the immunogenic protein in vivo. In some embodiments, the formulation further comprises a pharmaceutically acceptable excipient, adjuvant, or a combination thereof. In certain embodiments, the composition is a pharmaceutical composition or pharmaceutical formulation.

[0112] In some embodiments, the composition comprises 0.01, 0.05, 0.1, 0.5, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 95% (w/w) the LNP of the present disclosure, which encapsulates or does not encapsulate a payload, or any range defined by the foregoing endpoints, such as, included or excluded, 0.01% to 95% (w/w), 0.01% to 90% (w/w), 0.01% to 80% (w/w), 0.01% to 70% (w/w), 0.01% to 60% (w/w), 0.01% to 50% (w/w), 0.01% to 40% (w/w), 0.01% to 30% (w/w), 0.01% to 20% (w/w), 0.01% to 10% (w/w), 0.01% to 5% (w/w), 0.01% to 1% (w/w), 0.01% to 0.1% (w/w), 0.1% to 95% (w/w), 0.1% to 90% (w/w), 0.1% to 80% (w/w), 0.1% to 70% (w/w), 0.1% to 60% (w/w), 0.1% to 50%

(w/w), 0.1% to 40% (w/w), 0.1% to 30% (w/w), 0.1% to 20% (w/w), 0.1% to 10% (w/w), 0.1% to 5% (w/w), 0.1% to 1% (w/w), 1% to 95% (w/w), 1% to 90% (w/w), 1% to 80% (w/w), 1% to 70% (w/w), 1% to 60% (w/w), 1% to 50% (w/w), 1% to 40% (w/w), 1% to 30% (w/w), 1% to 20% (w/w), 1% to 10% (w/w), 1% to 5% (w/w), 5% to 95% (w/w), 5% to 90% (w/w), 5% to 80% (w/w), 5% to 70% (w/w), 5% to 60% (w/w), 5% to 50% (w/w), 5% to 40% (w/w), 5% to 30% (w/w), 5% to 20% (w/w), or 5% to 10% (w/w). The rest of the percentages of the composition can be an excipient as described herein.

[0113] In some embodiments, the composition is an mRNA vaccine, wherein the LNP encapsulates an mRNA configured to encode an immunogenic protein *in vivo*. The immunogenic protein can be a virus spike protein or other antigenic molecule of a pathogen. In certain embodiments, the composition of the present invention can be a COVID-19 mRNA vaccine.

[0114] An exemplary COVID-19 mRNA vaccine, as described herein, can be designed based on an mRNA technology to remove the glycan shields of a coronavirus (e.g., SARS-CoV-2) spike protein for better exposing the conserved regions of the spike protein. The mRNA vaccine of coronavirus spike protein has a deletion of glycosylation sites in the receptor binding domain (RBD) or the subunit 2 (S2) domain to expose highly conserved epitopes and elicit antibodies and CD8 T-cell response with broader protection against the alpha, beta, gamma, delta, omicron and various variants, as compared to the unmodified mRNA. The vaccine can be a Low Sugar Universal Vaccine (LSUV) as described in WO2022/221835 (where the mRNA comprises a sequence selected from SEQ ID NO 1-52), WO2022/221837A2 (where the mRNA comprises a sequence selected from SEQ ID No 1-21) and US20200046826A1 (where the mRNA comprises a sequence selected from SEQ ID No 1-20), which are herein incorporated by reference in their entirety.

[0115] In some embodiments, the composition/formulation of the present invention is configured to treat or prevent a disease (e.g., cancer). In such embodiments, the payload carried by the LNP can be a therapeutic reagent, a prophylactic reagent, or a nucleic acid configured to encode the therapeutic reagent or the prophylactic reagent *in vivo*. For example, the composition can be a personalized cancer vaccine (e.g., melanoma), a KRAS vaccine (KRAS-driven), or a checkpoint vaccine (e.g., PD-1, PDL-1 related).

[0116] In some embodiments, the composition/formulation of the present invention can be administered together with another composition (e.g., a vaccine or a medicine). Examples of another composition can be but are not limited to, influenza (flu) vaccine, adenovirus vaccine, anthrax vaccine, cholera vaccine, diphtheria vaccine, hepatitis A or B vaccine, HPV vaccine, measles vaccine, mumps

vaccine, smallpox vaccine, rotavirus vaccine, tuberculosis vaccine, pneumococcal vaccine, and Haemophilus influenzae type b vaccine.

[0117] *Combination compositions*

[0118] In some embodiments, the composition can be a combination composition (e.g., a combo vaccine) comprising a first LNP encapsulating a first payload and a second LNP encapsulating a second payload. The first LNP and the second LNP can be as the LNPs described herein but are different from each other in terms of the structure or properties of the copolymers thereof. For example, wherein the first LNP and the second LNP are different in size, copolymers forming the membrane thereof, payload encapsulated within the LNP, or a combination thereof.

[0119] For example, the first LNP comprises a glycan head configured to bind DC-SIGN, while the second LNP comprises a glycan head configured to bind CD1d. In another example, the first LNP comprises a glycan configured to target an antigen-presenting cell, while the second LNP comprises a glycan configured to target a cancer cell.

[0120] In some embodiments, the first payload and the second payload are different from each other. For example, the first payload can be a protein or peptide, while the second payload can be a nucleic acid. In certain embodiments, the first payload and the second payload can both be mRNA molecules but encode different proteins. For example, the first payload can be a mRNA configured to encode a spike protein of delta-SARS-CoV2, while the second payload can be a mRNA configured to encode a spike protein of omicron-SARS-CoV2.

[0121] *Additional components of the composition*

[0122] In some embodiments, the composition of the present disclosure can further comprise an adjuvant and/or a non-active substance, such as a pharmaceutically acceptable excipient. In certain embodiments, the adjuvant can be but is not limited to C34, Gluco-C34, 7DW8-5, C17, C23, C30, α -galactosylceramide (α -GalCer), Aluminum salt (e.g., aluminum hydroxide, aluminum phosphate, alum (potassium aluminum sulfate), mixed aluminum salts), Squalene, MF59, QS-21, Freund's complete adjuvant, Freund's incomplete adjuvant, AS03 (GlaxoSmithKline), MF59 (Seqirus), CpG 1018 (Dynavax), or a combination thereof.

[0123] In certain embodiments, the pharmaceutically acceptable excipient might comprise a solvent, dispersion media, diluent, dispersion, suspension aid, surface active agent, isotonic agent, thickening or emulsifying agent, preservative, polymer, peptide, protein, cell, hyaluronidase, or mixtures

thereof. Various excipients for formulating pharmaceutical compositions and techniques for preparing the composition are known in the art (see Remington: The Science and Practice of Pharmacy, 22nd Edition, Edited by Allen, Loyd V., Jr, Pharmaceutical Press). The use of a conventional excipient medium may be contemplated within the scope of the present disclosure, except insofar as any conventional excipient medium may be incompatible with a substance or its derivatives, such as by producing any undesirable biological effect or otherwise interacting in a deleterious manner with any other component(s) of the pharmaceutical composition. Formulation of standard pharmaceutically acceptable excipients may be carried out using routine methods in the pharmaceutical art (See Remington's Pharmaceutical Sciences, 19th Edition, Mack Publishing Company, Eastern Pennsylvania, USA.).

[0124] In some embodiments, the composition further comprises a phosphate conjugate. Without wishing to be bound by theories, the phosphate conjugate can increase *in vivo* circulation times and/or increase the targeted delivery of the LNP of the present disclosure. Phosphate conjugates for use with the present disclosure may be made using the methods described in the PCT Publication No.

WO2013/033438, filed on August 30, 2012, or U.S. Publication No. US2013/0196948, filed on June 23, 2011, the content of each of which is herein incorporated by reference in its entirety. As a non-limiting example, the phosphate conjugates may include a compound of any one of the formulas described in the PCT Publication No. WO2013/033438, filed on August 30, 2012, herein incorporated by reference in its entirety.

[0125] In some embodiments, the composition further comprises a conjugate to enhance the delivery of the LNP of the present disclosure. Without wishing to be bound by theories, the conjugate selected to be used may inhibit the phagocytic clearance of the LNP in a subject. In some examples, the conjugate may be a human membrane protein CD47 or a “self” peptide derived therefrom (e.g., the “self” particles described by Rodriguez et al. (Science 2013, 339, 971-975), herein incorporated by reference in its entirety).

[0126] In some embodiments where the payload is an immunogenic agent or a nucleic acid configured to encode the immunogenic agent, the composition further comprises an immunostimulatory agent to enhance the immune response induced by the immunogenic agent. As a non-limiting example, the composition may comprise a Th1 immunostimulatory agent, which may enhance a Th1-based response of the immune system (see PCT Publication No. WO2010/123569 and U.S. Publication No. 2011/0223201, each of which is herein incorporated by reference in its entirety).

[0127] In some embodiments, the composition does not include viral components (e.g., viral capsids, viral enzymes, or other viral proteins, for example, those needed for viral-based replication), nor is it packaged within, encapsulated within, linked to, or otherwise associated with a virus or viral particle.

[0128] **METHODS OF USE**

[0129] One aspect of the present disclosure is directed to methods of using the LNP or the targeting formulation of the present disclosure. Particularly, the methods are conducted to obtain a desired effect, such as targeted delivering a payload, preventing or treating a disease, or boosting an adaptive immune response in a subject. In some embodiments, the subject can be but not limited to an animal or a human, to whom the payload is designed to exhibit its efficacy, to whom the treatment or prevention of disease is needed, or to whom the adaptive immune response thereof is required to be boosted.

[0130] *Methods of targeted payload delivery in a subject*

[0131] In some embodiments, a method of targeted delivery of a payload in a subject is provided, which comprises administering an effective amount of the LNP to the subject or the targeting formulation of the present disclosure. The LNP and the payload are as described herein, and the payload is encapsulated by the LNP. Without wishing to be bound by any theories, the targeted delivery is fulfilled by the compound of the present disclosure. Particularly, the R₁ group of the compound of the present disclosure provides the desired binding affinity/specificity targeting a desired region of the subject via the glycosyl group thereof.

[0132] *Methods of preventing or treating a disease in a subject*

[0133] In some embodiments, a method of preventing or treating a disease in a subject is provided, which comprises administering an effective amount of the LNP to the subject or the formulation of the present disclosure. The LNP of this method encapsulates a payload, and the payload is a therapeutic agent or derives a therapeutic agent configured to prevent and/or treat the disease.

[0134] Without wishing to be bound by any theories, the LNP or the formulation of the present disclosure provides targeted delivery via the compound of the present disclosure. Therefore, by using the LNP of the present disclosure to deliver the payload, the efficacy of the payload can be more effectively performed. For example, in the embodiments that the R₁ group of the compound comprises a structure binding specifically to the DC-SIGN on dendritic cells, an antigenic or immunogenic payload can be effectively delivered to the dendritic cells to provoke immune responses for preventing disease of concern. This strategy is beneficial in delivering an antigen or a nucleic acid encoding an antigen of a

vaccine. Some other examples include having an R_1 group designed to target cancer cells so that an anti-tumor reagent can be delivered effectively to a cancer microenvironment. This strategy can increase the efficacy of the anti-tumor reagent and reduce the treatment's side effects.

[0135] In some embodiments, the disease is characterized by dysfunctional or aberrant protein or polypeptide activity. For example, the disease is selected from the group consisting of rare diseases, infectious diseases, cancer and proliferative diseases, genetic diseases (e.g., cystic fibrosis), autoimmune diseases, diabetes, neurodegenerative diseases, cardio- and reno-vascular diseases, and metabolic diseases.

[0136] In some embodiments, the disease can be cancer or infectious diseases. In certain embodiments, the disease can be a viral-associated infection, including, but not limited to, human parainfluenza virus 3, respiratory syncytial virus (RSV), cytomegalovirus (CMV), human metapneumovirus (hMPV), or SARS-CoV-2 (COVID-19) associated infections.

[0137] *Methods of boosting an adaptive immune response*

[0138] In some embodiments, a method of boosting an adaptive immune response is provided, comprising administering an effective amount of the LNP of the present disclosure to a subject. The LNP of this method encapsulates a payload within an inner space defined by a membrane of the LNP, and the payload is a therapeutic agent or derives a therapeutic agent configured to provoke an adaptive immune response in the subject.

[0139] Without wishing to be bound by any theories, the LNP of the present disclosure provides targeted delivery to an immune cell via the compound of the present disclosure. In some embodiments, the R_1 group of the compound comprises a structure that binds to an antigen-presenting cell with the desired specificity or affinity. For example, the R_1 group might comprise a structure binding specifically to the DC-SIGN on dendritic cells so that the LNP is able to deliver the immunogenic payload specifically to the dendritic cells to facilitate the onset of an adaptive immune response.

[0140] In some embodiments, the boosted adaptive immune response is against a disease, including but not limited to cancer or an infectious disease. The infectious disease, for example, can be a viral-associated infection, including, but not limited to, human parainfluenza virus 3, respiratory syncytial virus (RSV), cytomegalovirus (CMV), human metapneumovirus (hMPV), or SARS-CoV-2 (COVID-19) associated infections.

[0141] *Administration*

[0142] Regarding the methods of the present disclosure, in some embodiments, the subject is administered with a single dose of the LNP or the targeting formulation of the present disclosure, which encapsulates or does not encapsulate a payload. Yet in some embodiments, the subject is administered with the LNP in an initial dose followed by at least one booster dose, e.g., one, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen, sixteen, seventeen, eighteen, nineteen, twenty, or more follow-up doses, with an interval of each dose in about, 1, 2, 3, 4, 5, 6, 7 days, about 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 weeks, or about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 months, or any range defined by the foregoing endpoints, such as, included or excluded, 1 to 7 days, 1 to 5 days, 1 to 3 days, 1 to 10 weeks, 1 to 8 weeks, 1 to 6 weeks, 1 to 4 weeks, 1 to 2 weeks, 1 to 12 months, 1 to 8 months, 1 to 6 months, 1 to 4 months, 1 to 2 months, or 6 to 12 months. In certain embodiments, the LNP of the present disclosure encapsulating a payload is administered twice at the same or different doses, and the two administrations are separated by 1 day, 3 days, 5 days, 1 week, 2 weeks, 1 month, 2 months, 3 months, 6 months, 1 year, 1 to 5 days, 1 to 2 weeks, 1 to 3 months, 1 to 6 months, 1 month to 1 year, 3 months to 1 year, or 6 months to 1 year.

[0143] *Administration route.* The LNP or formulation as described herein may be administered by any route. Suitable routes include but are not limited to, oral, nasal, mucosal, submucosal, intravenous, intramuscular, intraperitoneal, subcutaneous, intradermal, transdermal, and buccal routes. Some practical topical applications include but are not limited to, a drop, spray, aerosol, gel, or ointment to the mucosal epithelium of the eye, nose, mouth, anus, or vagina. Other possible routes of administration are by spray, aerosol, or powder application through inhalation via the respiratory tract.

[0144] *Effective amount of administration.* The effective amount described herein refers to the amount sufficient to provide a desired effect. In the embodiments where the purpose of administering the LNP of the present disclosure is to treat a disease, the effective amount refers to a therapeutically effective amount, while in some other embodiments where the purpose is to prevent a disease, the effective amount refers to a prophylactically effective amount.

[0145] Yet in some other embodiments where the purpose of administering the LNP with payload is to boost an adaptive immune response, the effective amount can be determined as an amount sufficient to induce an antigen-specific immune response in a subject to whom the LNP and payload are administered. The antigen-specific immune response can be characterized by measuring an anti-antigenic polypeptide (i.e., the payload or the product of the payload) antibody titer produced in a subject to whom the LNP and payload are administered. In some embodiments, the measurement can be conducted using an Enzyme-linked immunosorbent assay (ELISA).

[0146] In some embodiments, an antibody titer is used to assess whether a subject has had an infection or to determine whether immunizations are required. In some embodiments, an antibody titer is used to determine the strength of an autoimmune response, to determine whether a booster immunization is needed or whether an immunization has been boosted, to determine whether a previous vaccine was effective, and/or to identify any recent or prior infections.

[0147] The effective amount of the methods of the present disclosure can be determined based on several factors, including but not limited to the conditions of the subjects (age, gender, species, body weight, health status, etc.), the progress of the disease to be treated, the administration route, the dosage and interval of the administration, and the nature of the payload. Regarding the nature of the payload, for example, in embodiments where the LNP of the present disclosure is used to carry an mRNA as in a mRNA vaccine, the effective amount can be determined based on the effective amount of the mRNA required to provoke sufficient immune response in the subject. Accordingly, in some embodiments that the payload is mRNA, the effective amount of the methods of the present disclosure is about 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 90, 100, 125, 150, 175, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 950 or 1000 micrograms (μg or ug), or any range defined by the foregoing endpoints, such as, include or exclude, 5 micrograms to 1000 micrograms, 5 micrograms to 900 micrograms, 5 micrograms to 800 micrograms, 5 micrograms to 700 micrograms, 5 micrograms to 600 micrograms, 5 micrograms to 500 micrograms, 5 micrograms to 400 micrograms, 5 micrograms to 300 micrograms, 5 micrograms to 200 micrograms, 5 micrograms to 175 micrograms, 5 micrograms to 150 micrograms, 5 micrograms to 125 micrograms, 5 micrograms to 100 micrograms, 5 micrograms to 90 micrograms, 5 micrograms to 80 micrograms, 5 micrograms to 70 micrograms, 5 micrograms to 60 micrograms, 5 micrograms to 50 micrograms, 5 micrograms to 40 micrograms, 5 micrograms to 30 micrograms, 5 micrograms to 20 micrograms, 5 micrograms to 10 micrograms, 10 micrograms to 1000 micrograms, 10 micrograms to 900 micrograms, 10 micrograms to 800 micrograms, 10 micrograms to 700 micrograms, 10 micrograms to 600 micrograms, 10 micrograms to 500 micrograms, 10 micrograms to 400 micrograms, 10 micrograms to 300 micrograms, 10 micrograms to 200 micrograms, 10 micrograms to 175 micrograms, 10 micrograms to 150 micrograms, 10 micrograms to 125 micrograms, 10 micrograms to 100 micrograms, 10 micrograms to 90 micrograms, 10 micrograms to 80 micrograms, 10 micrograms to 70 micrograms, 10 micrograms to 60 micrograms, 10 micrograms to 50 micrograms, 10 micrograms to 40 micrograms, 10 micrograms to 30 micrograms, 10 micrograms to 20 micrograms, 50 micrograms to 1000 micrograms, 50 micrograms to 900 micrograms, 50 micrograms to 800 micrograms, 50 micrograms to 700 micrograms, 50 micrograms to 600 micrograms, 50 micrograms to 500 micrograms, 50 micrograms to 400 micrograms, 50 micrograms to 300 micrograms, 50 micrograms to

200 micrograms, 50 micrograms to 175 micrograms, 50 micrograms to 150 micrograms, 50 micrograms to 125 micrograms, 50 micrograms to 100 micrograms, 50 micrograms to 90 micrograms, 50 micrograms to 80 micrograms, 50 micrograms to 70 micrograms, or 50 micrograms to 60 micrograms. 100 micrograms to 1000 micrograms, 100 micrograms to 900 micrograms, 100 micrograms to 800 micrograms, 100 micrograms to 700 micrograms, 100 micrograms to 600 micrograms, 100 micrograms to 500 micrograms, 100 micrograms to 400 micrograms, 100 micrograms to 300 micrograms, 100 micrograms to 200 micrograms, 100 micrograms to 175 micrograms, 100 micrograms to 150 micrograms, 300 micrograms to 1000 micrograms, 300 micrograms to 900 micrograms, 300 micrograms to 800 micrograms, 300 micrograms to 700 micrograms, 300 micrograms to 600 micrograms, 300 micrograms to 500 micrograms, 300 micrograms to 400 micrograms, 500 micrograms to 1000 micrograms, 500 micrograms to 900 micrograms, 500 micrograms to 800 micrograms, 500 micrograms to 700 micrograms, 500 micrograms to 600 micrograms, 600 micrograms to 800 micrograms, or 700 micrograms to 900 micrograms.

[0148] Nevertheless, given the targeted delivery provided by the LNP of the present disclosure, one can expect that the effective amount required in the methods of the present disclosure might be lower than the effective amount required in other non-targeted delivery methods. For example, the effective amount required in the methods of the present disclosure might be lower than the effective amount required in other non-targeted delivery methods by at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 95, or 99%, or any range defined by the foregoing endpoints, such as, included or excluded, 1 to 99%, 1 to 95%, 1 to 90%, 1 to 80%, 1 to 70%, 1 to 60%, 1 to 50%, 1 to 40%, 1 to 30%, 1 to 20%, 1 to 10%, 1 to 5%, 5 to 99%, 5 to 95%, 5 to 90%, 5 to 80%, 5 to 70%, 5 to 60%, 5 to 50%, 5 to 40%, 5 to 30%, 5 to 20%, 5 to 10%, 10 to 90%, 10 to 80%, 10 to 70%, 10 to 60%, 10 to 50%, 10 to 40%, 10 to 30%, 10 to 20%, 30 to 99%, 30 to 95%, 30 to 90%, 30 to 80%, 30 to 70%, 30 to 60%, 30 to 50%, 30 to 40%, 50 to 99%, 50 to 95%, 50 to 90%, 50 to 80%, 50 to 70%, 50 to 60%, 70 to 99%, 70 to 95%, 70 to 90%, 70 to 80%, 80 to 99%, 80 to 95%, 80 to 90%, 90 to 99%, or 95 to 99%.

[0149] Furthermore, in some embodiments where the LNP of the present disclosure is used to deliver an antigenic agent or a nucleic acid encoding the antigenic agent to induce antibodies against the antigenic agent, the titer of the antibody induced by the present disclosure, compared with the titer of the antibody induced by non-targeted delivery methods, increase 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 logs, or any range defined by the foregoing endpoints, such as, included or excluded 1 to 10 logs, 1 to 8 logs, 1 to 6 logs, 1 to 4 logs, 2 to 9 logs, 2 to 7 logs, 2 to 5 logs, 3 to 10 logs, 3 to 8 logs, 3 to 5 logs, or 4 to 6 logs.

[0150] In some other embodiments, where the LNP of the present disclosure is used to deliver an antigenic agent or a nucleic acid encoding the antigenic agent to induce an immune response against the antigenic agent, the antibody titer against the antigenic agent induced by the present disclosure, compared with that of non-targeted delivery methods, is 0.1, 0.2, 0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 times higher, or any range defined by the foregoing endpoints, such as, included or excluded, 0.1 to 10, 0.1 to 9, 0.1 to 8, 0.1 to 7, 0.1 to 6, 0.1 to 5, 0.1 to 4, 0.1 to 3, 0.1 to 2, 0.1 to 1, 0.1 to 0.5, 0.5 to 10, 0.5 to 9, 0.5 to 8, 0.5 to 7, 0.5 to 6, 0.5 to 5, 0.5 to 4, 0.5 to 3, 0.5 to 2, 0.5 to 1, 1 to 10, 1 to 9, 1 to 8, 1 to 7, 1 to 6, 1 to 5, 1 to 4, 1 to 3, 1 to 2, 3 to 10, 3 to 9, 3 to 8, 3 to 7, 3 to 6, 3 to 5, 3 to 4, 5 to 10, 5 to 9, 5 to 8, 5 to 7, 5 to 6, 7 to 10, 7 to 9, 7 to 8, or 8 to 10.

[0151] Yet in some embodiments where the LNP of the present disclosure is used to deliver an antigenic agent or a nucleic acid encoding the antigenic agent to induce an immune response against the antigenic agent, the immune response is induced 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, or 20 days earlier than the immune response induced by non-targeted delivery methods, or any range defined by the foregoing endpoints, such as, included or excluded, 1 to 20, 1 to 18, 1 to 14, 1 to 10, 1 to 6, 2 to 20, 2 to 18, 2 to 14, 2 to 10, 2 to 6, 5 to 20, 5 to 18, 5 to 14, or 5 to 10 days earlier.

[0152] In some embodiments, the LNP, as described herein in the methods of the present disclosure, is administered at a dosage level sufficient to deliver a payload from about 0.0001 mg/kg to about 100 mg/kg, from about 0.001 mg/kg to about 0.05 mg/kg, from about 0.005 mg/kg to about 0.05 mg/kg, from about 0.001 mg/kg to about 0.005 mg/kg, from about 0.05 mg/kg to about 0.5 mg/kg, from about 0.01 mg/kg to about 50 mg/kg, from about 0.1 mg/kg to about 40 mg/kg, from about 0.5 mg/kg to about 30 mg/kg, from about 0.01 mg/kg to about 10 mg/kg, from about 0.1 mg/kg to about 10 mg/kg, or from about 1 mg/kg to about 25 mg/kg, per subject body weight per day, one or more times a day, to obtain the desired *in vivo* effect.

[0153] **DEFINITION**

[0154] Unless specifically defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. Unless mentioned otherwise, the techniques employed or contemplated herein are standard methodologies well known to one of ordinary skill in the art. The practice of the present disclosure will employ, unless otherwise indicated, conventional techniques of microbiology, tissue culture, molecular biology, chemistry, biochemistry, and recombinant DNA technology, which are within the skill of the art.

The materials, methods, and examples are illustrative only and not limiting. The following is presented by way of illustration and is not intended to limit the scope of the disclosure.

[0155] Numbers expressing quantities of ingredients, properties such as molecular weight, reaction conditions and results, and so forth, used to describe and claim certain embodiments of the present disclosure are to be understood as being modified in some instances by the term "about." A skilled artisan in the field would understand the meaning of the term "about" in the context of the value that it qualifies. The numerical values presented in some embodiments of the present disclosure may contain certain errors resulting from the standard deviation in their respective testing measurements. For example, the term "about," as used herein, refers to a measurable value such as an amount, a temporal duration, and the like and is meant to encompass variations of $\pm 20\%$, $\pm 10\%$, $\pm 5\%$, $\pm 1\%$, or $\pm 0.1\%$ from the specified value, as such variations are appropriate.

[0156] As used herein, "substantially" means sufficient to work for the intended purpose. The term "substantially" thus allows for minor, insignificant variations from an absolute or perfect state, dimension, measurement, result, or the like, such as expected by a person of ordinary skill in the field, but that does not appreciably affect overall performance. When used with respect to numerical values or parameters or characteristics expressed as numerical values, "substantially" means within ten percent.

[0157] As used herein, "treat," "treatment," and "treating" refer to an approach for obtaining beneficial or desired results, for example, clinical results. For the purposes of this disclosure, beneficial or desired results may include inhibiting or suppressing the initiation or progression of an infection or a disease; ameliorating, or reducing the development of, symptoms of an infection or disease; or a combination thereof.

[0158] As used herein, "preventing" and "prevention" are used interchangeably with "prophylaxis" and can mean complete prevention of infection or prevention of the development of symptoms of that infection, a delay in the onset of a disease or its symptoms, or a decrease in the severity of a subsequently developed infection or its symptoms.

[0159] As used herein, "glycan" or "glycosyl group" refers to a polysaccharide, oligosaccharide, or monosaccharide. Glycans can be monomers or polymers of sugar residues and can be linear or branched. A glycan may include natural sugar residues (e.g., glucose, N-acetylglucosamine, N-acetylneuraminic acid, galactose, mannose, fucose, hexose, arabinose, ribose, xylose, etc.) and/or modified sugars (e.g., 2'-fluororibose, 2'-deoxyribose, phosphomannose, 6' sulfo N-acetylglucosamine, etc.).

[0160] As used herein, “alkyl” refers to a hydrocarbon chain that may be a straight chain or branched chain, saturated or unsaturated, containing the indicated number of carbon atoms. For example, C₁₋₆ indicates that the group may have from 1 to 6 (inclusive) carbon atoms in it. Non-limiting examples include methyl, ethyl, iso-propyl, tert-butyl, n-hexyl. A “heteroalkyl” group is an alkyl group in which at least one carbon of the chain has been replaced by a heteroatom. In some embodiments, the heteroalkyl group has 1 to 20 carbon atoms. The term “alkoxy” is intended to mean the moiety —OR, where R is alkyl. The term “aryloxy” is intended to mean the moiety —OR, where R is aryl.

[0161] As used herein, “alkenyl” refers to a hydrocarbon chain including at least one double bond, which may be a straight chain or branched chain, and containing the indicated number of carbon atoms. For example, C₂₋₆ indicates that the group may have from 2 to 6 (inclusive) carbon atoms in it. Non-limiting examples include ethenyl and prop-1-en-2-yl.

[0162] As used herein, “alkynyl” refers to a hydrocarbon chain including at least one triple bond, which may be a straight chain or branched chain, and containing the indicated number of carbon atoms. For example, C₂₋₆ indicates that the group may have from 2 to 6 (inclusive) carbon atoms in it. Non-limiting examples include ethynyl and 3,3-dimethylbut-1-yn-1-yl.

[0163] As used herein, “cycloalkyl” refers to a nonaromatic cyclic, bicyclic, fused, or spiro hydrocarbon radical having 3 to 10 carbons, such as 3 to 8 carbons, such as 3 to 7 carbons, wherein the cycloalkyl group which may be optionally substituted. Examples of cycloalkyls include five-membered, six-membered, and seven-membered rings. A cycloalkyl can include one or more elements of unsaturation; a cycloalkyl that includes an element of unsaturation is herein also referred to as a “cycloalkenyl”. Examples include cyclopropyl, cyclobutyl, cyclopentyl, cyclopentenyl, cyclohexyl, cyclohexenyl, cycloheptyl, and cyclooctyl.

[0164] As used herein, “heterocycloalkyl” refers to a nonaromatic 5-8 membered monocyclic, 8-12 membered bicyclic, or 11-14 membered tricyclic ring fused or spiro system radical having 1-3 heteroatoms if monocyclic, 1-6 heteroatoms if bicyclic, or 1-9 heteroatoms if tricyclic, said heteroatoms selected from O, N, or S (e.g., carbon atoms and 1-3, 1-6, or 1-9 heteroatoms of N, O, or S if monocyclic, bicyclic, or tricyclic, respectively), wherein 0, 1, 2 or 3 atoms of each ring may be substituted by a substituent. Heterocycloalkyls can also include oxidized ring members, such as —N(O)—, —S(O)—, and —S(O)₂—. Examples of heterocycloalkyls include five-membered, six-membered, and seven-membered heterocyclic rings. Examples include piperazinyl, pyrrolidinyl, dioxanyl, morpholinyl, tetrahydrofuranyl, and the like.

[0165] As used herein, “aryl” or “aryl group” refers to a moiety formed by the removal of one or more hydrogen (“H”) or deuterium (“D”) from an aromatic compound. The aryl group may be a single ring (monocyclic) or have multiple rings (bicyclic, or more) fused together or linked covalently. A “carbocyclic aryl” has only carbon atoms in the aromatic ring(s). A “heteroaryl” is intended to mean an aromatic ring system containing 5 to 14 aromatic ring atoms that may be a single ring, two fused rings or three fused rings wherein at least one aromatic ring atom is a heteroatom selected from, but not limited to, the group consisting of O, S and N. Heteroaryls can also include oxidized ring members, such as —N(O)—, —S(O)—, and —S(O)₂—. Examples include furanyl, thienyl, pyrrolyl, imidazolyl, oxazolyl, thiazolyl, isoxazolyl, pyrazolyl, isothiazolyl, oxadiazolyl, triazolyl, thiadiazolyl, pyridinyl, pyrazinyl, pyrimidinyl, pyridazinyl, triazinyl and the like. Examples also include carbazolyl, quinoliziny, quinolinyl, isoquinolinyl, cinnolinyl, phthalazinyl, quinazolinyl, quinoxalinyl, triazinyl, indolyl, isoindolyl, indazolyl, indoliziny, purinyl, naphthyridinyl, pteridinyl, carbazolyl, acridinyl, phenazinyl, phenothiazinyl, phenoxazinyl, benzoxazolyl, benzothiazolyl, 1H-benzimidazolyl, imidazopyridinyl, benzothieryl, benzofuranyl, isobenzofuran and the like.

[0166] As used herein, “amine” refers to a compound that contains a basic nitrogen atom with a lone pair. The term “amino” refers to the functional group or moiety —NH₂, —NHR, or —NR₂, where R is the same or different at each occurrence and can be an alkyl group or an aryl group.

[0167] As used herein, “halogen” or “halo” refers to fluorine, bromine, chlorine, or iodine. In particular, it typically refers to fluorine or chlorine when attached to an alkyl group and further includes bromine or iodine when on an aryl or heteroaryl group.

[0168] As used herein, the term “haloalkyl” refers to an alkyl as defined herein, which is substituted by one or more halo groups. The haloalkyl can be monohaloalkyl, dihaloalkyl, trihaloalkyl, or polyhaloalkyl, including perhaloalkyl. A monohaloalkyl can have one chloro or fluoro within the alkyl group. Chloro and fluoro are commonly present as substituents on alkyl or cycloalkyl groups; fluoro, chloro, and bromo are often present on aryl or heteroaryl groups. Dihalalkyl and polyhalalkyl groups can have two or more of the same halo atoms or a combination of different halo groups on the alkyl. Typically, the polyhalalkyl contains up to 12, or 10, or 8, or 6, or 4, or 3, or 2 halo groups. Non-limiting examples of haloalkyl include fluoromethyl, difluoromethyl, trifluoromethyl, chloromethyl, dichloromethyl, trichloromethyl, 2,2,2-trifluoroethyl, pentafluoroethyl, heptafluoropropyl, difluorochloromethyl, dichlorofluoromethyl, difluoroethyl, difluoropropyl, dichloroethyl and dichloropropyl. A perhalo-alkyl refers to an alkyl having all hydrogen atoms replaced with halo atoms, e.g., trifluoromethyl.

[0169] As used herein, unless otherwise specified, the term “heteroatom” refers to a nitrogen (N), oxygen (O), or sulfur (S) atom.

[0170] **EXAMPLE**

[0171] **Example 1: Synthesis of exemplary compounds of the present disclosure**

[0172] *Chemical Materials and Methods*

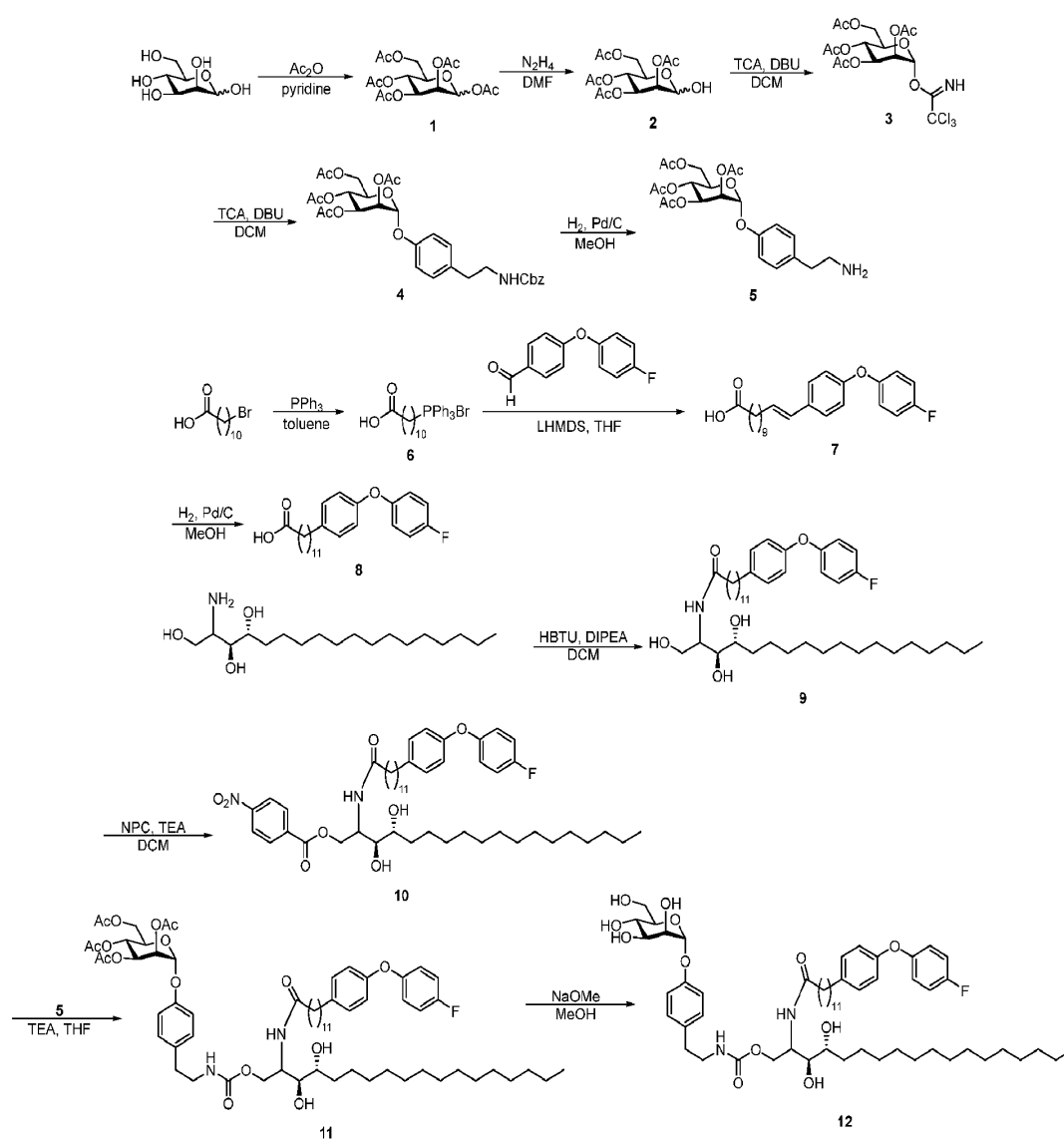
[0173] For chemical synthesis, all starting materials and commercially obtained reagents were purchased from Sigma-Aldrich and used as received unless otherwise noted. All reactions were performed in oven-dried glassware under a nitrogen atmosphere using dry solvents. ^1H and ^{13}C NMR spectra were recorded on Bruker AV-600 spectrometer, and were referenced to the solvent used (CDCl_3 at δ 7.24 and 77.23, CD_3OD at δ 3.31 and 49.2, and D_2O at δ 4.80, and $\text{DMSO}-d_6$ at δ 2.5 and 39.51 for ^1H and ^{13}C , respectively). Chemical shifts (δ) are reported in ppm using the following convention: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), integration, and coupling constants (J), with J reported in Hz. High-resolution mass spectra were recorded under ESI-TOF mass spectroscopy conditions. Silica gel (E, Merck) was used for flash chromatography. IMPACTTM system (Intein Mediated Purification with Affinity Chitinbinding Tag) was purchased from New England Biolabs. His-tag purification resin was purchased from Roche. HiTrap IMAC column (5 mL) was purchased from GE Healthcare Life Sciences. Gel permeation chromatography (GPC) equipped with Ultimate 3000 liquid chromatography associated with a 101 refractive index detector and Shodex columns was used to analyze the polymeric products using THF as the eluent at 30 °C with 1 mL min⁻¹ flow rate. The calibration was based on the narrow linear poly(styrene) Shodex standard (SM-105). The Mw and dispersity of the polymeric products were calculated using DIONEX chromeleon software. Transmission electron microscopy (TEM) images were obtained by a FEI Tecnai G2 F20 S-Twin.

