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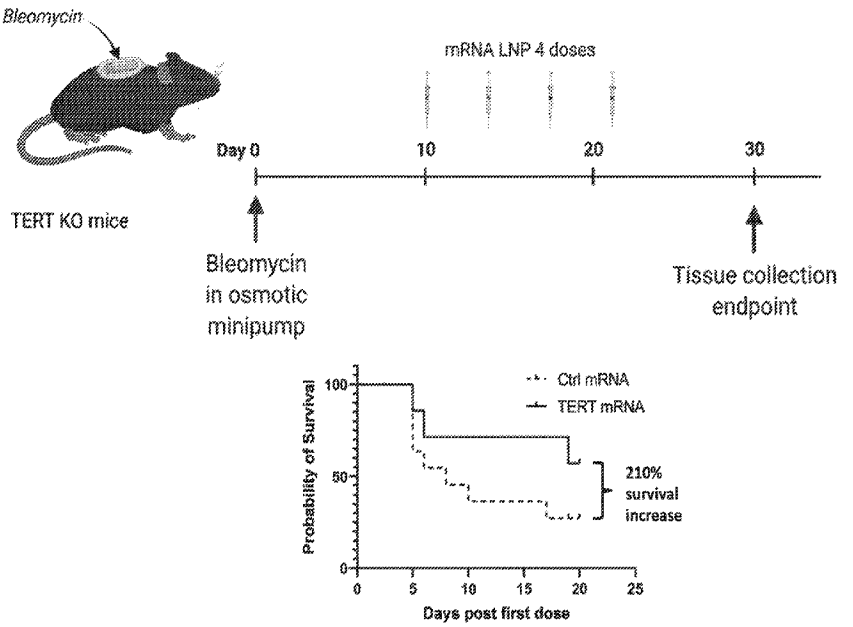
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(54) **Titre : COMPOSITIONS ET METHODES POUR L'ADMINISTRATION D'ARN**
(54) **Title: COMPOSITIONS AND METHODS FOR DELIVERY OF RNA**

FIG. 22



(57) **Abrégé/Abstract:**
The lipid nanoparticle compositions provided herein preferentially deliver and/or transfect the lung. Also provided herein are therapeutic polynucleotides, e.g. TERT mRNA, which may be delivered with the LNP formulations for the treatment of lung disease and fibrosis.

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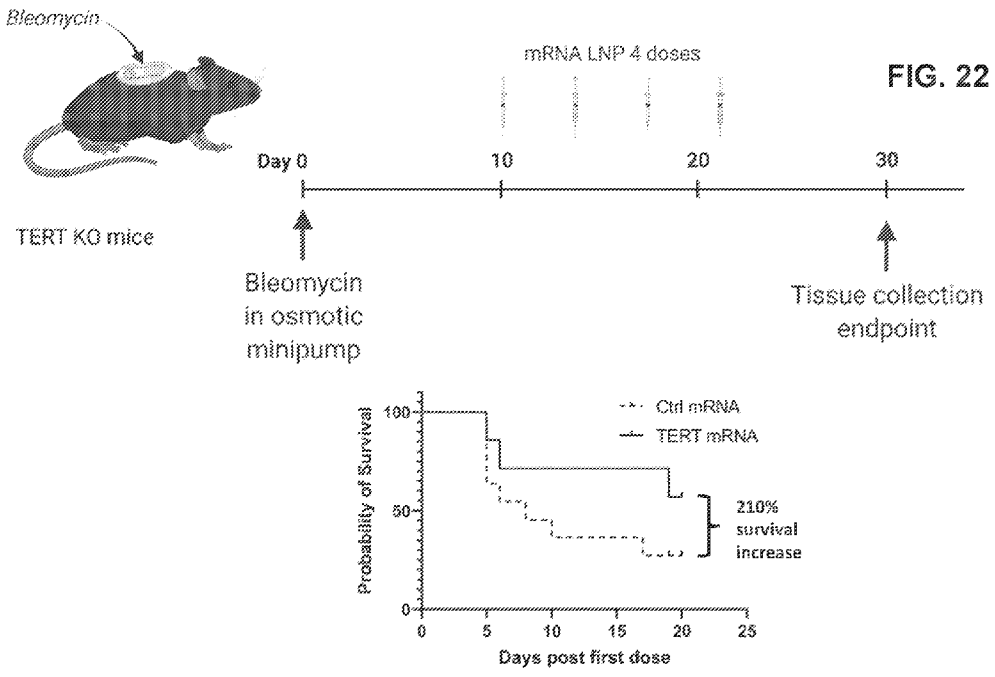


FIG. 22

(57) Abstract: The lipid nanoparticle compositions provided herein preferentially deliver and/or transfect the lung. Also provided herein are therapeutic polynucleotides, *e.g.* TERT mRNA, which may be delivered with the LNP formulations for the treatment of lung disease and fibrosis.

WO 2022/212576 A1

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WO 2022/212576 A1

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COMPOSITIONS AND METHODS FOR DELIVERY OF RNA

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of U.S. Provisional Patent Application No. 63/169,118, filed on March 31, 2021, the disclosure of which is hereby incorporated by reference in its entirety.

INCORPORATION OF THE SEQUENCE LISTING

[0002] The contents of the text file named "REJU_005_01WO_SeqList_ST25.txt," which was created on March 29, 2022 and is 205 KB in size, are hereby incorporated by reference in their entirety.

FIELD OF THE DISCLOSURE

[0003] The present disclosure relates generally to compositions and methods for delivery of ribonucleic acid (RNA) therapies in the treatment of lung and fibrotic diseases.

BACKGROUND

[0004] Numerous lung diseases have been identified for which there is no current treatment. Lung diseases, *e.g.*, pulmonary fibrosis, interstitial lung disease, and lung cancer, often induce fibrosis as part of disease progression, which further limits the extent to which patient recovery can occur. Delivery of polynucleotides to the lung for the treatment of lung disease are one method of treatment in development; however, the compositions and methods for delivery of these treatments are in need of improvement, and no treatment has been developed for treating the resulting fibrosis.

[0005] Thus, there remains a need in the art for delivery formulations capable of delivering polynucleotides, *e.g.*, mRNAs, to the lung which treat lung disease and/or lung fibrosis. The following disclosure addresses this need.

SUMMARY

[0006] Provided herein are delivery vehicles and compositions thereof for delivery of mRNA to lung cells at high transfection rates. In some embodiments, the mRNA is delivered to lung cells with a low toxicity. In some embodiments, the lung cells include lung alveolar epithelium and vascular endothelium, and the delivery vehicles disclosed herein are useful for delivery of mRNA useful for the treatment or prevention of lung diseases and disorders. In

some embodiments, the mRNA delivered to lung cells encodes a protein useful for treatment of a lung disease or disorder. In some embodiments, the mRNA encodes a TERT protein. In some embodiments, the protein is an antigen of a pathogen. In some embodiments, the lung diseases and disorder include, but are not limited to: pulmonary fibrosis, idiopathic pulmonary fibrosis, emphysema, interstitial lung diseases, chronic obstructive pulmonary disease (COPD), a lung infection, pneumonia, tuberculosis, gastric reflux, lung cancer, cystic fibrosis, dyskeratosis congenita, Alpha-1 antitrypsin deficiency, and other acquired or genetic diseases of the lung. The disclosure relates to telomerase reverse transcriptase (TERT) messenger ribonucleic acid (mRNA) therapies for the treatment of fibrotic diseases and conditions, *e.g.* of the lung, and lung diseases and conditions. Treatment with compositions comprising TERT mRNA may prevent, reverse or treat fibrosis and other pathological features of fibrotic disease and/or lung disease leading to improvements in overall organ function and subject health. Accordingly, in some embodiments, provided herein are compositions comprising one or more synthetic messenger ribonucleic acids (mRNAs) encoding telomerase reverse transcriptase (TERT).

[0007] In some embodiments, the composition comprises: (i) a ribonucleic acid (RNA) encoding telomerase reverse transcriptase (TERT) and (ii) a delivery vehicle, wherein the RNA encoding TERT comprises one or more modified nucleotides and wherein the delivery vehicle of (ii) is operably-linked to the RNA encoding TERT.

[0008] In some embodiments of the compositions of the disclosure, the delivery vehicle comprises one or more of a nanoparticle, a liposome, a cationic lipid, an exosome, an extracellular vesicle, a lipid nanoparticle, a natural lipoprotein particle, and an artificial lipoprotein particle.

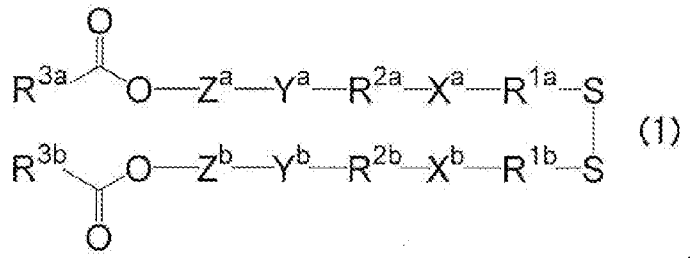
[0009] Provided herein are lipid nanoparticle particle (LNP) capable of transfecting at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, or at least 95% of a population of lung cells.

[0010] In some embodiments of the compositions of the disclosure, the delivery vehicle comprises a lipid nanoparticle (LNP). In some embodiments, the delivery vehicle comprises a cationic lipid.

[0011] In some embodiments, the delivery vehicle comprises a targeting moiety. In some embodiments, the targeting lipid results in the delivery vehicle specifically or selectively interacting with a lung cell. In some embodiments, the targeting moiety comprises cholesterol. In some embodiments, the targeting moiety is a lipid which specifically or selectively interacts with a lung cell. In some embodiments, the targeting lipid comprises 1,2-dioleoyl-3-

trimethylammonium-propane (DOTAP), N,N-distearyl-N,N-dimethylarnmonium bromide (DABB), or 1,2-dimyristoyl-sn-glycero-3-ethylphosphocholine (EPC).

[0012] In some embodiments of the compositions of the disclosure, including those in which the delivery vehicle is a lipid nanoparticle (LNP), the delivery vehicle comprises a compound of Formula I:

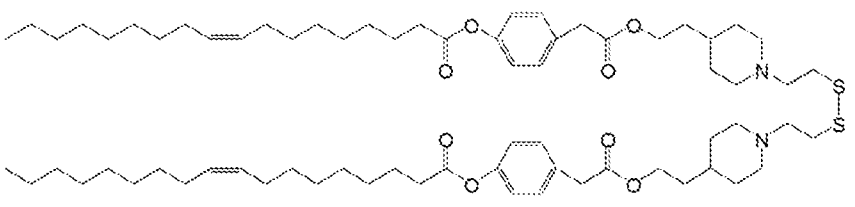


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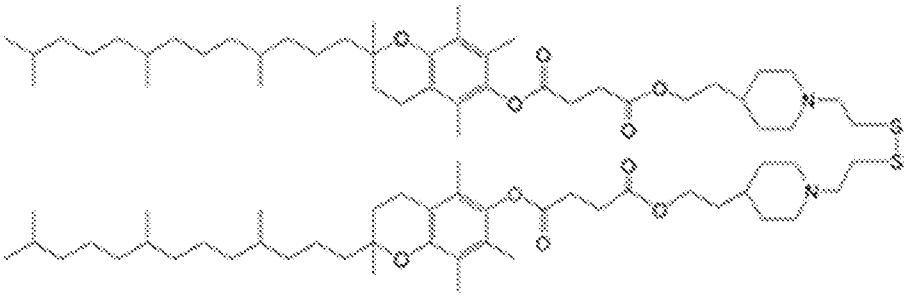
wherein R^{1a} and R^{1b} each independently represents an alkylene group having 1 to 6 carbon atoms, wherein X^a and X^b are each independently an acyclic alkyl tertiary amino group having 1 to 6 carbon atoms and 1 tertiary amino group, or 2 to 5 carbon atoms, and A cyclic alkylene tertiary amino group having 1 to 2 tertiary amino groups, wherein R^{2a} and R^{2b} each independently represent an alkylene group having 8 or less carbon atoms or an oxydialkylene group, wherein Y^a and Y^b each independently represent an ester bond, an amide bond, a carbamate bond, an ether bond or a urea bond; wherein Z^a and Z^b are each independently a divalent group derived from an aromatic compound having 3 to 16 carbon atoms, having at least one aromatic ring, and optionally having a hetero atom, and wherein R^{3a} and R^{3b} each independently represent a residue derived from a reaction product of a fat-soluble vitamin having a hydroxyl group and succinic anhydride or glutaric anhydride, or a sterol derivative having a hydroxyl group and succinic anhydride or a residue derived from a reaction product with glutaric anhydride or an aliphatic hydrocarbon group having 12 to 22 carbon atoms.

[0013] In some embodiments of the compositions of the disclosure, including those in which the delivery vehicle is a lipid nanoparticle (LNP), the compound of Formula I is:

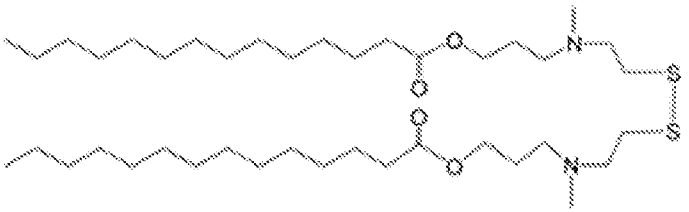


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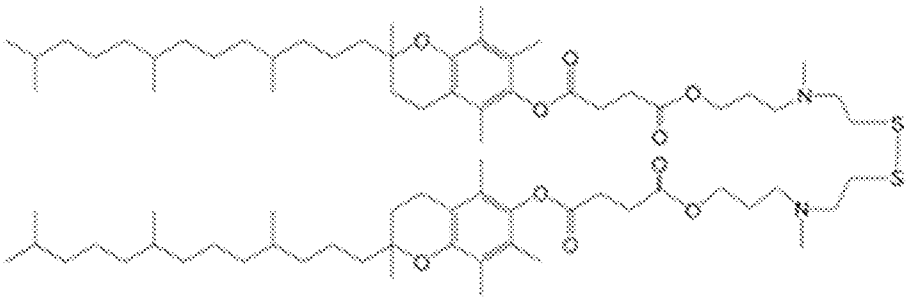
[0014] In some embodiments of the compositions of the disclosure, including those in which the delivery vehicle is a lipid nanoparticle (LNP), the compound of Formula I is:



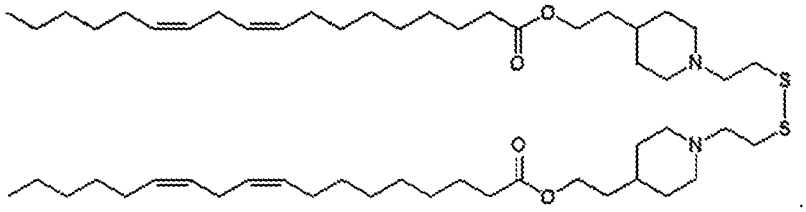
[0015] In some embodiments of the compositions of the disclosure, including those in which the delivery vehicle is a lipid nanoparticle (LNP), the compound of Formula I is:



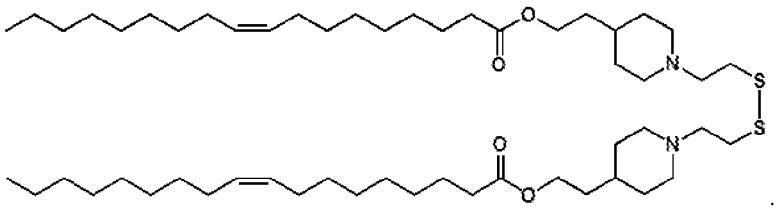
[0016] In some embodiments of the compositions of the disclosure, including those in which the delivery vehicle is a lipid nanoparticle (LNP), the compound of Formula I is:



[0017] In some embodiments of the compositions of the disclosure, including those in which the delivery vehicle is a lipid nanoparticle (LNP), the compound of Formula I is:



[0018] In some embodiments of the compositions of the disclosure, including those in which the delivery vehicle is a lipid nanoparticle (LNP), the compound of Formula I is:



[0019] In some embodiments, the RNA comprise a sequence of SEQ ID NOS: 1-5, 30-31, or 37-40, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0020] In some embodiments of the compositions of the disclosure, including those in which the delivery vehicle is a lipid nanoparticle (LNP), the RNA comprises a 5′ cap. In some embodiments, the 5′cap comprises an anti-reverse cap analog (ARCA). In some embodiments, the ARCA comprises an 3′-O-Me-m7G(5′)ppp(5′)G structure. In some embodiments, the 5′ cap comprises m7G(5′)ppp(5′)(2′OMeA)pG. In some embodiments, the 5′ cap comprises m7(3′OMeG)(5′)ppp(5′)(2′OMeA)pG.

[0021] In some embodiments of the compositions of the disclosure, including those in which the delivery vehicle is a lipid nanoparticle (LNP), the RNA further comprises at least one untranslated region (UTR). The UTR may comprise a sequence of SEQ ID NOs: 32-36, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto. In some embodiments, the at least one UTR is positioned 5′ to the RNA encoding TERT. In some embodiments, the at least one UTR is positioned 3′ to the RNA encoding TERT. In some embodiments, the UTR comprises a human sequence. In some embodiments, the UTR comprises a non-human or synthetic sequence. In some embodiments, the UTR comprises a chimeric sequence. In some embodiments, the UTR increases stability, increases half-life, increases a transcription rate or decreases a time until initiation of transcription of the RNA encoding TERT. In some embodiments, the UTR comprises a sequence having at least 70% identity to a UTR sequence isolated or derived from one or more of α-globin, β-globin, c-fos, and a tobacco etch virus.