[0174] The chemical materials and methods described herein apply to all examples described in the present disclosure.

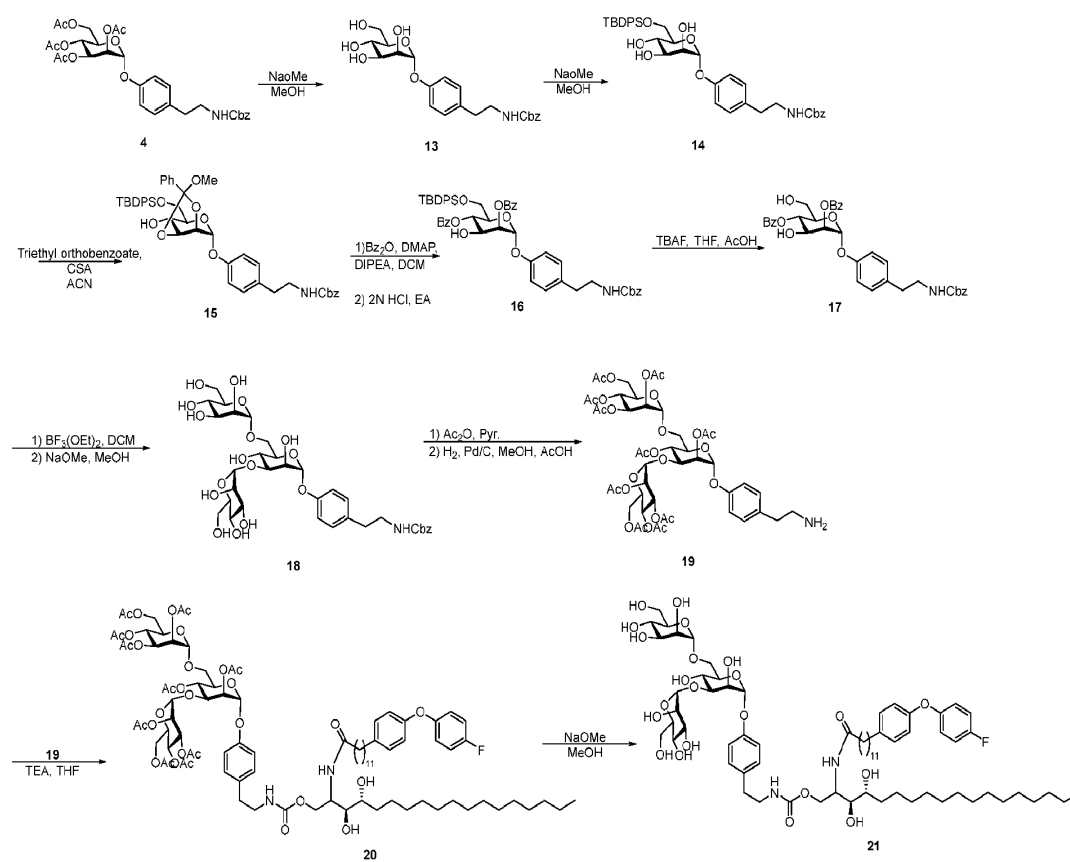
[0175] *Synthesis and Results*

[0176] The exemplary compounds described here were synthesized according to the synthesis Scheme 1, Scheme 2, and Scheme 3 below. The detailed synthesis procedures are described below.

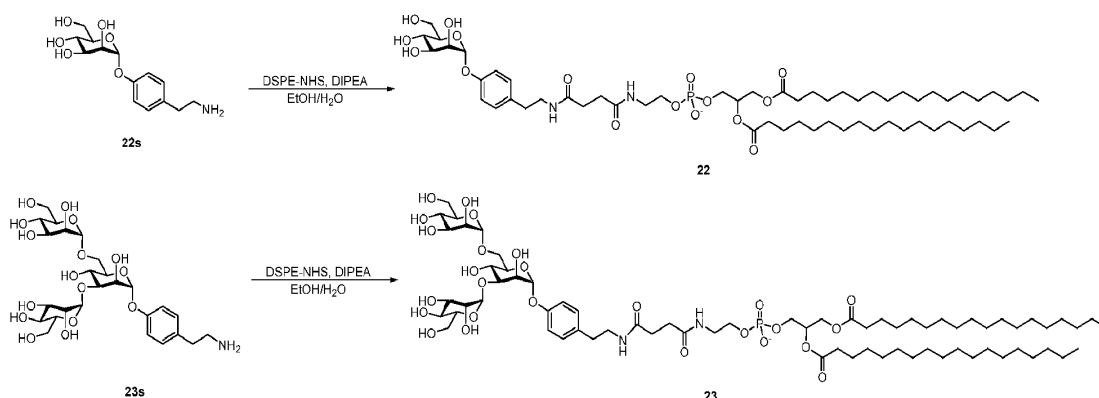
[0177] Scheme 1



[0178] Scheme 2



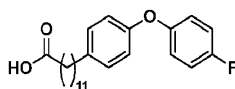
[0179] Scheme 3



[0180] Compounds 1 to 5

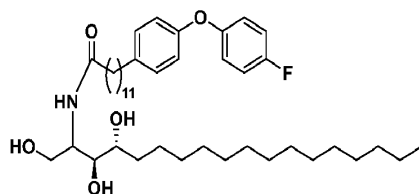
[0181] Compounds 1-5 were synthesized and characterized according to a published protocol (ACS Nano 2021, 15, 309–321).

[0182] Compound 8



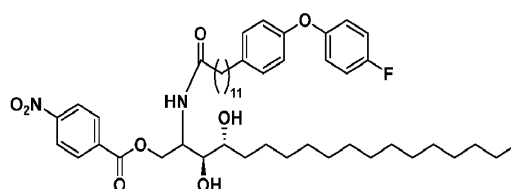
[0183] (11-Carboxynonyl)triphenylphosphonium bromide **6** (2.5 g, 10 mmol) was prepared by refluxing triphenylphosphine (10 mmol) and 11-bromoundecanoic acid (10 mmol). It was then dissolved in 50 ml of tetrahydrofuran (THF) and cooled to 0 °C. lithium bis(trimethylsilyl)amide (LHMDS; 1 M in THF, 20 mmol) was added to the solution to produce an orange ylide. After that, 4-(4-Fluorophenoxy)benzaldehyde (12 mmol) in 20 ml of THF was added dropwise to the solution and stirred for 4 h at room temperature. The reaction was quenched with methanol and concentrated. The residue was extracted with EA and brine and then dried over MgSO₄. After removal of the solvent, the mixture was chromatographed on silica gel (EA-Hex =1:2) to give the unsaturated fatty acid **7**. The saturated fatty acid was prepared by catalytic hydrogenation in 50 ml of methanol containing 10 mol% of 10% palladium on charcoal (Pd/C). The reaction mixture was stirred under H₂ at room temperature overnight. The hydrogenated product was filtered through Celite and the resulting solution was concentrated and chromatographed on silica gel (EA-Hex =1:2) to give the product as a yellow solid (66%).

[0184] Compound 9



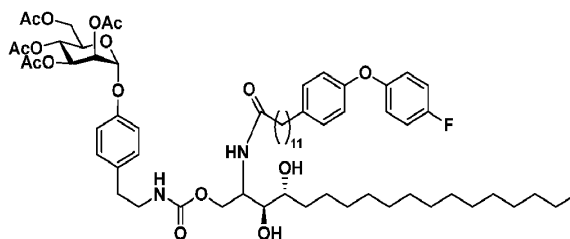
[0185] Compound 9. Compound 8 (1 mmol) in THF (10 mL) was added EDC (1.5 mmol), HOBT (1.5 mmol), DMAP (0.1 mmol), trimethylamine (2 mmol), and phytosphingosine (1.2 mmol), and the resulting solution was stirred under nitrogen at rt for 12 h. The solvent was then removed by evaporation, followed by extraction with EA/H₂O. The collected organic layer was washed with saturated NaHCO₃(aq), water and brine, and dried over MgSO₄. The crude product was purified by column chromatography on silica gel (EA/Hex 1:1) to yield 9 (74%).

[0186] **Compound 10**



[0187] Compound 9 (1 mmol) in THF (10 mL) was added 4-nitrophenylchloroformate (2 mmol), trimethylamine (2 mmol), and the resulting solution was stirred under nitrogen at rt for 12 h. The solvent was then removed by evaporation, and the crude compound was directly used for the next step without further purification.

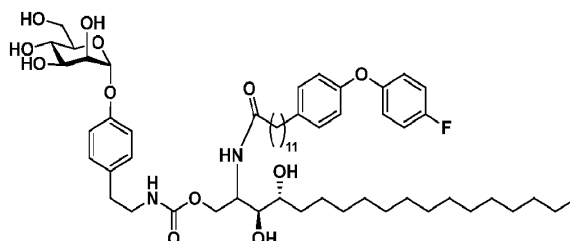
[0188] **Compound 11**



[0189] Compound 5 (1 mmol) in THF (10 mL) was added 10 (1 mmol) and trimethylamine (2 mmol), and the resulting solution was stirred under nitrogen at rt for 2 h. The solvent was then removed by evaporation, followed by extraction with EA/H₂O. The collected organic layer was washed with

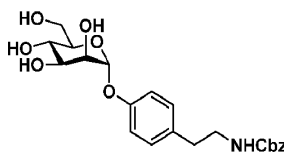
saturated $\text{NaHCO}_3(\text{aq})$, water and brine, and dried over MgSO_4 . The crude product was purified by column chromatography on silica gel (EA/Hex 1:1+10% MeOH) to yield **11** (59%).

[0190] **Compound 12**



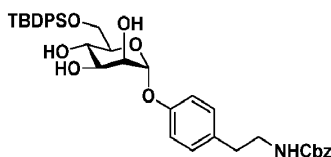
[0191] Compound **11** in MeOH was added NaOMe (0.2 eq), and the resulting solution was stirred under nitrogen at room temperature for 2 hours. The mixture was neutralized by IR-120 and then filtered and concentrated to dryness in vacuo to give compound **12** (quant.).

[0192] **Compound 13**



[0193] Compound **4** in MeOH was added NaOMe (0.2 eq), and the resulting solution was stirred under nitrogen at rt for 2 h. The mixture was neutralized by IR-120 and then filtered and concentrated to dryness in vacuo to give compound **13** (quant.).

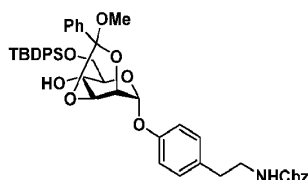
[0194] **Compound 14**



[0195] Compound **13** (1 mmol) in MeOH was added NaOMe (0.2 eq), and the resulting solution was stirred under nitrogen at rt for 2 h. The mixture was neutralized by IR-120 and then filtered and concentrated to dryness in vacuo. It was then dissolved in anhydrous DCM (10 mL) and treated with imidazole (1.5 mmol) at 0 °C, followed by the addition of TBDPSCI (1.2 mmol). The mixture was stirred at room temperature for 2.5 h under a nitrogen atmosphere. The reaction was quenched by the addition of

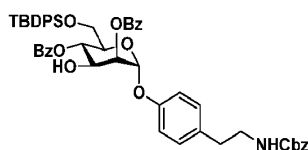
MeOH. After stirring at room temperature for 10 min, the solvent was removed under reduced pressure to give a dry residue that was purified by column chromatography with MeOH/DCM (1/10) to give compound **14** (82%).

[0196] **Compound 15**



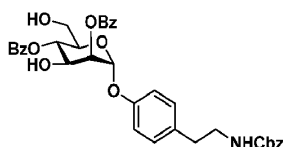
[0197] To a solution of compound **14** (1 mmol) and a catalytic amount of CSA (0.1 mmol) in CH₃CN (20 mL) was added trimethyl orthobenzoate (3 mmol) at room temperature under atmospheric pressure of nitrogen. After stirring for 30 min, Et₃N was added to quench the reaction, and the resulting mixture was dried under reduced pressure. The residue was purified by column chromatography with EA/Hex (1/2) to give compound **15** (79%).

[0198] **Compound 16**



[0199] Compound **15** (1 mmol) was dissolved in DCM (10 mL) and sequentially mixed with DIPEA (2 mmol), benzoic anhydride (2 mmol), and DMAP (0.1 mmol). After stirring for 2 hr, the solvent was evaporated under reduced pressure to give a dry residue and then poured into EA (20 mL) and 2 N HCl (10 mL) with vigorous stirring for 30 min. The solvent was then removed by evaporation, followed by extraction with EA/H₂O. The collected organic layer was washed with ice-cold saturated NaHCO₃(aq), water and brine, and dried over MgSO₄. The dry residue was purified by column chromatography with EA/Hex (1/2) to give compound **16** (71%).

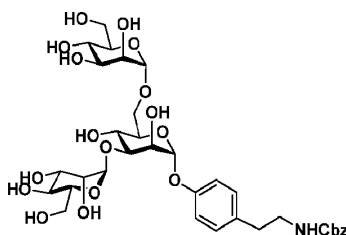
[0200] **Compound 17**



[0201] Compound **16** (1 mmol) was added AcOH (4 mmol) and 1 M TBAF (2.4 mmol in THF) at 0 °C. The resulting mixture was warmed up to room temperature gradually, stirred for another 2 h, and then diluted with EA. The organic layer was washed with saturated NaHCO₃(aq), water, and brine, dried with anhydrous MgSO₄, and concentrated under reduced pressure. The dry residue was purified by column chromatography with EA/Hex (1/2) to give compound **47** (88%).

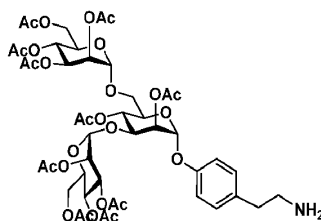
[0202]

[0203] **Compound 18**



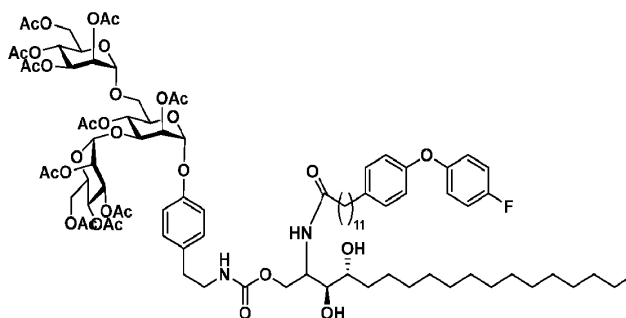
[0204] To a stirred solution of **17** (1 mmol) and 4 Å molecular sieve (0.1 g) in anhydrous DCM (10 mL) was cooled to -40°C and then BF₃(OEt)₂ (0.1 mmol) was added dropwise to the solution. A solution of **3** in anhydrous DCM was added dropwise to the above mixture and stirred for 1 h at -40°C. After that, the reaction was gradually warmed to room temperature and stirred for another 1 h. The solution was quenched by adding triethylamine, then filtered and added saturated. NaHCO₃ aq. and extracted with DCM. The organic layer was dried with MgSO₄ and evaporated to dryness. The residue was purified by flash column chromatography on silica gel to give a trisaccharide product. The product was then dissolved in MeOH, and NaOMe (0.2 eq) was added, and the resulting solution was stirred at room temperature for 2 h. The mixture was neutralized by IR-120 and then filtered and concentrated to dryness in vacuo. The deacetylated mixture was purified by Bio-Gel P-2 Gel (Biorad) with H₂O as eluent to obtain a pure trisaccharide. The compound was lyophilized to dryness to give compound **18** (39%).

[0205] **Compound 19**



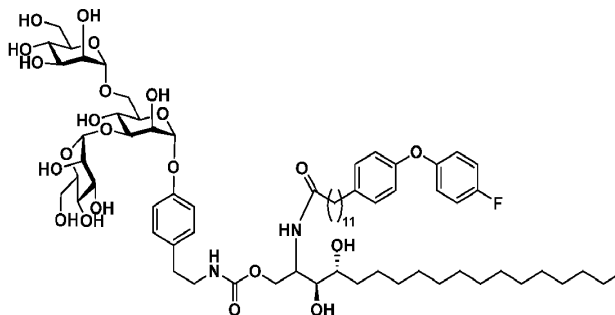
[0206] Compound **13** (1 mmol) in MeOH was added NaOMe (0.2 eq), and the resulting solution was stirred under nitrogen at rt for 2 h. The mixture was neutralized by IR-120 and then filtered and concentrated to dryness in vacuo.

[0207] **Compound 20**



[0208] Compound **19** (1 mmol) in THF (10 mL) was added **10** (1 mmol) and trimethylamine (2 mmol), and the resulting solution was stirred under nitrogen at rt for 2 h. The solvent was then removed by evaporation, followed by extraction with EA/H₂O. The collected organic layer was washed with saturated NaHCO₃(aq), water and brine, and dried over MgSO₄. The crude product was purified by column chromatography on silica gel (EA/Hex 1:1+10% MeOH) to yield **20**.

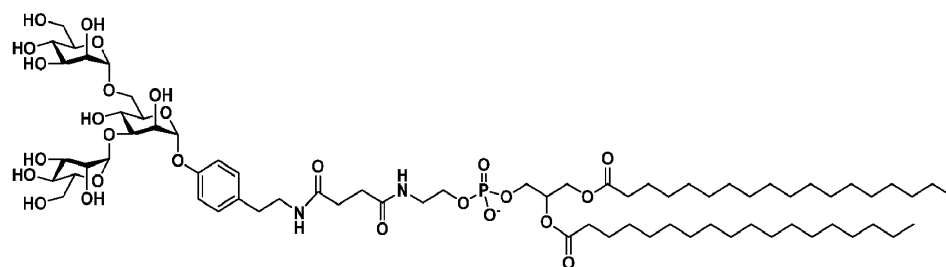
[0209] **Compound 21**



[0210] Compound **20** in MeOH was added NaOMe (0.2 eq), and the resulting solution was stirred under nitrogen at room temperature for 2 hours. The mixture was neutralized by IR-120 and then filtered and concentrated to dryness in vacuo to give compound **21** (quant.). The resulting compound **21** was examined using LCMS spectrum, which shows peaks at 1236.13, 1245.16, 1247.64, 1268.77, 1279.86, 1305.99, 1308.13, 1311.57, 1313.93, 1343.46, 1354.29, 1355.60, 1358.33, 1379.12, 1403.82, 1408.57, 1425.66, 1448.31, 1453.30, 1458.39, 1467.71, 1471.33, and 1491.66 (FIG. 12).

O[C@H]1O[C@@H](OC(=O)NCCc2ccc(O[C@H]3C[C@@H](CO)[C@H](O)[C@H]3O)cc2)O[C@H](COP(=O)([O-])OCCOC(=O)CCCCCCCCCCCCCCCCCC(=O)OCCCCCCCCCCCCCCCCCC(=O)O)O[C@H](C(=O)CCCCCCCCCCCCCCCCCC)O1

[0213] **Compound 23**



[0215] **Example 2: Preparation and characterization of the LNP of the present disclosure**

[0217] A lipid mix solution in EtOH (10 mg/ml) having a molar ratio of 50% SM-102, 10% DSPC, 38.5% cholesterol, and 1.5% DMG-PEG2000 was prepared. An LNP formulation was prepared by mixing the compound of the present disclosure with the lipid mix solution (with a molar ratio of 45% SM-102, 9% DSPC, 34.5% cholesterol, 1.5% DMG-PEG2000, and 10% compound of the present disclosure). The LNP formulation was added into a 1.5 mL tube. Then, a mRNA payload, diluted with citrate buffer before use (10 mM, pH4), was added to the tube at a final concentration of 0.18 ug/uL. The

mRNA aqueous solution in the tube was then quickly added to an ethanol solution and mixed well by vortex for 1 minute. The resulting solution was then dialyzed by micro float-A-Lyzer (8-10 kD) against PBS at 4°C overnight to obtain the LNP of this example. The resulting LNP can be stored at 4°C for a few days before use.

[0218] *Characterization of LNP*

[0219] *Size Measurement.* The LNP prepared above was examined using dynamic light scattering (DNP) to measure its size. First, 5 µL of the LNP solution was transferred to a clean 1.5 mL tube and diluted with 95 µL of PBS. The mixture was then transferred to a cuvette, and the particle size of the LNP was measured using a Nano ZS machine. The following table shows the sizes and the Polydispersity Index (PDI) of the LNP samples prepared.

[0220] Table: the size and PDI measurement

Sample	Size (nm) Mean ± SD	PDI Mean ± SD
Compound 24-LNP	138.5 ± 0.7074	0.1498 ± 0.002694
Compound 25-LNP	161 ± 0.3246	0.1221 ± 0.02095
Compound 12-LNP	177.5 ± 1.79	0.1381 ± 0.02234
Compound 22-LNP	191.7 ± 1.617	0.1625 ± 0.0294
Compound 23-LNP	170.7 ± 1.353	0.1109 ± 0.01918

[0221] *Zeta potential and encapsulation efficiency.* Next, the encapsulation efficiency of the LNP of the present disclosure was evaluated using a Quant-it Ribogreen assay. A 2000-fold diluted quant-it Ribogreen reagent with 1 X TE (working solution) was prepared. Then, an RNA standard dilution series from 0-50 ng/mL (100 µL) was prepared to obtain a standard curve. 5 µL of the LNP solution prepared above was transferred to a clean tube and diluted to a final volume of 100 µL. The working solution of the quant-it Ribogreen reagent (100 µL) was then added to the LNP sample. The fluorescence signal of the sample was then detected using a microplate reader (ex/em 485/535). According to the standard curve, the fluorescence signal was used to calculate the concentration of unencapsulated mRNA in solution (ng/mL). For zeta potential measurement, 0.75 mL DP-intermediate was introduced into capillary cells and measured at 25 °C using Malvern Zetasizer Pro equipment.

[0222] Table: Zeta potential and encapsulation efficiency

Sample	Zeta potential (mV)	Encapsulation efficiency (%)
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Compound 24-LNP	0.113	92.15
Compound 25-LNP	-4.382	86.69
Compound 12-LNP	0.932	81.47
Compound 22-LNP	-0.5107	82.86
Compound 23-LNP	0.3875	90.00

[0223] **Example 3: *In vitro* uptake and transfection of mRNA-LNPs in Dendritic cells.**

[0224] ***Experiment 3-1***

[0225] *Splenic cell preparation and BMDC culture.* This example tested the uptake of several exemplary LNPs (as shown in the table below) according to the embodiments of the present disclosure in bone marrow-derived dendritic cells (BMDCs) and splenic cells. To prepare splenic cells, the mouse spleen was homogenized with the frosted end of a glass slide and treated with RBC lysis buffer (Sigma) to deplete red blood cells (RBCs), followed by passing through the cell strainer (BD Biosciences). Bone marrow was isolated from mouse femurs and tibiae and treated with RBC lysis buffer (Sigma-Aldrich) to deplete RBCs. Cells were then cultured in RPMI-1640 containing 10% heat-inactivated FBS (Thermo Fisher Scientific), 1% Penicillin/Streptomycin (Thermo Fisher Scientific), 50 μ M 2-mercaptoethanol (Thermo Fisher Scientific), and 20 ng/ml recombinant mouse GM-CSF (eBioscience) at a density of 2×10^5 cells/ml. The cells were supplemented with an equal volume of the complete culture medium (RPMI-1640, 100 U/ml Pen/Strep, 55 μ M 2-mercaptoethanol, and 10% FBS) at day 3 and refreshed with one-half the volume of the medium at day 6. On day 8, the suspended cells were harvested.

[0226] Table of the exemplary LNPs tested in this experiment.

Example	L1: Ionizable lipid	L2: Phosphatidyl- choline	L3: Cholesterol	L4: PEG-Lipid	L5 the compound of the present disclosure
1	45 mol%	9 mol%	34.5 mol%	1.5 mol%	Compound 24 10 mol%
2	45 mol%	9 mol%	34.5 mol%	1.5 mol%	Compound 25 10 mol%
3 N.C. (no LNP)	none	none	none	none	none
4 P.C.	50 mol%	10 mol%	38.5 mol%	1.5 mol%	none

[0227] *Treatment of LNPs to splenic cells and BMDCs.* Splenic cells or BMDCs were incubated with different FITC-labeled LNP formulations in RPMI-1640 at 37 °C for 1 hour. Cells were blocked with an Fc receptor binding inhibitor (clone: 93, eBioscience) for 20 minutes. Splenocytes were stained with antibodies against CD3 (clone: 17A2, BV421-conjugated, Biolegend), CD19 (clone: 1D3, PECy7-conjugated, BD Biosciences). BMDCs were stained with antibodies against CD11c (clone N418 APC-conjugated, Biolegend). Labeled cells were analyzed using FACSC and Flow Cytometer (BD Biosciences).

[0228] *Flow Cytometry.* After incubation with different mRNA-LNPs, BMDC cells were washed with ice-cold FACS buffer (1% FBS in 1 × DPBS with 0.1% Sodium Azide), and incubated with purified anti-mouse CD16/32 antibody (BioLegend) in FACS buffer on ice for 20 min, followed by washing with FACS buffer. BMDCs were stained with APC anti-mouse CD11c antibody (BioLengend) at 4°C for 30 min, and washed with FACS buffer. Finally, BMDCs were stained with propidium iodide (Sigma-Aldrich). Flow cytometry was performed on a FACS Canto™ flow cytometer (BD Bioscience).

[0229] *Results.* The FACS results are shown in FIG. 1 and FIG. 2 and the table below. FIG. 1 shows that the BMDCs showed specific uptake of the LNPs made using compounds of the present disclosure compared with non-BMDCs. A traditional LNP (i.e., without using the compound of the present disclosure) showed slightly higher uptake by the BMDCs than the non-BMDCs, but the specificity was insignificant compared to that of the LNPs of the present disclosure (56.1/8.62 or 55.2/6.64 vs. 0.48/0.12). Similarly, in FIG. 2, dendritic cells (DCs) showed specific uptake of the LNPs of the present disclosure at least 3 times higher than B cells (30.6/10.7 and 38.3/11.9) and at least 6 times higher than T cells (30.6/0.5 and 38.3/0.68). DCs showed higher uptake of traditional LNPs but the inclination was less significant than that of the LNPs of the present disclosure.

[0230] Table of the uptake results (arbitrary unit of the FITC signals)

Experiment 3-1	L5 the compound of the present disclosure	FITC signal (A.U.)				
		BMDC	Non-BMDC	DCs	B cells	T cells
Example 1	Compound 24	56.1	8.62	30.6	10.7	0.50
Example 2	Compound 25	55.2	6.64	38.3	11.9	0.68
Example 3	Negative control	0.17	0.18	0.26	0.016	0.022
Example 4	Positive control	0.48	0.12	16.9	1.46	0.26

[0231] *Experiment 3-2*

[0232] Exemplary LNPs (as shown in the table below) made using different formulations according to the embodiments of the present disclosure were tested in this experiment. Both uptake and transfection were tested to assess whether the payload delivered by the LNPs of the present disclosure can be expressed properly in targeted cells. Bone marrow-derived dendritic cells (BMDCs) were isolated from murine tibia and femurs of 57BL/6 mice. Bone marrow cells were stimulated for 8 days with 20 ng/mL GM-CSF in RPMI medium (RPMI-1640, 100 U/ml Pen/Strep, 55uM 2-mercaptoethanol and 10% FBS). After 8 days of culture, 1×10^6 BMDCs (centrifuge 400 g, 5mins and replace medium with 1ml Opti-MEM) were plated in 6-well plates, and different samples of LNPs encapsulating mRNA were diluted by 0.25 mL Opti-MEM and incubated with BMDC.

[0233] For *uptake* analysis, FITC-labelled LNPs encapsulating mRNA that encodes a SARS COV2 Spike protein were incubated with the BMDCs at 37°C for 2 hours. For *transfection* analysis, the LNPs encapsulating eGFP mRNA were incubated with the BMDCs at 37°C for 4 hours. After 4 hours of transfection, BMDCs were supplemented with the 1.25ml complete RPMI medium and incubated at 37°C for 48 hours. The experiments were conducted using FACS, similar to that described above.

[0234] Table of the exemplary LNPs tested in this experiment.

Example	L1: Ionizable lipid	L2: Phosphatidyl- choline	L3: Cholesterol	L4: PEG-Lipid	L5 the compound of the present disclosure
1	47.5 mol%	9.5 mol%	36.5 mol%	1.5 mol%	5 mol% Compound 22
2	45 mol%	9 mol%	34.5 mol%	1.5 mol%	10 mol% Compound 22
3	40 mol%	8 mol%	30.5 mol%	1.5 mol%	20 mol% Compound 22
4	47.5 mol%	9.5 mol%	36.5 mol%	1.5 mol%	5 mol% Compound 23
5	45 mol%	9 mol%	34.5 mol%	1.5 mol%	10 mol% Compound 23
6	40 mol%	8 mol%	30.5 mol%	1.5 mol%	20 mol% Compound 23
7 (control)	50 mol%	10 mol%	38.5 mol%	1.5 mol%	none

[0235] *Results.* The FACS results are shown in FIG. 3 and FIG. 4 and the table below. LNPs made using the compounds of the present disclosure at different molar ratios all showed higher uptake than the negative control (“traditional” LNP without using the compound of the present disclosure). The data also confirms that the LNPs of the present disclosure not only can deliver the payload into the

targeted cells but also can transfect and allow the targeted cells to express the payload. Given the higher specificity towards the targeted cells, the transfection signals detected from the groups using the LNPs of the present disclosures were also significantly higher than those detected from the traditional group. This result suggests that using the LNPs of the present disclosure allows a lower dosage of the payload for a similar outcome.

[0236] Table showing the results of uptake and transfection (arbitrary unit of the FITC signals)

Experiment 3-2	L5 the compound of the present disclosure	FITC signal intensity (A.U.) derived from uptake	FITC signal intensity (A.U.) derived from transfection
Example 1	5 mol% Compound 22	12.0	1.58
Example 2	10 mol% Compound 22	6.11	2.35
Example 3	20 mol% Compound 22	11.0	1.88
Example 4	5 mol% Compound 23	13.4	2.11
Example 5	10 mol% Compound 23	13.6	1.67
Example 6	20 mol% Compound 23	23.6	2.30
Example 7 (control)	None (traditional LNP)	0.38	0.71

[0237] *Experiment 3-3*

[0238] To assess the binding of DC-SIGN to the LNPs of the present disclosure, ELISA plates were coated with exemplary LNPs in PBS at 4 °C overnight, respectively. The plates were incubated with diluted DC-SIGN ECD (15 to 0.075 nM in HEPES buffer containing 20 mM HEPES, 150 mM NaCl, 10 mM CaCl₂, 0.1% BSA) at pH 7.4, 6.0, and 5.0 for 1 hour at room temperature. The bound DC-SIGN ECD was detected using HRP-conjugated anti-DC-SIGN (B2) IgG antibody (Santa Cruz Biotechnology). After 1 hour of incubation at room temperature, the plates were treated with tetramethylbenzidine (TMB) for 10 min. The optical density was measured at 450 nm after adding 0.5 M sulfuric acid to the plates using a microplate reader. The apparent K_d was calculated using a nonlinear regression curve fit for total binding using GraphPad Prism.

[0239] **Example 4: *In vivo* delivery of luciferase mRNA-LNP**

[0240] This experiment tested the targeted delivery of the LNPs of the present disclosure (shown in the table below) *in vivo*. The LNPs tested in this experiment carried mRNA encoding luciferase. Mice were injected intravenously with the LNPs (200 μL) and maintained for one hour or six hours before *In vivo* Imaging System (IVIS®) measurement. For the IVIS measurement, the animals were first

anesthetized using the rodent anesthesia system with isoflurane (2.5% (vol/vol) in 0.2 L/min O₂ flow). Then, the animals were injected intravenously with D-luciferin solution (dissolved in 1X PBS; 150 mg/kg body weight). After 3 minutes from the injection, the animals were scanned using the IVIS imaging system (data not shown). After imaging, the animals were euthanized in a CO₂ chamber. The organs (heart, lungs, liver, spleen, kidneys, and lymph nodes) of the animals were collected, and the luminescence was detected and quantified using the IVIS system.

[0241] Table of the exemplary LNPs tested in this experiment.

Example	L1: Ionizable lipid	L2: Phosphatidyl- choline	L3: Cholesterol	L4: PEG-Lipid	L5 the compound of the present disclosure
1	45 mol%	9 mol%	34.5 mol%	1.5 mol%	10 mol% Compound 22
2	45 mol%	9 mol%	34.5 mol%	1.5 mol%	10 mol% Compound 12
7 (control)	50 mol%	10 mol%	38.5 mol%	1.5 mol%	none

[0242] *Results.* The results (FIG. 5) show that both compound 22-LNP and compound 12-LNP tend to accumulate in spleens and lymph nodes. While compound 12-LNP also accumulated in livers, compound 22-LNP showed high-level specificities targeting spleens and lymph nodes. The results demonstrate the targeting delivery functionalities of the lipid nanoparticle formulations of the present disclosure, which matches the observations of the experiments above.

[0243] Additionally, exemplary LNPs, according to the present disclosure, are prepared to carry not only the mRNAs encoding luciferase but also either an mRNA encoding wide-type SARS-CoV-2 spike proteins or an mRNA encoding a low-sugar profile SARS-CoV-2 spike proteins. Mice are injected intravenously with the LNPs (200 µL) and maintained for one hour or six hours before *In vivo* Imaging System (IVIS[®]) measurement. For the IVIS measurement, the animals are first anesthetized using the rodent anesthesia system with isoflurane (2.5% (vol/vol) in 0.2 L/min O₂ flow). Then, the animals are injected intravenously with D-luciferin solution (dissolved in 1X PBS; 150 mg/kg body weight). After 3 minutes from the injection, the animals are scanned using the IVIS imaging system (data not shown). After imaging, the animals are euthanized in a CO₂ chamber. The organs (heart, lungs, liver, spleen, kidneys, and lymph nodes) of the animals are collected, and the luminescence is detected and quantified using the IVIS system.

[0244] **Example 6: Immunization**

[0245] *Animals.* Balb/c mice (8 weeks) were purchased from the National Laboratory Animal Center, Taiwan. All the mice were maintained in a specific pathogen-free environment. Eight-week-old Balb/c mice were immunized i.m. twice at 2-week intervals. Each vaccination contains PBS (100 µl). Sera collected from immunized mice were subjected to ELISA analysis 10 days after the last immunization. The experimental protocol was approved by Academia Sinica's Institutional Animal Care and Utilization Committee (approval no. 22-08-1901).

[0246] *LNPs.* For neutralization assay, LNPs, according to an embodiment of the present disclosure, were prepared for this experiment. Two control LNPs were also prepared to compare the performance of the present disclosure's LNPs. The first control LNP was formed using SM-102 and DSPC ("L1+L2") without using the compound of the present disclosure. The second control LNP was a Moderna product for Spikevax ("LNP(M)"). All tested LNPs carried mRNA cargo encoding SARC-CoV-2 spike protein. For IgG titer assay, LNPs of the present disclosure were prepared to carry either a mRNA encoding wild-type SARC-CoV-2 spike protein or a mRNA encoding wild-type SARC-CoV-2 spike protein with low-sugar modification.

[0247] *Animal Immunizations.* BALB/c mice aged 6 to 8 wk old (n = 5) were immunized intramuscularly with 15 µg of LNPs in phosphate-buffered saline (PBS). Animals were immunized at week 0 and boosted with a second vaccination at week 2, and serum samples were collected from each mouse 2 weeks after the second immunization.

[0248] *Pseudovirus neutralization assay.* Pseudovirus was constructed by the RNAi Core Facility at Academia Sinica using a procedure similar to that described previously. Briefly, the pseudotyped lentivirus carrying SARS-CoV-2 spike protein was generated by transiently transfecting HEK-293T cells with pCMV-ΔR8.91, pLAS2w.Fluc.Ppuro. HEK-293T cells were seeded one day before transfection, and indicated plasmids were delivered into cells using TransITR-LT1 transfection reagent (Mirus). The culture medium was refreshed at 16 hours and harvested at 48 hours and 72 hours post-transfection. Cell debris was removed by centrifugation at 4,000 xg for 10 min, and the supernatant was passed through a 0.45-µm syringe filter (Pall Corporation). The pseudotyped lentivirus was aliquot and then stored at -80°C. To estimate the lentiviral titer by AlarmaBlue assay (Thermo Scientific), The transduction unit (TU) of SARS-CoV-2 pseudotyped lentivirus was estimated by using cell viability assay in responded to the limited dilution of lentivirus. In brief, HEK-293T cells stably expressing the human ACE2 gene were plated on a 96-well plate one day before lentivirus transduction. For the titrating pseudotyped lentivirus,

different amounts of lentivirus were added into the culture medium containing polybrene (final concentration 8 µg/ml). Spin infection was carried out at 1,100 xg in a 96-well plate for 30 minutes at 37 °C. After incubating cells at 37°C for 16 hr, the culture medium containing virus and polybrene was removed and replaced with fresh complete DMEM containing 2.5 µg/ml puromycin. After treating puromycin for 48 hrs, the culture media was removed, and the cell viability was detected using 10% AlamarBlue reagents according to the manufacturer's instructions. The survival rate of uninfected cells (without puromycin treatment) was set as 100%. The virus titer (transduction units) was determined by plotting the survival cells versus the diluted viral dose. For neutralization assay, heat-inactivated sera or antibodies were serially diluted and incubated with 1,000 TU of SARS-CoV-2 pseudotyped lentivirus in DMEM for 1 h at 37°C. The mixture was then inoculated with 10,000 HEK-293T cells stably expressing the human ACE2 gene in a 96-well plate. The culture medium was replaced with fresh complete DMEM (supplemented with 10% FBS and 100 U/mL penicillin/streptomycin) at 16 h postinfection and continuously cultured for another 48 h. The expression level of the luciferase gene was determined by using the Bright-Glo Luciferase Assay System (Promega). The relative light unit (RLU) was detected by Tecan i-control (Infinite 500). The percentage of inhibition was calculated as the ratio of RLU reduction in the presence of diluted serum to the RLU value of no serum control using the formula $(RLU^{\text{control}} - RLU^{\text{Serum}})/RLU^{\text{control}}$.

[0249] *Measurement of serum IgG titer.* ELISA was used to determine the IgG titer of the mouse serum. The wells of a 96-well ELISA plate (Greiner Bio-One) were coated with 100 ng SARS-CoV-2 spike protein (ACROBiosystems, wild-type, Delta, or Omicron, respectively) in 100mM sodium bicarbonate pH 8.8 at 4°C overnight. The wells were blocked with 200 µl 5% skim milk in 1X PBS at 37 °C for 1 hour and washed with 200 µl PBST (1X PBS, 0.05% Tween 20, pH 7.4) three times. Mice serum samples with 2-fold serial dilution were added into wells for incubation at 37 °C for 2 hours and washed with 200 µl PBST six times. The wells were incubated with 100 µl HRP conjugated anti-mouse secondary antibody (1:10000, in PBS) at 37 °C for 1 hour and washed with 200 µl PBST six times. 100 µl horseradish peroxidase substrate (1-Step™ Ultra TMB-ELISA Substrate Solution) (Thermo Scientific™) was added into wells, followed by 100 µl 1M H₂SO₄. After incubation for 30 minutes, absorbance (OD 450 nm) was measured using SpectraMax M5.

[0250] *Results.* FIG. 9 shows that all tested LNPs carrying the mRNA cargo were able to deliver and express the mRNA *in vivo*, thereby invoking immune responses that resulted in neutralization inhibition. Nevertheless, the inhibitory effect of those tested LNPs differed as the dilution factor increased. Both L1+L2 LNP and LNP (M) only showed a slightly higher inhibitory effect at 1:5000 dilution compared with the negative control, but the LNP of the present disclosure maintained around

40% inhibitory effect. The data demonstrates that the LNP of the present disclosure was able to invoke immune responses at a much lower concentration than other LNPs tested in this experiment.

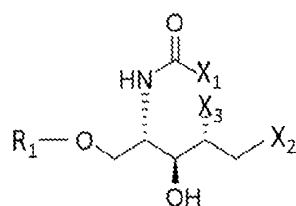
[0251] **FIG. 10** verifies that the LNPs of the present disclosure were capable of inducing antigen-specific IgG *in vivo*. The LNP, carrying mRNA encoding wide-type spike protein, induced IgGs that were still able to recognize the spike proteins of both the Delta variant and Omicron variant at a good level. The data shows that the targeted delivery feature of the LNP can at least partially overcome the immune escape due to the spike protein variations between variants.

[0252] Furthermore, it was observed that LNP carrying wild-type SARS-CoV-2 spike protein-encoding mRNA ("WT LNP") and LNP carrying mRNA encoding a low-sugar modified spike protein ("low-sugar LNP") induced comparable IgG titers against wide-type viruses, the WT LNP had lower IgG titers against the Delta and Omicron strains, suggesting an immune escape. In contrast, the low-sugar LNP maintains a high level of IgG titers against the two variant strains. The results demonstrate that removing glycan shields improves the immunogenicity of the LNP formulations.

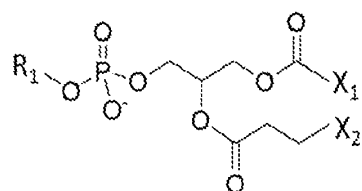
[0253] **FIG. 11** shows the results of an additional experiment. In this experiment, a Moderna LNP was prepared using Moderna's proprietary formulation. In addition, LNP made using the Moderna formulation and adding a compound of the present disclosure was also prepared to test whether the compound of the present disclosure improves the performance of the Moderna formulation. Animals were administered with the LNPs, and IgG titer assay and neutralization assay were all performed as described above in this example. The results demonstrate that the compound of the present disclosure increased the spike protein-specific IgGs. The serum obtained from mice administered with the LNP of the present disclosure's compound also exhibited better neutralization. This experiment confirmed the targeted delivery feature of the compound of the present disclosure and verified that it can be applied to commercially available LNP formulations.

[0254] **EXEMPLARY EMBODIMENTS**

[0255] Embodiment A1. A pharmaceutical formulation, comprising a lipid nanoparticle and a pharmaceutically-acceptable excipient; wherein the lipid nanoparticle comprises a membrane defining an inner space, wherein the membrane is formed with a plurality of lipid components; wherein the plurality of lipid components comprises a bi-functional compound comprising:



Formula 1; or



Formula 2;

wherein R_1 comprises a substituted or non-substituted glycosyl group; wherein X_1 and X_2 are each independently hydrogen, C_{1-30} alkyl, C_{1-30} alkenyl, C_{1-30} alkynyl, aryl, aryloxy, or a substituted version thereof, or $-(CH_2)_nX_4$, n is 0 to 30, and X_4 is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X_4 is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N, or a combination thereof; and wherein X_3 is hydrogen, C_{1-6} alkyl, or hydroxyl; wherein the membrane encapsulates a payload encoding a spike protein of SARS-CoV-2 wherein the spike protein has a reduced and/or deleted glycan profile.

[0256] Embodiment A2. The pharmaceutical formulation of Embodiment 1, wherein the spike protein comprises an amino acid substitution of asparagine (N) to glutamine (Q) at N-linked glycosylation sequons (N-X-S/T), wherein X is any amino acid residue except proline, and S/T denotes a serine or threonine residue.

[0257] Embodiment A3. The pharmaceutical formulation of Embodiment A1 or Embodiment A2, wherein the spike protein comprises an amino acid deletion or addition at N-linked glycosylation sequons (N-X-S/T) to eliminate N-linked glycan sequons.

[0258] Embodiment A4. The pharmaceutical formulation of any one of Embodiments A1 to A3, wherein the spike protein comprises an amino acid substitution of S/T to alanine (A) at O-linked glycosylation sites to eliminate O-linked glycosylation sites.

[0259] Embodiment A5. The pharmaceutical formulation of any one of Embodiments A1 to A4, wherein the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 2, 16, 18, or 20, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to

the amino acid sequence set forth in SEQ ID NO: 2, 16, 18 or 20; or the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 1, 15, 17, or 19 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 1, 15, 17 or 19 respectively.

[0260] Embodiment A6. The pharmaceutical formulation of any one of Embodiments A1 to A5, wherein the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 4, 22, 24, or 26, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 4, 22, 24, or 26, and wherein the spike protein comprises a receptor binding domain (RBD) lacking at least one glycosylation sites; or the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 3, 21, 23, or 25 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 3, 21, 23, or 25 respectively.

[0261] Embodiment A7. The pharmaceutical formulation of any one of Embodiments A1 to A6, wherein the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 6, 28, 30, or 32, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 6, 28, 30, or 32, and wherein the spike protein comprises a S2 subunit lacking at least one glycosylation sites; or the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 5, 27, 29, or 31 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 5, 27, 29, or 31 respectively.

[0262] Embodiment A8. The pharmaceutical formulation of any one of Embodiments A1 to A7, wherein the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 8 or 34, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 8 or 34, and wherein the spike protein comprises an S2 subunit comprising a single glycosylation site at N1194; or the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 7 or 33 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 7 or 33 respectively.

[0263] Embodiment A9. The pharmaceutical formulation of any one of Embodiments A1 to A8, wherein the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 10 or 36, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the

amino acid sequence of SEQ ID NO: 10 or 36, and wherein the spike protein comprises a receptor binding domain (RBD) lacking at least one glycosylation sites and an amino acid substitution of N801Q; or the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 9 or 35 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 9 or 35 respectively.

[0264] Embodiment A10. The pharmaceutical formulation of any one of Embodiments A1 to A9, wherein the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 12 or 38, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 12 or 38, and wherein the spike protein comprises a receptor binding domain (RBD) lacking at least one glycosylation sites and an amino acid substitution of N1194Q; or the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 11 or 37 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 11 or 37 respectively.

[0265] Embodiment A11. The pharmaceutical formulation of any one of Embodiments A1 to A10, wherein the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 14 or 40, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 14 or 40, and wherein the spike protein comprises a receptor binding domain (RBD) lacking at least one glycosylation sites and an amino acid substitution of N122Q, N165Q, N234Q, or a combination thereof; or the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 13 or 39 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 13 or 39 respectively.

[0266] Embodiment A12. The pharmaceutical formulation of any one of Embodiments A1 to A11, wherein the payload encodes an immunogenic peptide comprising an amino acid sequence selected from a group consisting of: TESIVRFPNITNL (SEQ ID NO: 41), NITNLCPFGEVFNATR (SEQ ID NO: 42), LYNSASFSTFK (SEQ ID NO: 43), LDSKVGGNYN (SEQ ID NO: 44), KSNLKPFERDIST (SEQ ID NO: 45), KPFERDISTEIYQAG (SEQ ID NO: 46), GPKKSTNLVKNKC (SEQ ID NO: 47), NCDVVIGIVNNTVY (SEQ ID NO: 48), PELDSFKEELDKYFKNHTS (SEQ ID NO: 49), VNIQKEIDRLNEVA (SEQ ID NO: 50), NLNESLIDLQ (SEQ ID NO: 51) and LGKYEYQYIKWP (SEQ ID NO: 52) or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95% or 90% identity to any of SEQ ID NOs: 41 to 52.

[0267] Embodiment A13. The pharmaceutical formulation of any one of Embodiments A1 to A11, wherein the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 53, 54, 55, 56, or 57, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 53, 54, 55, 56, or 57.

[0268] Embodiment A14. The pharmaceutical formulation of Embodiment A13, wherein the payload encodes an immunogenic peptide comprising an amino acid sequence selected from a group consisting of:

SEQ ID NO: 58 - SSANNCTFEYVSQ;
 SEQ ID NO: 59 - TESIVRFPNITNL;
 SEQ ID NO: 60 - KPFERDISTEIQAG;
 SEQ ID NO: 61 - GPKKSTNLVKNKC;
 SEQ ID NO: 62 - TEVPVAIHADQ;
 SEQ ID NO: 63 - RVYSTGSNVFQTR;
 SEQ ID NO: 64 - RRARSVASQS;
 SEQ ID NO: 65 - DPSKPSKRSF;
 SEQ ID NO: 66 - FIKQYGDCLGDI;
 SEQ ID NO: 67 - ENQKLIANQFNS;
 SEQ ID NO: 68 - GKIQDSLSTA;
 SEQ ID NO: 69 - NCDVVIGIVNNTVY;
 SEQ ID NO: 70 - PELDSFKEELDKYFKNHTS;
 SEQ ID NO: 71 - TSPDVDLGDISGINA;
 SEQ ID NO: 72 - VNIQKEIDRLNEVA;
 SEQ ID NO: 73 - NLNESLIDLQ; and
 SEQ ID NO: 74 - LGKYEQYIKWP;

or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, or 90% identity to any of SEQ ID NOs: 58 to 74

[0269] Embodiment A15. The pharmaceutical formulation of any one of Embodiments A1 to A14, wherein R_1 comprises a formula of R_2-R_A- , wherein R_2 is the substituted or non-substituted glycosyl group, R_A is an attachment group, and wherein the attachment group comprises an aryl, an alkyl, an amide, an alkylamide, a substituted version thereof, a combination thereof, or a covalent bond.

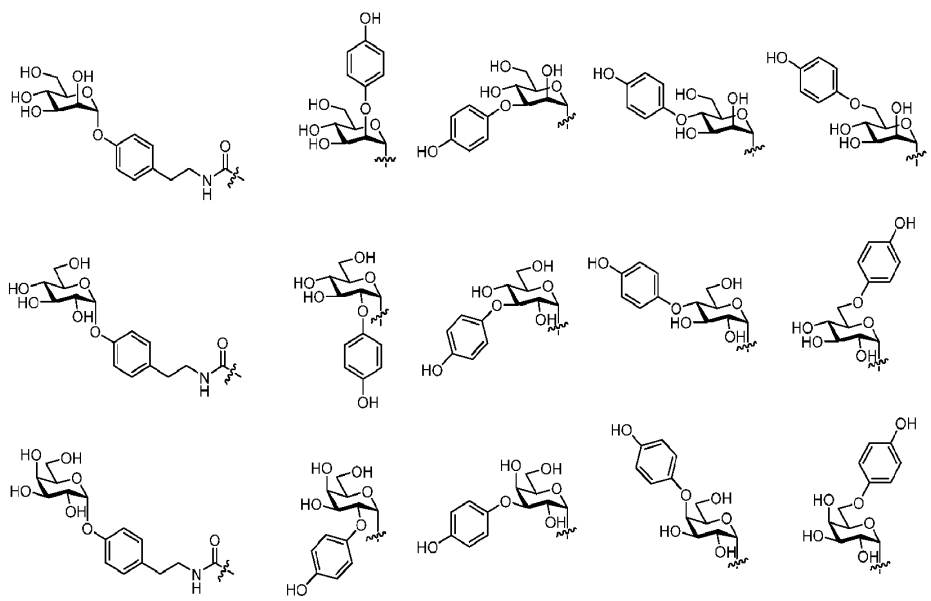
[0270] Embodiment A16. The pharmaceutical formulation of Embodiment A15, wherein R_A comprises the aryl having 0 to 3 substituents (e.g., 1 to 3 substituents), wherein the substituent is C_{1-6} alkyl, halide, or C_{1-6} alkyl halide.

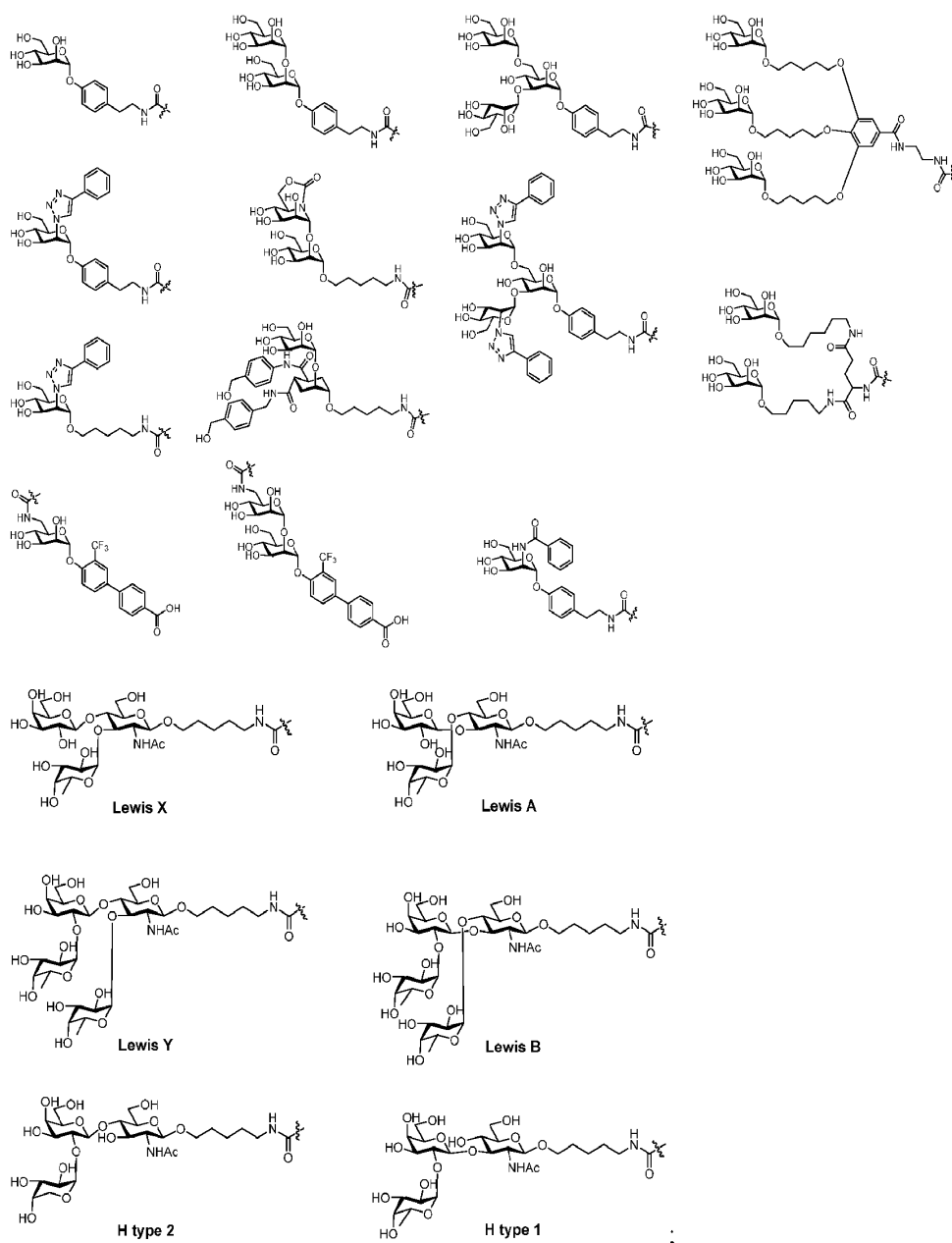
[0271] Embodiment A17. The pharmaceutical formulation of Embodiment A16, wherein R_A further comprises a polyethylene glycol (PEG) moiety having 2 to 72 (OCH_2CH_2) subunits.

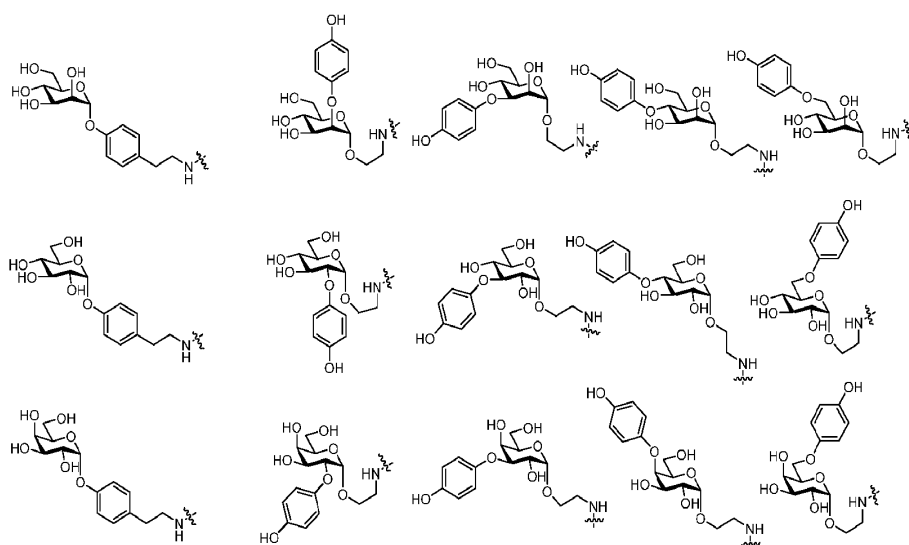
- [0272] Embodiment A18. The pharmaceutical formulation of Embodiment A16 or Embodiment A17, wherein the PEG moiety is linear.
- [0273] Embodiment A19. The pharmaceutical formulation of any one of Embodiments A1 to A18, wherein the glycosyl group comprises mannoside, fucoside, or a combination thereof.
- [0274] Embodiment A20. The pharmaceutical formulation of any one of Embodiments A1 to A19, wherein the glycosyl group comprises a terminal mannoside, a terminal fucoside, or both.
- [0275] Embodiment A21. The pharmaceutical formulation of any one of Embodiments A1 to A20, wherein the glycosyl group comprises a mono-mannoside, a di-mannoside, or a tri-mannoside.
- [0276] Embodiment A22. The pharmaceutical formulation of Embodiment A21, wherein the tri-mannoside is a linear or branched tri-mannoside.
- [0277] Embodiment A23. The pharmaceutical formulation of Embodiment A22, wherein the branched tri-mannoside is a α -1,3- α -1,6-trimannoside.
- [0278] Embodiment A24. The pharmaceutical formulation of any one of Embodiments A1 to A23, wherein R₁ is a substituted glycosyl group.
- [0279] Embodiment A25. The pharmaceutical formulation of Embodiment A24, wherein the glycosyl group comprises 1 to 6 substituents, wherein the substituent is C₁₋₆ alkyl, C₁₋₆ alkenyl, halogen, C₁₋₆ alkyl halide, C₁₋₆ alkoxy, amine, nitro, C₁₋₆ alkyl amine, amide, azido, aryl, cycloalkyl, heterocycloalkyl, sulfite, or a substituted version thereof, or a combination thereof.
- [0280] Embodiment A26. The pharmaceutical formulation of Embodiment A25, wherein the substituent of the glycosyl group is selected from the group consisting of aryl, 5-membered cycloalkyl, 6-membered cycloalkyl, 5-membered heterocycloalkyl, and 6-membered heterocycloalkyl, and a substituted version thereof, which comprises 1 to 6 substituents selected from the group consisting of C₁₋₆ alkyl, halogen, C₁₋₆ alkyl halide, C₁₋₆ alkoxy, amine, nitro, C₁₋₆ alkyl amine, amide, azido, carboxyl, hydroxyl, aryl, cycloalkyl, heterocycloalkyl, or a substituted version thereof, or a combination thereof.
- [0281] Embodiment A27. The pharmaceutical formulation of Embodiment A25 or Embodiment A26, wherein the substituent of the glycosyl group is a substituted or non-substituted aryl, optionally the substituent of the glycosyl group is a phenyl substituted with OH, CH₃, NH₂, CF₃, OCH₃, F, Br, Cl, NO₂, N₃, or a combination thereof.

[0282] Embodiment A28. The pharmaceutical formulation of Embodiment A25 or Embodiment A26, wherein the heterocycloalkyl comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N.

[0283] Embodiment A29. The pharmaceutical formulation of any one of Embodiments A1 to A28, wherein R₁ is selected from the group consisting of:



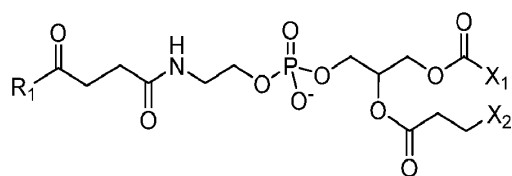




[0284] Embodiment A30. The pharmaceutical formulation of any one of Embodiments A1 to A29, wherein the compound is of Formula 1.

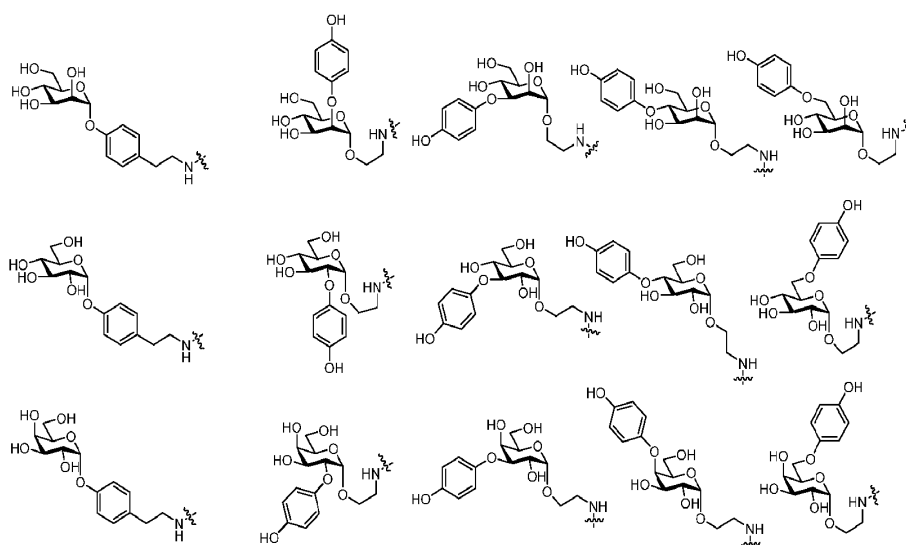
[0285] Embodiment A31. The pharmaceutical formulation of any one of Embodiments A1 to A30, wherein the compound is of Formula 2.

[0286] Embodiment A32. The pharmaceutical formulation of Embodiment A31, wherein the compound is of Formula 3:



Formula 3; and

wherein R_1 is selected from the group consisting of:



[0287] Embodiment A33. The pharmaceutical formulation of any one of Embodiments A1 to A32, wherein at least one of X_1 and X_2 comprises a saturated hydrocarbon chain, comprising at least 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 24, 26, 28, or 30 carbons.

[0288] Embodiment A34. The pharmaceutical formulation of any one of Embodiments A1 to A33, wherein X_1 and X_2 are each independently hydrogen, C_{4-30} alkyl, C_{4-30} alkenyl, C_{4-30} alkynyl, aryl, aryloxy, or a substituted version thereof, or $-(CH_2)_nX_4$, n is 4 to 30, and X_4 is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X_4 is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N, or a combination thereof.

[0289] Embodiment A35. The pharmaceutical formulation of Embodiment A34, wherein X_1 and X_2 are each independently hydrogen, C_{8-30} alkyl, C_{8-30} alkenyl, C_{8-30} alkynyl, aryl, aryloxy, or a substituted version thereof, or $-(CH_2)_nX_4$, n is 8 to 30, and X_4 is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X_4 is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N, or a combination thereof.

[0290] Embodiment A36. The pharmaceutical formulation of any one of Embodiments A1 to A35, provided that when one of X_1 and X_2 is hydrogen, the other one is not hydrogen.

[0291] Embodiment A37. The pharmaceutical formulation of any one of Embodiments A1 to A36, wherein X_4 is an aryl, aryloxy, heterocyclic group, cycloalkyl, heterocycloalkyl, or a combination

thereof, and wherein X_4 comprises 0 to 6 substituents, selected from the group consisting of C_{1-6} alkyl, halogen, C_{1-6} alkyl halogen, and C_{1-6} alkoxy.

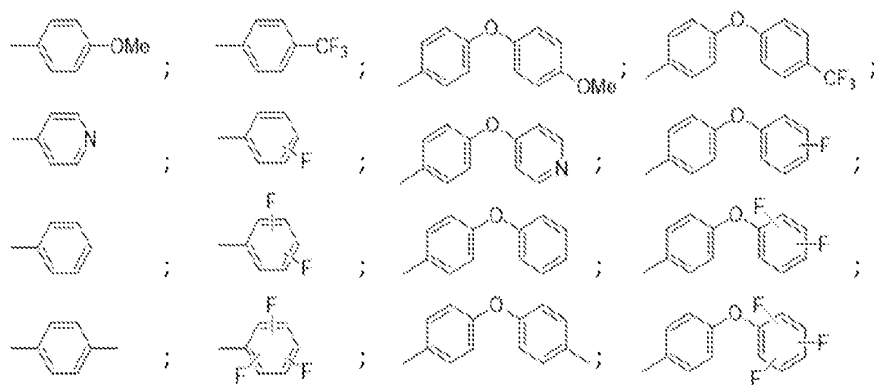
[0292] Embodiment A38. The pharmaceutical formulation of Embodiment A37, wherein the substituent is CH_3 , CF_3 , F, or OCH_3 .

[0293] Embodiment A39. The pharmaceutical formulation of Embodiment A37 or Embodiment A38, wherein X_4 comprises 1 to 3 substituents.

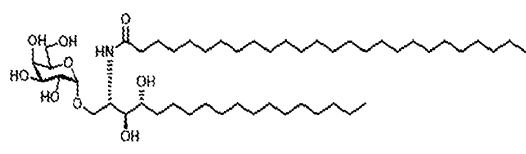
[0294] Embodiment A40. The pharmaceutical formulation of any one of Embodiments A37 to A39, wherein X_4 is $-R_3-O-R_4$, wherein R_3 and R_4 are each independently aryl, heterocyclic group, cycloalkyl, heterocycloalkyl, each comprising 0 to 6 substituents selected from the group consisting of C_{1-6} alkyl, halogen, C_{1-6} alkyl halogen, and C_{1-6} alkoxy.

[0295] Embodiment A41. The pharmaceutical formulation of any one of Embodiments A1 to A40, wherein one of X_1 and X_2 is C_{15-30} alkyl, and the other one is $-(CH_2)_nX_4$.

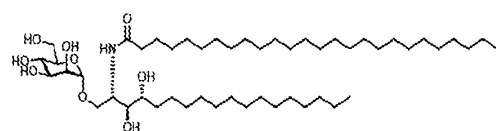
[0296] Embodiment A42. The pharmaceutical formulation of any one of Embodiments A1 to A41, wherein X_4 is selected from the group consisting of:



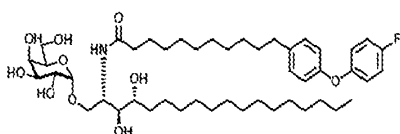
[0297] Embodiment A43. The pharmaceutical formulation of any one of Embodiments A1 to A42, wherein the compound is selected from the group consisting of:



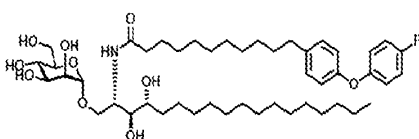
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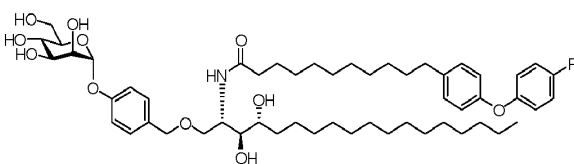
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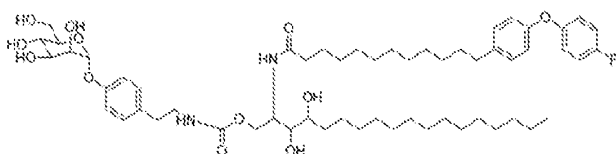
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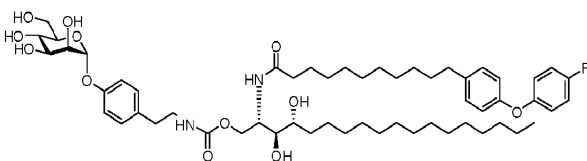
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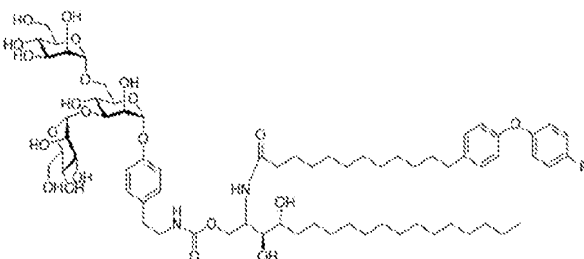
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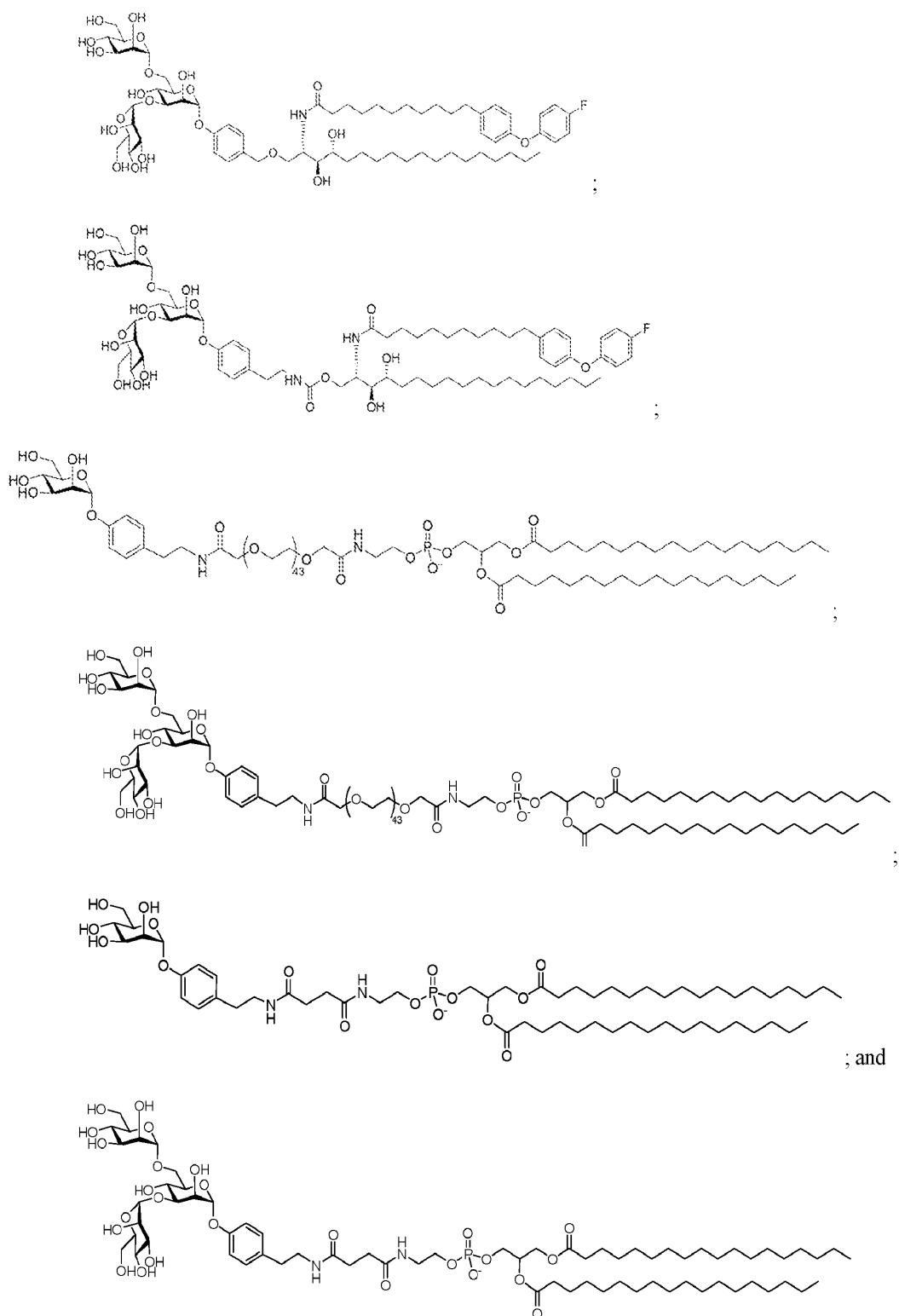
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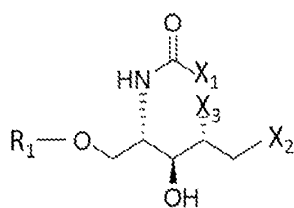


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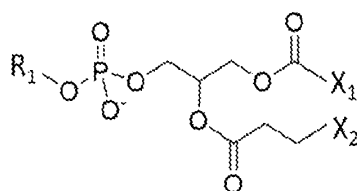


- [0298] Embodiment A44. The pharmaceutical formulation of any one of Embodiments A1 to A43, wherein the component is not glycolipid C34 or α -galactosylceramide.
- [0299] Embodiment A45. The pharmaceutical formulation of any one of Embodiments A1 to A44, comprising 0.01 to 95% (w/w) of the lipid nanoparticle.
- [0300] Embodiment A46. The pharmaceutical formulation of any one of Embodiments A1 to A45, wherein the lipid nanoparticle is a first lipid nanoparticle, and the composition further comprises a second lipid nanoparticle.
- [0301] Embodiment A47. The pharmaceutical formulation of Embodiment A46, wherein the first lipid nanoparticle and the second lipid nanoparticle are different in size, membrane components, payload encapsulated therewithin, or a combination thereof.
- [0302] Embodiment A48. The pharmaceutical formulation of any one of Embodiments A1 to A47, wherein the excipient comprises a solvent, dispersion media, diluent, dispersion, suspension aid, surface active agent, isotonic agent, thickening or emulsifying agent, preservative, polymer, peptide, protein, cell, hyaluronidase, or mixtures thereof.
- [0303] Embodiment A49. The pharmaceutical formulation of any one of Embodiments A1 to A48, further comprising an adjuvant.
- [0304] Embodiment A50. The pharmaceutical formulation of Embodiment A49, wherein the adjuvant comprises C34, Gluco-C34, 7DW8-5, C17, C23, C30, α -galactosylceramide, Aluminum salt, Squalene, MF59, or QS-21. Other examples of adjuvants in some vaccines that can be used in the composition of the present disclosure are aluminum hydroxide, aluminum phosphate, alum (potassium aluminum sulfate), mixed aluminum salts, Freund's complete adjuvant, Freund's incomplete adjuvant, AS03 (GlaxoSmithKline), MF59 (Seqirus), and CpG 1018 (Dynavax), or a combination thereof.
- [0305] Embodiment A51. A method of targeted payload delivery in a subject, comprising administering to the subject an effective amount of the pharmaceutical formulation of any one of Embodiments A1 to A50.
- [0306] Embodiment A52. The method of Embodiment A51, wherein the pharmaceutical formulation is administered in an initial dose and followed by one, two, three, four, five, or more booster doses.

- [0307] Embodiment A53. The method of Embodiment A51 or Embodiment A52, wherein the booster doses are administered about one month, about two months, about three months, about four months, about five months, or about six months or more following the initial dose.
- [0308] Embodiment A54. The method of any one of Embodiments A51 to A53, wherein the effective amount ranges from about 5 μg to 1000 μg .
- [0309] Embodiment A55. A method of preventing or treating a disease in a subject, comprising administering to the subject an effective amount of the pharmaceutical formulation of any one of Embodiments A1 to A50.
- [0310] Embodiment A56. The method of Embodiment A55, wherein the lipid nanoparticle is administered in an initial dose and followed by one, two, three, four, five, or more booster doses.
- [0311] Embodiment A57. The method of Embodiment A55 or Embodiment A56, wherein the booster doses are administered about one month, about two months, about three months, about four months, about five months, or about six months or more following the initial dose.
- [0312] Embodiment A58. The method of any one of Embodiments A55 to A57, wherein the effective amount ranges from about 5 μg to 1000 μg .
- [0313] Embodiment A59. A method of boosting an adaptive immune response, comprising administering to the subject an effective amount of the pharmaceutical formulation of any one of Embodiments A1 to A50.
- [0314] Embodiment A60. The method of Embodiment A59, wherein the lipid nanoparticle is administered in an initial dose and followed by one, two, three, four, five, or more booster doses.
- [0315] Embodiment A61. The method of Embodiment A59 or Embodiment A60, wherein the booster doses are administered about one month, about two months, about three months, about four months, about five months, or about six months or more following the initial dose.
- [0316] Embodiment A62. The method of any one of Embodiments A59 to A61, wherein the effective amount ranges from about 5 μg to 1000 μg .
- [0317] Embodiment B1. A compound for forming a lipid nanoparticle, wherein the component comprises the formula:



Formula 1; or



Formula 2;

wherein R_1 comprises a substituted or non-substituted glycosyl group; wherein X_1 and X_2 are each independently hydrogen, C_{1-30} alkyl, C_{1-30} alkenyl, C_{1-30} alkynyl, aryl, aryloxy, or a substituted version thereof, or $-(CH_2)_nX_4$, n is 0 to 30, and X_4 is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X_4 is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N, or a combination thereof; and wherein X_3 is hydrogen, C_{1-6} alkyl, or hydroxyl.

[0318] Embodiment B2. The compound of embodiment B1, wherein R_1 comprises a formula of R_2-R_A , wherein R_A is an attachment group and R_2 is the substituted or non-substituted glycosyl group, and wherein the attachment group comprises an aryl, an alkyl, an amide, an alkylamide, a substituted version thereof, a combination thereof, or a covalent bond.