[0022] In some embodiments of the compositions of the disclosure, including those in which the delivery vehicle is a lipid nanoparticle (LNP), the one or more modified nucleotides of the RNA encoding TERT comprise one or more of a modified adenine or analog thereof, a modified cytidine or analog thereof, a modified guanosine or analog thereof, and a modified uridine or analog thereof. In some embodiments, the one or more modified nucleotides of the RNA encoding TERT comprise one or more of 1-methylpseudouridine also known as N1-Methylpseudouridine, pseudouridine (N1m), 2-thiouridine, and 5-methylcytidine. In some embodiments, the one or more modified nucleotides of the RNA encoding TERT comprise 5-methoxyuridine (5-moU). In some embodiments, the one or more modified nucleotides of the RNA encoding TERT comprise one or more of m1A 1-methyladenosine, m6A N6-

methyladenosine, Am 2′-O-methyladenosine, i6A N6-isopentenyladenosine, io6A N6-(cis-hydroxyisopentenyl)adenosine, ms2io6A 2-methylthio-N6-(cis-hydroxyisopentenyl) adenosine, g6A N6-glycinylcarbamoyladenosine, t6A N6-threonylcarbamoyladenosine, ms2t6A 2-methylthio-N6-threonyl carbamoyladenosine, Ar(p) 2′-O-ribosyladenosine (phosphate), m6 2A N6,N6-dimethyladenosine, m6Am N6,2′-O-dimethyladenosine, m6 2Am N6,N6,2′-O-trimethyladenosine, m1Am 1,2′-O-dimethyladenosine, m3C 3-methylcytidine, m5C 5-methylcytidine, Cm 2′-O-methylcytidine, ac4C N4-acetylcytidine, f5C 5-formylcytidine, m4C N4-methylcytidine, hm5C 5-hydroxymethylcytidine, f5Cm 5-formyl-2′-O-methylcytidine, m1G 1-methylguanosine, m2G N2-methylguanosine, m7G 7-methylguanosine, Gm 2′-O-methylguanosine, m2 2G N2,N2-dimethylguanosine, Gr(p) 2′-O-ribosylguanosine (phosphate), yW wybutosine, o2yW peroxywybutosine, OHyW hydroxywybutosine, OHyW* undermodified hydroxywybutosine, imG wyosine, m2,7G N2,7-dimethylguanosine, m2,2,7G N2,N2,7-trimethylguanosine I inosine, m1I 1-methylinosine, Im 2′-O-methylinosine, Q queuosine, galQ galactosyl-queuosine, manQ mannosyl-queuosine, Ψ pseudouridine, D dihydrouridine, m5U 5-methyluridine, Um 2′-O-methyluridine, m5Um 5,2′-O-dimethyluridine, m1Ψ 1-methylpseudouridine, Ψm 2′-O-methylpseudouridine, s2U 2-thiouridine, ho5U 5-hydroxyuridine, chm5U 5-(carboxyhydroxymethyl)uridine, mchm5U 5-(carboxyhydroxymethyl)uridine, methyl ester mcm5U 5-methoxycarbonylmethyluridine, mcm5Um 5-methoxycarbonylmethyl-2′-O-methyluridine, mcm5s2U 5-methoxycarbonylmethyl-2-thiouridine, ncm5U 5-carbamoylmethyluridine, ncm5Um 5-carbamoylmethyl-2′-O-methyluridine, cmnm5U 5-carboxymethylaminomethyluridine, m3U 3-methyluridine, m1acp3Ψ 1-methyl-3-(3-amino-3-carboxypropyl) pseudouridine, cm5U 5-carboxymethyluridine, m3Um 3,2′-O-dimethyluridine, m5D 5-methyldihydrouridine, τm5U 5-taurinomethyluridine, τm5s2U 5-taurinomethyl-2-thiouridine, 2-Aminoadenosine, 2-Amino-6-chloropurineriboside, 8-Azaadenosine, 6-Chloropurineriboside, 5-Iodocytidine, 5-Iodouridine, Inosine, 2′-O-Methylinosine, Xanthosine, 4-Thiouridine, O6-Methylguanosine, 5,6-Dihydrouridine, 2-Thiocytidine, 6-Azacytidine, 6-Azauridine, 2′-O-Methyl-2-aminoadenosine, 2′-O-Methylpseudouridine, N1-Methyladenosine, 2′-O-Methyl-5-methyluridine, 7-Deazaguanosine, 8-Azidoadenosine, 5-Bromocytidine, 5-Bromouridine, 7-Deazaadenosine, 5-Aminoallyluridine, 5-Aminoallylcytidine, 8-Oxoguanosine, 2-Aminopurine-riboside, Pseudoisocytidine, N1-Methylpseudouridine, 5,6-Dihydro-5-Methyluridine, N6-Methyl-2-Aminoadenosine, 5-Carboxycytidine, 5-Hydroxymethyluridine, Thienoguanosine, 5-Hydroxycytidine, 5-Formyluridine, 5-Carboxyuridine, 5-Methoxyuridine, 5-Methoxycytidine, Thienouridine, 5-Carboxymethylesteruridine, Thienocytidine, 8-

Oxoadenoosine, Isoguanosine, N1-Ethylpseudouridine, N1-Methyl-2′-O-Methylpseudouridine, N1-Methoxymethylpseudouridine, N1-Propylpseudouridine, 2′-O-Methyl-N6-Methyladenosine, 2-Amino-6-Cl-purine-2′-deoxyriboside, 2-Amino-2′-deoxyadenosine, 2-Aminopurine-2′-deoxyriboside, 5-Bromo-2′-deoxycytidine, 5-Bromo-2′-deoxyuridine, 6-Chloropurine-2′-deoxyriboside, 7-Deaza-2′-deoxyadenosine, 7-Deaza-2′-deoxyguanosine, 2′-Deoxyinosine, 5-Propynyl-2′-deoxycytidine, 5-Propynyl-2′-deoxyuridine, 5-Fluoro-2′-deoxyuridine, 5-Iodo-2′-deoxycytidine, 5-Iodo-2′-deoxyuridine, N6-Methyl-2′-deoxyadenosine, 5-Methyl-2′-deoxycytidine, O6-Methyl-2′-deoxyguanosine, N2-Methyl-2′-deoxyguanosine, 8-Oxo-2′-deoxyadenosine, 8-Oxo-2′-deoxyguanosine, 2-Thiothymidine, 2′-Deoxy-P-nucleoside, 5-Hydroxy-2′-deoxycytidine, 4-Thiothymidine, 2-Thio-2′-deoxycytidine, 6-Aza-2′-deoxyuridine, 6-Thio-2′-deoxyguanosine, 8-Chloro-2′-deoxyadenosine, 5-Aminoallyl-2′-deoxycytidine, 5-Aminoallyl-2′-deoxyuridine, N4-Methyl-2′-deoxycytidine, 2′-Deoxyzebularine, 5-Hydroxymethyl-2′-deoxyuridine, 5-Hydroxymethyl-2′-deoxycytidine, 5-Propargylamino-2′-deoxycytidine, 5-Propargylamino-2′-deoxyuridine, 5-Carboxy-2′-deoxycytidine, 5-Formyl-2′-deoxycytidine, 5-[(3-Indolyl)propionamide-N-allyl]-2′-deoxyuridine, 5-Carboxy-2′-deoxyuridine, 5-Formyl-2′-deoxyuridine, 7-Deaza-7-Propargylamino-2′-deoxyadenosine, 7-Deaza-7-Propargylamino-2′-deoxyguanosine, Biotin-16-Aminoallyl-2′-dUTP, Biotin-16-Aminoallyl-2′-dCTP, Biotin-16-Aminoallylcytidine, N4-Biotin-OBEA-2′-deoxycytidine, Biotin-16-Aminoallyluridine, Dabcyl-5-3-Aminoallyl-2′-dUTP, Desthiobiotin-6-Aminoallyl-2′-deoxycytidine, Desthiobiotin-16-Aminoallyl-Uridine, Biotin-16-7-Deaza-7-Propargylamino-2′-deoxyguanosine, Cyanine 3-5-Propargylamino-2′-deoxycytidine, Cyanine 3-6-Propargylamino-2′-deoxyuridine, Cyanine 5-6-Propargylamino-2′-deoxycytidine, Cyanine 5-6-Propargylamino-2′-deoxyuridine, Cyanine 3-Aminoallylcytidine, Cyanine 3-Aminoallyluridine, Cyanine 5-Aminoallylcytidine, Cyanine 5-Aminoallyluridine, Cyanine 7-Aminoallyluridine, 2′-Fluoro-2′-deoxyadenosine, 2′-Fluoro-2′-deoxycytidine, 2′-Fluoro-2′-deoxyguanosine, 2′-Fluoro-2′-deoxyuridine, 2′-O-Methyladenosine, 2′-O-Methylcytidine, 2′-O-Methylguanosine, 2′-O-Methyluridine, Puromycin, 2′-Amino-2′-deoxycytidine, 2′-Amino-2′-deoxyuridine, 2′-Azido-2′-deoxycytidine, 2′-Azido-2′-deoxyuridine, Aracytidine, Arauridine, 2′-Azido-2′-deoxyadenosine, 2′-Amino-2′-deoxyadenosine, Araadenosine, 2′-Fluoro-thymidine, 3′-O-Methyladenosine, 3′-O-Methylcytidine, 3′-O-Methylguanosine, 3′-O-Methyluridine, 2′-Azido-2′-deoxyguanosine, Araguanosine, 2′-Deoxyuridine, 3′-O-(2-nitrobenzyl)-2′-Deoxyadenosine, 3′-O-(2-nitrobenzyl)-2′-Deoxyinosine, 3′-Deoxyadenosine, 3′-Deoxyguanosine, 3′-Deoxycytidine, 3′-Deoxy-5-Methyluridine, 3′-Deoxyuridine, 2′,3′-Dideoxyadenosine, 2′,3′-

Dideoxyguanosine, 2′,3′-Dideoxyuridine, 2′,3′-Dideoxythymidine, 2′,3′-Dideoxycytidine, 3′-Azido-2′,3′-dideoxyadenosine, 3′-Azido-2′,3′-dideoxythymidine, 3′-Amino-2′,3′-dideoxyadenosine, 3′-Amino-2′,3′-dideoxycytidine, 3′-Amino-2′,3′-dideoxyguanosine, 3′-Amino-2′,3′-dideoxythymidine, 3′-Azido-2′,3′-dideoxycytidine, 3′-Azido-2′,3′-dideoxyuridine, 5-Bromo-2′,3′-dideoxyuridine, 2′,3′-Dideoxyinosine, 2′-Deoxyadenosine-5′-O-(1-Thiophosphate), 2′-Deoxycytidine-5′-O-(1-Thiophosphate), 2′-Deoxyguanosine-5′-O-(1-Thiotriphosphate), 2′-Deoxythymidine-5′-O-(1-Thiophosphate), Adenosine-5′-O-(1-Thiophosphate), Cytidine-5′-O-(1-Thiophosphate), Guanosine-5′-O-(1-Thiophosphate), Uridine-5′-O-(1-Thiophosphate), 2′,3′-Dideoxyadenosine-5′-O-(1-Thiophosphate), 2′,3′-Dideoxycytidine-5′-O-(1-Thiophosphate), 2′,3′-Dideoxyguanosine-5′-O-(1-Thiophosphate), 3′-Deoxythymidine-5′-O-(1-Thiophosphate), 3′-Azido-2′,3′-dideoxythymidine-5′-O-(1-Thiophosphate), 2′,3′-Dideoxyuridine-5′-O-(1-Thiophosphate), 2′-Deoxyadenosine-5′-O-(1-Boranophosphate), 2′-Deoxycytidine-5′-O-(1-Boranophosphate), 2′-Deoxyguanosine-5′-O-(1-Boranophosphate), and 2′-Deoxythymidine-5′-O-(1-Boranophosphate).

[0023] In some embodiments of the compositions of the disclosure, including those in which the delivery vehicle is a lipid nanoparticle (LNP), the delivery vehicle comprises the RNA encoding TERT. In some embodiments, one or more of a surface, a layer or a volume of the delivery vehicle comprises the RNA encoding TERT. In some embodiments, the surface comprises an outer surface or an inner surface. In some embodiments, the layer comprises a lipid monolayer or lipid bi-layer. In some embodiments, the volume comprises an internal volume.

[0024] In some embodiments, the disclosure provides a composition comprising a (i) a ribonucleic acid (RNA) encoding telomerase reverse transcriptase (TERT) and (ii) a delivery vehicle, wherein the RNA encoding TERT comprises one or more modified nucleotides and wherein the delivery vehicle of (ii) is operably-linked to the RNA encoding TERT.

[0025] In some embodiments of the compositions of the disclosure, including those in which the delivery vehicle is a lipid nanoparticle (LNP), the composition further comprises a ribonucleic acid (RNA) encoding TElomerase RNA Component (TERC). In some embodiments, the delivery vehicle is operably-linked to a ribonucleic acid (RNA) encoding TElomerase RNA Component (TERC). In some embodiments, the delivery vehicle comprises the RNA encoding TERC. In some embodiments, one or more of a surface, a layer or a volume of the delivery vehicle comprises the RNA encoding TERC. In some embodiments, the surface comprises an outer surface or an inner surface. In some embodiments, the layer comprises a

lipid monolayer or lipid bi-layer. In some embodiments, the volume comprises an internal volume.

[0026] In some embodiments the RNA encoding TERT comprises a sequence of SEQ ID NOS: 1-5, 7, 9, 14-17, 19, 21, 23, 25, 27, 29-31, 37-40, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto. In some embodiments, the RNA encoding TERT comprises a UTR sequence of SEQ ID NOS: 32-34, 35, and 36, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0027] In some embodiments, the RNA comprises a self-replicating RNA. In some embodiments, the RNA comprises a circular RNA.

[0028] The disclosure provides a method of increasing telomerase activity in a cell, the method comprising contacting the cell and the composition of the disclosure. In some embodiments, the cell is in vivo, ex vivo or in vitro.

[0029] The disclosure provides a method of extending telomeres in a cell, the method comprising contacting the cell and the composition of the disclosure. In some embodiments, the cell is in vivo, ex vivo or in vitro.

[0030] The disclosure provides a cell comprising the composition of the disclosure.

[0031] The disclosure provides a formulation comprising the cell of the disclosure, which comprises a composition of the disclosure. In some embodiments of the formulation, a plurality of cells comprises a cell of the disclosure, which comprises a composition of the disclosure. In some embodiments of the formulation, each cell of the plurality is a cell of the disclosure, which comprises a composition of the disclosure.

[0032] The disclosure provides a method of treating a disease or disorder comprising administering to a subject an effective amount of a composition of the disclosure.

[0033] The disclosure provides a method of treating a disease or disorder comprising administering to a subject an effective amount of a cell of the disclosure, which comprises a composition of the disclosure.

[0034] The disclosure provides a method of treating a disease or disorder comprising administering to a subject an effective amount of a formulation of the disclosure.

[0035] The disclosure provides a method of delaying the onset of a disease comprising administering to a subject an effective amount of a composition of the disclosure.

[0036] The disclosure provides a method of delaying the onset of a disease comprising administering to a subject an effective amount of a cell of the disclosure, which comprises a composition of the disclosure.

[0037] The disclosure provides a method of delaying the onset of a disease comprising administering to a subject an effective amount of a formulation of the disclosure.

INCORPORATION BY REFERENCE

[0038] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] The novel features of the disclosure are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present disclosure will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the disclosure are utilized, and the accompanying drawings of which:

[0040] **FIG. 1** is a schematic illustrating long-term therapeutic benefit from transient, rapid telomere extension via telomerase reverse transcriptase (TERT) mRNA. In particular, the speed of telomere extension made possible by TERT mRNA treatment enables telomere maintenance by infrequent TERT mRNA dosing. The telomerase activity resulting from TERT mRNA delivery rapidly extends telomeres in a brief period, before the mRNA is turned over, thus allowing the protective anti-cancer mechanism of telomere-shortening to function most of the time. Between treatments, normal telomerase activity and telomere shortening is present, and therefore the anti-cancer safety mechanism of telomere shortening to prevent out-of-control proliferation remains intact, while the risk of short telomere-related disease remains low. In contrast, the best existing small molecule treatment for extending telomeres requires chronic delivery, and thus presents a chronic cancer risk, and even then has a small, inconsistent effect on telomere length, with no detectable effect on telomere length at all in about half of patients.

[0041] **FIG. 2** depicts a representative dynamic light scattering (DLS) plot of the mRNA-LNPs made using exemplary lipid components disclosed here.

[0042] **FIG. 3** depicts bioluminescent imaging of whole organs in mice that were injected with mRNA-LNPs.

[0043] **FIGS. 4A-4B** depict immunohistochemistry staining for tdTomato in lung cells from a mouse treated with an mRNA reporter (**FIG. 4A**) and an untreated control mouse (**FIG. 4B**).

[0044] **FIGS. 5A-5B** depict measurements of telomerase activity in mouse lung after delivery of TERT mRNA-LNP (**FIG. 5B**) and in mouse lung of an untreated control (**FIG. 5A**).

[0045] **FIG. 6A** is a bar graph depicting the transfection efficiency of an exemplary lung delivery vehicle formulation.

[0046] **FIGS. 6B-6F** depict representative images of lung sections harvested from the mice as described above, with the reporter protein shown as a darkened stain.

[0047] **FIGS. 7A-7C** depict computed tomography (CT) X-ray scans of mouse lungs tested for lung fibrosis. **FIG. 7D** is a bar graph quantifying the results shown in **FIGS. 7A-7C**.

[0048] **FIG. 8** depicts a graph showing the mortality of mice dosed with the formulation of Table 6A compared to other formulations of lung-targeted LNPs.

[0049] **FIGS. 9A-9D** depict various lung samples from mice treated with bleomycin for inducing lung fibrosis, and treated with CRE mRNA or saline to show delivery of the mRNA to alveolar cells.

[0050] **FIG. 10** shows the lung luminescence from intravenous (IV) and tracheal (OA) delivery of luciferase mRNA to the lung with SS-OP DOTAP and cKK DOTAP LNP formulations.

[0051] **FIG. 11** shows preferential delivery to the lung of the SS-OP DOTAP formulation administered intravenously. From left to right the LNP formulations of the dish are (1) SS-OP DOTAP 75:1 delivered orally; (2) SS-OP DOTAP 75:1 delivered intravenously; (3) PBS control (no LNP); and (4) cKK DOTAP 40:1 delivered orally.

[0052] **FIG. 12** shows the percentage of Tomato (+) cells in lung parenchyma with intravenous delivery of LNP formulations containing CRE mRNA.

[0053] **FIG. 13** shows lung luminescence relative to the flow rates used to formulate the LNP-compositions delivering firefly luciferase mRNA.

[0054] **FIG. 14** shows the ex vivo bioluminescence of the LNP formulations delivering luciferase RNA, wherein no structural lipid or cholesterol was required for RNA delivery.

[0055] **FIG. 15** shows the ex vivo lung mean radiance of LNP formulations delivering luciferase mRNA, wherein the RNA to LNP ratio was varied according to the ratios shown.

[0056] **FIG. 16** shows the ex vivo lung mean radiance of LNP formulations delivering luciferase mRNA, wherein the RNA to LNP ratio was varied according to the ratios shown, and no DOPC structural lipid was used in the formulation.

[0057] **FIGS. 17A** and **17B** show the ex vivo lung mean radiance of the LNP formulations delivering luciferase mRNA, wherein the percentage of PEGylated lipid is varied in the formulation.

[0058] **FIGS. 18A** and **18B** show the ex vivo lung mean radiance of the LNP formulations delivering luciferase mRNA, wherein the percentage of PEGylated lipid is below 1.5%, or not present in the formulation.

[0059] **FIG. 19** shows the ex vivo lung mean radiance of the LNP formulations delivering luciferase mRNA, wherein the percentage of DOTAP is varied in the formulation.

[0060] **FIGS. 20A** and **20B** show the ex vivo preferential delivery to lung of example LNP formulations, wherein the percentage of DOTAP is varied. **FIG. 20A** shows the liver mean radiance of the LNP formulations delivering luciferase mRNA according to the percentage of DOTAP. **FIG. 20B** shows the lung/liver delivery ratio of the LNP formulations according to the percentage of DOTAP.

[0061] **FIGS. 21A** and **21B** show transfection of the LNP formulations in alveolar epithelial cells. Shown are immunofluorescence staining of tdTomato expression, as induced in tomato fl/fl mice dosed with LNPs comprising Cre mRNA. AT1 and AT2 lung epithelial cell markers were also stained.

[0062] **FIG. 22** shows SS-OP DOTAP delivery of a therapeutic mRNA as a disease treatment, using the SS-OP DOTAP LNPs of Table 6A, comprising TERT mRNA. The LNP TERT mRNA formulations were delivered to a lung fibrosis model mouse, induced by bleomycin at Day 0. Relative to the control mRNA, delivery of the TERT mRNA extended the survival rate of the mouse by 210% at the endpoint.

DETAILED DESCRIPTION

[0063] The compositions and methods of the disclosure provide lipid nanoparticles (LNP) comprising an SS-OP lipid, or analog thereof, such as the compounds of Formula I described herein, and a cationic lipid for intravenous delivery to the lung, *e.g.*, for the treatment of lung disease and/or lung fibrosis. In some variations the SS-OP lipid or analog thereof may be replaced or combined with a cKK lipid or analog thereof. As disclosed herein, the aforementioned LNPs may have improved lung transduction efficiency and/or lung specificity compared to known LNP formulations.

[0064] Also provided herein are ribonucleic acids (RNA) encoding telomerase reverse transcriptase (TERT) to be delivered to the lung to treat, for example, lung fibrosis. The RNA encoded TERT may optionally be delivered with the aforementioned SS-OP LNP compositions, or with other LNPs known in the art.

[0065] Telomerase reverse transcriptase (TERT) is an enzyme known to maintain and extend chromosomal ends (telomeres). The TERT enzyme is a catalytic subunit of the ribonucleoprotein telomerase. TERT adds simple sequence repeats to telomeres by copying a template sequence 5′-GGTTAG-3′ within the RNA component of telomerase. This addition of repetitive deoxyribonucleic acid (DNA) sequences helps slow telomere shortening, which occurs over time, *e.g.,* due to incomplete DNA replication during mitosis.

[0066] TERT translocates between the nucleus and cytoplasm and has been shown to be a critical factor in a number of other biological processes, including cell proliferation and cancer metastasis. Thus, the level of TERT in the nucleus may be a critical step in regulating cell and organismal health.

[0067] Telomerase reverse transcriptase (TERT) is also known in the art as TRT, cutaneous malignant melanoma 9 (CMM9), dyskeratosis congenita autosomal dominant 2 (DKCA2), autosomal recessive dyskeratosis congenita-4 (DKCB4), human ever shorter telomeres 2 (HEST2), pulmonary fibrosis/bone marrow failure telomere related 1 (PFBMFT1), telomerase catalytic subunit (TCS1), and telomerase associated protein 2 (TP2).

[0068] In some embodiments, the treatments described herein may stop, slow, or reverse progression of a fibrotic disease, *e.g.,* a lung disease, or other lung diseases.

[0069] TERT mRNA is transient and only requires a few hours to extend telomeres in human cells before being degraded. Therefore, TERT mRNA leaves the protective anti-cancer telomere shortening mechanism intact. The present disclosure provides compositions and methods for delivery of TERT mRNA and treatment of fibrotic diseases and lung diseases.

[0070] During normal aging, telomeres shorten by approximately 30–100 base pairs per year due to oxidation and incomplete DNA replication during S phase of the cell cycle (Kurenova EV, *et al.* Telomere functions. A review. Biochemistry (Mosc) 1997; 62:1242-53). Telomerase, consisting of the TERT protein and a polynucleotide template (TERC), extends telomeres, but in humans, it is inactive in most somatic cell types and is only active at low levels that are insufficient to prevent net telomere shortening in many progenitor cell types. The exception is the spermatogenic lineage, in which telomerase is active enough to maintain telomere length over the human lifespan (Takubo K, Aida J, Izumiyama-

Shimomura N, et al. Changes of telomere length with aging. Geriatric Gerontology Int 2010; 10 Suppl 1:S197-206). As the TERC component is present at high levels in all cell types, typically over 10,000 copies per cell, TERT is the limiting component. Because short telomeres limit the proliferative and regenerative capacities of cells, they are associated with aging, early death, and a vast number of diseases and conditions.

[0071] Telomeres comprise repetitive DNA sequences at the ends of linear chromosomes that, when sufficiently long, can allow each chromosome end to form a loop that protects the ends from acting as double-stranded or single-stranded DNA breaks. Telomeres can shorten over time, due in part to oxidative damage and incomplete DNA replication, eventually leading to critically short telomeres unable to form the protective loop, exposure of the chromosome ends, chromosome-chromosome fusions, DNA damage responses, and cellular senescence, apoptosis, or malignancy.

[0072] Telomere length maintenance can play a role in preventing cellular senescence and apoptosis and resulting cellular and organ dysfunction. In many diseases, the need for cell replication to replace cells damaged or killed by the underlying disease mechanism shortens telomeres more rapidly than normal, exhausting the replicative capacity of cells, and leading to tissue dysfunction, exacerbated or additional symptoms, disability, or death. Further, genetic mutations of telomerase enzyme (TERT) can be linked to fatal inherited diseases of inadequate telomere maintenance, including dyskeratosis congenita and forms of lung fibrosis, lung disease and aplastic anemia. Chromosome-chromosome fusions and cellular senescence due to short telomeres can increase risk of cancer. Short telomeres are also associated with deleterious conditions and diseases of aging and poor outcomes in a large number of diseases. Lung diseases contributing to lung fibrosis include but are not limited to: pulmonary fibrosis, lung cancer, familial pulmonary fibrosis, idiopathic pulmonary fibrosis, pulmonary fibrosis associated with dyskeratosis congenita, an interstitial lung disease, pneumonia, interstitial pneumonia, tuberculosis, bronchitis, emphysema, lung cancer, chronic obstructive pulmonary disease (COPD), aging-associated fibrosis, pulmonary hypertension, asthma, and cystic fibrosis.

[0073] The prospect of preventing, delaying, or treating dysfunction, conditions, and diseases by telomere extension motivates a need for safe and effective treatments to extend telomeres in animal cells in vivo and/or in vitro, and safe and effective compositions and methods for delivering therapies to the animal cells to extend telomeres. Further, there is a need to safely and rapidly extend telomeres in cells for use in cell therapy, cell and tissue engineering, and regenerative medicine. At the same time, however, there can be a danger in

the constitutive, as opposed to transient, activation of telomerase activity. Indeed, for cell therapy applications, there is a need to avoid cell immortalization. To this end, transient, rather than constitutive, telomerase activity can be advantageous for safety, *e.g.*, if the elevated telomerase activity is not only brief but extends telomeres rapidly enough that the treatment does not need to be repeated continuously.

[0074] Thus, there is need for therapies that safely extend telomeres to potentially prevent, delay, ameliorate, or treat these and other conditions and diseases, to do the same for the gradual decline in physical form and function and mental function that accompanies chronological aging, and to enable cell therapies and regenerative medicine. Furthermore, there is need for improved methods of delivering these therapies, *e.g.*, nucleic acid molecules encoding telomerase, to cells.

[0075] Unless otherwise defined herein, scientific and technical terms used in this application shall have the meanings that are commonly understood by those of ordinary skill in the art. Generally, nomenclature used in connection with, and techniques of, chemistry, molecular biology, cell and cancer biology, immunology, microbiology, pharmacology, and protein and nucleic acid chemistry, described herein, are those well-known and commonly used in the art.

[0076] As used herein and in the appended claims, the singular forms "a," "and," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a drug candidate" refers to one or mixtures of such candidates, and reference to "the method" includes reference to equivalent steps and methods known to those skilled in the art, and so forth.

[0077] As used herein, the term "approximately" or "about," as applied to one or more values of interest, refers to a value that is similar in magnitude and/or within a similar range to a stated reference value. In certain embodiments, the term "approximately" or "about" may refer to a range of values that fall within 25%, 20%, 19%, 18%, 17%, 16%, 15%, 14%, 13%, 12%, 11%, 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, 1%, or less in either direction (greater than or less than) of the stated reference value unless otherwise stated or otherwise evident from the context (except where such number would exceed 100% of a possible value).

[0078] Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictates otherwise, between the upper and lower limit of that range and any other stated or intervening value in that stated range is encompassed within the disclosure. The upper and lower limits of these smaller ranges may independently be included in the smaller ranges is also encompassed within the disclosure,

subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the disclosure.

[0079] "G," "C," "A," "T" and "U" generally stand for the bases, guanine, cytosine, adenine, thymidine and uracil, respectively. Nucleobases can form nucleosides by the addition of a five carbon sugar. If the sugar is ribose then the nucleoside is a ribonucleoside. Nucleosides can in turn form nucleotides by the addition of one or more linker groups such as phosphate groups. Nucleotides can in turn form polymers (polynucleotides) which include short polymers (oligonucleotides). However, it will be understood that the terms "base", "nucleobase", "nucleoside", "ribonucleoside", "nucleotide", "ribonucleotide" can also refer to a modified base, nucleobase, nucleoside, ribonucleoside, nucleotide, or ribonucleotide, as further detailed below, or a surrogate replacement moiety (see, *e.g.*, Table 2 and elsewhere herein). The skilled person is well aware that guanine, cytosine, adenine, thymidine, uracil can be replaced by other moieties without substantially impairing one or more of certain properties (such as base pairing properties, translatability, or protein binding properties) of an oligonucleotide or polynucleotide comprising a nucleotide bearing such replacement moiety. Sequences containing such replacement moieties are suitable for the compositions and methods featured in the disclosure. Similarly, the skilled person is well aware that ribose can be replaced with other moieties without impairing certain properties (such as base pairing properties, translatability, or protein binding properties) of an oligonucleotide or polynucleotide comprising a nucleotide bearing such replacement moiety. Sequences containing such replacement moieties are suitable for the compositions and methods featured in the disclosure. Similarly, the skilled person is well aware that phosphate can be replaced with other moieties without impairing certain properties (such as base pairing properties, translatability, or protein binding properties) of an oligonucleotide or polynucleotide comprising a nucleotide bearing such replacement moiety. Sequences containing such replacement moieties are suitable for the compositions and methods featured in the disclosure.

[0080] As used herein, the terms "polypeptide," "peptide," and "protein" refer to polymers of amino acids of any length. The terms also encompass an amino acid polymer that has been modified; for example, to include disulfide bond formation, glycosylation, lipidation, phosphorylation, or conjugation with a labeling component.

[0081] As used herein, the terms "identity" and "identical" refer, with respect to a polypeptide or polynucleotide sequence-of-interest, to the percentage of exact matching residues in an alignment of that the sequence-of-interest to a reference sequence, such as an

alignment generated by the BLAST algorithm. Identity is calculated, unless specified otherwise, across the full length of the reference sequence. Thus a sequence-of-interest "shares at least x% identity to" a reference sequence if, when the reference sequence is aligned (as a query sequence) is aligned to the sequence-of-interest (as subject sequence), at least x% (rounded down) of the residues in the subject sequence are aligned as an exact match to a corresponding residue in the query sequence, the denominator being the full length of the reference sequence plus the lengths of any gaps inserted into the reference sequence by alignment of the reference sequence to the sequence-of-interest. Where the subject sequence has variable positions (*e.g.*, residues denoted X), an alignment to any residue in the query sequence is counted as a match. Sequence alignments may be performed using the NCBI Blast service (BLAST+ version 2.12.0) or another program giving the same results.

[0082] The term "native" or "wild-type" as used herein refers to a nucleotide sequence, *e.g.* gene, or gene product, *e.g.* RNA or polypeptide, that is present in a wild-type cell, tissue, organ or organism. The term "variant" as used herein refers to a mutant of a reference polynucleotide or polypeptide sequence, for example a native polynucleotide or polypeptide sequence, *i.e.*, having less than 100% sequence identity with the reference polynucleotide or polypeptide sequence. Put another way, a variant comprises at least one nucleotide difference (*e.g.*, nucleotide substitution, nucleotide insertion, nucleotide deletion) or one amino acid difference (*e.g.*, amino acid substitution, amino acid insertion, amino acid deletion) relative to a reference polynucleotide sequence, *e.g.* a native polynucleotide or polypeptide sequence. For example, a variant may be a polynucleotide having a sequence identity of 50% or more, 60% or more, or 70% or more with a full length native polynucleotide sequence, *e.g.* an identity of 75% or 80% or more, such as 85%, 90%, or 95% or more, for example, 98% or 99% identity with the full length native polynucleotide sequence. As another example, a variant may be a polypeptide having a sequence identity of 70% or more with a full length native polypeptide sequence, *e.g.* an identity of 75% or 80% or more, such as 85%, 90%, or 95% or more, for example, 98% or 99% identity with the full length native polypeptide sequence. Variants may also include variant fragments of a reference, *e.g.* native, sequence sharing a sequence identity of 70% or more with a fragment of the reference, *e.g.* native, sequence, *e.g.* an identity of 75% or 80% or more, such as 85%, 90%, or 95% or more, for example, 98% or 99% identity with the native sequence.

[0083] As used herein, the term "codon optimized" refers to any process used to improve gene expression and increase the translational efficiency of a gene of interest by

accommodating the codon bias of the host organism, and/or to reduce the immunogenicity of the polynucleotide.

[0084] The terms "treating" or "treatment" are used herein to generally mean obtaining a desired pharmacologic and/or physiologic effect with a therapeutic agent. The effect may be prophylactic in terms of completely or partially preventing a disease or symptom thereof, *e.g.* reducing the likelihood that the disease or symptom thereof occurs in the subject, and/or may be therapeutic in terms of completely or partially reducing a symptom, or a partial or complete cure for a disease and/or adverse effect attributable to the disease. "Treatment" as used herein covers any treatment of a disease in a mammal, and includes: (a) preventing the disease from occurring in a subject which may be predisposed to the disease but has not yet been diagnosed as having it; (b) inhibiting or slowing the onset or development of the disease; or (c) relieving the disease, *e.g.*, causing regression of the disease or symptoms associated with the disease. The therapeutic agent may be administered before, during or after the onset of disease. The treatment of ongoing disease, where the treatment stabilizes or reduces the undesirable clinical symptoms of the patient, may be of particular interest. In some embodiments, treatment is performed prior to complete loss of function in the affected tissues. In some embodiments, the subject therapy will be administered before the symptomatic stage of the disease; and, in some embodiments, during the symptomatic stage of the disease; and, in some embodiments, after the symptomatic stage of the disease.

[0085] In some embodiments, therapies as described herein treat fibrotic diseases or lung diseases, including but not limited to fibrotic lung diseases.

[0086] The terms "individual," "subject," and "patient" are used interchangeably herein and refer to any subject for whom treatment or therapy is desired. The subject may be a mammalian subject. Mammalian subjects include, e. g., humans, non-human primates, rodents, (*e.g.*, rats, mice), lagomorphs (*e.g.*, rabbits), ungulates (*e.g.*, cows, sheep, pigs, horses, goats, and the like), etc. In some embodiments, the subject is a human. In some embodiments, the subject is a non-human primate, for example a cynomolgus monkey. In some embodiments, the subject is a companion or service animal (*e.g.* cats or dogs).

[0087] A subject "in need thereof," as used herein, refers to any subject suffering from or identified to be at risk of developing a fibrotic disease or lung disease.

[0088] It is to be understood that this disclosure is not limited to the particular methodology, products, apparatus and factors described, as such methods, apparatus and formulations may vary. It is also to be understood that the terminology used herein is for the

purpose of describing particular embodiments only, and it is not intended to limit the scope of the present disclosure which will be limited only by appended claims.

I. Synthetic mRNAs

[0089] A synthetic ribonucleic acid (RNA) as used herein may refer to any RNA sequence comprising a mutation (point or deletion) or additional nucleotides not found in the wild type sequence. For example, a synthetic TERT messenger RNA (mRNA) may refer to a wild type sequence encoding a human TERT sequence, flanked by the addition of 1, 2, 3, 10, 100 or more nucleotides. Similarly, the nucleotides themselves may encode amino acids distinct from the wild type, or be modified to reduce immunogenicity in the cell or tissue. An mRNA sequence in some embodiments may comprise any of the following modifications, including but not limited to an untranslated region (UTR), a 5′ cap, and a poly-adenosine tail. In some embodiments, the RNA may be circular and/or self-replicating.

[0090] Illustrative methods of making circular mRNAs are provided in Chen et al. *Science*. 1995 Apr 21;268(5209):415-7; Perriman R. (2002) Circular mRNA Encoding for Monomeric and Polymeric Green Fluorescent Protein. In: Hicks B.W. (eds) Green Fluorescent Protein. Methods in Molecular Biology, vol 183. Humana Press; Wang et al. *RNA*. 2015 Feb;21(2):172-9. doi: 10.1261/rna.048272.114. Epub 2014 Dec 1; Wesselhoeft et al. *Nat Commun.* 2018 Jul 6;9(1):2629; and Wesselhoeft et al. *Mol Cell.* 2019 May 2;74(3):508-520.e4. Illustrative methods of making self-replicating mRNAs are provided in Tews B.A., Meyers G. (2017) Self-Replicating RNA. In: Kramps T., Elbers K. (eds) RNA Vaccines. *Methods in Molecular Biology*, vol 1499. Humana Press; Leyman et al. *Mol Pharm.* 2018 Feb 5;15(2):377-384; and Huysmans et al. *Mol Ther Nucleic Acids.* 2019 Sep 6;17:388-395.