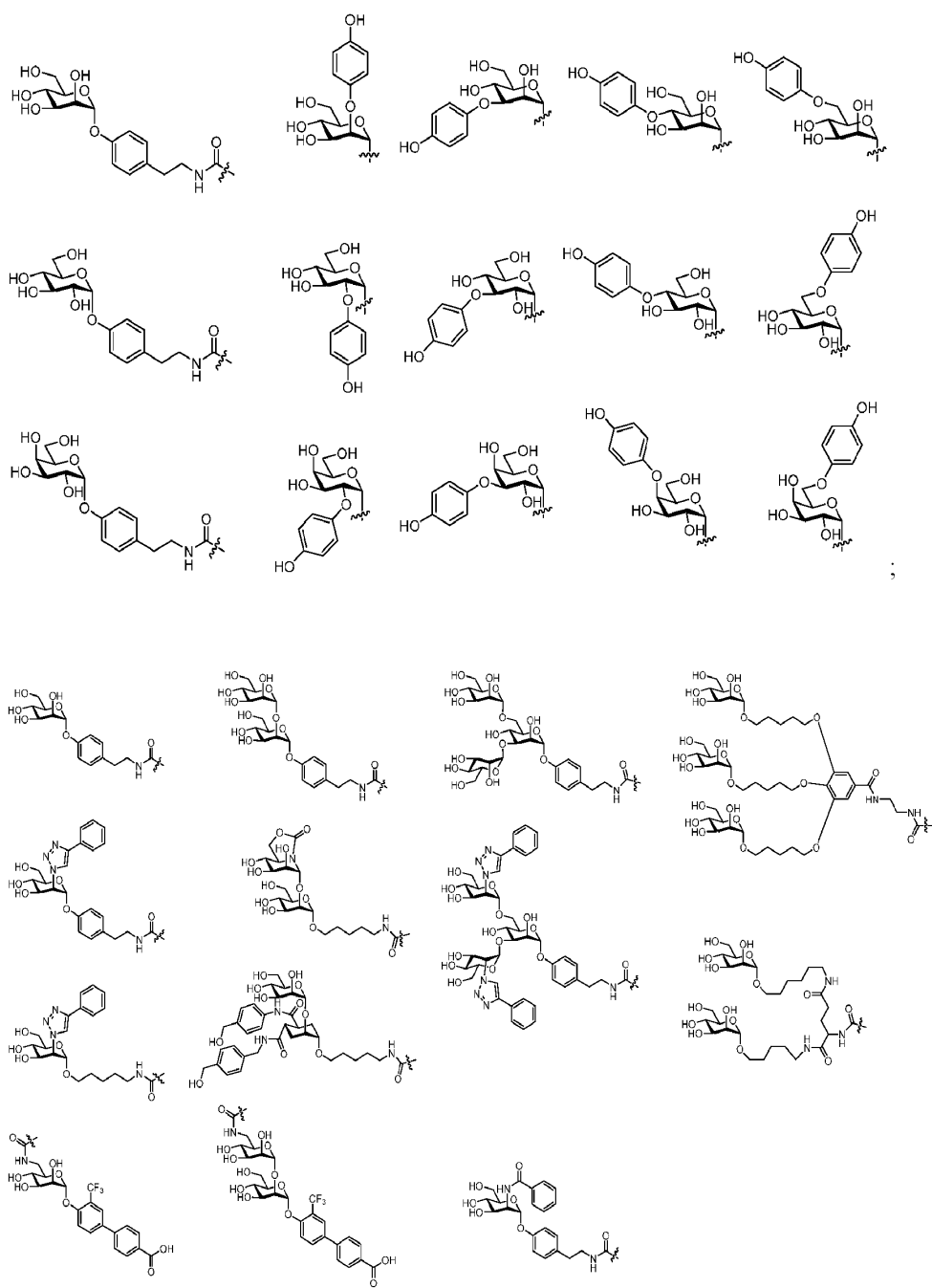
[0319] Embodiment B3. The compound of embodiment B2, wherein R_A comprises the aryl having 0 to 3 substituents, wherein the substituent is C_{1-6} alkyl, halide, or C_{1-6} alkyl halide.

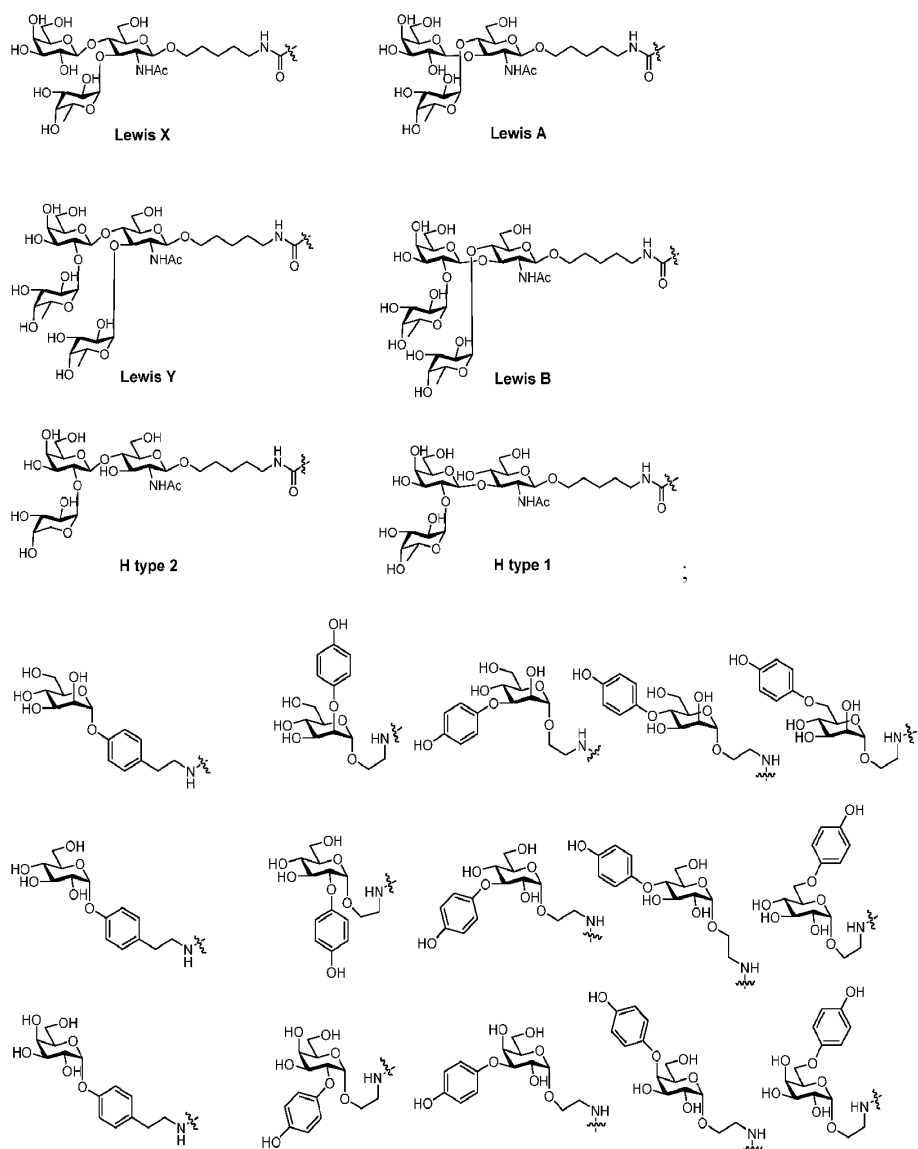
[0320] Embodiment B4. The compound of embodiment B3, wherein R_A further comprises a polyethylene glycol (PEG) moiety having 2 to 72 (OCH_2CH_2) subunits.

[0321] Embodiment B5. The copolymer of embodiment B3 or embodiment B4, wherein the PEG moiety is linear.

[0322] Embodiment B6. The compound of any one of embodiments B1 to B5, wherein the glycosyl group comprises mannoside, fucoside, or a combination thereof.

- [0323] Embodiment B7. The compound of any one of embodiments B1 to B6, wherein the glycosyl group comprises a terminal mannoside, a terminal fucoside, or both.
- [0324] Embodiment B8. The compound of any one of embodiments B1 to B7, wherein the glycosyl group comprises a mono-mannoside, a di-mannoside, or a tri-mannoside.
- [0325] Embodiment B9. The compound of embodiment B8, wherein the tri-mannoside is a linear or branched tri-mannoside.
- [0326] Embodiment B10. The compound of embodiment B9, wherein the branched tri-mannoside is a α -1,3- α -1,6-trimannoside.
- [0327] Embodiment B11. The compound of any one of embodiments B1 to B10, wherein R_1 is a substituted glycosyl group.
- [0328] Embodiment B12. The compound of embodiment B11, wherein the glycosyl group comprises 1 to 6 substituents, wherein the substituent is C_{1-6} alkyl, C_{1-6} alkenyl, halogen, C_{1-6} alkyl halide, C_{1-6} alkoxy, amine, nitro, C_{1-6} alkyl amine, amide, azido, aryl, cycloalkyl, heterocycloalkyl, sulfite, or a substituted version thereof, or a combination thereof.
- [0329] Embodiment B13. The compound of embodiment B12, wherein the substituent of the glycosyl group is selected from the group consisting of aryl, 5-membered cycloalkyl, 6-membered cycloalkyl, 5-membered heterocycloalkyl, and 6-membered heterocycloalkyl, and a substituted version thereof, which comprises 1 to 6 substituents selected from the group consisting of C_{1-6} alkyl, halogen, C_{1-6} alkyl halide, C_{1-6} alkoxy, amine, nitro, C_{1-6} alkyl amine, amide, azido, carboxyl, hydroxyl, aryl, cycloalkyl, heterocycloalkyl, or a substituted version thereof, or a combination thereof.
- [0330] Embodiment B14. The compound of embodiment B12 or embodiment B13, wherein the substituent of the glycosyl group is a substituted or non-substituted aryl, optionally the substituent of the glycosyl group is a phenyl substituted with OH, CH_3 , NH_2 , CF_3 , OCH_3 , F, Br, Cl, NO_2 , N_3 , or a combination thereof.
- [0331] Embodiment B15. The compound of embodiment B12 or embodiment B13, wherein the heterocycloalkyl comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N.
- [0332] Embodiment B16. The compound of any one of embodiments B1 to B15, wherein R_1 is selected from the group consisting of:

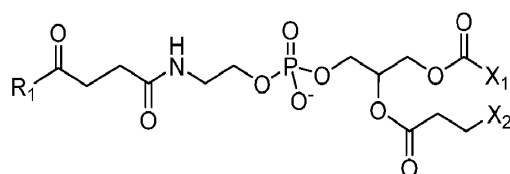




[0333] Embodiment B17. The compound of any one of embodiments B1 to B16, wherein the compound is of Formula 1.

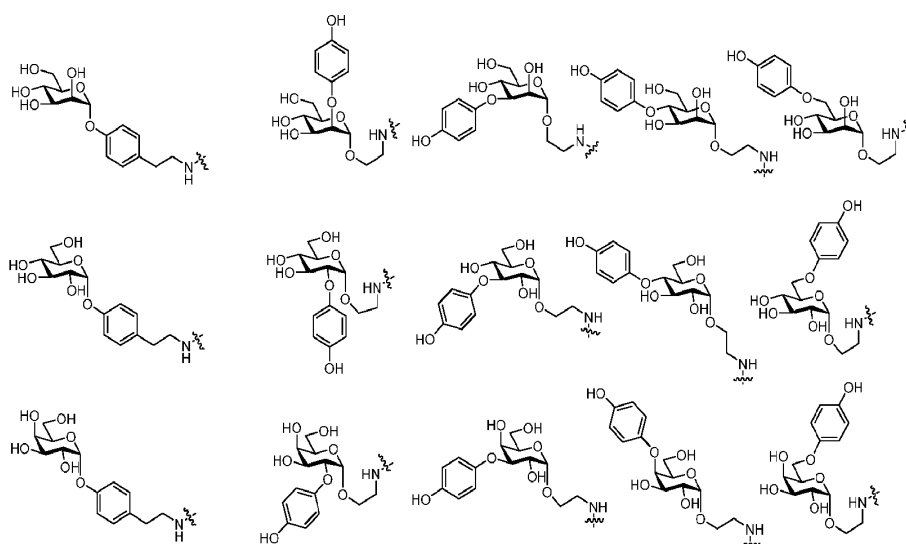
[0334] Embodiment B18. The compound of any one of embodiments B1 to B16, wherein the compound is of Formula 2.

[0335] Embodiment B19. The compound of embodiment B18, wherein the compound is of Formula 3:



Formula 3; and

wherein R_1 is selected from the group consisting of:



[0336] Embodiment B20. The compound of any one of embodiments B1 to B19, wherein at least one of X_1 and X_2 comprises a saturated hydrocarbon chain, comprising at least 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 24, 26, 28, or 30 carbons.

[0337] Embodiment B21. The compound of any one of embodiments B1 to B20, wherein X_1 and X_2 are each independently hydrogen, C_{4-30} alkyl, C_{4-30} alkenyl, C_{4-30} alkynyl, aryl, aryloxy, or a substituted version thereof, or $-(CH_2)_nX_4$, n is 4 to 30, and X_4 is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X_4 is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N, or a combination thereof.

[0338] Embodiment B22. The compound of embodiment B21, wherein X_1 and X_2 are each independently hydrogen, C_{8-30} alkyl, C_{8-30} alkenyl, C_{8-30} alkynyl, aryl, aryloxy, or a substituted version thereof, or $-(CH_2)_nX_4$, n is 8 to 30, and X_4 is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X_4 is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N, or a combination thereof.

[0339] Embodiment B23. The compound of any one of embodiments B1 to B22, provided that when one of X_1 and X_2 is hydrogen, the other one is not hydrogen.

[0340] Embodiment B24. The compound of any one of embodiments B1 to B23, wherein X_4 is an aryl, aryloxy, heterocyclic group, cycloalkyl, heterocycloalkyl, or a combination thereof, and wherein X_4 comprises 0 to 6 substituents, selected from the group consisting of C_{1-6} alkyl, halogen, C_{1-6} alkyl halogen, and C_{1-6} alkoxy.

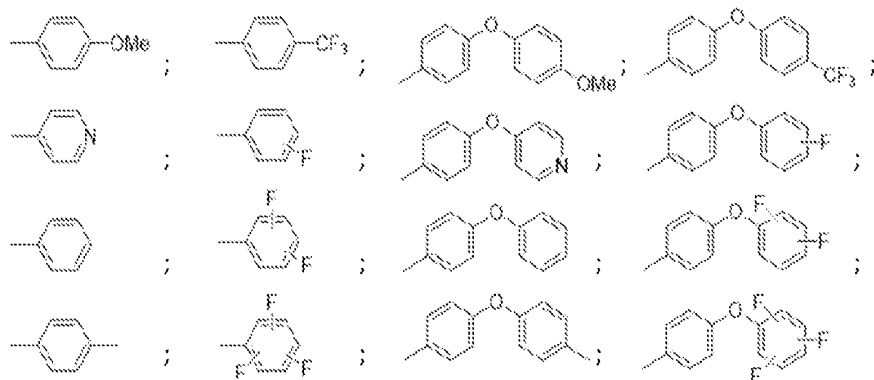
[0341] Embodiment B25. The compound of embodiment B24, wherein the substituent is CH_3 , CF_3 , F, or OCH_3 .

[0342] Embodiment B26. The compound of embodiment B24 or embodiment B25, wherein X_4 comprises 1 to 3 substituents.

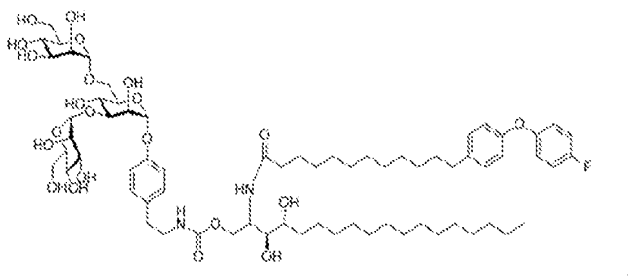
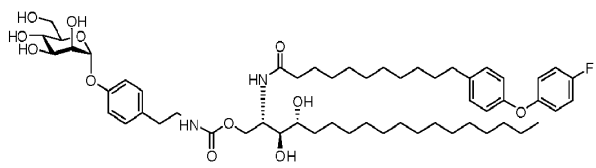
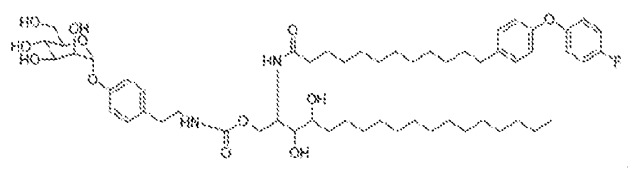
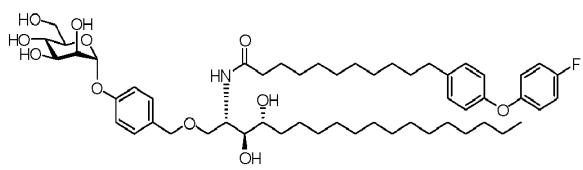
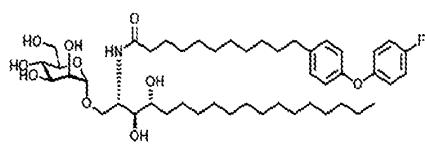
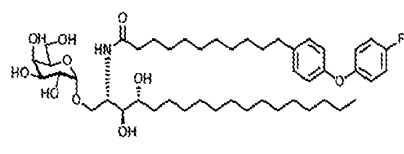
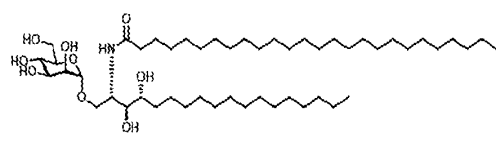
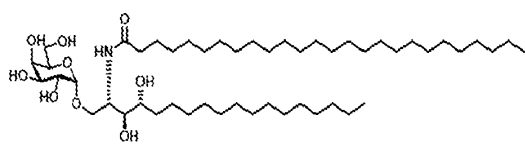
[0343] Embodiment B27. The compound of any one of embodiments B24 to B26, wherein X_4 is $-R_3-O-R_4$, wherein R_3 and R_4 are each independently aryl, heterocyclic group, cycloalkyl, heterocycloalkyl, each comprising 0 to 6 substituents selected from the group consisting of C_{1-6} alkyl, halogen, C_{1-6} alkyl halogen, and C_{1-6} alkoxy.

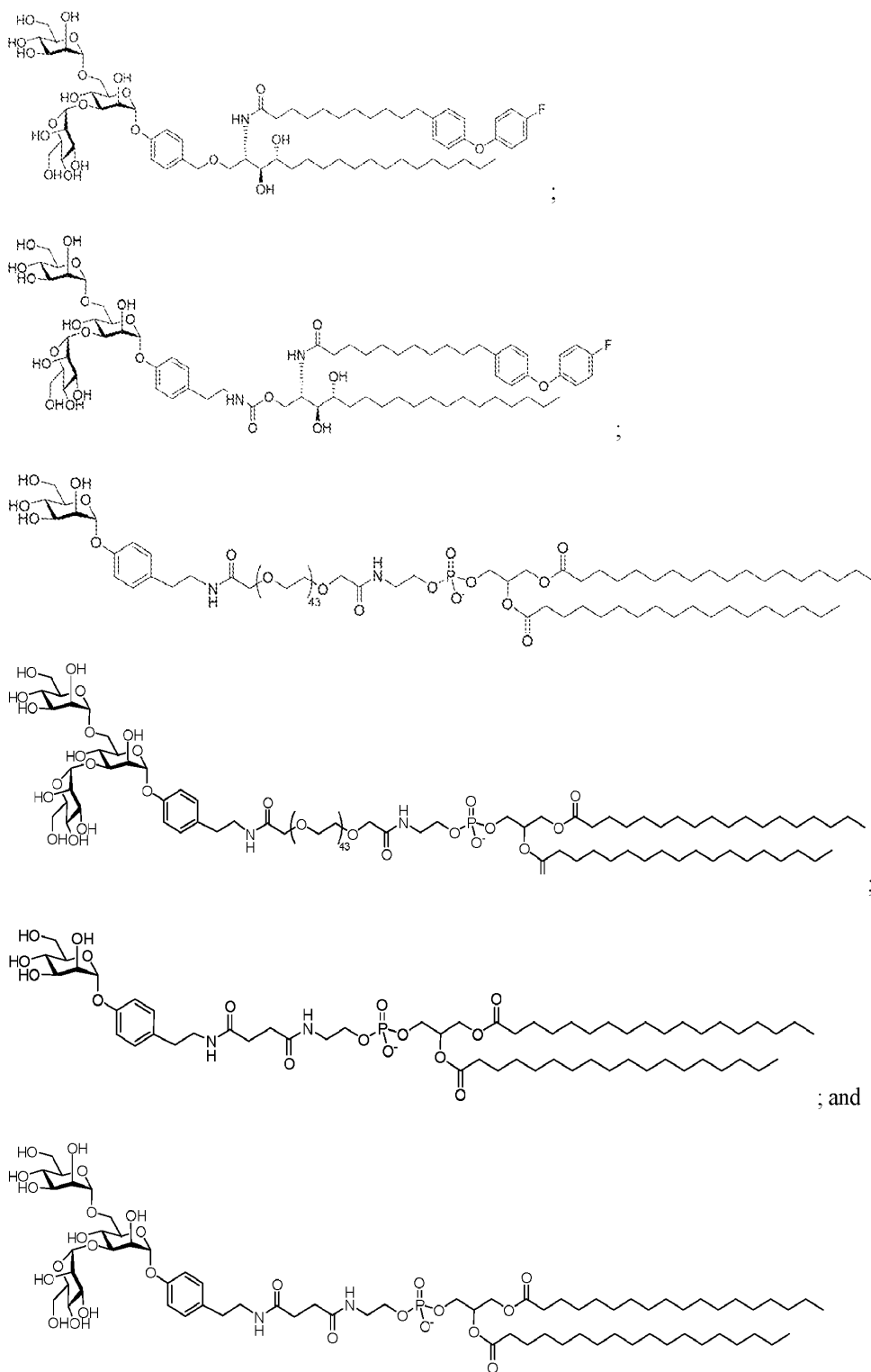
[0344] Embodiment B28. The compound of any one of embodiments B1 to B27, wherein one of X_1 and X_2 is C_{15-30} alkyl, and the other one is $-(CH_2)_nX_4$.

[0345] Embodiment B29. The compound of any one of embodiments B1 to B28, wherein X_4 is selected from the group consisting of:



[0346] Embodiment B30. The compound of any one of embodiments B1 to B29, selected from the group consisting of:





- [0347] Embodiment B31. The component of any one of embodiments B1 to B30, wherein the component is not glycolipid C34 or α -galactosylceramide.
- [0348] Embodiment B32. A formulation for forming a lipid nanoparticle, comprising the compound of any one of embodiments B1 to B31, wherein the compound comprises 1 to 10 mol% of the composition.
- [0349] Embodiment B33. The formulation of embodiment B32, further comprises an ionizable lipid, a helper lipid, or a mixture thereof, wherein the ionizable lipid comprises 30 to 60 mol% of the composition, the helper lipid comprises 5 to 60 mol% of the composition, and the rest percent is a carrier or a solvent.
- [0350] Embodiment B34. The formulation of embodiment B33, wherein the ionizable lipid comprises heptadecan-9-yl 8-[2-hydroxyethyl-(6-oxo-6-undecyloxyhexyl)amino]octanoate (SM-102TM), (4-hydroxybutyl)azanediyl)bis(hexane-6,1-diyl)bis(2-hexyldecanoate) (ALC-0315TM, Pfizer), or a combination thereof.
- [0351] Embodiment B35. The formulation of embodiment B33 or embodiment B34, wherein the helper lipid comprises a phosphatidylcholine, a cholesterol or a derivative thereof, a polyethylene glycol-lipid (PEG-lipid), or a mixture thereof, wherein the phosphatidylcholine comprises 5 to 10 mol% of the composition, the cholesterol or a derivative thereof comprises 30 to 40 mol% of the composition, and the polyethylene glycol-lipid (PEG-lipid) comprises 1 to 10 mol% of the composition.
- [0352] Embodiment B36. The formulation of embodiment B35, wherein the phosphatidylcholine comprises distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylethanolamine (DPOE), or a mixture thereof.
- [0353] Embodiment B37. The formulation of embodiment B35 or embodiment B36, wherein the cholesterol or a derivative thereof is a cholesterol, campesterol, beta-sitosterol, brassicasterol, ergosterol, dehydroergosterol, stigmasterol, fucosterol, DC-cholesterol HCl, OH-Chol, HAPC-Chol, MHAPC-Chol, DMHAPC-Chol, DMPAC-Chol, cholesteryl chloroformate, GL67, cholesteryl myristate, cholesteryl oleate, cholesteryl nervonate, LC10, cholesteryl hemisuccinate, (3 β ,5 β)-3-hydroxycholestan-24-oic acid, alkyne cholesterol, 27-alkyne cholesterol, E-cholesterol alkyne, trifluoroacetate salt (Dios-Arg, 2H-Cho-Arg, or Cho-Arg), or a mixture thereof.
- [0354] Embodiment B38. The formulation of any one of embodiments B35 to B37, wherein the PEG-lipid is DMG-PEG, DSG-PEG, mPEG-DPPE, DOPE-PEG, mPEG-DMPE, mPEG-DOPE, DSPE-

PEG-amine, DSPE-PEG, mPEG-DSPE, PEG PE, m-PEG-Pentacosadiynoic acid, bromoacetamido-PEG, amine-PEG, azide-PEG, or a mixture thereof.

[0355] Embodiment B39. The formulation of any one of embodiments B33 to B38, further comprising a payload.

[0356] Embodiment B40. The formulation of embodiment B39, wherein the payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof.

[0357] Embodiment B41. The formulation of embodiment B40, wherein the nucleic acid is RNA or DNA.

[0358] Embodiment B42. The formulation of embodiment B41, wherein the payload encodes a polypeptide.

[0359] Embodiment B43. The formulation of any one of embodiments B39 to B42, wherein the payload is immunogenic, or the payload is a nucleic acid configured to encode an immunogenic polypeptide or protein.

[0360] Embodiment B44. The formulation of any one of embodiments B39 to B43, wherein the payload is a first payload, and the composition further encapsulates a second payload, wherein the second payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof.

[0361] Embodiment B45. The formulation of embodiment B44, wherein the first payload and the second payload are different.

[0362] Embodiment B46. The formulation of any one of embodiments B32 to B45, further comprising a pharmaceutically acceptable excipient, adjuvant, or a combination thereof.

[0363] Embodiment B47. A lipid nanoparticle, comprising a membrane defining an inner space, wherein the membrane is formed with a plurality of lipid components comprising the compound of any one of embodiments B1 to B31.

[0364] Embodiment B48. The lipid nanoparticle of embodiment B47, wherein the plurality of the lipid components further comprises an ionizable lipid, a helper lipid, or a combination thereof.

[0365] Embodiment B49. The lipid nanoparticle of embodiment B47 or embodiment B48, wherein the membrane is formed via hydrophobic interaction between the plurality of the lipid components.

[0366] Embodiment B50. The lipid nanoparticle of embodiment B49, wherein the ionizable lipid comprises heptadecan-9-yl 8-[2-hydroxyethyl-(6-oxo-6-undecyloxyhexyl)amino]octanoate (SM-102TM), (4-hydroxybutyl)azanediyldis(hexane-6,1-diyl)bis(2-hexyldecanoate) (ALC-0315TM, Pfizer), or a combination thereof.

[0367] Embodiment B51. The lipid nanoparticle of embodiment B49 or embodiment B50, wherein the helper lipid comprises a phosphatidylcholine, a cholesterol or a derivative thereof, a polyethylene glycol-lipid (PEG-lipid), or a mixture thereof.

[0368] Embodiment B52. The lipid nanoparticle of embodiment B51, wherein the phosphatidylcholine comprises distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylethanolamine (DPOE), or a mixture thereof.

[0369] Embodiment B53. The lipid nanoparticle of embodiment B51 or embodiment B52, wherein the cholesterol or a derivative thereof is a cholesterol, campesterol, beta-sitosterol, brassicasterol, ergosterol, dehydroergosterol, stigmasterol, fucosterol, DC-cholesterol HCl, OH-Chol, HAPC-Chol, MHAPC-Chol, DMHAPC-Chol, DMPAC-Chol, cholesteryl chloroformate, GL67, cholesteryl myristate, cholesteryl oleate, cholesteryl nervonate, LC10, cholesteryl hemisuccinate, (3 β ,5 β)-3-hydroxycholestan-24-oic acid, alkyne cholesterol, 27-alkyne cholesterol, E-cholesterol alkyne, trifluoroacetate salt (Dios-Arg, 2H-Cho-Arg, or Cho-Arg), or a mixture thereof.

[0370] Embodiment B54. The lipid nanoparticle of any one of embodiments B51 to B53, wherein the PEG-lipid is DMG-PEG, DSG-PEG, mPEG-DPPE, DOPE-PEG, mPEG-DMPE, mPEG-DOPE, DSPE-PEG-amine, DSPE-PEG, mPEG-DSPE, PEG PE, m-PEG-Pentacosadiynoic acid, bromoacetamido-PEG, amine-PEG, azide-PEG, or a mixture thereof.

[0371] Embodiment B55. The lipid nanoparticle of any one of embodiments B47 to B54, wherein the membrane encapsulates a payload.

[0372] Embodiment B56. The lipid nanoparticle of embodiment B55, wherein the payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof.

[0373] Embodiment B57. The lipid nanoparticle of embodiment B56, wherein the nucleic acid is RNA or DNA.

[0374] Embodiment B58. The lipid nanoparticle of embodiment B57, wherein the payload encodes a polypeptide.

[0375] Embodiment B59. The lipid nanoparticle of any one of embodiments B55 to B58, wherein the payload is immunogenic, or the payload is a nucleic acid configured to encode an immunogenic polypeptide or protein.

[0376] Embodiment B60. The lipid nanoparticle of any one of embodiments B55 to B59, wherein the payload is a first payload, and the membrane further encapsulates a second payload.

[0377] Embodiment B61. The lipid nanoparticle of embodiment B60, wherein the second payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof.

[0378] Embodiment B62. The lipid nanoparticle of embodiment B60 or embodiment B61, wherein the first payload and the second payload are different.

[0379] Embodiment B63. The lipid nanoparticle of any one of embodiments B47 to B62, being made from the composition of any one of embodiments B29 to B43.

[0380] Embodiment B64. The lipid nanoparticle of any one of embodiments B47 to B63, wherein the membrane is a bi-layer structure.

[0381] Embodiment B65. The lipid nanoparticle of any one of embodiments B47 to B64, having a diameter of 0.01 to 5 microns.

[0382] Embodiment B66. The lipid nanoparticle of any one of embodiments B47 to B65, wherein the plurality of the lipid components does not comprise glycolipid C34 or α -galactosylceramide (α -GalCer).

[0383] Embodiment B67. A formulation, comprising the lipid nanoparticle of any one of embodiments B47 to B66.

[0384] Embodiment B68. The formulation of embodiment B67, comprising 0.01 to 95% (w/w) of the lipid nanoparticle.

[0385] Embodiment 69. The formulation of embodiment 67 or embodiment 68, wherein the lipid nanoparticle is a first lipid nanoparticle, and the composition further comprises a second lipid nanoparticle.

[0386] Embodiment B70. The formulation of embodiment B69, wherein the first lipid nanoparticle and the second lipid nanoparticle are different in size, membrane components, payload encapsulated therewithin, or a combination thereof.

[0387] Embodiment B71. The formulation of any one of embodiments B67 to B70, further comprising an excipient, an adjuvant, or a combination thereof.

[0388] Embodiment B72. The formulation of embodiment B71, wherein the excipient comprises a solvent, dispersion media, diluent, dispersion, suspension aid, surface active agent, isotonic agent, thickening or emulsifying agent, preservative, polymer, peptide, protein, cell, hyaluronidase, or mixtures thereof.

[0389] Embodiment B73. The formulation of embodiment B71 or embodiment B72, wherein the adjuvant comprises C34, Gluco-C34, 7DW8-5, C17, C23, C30, α -galactosylceramide, Aluminum salt, Squalene, MF59, or QS-21. Other examples of adjuvants in some vaccines that can be used in the composition of the present disclosure are aluminum hydroxide, aluminum phosphate, alum (potassium aluminum sulfate), mixed aluminum salts, Freund's complete adjuvant, Freund's incomplete adjuvant, AS03 (GlaxoSmithKline), MF59 (Seqirus), and CpG 1018 (Dynavax), or a combination thereof.

[0390] Embodiment B74. A kit for preparing a lipid nanoparticle, comprising: a first reagent, comprising the compound of any one of embodiments B1 to B31; and a second reagent, comprising an ionizable lipid, a helper lipid, or a mixture thereof.

[0391] Embodiment B75. The kit of embodiment B74, wherein the second reagent comprises the ionizable lipid.

[0392] Embodiment B76. The kit of embodiment B75, wherein the kit further comprises a third reagent comprising a helper lipid.

[0393] Embodiment B77. The kit of any one of embodiments B74 to B76, wherein ionizable lipid comprises heptadecan-9-yl 8-[2-hydroxyethyl-(6-oxo-6-undecyloxyhexyl)amino]octanoate (SM-102TM), (4-hydroxybutyl)azanediylbis(hexane-6,1-diyl)bis(2-hexyldecanoate) (ALC-0315TM, Pfizer), or a combination thereof.

[0394] Embodiment B78. The kit of any one of embodiments B74 to B77, wherein the helper lipid comprises a phosphatidylcholine, a cholesterol or a derivative thereof, a polyethylene glycol-lipid (PEG-lipid), or a mixture thereof.

- [0395] Embodiment B79. The kit of embodiment B78, wherein the phosphatidylcholine comprises distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylethanolamine (DPOE), or a mixture thereof.
- [0396] Embodiment B80. The kit of embodiment B78 or embodiment B79, wherein the cholesterol or a derivative thereof is a cholesterol, campesterol, beta-sitosterol, brassicasterol, ergosterol, dehydroergosterol, stigmasterol, fucosterol, DC-cholesterol HCl, OH-Chol, HAPC-Chol, MHAPC-Chol, DMHAPC-Chol, DMPAC-Chol, cholesteryl chloroformate, GL67, cholesteryl myristate, cholesteryl oleate, cholesteryl nervonate, LC10, cholesteryl hemisuccinate, (3 β ,5 β)-3-hydroxycholan-24-oic acid, alkyne cholesterol, 27-alkyne cholesterol, E-cholesterol alkyne, trifluoroacetate salt (Dios-Arg, 2H-Cho-Arg, or Cho-Arg), or a mixture thereof.
- [0397] Embodiment B81. The kit of any one of embodiments B78 to B80, wherein the PEG-lipid is DMG-PEG, DSG-PEG, mPEG-DPPE, DOPE-PEG, mPEG-DMPE, mPEG-DOPE, DSPE-PEG-amine, DSPE-PEG, mPEG-DSPE, PEG PE, m-PEG-Pentacosadiynoic acid, bromoacetamido-PEG, amine-PEG, azide-PEG, or a mixture thereof.
- [0398] Embodiment B82. The kit of any one of embodiments B74 to B81, further comprising a fourth reagent, comprising a payload, wherein the payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof.
- [0399] Embodiment B83. The kit of embodiment B82, wherein the nucleic acid is RNA or DNA.
- [0400] Embodiment B84. The kit of embodiment B83, wherein the payload encodes a polypeptide.
- [0401] Embodiment B85. The kit of any one of embodiments B82 to B84, wherein the payload is immunogenic, or the payload is a nucleic acid configured to encode an immunogenic polypeptide or protein.
- [0402] Embodiment B86. A method of targeted payload delivery in a subject, comprising administering to the subject an effective amount of the lipid nanoparticle of any one of embodiments 47 to 54, wherein the payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof, and the payload is encapsulated by the lipid nanoparticle.
- [0403] Embodiment B87. The method of embodiment B86, wherein the nucleic acid is RNA or DNA.

- [0404] Embodiment B88. The method of embodiment B87, wherein the payload encodes a polypeptide.
- [0405] Embodiment B89. The method of any one of embodiments B86 to B88, wherein the payload is immunogenic, or the payload is a nucleic acid configured to encode an immunogenic polypeptide or protein.
- [0406] Embodiment B90. The method of any one of embodiments B86 to B89, wherein the payload is a first payload, and the membrane further encapsulates a second payload, wherein the second payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof.
- [0407] Embodiment B91. The method of embodiment B90, wherein the first payload and the second payload are different.
- [0408] Embodiment B92. The method of any one of embodiments B86 to B91, wherein the lipid nanoparticle is administered together with an excipient, an adjuvant, or a combination thereof.
- [0409] Embodiment B93. The method of embodiment B92, wherein the excipient comprises a solvent, dispersion media, diluent, dispersion, suspension aid, surface active agent, isotonic agent, thickening or emulsifying agent, preservative, polymer, peptide, protein, cell, hyaluronidase, or mixtures thereof.
- [0410] Embodiment B94. The method of embodiment B92 or embodiment B93, wherein the adjuvant comprises C34, Gluco-C34, 7DW8-5, C17, C23, C30, α -galactosylceramide, Aluminum salt, Squalene, MF59, or QS-21. Other examples of adjuvants in some vaccines that can be used in the composition of the present disclosure are aluminum hydroxide, aluminum phosphate, alum (potassium aluminum sulfate), mixed aluminum salts, Freund's complete adjuvant, Freund's incomplete adjuvant, AS03 (GlaxoSmithKline), MF59 (Seqirus), and CpG 1018 (Dynavax), or a combination thereof.
- [0411] Embodiment B95. A method of preventing or treating a disease in a subject, comprising administering to the subject an effective amount of the lipid nanoparticle of any one of embodiments B47 to B54, wherein the payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof, and the payload is encapsulated within the lipid nanoparticle; and wherein the payload is a therapeutic agent or derives a therapeutic agent.
- [0412] Embodiment B96. The method of embodiment B95, wherein the nucleic acid is RNA or DNA.

[0413] Embodiment B97. The method of embodiment B96, wherein the payload encodes a polypeptide.

[0414] Embodiment B98. The method of any one of embodiments B95 to B97, wherein the payload is immunogenic, or the payload is a nucleic acid configured to encode an immunogenic polypeptide or protein.

[0415] Embodiment B99. The method of any one of embodiments B95 to B98, wherein the payload is a first payload, and the membrane further encapsulates a second payload, wherein the second payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof.

[0416] Embodiment B100. The method of embodiment B99, wherein the first payload and the second payload are different.