TERT mRNAs

[0091] In some embodiments, a composition may comprise a reverse transcriptase telomerase (TERT) mRNA sequence to treat one or more phenotypes or symptoms associated with a fibrotic disease or lung disease. In some embodiments, a TERT mRNA refers to an mRNA encoding any full length, functional fragment or portion of a TERT protein, including wild type sequences or variants thereof.

[0092] In some embodiments, a TERT mRNA may comprise a codon-optimized sequence. In some embodiments, a TERT mRNA may comprise a uridine depleted human TERT sequence. In some embodiments, the codon-optimized sequence may comprise SEQ ID NO: 1, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0093] In some embodiments, a TERT mRNA may comprise a mutant human TERT sequence. In some embodiments, the mutant human TERT mRNA may encode a Y707F mutation in the resulting peptide sequence. In some embodiments a mutation in the TERT mRNA sequence encodes a mutation in the nuclear export signal which may result in nuclear retention of the TERT peptide. In some embodiments, the mutant TERT mRNA sequence may comprise SEQ ID NO: 2, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0094] In some embodiments, a mouse TERT mRNA may comprise a codon-optimized sequence. In some embodiments, a TERT mRNA may comprise a uridine depleted mouse TERT sequence. In some embodiments, the codon-optimized sequence may comprise SEQ ID NO: 3, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0095] In some embodiments, a mouse TERT mRNA may comprise a mutant mouse TERT sequence. In some embodiments, the mutant mouse TERT mRNA may encode a Y707F mutation in the resulting peptide sequence. In some embodiments a mutation in the TERT mRNA sequence encodes a mutation in the nuclear export signal which may result in nuclear retention of the TERT peptide. In some embodiments, the mutant mouse TERT mRNA sequence may comprise SEQ ID NO: 4, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0096] In some embodiments, a mouse TERT mRNA may comprise a mutant mouse TERT sequence. In some embodiments, the mutant mouse TERT mRNA may encode a Y697F mutation in the resulting peptide sequence. In some embodiments a mutation in the TERT mRNA sequence encodes a mutation in the nuclear export signal which may result in nuclear retention of the TERT peptide. In some embodiments, the mutant mouse TERT mRNA sequence may comprise a sequence of SEQ ID NO: 5, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0097] The compositions of the disclosure may comprise a ribonucleic acid, *e.g.*, a synthetic ribonucleic acid coding for a telomerase reverse transcriptase (TERT), wherein telomeres are extended within a cell treated with the compound. The ribonucleic acids used in the transient expression of TERT can comprise a ribonucleic acid coding for a TERT protein. The ribonucleic acids can further comprise one or more sequences that affect the expression

and/or stability of the ribonucleic acid in a cell. For example, the ribonucleic acids can contain a 5′ cap and untranslated region (UTR) to the 5′ and/or 3′ side of the coding sequence. The ribonucleic acids may further contain a 3′ tail, such as a poly-A tail. The poly-A tail can, for example, increase the stability of the ribonucleic acid. In some embodiments, the poly-A tail comprises at least 25 nucleotides, at least 50 nucleotides, at least 75 nucleotides, at least 100 nucleotides, at least 125 nucleotides, at least 150 nucleotides, at least 200 nucleotides, at least 225 nucleotides, at least250 nucleotides. In some embodiments, the poly-A tail comprises between 1 and 25 nucleotides, between 25 and 50 nucleotides, between 50 and 75 nucleotides, between 75 and 100 nucleotides, between 100 and 125 nucleotides, between 125 and 150 nucleotides, between 150 and 175 nucleotides, between 175 and 200 nucleotides, between 200 and 225 nucleotides, or between 225 and 250 nucleotides, inclusive of the endpoints for each range. In some embodiments, the poly-A tail comprises between 100 and 200 nucleotides, inclusive of the endpoints.

[0098] In some embodiments, the 5′ cap of the ribonucleic acid is a non-immunogenic cap. In some embodiments, the 5′ cap may increase the translation of the ribonucleic acid. In some embodiments, the 5′ cap may be treated with phosphatase to modulate the innate immunogenicity of the ribonucleic acid. In some embodiments, the 5′ cap is an anti-reverse cap analog (“ARCA”), such as a 3′-O-Me-m7G(5′)ppp(5′)G RNA cap structure analog. In some embodiments, the 5′ cap is m7G(5′)ppp(5′)(2′OmeA)pG (also known as CleanCap© AG). In some embodiments, the 5′ cap is m7(3′OmeG)(5′)ppp(5′)(2′OmeA)pG (also known as CleanCap®AG (3′ OMe)).

[0099] The above features, or others, may increase translation of the TERT protein encoded by the ribonucleic acid, may increase or decrease the stability of the ribonucleic acid itself in a cell type-specific or cell type-independent manner, or may do both. In some embodiments, the 5′ UTR and/or the 3′ UTR are from a gene that has a very stable mRNA and/or an mRNA that is rapidly translated, for example, α-globin or β-globin, c-fos, or tobacco etch virus. In some embodiments, the 5′ UTR and 3′ UTR are from different genes or are from different species than the species into which the compositions are being delivered. The UTRs may also be assemblies of parts of UTRs from the mRNAs of different genes, where the parts are selected to achieve a certain combination of stability and efficiency of translation. The UTRs may also comprise designed sequences that confer properties to the RNA such as cell type-specific stability or cell type-independent stability.

[0100] The ribonucleic acids of the present disclosure may comprise one or more modified nucleosides, and/or comprise primary sequences of nucleosides, that modulate translation,

stability, or immunogenicity of the RNA. Most mature RNA molecules in eukaryotic cells contain nucleosides that are modified versions of the canonical unmodified RNA nucleosides, adenine, cytidine, guanosine, and uridine. For example, the 5′ cap of mature RNA comprises a modified nucleoside, and other modified nucleosides often occur elsewhere in the RNA. Those modifications may prevent the RNA from being recognized as a foreign RNA. Synthetic RNA molecules made using certain nucleosides are much less immunogenic than unmodified RNA. The immunogenicity can be reduced even further by purifying the synthetic mRNA, for example by using high performance liquid chromatography (HPLC). The modified nucleosides may be, for example, chosen from the nucleosides listed below. The nucleosides are, in some embodiments, pseudouridine, 1-methylpseudouridine, 2-thiouridine, 5-methoxyuridine, or 5-methylcytidine. The primary sequence may be modified in ways that increase or decrease immunogenicity. Under some circumstances, it may be desirable for the modified RNA to retain some immunogenicity.

[0101] Accordingly, in some embodiments, the ribonucleic acids of the instant compositions comprise a 1-methylpseudouridine, pseudouridine, a 5-methoxyuridine (5-moU), a 2-thiouridine, a 5-methylcytidine, or another modified nucleoside. Modified nucleosides found in eukaryotic cells include m1A 1-methyladenosine, m6A N6-methyladenosine, Am 2′-O-methyladenosine, i6A N6-isopentenyladenosine, io6A N6-(cis-hydroxyisopentenyl)adenosine, ms2io6A 2-methylthio-N6-(cis-hydroxyisopentenyl) adenosine, g6A N6-glycinylcarbamoyladenosine, t6A N6-threonylcarbamoyladenosine, ms2t6A 2-methylthio-N6-threonyl carbamoyladenosine, Ar(p) 2′-O-ribosyladenosine (phosphate), m6 2A N6,N6-dimethyladenosine, m6Am N6,2′-O-dimethyladenosine, m6 2Am N6,N6,2′-O-trimethyladenosine, m1Am 1,2′-O-dimethyladenosine, m3C 3-methylcytidine, m5C 5-methylcytidine, Cm 2′-O-methylcytidine, ac4C N4-acetylcytidine, f5C 5-formylcytidine, m4C N4-methylcytidine, hm5C 5-hydroxymethylcytidine, f5Cm 5-formyl-2′-O-methylcytidine, m1G 1-methylguanosine, m2G N2-methylguanosine, m7G 7-methylguanosine, Gm 2′-O-methylguanosine, m2 2G N2,N2-dimethylguanosine, Gr(p) 2′-O-ribosylguanosine (phosphate), yW wybutosine, o2yW peroxywybutosine, OhyW hydroxywybutosine, OhyW* undermodified hydroxywybutosine, imG wyosine, m2,7G N2,7-dimethylguanosine, m2,2,7G N2,N2,7-trimethylguanosine I inosine, m1I 1-methylinosine, Im 2′-O-methylinosine, Q queuosine, galQ galactosyl-queuosine, manQ mannosyl-queuosine, Ψ pseudouridine, D dihydrouridine, m5U 5-methyluridine, Um 2′-O-methyluridine, m5Um 5,2′-O-dimethyluridine, m1Ψ 1-methylpseudouridine, Ψm 2′-O-methylpseudouridine, s2U 2-thiouridine, ho5U 5-hydroxyuridine, chm5U 5-(carboxyhydroxymethyl)uridine, mchm5U 5-

(carboxyhydroxymethyl)uridine, methyl ester mcm5U 5-methoxycarbonylmethyluridine, mcm5Um 5-methoxycarbonylmethyl-2′-O-methyluridine, mcm5s2U 5-methoxycarbonylmethyl-2-thiouridine, ncm5U 5-carbamoylmethyluridine, ncm5Um 5-carbamoylmethyl-2′-O-methyluridine, cmnm5U 5-carboxymethylaminomethyluridine, m3U 3-methyluridine, m1acp3Ψ 1-methyl-3-(3-amino-3-carboxypropyl) pseudouridine, cm5U 5-carboxymethyluridine, m3Um 3,2′-O-dimethyluridine, m5D 5-methyldihydrouridine, τm5U 5-taurinomethyluridine, τm5s2U 5-taurinomethyl-2-thiouridine, 2-Aminoadenosine, 2-Amino-6-chloropurineriboside, 8-Azaadenosine, 6-Chloropurineriboside, 5-Iodocytidine, 5-Iodouridine, Inosine, 2′-O-Methylinosine, Xanthosine, 4-Thiouridine, O6-Methylguanosine, 5,6-Dihydrouridine, 2-Thiocytidine, 6-Azacytidine, 6-Azauridine, 2′-O-Methyl-2-aminoadenosine, 2′-O-Methylpseudouridine, N1-Methyladenosine, 2′-O-Methyl-5-methyluridine, 7-Deazaguanosine, 8-Azidoadenosine, 5-Bromocytidine, 5-Bromouridine, 7-Deazaadenosine, 5-Aminoallyluridine, 5-Aminoallylcytidine, 8-Oxoguanosine, 2-Aminopurine-riboside, Pseudoisocytidine, N1-Methylpseudouridine, 5,6-Dihydro-5-Methyluridine, N6-Methyl-2-Aminoadenosine, 5-Carboxycytidine, 5-Hydroxymethyluridine, Thienoguanosine, 5-Hydroxycytidine, 5-Formyluridine, 5-Carboxyuridine, 5-Methoxyuridine, 5-Methoxycytidine, Thienouridine, 5-Carboxymethylesteruridine, Thienocytidine, 8-Oxoadenoosine, Isoguanosine, N1-Ethylpseudouridine, N1-Methyl-2′-O-Methylpseudouridine, N1-Methoxymethylpseudouridine, N1-Propylpseudouridine, 2′-O-Methyl-N6-Methyladenosine, 2-Amino-6-Cl-purine-2′-deoxyriboside, 2-Amino-2′-deoxyadenosine, 2-Aminopurine-2′-deoxyriboside, 5-Bromo-2′-deoxycytidine, 5-Bromo-2′-deoxyuridine, 6-Chloropurine-2′-deoxyriboside, 7-Deaza-2′-deoxyadenosine, 7-Deaza-2′-deoxyguanosine, 2′-Deoxyinosine, 5-Propynyl-2′-deoxycytidine, 5-Propynyl-2′-deoxyuridine, 5-Fluoro-2′-deoxyuridine, 5-Iodo-2′-deoxycytidine, 5-Iodo-2′-deoxyuridine, N6-Methyl-2′-deoxyadenosine, 5-Methyl-2′-deoxycytidine, O6-Methyl-2′-deoxyguanosine, N2-Methyl-2′-deoxyguanosine, 8-Oxo-2′-deoxyadenosine, 8-Oxo-2′-deoxyguanosine, 2-Thiothymidine, 2′-Deoxy-P-nucleoside, 5-Hydroxy-2′-deoxycytidine, 4-Thiothymidine, 2-Thio-2′-deoxycytidine, 6-Aza-2′-deoxyuridine, 6-Thio-2′-deoxyguanosine, 8-Chloro-2′-deoxyadenosine, 5-Aminoallyl-2′-deoxycytidine, 5-Aminoallyl-2′-deoxyuridine, N4-Methyl-2′-deoxycytidine, 2′-Deoxyzebularine, 5-Hydroxymethyl-2′-deoxyuridine, 5-Hydroxymethyl-2′-deoxycytidine, 5-Propargylamino-2′-deoxycytidine, 5-Propargylamino-2′-deoxyuridine, 5-Carboxy-2′-deoxycytidine, 5-Formyl-2′-deoxycytidine, 5-[(3-Indolyl)propionamide-N-allyl]-2′-deoxyuridine, 5-Carboxy-2′-deoxyuridine, 5-Formyl-2′-deoxyuridine, 7-Deaza-7-Propargylamino-2′-deoxyadenosine, 7-Deaza-7-Propargylamino-2′-deoxyguanosine, Biotin-

16-Aminoallyl-2′-dUTP, Biotin-16-Aminoallyl-2′-dCTP, Biotin-16-Aminoallylcytidine, N4-Biotin-OBEA-2′-deoxycytidine, Biotin-16-Aminoallyluridine, Dabcyl-5-3-Aminoallyl-2′-dUTP, Desthiobiotin-6-Aminoallyl-2′-deoxycytidine, Desthiobiotin-16-Aminoallyl-Uridine, Biotin-16-7-Deaza-7-Propargylamino-2′-deoxyguanosine, Cyanine 3-5-Propargylamino-2′-deoxycytidine, Cyanine 3-6-Propargylamino-2′-deoxyuridine, Cyanine 5-6-Propargylamino-2′-deoxycytidine, Cyanine 5-6-Propargylamino-2′-deoxyuridine, Cyanine 3-Aminoallylcytidine, Cyanine 3-Aminoallyluridine, Cyanine 5-Aminoallylcytidine, Cyanine 5-Aminoallyluridine, Cyanine 7-Aminoallyluridine, 2′-Fluoro-2′-deoxyadenosine, 2′-Fluoro-2′-deoxycytidine, 2′-Fluoro-2′-deoxyguanosine, 2′-Fluoro-2′-deoxyuridine, 2′-O-Methyladenosine, 2′-O-Methylcytidine, 2′-O-Methylguanosine, 2′-O-Methyluridine, Puromycin, 2′-Amino-2′-deoxycytidine, 2′-Amino-2′-deoxyuridine, 2′-Azido-2′-deoxycytidine, 2′-Azido-2′-deoxyuridine, Aracytidine, Arauridine, 2′-Azido-2′-deoxyadenosine, 2′-Amino-2′-deoxyadenosine, Araadenosine, 2′-Fluoro-thymidine, 3′-O-Methyladenosine, 3′-O-Methylcytidine, 3′-O-Methylguanosine, 3′-O-Methyluridine, 2′-Azido-2′-deoxyguanosine, Araguanosine, 2′-Deoxyuridine, 3′-O-(2-nitrobenzyl)-2′-Deoxyadenosine, 3′-O-(2-nitrobenzyl)-2′-Deoxyinosine, 3′-Deoxyadenosine, 3′-Deoxyguanosine, 3′-Deoxycytidine, 3′-Deoxy-5-Methyluridine, 3′-Deoxyuridine, 2′,3′-Dideoxyadenosine, 2′,3′-Dideoxyguanosine, 2′,3′-Dideoxyuridine, 2′,3′-Dideoxythymidine, 2′,3′-Dideoxycytidine, 3′-Azido-2′,3′-dideoxyadenosine, 3′-Azido-2′,3′-dideoxythymidine, 3′-Amino-2′,3′-dideoxyadenosine, 3′-Amino-2′,3′-dideoxycytidine, 3′-Amino-2′,3′-dideoxyguanosine, 3′-Amino-2′,3′-dideoxythymidine, 3′-Azido-2′,3′-dideoxycytidine, 3′-Azido-2′,3′-dideoxyuridine, 5-Bromo-2′,3′-dideoxyuridine, 2′,3′-Dideoxyinosine, 2′-Deoxyadenosine-5′-O-(1-Thiophosphate), 2′-Deoxycytidine-5′-O-(1-Thiophosphate), 2′-Deoxyguanosine-5′-O-(1-Thiophosphate), 2′-Deoxythymidine-5′-O-(1-Thiophosphate), Adenosine-5′-O-(1-Thiophosphate), Cytidine-5′-O-(1-Thiophosphate), Guanosine-5′-O-(1-Thiophosphate), Uridine-5′-O-(1-Thiophosphate), 2′,3′-Dideoxyadenosine-5′-O-(1-Thiophosphate), 2′,3′-Dideoxycytidine-5′-O-(1-Thiophosphate), 2′,3′-Dideoxyguanosine-5′-O-(1-Thiophosphate), 3′-Deoxythymidine-5′-O-(1-Thiophosphate), 3′-Azido-2′,3′-dideoxythymidine-5′-O-(1-Thiophosphate), 2′,3′-Dideoxyuridine-5′-O-(1-Thiophosphate), 2′-Deoxyadenosine-5′-O-(1-Boranophosphate), 2′-Deoxycytidine-5′-O-(1-Boranophosphate), 2′-Deoxyguanosine-5′-O-(1-Boranophosphate), and 2′-Deoxythymidine-5′-O-(1-Boranophosphate).

[0102] Without intending to be bound by theory, the presence of the modified nucleosides, and/or sequences of nucleosides that alter secondary structure of the RNA and/or binding of RNA to RNA binding proteins or microRNA, may enable mRNA to avoid activation of an

immune response mediated by various receptors, including the Toll-like receptors and RIG-1. Non-immunogenic mRNA has been used as a therapeutic agent in mice via topical delivery. Kormann et al. (2011) Nature Biotechnology 29:154-157. In some embodiments, the ribonucleic acids comprise more than one of the above nucleosides or combination of the above nucleosides. In some embodiments, the ribonucleic acids comprise 1-methylpseudouridine, 5-methoxyuridine, or pseudouridine and 5-methylcytidine.