[0417] Embodiment B101. The method of any one of embodiments B95 to B100, wherein the lipid nanoparticle is administered together with an excipient, an adjuvant, or a combination thereof.

[0418] Embodiment B102. The method of embodiment B101, wherein the excipient comprises a solvent, dispersion media, diluent, dispersion, suspension aid, surface active agent, isotonic agent, thickening or emulsifying agent, preservative, polymer, peptide, protein, cell, hyaluronidase, or mixtures thereof.

[0419] Embodiment B103. The method of embodiment B101 or embodiment B102, wherein the adjuvant comprises C34, Gluco-C34, 7DW8-5, C17, C23, C30, α -galactosylceramide, Aluminum salt, Squalene, MF59, or QS-21. Other examples of adjuvants in some vaccines that can be used in the composition of the present disclosure are aluminum hydroxide, aluminum phosphate, alum (potassium aluminum sulfate), mixed aluminum salts, Freund's complete adjuvant, Freund's incomplete adjuvant, AS03 (GlaxoSmithKline), MF59 (Seqirus), and CpG 1018 (Dynavax), or a combination thereof.

[0420] Embodiment B104. The method of any one of embodiments B95 to B103, wherein the lipid nanoparticle is administered in an initial dose and followed by one, two, three, four, five, or more booster doses.

[0421] Embodiment B105. The method of embodiment B104, wherein the booster doses are administered about one month, about two months, about three months, about four months, about five months, or about six months or more following the initial dose.

- [0422] Embodiment B106. The method of any one of embodiments B95 to B105, wherein the effective amount ranges from about 5 µg to 1000 µg.
- [0423] Embodiment B107. A method of boosting an adaptive immune response, comprising administering to the subject an effective amount of the lipid nanoparticle of any one of embodiments B47 to B54, wherein the payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof, and the payload is encapsulated within the lipid nanoparticle; and wherein the payload is immunogenic or derives an immunogenic biomolecule.
- [0424] Embodiment B108. The method of embodiment B107, wherein the nucleic acid is RNA or DNA.
- [0425] Embodiment B109. The method of embodiment B108, wherein the payload encodes a polypeptide.
- [0426] Embodiment B110. The method of any one of embodiments B107 to B109, wherein the payload is a first payload, and the membrane further encapsulates a second payload, wherein the second payload is a nucleic acid, a compound, a polypeptide, a protein, a glycan, or a combination thereof.
- [0427] Embodiment B111. The method of embodiment B110, wherein the first payload and the second payload are different.
- [0428] Embodiment B112. The method of any one of embodiments B107 to B111, wherein the lipid nanoparticle is administered together with an excipient, an adjuvant, or a combination thereof.
- [0429] Embodiment B113. The method of embodiment B112, wherein the excipient comprises a solvent, dispersion media, diluent, dispersion, suspension aid, surface active agent, isotonic agent, thickening or emulsifying agent, preservative, polymer, peptide, protein, cell, hyaluronidase, or mixtures thereof.
- [0430] Embodiment B114. The method of embodiment B112 or embodiment B113, wherein the adjuvant comprises C34, Gluco-C34, 7DW8-5, C17, C23, C30, α-galactosylceramide, Aluminum salt, Squalene, MF59, or QS-21. Other examples of adjuvants in some vaccines that can be used in the composition of the present disclosure are aluminum hydroxide, aluminum phosphate, alum (potassium aluminum sulfate), mixed aluminum salts, Freund's complete adjuvant, Freund's incomplete adjuvant, AS03 (GlaxoSmithKline), MF59 (Seqirus), and CpG 1018 (Dynavax), or a combination thereof.

[0431] Embodiment B115. The method of any one of embodiments B107 to B114, wherein the lipid nanoparticle is administered in an initial dose and followed by one, two, three, four, five, or more booster doses.

[0432] Embodiment B116. The method of embodiment B115, wherein the booster doses are administered about one month, about two months, about three months, about four months, about five months, or about six months or more following the initial dose.

[0433] Embodiment B117. The method of any one of embodiments B107 to B116, wherein the effective amount ranges from about 5 μ g to 1000 μ g.

[0434] SEQUENCES

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SEQ ID NO: 4 Protein sequence of S- (deg-RBD) for Wuhan strain (from N-terminus to C-terminus)	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVVYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSNGTKRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSTQSLIVNNATNVVIKVFCEQFCNDPFLG VYYHKNNKSWMESEFRVYSSANNCTFEYVSQPFMDLEGKQGNFK NLREFVFKNIDGYFKIYSKHTPINLVRDLPGQFSALEPLVDLPIGINITR FQTLALHRSYLTGDDSSSGWTAGAAAYYVGYLQPRTFLLKYNENG TITDAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQPAEAIIVRFPQ ITNLCPFGEVFQATRFASVYAWNKRKISNCVADYSVLVNSASFSTFK CYGVSPTKLNLDLCTNVYADSFVIRGDEVRIAPGQTGKIADYNYKL PDDFTGCVIAWNSNNLDSKVGGNYNLYRLFRKSNLKPFERDISTEI YQAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELL HAPATVCGPKKSTNLVKNKCVNFNGLTGTGVLTESNKKFLPFQ FGRDIADTTDAVRDPQTLEILDITPCSFGGVSIVPTGNTSNQVAVLY QDVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAHEVNN SYECDIPIGAGICASYQTQTNSPRRARSVASQSIIAYTMSLGAENSV YSNNSIAIPTNFTISVTTEILPVSMKTSTVDCTMYICGDSTECNLLQ YGSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFNF SQILPDPSKPSKRSFIEDLLFNKVTADAGFIKQYGDCLGDIAARDLIC AQKFNGLTVLPPLTDEMIAQYTSALLAGTITSGWTFGAGAALQIPF AMQMAYRFNGIGVTVQNVLYENQKLIANQFNSAIGKIQDSLSTASAL GKLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRLDPPEAEVQ IDRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKR VDFCGKGYHLSFPQSAPHGVVFLHVTYVPAQEKNFTTAPAICHDG KAHFPREGVFVSNGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIV NNTVYDPLQPELDSFKEELDKYFKNHTSPDVLGDISGINASVNIQ KEIDRLNEVAKNLNESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIV MVTIMLCCMTSCCCLKGCCSCGSCCKFDEDDSEPVLKGVKLHYT
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SEQ ID NO: 6 Protein sequence of S- (deg-S2) for Wuhan strain (from N-terminus to C-terminus)	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVVYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSGTNGTKRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSTQSLIVNNATNVVIKVCEFQFCNDPFLG VYYHKNKSWMESEFRVYSSANNCTFEYVSQPFLMDLEGKQGNFK NLREFVFKNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGINITR FQTLALHRSYLTGPDSSSGWTAGAAAYYVGYLQPRTFLLKYNENG TITDAVDCALDPLSEKCTLKSFTVEKGIYQTSNFRVQPTESIVRFPNI TNLCPFGEVFNATRFASVYAWNKRISNCVADYSVLVNSASFSTFKC YGVSPTKLNDLCFTNVYADSFVIRGDEVRIAPGQTGKIADYNYKLP DDFTGCVIAWNSNNLDSKVGGNVNYLYRLFRKSNLKPFERDISTEY QAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELLH APATVCGPKKSTNLVKNKCVNFNFGLTGTGVLTESNKKFLPFQGF GRDIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLYQ DVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNS YECDIPIGAGICASYQTQTNSPRRARSVASQSIIAYTMSLGAENSVAY SQNSIAIPTQFTISVTTEILPVSMKTSVDCTMYICGDSTECNLLQY

	GSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFQFS QILPDPSPSKRSFIEDLLFNKVTLADAGFIKQYGDCLGDIAARDLICA QKFNGLTVLPPLLTDEMQYTSALLAGTITSGWTFGAGAALQIPFA MQMAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDSLSTASALG KLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRLDPPEAEVQI DRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKRV DFCGKGYHLMSPQSAPHGVVFLHVTVYVPAQEKQFTTAPAICHGDK AHFPREGVFVSQGTHWFTVQRNFYEPQIITDNTFVSGNCDVVIGIV QNTVYDPLQPELDSFKEELDKYFKQHTSPDVLGDISGIQASVVNIQ KEIDRLNEVAKNLQESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIV MVTIMLCCMTSCCCLKGCCSCGSCCKFDEDDSEPVLKGVKLHYT
SEQ ID NO: 7 Nucleic acid sequence of S-(S2-1194) for Wuhan strain (from 5'- end to 3'-end)	atgttcgtcttctggtcctgctgctcctggtctcctcacagtgcgtcaatctgacaactcggactcagctgcc cctgcttatactaataagctcaccagaggcgtgtactatcctgacaagggttttagaagctccgctgctgactct acacagatctgtttctgccattcttagcaacgtgacctggtccacgccatccacgtgagcggcaccatggtg cacaagcggctcgacaatcccgctgctgcttfaacgatggcgtgtactcgcctctaccgagaagagcaac atcatcagaggctggatctttggcaccacactggactccaagacacagtctcgtgcatcgtgaacaatgcca ccaacgtggtcatcaagggtgctgaggtccagttttgaatgatccctcctggcgtgctactatcacaagaaca ataagagctggatggagtcgagtttagagtgatcttagcgcacaactgcacattgagtagtgagcca gccttctcgtatggactggagggcaggcaggcaattcaagaacctgaggggagtcgtgttaagaatc gacggctacttcaaatctactctaagcacacccccatcaacctggtgctgacgtgctcagggcttcagc gccctggagccctggtggtatcgtcctatcggtcatcaacatcacccggttcagacactgctgcccctgcac agaagctacgtgacacccggcgactcctctagcggatggaccgcccggcgctgcccctactatgtgggcta cttcagccccggactcctcgtgtaagtaaacgagaatggcaccatcacagacgcagtgattggtgcc tggacccctgagcgagacaaagtgtacactgaagtcctttaccgtggagaaggcatctatcagacatcca atttcaggtgagccaacaggagtcctcgtgcttcttaatatcacaacctgtgcccattggcgaggtgt tcaacgcaacccgcttcgcagcgtgtacgcctggaataggagcgatcagcaactgcgtggcgcgactat agcgtgctgtacaactccgctcttctcagcacctttaagtgtatggcgtgtcccccacaaagctgaatgacct gtgctttaccaacgtctacgcccgttctcgtgatcagggcgacgaggtgctgcccagatcgcggcgcca gacaggcaagatcgagactacaattataagctgccagacgatttcacggctgctggtatcgcctggaacag caacaatctggattcacaagtgggcggaactacaattatctgtacggctgtttagaagagcaatctgaag cccttcgagaggacatctctacagaaatctaccagccggcgacacccctgcaatggcgtggagggcttt aactgttattccactccagtcctacggcttcagcccacaaacggcggtggctatcagccttaccgctggt ggtgctgagctttgagctgtgcacgcccagcaacagtgtgcggcccagaagtcaccaatctggtga agaacaagtgcgtgaactcaactcaacggcctgaccggcacagcgctgctgaccgagtcacaagaagaa gttctgctcatttcagcagttcggcaggacatcgagataccacagacgcgtgctgacccacagaccc tggagatcctggacatcacacccgtctcttcggcggtgagcgtgatcacacccggcaccatacaagca accaggtggccgtgctgtatcaggacgtgaattgtaccgaggtgcccgtgctatccacgcccagatcagctga cccaacatggcgggtgtacagaccggctccaacgtcttcagacaagagccggatgcctgtatcggagc agagcacgtgaacaattctatgagtcgacatccaatggcgccgcatctgtgctcttaccagaccca gacaaactctccagaagagcccgagcgtggcctccagtcctatcagcctataccatgtccctggcgcc cgagaacagcgtggcctactctcagaaatagcatgccatccaacccagttcacatctctgtgaccacaga gatcctgcccgtgtccatgaccaagacatctgtggactgcacaatgtatatctgtggcgattctaccgagtgca gcaacctgctgtccagtagcgcagctttgtaccagctgaatagagccctgacaggcatcgcctgtggagc aggataagaacacagaggtgttcgcccaggtgaagcaaatctacaagacccccctatcaaggacttt ggcggtctcgaatttccagatcctgctgatccatcaagccttctaagcggagctttatcaggaacctgt gttcaacaaggtgacctggccgatgcggctcatcaagcagtatggcgtgctggtggcgacatcgagc cagggaacctgctgcccagaagttaatggcctgacctgctgcccacctgctgacagatgagatgat cgcacagtacacaagcgcctgctggcggcaccatcacatccggatggaccttcggcgagagccgcc ctccagatcccccttgcagatggcctataggtcaacggcatcggcggtgaccagaatgtgctgtacg

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SEQ ID NO: 8 Protein sequence of S- (S2-1194) for Wuhan strain (from N-terminus to C-terminus)	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVVYYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSNGTKRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSTQSLIVNNATNVVIKVFCEQFCNDPFLG VYYHKNNKSWMESEFRVYSSANNCTFEYVSQPFLLMDLEGKQGNFK NLREFVFKNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGINITR FQTLALHRSYLTGPDSSSGWTAGAAAYYVGYLQPRFTLLKYNENG TITDAVDCALDPLSEKCTLSFTVEKGIYQTSNFRVQPTESIVRFPNI TNLCPFGEVFNATRFASVYAWNRKRISNCVADYSVLVNSASFSTFKC YGVSPTKLNLDLCTNVYADSFVIRGDEVRIAPGQTGKIADYNYKLP DDFTGCVIAWNSNNLDSKVGGNYNYLYRLFRKSNLKPFERDISTEY QAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELLH APATVCGPKKSTNLVKNKCVNFNFGLTGTGVLTESNKKFLPFQGF GRDIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLYQ DVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNS YECDIPIGAGICASYQTQNSPRRARSVASQSIIAYTMSLGAENSVAY SQNSIAIPTQFTISVTTEILPVSMTKTSVDCTMYICGDSTECNLLQY GSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFQFS QILPDPSKPSKRSFIEDLLFNKVTLADAGFIKQYGDCLGDIAARDLCA QKFNGLTVLPPLLTDEMAQYTSALLAGTITSGWTFGAGAALQIPFA MQMAYRFNGIGVTONVLYENQKLIANQFNSAIGKIQDSLSTASALG KLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRLDPPEAEVQI DRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLQSKRV DFCGKGYHLSFPQSAPHGVVFLHVTYVPAQEKQFTTAPAICHGDK AHFPREGVFVSQGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIV QNTVYDPLQPELDSFKEELDKYFKQHTSPDVLGDISGIQASVVNIQ KEIDRLNEVAKNLNESLIDLQELGKYEYIKWPWYIWLGFIAGLIAIV MVTIMLCCMTSCCCLKGCCCGSCCKFDEDDSEPVLGKVKLHYT
SEQ ID NO: 9 Nucleic acid sequence of S-(deg-RBD-801)	atgttcgtcttctggtcctgctgctcctcctcacagtgcgtcaatctgacaactcggactcagctcca cctgcttataactaagcttcaccagaggcgtgtactatcctgacaagggttttagaagctccgtgctgactct acacagatctgttttccattcttagcaacgtgacctggtccacgccatccagtgagcggccaatgg cacaagcgggttcacaatcccgtgctgcttttaacgatggcgtgtacttcgctctaccgagaagagcaac atcatcagagcgtgatcttggcaccacactggactccaagacacagtctctgctgatcgtgaacaatcca ccaacgtggtcatcaaggtgtgcgagttccagttttgtaatgatcccttcctggcgctgtactatcacaagaaca

for Wuhan strain (from 5'-end to 3'-end)	ataagagctggatggagtcgagtttagagtgattctagcgccaacaactgcacatttagtactgagcca gcctttcctgatggacctggaggcgaagcaggcgcaattcaagaacctgagggaagtcgtgtttaagaatatac gacggctacttcaaaatctactctaagcacacccccatcaacctggcgcgacgtgctcagggcttcagc gccctggagcccctgggtggtatctgcctatcgcatcaacatcacccgggttcagacactgtgcccctgcac agaagctacctgacacccggcgactcctctagcgatggaccgcccggcgctgcccctactatgtgggcta cctccagccccggaccttctgctgaagtacaacgagaatggcaccatcacagacgcagtggttgccgccc tggaccacctgagcgagacaaagtgtactactgaagtcctttaccgtggagaaggcagctatcagacatcca atttcagggtgacgccaagcggagcgatcgtgcttccgaaatcacaacctgtgccatttggcgagg tgttcgagcgcaacccgcttcgacgctgtacgcctgggaatagggaagcgatcagcaactgctgtggcgac tatagcgtgctgtacaactccgctctttcagcaccttaagtctatggcggtgtccccacaaagctgaatgac ctgtgctttaccaacgtctacgcccgttctgtgatcaggggcgacgaggtgcccagatcgccccggc cagacaggcaagatcgacactacaattataagctgccagacgattcaccggtgctgtgatcgctggaac agcaacaatctggattccaagtggcggaactacaattatctgtaccggtgtttagaagagcaatctga agcccttcgagaggacatctctacagaaatctaccaggccggcagcaccccttgaatggcggtgaggggc tttactgttattcccactccagtcctacggcttcagcccacaaacggcggtgggtatcagccttaccgctg gtggtgctgagctttgagctgctgcagccccagcaacagtgctggccccagaagtcaccaatctgtg aagaacaagtgcgtgaactcaactcaacggcctgaccggcacaggcggtgctgacaggagtcacaaga gtctctgcaattcagcagttcggcaggacatcgagataccacagacggcggtgcccagccacagaccc tggagatcctggacatcacacccgtctttcggcggtgagcgtgatcacacccggcaccatacaagca accagggtggccgtgctgtatcaggacgtgaattgtaccgaggtgcccgtggctatccacggatcagctga ccccaacatggcggtgtacagcacggctccaacgtcttcagacaagccggatgctgacggagc agagcacgtgaacaattcctatgagtcgacatcccaatcgccggcgatctgtgctcttaccagacca gacaactctcccagaagagcccgagcgtggcctccagtcctatcagcctatacatgtccctggcgcc cgagaacagcgtggcctactctaaatagcatcgccatccaaccaactcacaatctctgtgaccacaga gatcctgcccgtgtccatgaccaagacatctgtggactgcacaatgtatatctgtggcgattctaccgagtgca gcaacctgctgtccagtagcggcagctttgtaccagctgaatagagccctgacaggcatcgccgtggagc aggataagaacacagagggtgttcgcccagggtgaagcaaatctacaagacccccctatcaaggacttt ggcggtctcgaatttccagatcctgctgatccatcaagccttctaagcggagctttatcaggacgtgct gtcaacaaggtgacctggccgatgcccgtctcatcaagcagtatggcgattgctggcgacatcgagc cagggaacctgatctgcccagaagttaatggcctgaccgtgctgcccacctgctgacagatgagatgat cgcacagtacacaagcgcctgctggccggcaccatcacatccggatggaccttcggcgaggaagccgc ctccagatcccccttgcagatggcctataggttcaacggcatcgcgctgaccagaatgtgctgtacg agaaccagaagctgacccaatcagtttaactccgcatcggaagatccaggacagcctgtcctctacag ccagcgccctggcgaagctccagatgtgtgaatcagaacgcccagggcctgaataccctggtgaagca gctgagcagcaacttcggcgccatctctagcgtgctgaatgacatcctgagccgctggacaaggtggagg cagagggtgagatcgaccggctgacaccggccggctccagagcctccagacctatgtgacacagcagct gatcaggggccgagatcaggggccagcgccaatctggcagcaaccaagatgtccgagtgctgtggg ccagtctaagagagtgacttttggcaagggtatcacctgatgtcctcctcagctgccccacacggc gtgtgtttctgcacgtgacctacgtgcccggccaggagaagaacttaccacagcccctgcatctgccac gatggcaaggcccactttccaaggaggggcggttctgtgtccaacggcacccactgtttgtgacacagcg caatttctacgagcccagatcatcacacagacaacaccttctgtgagcggcaactgtgacgtgtgcatcgg catcgtgaacaataccgtgtatgatccactccagcccagctggacagctttaaggaggagctgataagtat ttcaagaatcacacctcccctgacgtggatctggcgacatcagcggcatcaatgctccgtgtgaacatcc agaaggagatcgaccgctgaacgaggtgtgaagaatctgaacgagagcctgacacccaggagct gggcaagtatgagcagtagatcaagtggccctggtacatctggctggcctcatcgccgctgacgcat cgtgatggtgacatcatgctgtgtatgacatcctgctgttcttcctgaagggtgctgtagctgtgctc ctgctgtaagtgtgacggatgactctgaacctgtgctgaaggcggtgaagctgcatcacctaa
SEQ ID NO: 10	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVYYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVS GTNGTKRFDNPVLPFNDGVYFAS

Protein sequence of S-(deg-RBD-801) for Wuhan strain (from N-terminus to C-terminus)	TEKSNIIRGWIFGTTLDSTQSLIVNNATNVVIKVCEVFQFCNDPFLG VYYHKNKSWMESEFRVYSSANNCTFEYVSQPFLMDLEGKQGNFK NLREFVFKNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGINITR FQTLALHRSYLT PGDSSSGWTAGAAAYYVGYLQPRTFLLKYNENG TITDAVDCALDPLSETKCTLKSTVEKGIYQTSNFRVQP[A][E]AIVRFPQ ITNLCPFGEVFQ[Q]ATRFASVYAWNRRKISNCVADYSVLYNSASFSTFK CYGVSPTKLNLDLCTNVYADSFVIRGDEVRQIAPGQTGKIADYNYKL PDDFTGCVIAWNSNNLDSKVGGNYNYLYRLFRKSNLKPFERDISTEI YQAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELL HAPATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQ FGRDIADTTDAVRDPQTLEILDITPCSFSGGVSVITPGTNTSNQVAVLY QDVNCTEVPVAIHADQLTPTWRVYSTGNSVVFQTRAGCLIGAEHVNN SYECDIPIGAGICASYQTQTSNPRRARSVASQSIIAYTMSLGAENSV YSNNSIAIPTNFTISVTTEILPVSMKTSTVDCCTMYICGDSTECNLLQ YGSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFQ[F] SQILPDPSKPSKRSFIEDLLFNKVTLADAGFIKQYGDCLGDIAARDLIC AQKFNGLTVLPLLTDemiaQYTSALLAGTITSGWTFGAGAALQIPF AMQMAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDSLSTASAL GKLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRLDPPEAEVQ IDRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKR VDFCGKGYHLMSPQSAPHGVVFLHVTYVPAQEKNFTTAPAICHDG KAHFPREGVVFVSNGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIV NNTVYDPLQPELDSFKEELDKYFKNHTSPDVLGDISGINASVUNI KEIDRLNEVAKNLNESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIV MVTIMLCCMTSCCCLKGCCSCGSCCKFDEDDSEPVLKGVKLHYT
SEQ ID NO: 11 Nucleic acid sequence of S-(deg-RBD-1194) for Wuhan strain (from 5'-end to 3'-end)	atgttcgtcttctggtcctgctgctcctggtctcctcacagtgcgtcaatctgacaactcggactcagctcca cctgcttatactaataagctccaccagaggcgtgtactatcctgacaagggttttagaagctccgctgcactct acacaggatctgtttctgccattcttagcaacgtgacctggtccacgccatccacgtgagcggcaccatgg cacaagcggttcgacaatcccgctgctgctctttaacgatggcgtgtactctgacctaccgagaagagcaac atcatcagaggctggtatcttggcaccactggactccaagacacagtctctgctgacgtgaacaatgcc ccaacgtggtcatcaagggtgctgagttccagttttgaatgacccctcctggcgctgtactatcacaagaaca ataagagctggtgatggagtcgagtttagagtgtattctagcgccaacaactgcacatttgatagctgagcca gccttctgtagtgacctggaggcgcaagcaggcgcaattcaagaacctgaggagttcgtgtttaagaatc gacggctacttcaaaatctacttaagcacacccccatcaacctggtgctgacgtgacctgacctcagggcttcagc gacctggagccctggtggtatctgctatcggtcatcaacatcacccggtttcagacactgctggccctgcac agaagctacctgacacccgctgactcctctagcggatggaccgctgctgacctactatgtgggcta cctccagccccggaccttctgctgaagtacaacgagaatggcaccatcacagacgagtggtattgcgcc tggacccctgagcgagacaaagtgtacactgaagtcctttaccgtggagaaggcagctatcagacatcca atttcagggtgcagccagcgcgagcgtgctgcttctgaaatcacaaactgtgccatttggcgagg tgttcgagcgaacccgcttccagcgtgtacgctggaatagggaagcgatcagcaactgctggtgac tatagcgtgctgtacaactccgctcttccagcaccttaagtgtatggcgtgtccccacaaagctgaatgac ctgtgctttaccaacgtctacgctgattcttctgtatcagggcgacgaggtgcgacagatgcaccccgcc cagacaggcaagatgcagactacaattataagctgcagacgatttcacggctgctgacgctggaac agcaacaatctgattccaaagtggcggaactacaattatctgtaccgctgttttagaaagagcaatctga agcccttcgagaggacatctctacagaaatctaccaggccggcagcacccttgcaatggcgtgagggc tttaactgtatttccactccagctctacgcttccagccacaaacggcgtgggtatcagccttaccgctg gtggtgctgagcttgcgtgctgcacgccccagcaacagtgctgcgccccaggaagtcaccaatctggtg aagaacaagtgcgtgaacttcaactcaacggcctgaccggcacaggcgtgctgacggatccaacaagaa gttctgctcatttcagcagttcggcaggacatcgagataccacagacgcgctgctgacccacagaccc

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SEQ ID NO: 12 Protein sequence of S- (deg-RBD-1194) for Wuhan strain (from N- terminus to C-terminus)	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVVYYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSGTNGTKRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSTQSLIVNNATNVVIKVCFFQFCNDPFLG VYYHKNNKSWMESEFRVYSSANNCTFEYVSQPFLMDLEGKQGNFK NLREFVFKNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGINIR FQTLALHRSYLPDSSSGWTAGAAAYYVGYLQPRTFLLKYNNENG TITDAVDCALDPLSEKCTLKSFTVEKGIYQTSNFRVQPAEAIIVRFPQ ITNLCPFGEVFAATRFASVYAWNKRISNCVADYSVLVNSASFSTFK CYGVSPTKLNDLCFTNVYADSFVIRGDEVRIAPGQTGKIADYNYKL PDDFTGCVIAWNSNNLDSKVGGNYNYLYRLFRKSNLKPFERDISTEI YQAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELL HAPATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQQ FGRDIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLY QDVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNN SYECDIPIGAGICASYQTQTNSPRRARSVASQSIIAYTMSLGAENSVA YSNNSIAIPTNFTISVTTEILPVSMTKTSVDCTMYICGDSTECNLLLQ YGSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFNF SQILPDPSKPSKRSFIEDLLFNKVTLADAGFIKQYGDCLGDIAARDLIC AQKFNGLTVLPPLTDEMIAQYTSALLAGTITSGWTFGAGAALQIPF AMQMAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDSLSTASAL

	GKLQDVVNQNAQALNTLVKQLSSNFGAIISSVLNDILSRLDPPEAEVQ IDRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKR VDFCGKGYHLMSPQSAHPGVVFLHVTYVPAQEKNFTTAPAICHG KAHFPREGVVFVSNTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIV NNTVYDPLQPELDSFKEELDKYFKNHTSPDVDLGDISGINASVUNI KEIDRLNEVAKNLQESLIDLQELGKYEYIKWPWYIWLGFIAGLIAIV MVTIMLCCMTSCCSCLKGCCSCGSCCKFDEDDSEPVLKGVKLHYT
SEQ ID NO: 13 Nucleic acid sequence of S-(deg-RBD-122- 165-234) for Wuhan strain (from 5'-end to 3'-end)	atgttcgtcttctggtcctgctgcctctggtctcctcacagtgcgtcaatctgacaactcggactcagctgcc cctgcttatactaatagcttcaccagaggcgtgtactatcctgacaagggttttagaagctccgctgctgactct acacaggatctgtttctgccattcttagcaacgtgacctggtccacgccatccacgtgagcggcaccatgg cacaagcgggtcgacaatcccgtgctgccttttaacgatggcgtgtactcgcctctaccgagaagagcaac atcatcagaggctggtatctttggcaccacactggactcgaacacagctctctgctgacgtgaaccaaagcca ccaacgtggtcatcaaggctgctgaggttccagttttgtaatgateccttctggcgtgtactatcacaagaaca ataagagctggtgagtgccgagtttagagtgattctagcgccaacagtgacatttgatagctgagcca gccttctgctgacctggaggcgaagcagggaattcaagaacctgaggagtgctgtttaagaatatac gacggctacttcaaatctacttaagcacacccccatcaacctggtgcgagacctgcctcagggtctcagc gccctggagcccctggtggtctgcctatcggtatccagatcaccgggttcagacactgctggtccctgcac agaagctacctgacacccggcgactcctctagcggatggaccgcccgcgtgccctactatgtgggcta cctccagccccggaccttctgctgaagtacaacgagaatggcaccatcacagacgcagtgattgctgcc tggacccctgagcagacaaaagtgtacactgaagtcctttaccgtggagaaggcatctatcagacatcca atttcagggtgcagccaagcggagcgtatcgtgcgttctcgaatcacaacctgtgccatttggcagg tgttcaggccaacccgttcgcccagcgtgtacgcctggaataggagcggatcagcaactgctggtccgac tatagcgtgctgtacaactccgctctttcagcacctttaagtctatggcgtgtccccacaaagctgaatgac ctgtgctttaccaacgtctacgcggtattcttctgtatcaggggcgacgaggtgcgcagatcgccccggc cagacaggcaagatcgagactacaattataagctgccagacgattcaccggtcgtgctgatcgctggaac agcaacaatctggaattccaaagtggcggaactacaattatctgtaccggtgtttagaagagcaatctga agcccttcgagaggacatctctacagaaatctaccaggccggcagcaccccttgcaatgctggtgagggc tttaactgtatttcccactccagctctacggcttcagcccacaaaggcgtgggtatcagccttaccgctg gtggtgctgagctttgagctgctgcagccccagcaacagtgctgcgccccagaagtcaccaatctgtg aagaacaagtgcgtgaactcaactcaacggcctgaccggcacaggcgtgctgacaggagccaacaagaa gttctgctcatttcagcagttcggcaggacatcgagataccacagacgcctgctgcgacccacagacc tggagatcctggacatcacacccgtctcttcggcggcgtgagcgtgatcacacccggcaccatacaagca accagggtggcgtgctgtatcaggacgtgaattgtaccgaggtgccgtgctatccacgccgatcagctga ccccaatggcgggtgtacagcaccggctccaacgtcttcagacaagccggtgctgctgagc agagcacgtgaacaattcctatgagtcgacatcccaatcggcgccgcatctgtgctcttaccagacca gacaaactctccagaagagcccgagcgtggcctccagctatcatcgcctatacatgtccctggcgc cgagaacagcgtggcctactctaacaatagcatcgccatccaaccaactcacaatctctgtgaccacaga gatcctgcccgtgtccatgaccaagacatctgtggactgcacaatgtatatctgtggcgtatttaccagtgca gcaacctgctgctccagtagcggcagctttgtaccagctgaatagagccctgacaggcatcgccgtggagc aggataagaacacacagaggtgttcgcccaggtgaagcaaatctacaagacccccctatcaaggacttt ggcggctcaattttccagatcgtcctgatccatccaagccttctaagcggagctttatcaggacctgctg ttcaacaagggtgacctggccgatgcccgttcacaaagcagtagtgcgattgctggcgacatcgagcc agggacctgactgcgcccagaagttaatggcctgaccgtgctgcccacctgctgacagatgagatgatc gcacagtacacaagcgccctgctggccggcaccatcacatccggatggacctgcgagcaggagccgccc tccagatcccctttgcatgcatggttataggttaacggcatcggcgtgaccagaatgtgctgtacga gaaccagaagctgacgccaatcagtttaactccgcatcggcaagatccaggacagcctgctctacagc cagcgccctgggcaagctccaggtggtgtaatcagaacgcccagccctgaataacctggtgaagcag ctgagcagcaactcggcgcatctctagcgtgctgaatgacatcctgagccggctggacaaggtggagc agaggtgcagatcgaccgctgatcaccggccgctccagagcctccagacctatgtacacagcagctg

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SEQ ID NO: 14 Protein sequence of S- (deg-RBD-122-165- 234) for Wuhan strain (from N-terminus to C- terminus)	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVYYPDKVFRSSV LHSTQDLFLPFSNVTFWFAIHVSGTNGTKRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSTQSLIVN[Q]ATNVVIKVCFFQFCNDPFLG VYYHKNNKSWMESEFRVYSSAN[Q]CTFEYVSQPFMDLEGKQGNFK NLREFVFKNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGI[Q]IT RFQTLALHRSYLTGPDSSSGWTAGAAAYVGYLQPRFTLLKYNN GTITDAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQ[Q]E[Q]IVRFP [Q]ITNLCPFGEVF[Q]ATRFASVYAWNKRISNCVADYSVLVNSASFSTF KCYGVSPTKLNLCFTNVYADSFVIRGDEVRIAPGQTGKIADYNYK LPDDFTGCVIAWNSNNLDSKVGGNYNLYRLFRKSNLKPFERDISTE IYQAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELL HAPATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQ FGRDIADTTDAVRDPQTLEILDITPCSFSGGVSVITPGTNTSNQVAVLY QDVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNN SYECDIPIGAGICASYQTQTSNPRRARSVASQSIIAYTMSLGAENSV YSNNSIAIPTNFTISVTTEILPVSMKTSTVDCMYICGDSTECNLLQ YGSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFNF SQILPDPSKPSKRSFIEDLLFNKVTADAGFIKQYGDCLGDIAARDLIC AQKFNGLTVLPLLTDEMIQYTSALLAGTITSGWTFGAGAALQIPF AMQMAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDSLSTASAL GKLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRLDPPEAEVQ IDRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKR VDFCGKGYHLSFQPSAPHGVVFLHVTYVPAQEKNTTAPAICHDG KAHFPREGVVFVSNGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIV NNTVYDPLQPELDSFKEELDKYFKNHTSPDVLGDISGINASVUNI KEIDRLNEVAKNLNESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIV MVTIMLCCMTSCCCLKGCCSCGSCCKFDEDDSEPVLKGVKLHYT
SEQ ID NO: 15 Nucleic acid sequence of WT S (Delta strain) (from 5'-end to 3'-end)	atgttcgtcttctggtcctgctgctcctcctcacagtcgctcaatctggaactcggactcagctgcca cctgcttatactaataagctccaccagaggcgtgtactatcctgacaagggtttagaagctccgtgctgactct acacaggatctgtttctgccattcttagcaacgtgacctggtccacgccatccacgtgagcggcaccatgg cacaagcgggtcgacaatcccgctgctgctttaaagatggcgtgtacttcgctctatcgagaagagcaac atcatcagaggctggatctttggcaccacactggactccaagacacagctctctgctgacgtgaacaatgcca ccaacgtggtcatcaagggtgtgagtgatcagtttgaatgatccctcctggacgtgtactatcacaagaaca ataagagctggatggagtcggagtgatctagcgccaacaactgcacatttgagtacgtgagcagccttt cctgacgtgacctggaggcgaagcagggcaatttcaagaacctgaggagggttcgtgttaagaatcgcacgg ctacttcaaaatctacttaagcacacccccatcaacctggcgcgacctgcctcagggccttcagcgccctg gagccctgggtggtatctgcctatcggtcatcaacatcacccgggttcagacactgctggccctgcacagaagc

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SEQ ID NO: 16 Protein sequence of WT S (Delta strain) (from N-terminus to C- terminus)	MFVFLVLLPLVSSQCVNLRTRTQLPPAYTNSFTRGVYYPDKVFRSSV LHSTQDLFLPFSNVTWFHAIHVSNGTKRFDNPVLPFNDGVYFASI EKSNIIRGWIFGTTLDSTQSLIVNNA TNVVIKVCEVFQCFNDPFLDV YYHKNNKSWMESGVYSSANNCTFEYVSQPFLMDLEGKQGNFKNLR EFVFKNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGINITRFQT LLALHRSYLPDGDSSGWTAGAAAYYVGYLQPRFTLLKYNNNGTIT DAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQPTEIVRFPNITNL

	CPFGEVFNA TRFASVY A WNRKRISNCVADYSVLVNSASFSTFKCYG VSP TKLNDLCFTNVYADSFVIRGDEV RQIAPGQTGKIADYNYKL PDD FTGCVIAWNSNNLDSKVG GNYNYRYRLFRKSNLKPFERDISTEIYQA GSKPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELLHAP ATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQQFGR DIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLYQGV NCTEVPVAIHADQLTPTWRVYSTG SNVFQTRAGCLIGA EHVNNSEY CDIPIGAGICASYQTQ TNSRRRARSVASQSIIAYTMSLGAENSVAYS NSIAIPTNFTISVTTEILPVSMKTSVDC TMYICGDSTEC SNLLQYGS FCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFNFSQIL PDPSPKPSKRSFIEDLLFNKVT LADAGFIKQYGDCLGDIAARDLICAQK FNGLTVLPLLLTDEMIAQYTSALLAGTITSGWTFGAGAALQIPFAMQ MAYRFNGIGV TQNVLYENQKLIANQFN SAIGKIQDLSSTASALGKL QNVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRLDKVEAEVQIDR LITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKRVDF CGKGYHLMSPQSA PHGVVFLHVTYVPAQEKNFTTAPAICHGDGKAH FPREGVFVSNGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIVNNT VYDPLQPELDSFKEELDKYFKNHTSPD VDLGDISGINASVNIQKEID RLNEVAKNLNESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVMTI MLCCMTSCCCLKGCCSCGSCCKFDEDDSEPV LKGVKLHYT
SEQ ID NO: 17 Nucleic acid sequence of WT S (Wuhan strain S-2P strain) (from 5'-end to 3'-end)	atgttcgtcttctggtcgtcgtcctctggtctctcacagtcgctcaatctgacaactcggactcagtcgcca cctgcttatactaatagcttaccagaggcgtgtactatcctgacaaggctttagaagctccgtgctgcactct acacaggatctgtttctgccattcttagcaacgtgacctggtccacgccatccacgtgagcggcaccaatgg cacaagcgggttcgacaatcccgctgctgccttttaacgatggcgtgtactctgcctctaccgagaagagcaac atcatcagaggctggatctttggcaccacactggactccaagacacagctctctgctgacgtgaaacaatgcc ccaacgtggtcatcaaggtgtgcgagttccagtttgtaatgatcccttctggcgctgtactatcacaagaaca ataagagctggatggagtcgagtttagagtgattcttagcggccaacaactgcacattgagtagctgagcca gctttctctgatggacctggaggcgcaagcaggggcaatttcaagaacctgaggggatctggttttaagaatac gacggctacttcaaaatctactctaagcacacccccatcaacctggtgctgcgacctgcctcagggtctcagc gccccggagccccgtgtggtatctgacctcggcatcaatcaccgggttcagacactgctggccccctcac agaagctacctgacacccggcgactcctctagcggatggaccgccccgctgcgcgcctactatgtgggcta cctcagccccggaccttctgctgaagtacaacgagaatggcaccatcacagacgcagtggaattgcgcc tggacccccgtagcgagacaaaagtgtacactgaagtcctttaccgtggagaaggcgcatctatcagacatcca atttcagggtgcagccaaccgagctctatcgtgcgttcttaatatcacaacctgtgcccatttggcgagggtgt tcaacgcaaccgccttcgccaagcgtgtacgcctggaataggaaaggatcagcaactgcgtggccgactat agcgtgctgtacaactccgctctttcagcacctttaagtgctatggcgtgtcccccacaagctgaatgacct gtgctttaccaacgtctacgcccattcttctgtgatcagggggcgacgagggtgcgcagatcgcccccggcca gacaggccaagatcgagactacaattataagctgccagacgatttaccggctgcgtgatcgcctggaaacag caacaatctggaattccaagtggcgcgcaactacaattatctgtaccggctgttttagaaagagcaatctgaag cccttcgagaggacatctctacagaaatctaccaggccggcagcaccctgtcaatggcgtggagggtctt aactgttatttccactcagtcctacggcttcagcccacaaaacggcgtgggtatcagccttaccgcgtggt ggtgctgagctttgagctgctgcacgccccagcaacagtgtgcggccccaaagagtcaccaatctggtga agaacaagtgcgtgaacttcaactcaacggcctgaccggcacaggcgtgctgacagagtcacaacaagaa gttcctgccaattcagcagttcggcagggaacatcgcagataccacagacgcgtgcgcgacccacagaccc tggagatcctggacatcacacctgctctttcggcgcgctgagcgtgatcacaccggcaccataacagca accagggtggccgtgctgtatcaggacgtgaattgtaccgaggtgcccgtgctatcacgcgcctcagctga ccccaatggcggggtgtacagcaccgggtcccaactgtcttcagacaagagcggatgcctgacgtgagc agagcacgtgaacaattctatgagtcgacatcccaatcgcgcgcatctgtctcttaccagaccaca gacaactctcccaagagccggagcgtggcctccagctctatcgtctataccattgtccctggggcg cgagaacagcgtggccttacttcaacaatagcatcccatcccaaccgaacttcaatctctctgaccacaga

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SEQ ID NO: 18 Protein sequence of WT S (Wuhan strain S-2P strain) (from N-terminus to C-terminus)	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVVYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSGTNGTKRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSKTQSLIVNNATNVVIKVCFCNDPFLG VYYHKNNKSWMESEFRVYSSANNCTFEYVSQPFLMDLEGKQGNFK NLREFVFKNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGINTR FQTLALHRSYLT PGDSSSGWTAGAAAYYVGYLQPRTFLLKYNENG TITDAVDCALDPLSETKCTLKSFTVEKGIYQTSNFRVQPTESIVRFPNI TNLCPFGEVFNATRFASVYAWNKRISNCVADYSVLVNSASFSTFKC YGVSPTKLNDLCFTNVYADSFVIRGDEVQRQIAPGQTGKIADYNYKLP DDFTGCVIAWNSNNLDSKVGGNVNYLYRLFRKSNLKPFERDISTEY QAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVVSFELLH APATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQQF GRDIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLYQ DVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNS YECDIPIGAGICASYQTQTNSPRRARSVASQSIIAYTMSLGAENSVAY SNNISAIPTNFTISVTTEILPVSMTKTSVDCTMYICGDSTECNLLLQY GSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFNFS QILPDPSKPSKRSFIEDLLFNKVTLADAGFIKQYGDCLGDIAARDLICA QKFNGLTVLPLLTDEMIQYTSALLAGTITSGWTFGAGAALQIPFA MQMAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDSLSTASALG KLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRLDPPPEAEVQI DRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKRV DFCGKGYHLSFPQSAPHGVVFLHVTYVPAQEKNFTTAPAICHGDK AHFPREGVFVSNNGTHWFTVQRNFYEPQIITDNTFVSGNCDVVIGIVN NTVYDPLQPELDSFKEELDKYFKNHTSPDVLGDISGINASVUNIKE

	IDRLNEVAKNLNESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVM VTIMLCCMTSCCSCLKGCCSCGSCCKFDEDDSEPVLKGVKLHYT
SEQ ID NO: 19 Nucleic acid sequence of WT S (Delta S-2P strain) (from 5'-end to 3'-end)	atgttcgtcttctggtcctgctgctctggtctcctcacagtcgctcaatctgcgaactcggactcagctgcca cctgcttatactaataagcttcaccagaggcgtgtactatcctgacaagggttttagaagctccgtgctgcaactct acacaggatctgttttgcattcttttagcaacgtgacctggtccacgccatccacgtgagcggcaccatgg cacaagcgggttcgacaatcccgtgctgcttttaacgatggcgtgtacttcgctctatcgagaagagcaac atcatcagaggctggtatcttggcaccacactggactccaagacacagtctctgctgacgtgaacaatgcc ccaacgtggtcatcaagggtgctgaggtccagttttgtaagtatcccttcctggacgtgtactatcacaagaaca ataagagctggtgaggtccggaggtgtattctagcggccaacaactgcacatttagtactgagcagccttt cctgatggacctggagggaagcagggaattcaagaacctgagggaagtgcgttttaagaatatcgacgg ctacttcaaaatctacttaagcacacccccatcaacctggtgcgcgacctgctcagggcttcagcgcctg gagccctggtggtatctgctatcgcatcaacatcacccgggttcagacactgctgcccctgcacagaagc tacctgacacccggcgcactccttagcggatggaccgcccgcgtgcgcctctatgtggctacctcca gccccggacctcctgctgaagtacaacgagaatggcaccatcacagacgagtgattgcgccctggacc ccctgagcggagacaaagtgtacactgaagtcctttaccgtggagaaggccatctatcagacatccaatttcag ggtgcagccaaccgagctatctgctgctttcctaataatcacaacctgtgccatttggcagaggtgtcaacg caaccgcttcgcgcagctgtacgctgggaatagggaagcggatcagcaactgcgtgcccgaactatagcgtg ctgtacaactccgctcttcagcacctttaagtctatggcgtgtccccacaaagctgaatgacctgtgttta ccaacgtctacgcccgttcttcgtgatcaggggcgacgaggtgcgcagatcgcgcccgccagacagg caagatcgcagactacaattataagctgccagacgatttcaccggctgcgtgctgcctggaacagcaaca tctggattccaagtgggcggaactacaattatcggtaccggctgtttagaagagcaatctgaagcccttc gagaggggacatctctacagaatctaccaggccggcagcaagccttgcattggcgtggagggtcttaactgt tatttccactccagctctacggcttcagcccacaacggcgtgggtatcagccttaccgctggtgtgtgtct gagctttgagctgctgcagcggccagcaacagtgctgcggccccagaagtcaccaatctggtgaagaaca agtgcgtgaacttcaactcaacggcctgaccggcacaggcgtgctgaccgagctccaacaagaagttcctgc catttcagcagttcggcaggagacatcgagataccacagacgcccgtgcgcgacccacagacctggagat cctggacatcacacctgctcttccggcggcgtgagcgtgatcacaccggcaccaatacaagcaaccagg tgccgtgctgtatcaggcgtgaattgtaccgaggtgccgtggtatccacgccgatcagctgaccccaa catggcgggtgtacagaccggctccaacgtctccagacaagagccggtgctgacgagcagagca cgtgaacaattctatgagtgacatccaatcgccggcatctgtgctcttaccagaccagacaaa ctctgcgagaagagcccggagcgtggcctccagctctatcagcctatacatgtccctggcggcggagaa cagcgtggtcctacttaacaatagcatcgccatcccaaccaacttcacaatctctgtgaccacagagatcctg cccgtgtccatgaccaagacatctgtgactgcacaatgtatctgtggcgattctaccgagtgagcaacct gctgctccagtagcgcagctttgtaccagctgaatagagccctgacaggcatcgccgtggagcaggataa gaacacacaggagggtgttcgcccagggtgaagcaaatctacaagacccccctatcaaggactttggcgtt caatttttccagatcctgctgctgacatccaagccttctaagcggagctttatcgaggacctgtgttcaaca ggtgacctggcggatgcccgttcacaaagcagtatggcgattgcctgggcgacatcgacggcaggacc tgatctgcgcccagaagttaattggcgtgaccgtgctgcccacctgctgacagatgagatgcacagta cacaagcggcctgctggccggcaccatcacatccggatggaccttcggcgcagagcggccctccagatc cccttggccatgcagatgcttataggttcaacggcatcggtgacccagaatgtgctgtacgagaaccag aagctgatcgccaatcagtttaactcggccatcggaagatccaggacagcctgctctacagccagcgc ctgggcaagctccagaatgtgtgaatcagaaccccaggccctgaataccctggtgaagcagctgagca gcaacttcggcgcctatctagcgtgctgaatgacatcctgagccggctggacccgggaggcagaggt gcagatcgaccggctgacccggcggctccagagcctccagacctatgtgacacagcagctgacagg gcccggagatcaggggcagccaatctggcagcaaccaagatgtccgagtgctgctggccagtcta agagagtggaacttttggcgaaggctatcacctgatgtcttccctcagctgtccccacacggcgtggtgtt ctgcacgtgacctacgtgcccggcaggagaagaacttcaccacagcccctgcatctgacacagtgcaa ggcccactttccaaggagggtgctgtgttccaacggcaccactgtgttggacacagcgaatttctac gagcccagatcatcaccacagacaacacctgtgagcggcaactgtgacgtgtgcatcgccatcgtgaa caataccgtgtatgatccactcagcccagctggacagctttaaggaggagctggataagtattcaagaat

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SEQ ID NO: 20 Protein sequence of WT S (Delta strain S- 2P strain) (from N- terminus to C-terminus)	MFVFLVLLPLVSSQCVNLRTRTLQPPAYTNSFTRGVVYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVS GTNGTKRFDNPVLPFNDGVYFASI EKSNIIRGWIFGTTLD SKTQSLIVNNA TNVVIK VCE FQFCNDPFLDV YYHKNNKSWMESGVYSSANNCTFEYVSQPF LMDLEGKQGNFKNLR EFVFKNIDGYFKIY SKHTPINLVRDL PQGFSALEPLVDLPIGINITRFQT LLALHRSYLT P DSSSGW TAGAAAYVGVYLQPRTFLLKY NENG TIT DAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQPTESIVRFPNITNL CPFGEVFNATRFASVYAWNKRISNCVADYSVLVNSASFSTFKCYG VSPTKLNLDLCFTNVYADSFVIRGDEV RQIAPGQTGKIADYNYKL PDD FTGCVIAWNSNNLDSKVG GNYNRYRLFRKSNLKPFERDISTE IYQA GSKPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELLHAP ATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQQFGR DIADTTDAVRDPQTLEILDITPCSFGGVS VITPGTNTSNQVAVLYQGV NCTEVPVAIHADQLTPTWRVYSTG SNVFQTRAGCLIGA EHVNNSYE CDIPIGAGICASYQTQTNSRRRARSVASQSIIAYTMSLGAENSVAYSN NSIAIPTNFTISVTTEILPVSMTKTSVDCTMYICGDSTEC SNLLQYGS FCTQLNRALTGIAVEQDKNTQE VFAQVKQIYKTPPIKDFGGFNFSQIL PDPSPKPSKRSFIEDLLFNKVT LADAGFIKQYGDCLGDIAARDLICAQK FNGLTVLPPLLTD EMI AQYTSALLAGTITSGWTFGAGAALQIPFAMQ MAYRFNGIGVTQNVLYENQKLIANQFN SAIGKIQDSL SSTA SALGKL QNVVNQNAQALNTLVKQLSSNF GAISSVLNDILSRLD PPEAEVQIDR LITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKRVDF CGKGYHLMSPQSA PHGVVFLHVTYVPAQEKNFTTAPAICH DGAH FPREGV FVSNGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIVNNT VYDPLQPELDSFKEELDKY FKNHTSPD VDLGDISGINASV VNIQKEID RLNEVAKNLNESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVMVTI MLCCMTSCCCLKGCCSCGSCCKFDEDDSEPVLKGVKLHYT
SEQ ID NO: 21 Nucleic acid sequence of S-(deg-RBD) for Delta strain (from 5'- end to 3'-end)	atgttgcgtcttctggtcgtgctgctctggtctcctcacagtgcgtcaatctgcgaactcggactcagctgcc cctgcttatactaatagtctcaccagaggcgtgtactatcctgacaagggtgttagaagctccgtgctgcactct acacaggatctgtttctgccattcttagcaacgtgacctggttccacgccatccacgtgagcggccaccaatgg cacaagcgggttcgacaatcccgctgctgcctttaacgatggcgtgtacttcgctctatcgagaagagcaac atcatcagaggctggatctttggcaccacactggaactccaagacacagctctctgctgatcgtgaacaatgcc ccaacgtggtcatcaaggtgtgcgagttccagtttgtatgatcccttcctggacgtgtactatcacaagaaca ataagagctggatggagtcggagtgatgtattctagcgccaacaactgcacatttgagtacgtgagccagcttt cctgatggacctggaggcgcaagcaggcgcaatttcaagaacctgaggggagttcgtgttttaagaatatcgacgg ctacttcaaaaatctactctaa gcaacccccatcaacctggtgcgcgacctgcctcagggtctcagcgcctg gagccccctggtgctatcggtatcgatcaacatccccgggttcagacactgtggccccgcacagaagc tacctgacacccggcgactccttagcggatggaccgcggcgctgcgcgctactatgtgggtctacctcca gccccggaccttctgctgaagtacaaacgagaatggcaccatcacagacgacgtggtgattggccctggacc ccctgagcgagacaaagtgttacactgaagctccttaccgtggagaaaggcctatcatcagacatccaatttcag ggtgcagccagccgaggcgatcgtgcgcttctgaaatcacaacctgtgccatttggcgagggtgttcga ggcaacccgcttgcagcagctgtacgccttggaatagggaagcggatcagcaactgcgtggccgactatagc gtgctgtacaactcgcgccttcttagcacctttaagtgtatggcgtgtcctcccccacaagctgaatgacctgtgc tttaccaacgtctacgcccgaattcttctggtacagggcgacgaggtgcgcagatcgccccggccagaca

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SEQ ID NO: 22 Protein sequence of S- (deg-RBD) for Delta strain (from N-terminus to C-terminus)	MFVFLVLLPLVSSQCVNLRTRTQLPPAYTNSFTRGVYYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVS GTNGTKRFDNPVLPFNDGVYFASI EKSNIIRGWIFGTTLD SKTQSLIVNNA TNVVIKVCE FQFCNDPFLDV YYHKNNKSWMESGVYSSANNCTFEYVSQPFLMDLEGKQGNFKNLR EFVFKNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGINITRFQT LLALHRSYLT PGDSSSGW TAGAAAYVGYLQPRTFLLKY NENG TIT DAVDCALDPLSETKCTLKSFTVEKGIYQTSNFRVQPAEAIVRFPQITN LCPFGEVFQATRFASVYAWNKRISNCVADYSVLNYSASFSTFKCYG VSPTKLNDLCFTNVYADSFVIRGDEV RQIAPGQTGKIADYNYKLPDD FTGCVIAWNSNNLDSKVGGNYNYRYRLFRKSNLKPFERDISTEYIQA GSKPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVVL SFELLHAP ATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQQFGR DIADTTDAVRDPQTL EILDITPCSFGGVSVITPGTNTSNQVAVLYQGV NCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGA EHVNN SYE

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SEQ ID NO: 23 Nucleic acid sequence of S-(deg-RBD) for Wuhan S-2P strain (from 5'-end to 3'-end)	atgttcgtcttctgctcgtcgtcctcgtcgtcctcagtcgctcaatctgacaactcggactcagctgccacctgtatatactaatagcttcaccagaggcgtgtactatcctgacaaggctttagaagctccgctgcactctacacaggatctgtttctgccattcttagcaacgtgacctggttcacgccatccacgtgagcggcaccatggcacaaagcgggtcgacaatcccgctgctgctttaaagatggcgtgtacttcgctctaccgagaagagcaacatcatcagaggctggatctttggcaccactggactccaagacacagtcctgctgctgctgctgaacaatgccccaacgtgctcatcaaggctgctgagttccagtttgaatgacccctcctggcgtgtactatcacaagaacaataagagctggatggagtcggagtttagagtgattctagcggcaacaactgcacattgagtagcagccagccttctgtagcctggaggcgcaagcaggcgcaatttcaagaacctgaggagttcgtgtttaaataatcgacggctacttcaaaatctacttcaagcacaccccccatcaacctggtgctgacgtgcctcagggtctcagcggccttgagccctggtggatctgcctatcggcatcaacatcacccgggttcagacactgctggtccctgcacagaagctacgtgacacccggcgactcctctagcggatggacggcggcgctgcccgtactatgtgggctacctccagccccggacctcctgctgaagtacaacgagaatggcaccatcacagcagtggtgattggcctgtggacccccctgagcgagacaaagtgtacactgaagtcctttaccgtggagaaggcgatctatcagacatccaattcagggtgagccagccgagcgatcgcttctcctgaatcacaaactgtgcccatttggcgagggtgttcgaggcaacccgcttcgccagcgtgtacgcctggaataggaagcggatcagcaactgcgtggccgactatagcgtgctgtacaactccgctcttctcagcacctttaaagtctatggcgtgtccccacaaagctgaatgacctgtgctttaccaactctacgccgattcttctgtgatcaggggcgacgaggtgcgcagatcgccccggccagacaggcaagatcgagactacaattataagctgccagacgatttaccggctgctgtatcgctggaaagcaacaatctggattccaagtggcggaactacaattatctgtaccgctgtttagaagagcaatctgaagcccttcgagaggacatctctacagaaatctaccaggccggcagcaccccttgaatggcgtggagggtttaaactgttattcccactcagtcctacggcttcagcccacaaacggcgtgggtatcagccttaccgctgtgtgtgctgagctttgagctgctgcacgccccagcaacagtgctgcggccccagaagtcaccaatctgtgaagaacaagtgcgtgaacttcaactcaacggcctgaccggcacaggcgtgctgacaggccaacaagaaattcctgcccatttcagcagttcggcaggacatcgagataccacagacggcgtgcgcgacccacagacccgtgagatcctggacatcacaccctgctcttccggcggtgagcgtgatcacaccggcaccataacaagcaaccagggtggcgtgctgtatcaggacgtgaattgtaccgaggtgcccgtggctatccacgccgatcagctgaccccaacatggcgggtgtacagaccggctccaacgtcttcagacaagacccggatgctgtatcggagcagagcacgtgaacaattcctatgagtcgacatcccaatcgccggcgcgtatgtgctcttaccagacccaacaaactctcccagaagagcccgagcgtggcctccagtcctatcatgcctataccatgtccctggcgccgagaacagcgtggcctacttcaaatagcatcgccatccaaccaactcacaatctctgtgaccacagagatcctgcccgtgtccatgaccaagacatctgtggactgcacaatgtatatctgtggcgtattctaccgagtgcaaacctgctgctccagtagcgagctttgtaccagctgaatagagccctgacaggcatcgccgtggagcaggataagaacacagagaggtgtcccgaggtaagcaaatctacaagacccccctatcaaggactttggcggttcaattttccagatcctgctgatccatcaagccttcaagcggagctttatcgaggacgtgctgttcaacaagtgacctggccgatggcgttcatcaagcagtagtgcgattgcctggcgacatcgagccagggacgtgatctgcgcccagaagttaattggcctgaccgtgctgcccctgctgacagatgagatgacgcacagtacacaagcgccctgctggccggcaccatcacatccggatggaccttcggcgagagccgccc

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SEQ ID NO: 24 Protein sequence of S- (deg-RBD) for Wuhan S-2P strain (from N- terminus to C-terminus)	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVYYPDKVFRSSV LHSTQDLFLPFSNVTFWFAIHVSGTNGTKRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSKTQSLIVNNA TNVVIK VCEFQFCNDPFLG VYYHKNNKSWMESEFRVYSSANNCTFEYVSQPFLMDLEGKQGNFK NLREFVFKNIDGYFKIY SKHTPINLVRDLPQGFSALEPLVDLPIGINTR FQTLALHRSYLT PGDSSSGWTAGAAAYYVGYLQPRFTLLKYNENG TITDAVDCALDPLSETKCTLKSFTVEKGIYQTSNFRVQPAEAIVRFPQI TNLCPFGEVFQATRFASVYAWNRKRISNCVADYSVLYNSASFSTFKC YGVSPTKLNDLCFTNVYADSFVIRGDEVQRQIAPGQTGKIADYNYKLP DDFTGCVIAWNSNNLDSKVGGNYNYLYRLFRKSNLKPFRDISTEY QAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELLH APATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQFQ GRDIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLYQ DVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNS YECDIPIGAGICASYQTQTNSPRRARSVASQSIIAYTMSLGAENSVAY SNNSIAIPTNFTISVTTEILPVSMTKTSVDCTMYICGDSTECNLLLQY GSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFNFS QILPDPSKPSKRSFIEDLLFNKVTLADAGFIKQYGDCLGDIAARDLICA QKFNGLT VLPPLLTDEMI AQYTSALLAGTITSGWTFGAGAALQIPFA MQMAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDSLSTASALG KLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRDPPAEVQI DRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKRV DFCGKGYHLSFPQSAPHGVVFLHVTVYVPAQEKNFTTAPAICHGDK AHFPREGVFVSNGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIVN NTVYDPLQPELDSFKEELDKYFKNHTSPDVLGDISGINASVUNIQKE IDRLNEVAKNLNESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVM VTIMLCCMTSCCCLKGCCSCGSCCKFDEDDSEPV LKGVKLHYT
SEQ ID NO: 25 Nucleic acid sequence of S-(deg-RBD) for	atgttcgtcttctggtcctgctgcctctggtctcctcacagtgcgtcaatctgcgaactcggactcagctgcca cctgcttataactaatagcttcaccagagggtgtactatcctgacaagggttttagaagctccgtgctgcaactct acacaggatctgtttctccattcttagcaacgtgacgtggtccacgcatccacgtgagcggcaccatgg cacaagcggttcgacaatcccgctgctgccttttaacgatggcgtgtactcgcctctatcgagaagagcaac atcatcagaggctggtatcttggcaccacactggactccaagacacagtctctgctgatcgtaacaatgcca ccaacgtggtcatcaagggtgctgcagttccagttttgtaatgatccctcctgagcgtgtactatcacaagaaca

Delta S-2P strain (from 5'-end to 3'-end)	ataagagctggatggagtcggagtgattctagcgccaacaactgcacatttgagtacgtgagccagccctt cctgatggacctggaggcaagcagggaatttcaagaacctgaggagtgctgtttaagaatctgacgg ctacttcaaaatctacttaagcacacccccatcaacctgggtgcgcgacctgacctagggttcagcgccctg gagccctggatctgcctatcgcatcaacatcacccgggttcagacactgctgcccctgcacagaagc tacctgacacccggcactcctctagcggatggaccggcgctgcccctactatgtgggtacctcca gccccggacctctctgctgaagtacaacgagaatggcacatcacagacgcagtggattgcccctggacc ccctgagcgagacaaagtgtactgaagtcctttaccgtggagaagggcattatcagacatccaatttcag ggtgcagccagccgaggcgatcgctgttctctgaaatcacaaacctgtgccatttggcgaggtgttcga ggcaaccgccttcgacgctgtacgcctggaatagggaagcgatcagcaactgctgtgcccactatagc gtgtgtacaactccgctcttctagcacctttaagtctatggcgtgtccccacaaagctgaatgacctgtgc ttaccaactgtctacgcgattcttctgtatcaggggcgacgaggtgcgcccagatgccccggccagaca ggcaagatcgacactacaattataagctgcccagacatttaccggctgctgtatgcctggaacagcaac aatctggattccaaagtggcggaactacaattatcgtaccggctgtttagaagagcaatctgaagccctt cgagaggacatctctacagaatctaccaggccggcagcaagcctgtcaatgctgtggagggtttaact gtatttccactccagtcctacggcttcagcccacaaacggcgtgggtatcagccttaccgctgtgtgt gctgagctttagctgtgctgacgcccagcaacagtgctgcggcccaagaagtcaccaatctgtgaaga acaagtgcgtgaactcaactcaacggcctgaccggcacaggcgtgctgaccgagtcacaagaagttc ctgcccatttcagcagttcggcaggacatcgagataccacagacgctgtgcgcgaccacagacctgg agatcctggacatcacacctgtcttctggcggtgagcgtgatcacaccggcaccaatacaagcaacc aggtggccgtgctgtatcaggcgctgaattgtaccgaggtgcccgtgctatccacgcccagatcagctgacc caacatggcgggtgtacagcaccggctccaacgtcttccagacaagagccggtatgcctgatcgagcaga gcacgtgaacaattctatgagtgacatcccaatcgcgccggcatctgtcctcttaccagaccagac aaactctcgagaagagccggagcgtggcctccagctatcatcgccataccatgtccctggcgccga gaacagcgtggcctactctacaatagcatcgccatcccaaccaacttcacaatctctgtgaccacagagatc ctgcccgtgtccatgaccaagacatctgtggactgcacaatgtatatctgtggcgattctacagtgctgcaa cctgctgctccagtagcggcagctttgtaccagctgaatagagccctgacagcgatcgccgtgagcagga taagaacacacaggggtgtcgcccagggtgaagcaaatctacaagacccccctatcaaggactttggcg gcttcaattttccagatcctgctgatccatccaagccttcaagcggagcttatacaggacgtgctgttcaa caaggtgacctgtggccgatgcggcttcatcaagcagtatggcgattgcctggcgacatcgagccaggg acctgatctgcgcccagaagttaatggcctgaccgtgctgcccacctgctgacagatgagatgatcgac agtacacaagcgccctgctggccgacatcacatccggtgaccttcggcgagcagccgcccctcca gatcccccttgcagtgatggcctatagggttaacggcatcgcgctgaccagaatgtgctgtacgagaac cagaagctgatgccaatcagtttaactccgcatcggaagatccaggacagcctgtcctctacagccagc gccctgggcaagctccagaatgtggtgaatcagaacgccagccctgaataccctgtggaagcagctga gcagcaacttcggcgccatctctagcgtgctgaatgacatcctgagccgctgaccccgaggcaga ggtgcagatcgaccgctgatcacccggcggctccagagcctccagacctatgtgacacagcagctgatca gggccgcccagatcaggccagcgaatctggcagcaaccaagatgtccgagtgctgctggccagt ctaagagagtggaacttttggcaagggtatcacctgatgtccttccctcagctgtccccacacggcgtgtg tttctgacgtgacctacgtgcccggcccaggagaagaacttcaccacagccctgcatctgcccagatggc aaggcccactttccaaggaggggcgtgttctgttccaacggcacccactgtttgtgacacagcgcaatttct acgagccccagatcacaccagacaacaccttctgtgagcggcaactgtgacgtgtgcatcgcatcgtg aacaataccgtgtatgatccatccagcccagctggacagctttaaggagagctggataagtatttcaaga atcacacctcccctgacgtggatctggcgacatcagcggcatcaatgcctccgtgtgtgaacatccagaagg agatcgaccgctgaacgaggtggctaagaatctgaacgagagcctgatcgacctccaggagctgggcaa gtatgagcagatcatcaagtggccctgtacatctggctggcttcatcgccgctgatcgccatcgtgatg gtgacctatgctgtgctgtatgacatcctgtgttcttgcctgaagggtgctgtgtagctgtgctcctgctgta agttgacgaggtgactctgaacctgtgctgaagggtgtaagctgcattacaccta
SEQ ID NO: 26	MFVFLVLLPLVSSQCVNLRTRTQLPPAYTNSFTRGVYYPDKVFRSSV LHSTQDLFLPFSNVTWFHAIHVS GTNGTKRFDNPVLPFNDGVYFASI EKSNIIRGWIFGTTLD SKTQSLIVNNA TNVVIKVCEFQFCNDPFLDV

Protein sequence of S-(deg-RBD) for Delta S-2P strain (from N-terminus to C-terminus)	YYHKNNKSWMESGVYSSANNCTFEYVSQPFLMDLEGKQGNFKNLR EFVFKNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGINITRFQT LLALHRSYLT PGDSSSGW TAGAAAYVGYLQPRFTLLKYNNNGTIT DAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQPAEAIVRFPQITN LCPFGEVFAQTRFASVYAWNKRISNCVADYSVLVNSASFSTFKCYG VSPTKLNLDLCFTNVYADSFVIRGDEV RQIAPGQTGKIADYNYKLPDD FTGCVIAWNSNNLDSKVGGNYNRYRLFRKSNLKPFERDISTEYIQA GSKPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELLHAP ATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQQFGR DIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLYQGV NCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGA EHVNNSYE CDIPIGAGICASYQTQTSRARRSVASQSIAYTMSLGAENSVAYSN NSIAIPTNFTISVTTEILPVSMTKTSV DCTMYICGDSTEC SNLLQYGS FCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFNFSQIL PDPSPKPSKRSFIEDLLFNKVT LADAGFIKQYGDCLGDIAARDLICAQK FNGLT VLP LLTDEMIAQYTSALLAGTITSGWTFGAGAALQIPFAMQ MAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDSLSTASALGKL QNVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRDL PPEAEVQIDR LITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKRVDF CGKGYHLMSPQSAPHGVVFLHVTYVPAQEKNFTTAPAICHDGKAH FPREGV FVSNGTHW FVTQRNFYEPQIITDNTFVSGNCDVVIGIVNNT VYDPLQPELDSFKEELDKYFKNHTSPD VDLGDISGINASV VNIQKEID RLNEVAKNL NESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVMVTI MLCCMTSCC SCLKGCCSCGSCCKFDEDDSEPVLKGVKLHYT
SEQ ID NO: 27 Nucleic acid sequence of S-(deg-S2) for Delta strain (from 5'-end to 3'-end)	atgttcgtcttctgctgctgctgctgctgctcctcacagtgcgtcaatctgcgaactcggactcagctgccac cctgcttatactaataagcttcaccagaggcgtgtactatcctgacaagggtgtagaagctccgctgctgactct acacaggatctgttctgcccattcttagcaacgtgacctgggtccagccatccacgtgagcggcaccatgg cacaagcgggttcgacaatcccgctgctgctctttaaagcgtgctgactctgcccctatcgagaagagcaac atcatcagaggctggtatctttggcaccacactggactccaagacacagtctgctgacgtgaaacaatgcca ccaacgtggtcatcaagggtgctgagtgccagttttgtaagtatcccttctgagcgtgtactatcacaagaaca ataagagctggtgagtgccgagtgatcttagcgccaacaactgcacattgagtgactgagccagccttt cctgagtgacgtgagggcaagcagggcaattcaagaacctgagggagtgctgtttaaagaatcgcaggg ctacttcaaaatctacttaagcacacccccatcaacctgggtgcgcgacctgcctcagggtctcagcgccctg gagccctggtggtatctgctatcgcatcaacatcacccggtttcagacactgctgcccctgcacagaagc tacctgacacccggcgactcctctagcggatggaccgcccgcgtgcccctactatgtggctacctcca gccccggacttctgctgaagtacaacgagaatggcaccatcacagacgcagtggaattgcgccctggacc ccctgagcgagacaaagtgtactgaagtcccttaccgtggagaagggtcatcagacatccaatttcag ggtgagccaaccgagtgatctgctgcttctcaatatcacaacctgtgcccatttgcgaggtgttcaacg caacccgcttcgcccagctgtacgcctggaataggagcggatcagcaactgcgtggccgactatagcgtg ctgtacaactccgctcttccagcacctttaaagtctatgctgctgtccccacaaagctgaatgacctgtcttta ccaacgtctacgcgattcttctgctatcagggcgacgaggtgcgcagatcgccccggccagacagg caagatcgagactacaattataagctgccagacgatttcaccggctgctgctgacgcttggaacagcaaca tctgattccaaagtggcggaactacaattatcggtaccggctgttagaaagagcaatctgaagcccttc gagaggacatctctacagaaatctaccaggccggcagcaagccttgcaatggcgtgagggctttaaactgt tatttccactccagtcctacggcttccagcccacaaacggcgtgggtatcagccttaccgctggtggtgct gagctttgagctgctgcacgcccagcaacagtgctggccccagaagtcaccaatctggtgaagaaca agtgctgaactcaactcaacggcctgaccggcacaggcgtgctgaccgagtcacaagaagttcctgctc catttcagcagttcggcaggacatcgagataccacagacgcgtgcccgcagccacagacctggagat cctggacatcacacctgctcttccggcggtgagcgtgacacacccggcaccataacagcaaccagg tgccctgctgtatcaggcgctgaattgtaccgaggtgccctggtgctatccacgccgacagctgaccccaa

	catggcgggtgtacagcaccggctccaacgtcttcagacaagagccggatgcctgatcggagcagagca cgtgaacaattcctatgagtcgacatccaatcgcgccggcatctgtccctctaccagaccagacaaa ctctcgagaagagcccggagcgtggcctccagcttatcatcgctatacatgtccctggcgccgagaa cagcgtggcctactctcagaatagcatgccatccaacccagttcacaatctctgtgaccacagagatcctg cccgtgtccatgaccaagacatctgtgactgcacaatgtatatctgtggcgattctaccgagtcagcaacct gctgctccagtacggcagctttgtaccagctgaatagagccctgacaggcatcgccgtggagcaggataa gaacacacagagggtgttcgcccagggtgaagcaaatctacaagacccccctatcaaggactttggcgctt ccaatttcccagatcgtcctgatccatcaagccttctaagcggagctttatcaggacctgctgttcaaca ggtgacctggccgatgcccgttcacaaagcagtatggcgattgctggcgacatcgacggcaggacc tgatctcgcccagaagttaattggcctgaccgtgctgcccacctgctgacagatgagatgacgcacagta cacaagcgccctgctggccggcaccatcacatccggatggacctggcgaggagccgcccctccagatc cccttggccatgcagatggcctataggttcaacggcatcgccgtgacccagaatgtgctgtacgagaaccag aagctgatcgccaatcagtttaactcggccatcggaagatccaggacagcctgctcctacagccagcgcc ctgggcaagctccagaatgtgtgaatcagaacgccaggccctgaataccctggtgaagcagctgagca gcaacttcggcgccatctctagcgtgctgaatgacatcctgagccgctggacaaggtggaggcagaggtg cagatcgaccgctgatcaccggccggctccagagcctccagacctatgtgacacagcagctgatcaggg ccgcccagatcaggggccagcgccaatctggcagcaaccaagatgtccagtgctgctgggccagttaa gagagtggaacttttggcagggttatcacctgatgtccttcctcagtcgtccccacacggcggtgtgtttct gcacgtgacctacgtgcccggcccaggagaagcagttcacacagccccctgcatctgcccagatggcaag gcccacttccaaggagggtgctgttcgtgtccaggggcaccactgtgtgtgacacagcgcaatttctacg agccccagatcatcaccacagacaacaccttcgtgagcggaactgtgacgtggtcatcgccatcgtgcag aataccgtgtatgatccactccagcccagctggacagctttaaggaggagctggataagtatttcaagcaac acacctcccctgacgtggatctggcgacatcagcgccatccaagcctccgtggtgaacatccagaaggag atcgaccgcctgaacgaggtggctaagaatctgcaggagagcctgatcgacctccaggagctgggcaagt atgagcagtatcatcaagtggccctgtacatctggctgggcttcacgcccggcctgatcgccatcgtgatgt gacctcatgctgtgctgtatgacatcctgctgttcttgctgaagggtgctgctgagctgtggtcctcgtgtaa gtttgacgaggatgactctgaacctgtgctgaagggtggaagctgcaftaacctaa
SEQ ID NO: 28 Protein sequence of S- (deg-S2) for Delta strain (from N-terminus to C-terminus)	MFVFLVLLPLVSSQCVNLRTRTQLPPAYTNSFTRGVYYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSNGTKRFDNPVLPFNDGVYFASI EKSNIIRGWIFGTTLDSTQSLIVNNAATNVVIVCEVFQCNDFPFLDV YYHKNNKSWMESGVYSSANNCTFEYVSQPFMDLEGKQGNFKNLR EFVFNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGINITRFQT LLALHRSYLTGPDSSSGWTAGAAAYYVGYLQPRFTLLKYNNENGIT DAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQPTESIVRFPNITNL CPFGEVFNATRFASVYAWNKRISNCVADYSVLNSASFSTFKCYG VSPTKLNDLCFTNVYADSFVIRGDEVRIAPGQTGKIADYNYKLPPD FTGCVIAWNSNNLDSKVGGNYNRYRLFRKSNLKPFERDISTEYIQA GSKPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELLHAP ATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQQFGR DIADTTDAVRDPQTLEILDITPCSFGGVSIVTPTNTSNQVAVLYQGV NCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAETHVNNSEY CDIPIGAGICASYQTQTSNRRRARSVASQSIAYTMSLGAENSVAYSQ NSIAIPTQFTISVTTEILPVSMTKTSVDCTMYICGDSTECNLLLQYGS FCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFQFSQIL PDPSKPSKRSFIEDLLFNKVTADAGFIKQYGDCLGDIAARDLICAQK FNGLTVLPPLLDDEMIAQYTSALLAGTITSGWTFGAGAALQIPFAMQ MAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDLSSTASALGKL QNVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRDLKVEAEVQIDR LITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLQSKRVDF CGKGYHLSFQPSAPHGVVFLHVTYVPAQEKQFTTAPAICHGDKAH