[0103] In some embodiments, an immune response to the mRNA may be desired, and the RNA may be modified to induce an optimal level of innate immunity. In other embodiments, an immune response to the mRNA may not be desired, and the RNA may be modified in order to minimize such a reaction. The RNA can be modified for either situation.

[0104] The ribonucleic acid molecules can be synthetic ribonucleic acids. The term "synthetic", as used herein, can mean that the ribonucleic acids are in some embodiments prepared using the tools of molecular biology under the direction of a human, for example as described below. The synthetic ribonucleic acids may, for example, be prepared by in vitro synthesis using cellular extracts or purified enzymes and nucleic acid templates. The synthetic ribonucleic acids may in some embodiments be prepared by chemical synthesis, either partially or completely. Alternatively, or in addition, the synthetic ribonucleic acids may in some embodiments be prepared by engineered expression in a cell, followed by disruption of the cell and at least partial purification of the ribonucleic acid.

[0105] The ribonucleic acids of the present disclosure may be prepared using a variety of techniques, as would be understood by one of ordinary skill in the art. In some embodiments, the ribonucleic acids may be prepared by in vitro synthesis. In some embodiments, the ribonucleic acids may be prepared by chemical synthesis. In some embodiments, the ribonucleic acids may be prepared by a combination of in vitro synthesis and chemical synthesis. As described above, the term "synthetic" should be understood to include ribonucleic acids that are prepared either by chemical synthesis, by in vitro synthesis, by expression in vivo and at least partial purification, or by a combination of such, or other, chemical or molecular biological methods.

[0106] The ribonucleic acids may, in some embodiments, be purified. As noted above, purification may reduce immunogenicity of the ribonucleic acids and may be advantageous in some circumstances. In some embodiments, the ribonucleic acids are purified by one or more of HPLC, DNAse treatment, protease treatment, or by affinity capture and elution.

[0107] The protein structure of TERT can include at least three distinct domains: a long extension at the amino-terminus (the N-terminal extension, NTE) that contains conserved

domains and an unstructured linker region; a catalytic reverse-transcriptase domain in the middle of the primary sequence that includes seven conserved reverse transcriptase (RT) motifs; and a short extension at the carboxyl-terminus. In some embodiments, the ribonucleic acid codes for a full-length TERT. In some embodiments, the ribonucleic acid codes for a catalytic reverse transcriptase domain of TERT. In some embodiments, the ribonucleic acid codes for a polypeptide having TERT activity. TERT activity may be measured using known methods including the telomerase repeat amplification protocol (TRAP).

[0108] The TERT encoded by the ribonucleic acids of the instant disclosure may be a mammalian, avian, reptilian, or fish TERT. In some embodiments, the TERT is a mammalian TERT, such as human TERT. Meyerson et al. (1997) Cell 90:785-795; Nakamura et al. (1997) Science 277:955-959; Wick et al. (1999) Gene 232:97-106.

[0109] The amino acid sequence of two human TERT isoforms are available as NCBI Reference Sequences: NP_937983.2 and NP_001180305.1.

[0110] The amino acid sequence of human TERT isoform 1 may comprise or consist of the sequence of SEQ ID NO: 6 (also described at GenBank Accession No. NP_937983.2).

[0111] The nucleic acid sequence of human TERT isoform 1 may comprise or consist of the sequence of SEQ ID NO: 7 (also described at GenBank Accession No. NM_198253.3).

[0112] The amino acid sequence of human TERT isoform 2 may comprise or consist of the sequence of SEQ ID NO: 8 (also described at GenBank Accession No. NP_001180305.1).

[0113] The amino acid sequence of human TERT isoform 2 may comprise or consist of the sequence of SEQ ID NO: 9 (also described at GenBank Accession No. NM_001193376.3).

[0114] In some embodiments, a human TERT mRNA may comprise a wild type TERT sequence. In some embodiments, the wild type TERT sequence may comprise a sequence of SEQ ID NO: 30, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0115] In some embodiments, a mouse TERT mRNA may comprise a wild type TERT sequence. In some embodiments, the wild type TERT sequence may comprise SEQ ID NO: 31, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0116] In some embodiments, a TERT mRNA may comprise a nucleic acid sequence at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 91%, at least 92%, at least 93%, at least 94%, at least 95%, at

least 96%, at least 97%, at least 98%, or at least 99% identical to any one of SEQ ID NOS: 1-5, 7, 9 or 30.

[0117] In some embodiments, a TERT mRNA may encode a modified TERT protein containing one or more amino acid substitutions, deletions, and/or insertions as compared to SEQ ID NOS: 6 or 8, while retaining substantial TERT activity. In some embodiments, a TERT mRNA may encode an amino acid sequence at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 91%, at least 92%, at least 93%, at least 94%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% to SEQ ID NO: 6 or SEQ ID NO: 8.

[0118] In other embodiments, a TERT mRNA may encode an amino acid sequence with a mutation of L55Q, P65A, V70M, A202T, A279T, V299M, H412Y, a deletion of residue 441, R522K, K570N, R631Q, G682D, V694M, Y697F, P704S, Y707F, A716T, P721R, T726M, Y772C, P785L, V791I, R811C, L841F, R865H, V867M, R901W, K902N, P923L, S948R, R979W, V1025F, A1062T, V1090M, T1110M, and/or F1127L relative to the amino acid sequences of SEQ ID NO: 6. In some embodiments, the TERT mRNA may encode a TERT isoform in which the translated protein lacks amino acid residues 711-722, 764-807, 808-1132, or 885-947 relative to the amino acid sequences of SEQ ID NO: 6. In some embodiments about 1, about 5, about 10, about 20, or about 100 amino acids preceding or following the domain are also deleted from the amino acid sequence of SEQ ID NO: 6.

[0119] In some embodiments, the TERT mRNA may encode an amino acid sequence in which one or more of the protein regions are deleted or repeated relative to the amino acid sequences of SEQ ID NO: 6: residues 1-230 corresponding to the RNA-interacting domain 1, residues 58-197 corresponding to a "GQ" residue motif, residues 137-141 associated with the specificity of telomeric DNA and primer elongation, residues 210-320 corresponding to a disordered region, residues 231-324 associated with a linker sequence, residues 301-538 associated with oligomerization, residues 325-550 or 460-594 corresponding to an RNA-interacting domain, residues 376-521 corresponding to a "QFP" residue motif, residues 397-417 corresponding to a "CP" residue motif, residues 825-884 corresponding to a DNA repeat template, residues 618-729 corresponding to a reverse transcriptase like element, residues 914-928 associated with oligomerization, residues 930-934 associated with a primer grip sequence, and/or residues 936-1132 corresponding to the C-terminus. In some embodiments about 1, about 5, about 10, about 20, or about 100 amino acids preceding or following the domain are also deleted or repeated.

[0120] In some embodiments, a TERT mRNA may comprise or consist of a nucleotide sequence at least at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 91%, at least 92%, at least 93%, at least 94%, at least 95%, at least 96%, at least 97%, at least 98%, at least 99% or more identical to any subsequence of a disclosed nucleic acid sequence, *e.g.*, any 100 base pair (bp), 200 bp, 300 bp, 400 bp, 500 bp, or more of a disclosed nucleic acid sequence. In some embodiments, a TERT mRNA may encode an amino acid sequence at least at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 91%, at least 92%, at least 93%, at least 94%, at least 95%, at least 96%, at least 97%, at least 98%, at least 99% or more identical to any of one of the disclosed polypeptide sequences, or to any subsequence of a disclosed polypeptide sequence, *e.g.*, any 50 amino acid (aa), 100 aa, 200 aa, 300 aa, 400 aa, 500 aa, or more of a disclosed polypeptide sequence.

[0121] Non-limiting TERT sequences of the disclosure, include TERT nucleic acid and amino acid sequences listed in Table 1.

Table 1: Non-human TERT sequences

TERT Species	Amino Acid SEQ ID NO:	Amino Acid Sequence	Example Nucleic Acid SEQ ID NO:	Example Nucleic Acid Sequence
Cat		ASO67359.1		KX620456.1
Dog		NP_001026800.1		NM_001031630.1
Mouse		AAI27069.1		BC127068.1
Mouse, isoform 1	10	NP_033380.1	14	NM_009354.2
Mouse, isoform 2	11	NP_001349316.1	15	NM_001362387.1
Mouse, isoform 3	12	NP_001349317.1	16	NM_001362388.1
Mouse		EDL37055.1		Machine reverse translation of EDL37055.1
Cow		NP_001039707.1		NM_001046242.1

Sheep, isoform 1		XP_027835754.1		XM_027979953.1
Sheep, isoform 2		XP_027835755.1		XM_027979954.1
Pig		NP_001231229.1		NM_001244300.1
African Elephant		XP_023401395.1		XM_023545627.1
Chicken		NP_001026178.1		NM_001031007.1
Rat	13	NP_445875.1	17	NM_053423.1
Zebrafish		NP_001077335.1		NM_001083866.1
Japanese medaka		NP_001098286.1		NM_001104816.1
Horse, isoform 1		XP_023481649.1		XM_023625881.1
Horse, isoform 2		XP_023481650.1		XM_023625882.1
Horse, isoform 3		XP_023481651.1		XM_023625883.1

[0122] In some embodiments of the compositions and methods of the disclosure, an amino acid sequence of TERT may comprise or consist of a sequence of SEQ ID NOS: 6-8 or 10-13, or an amino acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto. In some embodiments of the compositions and methods of the disclosure, an amino acid sequence of a portion of TERT, functional or non-functional, may comprise or consist of a sequence having at least 70%, 75%, 80%, 85%, 90%, 95%, 97%, 99% identity to a subsequence of one or more of SEQ ID NOS: 6-8 or 10-13.

[0123] In some embodiments of the compositions and methods of the disclosure, a nucleic acid sequence of TERT may comprise or consist of a sequence of SEQ ID Nos: 1-5, 7, 9, 14-17, 30 or 31, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto..

[0124] The amino acid sequence of non-human primate TERT isoform 1 may comprise or consist of the sequence of SEQ ID NO: 18 (also described at GenBank Accession No. XP_016808391.2).

[0125] The nucleic acid sequence of non-human primate TERT isoform 1 may comprise or consist of the sequence of SEQ ID NO: 19 (also described at GenBank Accession No. XM_016952902.2).

[0126] The amino acid sequence of non-human primate TERT isoform 2 may comprise or consist of the sequence of SEQ ID NO: 20, GenBank Accession No. PNI27662.1.

[0127] The nucleic acid sequence of non-human primate TERT isoform 2 may comprise or consist of the sequence of SEQ ID NO: 21 (reverse machine translation of GenBank Accession No. PNI27662.1).

[0128] The amino acid sequence of non-human primate TERT isoform 3 may comprise or consist of the sequence of SEQ ID NO: 22 (also described at GenBank Accession No. PNI27663.1).

[0129] The nucleic acid sequence of non-human primate TERT isoform 3 may comprise or consist of the sequence of SEQ ID NO: 23 (reverse machine translation of GenBank Accession No. PNI27663.1).

[0130] The amino acid sequence of non-human primate TERT isoform 4 may comprise or consist of the sequence of SEQ ID NO: 24 (also described at GenBank Accession No. PNI27664.1).

[0131] The nucleic acid sequence of non-human primate TERT isoform 4 may comprise or consist of the sequence of SEQ ID NO: 25 (reverse machine translation of GenBank Accession No. PNI27664.1).

[0132] The amino acid sequence of non-human primate TERT isoform 5 may comprise or consist of the sequence of SEQ ID NO: 26 (also described at GenBank Accession No. PNI27665.1).

[0133] The nucleic acid sequence of non-human primate TERT isoform 5 may comprise or consist of the sequence of SEQ ID NO: 27 (reverse machine translation of GenBank Accession No. PNI27665.1).

[0134] The amino acid sequence of non-human primate TERT isoform 6 may comprise or consist of the sequence of SEQ ID NO: 28 (also described at GenBank Accession No. PNI27666.1).

[0135] The nucleic acid sequence of non-human primate TERT isoform 6 may comprise or consist of the sequence of SEQ ID NO: 29 (reverse machine translation of GenBank Accession No. PNI27666.1).

[0136] In some embodiments of the compositions and methods of the disclosure, an amino acid sequence of TERT may comprise or consist of a sequence of SEQ ID NOS: 6, 8, 10-13, 18, 20, 22, 24, 26, or 28, or an amino acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0137] In some embodiments of the compositions and methods of the disclosure, a nucleic acid sequence of TERT may comprise or consist of a sequence of SEQ ID Nos: 1-5, 7, 9, 14-17, 19, 21, 23, 25, 27, 29, 30, or 31, sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto. In some embodiments, the instant ribonucleic acids may correspond to the native gene sequences coding for the above-listed TERT proteins or may correspond to variants that are made possible due to the redundancy of the genetic code, as would be understood by one of ordinary skill in the art. In some embodiments, the codon selection may be optimized to optimize protein expression and/or reduced or increased immunogenicity using algorithms and methods known by those of ordinary skill in the art.

[0138] In some embodiments, an mRNA sequence may be synthesized as an unmodified or modified mRNA. An mRNA may be modified to enhance stability and/or evade immune detection and degradation. A modified mRNA may include, for example, one or more of a nucleotide modification, a nucleoside modification, a backbone modification, a sugar modification, and/or a base modification. In some embodiments, the modified nucleoside is pseudouridine or a pseudouridine analog. In some embodiments, the pseudouridine analog is N-1-methylpseudouridine. In some embodiments, the modified nucleoside is 5-methoxyuridine. In some embodiments a modified nucleoside as used herein may comprise any of the moieties listed in Table 2.

Table 2

Common name
pseudouridine
N-1-methylpseudouridine
5-methoxyuridine

1,2′-*O*-dimethyladenosine
1-methyl-3-(3-amino-3-carboxypropyl) pseudouridine
1-methyladenosine
1-methylguanosine
1-methylinosine
1-methylpseudouridine
2,2-dimethyl-guanosine
2′,3′-dideoxyadenosine
2′,3′-Dideoxycytidine
2′,3′-Dideoxyguanosine
2′,3′-Dideoxyinosine
2′,3′-dideoxynucleosides
2′,3′-Dideoxythymidine
2′,3′-dideoxythymine
2′,3′-Dideoxyuridine
2,6-diaminopurine
2′-*O*-ribosyladenosine (phosphate)
2′-Amino-2′-deoxyadenosine
2-Amino-2′-deoxyadenosine
2′-Amino-2′-deoxyuridine
2-Amino-6-chloropurineriboside
2-Amino-6-Cl-purine-2′-deoxyriboside
2-aminoadenosine
2-Aminoadenosine
2-Aminopurine-2′-deoxyriboside
2-Aminopurine-riboside
2′-Azido-2′-deoxyadenosine
2′-Azido-2′-deoxycytidine
2′-Azido-2′-deoxyguanosine
2′-Azido-2′-deoxyuridine
2′-Deoxyinosine
2′-Deoxy-P-nucleoside

2′-Deoxyuridine
2′-Deoxyzebularine
2′-Fluoro-2′-deoxyadenosine
2′-Fluoro-2′-deoxycytidine
2′-Fluoro-2′-deoxyguanosine
2′-Fluoro-2′-deoxyuridine
2′-Fluoro-thymidine
2-methyl-adenosine
2-methyl-guanosine
2-methylthio-N^6-(*cis*-hydroxyisopentenyl) adenosine
2-methylthio-N-6-isopentenyl-adenosine
2-methylthio-N^6-threonylcarbamoyladenosine
2′-O-Methyl-2-aminoadenosine
2′-O-Methyl-5-methyluridine
2′-*O*-methyladenosine
2′-*O*-methylcytidine
2′-*O*-methylguanosine
2′-*O*-methylinosine
2′-O-Methyl-N6-Methyladenosine
2′-*O*-methylpseudouridine
2′-*O*-methyluridine
2′-*O*-ribosylguanosine (phosphate)
2-Thio-2′-deoxycytidine
2-Thiocytidine
2-Thiothymidine
2-thiouridine
3,2′-*O*-dimethyluridine
3′-Amino-2′,3′-dideoxyadenosine
3′-Amino-2′,3′-dideoxycytidine
3′-Amino-2′,3′-dideoxyguanosine
3′-Amino-2′,3′-dideoxythymidine
3′-Azido-2′,3′-dideoxyadenosine

3′-Azido-2′,3′-dideoxycytidine
3′-Azido-2′,3′-dideoxythymidine
3′-Azido-2′,3′-dideoxyuridine
3′-Deoxy-5-Methyluridine
3′-Deoxyadenosine
3′-deoxyadenosine (cordycepin)
3′-Deoxycytidine
3′-Deoxyguanosine
3′-deoxythymine
3′-Deoxyuridine
3-methylcytidine
3-methyluridine
3′-O-(2-nitrobenzyl)-2′-Deoxyadenosine
3′-O-(2-nitrobenzyl)-2′-Deoxyinosine
3′-O-Methyladenosine
3′-O-Methylcytidine
3′-O-Methylguanosine
3′-O-Methyluridine
4-acetyl-cytidine
4-Thiothymidine
4-Thiouridine
5-(carboxyhydroxymethyl) uridine methyl ester
5-(carboxyhydroxymethyl)uridine
5,2′-*O*-dimethyluridine
5,6-Dihydro-5-Methyluridine
5,6-Dihydrouridine
5-[(3-Indolyl)propionamide-N-allyl]-2′-deoxyuridine
5-Aminoallyl-2′-deoxycytidine
5-Aminoallyl-2′-deoxyuridine
5-Aminoallylcytidine
5-Aminoallyluridine
5-Bromo-2′,3′-dideoxyuridine

5-Bromo-2′-deoxycytidine
5-Bromo-2′-deoxyuridine
5-Bromocytidine
5-Bromouridine
5-carbamoylmethy1-2′-*O*-methyluridine
5-carbamoylmethyluridine
5-Carboxy-2′-deoxycytidine
5-Carboxycytidine
5-carboxymethylaminomethyl-2-thio-uridine
5-carboxymethylaminomethyluridine
5-Carboxymethylesteruridine
5-carboxymethyluridine
5-Carboxyuridine
5-Fluoro-2′-deoxyuridine
5-fluoro-uridine
5-Formyl-2′-deoxycytidine
5-Formyl-2′-deoxyuridine
5-formyl-2′-*O*-methylcytidine
5-formylcytidine
5-Formyluridine
5-Hydroxy-2′-deoxycytidine
5-Hydroxycytidine
5-Hydroxymethyl-2′-deoxycytidine
5-Hydroxymethyl-2′-deoxyuridine
5-hydroxymethylcytidine
5-Hydroxymethyluridine
5-hydroxyuridine
5-Iodo-2′-deoxycytidine
5-Iodo-2′-deoxyuridine
5-Iodocytidine
5-Iodouridine
5-methoxyaminomethyl-2-thio-uridine

5-methoxycarbonylmethy1-2′-*O*-methyluridine
5-methoxycarbonylmethyl-2-thiouridine
5′-methoxycarbonylmethyl-uridine
5-methoxycarbonylmethyluridine
5-Methoxycytidine
5-Methoxyuridine
5-methoxy-uridine
5-Methyl-2′-deoxycytidine
5-methyl-2-thio-uridine
5-methylaminomethyl-uridine
5-methylcytidine
5-methyldihydrouridine
5-methyluridine
5-Propargylamino-2′-deoxycytidine
5-Propargylamino-2′-deoxyuridine
5-Propynyl-2′-deoxycytidine
5-taurinomethyl-2-thiouridine
5-taurinomethyluridine
6-Aza-2′-deoxyuridine
6-Azacytidine
6-Azauridine
6-chloropurine riboside
6-Chloropurine-2′-deoxyriboside
6-O-methylguanosine
6-Thio-2′-deoxyguanosine
7-Deaza-2′-deoxyadenosine
7-Deaza-2′-deoxyguanosine
7-Deaza-7-Propargylamino-2′-deoxyadenosine
7-Deaza-7-Propargylamino-2′-deoxyguanosine
7-Deazaadenosine
7-Deazaguanosine
7-methylguanosine

7-methyl-guanosine
8-Azaadenosine
8-Azidoadenosine
8-Chloro-2′-deoxyadenosine
8-Oxo-2′-deoxyadenosine
8-Oxo-2′-deoxyguanosine
8-Oxoadenoosine
8-Oxoguanosine
a 2′-deoxynucleoside
ac4C N4-acetylcytidine
Am 2′-O-methyladenosine
an -O-methylnucleoside
Ar(p) 2′-O-ribosyladenosine (phosphate)
Araadenosine
Aracytidine
Araguanosine
Arauridin
benzimidazole riboside
beta-D-mannosyl-queosine
Biotin-16-7-Deaza-7-Propargylamino-2′-deoxyguanosine
Biotin-16-Aminoallyl-2′-dCTP
Biotin-16-Aminoallyl-2′-dUTP
Biotin-16-Aminoallylcytidine
Biotin-16-Aminoallyluridine
chm5U 5-(carboxyhydroxymethyl)uridine
2′-O-methylcytidine
5-carboxymethyluridine
5-carboxymethylaminomethyluridine
Cyanine 3-5-Propargylamino-2′-deoxycytidine
Cyanine 3-6-Propargylamino-2′-deoxyuridine
Cyanine 3-Aminoallylcytidine
Cyanine 3-Aminoallyluridine

Cyanine 5-6-Propargylamino-2′-deoxycytidine
Cyanine 5-6-Propargylamino-2′-deoxyuridine
Cyanine 5-Aminoallylcytidine
Cyanine 5-Aminoallyluridine
Cyanine 7-Aminoallyluridine
dihydrouridine
Dabcyl-5-3-Aminoallyl-2′-dUTP
Desthiobiotin-16-Aminoallyl-Uridine
Desthiobiotin-6-Aminoallyl-2′-deoxycytidine
dihydrouridine
5-formylcytidine
5-formyl-2′-O-methylcytidine
N6-glycinylcarbamoyladenosine
galactosyl-queuosine
2′-O-methylguanosine
2′-O-ribosylguanosine (phosphate)
5-hydroxymethylcytidine
5-hydroxyuridine
hydroxywybutosine
N6-isopentenyladenosine
2′-O-methylinosine
wyosine
inosine
N6-(cis-hydroxyisopentenyl)adenosine
Isoguanosine
l-methylguanosine
1-methyladenosine
1-methyl-3-(3-amino-3-carboxypropyl) pseudouridine
1,2′-O-dimethyladenosine
1-methylguanosine
1-methylinosine
1-methylpseudouridine

N2,N2-dimethylguanosine
N2,N2,7-trimethylguanosine I inosine
N2,7-dimethylguanosine
N2-methylguanosine
3-methylcytidine
3-methyluridine
3,2′-O-dimethyluridine
N4-methylcytidine
5-methylcytidine
5-methyldihydrouridine
5-methyluridine
5,2′-O-dimethyluridine
N6,N6-dimethyladenosine
N6,N6,2′-O-trimethyladenosine
N6-methyladenosine
N6,2′-O-dimethyladenosine
7-methylguanosine
mannosyl-queuosine
5-(carboxyhydroxymethyl)uridine
5-methoxycarbonylmethyl-2-thiouridine
5-methoxycarbonylmethyl-2′-O-methyluridine
5-methoxycarbonylmethyluridine
2-methylthio-N6-(cis-hydroxyisopentenyl) adenosine
2-methylthio-N6-threonyl carbamoyladenosine
N1-Ethylpseudouridine
N1-Methoxymethylpseudouridine
N1-Methyl-2′-O-Methylpseudouridine
N1-Methyladenosine
N1-Propylpseudouridine
N^2,7-dimethylguanosine
N^2,N^2,7-trimethylguanosine
N^2,N^2-dimethylguanosine

N2-Methyl-2′-deoxyguanosine
N^2-methylguanosine
N^4-acetylcytidine
N4-Biotin-OBEA-2′-deoxycytidine
N4-Methyl-2′-deoxycytidine
N^4-methylcytidine
N^6-(cis-hydroxyisopentenyl)-adenosine
N^6,2′-O-dimethyladenosine
N^6,N^6,2′-O-trimethyladenosine
N^6,N^6-dimethyladenosine
N^6-glycinylcarbamoyladenosine
N^6-isopentenyladenosine
N6-isopentenyl-adenosine
N6-Methyl-2-Aminoadenosine
N6-Methyl-2′-deoxyadenosine
N^6-methyladenosine
N6-methyl-adenosine
N^6-threonylcarbamoyladenosine
ncm5U 5-carbamoylmethyluridine
ncm5Um 5-carbamoylmethyl-2′-O-methyluridine
Nl-methyladenosine
N-uridine-5-oxyaceticacidmethylester
peroxywybutosine
O6-Methyl-2′-deoxyguanosine
O6-Methylguanosine
hydroxywybutosine
undermodified hydroxywybutosine
O-Methylpseudouridine
peroxywybutosine
Pseudoisocytidine
Puromycin
queosine

2-thiouridine
N6-threonylcarbamoyladenosine
Thienocytidine
Thienoguanosine
Thienouridine
2′-O-methyluridine
undermodified hydroxywybutosine
uridine-5-oxyaceticacid(v)
uridine-5-oxyaceticacidmethylester
wybutosine
wybutoxosine
wyosine
Xanthosine
5-taurinomethyl-2-thiouridine
5-taurinomethyluridine
2′-O-methylpseudouridine

[0139] In some embodiments, an RNA, *e.g.* an mRNA, may be synthesized from naturally occurring bases and/or base analogs (modified bases) including, but not limited to, purines (adenine (A), guanine (G)) or pyrimidines (thymine (T), cytosine (C), uracil (U)), and analogues and derivatives thereof, *e.g.* 1-methyl-adenine, 2-methyl-adenine, 2- methylthio-N-6-isopentenyl-adenine, N6-methyl-adenine, N6-isopentenyl-adenine, 2-thio- cytosine, 3-methyl-cytosine, 4-acetyl-cytosine, 5-methyl-cytosine, 2,6-diaminopurine, 1-methyl- guanine, 2-methyl-guanine, 2,2-dimethyl-guanine, 7-methyl-guanine, inosine, 1-methyl-inosine, pseudouracil (5-uracil), pseudouridine, N-1-methyl-pseudouridine, dihydro-uracil, 2-thio-uracil, 4-thio-uracil, 5-carboxymethylaminomethyl-2-thio-uracil, 5-(carboxyhydroxymethyl)-uracil, 5-fluoro-uracil, 5-bromo-uracil, 5-carboxymethylaminomethyl-uracil, 5-methyl-2-thio-uracil, 5-methyl-uracil, N- uracil-5-oxyacetic acid methyl ester, 5-methylaminomethyl-uracil, 5-methoxyaminomethyl-2-thio-uracil, 5′-methoxycarbonylmethyl-uracil, 5-methoxy-uracil, uracil-5-oxyacetic acid methyl ester, uracil-5-oxyacetic acid (v), 1-methyl-pseudouracil, queosine, beta-D-mannosyl-queosine, wybutoxosine, and phosphoramidates, phosphorothioates, peptide nucleotides, methylphosphonates, 7-deazaguanosine, 5-methylcytosine and inosine.

[0140] In some embodiments, an RNA, *e.g.*, an mRNA, may be synthesized from naturally occurring nucleosides and/or nucleoside analogs (modified nucleosides) including, but not limited to, nucleosides comprising adenosine (A), guanosine (G)) or pyrimidines (thymine (T), cytidine (C), uridine (U)), and nucleoside comprising analogues and derivatives thereof, *e.g.*, 3′-deoxyadenosine (cordycepin), 3′-deoxyuridine, 3′-deoxycytosine, 3′-deoxyguanosine, 3′-deoxythymine, 2′,3′-dideoxynucleosides, 2′,3′- dideoxyadenosine, 2′,3′-dideoxyuridine, 2′,3′-dideoxycytosine, 2′,3′- dideoxyguanosine, 2′,3′-dideoxythymine, a 2′-deoxynucleoside, -O-methylnucleoside, 1-methyl-adenine, 2-methyl-adenine, 2-methylthio-N-6-isopentenyl-adenine, N6-methyl-adenine, N6-isopentenyl-adenine, 2-thio-cytosine, 3-methyl-cytosine, 4-acetyl-cytosine, 5-methyl-cytosine, 2,6-diaminopurine, 1-methyl-guanine, 2-methyl-guanine, 2,2-dimethyl-guanine, 7-methyl-guanine, inosine, 1-methyl-inosine, pseudouridine, N-1-methyl-pseudouridine, dihydro-uracil, 2-thio-uracil, 4-thio-uridine, 5-carboxymethylaminomethyl-2-thio-uridine, 5-(carboxyhydroxymethyl)-uridine, 5-fluoro-uridine, 5-bromo-uridine, 5-carboxymethylaminomethyl-uridine, 5-methyl-2-thio-uridine, 5-methyl-uridine, N-uridine-5-oxyacetic acid methyl ester, 5-methylaminomethyl-uridine, 5-methoxyaminomethyl-2-thio-uridine, 5′-methoxycarbonylmethyl-uracil, 5-methoxy-uracil, uracil-5-oxyacetic acid methyl ester, uracil-5-oxyacetic acid (v), 1-methyl-pseudouridine, queosine, beta-D-mannosyl-queosine, wybutoxosine, 7-deazaguanosine, 5-methylcytosine, and inosine.

[0141] The preparation of such base, nucleoside, nucleotide, and backbone analogues, modifications, and derivatives is known to a person skilled in the art *e.g.* from the U.S. Patent Nos. 4,373,071, U.S. Patent No. 4,401,796, U.S. Patent No. 4,415,732, U.S. Patent No. 4,458,066, U.S. Patent No. 4,500,707, U.S. Patent No. 4,668,777, U.S. Patent No. 4,973,679, U.S. Patent No. 5,047,524, U.S. Patent No. 5,132,418, U.S. Patent No. 5,153,319, U.S. Patent Nos. 5,262,530 and 5,700,642, all of which are incorporated by reference in their entirety.

[0142] In some embodiments, uracil nucleosides of the mRNA are about 80%, about 90%, 95%, 99%, or 100% depleted and replaced with a uracil nucleoside analog, *e.g.*, pseudouridine, 5-methoxyuridine, or N-1-methyl-pseudouridine.

[0143] In some embodiments, an RNA may contain an RNA backbone modification. Typically, a backbone modification is a modification in which the phosphates of the backbone of the nucleotides contained in the RNA are chemically modified. Exemplary backbone modifications may include, but are not limited to, modifications in which the phosphodiester linkage is replaced with a member from the group consisting of peptides, methylphosphonates, methylphosphoramidates, phosphoramidates, phosphorothioates (*e.g.*, cytidine 5′-0-(1-

thiophosphate)), boranophosphates, and/or positively charged guanidimum groups, or other means of replacing the phosphodiester linkage.

[0144] In some embodiments, an RNA may contain sugar modifications. A sugar modification may include but is not limited to, 2′ O-methyl sugar modifications, 2′ fluoro sugar modifications (*e.g.* 2′-fluororibose), 3′ amino sugar modifications, 2′ thio sugar modifications, 2′-O-alkyl sugar modifications, 5-methylthioribose, and sugar modifications of 2′-deoxy-2′-fluoro-ribonucleotide (2′-fluoro-2′-deoxycytidine, 2′-fluoro-2′-deoxyuridine), 2′-deoxy-2′-deamine-ribonucleotide (2′-amino-2′-deoxycytidine, 2,-amino-2′-deoxyuridine), 2′-O-alkylribonucleotide, 2′-deoxy-2′-C-alkylribonucleotide (2′-O-methylcytidine, 2′-methyluridine), 2′-C-alkylribonucleotide, and isomers thereof (2′-aracytidine, 2′-arauridine), or azidophosphates (2′-azido-2′-deoxycytidine, 2′-azido-2′-deoxyuridine).

[0145] In some embodiments, an RNA may be synthesized from one or more of the nucleotide triphosphates comprising any of the nucleosides and nucleotides disclosed herein, or any of the following nucleoside triphosphates: 2′-Deoxyadenosine-5′-O-(1-Thiotriphosphate), 2′-Deoxycytidine-5′-O-(1-Thiotriphosphate), 2′-Deoxyguanosine-5′-O-(1-Thiotriphosphate), 2′-Deoxythymidine-5′-O-(1-Thiotriphosphate), Adenosine-5′-O-(1-Thiotriphosphate), Cytidine-5′-O-(1-Thiotriphosphate), Guanosine-5′-O-(1-Thiotriphosphate), Uridine-5′-O-(1-Thiotriphosphate), 2′,3′-Dideoxyadenosine-5′-O-(1-Thiotriphosphate), 2′,3′-Dideoxycytidine-5′-O-(1-Thiotriphosphate), 2′,3′-Dideoxyguanosine-5′-O-(1-Thiotriphosphate), 3′-Deoxythymidine-5′-O-(1-Thiotriphosphate), 3′-Azido-2′,3′-dideoxythymidine-5′-O-(1-Thiotriphosphate), 2′,3′-Dideoxyuridine-5′-O-(1-Thiotriphosphate), 2′-Deoxyadenosine-5′-O-(1-Boranotriphosphate), 2′-Deoxycytidine-5′-O-(1-Boranotriphosphate), 2′-Deoxyguanosine-5′-O-(1-Boranotriphosphate), and 2′-Deoxythymidine-5′-O-(1-Boranotriphosphate).

[0146] In some embodiments, an mRNA may include the addition of a “cap” on the N-terminal (5′) end, and a “tail” on the C-terminal (3′) end. The presence of the cap may provide resistance to nucleases found in eukaryotic cells. The presence of a “tail” may protect the mRNA from exonuclease degradation.

Cap structure

[0147] In some embodiments, an mRNA may include a 5′ cap structure. A 5′ cap may comprise for example, a triphosphate linkage and a guanine nucleotide in which the 7-nitrogen is methylated. Examples of cap structures include, but are not limited to, m7G(5′)ppp (5′)A, G(5′)ppp(5′)A, and G(5′)ppp(5′)G. Naturally occurring cap structures comprise a 7-methyl

guanosine that is linked via a triphosphate bridge to the 5′-end of the first transcribed nucleotide, resulting in a dinucleotide cap of m7G(5′)ppp(5′)N, where N is any nucleoside. *In vivo*, the cap is added in the nucleus by the enzyme guanylyl transferase immediately after initiation of transcription.

[0148] In some embodiments, a 5′cap may comprise an m7(3′OmeG)(5′)ppp(5′)(2′OmeA)pG or (CleanCap™ 3′ OMe) structure. In some embodiments, a 5′ cap may comprise a m7G(5′)ppp(5′)G. In some embodiments, the Anti-Reverse Cap Analog ("ARCA") or modified ARCA, is a 5′ cap in which the 2′ or 3′ OH group is replaced with -OCH3. In some embodiments, the ARCA comprises an 3′-O-Me-m7G(5′)ppp(5′)G structure. In some embodiments, the 5′ cap comprises m7G(5′)ppp(5′)(2′OmeA)pG. Additional mRNA caps may include, but are not limited to, a chemical structures selected from the group consisting of m7GpppG, m7GpppA, m7GpppC; unmethylated caps (*e.g.*, GpppG); a 44emethylated cap (*e.g.*, m2′7GpppG), a trimethylated cap analog, or anti reverse cap analogs (*e.g.*, ARCA; m7,2′0meGpppG, m72′dGpppG, m7'3′0meGpppG, m7,3 dGpppG and their tetraphosphate derivatives) (see, *e.g.*, Jemielity, J. et al, 'Wove anti-reverse cap analogs with superior translational properties", RNA, 9: 1108-1122 (2003)).

[0149] In some embodiments, a suitable cap is a 7-methyl guanylate ("m7G") linked via a triphosphate bridge to the 5 '-end of the first transcribed nucleotide, resulting in m7G(5′)ppp(5′)N, where N is any nucleoside. A embodiment of a m7G cap utilized in embodiments of the disclosure is m7G(5′)ppp(5′)G. In some embodiments, the cap is a Cap0 structure. Cap0 structures lack a 2′-0- methyl residue of the ribose attached to bases 1 and 2. In some embodiments, the cap is a Capl structure. Capl structures have a 2′-0-methyl residue at base 2. In some embodiments, the cap is a Cap2 structure. Cap2 structures have a 2′-0-methyl residue attached to both bases 2 and 3.

[0150] A variety of m7G cap analogs are known in the art, many of which are commercially available. These include the m7 GpppG described above, as well as the ARCA 3′- OCH3 and 2′-OCH3 cap analogs (Jemielity, J. et al., RNA, 9: 1108-1122 (2003)). Additional cap analogs for use in embodiments of the disclosure include N7-benzylated dinucleoside tetraphosphate analogs (described in Grudzien, E. et at, RNA, 10: 1479-1487 (2004)), phosphorothioate cap analogs (described in Grudzien-Nogalska, E., et al, RNA, 13: 1745-1755 (2007)), and cap analogs (including biotinylated cap analogs) described in U.S. Patent Nos. 8,093,367 and 8,304,529, incorporated by reference herein.