	FPREGVFSVSGTHWFVTQRNFYEPQIIITDNTFVSGNCDVVIGIVQNT VYDPLQPELDSFKEELDKYFKQHTSPDVLGDISGIQASVVNIQKEID RLNEVAKNLQESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVMTI MLCCMTSCCSCLKGCCSCGSCCKFDEDDSEPVLKGVKLHYT
SEQ ID NO: 29 Nucleic acid sequence of S-(deg-S2) for Wuhan S-2P (from 5'- end to 3'-end)	atgttcgtcttctggtcctgctgctcctggtctcctcacagtgcgtcaatctgacaactcggactcagctgcca cctgcttatactaataagcttcaccagaggcgtgtactatcctgacaagggttttagaagctccgtgctgcaactct acacaggatctgtttctgccattcttttagcaacgtgacctggttccacgccatccacgtgagcggaccaatgg cacaagcgggtcgacaatcccggtgctgcttttaacgatggcgtgtacttcgecttaccgagaagagcaac atcatcagaggctggtatctttggcaccacactggactccaagacacagtctctgctgacgtgaacaatgcca ccaacgtggtcatcaagggtgctgaggtccagttttgtaatgatcccttcctggcgtgtactatcacaagaaca ataagagctggatggagtcagggttttagagtgtattctagcgccaacaactgcacatttgagtacgtgagcca gcttctctgctgacctggaggcgaagcaggcgaattcaagaacctgaggagtgctgttttaagaatc gacggctacttcaaaatctacttaagcacaccccatcaacctggtgcgcgacctgcctcagggctcagc gcccgtggagcccctggtggtatctgctatcggcatcaacatcacccggtttcagacactgctggcccctgcac agaagctacctgacacccggcgactcctctagcggatggaccgcccgcgtgcgcgctactatgtggcta cctccagcccggaccttctgctgaagtacaacgagaatggcaccatcacagacgagtgattgcgccc tggaccctctgagcgagacaaagtgtacactgaagtccttaccgtggagaaggcctatcatcagacatcca atttcagggtgcagccaacaggatctatcgtgcgttcttaataacacaacctgtgcccatttggcgagggtgt tcaacgcaaccgcttcgcccagcgtgtacgctgggaatagggaagcggatcagcaactgcgtgcccgcgactat agcgtgctgtacaactcgcctcttccagcacctttaagtctatggcgtgtccccacaaagctgaatgacct gtgctttaccaacgtctacgcccgttctctgctgacggggcgacgagggtgcgcagatcgcggcccggcca gacaggcaagatcgcagactacaattataagctgcccagacgatttcacggctgcgtgtatcgcctggaacag caacaatctggtattcaaaagtggcgggcaactacaattatctgtaccggctgttttagaaagagcaatctgaag cccttcgagaggacatctctacagaatctaccaggccggcagcacccttgcgaatggcgtgtgagggtctt aactgttattccactccagtcctacggcttccagcccacaaacggcgtggtctatcagccttaccgctggt ggtgctgagctttgagctgctgcacgcccagcaacagtgtgcggcccgaagagtcaccacatctggtga agaacaagtgcgtgaacttcaactcaacggcctgaccggcacaggcgtgctgacgcagtgccaacaagaa gttctgcccatttcagcagttcggcaggacatcgcagataccacagacgcccgtgcgcgaccacagaccc tggagatcctggacatcacacctgctcttctggcggcgtgagcgtgatcacacccggcaccatacaagca accagggtggcctgctgtatcaggacgtgaattgtaccgaggtgcccgtgctatcacgcccgatcagctga ccccaatggtgggtgtacagcaccgctccaacgtcttccagacaagagccggatgectgacggagc agagcacgtgaacaattcctatgagtgcgacatcccaatcggcggcgcgtatctgctcttaccagaccca gacaaactctcccagaagagcccggagcgtggcctccagtcctatcatgectatacatgtccctggcgc cgagaacagcgtggcctactctcagaatagcatgccaatccacccagttcacaatctctgtgaccacaga gatcctgcccgtgtccatgaccaagacatctgtggactgcacaatgtatctgtggcgtattctaccagtgca gcaacctgctgctccagtagcggcgtttgtaccagctgaatagagccctgacaggcatcgcgtggagc aggataagaacacacaggaggtgttcgcccaggtgaagcaaatctacaagacccccctatcaaggacttt ggcggcttccaatttccagatcctgctgatccatccaagccttctaagcggagctttatcgaggacctgct gttcaacaaggtgacctggccgatgcccgtctcatcaagcagtatggcgattgctggcgacatcgcagc cagggacctgctgctgcccagaagttaattggcctgaccgtgctgcccacctgctgacagatgagatgat cgcacagtacacaagcgcctgctggcggcaccatcacatccggatggaccttcgcgcgagagccgccc ctccagatccccttggccatgcagatggcctataggttcaacggcatcggcgtgaccagaatgtgctgtacg agaaccagaagctgacgccaatcagtttaactccgcatcggcaagatccaggacagcctgtctctacag ccagcgccttgggcaagctcaggatgtgtgaatcagaacgcccaggccctgaataacctgtgtgaagca gctgagcagcaacttcggcgccatctctagcgtgctgaatgacatcctgagccggcgtgacccggtgagg cagaggtgcagatcaccggctgacacggcggcctcagagcctccagacctatgtgacacagcagct gatcaggggccgagatcagggccagcgaatctggcagcaaccaagatgtccgagtgctgtgctggg ccagttaagagagtgactttgtggcaaggctatcacctgatgtcttccctcagctgctgcccacacggc gtggtgttctgcacgtgacctcgtgcccggcaggagaagcagttcaccacagcccctgcatctgcccac gatggcaaggcccactttccaaggagggtgttctgtgtcccaggccaccactggtttgtgacacagc

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SEQ ID NO: 30 Protein sequence of S- (deg-S2) for Wuhan S- 2P (from N-terminus to C-terminus)	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVVYYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSNGTKRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSTKQSLIVNNATNVVIKVFCEQFCNDPFLG VYYHKNNKSWMESEFRVYSSANNCTFEYVSQPFMLDLEKQGNFK NLREFVFKNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGINITR FQTLALHRSYLTGPDSSSGWTAGAAAYYVGYLQPRFTLLKYNNENG TITDAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQPTESIVRFPNI TNLCPFGEVFNATRFASVYAWNKRKISNCVADYSVLNYSASFSTFKC YGVSPTKLNDLCFTNVYADSFVIRGDEVRIAPGQTGKIADYNYKLP DDFTGCVIAWNSNNLDSKVGNYNYLYRLFRKSNLKPFRDISTEYI QAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVVSFELLH APATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQQF GRDIADTTDAVRDPQTLEILDITPCSFGGVSIVTPTNTSNQVAVLYQ DVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNS YECDIPIGAGICASYQTQTNSPRRARSVASQSIIAYTMSLGAENSVAY SQNSIAIPTQFTISVTTEILPVSMTKTSVDCTMYICGDSTECNLLLQY GSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFQFS QILPDPSKPSKRSFIEDLLFNKVTLADAGFIKQYGDCLGDIAARDLICA QKFNGLTVLPPLTDEMAQYTSALLAGTITSGWTFGAGAALQIPFA MQMAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDLSSTAALG KLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRLDPPAEVQI DRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLQSKRV DFCGKGYHLMSFPQSAPHGVVFLHVTVPAQEKQFTTAPAICHGDK AHFPREGVFSQGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIVQ NTVYDPLQPELDSFKEELDKYFKQHTSPDVLGDISGIQASVUNIKE IDRLNEVAKNLQESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVM VTIMLCCMTSCCCLKGCCSCGSCCKFDEDDSEPVKGVKLHYT
SEQ ID NO: 31 Nucleic acid sequence of S-(deg-S2) for Delta S-2P strain (from 5'- end to 3'-end)	atgttcgtcttctggtcctgctgcctctggtctcctcacagtgcgtcaatctgcgaactcggactcagctcca cctgcttatactaataagcttcaccagaggcgtgtactatcctgacaagggtttagaagctccgtgctgcaactt acacaggatctgtttctgccattcttagcaacgtgacgtggtccacgcatccacgtgagcggcaccaatgg cacaagcgggtcgacaatcccgctgctgcttttaacgatggcgtgtacttcgctctatcgagaagagcaac atcatcagaggctggatcttggcaccacactggactccaagacacagtctctgctgacgtgaacaatgcca ccaacgtggtcatcaagggtgctgaggtccagttttgaatgatccctcctggacgtgtactatcacaagaaca ataagagctggatggagtcggagtgattctagcgccaacaactgcacatttgagtacgtgagccagccttt cctgatggacctggaggcgaagcagggcaattcaagaacctgaggaggttcgtgttaagaatatcgacgg ctacttcaaaatctacttaagcacacccccatcaacctggtgctgcgacctgcctcagggcttcagcgccctg gagccctggtggtatcgctatcgcatcaacatcacccggttcagacactgctggccctgcacagaagc tacctgacacccgctgactccttagcggatggacggccggcgtgctgcgcctactatgtggctacctcca gccccggacctcctgctgaagtacaacgagaatggcaccatcacagacgcagtgattgcccctggacc ccctgagcgagacaaagtgtactgaagtctttaccgtggagaaggcgcatcatcagatccaatttcag ggtgcagccaaccgagtctatcgctgcttcttaatatcacaacctgtgccatttggcaggtgttcaacg caaccgcttcgacgcgtgtacgcctggaataggaagcggatcagcaactgcgtggccgactatagcgtg

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SEQ ID NO: 32 Protein sequence of S- (deg-S2) for Delta S-2P strain (from N-terminus to C-terminus)	MFVFLVLLPLVSSQCVNLRTRTQLPPAYTNSFTRGVYYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVS GTNGTKRFDNPVLPFNDGVYFASI EKSNIIRGWIFGTTLD SKTQSLIVNNA TNVVIKVCE FQFCNDPFLDV YYHKNNKSWMESGVYSSANNCTFEYVSQPFLMDLEGKQGNFKNLR EFVFKNIDGYFKIY SKHTPINLV RDLPQGFSALEPLVDLPIGINITRFQT LLALHRSYLP GDSSSGW TAGAAAYVGYLQPRTFLLKY NENG TIT DAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQPTESIVRFPNITNL CPFGEVFNATRFASVYAWNKRKISNCVADYSVLN\$AS\$STFKCYG VSPTKLNDLCFTNVYADSFVIRGDEV RQIAPGQTGKIADYNYKL PDD FTGCVIAWNSNNLDSKVG GNYNYRYRLFRKSNLKPFERDISTE IYQA GSKPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVVL SFELLHAP ATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQQFGR

	DIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLYQGV NCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAHEVNNSEY CDIPIGAGICASYQTQNSRRRARSVASQSIIAYTMSLGAENSVAYSQ NSIAIPTQFTISVTTEILPVSMTKTSVDCTMYICGDSTECNLLQYGS FCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFQFSQIL PDPSKPSKRSFIEDLLFNKVTADAGFIKQYGDCLGDIAARDLICAQK FNGLTVLPPLLTDEMIAQYTSALLAGTITSGWTFGAGAALQIPFAMQ MAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDSLSSASALGKL QNVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRDLPPAEVQIDR LITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKRVDF CGKGYHLMSPQSAPHGVVFLHVTYVPAQEKQFTTAPAICHGDKAH FPREGVFSQGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIVQNT VYDPLQPELDSFKEELDKYFKQHTSPDVLGDISGIQASVVNIQKEID RLNEVAKNLQESLIDLQELGKYEYIKWPWYIWLGFIAGLIAIVMVTI MLCCMTSCCSCLKGCCSCGSCCKFDEDDSEPVLKGVKLHYT
SEQ ID NO: 33 Nucleic acid sequence of S-(S2-1194) for Wuhan S-2P strain (from 5'-end to 3'-end)	atgttcgtcttcctgctgctgctcctgctcctcacagtcgctcaatctgacaactcggactcagctcca cctgcttatactaataagctaccagaggcgtgtactatcctgacaagggtttagaagctccgctgctgcaact acacaggatctgtttctgccattcttagcaacgtgacctggttcacgccatccacgtgagcggcaccaatgg cacaagcggttcgacaatccgctgctgctcttaacatggcgtgtactcgcctctaccgagaagagcaac atcatcagaggctggtatctttggcaccactgactcgaagacacagtctctgctgacgtgaacaatgcc ccaacgtggtcatcaagggtgctgaggttccagttttgtaatgacccctcctggcgctgtactatcacaagaaca ataagagctggtgagtgccgagtttagagtgattctagcgccaacactgcacattgagtagctgagcca gccttctcgtatggacctggaggcgcaagcaggcgcaattcaagaacctgaggagtgctgtttagaatatac gacggctacttcaaaatctacttaagcacacccccatcaacctggtgcgcgacctgcctcagggtctcagc gcccgtgagccctggtggtatctgctatcggcatcaacatcacccggttcagacactgctgcccctgcac agaagctacgtgacacccggcgactcctctagcggatggaccgcccggcgctgcccctactatgtgggcta cctccagccccggacctcctctgtagtaagtaaacgagaatggcaccatcacagacgcagtggtattggccc tggacccccgtgagcgagacaaggtgtacactgaagtcctttaccgtggagaaggcgcatctatcagacatcca atttcagggtgcagccaaccgaggtctatcgtgcgctttcctaatacacaaacctgtgccatttggcgaggtgt tcaacgcaaccgcttcgcccagcgtgtacgcccgtgaatagggaagcgatcagcaactgcgtggccgactat agcgtgctgtacaactcgcctcttcagcaccttaagtctatggcgtgtccccacaaagctgaatgacct gtgctttacaacgctctacgcccgttcttcgtgacagggcgacgaggtgcgcgagatgcggcccgccca gacaggcaagatcgagactacaattataagctgcagacgatttaccggctgctgtagcgcctggaacag caacaatctggttccaaagtggcgccgaactacaattatctgtaccggctgtttagaagagcaatctgaag cccttcgagaggacatctacagaaatctaccaggccggcagcacccttgcaatggcgtgagggcctt aactgtatttccactccagctcactcagcctccagcccacaaacggcggtggctatcagccttaccgctggt ggtgctgagctttgagctgctgcacgccccagcaacagtgtgcggcccagaagtcaccaatctggtga agaacaagtgcgtgaactcaactcaacggcctgaccggcacaggcgtgctgaccgagtcacaagaagaa gttctgctcattcagcagttcggcaggacatcgacataccacagacgcgctgcgcgacccacagaccc tggagatcctggacatcacacccgtctctttcggcgcgctgagcgtgatcacaccggcaccataacaagca accagggtggcgtgctgtatcaggacgtgaattgtaccgaggtgcccgtggctatccacgcccagatcagctga ccccacatggcggtgtacagaccggctccaacgtcttcagacaagagccggatgctgacgagc agagcacgtgaacaattcctatgagtcgacatcccaatcggcgccgcatctgtgctcttaccagaccca gacaaactctccagaagagccggagcgtggcctccagctatcatgcctataccatgtccctggcgcg cgagaacagcgtggcctactctcagaatagcatgccatccaaccagttcacaatctctgtaccacaga gatcctgcccgtgtccatgaccaagacatctgtggactgcacaatgtatctgtggcgattctaccgagtgca gcaacctgctgctccagtaggcagctttttaccagctgaatagagccctgacaggcatgcccgtgagc aggataagaacacagagaggtgtcgcagggtgaagcaaatctacaagacccccctatcaaggacttt ggcggtctccaattttccagatcctgctgacatccaagccttctaagcggagctttatcaggacgtgct gttcaacaaggtgacctggccgatgcccgtctcatcaagcagtatggcgattgcctggcgacatcgacgc

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SEQ ID NO: 34 Protein sequence of S- (S2-1194) for Wuhan S-2P strain (from N- terminus to C-terminus)	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVYYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSGTNGTKRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSKTQSLIVNNATNVVIKVFCEFDQNDPFLG VYYHKNNKSWMESEFRVYSSANNCTFEYVSQPLMDLEGKQGNFK NLREFVFNIDGYFKIYSKHTPINLVRDL PQGSALEPLVDLPIGINITR FQTLALHRSYLT PGDSSSGWTAGAAAYYVGYLQPRTFLLKYNENG TITDAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQPTESIVRFPNI TNLCPFGEVFNATRFASVYAWNRKRISNCVADYSVLVNSASFSTFKC YGVSPTKLNDLCFTNVYADSFVIRGDEV RQIAPGQTGKIADYNYKLP DDFTGCVIAWNSNNLDSKVGNYNYLYRLFRKSNLKPFERDISTEY QAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELLH APATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQFQ GRDIADTTDAVRDPQTLEILDITPCSF GGVS VITPGTNTSNQVAVLYQ DVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNS YECDIPIGAGICASYQTQTN SPRRARSVASQSIIAYTMSLGAENSVAY SQNSIAIPTQFTISVTTEILPVSM TKTSVDCTMYICGDSTEC SNLLQY GSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFQFS QILPDPSKPSKRSFIEDLLFNKVT LADAGFIKQYGDCLGDIAARDLICA QKFNGLTVLPPLTDEMI AQYTSALLAGTITSGWTFGAGAALQIPFA MQMAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDLSSTASALG KLQDVVNQNAQALNTLVKQLSSNF GAISSVLNDILSRDPPAEAVQI DRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKRV DFCGKGYHLMSFPQSAPHGVVFLHV TYVPAQEKQFTTAPAICH DGK AHFPREGVFVSQGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIVQ NTVYDPLQPELDSFKEELDKYFKQHTSPDVLGDISGIQASVUNIQKE IDRLNEVAKNLNESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVM VTIMLCCMTSCCCLKGCCSCGSCCKFDEDDSEPV LKGVKLHYT
SEQ ID NO: 35 Nucleic acid sequence of S-(deg-RBD-801)	atgttcgtcttcctggtcctgctgctcctggtctcctcacagtgcgtcaatctgacaactcggactcagctgcc cctgcttataactaatagcttcaccagaggcgtgtactatcctgacaagggttttagaagctccgtgctgactct acacaggatctgttttccattcttagcaacgtgacctggtccacgccatccagctgagcggcaccatgg cacaaagcggttcgacaatcccgctgctgcttttaacgatggcgtgtactcgcctctaccgagaagagcaac

for Wuhan S-2P strain (from 5'-end to 3'-end)	atcatcagaggctggatcttggcaccacactggactccaagacacagtctctgctgacgtgaacaatgcca ccaacgtggatcatcaagggtgctgaggttccagtttggtaatgatcccttcctggcgctgtactatcacaagaaca ataagagctggatggagtcgaggttagagtgattctagcgccaacaactgcacatttgagtagtgagcca gcctttcctgatggacctggagggaagcagggcaattcaagaacctgaggaggtcgtgtttaagaatc gacggctacttcaaaatctactctaaacacacccccatcaacctgggtgcgacgtgacctcagggcttcagc gacctggagccctgggtgatctgctatcgccatcaacatcacccggtttcagacactgctggccctgcac agaagctacctgacacccggcgactcctctagcgatggacgcggcgctgcgcgctactatgtgggcta cctccagccccggacctcctgctgaagtacaacgagaatggcaccatcacagacgcagtgattgcgccc tggacccccctgagcgagacaaagtgtacactgaagtcctttaccgtggagaaggcatctatcagacatcca atttcagggtgcagccagccgaggcgatgctgcgtttcctgaaatcacaacctgtgcccatttggcgagggt gttcgaggcaacccgcttcgacgctgtacgcctggaatagggaagcgagatcagaactgctggccgact atagcgtgctgtacaactcgcctcttcagcacctttaagtctatggcgtgtcccccacaaagtgaatgac ctgtgctttaccaactctacgcgattcttcgtgatcaggggcgacgaggtgcgcagatgcgcccccgc cagacaggcaagatgcagactacaattataagctgccagacgatttcaccggctgctgctgacgctggaaac agcaacaatctggattccaaagtggcggaactacaattatctgtaccgctgtttagaagagcaatctga agcccttcgagaggacatctctacagaaatctaccaggccggcagcacccttgcaatggcgtggagggc tttaactgttttccactccagtcctacggctccagcccacaaacggcgtgggctatcagccttaccgctg gtgggtgctgagcttggagctgctgcaccccagcaacagtgtgcggcccaagaagtcaccaatctggtg aagaacaagtgcgtgaacttcaactcaacggcctgaccggcacaggcgtgctgaccgagtcacaagaag gttcctgcccatttcagcagttcggcaggacatcgagataccacagacgcgctgcgcgaccacagaccc tggagatcctggacatcacacctgctcttctggcgcgctgagcgtgatcaccccggcaccatacaagca accagggtggccgtgctgtatcaggacgtgaattgtaccgagggtgcccgtgctatccacgcccgatcagctga ccccaacatggcggtgtacagcaccggctccaacgtcttcagacaagagccggatgcctgatcggagc agagcacgtgaacaattcctatgagtgacatccaatggcgccggcatctgtgctcttaccagaccca gacaactctccagaagagcccgagcgtggcctccagtcctatcatcgcctataccatgtccctgggcgc cgagaacagcgtggcctactctaacatagcatcgccatcccaaccaactcacaatctctgtgaccacaga gatcctgcccgtgtccatgaccaagacatctgtggactgcacaatgtatctgtggcgattctaccgagtgca gcaacctgctgctccagtagcgagctttgtaccagctgaatagagccctgacaggatcgcgctggagc aggataagaaacacagaggtgttcgcccagggtgaagcaatctacaagacccccctatcaaggacttt ggcggttccaattttccagatcctgcctgatccatccaagccttctaagcggagctttatcgaggacctgct gttcaacaagtgaccctggccgatgcggccttcatcaagcagtatggcgattgctggcgacatcgagc cagggacctgatctgcgccagaagttaattggcctgaccgtgctgcaaccctgctgacagatgagatgat cgcacagtacacaagcgccctgctggccggcaccatcacatccggatggaccttgcggcaggagccgcc ctccagatcccccttgcagatgcagctataggttcaacggcatcgcgctgaccagaatgtgctgtacg agaaccagaagctgacgccaatcagtttaactccgccatcggaagatccaggacagcctgtcctctacag ccagcgccctgggaagctccagatgtgtgaatcagaacgcccaggccctgaataccctggtgaagca gctgagcagcaacttcggcgccatctctagcgtgctgaatgacatcctgagccgctggagccggaggg cagagggtgcagatcgaccggctgacaccggccggcctccagagcctccagacctatgtgacacagcagct gatcaggggccgagatcagggccagcgccaatctggcagcaaccaagatgtccgagtgctgctggg ccagttaagagagtgacttttggcaagggtatcacctgatgtcttcctcagctgtccccacacggc gtggttttctgcagtgacctacgtgcccgccaggagaagaacttaccacagcccctgcatctgccac gatggcaaggcccactttcaaggaggggcgtgttcgtgtccaacggcaccactgtttgtgacacagcg caatttctacgagcccagatcatcacacagacaacaccttctgtagcggcaactgtgacgtggtcatcgg catcgtgaacaataccgtgtatgacactccagcccagcgtggacagctttaaggaggagctggataagtat ttcaagaatcacacctcccctgacgtggatctggcgacatcagcggcatcaatgctcctggtgtgaacatcc agaaggagatcgaccctgaacgaggtggctaagaatctgaacgagagcctgacacctccaggagct gggcaagtatgagcagatcaatggcctggtacatctggctgggttcacgcggcctgacgcat cgtgatggtgaccatcatgctgtgtgtatgacatcctgctgttcttcctgaagggtcgtgtagctgtggctc ctgctgtaagttagcaggatgactctgaacctgtgctgaagggtggaagctgattacaccta
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SEQ ID NO: 36 Protein sequence of S-(deg-RBD-801) for Wuhan S-2P strain (from N-terminus to C-terminus)	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVVYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSNGTHKRFNDNPVLPFNDGVYFAS TEKSNIRGWIFGTTLDSTKQSLIVNNA TNVVIKVCEFQFCNDPFLG VYYHKNNKSWMESEFRVYSSANNCTFEYVSQPFMLDLEGGKQGNFK NLREFVFKNIDGYFKIY SKHTPINLVRDLPQGFSALEPLVDLPIGINTR FQTLALHRSYLPDSSSGWTAGAAAYYVGYLQPRFTLLKYNENG TITDAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQPAEAIVRFPQI TNLCPFGEVFQATRFASVYAWNKRKISNCVADYSVLVNSASFSTFKC YGVSPTKLNDLCFTNVYADSFVIRGDEVQRQIAPGQTKGIADYNYKLP DDFTGCVIAWNSNNLDSKVGGNYNYLYRLFRKSNLKPFRDISTEIIY QAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELLH APATVCGPKKSTNLVKNKCVNFNGLTGTGVLTESNKKFLPFQQF GRDIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLYQ DVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNS YECDIPIGAGICASYQTQTNSPRRARSVASQSIIAYTMSLGAENSVAY SNNIAIPTNFTISVTTEILPVSMTKTSVDCCTMYICGDSTECNLLLQY GSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGGFQS QILPDPSKPSKRSFIEDLLFNKVTADAGFIKQYGDCLGDIAARDLICA QKFNGLTVLPPLTDemiaQYTSALLAGTITSGWTFGAGAALQIPFA MQMAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDSLSTASALG KLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRLDPPAEVQI DRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKRV DFCGKGYHLSMFPQSAPHGVVFLHVTYVPAQEKNFTTAPAICHGDK AHFPREGVFVSNGTHWVFVTQRNFYEPQIITDNTFVSGNCDVVIGIVN NTVYDPLQPELDSFKEELDKYFKNHTSPDVLGDISGINASVNNIQKE IDRLNEVAKNLNESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVM VTIMLCCMTSCCCLKGCCSCGSCCKFDEDDSEPVLGKVKLHYT
SEQ ID NO: 37 Nucleic acid sequence of S-(deg-RBD-1194) for Wuhan S-2P strain (from 5'-end to 3'-end)	atgttcgtcttctggtcctcgtcgcctctggtctcctcacagtcgctcaatctgacaactcggactcagctgcc cctgcttatacataatagcttaccagaggcgtgtactatcctgacaaggctttagaagctccgtgctgcactct acacaggatctgtttctgccattcttagcaacgtgacctggttccacgccatccacgtgagcggcaccatgg cacaagcgggttcgacaatcccgctgctgctctttaaactgatggcgtgtacttcgacctaccgagaagagcaac atcatcagaggctggatctttggcaccacactggactccaagacacagctctgctgacgtggaacaatgcc ccaacgtggtcatcaaggtgtgcgagttccagtttgaatgaccccttcctggcgctgtactatcacaagaaca ataagagctggatggagtcgagtttagagtggtattctagcggccaacaactgcacattgagtagctgagcca gctttcctgatggacctggaggcgcaagcaggcgcaatttcaagaacctgagggagttcgtgtttaagaatac gacggctacttcaaaatctactctaagcacacccccatcaacctggtgctgcgacctgcctcagggttcagc gccccggagccccctgtgtggtatctgacctcggcatcaacatcacccgggttcagacactgctggccccctcac agaagctacctgacacccggcgactcctctagcggatggaccgccccgctgctgcgacctactatgttggcta cctcagccccggaccttctgctgaagtacaacgagaatggcaccatcacagacgcagtggtattgcgcc tggacccccctgagcgagacaaaagtgtacactgaagtcctttacgctggagaaggcgcatctatcagacatcca atttcagggtgcagccagccgaggcgatcgtgcgctttcctgaaatcacaacctgtgccatttggcgaggt gttcagggcaaccgcttcgccagcgtgtacgcctggaaatagggaagcggatcagcaactgcgtggccgact atagcgtgctgtacaactccgcctcttcagcaacctttaaagtgtatggcgtgtccccacaagctgaatgac ctgtgctttaccaacgtctacgccgactctacgagggcgacgaggtgcgacagatgcgccccggc cagacaggcaagatgcagactacaattataagctgccagacgttattaccgctgctgtgatcgccttggaac agcaacaactctggaattccaagtggcggaactacaattatctgtaccgctgtgtttagaagaagcaatctga agcccttcgagagggaactctctacagaaattctaccaggccggcagcacccttgcataatggcgctggagggc tttaactgttatttccactcagtcctacggcttcagccccacaacggcgctgggctatcagccttaccgctg gtggtgctgagctttgagctgctgcacgccccagcaacagtggtgcggccccagaagtcaccaatctgtg aagaacaagtgcgtgaattcaacttcaacggcctgacggcagcagcgtgctgacggcaggtccaacaaga

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SEQ ID NO: 38 Protein sequence of S- (deg-RBD-1194) for Wuhan S-2P strain (from N-terminus to C- terminus)	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVVYYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSGTNGTKRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSTQSLIVNNA TNVVIK VCEFQFCNDPFLG VYYHKNNKSWMESEFRVYSSANNCTFEYVSQPFLMDLEGKQGNFK NLREFVFKNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGINITR FQTLALHRSYLPDSSSGWTAGAAAYYVGYLQPRTFLLKYNENG TITDAVDCALDPLSEKTKLSFTVEKGIYQTSNFRVQPAEAIVRFPQI TNLCPFGEVVFQATRFASVYAWNRKRISNCVADYSLVYNASFSSTFKC YGVSPTKLNDLCFTNVYADSFVIRGDEV RQIAPGQTGKIADYNYKLP DDFTGCVIAWNSNNLDSKVGGNYNLYRLFRKSNLKPFERDISTEY QAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVVL SFELLH APATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQGF GRDIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLYQ DVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNS YECDIPIGAGICASYQTQTNSPRRARSVASQSIIAYTMSLGAENSVAY SNNSIAIPTNFTISVTTEILPVSMTKTSVDCTMYICGDSTEC SNLLLQY GSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFNFS QILPDPSKPSKRSFIEDLLFNKVTLADAGFIKQYGDCLGDIAARDLICA QKFNGLTVLPPLLTDEMI AQYTSALLAGTITSGWTFGAGAALQIPFA MQMAYRFNGIGVTVQNVLYENQKLIANQFNSAIGKIQDSLSTASALG

	KLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRLDPPAEVQI DRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLQSKRV DFCGKGYHLSFPQSAPHGVVFLHVITYVPAQEKNFTTAPAICHGDK AHFPREGVVFVSNGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIVN NTVYDPLQPELDSFKEELDKYFKNHTSPDVLGDISGINASVUNIKE IDRLNEVAKNLQESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVM VTIMLCCMTSCCCLKGCCSCGSCCKFDEDDSEPVLKGVKLHYT
SEQ ID NO: 39 Nucleic acid sequence of S-(deg-RBD-122- 165-234) for Wuhan S- 2P strain (from 5'-end to 3'-end)	atgttcgtcttctggtcctgctgcctctggtctcctcacagtgcgtcaatctgacaactcggactcagctgcca cctgcttatactaataagcttcaccagaggcgtgtactatcctgacaagggttttagaagctccgctgctgactct acacaggatctgtttctgccattcttagcaacgtgacctggtccacgccatccacgtgagcggcaccatgg cacaagcgggttcgacaatcccgtgctgccttttaacgatggcgtgtactcgcctctaccgagaagagcaac atcatcagaggctggtatcttggcaccacactggactccaagacacagtctctgctgacgtgaaccaagcca ccaacgtggtcatcaaggtgtgcgagttccagttttgaatgatcccttcctggcgtgtactatcacaagaaca ataagagctggatggagtcagggttagtgatgtattctagcgccaaccagtgacatttgatgacgtgagcca gccttctgtagtgcctggaggcgaagcaggcgaattcaagaacctgaggagtgctgtttaagaatc gacggctacttcaaaatctacttaagcacacccccatcaacctgtgctgcgacctgcctcagggtcagc gcccgtgagccccgtggtgctgctatcgcatccagatcaccggttcagacactgctgcccctgcac agaagctacctgacacccggcactcctctagcggatggaccgcccgcgtgcccctactatgtgggcta cctccagccccggacctctctgctgaagtacaacgagaatggcaccatcacagacgagtgattgcgccc tggaccctctgagcgagacaaagtgtacactgaagtccttacgtggagaaggcactctatcagacatcca atttcagggtgcagccagcggaggcgcgtgcttctcgaatacacaacctgtgcccatttggcagggt gttcgaggcaaccgcttcgccagcgtgtacgcctggaatagggaagcggatcagcaactgcgtggccgact atagcgtgctgtacaactccgctcttccagcacctttaagtctatggcgtgtccccacaaagctgaatgac ctgtgctttaccaacgtctacgcccgttctctgtatcaggggcgacgaggtgcgacagatgcaccccgcc cagacaggcaagatgcagactacaattataagctgcagacgatttcaccggtcgtgctgacgcctggaa agcaacaatctggattccaagtgggcggcaactacaattatctgtaccggtcgtgttagaaagagcaatctga agcccttcgagaggagactctctacagaaatctaccaggccggcagcacccttgcaatggcgtggagggc tttaactgttattccactccagtcctacggccttcagcccacaaacggcgtgggctatcagccttaccgctg gtgggtgctgagctttagctgctgcacgccccagcaacagtgtgcggccccagaagtcacccaatgtggtg aagaacaagtgcgtgaacttcaactcaacggcctgaccggcacaggcgtgctgacccagtcacaagaagaa gttctgcccatttcagcagttcggcagggacatcgagataccacagacgcgctgcgacccacagaccc tggagatcctggacatcacacccgtctcttctggcggcgtgagcgtgatcacacccggcaccatacaagca accagggtgcccgtgctgtatcaggacgtgaattgtaccgaggtgcccgtggctatcacgcccgatcagctga ccccaatgctgcgggtgtacagcaccggtcacaacgtcttccagacaagagccggatgctgacggagc agagcacgtgaacaattcctatgagtcgacatcccaatcgccgcccgcgtctgctcttaccagaccca gacaaactctcccagaagagccccgagcgtggcctccagctatcatcgectatacatgctccctggcgcc cgagaacagcgtggcctactctacaatagcatcgccatcccaaccaacttcacaatctctgtgaccacaga gatcctgcccgtgtccatgaccaagacatctgtggactgcacaatgtatatctgtggcgattctaccagtgca gcaacctgctgctccagtagcggcagctttgtaccagctgaatagagccctgacaggcatcgccgtggagc aggataagaacacacaggaggtgttcgccaggtgaagcaaatctacaagacccccctatcaaggacttt ggcggcttcaattttccagatcctgcctgatccatccaagccttctaagcggagccttatcgaggacctgctg ttcaacaagggtgacctggccgatgcccgttcatcaagcagtatggcgattgctggcgacatcgacgcc agggacctgatctgcgccagaagttaatggcctgaccgtgctgcccacctgctgacagatgagatgatc gcacagtacacaagcgcctgctgcccggcaccatcacatccgatggacctgcgcagagacggccc tccagatccccttgcctgagatggcctatagggtcaacggcatcgccgtgacccagaatgtgctgtacga gaaccagaagctgatcgccaatcagtttaactccgcatcggaagatccaggacagcctgtcctctacagc cagcgccctgggcaagctccaggtgtgtgaatcagaaccccagccctgaataacctgtgtgaagcag ctgagcagcaactcggcgcctatcttagcgtgctgaatgacatcctgagccggctgacccggcggagc agaggtgcagatcgacggctgatcaccggccgctccagagcctccagacctatgtgacacagcagctg atcaggcccgagatcaggccagcgaatctggcagcaaccaagatgtccgagtcgtgctggc

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SEQ ID NO: 40 Protein sequence of S- (deg-RBD-122-165- 234) for Wuhan S-2P strain (from N-terminus to C-terminus)	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVYYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSGTNGTKRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSKTQSLIVNQATNVVIKVCEVFQCNDFLFG VYYHKNNKSWMESEFRVYSSANQCTFEYVSQPFLMDLEKQGNFK NLREFVFKNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDLPIGIQITR FQTLALHRSYLTTPGDSSSGWTAGAAAYYVGYLQPRTFLLKYNENG TITDAVDCALDPLSETKCTLKSFTVEKGIYQTSNFRVQPAEIVRFPQI TNLCPFGEVFAQTRFASVYAWNRKRISNCVADYSLYNSASFSTFKC YGVSPTKLNDLCFTNVYADSFVIRGDEVRIAPGQTGKIADYNYKLP DDFTGCVIAWNSNNLDSKVGGNYNYLYRLFRKSNLKPFERDISTEY QAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELLH APATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQF GRDIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLYQ DVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNS YECDIPIGAGICASYQTQTNSPRRARSVASQSIAYTMSLGAENSVAY SNNSIAIPTNFTISVTTEILPVSMTKTSVDCMYICGDSTECNLLLQY GSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFNFS QILPDPSKPSKRSFIEDLLFNKVTLADAGFIKQYGDCLGDIAARDLICA QKFNGLTVLPPLLTDEMAQYTSALLAGTITSGWTFGAGAALQIPFA MQMAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDSLSSASALG KLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRDPPAEVQI DRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKRV DFCGKGYHLMSFPQSAPHGVVFLHVITYVPAQEKNFTTAPAICHGDK AHFPREGVFVSNGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIVN NTVYDPLQPELDSFKEELDKYFKNHTSPDVLGDISGINASVUNIKE IDRLNEVAKNLNESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVM VTIMLCCMTSCCCLKGCCSCGSCCKFDEDDSEPVKGVKLHYT
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SEQ ID NO: 42	NITNLCPFGEVFNATR
SEQ ID NO: 43	LYNSASFSTFK
SEQ ID NO: 44	LDSKVGGNYN
SEQ ID NO: 45	KSNLKPFERDIST
SEQ ID NO: 46	KPFERDISTEYQAG

SEQ ID NO: 47	GPKKSTNLVKNC
SEQ ID NO: 48	NCDVVIGIV[N]NTVY
SEQ ID NO: 49	PELDSFKEELDKYFK[N]HTS
SEQ ID NO: 50	VNIQKEIDRLNEVA
SEQ ID NO: 51	NL[N]ESLIDLQ
SEQ ID NO: 52	LGKYEQYIKWP
SEQ ID NO: 53 Delta: SARS-CoV-2 Delta Strain Spike protein sequence	MFVFLVLLPLVSSQCVNLRTTQLPPAYTNSFTRGVYYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSGTNGTTRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSKTQSLIVNNAATNVVIKVCFFQFCNDPFLG VYYHKNNKSWMESGVYSSANNCTFEYVSQPFLMDLEGKQGNFKNL REFVFKNIDGYFKIYKHTPINLVRDLPQGFSALEPLVDLPIGINITRFQ TLLALHRSYLT PGDSSSGWTAGAAAYYVGYLQPRTFLLKYNENG TI TDAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQPTESIVRFPNITN LCPFGEVFNATRFASVYAWNRKRISNCVADYSVLVNSASFSTFKCYG VSPTKLNDLCFTNVYADSFVIRGDEVQRQIAPGQTGKIADYNYKLPDD FTGCVIAWNSNNLDSKVGGNYNRYRLFRKSNLKPFERDISTEYIQA GSKPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELLHAP ATVCGPKKSTNLVKNCVNFNFNGLTGTGVLTESNKKFLPFQQFGR DIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLYQGV NCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNNSEY CDIPIGAGICASYQTQTSRRRARSVASQSIAYTMSLGAENSVAYSN NSIAIPTNFTISVTTEILPVSMTKTSVDCTMYICGDSTECNLLQYGS FCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFNFSQIL PDPSKPSKRSFIEDLLFNKVTADAGFIKQYGDCLGDIAARDLICAQK FNGLTVLPPLTDEMIAQYTSALLAGTITSGWTFGAGAALQIPFAMQ MAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDSLSTASALGKL QNVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRDLKVEAEVQIDR LITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKRVDF CGKGYHLMSFPQSAPHGVVFLHVTYVPAQEKNTTAPAICHGDKAH FPREGVFSNGTHWFTQRFYEPQIITDNTFVSGNCDVVIGIVNNT VYDPLQPELDSFKEELDKYFKNHTSPDVLGDISGINASVVNIQKEID RLNEVAKNLNESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVMTI MLCCMTSCCCLKGCCSCGSCCKFDEDDSEPVLGKVKLHYT
SEQ ID NO: 54 WH: SARS-CoV-2 Wuhan-Hu-1 strain Spike protein sequence	MFVFLVLLPLVSSQCVNLTRTQLPPAYTNSFTRGVYYPDKVFRSSV LHSTQDLFLPFFSNVTWFHAIHVSGTNGTKRFDNPVLPFNDGVYFAS TEKSNIIRGWIFGTTLDSKTQSLIVNNAATNVVIKVCFFQFCNDPFLG VYYHKNNKSWMESEFRVYSSANNCTFEYVSQPFLMDLEGKQGNFK NLREFVFKNIDGYFKIYKHTPINLVRDLPQGFSALEPLVDLPIGINITR FQTLALHRSYLT PGDSSSGWTAGAAAYYVGYLQPRTFLLKYNENG TITDAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQPTESIVRFPNI TNLCPFGEVFNATRFASVYAWNRKRISNCVADYSVLVNSASFSTFKC YGVSPTKLNDLCFTNVYADSFVIRGDEVQRQIAPGQTGKIADYNYKLP DDFTGCVIAWNSNNLDSKVGGNYNLYRLFRKSNLKPFERDISTEYI QAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVLSFELLH

	APATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFLPFQQF GRDIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVAVLYQ DVNCTEVPVAIHADQLTPTWRVYSTGSNVFQTRAGCLIGAEHVNNS YECDIPIGAGICASYQTQTNSPRRARSVASQSIIAYTMSLGAENSVAY SNNSIAIPTNFTISVTTEILPVSMTKTSVDCTMYICGDSTEC SNLLQY GSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGGFNFS QILPDPSKPSKRSFIEDLLFNKVTLADAGFIKQYGDCLGDIAARDLICA QKFNGLTVLPPLLTDEMQYTSALLAGTITSGWTFGAGAALQIPFA MQMAYRFNGIGVTQNVLYENQKLIANQFN SAIGKIQDSLSTASALG KLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRDLKVEAEVQI DRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQSKRV DFCGKGYHLMSPQSAPHGVVFLHVTYVPAQEKNFTTAPAICHGDK AHFPREGVFVSNGTHWFVTQRNFYEPQIITDNTFVSGNCDVVIGIVN NTVYDPLQPELDSFKEELDKYFKNHTSPDVLGDISGINASVVNIQKE IDRLNEVAKNLNESLIDLQELGKYEQYIKWPWYIWLGFIAGLIAIVM VTIMLCCMTSCCCLKGCCSCGSCCKFDEDDSEPV LKGVKLHYT
SEQ ID NO: 55 RBM-001	VNLRTRTQLPPAYTNSFTRGVYYPDKVFRSSVLHSTQDLFLPFFSNVT WFHAIHVSGTNGTKRFDNPVLPFNDGVYFASIEKSNIIRGWIFGTTLD SKTQSL LIVNNATNVVIK VCEFQCNDPFLDVYHKNKNSWMESGV YSSANNCTFEYVSQPFLMDLEGKQGNFKNLREFVFNIDGYFKIYSK HTPINLVRDLPQGFSALEPLVDLPIGINITRFQTLLALHRSYLT PGDSSS GWTAGAAAYYVGYLQPRFTLLKYNENGTITDAVDCALDPLSETKCT LKSFTVEKGIYQTSNFRVQPTESIVRFPNITNLCPFGEVFNATRFASVY AWNKRKISNCVADYSVLVNSASFSTFKCYGVSPTKLNDLCFTNVYA DSFVIRGDEV RQIAPGQTGKIADYNYKL PDDFTGCVIAWNSNNLDSK VGGNYNYRYRLFRKSNLKPFERDISTEIQAGSKPCNGVEGFNCYFP LQSYGFQPTNGVGYQPYRVVLSFELLHAPATVCGPKKSTNLVKNK CVNFNFNGLTGTGVLTESNKKFLPFQQFGRDIADTTDAVRDPQTLEI LDITPCSFGGVSVITPGTNTSNQVAVLYQGVNCTEVPVAIHADQLTPT WRVYSTGSNVFQTRAGCLIGAEHVNNSYECDIPIGAGICASYQTQTN SRGSAGSVASQSIIAYTMSLGAENSVAYSNNNSIAIPTNFTISVTTEILPV SMTKTSVDCTMYICGDSTEC SNLLQYGSFCTQLNRALTGIAVEQDK NTQEVFAQVKQIYKTPPIKDFGGFNFSQILPDPSKPSKRSFIEDLLFNK VTLADAGFIKQYGDCLGDIAARDLICAQKFNGLTVLPPLLTDEMQY YTSALLAGTITSGWTFGAGAALQIPFAMQMAYRFNGIGVTQNVLYE NQKLIANQFN SAIGKIQDSLSTASALGKLQNVVNQNAQALNTLVKQ LSSNFGAISSVLNDILSRDPPEAEVQIDRLITGRLQSLQTYVTQQLIR AAEIRASANLAATKMSECVLGQSKRVDFCGKGYHLMSPQSAPHGV VFLHVTYVPAQEKNFTTAPAICHGDKAHFPREGVFVSNGTHWFVTQ RNFYEPQIITDNTFVSGNCDVVIGIVNNTVYDPLQPELDSFKEELDK YFKNHTSPDVLGDISGINASVVNIQKEIDRLNEVAKNLNESLIDLQE LGKYEQYIKWPLVPRGSPGSGYIPEAPRDGQAYVRKDG EWVLLSTF LG
SEQ ID NO: 56 Smg protein	MKVKLLVLLCTFTATYAGTQCVNLTRTQLPPAYTNSFTRGVYYPD KVFRSSVLHSTQDLFLPFFSNVTWFHAIHVSGTNGTKRFDNPVLPFN DGVYFASTEKSNIIRGWIFGTTLD SKTQSL LIVNNATNVVIK VCEFQF CNDPFLGVYHKNKNSWMESEFRVYSSANNCTFEYVSQPFLMDLEG KQGNFKNLREFVFNIDGYFKIYSKHTPINLVRDLPQGFSALEPLVDL PIGINITRFQTLLALHRSYLT PGDSSSGWTAGAAAYYVGYLQPRFTLL

	KYNENGTITDAVDCALDPLSETKCTLSFTVEKGIYQTSNFRVQPTES IVRFPNITNLCPFGEVFNATRFASVYAWNKRKISNCVADYSVLYNSA SFSTFKCYGVSPTKLNDLCFTNVYADSFVIRGDEVQRQIAPGQTGKIAD YNYKLPDDFTGCVIAWNSNNLDSKVGGNYYLYRLFRKSNLKPFR DISTEIYQAGSTPCNGVEGFNCYFPLQSYGFQPTNGVGYQPYRVVVL SFELLHAPATVCGPKKSTNLVKNKCVNFNFNGLTGTGVLTESNKKFL PFQQFGRDIADTTDAVRDPQTLEILDITPCSFGGVSVITPGTNTSNQVA VLYQDVNCTEVPVAIHADQLTPTWRVYSTGNSNVFQTRAGCLIGAEH VNNSYECDIPIGAGICASYQTQTNSPGSAGSVASQSIIAYTMSLGAEN SVAYSNNIAIPTNFTISVTTEILPVSMTKTSVDCTMYICGDSTECNSL LLQYGSFCTQLNRALTGIAVEQDKNTQEVFAQVKQIYKTPPIKDFGG FNFSQILPDPSKPSKRSFIEDLLFNKVTADAGFIKQYGDCLGDIAARD LICAQKFNGLTVLPPLTDEMIAQYTSALLAGTITSGWTFGAGAALQI PFAMQMAYRFNGIGVTQNVLYENQKLIANQFNSAIGKIQDSLSTAS ALGKLQDVVNQNAQALNTLVKQLSSNFGAISSVLNDILSRDLPPEAE VQIDRLITGRLQSLQTYVTQQLIRAAEIRASANLAATKMSECVLGQS KRVDFCGKGYHLMSPQSAPHGVVFLHVTYVPAQEKNFTTAPAICH DGKAHFPRREGVFSNGTHWFVTQRNFYEPQIITDNTFVSGNCDVVI GIVNNTVYDPLQPELDSFKEELDKYFKNHTSPDVLGDISGINASVV NIQKEIDRLNEVAKNLNESLIDLQELGKYEQDIRSLVPRGSPGSGYIPE APRDGQAYVRKDGWVLLSTFLGHHHHHH
SEQ ID NO: 57	QCVNLTTRTQLPPAYTNSFTRGVYYPDKVFRSSVLHSTQDLFLPFFSN VTWFHAIHVSGTNGTKRFDNPVLPFNDGVYFASTEKSNIRGWIFGTT LDSKTQSLNATNVIKVECFQCNDPFLGVYHKNKSWMES EFRVYSSANNCTFEYVSQPFLMDLEGKQGNFKNLREFVFNIDGYFK IYSKHTPINLVRDLPQGFSALEPLVDLPIGINITRFQTLALHRSYLTGP DSSSGWTAGAAAYYVGYLQPRFTLLKYNENGTITDAVDCALDPLSE TKCTLSFTVEKGIYQTSNFRVQPTESIVRFPNITNLCPFGEVFNATRF ASVYAWNKRKISNCVADYSVLYNSASFSTFKCYGVSPTKLNDLCFT NVYADSFVIRGDEVQRQIAPGQTGKIADYNYKLPDDFTGCVIAWNSN NLDSKVGGNYYLYRLFRKSNLKPFRDISTEIYQAGSTPCNGVEGF NCYFPLQSYGFQPTNGVGYQPYRVVVL SFELLHAPATVCGPKKSTN LVKNKCVNFNFNGLTGTGVLTESNKKFLPFQQFGRDIADTTDAVRD PQTLEILDITPCSFGGVSVITPGTNTSNQVA VLYQDVNCTEVPVAIHA DQLTPTWRVYSTGNSNVFQTRAGCLIGAEHVNNSYECDIPIGAGICAS YQTQTNSPRRARSVASQSIIAYTMSLGAENSVAYSNNIAIPTNFTISV TTEILPVSMTKTSVDCTMYICGDSTECNSNLLQYGSFCTQLNRALTGI AVEQDKNTQEVFAQVKQIYKTPPIKDFGGFNFSQILPDPSKPSKRSFIE DLLFNKVTADAGFIKQYGDCLGDIAARDLICAQKFNGLTVLPPLT DEMIAQYTSALLAGTITSGWTFGAGAALQIPFAMQMAYRFNGIGVT QNVLYENQKLIANQFNSAIGKIQDSLSTASALGKLQDVVNQNAQAL NTLVKQLSSNFGAISSVLNDILSRDKVEAEVQIDRLITGRLQSLQTY VTQQLIRAAEIRASANLAATKMSECVLGQSKRVDFCGKGYHLMSP QSAPHGVVFLHVTYVPAQEKNFTTAPAICHDGKAHFPRREGVFSNG THWFVTQRNFYEPQIITDNTFVSGNCDVVI GIVNNTVYDPLQPELDS FKEELD KYFKNHTSPDVLGDISGINASVNIQKEIDRLNEVAKNLNESLIDLQ ELGKYEQY

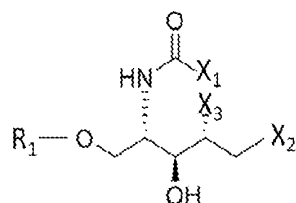
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SEQ ID NO: 63 E6	RVYSTGSNVFQTR
SEQ ID NO: 64 E7	RRARSVASQS
SEQ ID NO: 65 E8	DPSKPSKRSF
SEQ ID NO: 66 E9	FIKQYGDCLGDI
SEQ ID NO: 67 E10	ENQKLIANQFNS
SEQ ID NO: 68 E11	GKIQDSLSTA
SEQ ID NO: 69 E12	NCDVVIGIVNNTVY
SEQ ID NO: 70 E13	PELDSFKEELDKYFKNHTS

SEQ ID NO: 71 E14	TSPDVDLGDISGINA
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SEQ ID NO: 73 E16	NLNESLIDLQ
SEQ ID NO: 74 E17	LGKYEQYIKWP

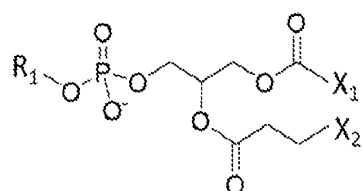
What is claimed is:

1. A pharmaceutical formulation, comprising a lipid nanoparticle and a pharmaceutically-acceptable excipient; wherein the lipid nanoparticle is formed with a plurality of lipid components;

wherein the plurality of lipid components comprises a bi-functional compound comprising:



Formula 1; or



Formula 2;

wherein R₁ comprises a substituted or non-substituted glycosyl group;

wherein X₁ and X₂ are each independently hydrogen, C₁₋₃₀ alkyl, C₁₋₃₀ alkenyl, C₁₋₃₀ alkynyl, aryl, aryloxy, or a substituted version thereof, or

-(CH₂)_nX₄, n is 0 to 30, and X₄ is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X₄ is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N, or a combination thereof; and

wherein X₃ is hydrogen, C₁₋₆ alkyl, or hydroxyl;

wherein the lipid nanoparticle encapsulates a payload encoding a spike protein of Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV) wherein the spike protein has a reduced and/or deleted glycan profile.

2. The pharmaceutical formulation of claim 1, wherein the spike protein comprises an amino acid substitution of asparagine (N) to glutamine (Q) at N-linked glycosylation sequons (N-X-S/T),

wherein X is any amino acid residue except proline, and S/T denotes a serine or threonine residue.

3. The pharmaceutical formulation of claim 1, wherein the spike protein comprises an amino acid deletion or addition at N-linked glycosylation sequons (N-X-S/T) to eliminate N-linked glycan sequons.
4. The pharmaceutical formulation of claim 1, wherein the spike protein comprises an amino acid substitution of S/T to alanine (A) at O-linked glycosylation sites to eliminate O-linked glycosylation sites.
5. The pharmaceutical formulation of claim 1, wherein

the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 2, 16, 18, or 20, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence set forth in SEQ ID NO: 2, 16, 18 or 20; or

the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 1, 15, 17, or 19 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 1, 15, 17 or 19 respectively.
6. The pharmaceutical formulation of claim 1, wherein

the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 4, 22, 24, or 26, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 4, 22, 24, or 26, and wherein the spike protein comprises a receptor binding domain (RBD) lacking at least one glycosylation sites; or

the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 3, 21, 23, or 25 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 3, 21, 23, or 25 respectively.
7. The pharmaceutical formulation of claim 1, wherein

the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 6, 28, 30, or 32, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 6, 28, 30, or 32, and wherein the spike protein comprises a S2 subunit lacking at least one glycosylation sites; or

the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 5, 27, 29, or 31 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 5, 27, 29, or 31 respectively.

8. The pharmaceutical formulation of claim 1, wherein

the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 8 or 34, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 8 or 34, and wherein the spike protein comprises an S2 subunit comprising a single glycosylation site at N1194; or

the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 7 or 33 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 7 or 33 respectively.

9. The pharmaceutical formulation of claim 1, wherein

the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 10 or 36, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 10 or 36, and wherein the spike protein comprises a receptor binding domain (RBD) lacking at least one glycosylation sites and an amino acid substitution of N801Q; or

the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 9 or 35 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 9 or 35 respectively.

10. The pharmaceutical formulation of claim 1, wherein

the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 12 or 38, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 12 or 38, and wherein the spike protein comprises a receptor binding domain (RBD) lacking at least one glycosylation sites and an amino acid substitution of N1194Q; or

the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 11 or 37 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 11 or 37 respectively.

11. The pharmaceutical formulation of claim 1, wherein

the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 14 or 40, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 14 or 40, and wherein the spike protein comprises a receptor binding domain (RBD) lacking at least one glycosylation sites and an amino acid substitution of N122Q, N165Q, N234Q, or a combination thereof; or

the payload encoding the spike protein is an RNA comprising a nucleotide sequence set forth in SEQ ID NO: 13 or 39 respectively, or a nucleotide sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the nucleotide sequence set forth in SEQ ID NO: 13 or 39 respectively.

12. The pharmaceutical formulation of claim 1, wherein the payload encodes an immunogenic peptide comprising an amino acid sequence selected from a group consisting of: TESIVRFPNITNL (SEQ ID NO: 41), NITNLCPFGEVFNATR (SEQ ID NO: 42), LYNSASFSTFK (SEQ ID NO: 43), LDSKVGGNYN (SEQ ID NO: 44), KSNLKPFERDIST (SEQ ID NO: 45), KPFERDISTEIQAG (SEQ ID NO: 46), GPKKSTNLVKNNK (SEQ ID NO: 47), NCDVVIGIVNNTVY (SEQ ID NO: 48), PELDSFKEELDKYFKNHTS (SEQ ID NO: 49), VNIQKEIDRLNEVA (SEQ ID NO: 50), NLNESLIDLQ (SEQ ID NO: 51) and LGKYEQYIKWP (SEQ ID NO: 52) or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95% or 90% identity to any of SEQ ID NOs: 41 to 52.

13. The pharmaceutical formulation of claim 1, wherein the spike protein comprises an amino acid sequence set forth in SEQ ID NO: 53, 54, 55, 56, or 57, or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95%, 90%, 85%, or 80% identity to the amino acid sequence of SEQ ID NO: 53, 54, 55, 56, or 57.
14. The pharmaceutical formulation of claim 13, wherein the payload encodes an immunogenic peptide comprising an amino acid sequence selected from a group consisting of:

SEQ ID NO: 58 - SSANNCTFEYVSQ;

SEQ ID NO: 59 - TESIVRFPNITNL;

SEQ ID NO: 60 - KPFERDISTEYQAG;

SEQ ID NO: 61 - GPKKSTNLVKNKC;

SEQ ID NO: 62 - TEVPVAIHADQ;

SEQ ID NO: 63 - RVYSTGSGNVFQTR;

SEQ ID NO: 64 - RRARSVASQS;

SEQ ID NO: 65 - DPSKPSKRSF;

SEQ ID NO: 66 - FIKQYGDCLGDI;

SEQ ID NO: 67 - ENQKLIANQFNS;

SEQ ID NO: 68 - GKIQDSLSTA;

SEQ ID NO: 69 - NCDVVIGIVNNTVY;

SEQ ID NO: 70 - PELDSFKEELDKYFKNHTS;

SEQ ID NO: 71 - TSPDVDLGDISGINA;

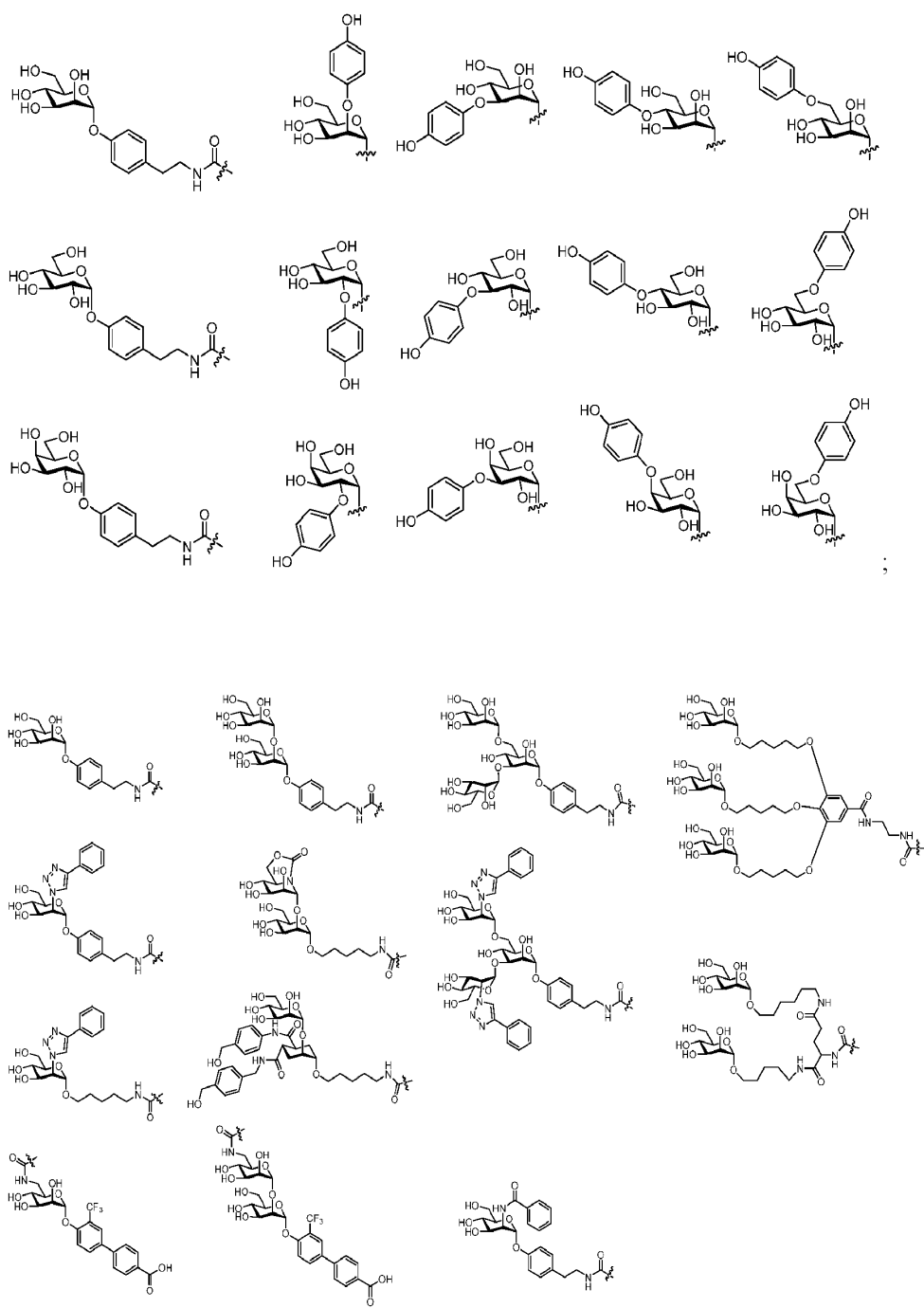
SEQ ID NO: 72 - VNIQKEIDRLNEVA;

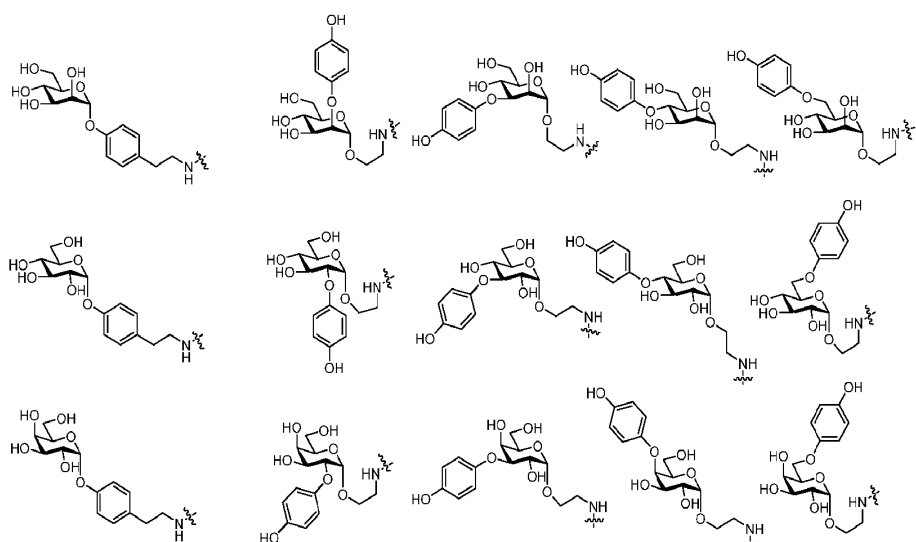
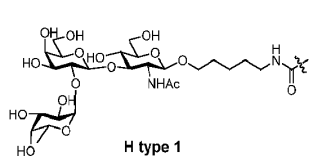
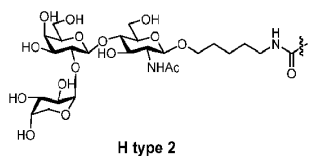
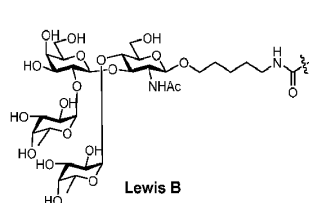
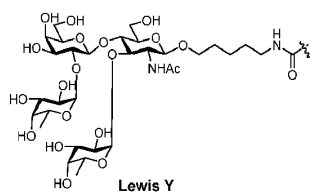
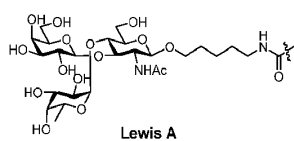
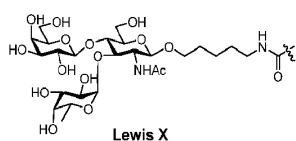
SEQ ID NO: 73 - NLNESLIDLQ; and

SEQ ID NO: 74 - LGKYEQYIKWP;

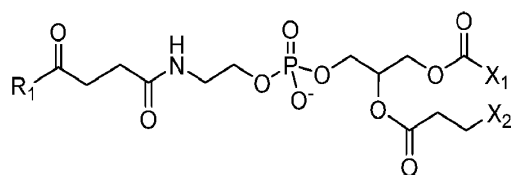
or an amino acid sequence having at least about 99%, 98%, 97%, 96%, 95% or 90% identity to any of SEQ ID NOs: 58 to 74

15. The pharmaceutical formulation of claim 1, wherein R_1 comprises a formula of R_2-R_A , wherein R_2 is the substituted or non-substituted glycosyl group, and R_A is an attachment group, and wherein the attachment group comprises an aryl, an alkyl, an amide, an alkylamide, a substituted version thereof, a combination thereof, or a covalent bond.
16. The pharmaceutical formulation of claim 15, wherein R_A comprises an aryl having 1 to 3 substituents, wherein the substituent is C_{1-6} alkyl, halide, or C_{1-6} alkyl halide.
17. The pharmaceutical formulation of claim 16, wherein R_A further comprises a polyethylene glycol (PEG) moiety having 2 to 72 (OCH_2CH_2) subunits.
18. The pharmaceutical formulation of claim 1, wherein the glycosyl group comprises mannoside, fucoside, or a combination thereof.
19. The pharmaceutical formulation of claim 1, wherein the glycosyl group comprises a mono-mannoside, a di-mannoside, or a tri-mannoside.
20. The pharmaceutical formulation of claim 1, wherein R_1 is a substituted glycosyl group, wherein the glycosyl group comprises 1 to 6 substituents, wherein the substituent is C_{1-6} alkyl, C_{1-6} alkenyl, halogen, C_{1-6} alkyl halide, C_{1-6} alkoxy, amine, nitro, C_{1-6} alkyl amine, amide, azido, aryl, cycloalkyl, heterocycloalkyl, sulfite, or a substituted version thereof, or a combination thereof.
21. The pharmaceutical formulation of claim 1, wherein R_1 is selected from the group consisting of:

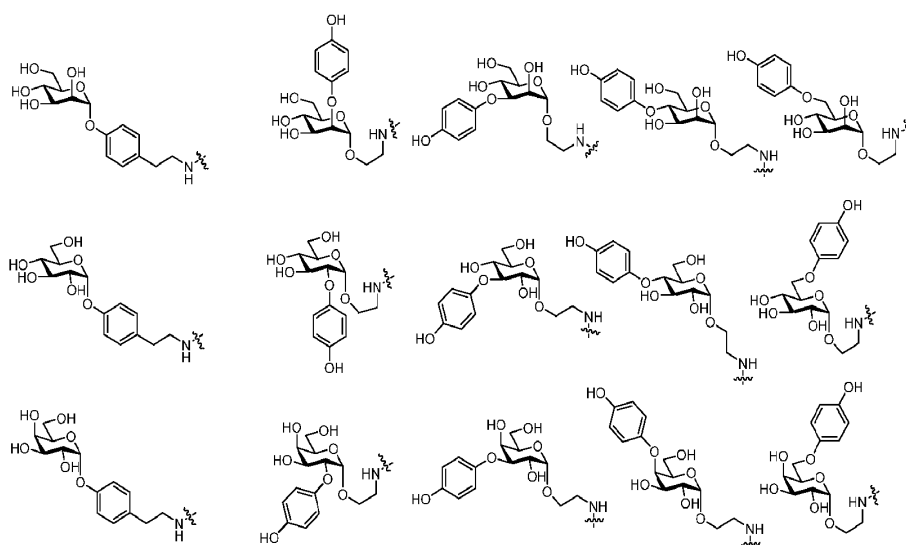




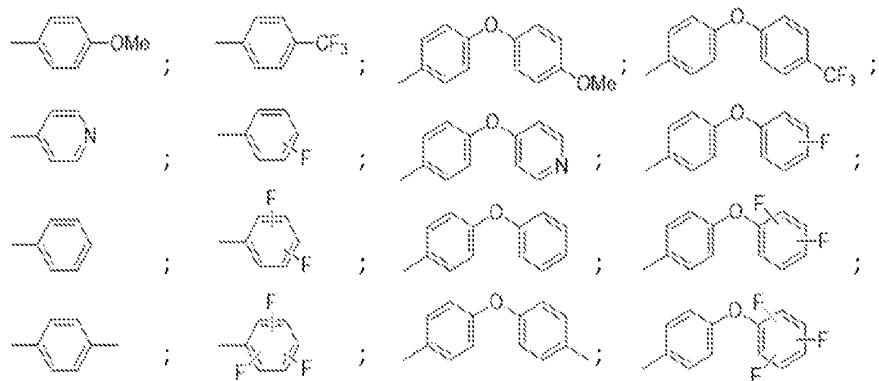
22. The pharmaceutical formulation of claim 1, wherein the compound is of Formula 3:



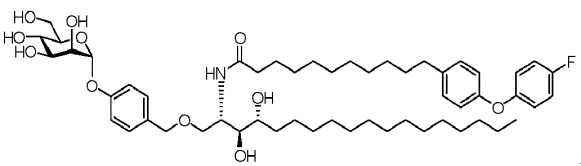
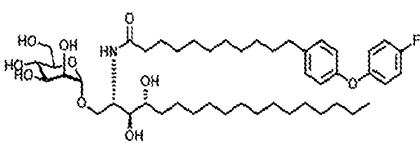
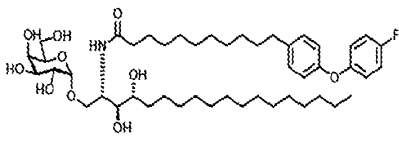
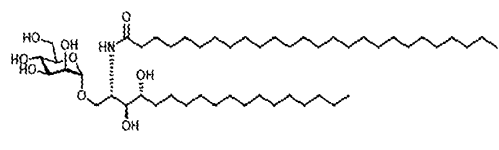
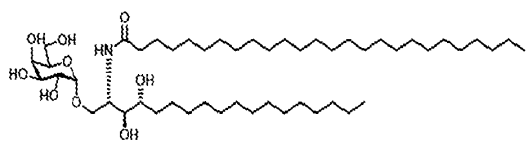
wherein R_1 is selected from the group consisting of:

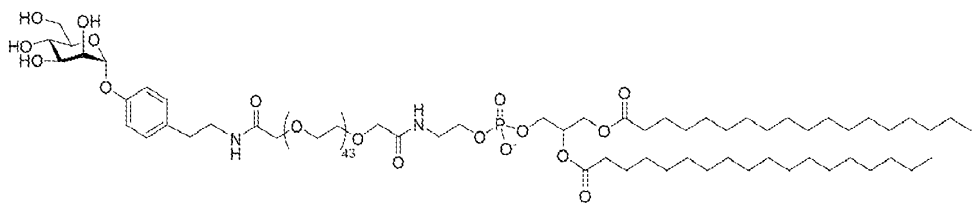
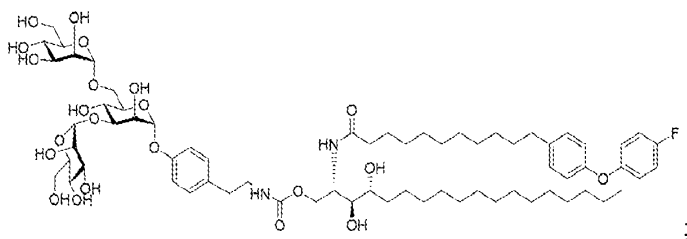
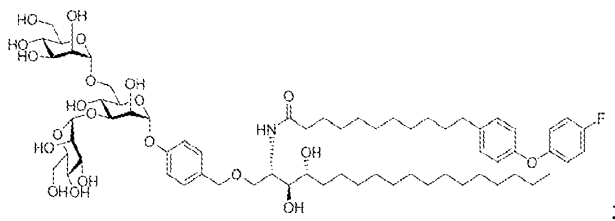
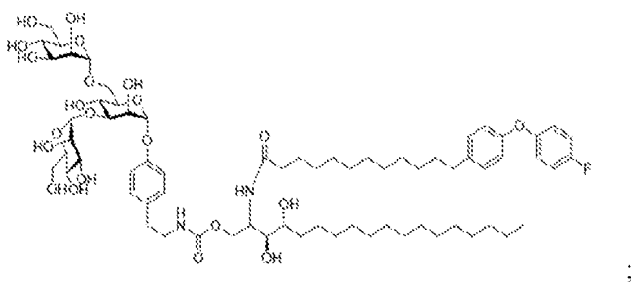
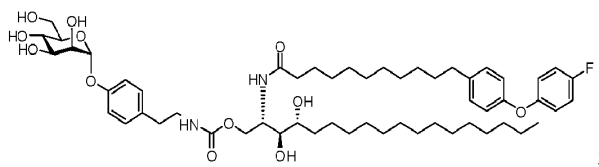
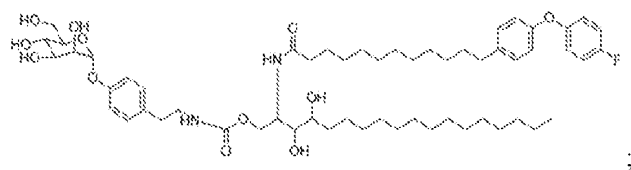


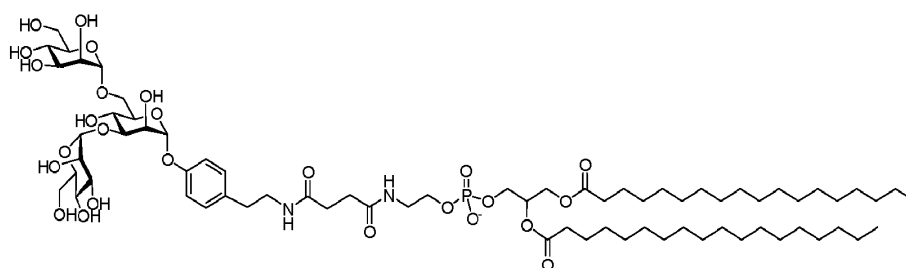
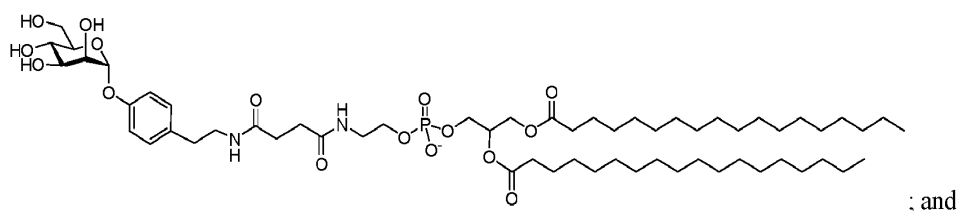
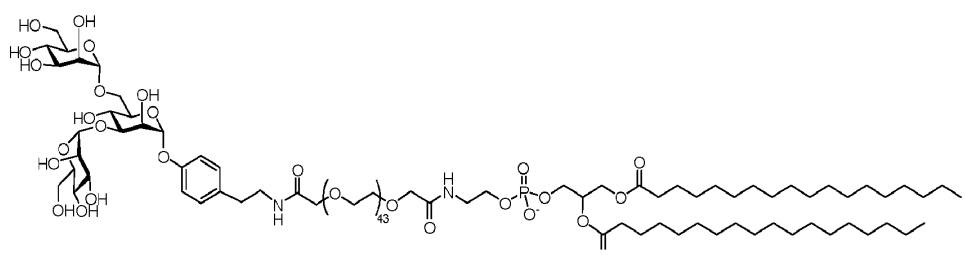
23. The pharmaceutical formulation of claim 1, wherein at least one of X_1 and X_2 comprises a saturated hydrocarbon chain, comprising at least 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 24, 26, 28, or 30 carbons.
24. The pharmaceutical formulation of claim 1, wherein X_1 and X_2 are each independently hydrogen, C_{4-30} alkyl, C_{4-30} alkenyl, C_{4-30} alkynyl, aryl, aryloxy, or a substituted version thereof, or $-(CH_2)_nX_4$, n is 4 to 30, and X_4 is hydrogen, aryl, aryloxy, heterocyclic group, or a substituted version thereof, provided that when X_4 is a heterocyclic group, the heterocyclic group comprises 1 to 3 heteroatoms, selected from the group consisting of O, S, and N, or a combination thereof.
25. The pharmaceutical formulation of claim 1, wherein X_4 is an aryl, aryloxy, heterocyclic group, cycloalkyl, heterocycloalkyl, or a combination thereof, and wherein X_4 comprises 0 to 6 substituents, selected from the group consisting of C_{1-6} alkyl, halogen, C_{1-6} alkyl halogen, and C_{1-6} alkoxy.
26. The pharmaceutical formulation of claim 25, wherein X_4 is $-R_3-O-R_4$, wherein R_3 and R_4 are each independently aryl, heterocyclic group, cycloalkyl, heterocycloalkyl, each comprising 0 to 6 substituents selected from the group consisting of C_{1-6} alkyl, halogen, C_{1-6} alkyl halogen, and C_{1-6} alkoxy.
27. The pharmaceutical formulation of claim 1, wherein X_4 is selected from the group consisting of:



28. The pharmaceutical formulation of any one of claims 1 to 27, wherein the compound is selected from the group consisting of:







29. The pharmaceutical formulation of claim 1, wherein the component is not glycolipid C34 or α -galactosylceramide.
30. The pharmaceutical formulation of claim 1, wherein the excipient comprises a solvent, dispersion media, diluent, dispersion, suspension aid, surface active agent, isotonic agent, thickening or emulsifying agent, preservative, polymer, peptide, protein, cell, hyaluronidase, or mixtures thereof.
31. The pharmaceutical formulation of claim 1, further comprising an adjuvant, wherein the adjuvant comprises C34, Gluco-C34, 7DW8-5, C17, C23, C30, α -galactosylceramide, Aluminum salt, Squalene, MF59, or QS-21. Other examples of adjuvants in some vaccines that can be used in the composition of the present disclosure are aluminum hydroxide, aluminum phosphate, alum (potassium aluminum sulfate), mixed aluminum salts, Freund's complete adjuvant, Freund's

incomplete adjuvant, AS03 (GlaxoSmithKline), MF59 (Seqirus), and CpG 1018 (Dynavax), or a combination thereof.