[0151] In some embodiments, the 5′ cap is inosine, Nl-methyl-guanosine, 2′fluoro-guanosine, 7-deaza-guanosine, m7(3′OmeG)(5′)ppp(5′)(2′OmeA)pG, CleanCap™, m7(3′OmeG)(5′)ppp(5′)(2′OmeA)pG, 8-oxo-guanosine, 2-amino-guanosine, LNA-guanosine, 2-azido-guanosine, Cap2, Cap4, CAP-003, or CAP-225.

[0152] In some embodiments, the 5′ cap comprises or consists of an internal ribosome entry site (IRES). In some embodiments the IRES is within the 5′ UTR. In some embodiments, the 5′ cap comprises or consists of a 2A self-cleavage peptide, *e.g*, one or more of P2A, T2A, E2A and F2A.

Tail structure

[0153] The presence of a "tail" may serve to protect an mRNA from exonuclease degradation. The poly-A tail is thought to stabilize natural messengers and synthetic sense RNA. Therefore, in certain embodiments a long poly-A tail can be added to an mRNA molecule thus rendering the RNA more stable. Poly-A tails can be added using a variety of art-recognized techniques. For example, long poly-A tails can be added to synthetic or in vitro transcribed RNA using poly-A polymerase (Yokoe, et al. Nature Biotechnology. 1996; 14: 1252-1256). A transcription vector can also encode long poly-A tails. In addition, poly-A tails can be added by transcription directly from PCR products. Poly-A may also be ligated to the 3′ end of a sense RNA with RNA ligase (see, *e.g.*, Molecular Cloning A Laboratory Manual, 2nd Ed., ed. By Sambrook, Fritsch and Maniatis (Cold Spring Harbor Laboratory Press: 1991 edition)).

[0154] In some embodiments, an mRNA may include a 3′ poly(A) tail structure. The length of the poly-A tail may be at least about 10, 50, 100, 200, 300, 400 or at least about 500 nucleotides. In some embodiments, a poly-A tail on the 3′ terminus of an mRNA may include about 10 to 300 adenosine nucleotides (*e.g.,* about 10 to 200 adenosine nucleotides, about 10 to 150 adenosine nucleotides, about 10 to 100 adenosine nucleotides, about 20 to 70 adenosine nucleotides, or about 20 to 60 adenosine nucleotides). In some embodiments, the poly A tail is 120 adenosine nucleotides.

[0155] In some embodiments, an mRNA may include a 3′ poly-C tail structure. A poly-C tail on the 3′ terminus of mRNA may include about 10 to 200 cytosine nucleotides (*e.g.*, about 10 to 150 cytosine nucleotides, about 10 to 100 cytosine nucleotides, about 20 to 70 cytosine nucleotides, about 20 to 60 cytosine nucleotides, or about 10 to 40 cytosine nucleotides). The poly-C tail may be added to the poly-A tail or may substitute the poly-A tail. In some embodiments, the length of the poly-A or poly C tail is associated with the stability of a modified sense mRNA and, therefore, the transcription of the protein. For example, because

the length of the poly-A tail may influence the half-life of a sense mRNA molecule, the length of the poly-A tail may be adjusted to modify the level of resistance of the mRNA to nucleases, thereby providing more control over the time course of polynucleotide expression and/or polypeptide production.

5′ an' 3′ Untranslated Regions (UTRs)

[0156] In some embodiments, an mRNA may include 5′ untranslated region (UTR) and/or a 3′ UTR. In some embodiments, a 5′ UTR may include one or more elements that affect the stability or translation of an mRNA. In some embodiments, the 5′UTR for example, may include an iron responsive element. In some embodiments, 5′ UTR may be between about 50 to about 100, or from about 50 to about 500 nucleotides in length. In some embodiments, 3′ UTR includes one or more of a poly-A signal, a binding site for proteins that may affect mRNA stability or localization, or one or more binding sites for miRNAs. In some embodiments, 3′ UTR may be between about 0 and about 50 nucleotides, or about 50 to about 100 nucleotides in length.

[0157] Example 3′ an' 5′ UTR sequences may be derived from mRNAs with relatively long half-lives (*e.g.,* globin, actin, GAPDH, tubulin, histone, or citric acid cycle enzymes) to increase the stability of the sense mRNA molecule. For example, 5′ UTR sequence may include a partial sequence of a cytomegalovirus (CMV) immediate-early 1 (IE1) gene, or a fragment thereof to improve the nuclease resistance and/or improve the half-life of the polynucleotide. Generally, these modifications improve the stability and/or pharmacokinetic properties (*e.g.*, half-life) of the polynucleotide relative to their unmodified counterparts, and include, for example modifications made to improve such polynucleotides resistance to in vivo nuclease digestion.

[0158] In some embodiments, a UTR may improve tissue specific expression, *e.g.*, in the lung. In some embodiments, the 3′ UTR is a mouse alpha-globin 3′ UTR. In some embodiments, the 3′ UTR comprises a sequence of SEQ ID NO: 32, or a nucleic acid sequence at least 70%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0159] In some embodiments, the 3′ UTR is a wild type human beta-globin 3′ UTR. In some embodiments, the 3′ UTR comprises a sequence of SEQ ID NO: 33, or a nucleic acid at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0160] In some embodiments, the 3′ UTR is a variant human beta-globin 3′ UTR. In some embodiments, the 3′ UTR comprises a sequence of SEQ ID NO: 34, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0161] In some embodiments, the 5′ UTR is a synthetic 5′ UTR. In some embodiments, the 5′ UTR comprises a sequence of SEQ ID NO: 35, or a nucleic acid at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0162] In some embodiments, the 5′ UTR is a human beta-globin 5′ UTR. In some embodiments, the 5′ UTR comprises a sequence of SEQ ID NO: 36, or a nucleic acid at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0163] In some embodiments, the UTR may be any of, or functional variants of, those described in any of PCT Application No. WO2017053297A1 and Patent No. US10519189B2, both of which are incorporated herein in their entirety.

Exemplary therapeutic TERT mRNA sequences

[0164] In some embodiments, a TERT mRNA may refer to the full length mRNA sequence, *ie.* coding and non-coding, delivered to the tissue, *e.g.* the lung. Example sequences include the sequences comprising mouse TERT of SEQ ID NOS: 37 and 38, and the sequences comprising human TERT of SEQ ID NOS: 39 and 40.

[0165] In some embodiments, the mouse TERT mRNA comprises a sequence of SEQ ID NO: 37, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0166] In some embodiments, the mouse TERT mRNA comprises a sequence of SEQ ID NO: 38, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0167] In some embodiments, the human TERT mRNA comprises a sequence of SEQ ID NO: 39, or a nucleic acid at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0168] In some embodiments, the human TERT mRNA comprises a sequence of SEQ ID NO: 40, or a nucleic acid sequence at least 70%, at least 75%, at least 80%, at least 85%, at

least 90%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical thereto.

[0169] In some embodiments, a TERT mRNA may comprise a nucleic acid sequence at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 91%, at least 92%, at least 93%, at least 94%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical to any one of SEQ ID NOS: 38-40.

[0170] The disclosure provides compositions for the extension of telomeres in a cell, the compositions comprising a compound of the present disclosure, as described above, and a further component. In some embodiments, the further component comprises a telomerase RNA component (TERC). In some embodiments, the compositions further comprise a telomerase RNA component (TERC). In some embodiments, the compositions further comprise one or more additional components that may facilitate delivery of the RNA to cells in vitro and/or in vivo. In some embodiments, the one or more additional components comprise a nanoparticle. In some embodiments, the nanoparticle comprises a lipid. In some embodiments, the nanoparticle or the lipid comprise a coatsome-like lipid or a compound of the disclosure. In some embodiments, the nanoparticle or the lipid comprise a compound of the disclosure according to Formula I.

II. Delivery vehicles

[0171] In some embodiments, one or more mRNAs may be delivered to a cell or tissue via delivery vehicles. In some embodiments a delivery vehicle may be a nanoparticle. In some embodiments, the delivery vehicle is a lipid nanoparticle (LNP) including but not limited to a nanoparticle comprising lipids and/or polymers, a liposome, a liposomal nanoparticle, a cationic lipid, or an exosome. As used herein, liposomal nanoparticles may be characterized as microscopic vesicles having an interior aqueous space sequestered from an outer medium by a membrane of one or more bilayers.

[0172] In some embodiments, the nanoparticle is a polymeric nanoparticle. In some embodiments, the nanoparticle is a metal nanoparticle. In other embodiments, the delivery vehicle comprises or consists of a recombinant virus or virus-like particle, *e.g.*, an adenovirus, adeno-associated virus (AAV), herpesvirus, or retrovirus, *e.g.*, lentivirus. In some embodiments, the delivery vehicle comprises or consists of a modified viral vector, *e.g.*, an adenovirus dodecahedron or recombinant adenovirus conglomerate. In other embodiments, the

delivery vehicle may comprise or consist of calcium phosphate nucleotides, aptamers, cell-penetrating peptides or other vectorial tags.

[0173] In some embodiments, a suitable delivery vehicle is a lipid nanoparticle (LNP), Exemplary LNPs may comprise one or more different lipids and/or polymers. In some embodiments, an LNP comprises one or more of ionizable lipids, cationic lipids, structural lipids, cholesterols, and/or insulator lipids (*e.g.*, PEGylated lipids).

[0174] Compositions of the disclosure may comprise one or more components that may facilitate delivery of the RNA to cells. Collectively or in part, components of the composition may comprise a delivery vehicle. In some embodiments, the delivery vehicle facilitates targeting and uptake of the ribonucleic acid of a composition of the disclosure to a target cell. Exemplary delivery vehicles include, but are not limited to, nanoparticles, lipid nanoparticles (LNPs), liposomes, micelles, exosomes, cationic lipids and a natural or artificial lipoprotein particle.

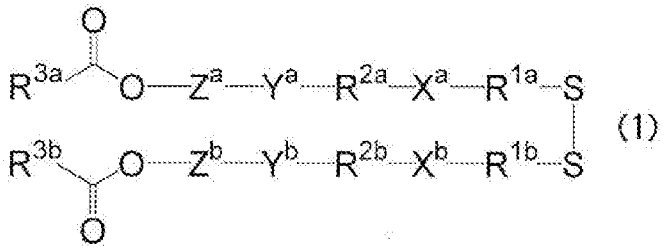
Ionizable lipids

[0175] In some embodiments of the disclosure, an LNP may comprise an ionizable lipid, *e.g.* SS-OP or analogs thereof. The charge of the lipid may depend on pH of the surrounding solution, making it an ionizable lipid. The ionizable lipid may also be cleavable. The ionizable lipid may be cationic at ranges of pH found in endosomes or lysosomes in mammalian cells.

[0176] An ionizable lipid may refer to any of a number of lipid species that have a net positive charge at a selected pH, such as a physiological pH. In some embodiments, an LNP may comprise an ionizable lipid as disclosed in either of WO 2010/053572 or WO 2012/170930, or variations thereof, both of which are incorporated herein by reference in their entirety.

[0177] In some embodiments, an LNP for lung delivery of a TERT mRNA may comprise one or more of MC3 (((6Z,9Z,28Z,31Z)-heptatriaconta-6,9,28,31-tetraen-19-yl 4-(dimethylamino)butanoate), 1,2-dilineoyl-3- dimethylammonium-propane (DLinDAP), DLin-MC3-DMA 4-(dimethylamino)-butanoic acid, (10Z,13Z)-1-(9Z,12Z)-9,12-octadecadien-1-yl-10,13-nonadecadien-1-yl ester and/or cKK-E12 3,6-Bis(4-(bis(2-hydroxydodecyl)amino)butyl)piperazine-2,5-dione. In some embodiments the LNP comprises 2,2-dilinoleyl-4-dimethylaminoethyl-[l ,3]-dioxolane (Dlin-KC2- DMA, 1) and/or (6Z,9Z,28Z,31 Z)-Heptatriaconta-6,9,28,31-tetraen-19-yl 4-(dimethylamino)butanoate.

[0178] In some embodiments, the ionizable lipid may comprise SS-OP or analogs thereof. In some embodiments, the ionizable lipid is a compound of Formula (1):



(1)

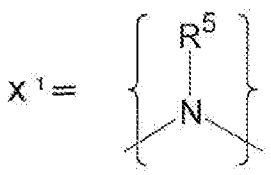
[0179] In the formula (1): R^{1a} and R^{1b} each independently represents an alkylene group having 1 to 6 carbon atoms, and may be linear or branched. The alkylene group may have 1 to 4 carbon atoms, or may have 1 to 2. Specific examples of the alkylene group having 1 to 6 carbon atoms include a methylene group, an ethylene group, a trimethylene group, an isopropylene group, a tetramethylene group, an isobutylene group, a pentamethylene group, and a neopentylene group. R^{1a} and R^{1b} may be each independently a methylene group, an ethylene group, a trimethylene group, an isopropylene group, or a tetramethylene group, and may be an ethylene group.

[0180] R^{1a} may be different or be the same as R^{1b}.

[0181] X^a and X^b are each independently an acyclic alkyl tertiary amino group having 1 to 6 carbon atoms and 1 tertiary amino group, or 2 to 5 carbon atoms, and a cyclic alkylene tertiary amino group having 1 to 2 tertiary amino groups, and/or each independently a cyclic alkylene having 2 to 5 carbon atoms and 1 to 2 tertiary amino groups and an alkylene tertiary amino group.

[0182] The alkyl group having 1 to 6 carbon atoms in the acyclic alkyl tertiary amino group having 1 to 6 carbon atoms and 1 tertiary amino group is branched even if it is linear. The alkyl group may be annular. The alkyl group may have 1 to 3 carbon atoms. Specific examples of the alkyl group having 1 to 6 carbon atoms include methyl group, ethyl group, propyl group, isopropyl group, n-butyl group, sec-butyl group, isobutyl group, tert-butyl group, pentyl group, and isopentyl group. Neopentyl group, t-pentyl group, 1,2-dimethylpropyl group, 2-methylbutyl group, 2-methylpentyl group, 3-methylpentyl group, 2,2-dimethylbutyl group, 2,3-dimethylbutyl group, A cyclohexyl group etc. can be mentioned.

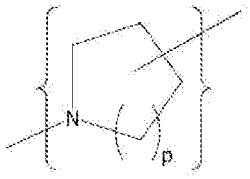
[0183] A specific structure of an acyclic alkyl tertiary amino group having 1 to 6 carbon atoms and 1 tertiary amino group is represented by X^1.



[0184] R^5 of X^1 represents an alkyl group having 1 to 6 carbon atoms and may be linear, branched or cyclic. The alkyl group may have 1 to 3 carbon atoms. Specific examples of the alkyl group having 1 to 6 carbon atoms include methyl group, ethyl group, propyl group, isopropyl group, n-butyl group, sec-butyl group, isobutyl group, tert-butyl group, pentyl group, and isopentyl group. Neopentyl group, t-pentyl group, 1,2-dimethylpropyl group, 2-methylbutyl group, 2-methylpentyl group, 3-methylpentyl group, 2,2-dimethylbutyl group, 2,3-dimethylbutyl group, A cyclohexyl group etc. can be mentioned.

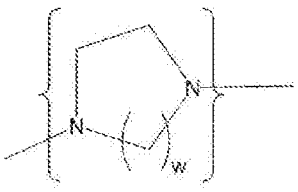
[0185] The number of carbon atoms in the cyclic alkylene tertiary amino group having 2 to 5 carbon atoms and 1 to 2 tertiary amino groups may be 4 to 5. Specific examples of the cyclic alkylene tertiary amino group having 2 to 5 carbon atoms and 1 to 2 tertiary amino groups include aziridylene group, azetidylene group, pyrrolidylene group, piperidylene group, imidazolidylene group, a piperazylene group, optionally a pyrrolidylene group, a piperidylene group or a piperazylene group.

[0186] Number is 2 to 5 carbon atoms, and specific structure of alkylene tertiary amino groups containing 1 annular tertiary amino group represented by X^2.

$X^2 =$ 

[0187] P of X^2 is 1 or 2. When p is 1, X^2 is a pyrrolidylene group, and when p is 2, X^2 is a piperidylene group.

[0188] A specific structure of a cyclic alkylene tertiary amino group having 2 to 5 carbon atoms and 2 tertiary amino groups is represented by X^3.

$X^3 =$ 

[0189] W of X^3 is 1 or 2. When w is 1, X^3 is an imidazolidylene group, and when w is 2, X^3 is a piperazylene group.

[0190] X^a may be different be identical to X^b.

[0191] R^{2a} and R^{2b} each independently represent an alkylene group or an oxydialkylene group having 8 or less carbon atoms, optionally each independently an alkylene group having 8 or less carbon atoms.

[0192] The alkylene group having 8 or less carbon atoms may be linear or branched but is optionally linear. The number of carbon atoms contained in the alkylene group is optionally 6 or less, and optionally 4 or less. Specific examples of the alkylene group having 8 or less carbon atoms include methylene group, ethylene group, propylene group, isopropylene group, tetramethylene group, isobutylene group, pentamethylene group, hexamethylene group, heptamethylene group, octamethylene group, and the like. In some embodiments included are a methylene group, an ethylene group, a propylene group, and a tetramethylene group.

[0193] The oxydialkylene group having 8 or less carbon atoms refers to an alkylene group (alkylene-O-alkylene) via an ether bond, and the total number of carbon atoms of two alkylene groups is 8 or less. Here, the two alkylenes may be the same or different, but are optionally the same. Specific examples of the oxydialkylene group having 8 or less carbon atoms include an oxydimethylene group, an oxydiethylene group, an oxydipropylene group, and an oxydibutylene group.

[0194] R^{2a} may be same or different and R^{2b}.

[0195] Y^a and Y^b are each independently an ester bond, an amide bond, a carbamate bond, an ether bond or a urea bond, optionally each independently an ester bond, an amide bond or a carbamate bond. While Y binding orientation of Y^a and Y^b are not limited, if Y^a and Y^b is an ester bond, optionally, -Z^a -CO-–-R^{2a} - and -Z^b -CO-O-R^{2b} -Structure.

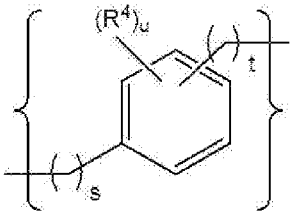
[0196] Y^a may be different or identical to Y^b.

[0197] Z^a and Z^b are each independently a divalent group derived from an aromatic compound having 3 to 16 carbon atoms, having at least one aromatic ring, and optionally having a hetero atom. Represents. The number of carbon atoms contained in the aromatic compound is optionally 6 to 12, or 6 to 7. Moreover, the number of aromatic rings contained in the aromatic compound is optionally one.

[0198] As the types of aromatic rings contained in the aromatic compound having 3 to 16 carbon atoms, as for aromatic hydrocarbon rings, benzene ring, naphthalene ring, anthracene ring, and aromatic heterocycles as imidazole ring, pyrazole ring, oxazole ring, Isoxazole ring, thiazole ring, isothiazole ring, triazine ring, pyrrole ring, furanthiophene ring, pyrimidine ring, pyridazine ring, pyrazine ring, pyridine ring, purine ring, pteridine ring, benzimidazole ring, indole ring, benzofuran ring, quinazoline ring, phthalazine ring, quinoline ring, isoquinoline ring, coumarin ring, chromone ring, benzodiazepine ring, phenoxazine ring, phenothiazine ring, acridine ring, etc., optionally benzene ring, naphthalene ring, anthracene ring. The aromatic ring may have a substituent. Examples of the substituent include an acyl group having 2 to 4 carbon atoms, an alkoxycarbonyl group having 2 to 4 carbon atoms, a carbamoyl

group having 2 to 4 carbon atoms, and 2 to 2 carbon atoms. 4 acyloxy groups, acylamino groups having 2 to 4 carbon atoms, alkoxycarbonylamino groups having 2 to 4 carbon atoms, fluorine atoms, chlorine atoms, bromine atoms, iodine atoms, alkylsulfanyl groups having 1 to 4 carbon atoms, 1 carbon atom Alkylsulfonyl group having 4 to 4, arylsulfonyl group having 6 to 10 carbon atoms, nitro group, trifluoromethyl group, cyano group, alkyl group having 1 to 4 carbon atoms, ureido group having 1 to 4 carbon atoms, 1 to carbon atoms 4 alkoxy groups, aryl groups having 6 to 10 carbon atoms, aryloxy groups having 6 to 10 carbon atoms, and the like. Some examples include acetyl groups, methoxycarbonyl groups, methyl carbonate groups, and the like, moyl group, acetoxy group, acetamide group, methoxycarbonylamino group, fluorine atom, chlorine atom, bromine atom, iodine atom, methylsulfanyl group, phenylsulfonyl group, nitro group, trifluoromethyl group, cyano group, methyl group, ethyl group Propyl group, isopropyl group, t-butyl group, ureido group, methoxy group, ethoxy group, propoxy group, isopropoxy group, t-butoxy group, phenyl group and phenoxy group.

[0199] A specific structure of Z^a and Z^b includes Z^1.

$Z^1 =$ 

[0200] Wherein, s represents an integer of 0 to 3, t represents an integer of 0 to 3, u represents an integer of 0 to 4, represents a u-number of R 4 is independently a substituent.

[0201] S in Z^1 is optionally an integer of 0 to 1.

[0202] T in Z^1 is optionally an integer of 0 to 2.

[0203] U in Z^1 is optionally an integer of 0 to 2.

[0204] R 4 in Z^1 is a substituent of an aromatic ring (benzene ring) contained in an aromatic compound having 3 to 16 carbon atoms that does not inhibit the reaction in the process of synthesizing the ionizable lipid. Examples of the substituent include an acyl group having 2 to 4 carbon atoms, an alkoxycarbonyl group having 2 to 4 carbon atoms, a carbamoyl group having 2 to 4 carbon atoms, an acyloxy group having 2 to 4 carbon atoms, and an acylamino group having 2 to 4 carbon atoms, an alkoxycarbonylamino group having 2 to 4 carbon atoms, fluorine atom, chlorine atom, bromine atom, iodine atom, alkylsulfanyl group having 1 to 4 carbon atoms, alkylsulfonyl group having 1 to 4 carbon atoms, 6 to 10 carbon atoms Arylsulfonyl group, nitro group, trifluoromethyl group, cyano group, alkyl group having 1 to 4 carbon atoms, ureido group having 1 to 4 carbon atoms, alkoxy group having 1 to 4 carbon

atoms, aryl group having 6 to 10 carbon atoms And aryloxy groups having 6 to 10 carbon atoms, and examples include acetyl, methoxycarbonyl, methylcarbamoyl, acetoxy, Mido group, methoxycarbonylamino group, fluorine atom, chlorine atom, bromine atom, iodine atom, methylsulfanyl group, phenylsulfonyl group, nitro group, trifluoromethyl group, cyano group, methyl group, ethyl group, propyl group, isopropyl group, T-butyl group, ureido group, methoxy group, ethoxy group, propoxy group, isopropoxy group, t-butoxy group, phenyl group and phenoxy group. When a plurality of R^4 are present, each R^4 may be the same or different.

[0205] Z^a may be different even identical to the Z^b.

[0206] R^{3a} and R^{3b} are each independently a residue derived from a reaction product of a fat-soluble vitamin having a hydroxyl group and succinic anhydride or glutaric anhydride, or a sterol derivative having a hydroxyl group and succinic anhydride or glutaric acid. Represents a residue derived from a reaction product with an anhydride, or an aliphatic hydrocarbon group having 12 to 22 carbon atoms, and optionally each independently a fat-soluble vitamin having a hydroxyl group and succinic anhydride or glutaric anhydride. Or a C 12-22 aliphatic hydrocarbon group, and optionally each independently an aliphatic hydrocarbon group having 12-22 carbon atoms.

[0207] Examples of the fat-soluble vitamin having a hydroxyl group include retinol, ergosterol, 7-dehydrocholesterol, calciferol, corcalciferol, dihydroergocalciferol, dihydrotaxolol, tocopherol, and tocotrienol. The fat-soluble vitamin having a hydroxyl group is optionally tocopherol.

[0208] Examples of the sterol derivative having a hydroxyl group include cholesterol, cholestanol, stigmasterol, β-sitosterol, lanosterol, ergosterol and the like, optionally cholesterol or cholestanol.

[0209] The aliphatic hydrocarbon group having 12 to 22 carbon atoms may be linear or branched. The aliphatic hydrocarbon group may be saturated or unsaturated. In the case of an unsaturated aliphatic hydrocarbon group, the number of unsaturated bonds contained in the aliphatic hydrocarbon group is usually 1 to 6, optionally 1 to 3, or 1 to 2. Unsaturated bonds include carbon-carbon double bonds and carbon-carbon triple bonds. The number of carbon atoms contained in the aliphatic hydrocarbon group is optionally 13 to 19, or 13 to 17. The aliphatic hydrocarbon group includes an alkyl group, an alkenyl group, an alkynyl group and the like, and optionally includes an alkyl group or an alkenyl group. Specific examples of the aliphatic hydrocarbon group having 12 to 22 carbon atoms include dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, nonadecyl, icosyl, heicosyl, docosyl, Dodecenyl group, tridecenyl group, tetradecenyl group, pentadecenyl group, hexadecenyl group,

heptadecenyl group, octadecenyl group, nonadecenyl group, icocenyl group, henicocenyl group, dococenyl group, dodecadienyl group, tridecadienyl group, tetradecadienyl group, pentadecadienyl group Group, hexadecadienyl group, heptadecadienyl group, octadecadienyl group, nonadecadienyl group, icosadenyl group, henicosadienyl group, docosadienyl group, octadecatrienyl group, icosatrienyl group, Cosatetraenyl group, icosapentaenyl group, docosahexaenyl group, isostearyl group, 1-hexylheptyl group, 1-hexylnonyl group, 1-octylnonyl group, 1-octylundecyl group, 1-decylundecyl group, etc. be able to. The aliphatic hydrocarbon group having 12 to 22 carbon atoms is optionally a tridecyl group, a pentadecyl group, a heptadecyl group, a nonadecyl group, a heptadecenyl group, a heptadecadienyl group, or a 1-hexylnonyl group, or a tridecyl group, A heptadecyl group, a heptadecenyl group, and a heptadecadienyl group.

[0210] In one embodiment of the present disclosure, the aliphatic hydrocarbon group having 12 to 22 carbon atoms represented by R^{3a} and R^{3b} is derived from a fatty acid. In this case, the carbonyl carbon derived from the fatty acid is contained in —CO—O— in the formula (1). Specific examples of the aliphatic hydrocarbon group include a heptadecenyl group when linoleic acid is used as the fatty acid, and a heptadecenyl group when oleic acid is used as the fatty acid.

[0211] R^{3a} may be different be the same as R^{3b}.

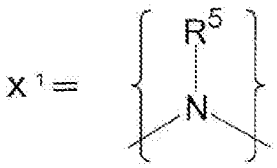
[0212] In one embodiment of the present disclosure, R^{1a} is the same as R^{1b}, X^a is the same as X^b, R^{2a} is the same as R^{2b}, Y^a is the same as Y^b, and Z^a is identical to the Z^b, R^{3a} is the same as R^{3b}.

[0213] Preferable examples of the ionizable lipid represented by the formula (1) include the following ionizable lipids: Ionizable lipid (1-1); R 1a and R 1b are each independently an alkylene group having 1 to 6 carbon atoms (eg, methylene group, ethylene group); X a and X b are each independently an acyclic alkyl tertiary amino group having 1 to 6 carbon atoms and 1 tertiary amino group (eg, —N (CH 3) —), Or a cyclic alkylene tertiary amino group having 2 to 5 carbon atoms and 1 to 2 tertiary amino groups (eg, piperidylene group); R^{2a} and R^{2b} are each independently an alkylene group having 8 or less carbon atoms (eg, methylene group, ethylene group, propylene group); Y^a and Y^b are each independently an ester bond or an amide bond; Z^a and Z^b are each independently a divalent group derived from an aromatic compound having 3 to 16 carbon atoms, having at least one aromatic ring, and optionally having a hetero atom. (Eg, —C 6 H 4 —CH 2 —, —CH 2 —C 6 H 4 —CH 2 —); R^{3a} and R^{3b} are each independently a residue derived from a reaction product of a fat-soluble vitamin having a hydroxyl group (eg, tocopherol) and succinic anhydride or glutaric anhydride,

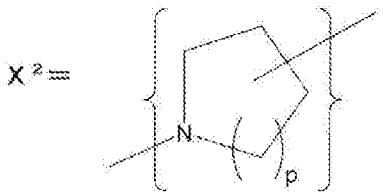
or an aliphatic group having 12 to 22 carbon atoms A hydrocarbon group (*eg,* heptadecenyl group, heptadecadienyl group, 1-hexylnonyl group);

[0214] Ionizable lipid (1-2); R^{1a} and R^{1b} are each independently an alkylene group having 1 to 4 carbon atoms (eg, methylene group, ethylene group); X a and X b are each independently an acyclic alkyl tertiary amino group having 1 to 3 carbon atoms and 1 tertiary amino group (eg, —N (CH 3) —), Or a cyclic alkylene tertiary amino group having 2 to 5 carbon atoms and 1 tertiary amino group (eg, piperidylene group); R^{2a} and R^{2b} are each independently an alkylene group having 6 or less carbon atoms (eg, methylene group, ethylene group, propylene group); Y^a and Y^b are each independently an ester bond or an amide bond; Z a and Z b are each independently a divalent group derived from an aromatic compound having 6 to 12 carbon atoms, one aromatic ring, and optionally having a hetero atom (Eg, —C 6 H 4 —CH 2 —, —CH 2 —C 6 H 4 —CH 2 —); R^{3a} and R^{3b} are each independently a residue derived from a reaction product of a fat-soluble vitamin having a hydroxyl group (eg, tocopherol) and succinic anhydride, or an aliphatic hydrocarbon group having 13 to 19 carbon atoms (eg, , Heptadecenyl group, heptadecadienyl group, 1-hexylnonyl group).

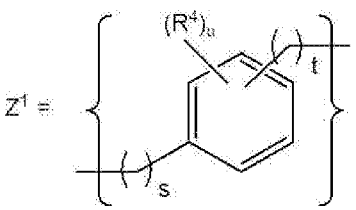
Ionizable lipid (1-3); R^{1a} and R^{1b} are each independently an alkylene group having 1 to 2 carbon atoms (eg, methylene group, ethylene group); X^a and X^b are each independently X^1:



wherein R^5 is an alkyl group having 1 to 3 carbon atoms (eg, a methyl group)), or X^2:



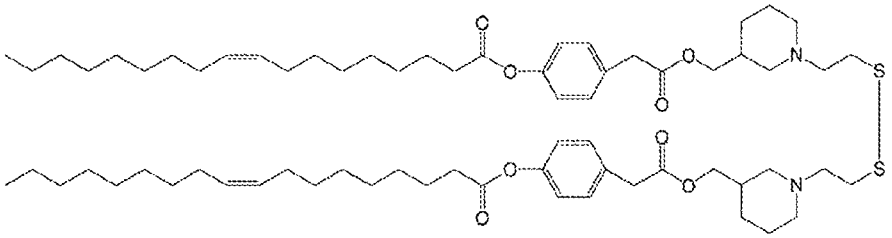
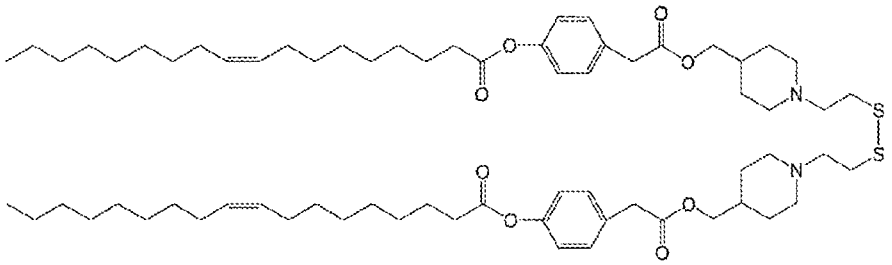
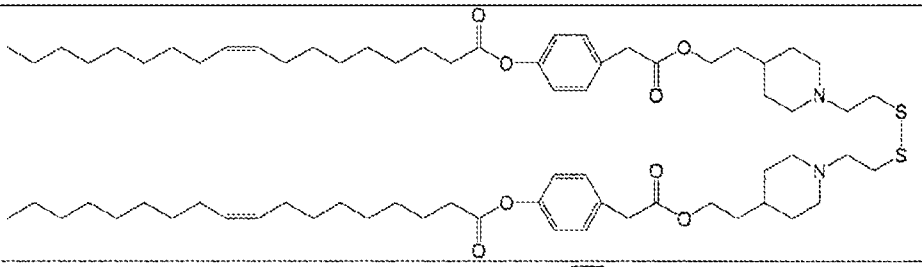
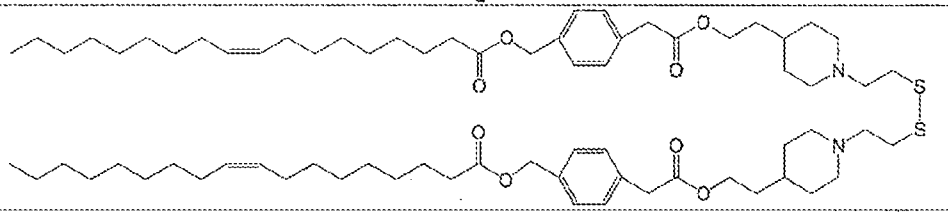
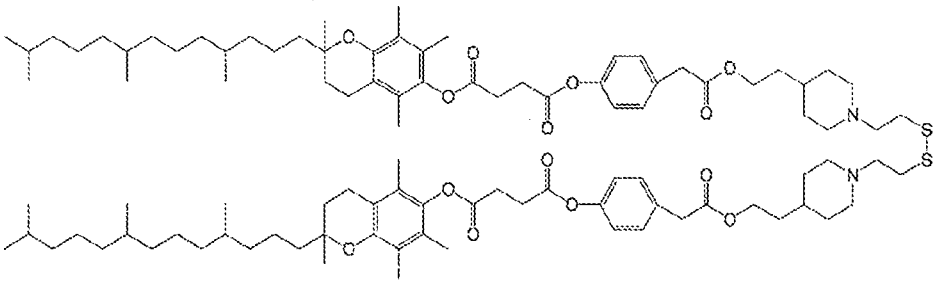
wherein p is 1 or 2), R^{2a} and R^{2b} are each independently an alkylene group having 4 or less carbon atoms (eg, methylene group, ethylene group, propylene group); Y^a and Y^b are each independently an ester bond or an amide bond; Z^a and Z^b are each independently Z^1:



wherein s is an integer from 0 to 1, t is an integer from 0 to 2, u is an integer from 0 to 2 (optionally 0), and $(R^4)u$ are each independently represents a substituent. R^{3a} and R^{3b} are each independently a residue derived from a reaction product of a fat-soluble vitamin having a hydroxyl group (eg, tocopherol) and succinic anhydride, or an aliphatic hydrocarbon group having 13 to 17 carbon atoms (eg, Heptadecenyl group, heptadecadienyl group, 1-hexylnonyl group);

[0215] Specific examples of the ionizable lipid according to Formula 1 of the present disclosure include the following O-Ph-P3C1, O-Ph-P4C1, O-Ph-P4C2, O-Bn-P4C2, E-Ph-P4C2, L-Ph- P4C2, HD-Ph-P4C2, O-Ph-amide-P4C2, and O-Ph-C3M as seen in Tables 3, 4, and 5.

Table 3: Ionizable lipids

O-Ph-P3C1	
O-Ph-P4C1	
O-Ph-P4C2	
O-Bn-P4C2	
E-Ph-P4C2	

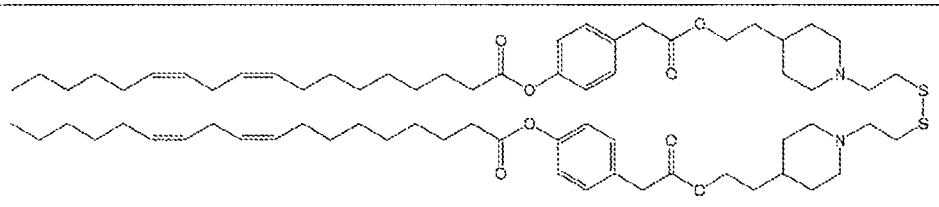
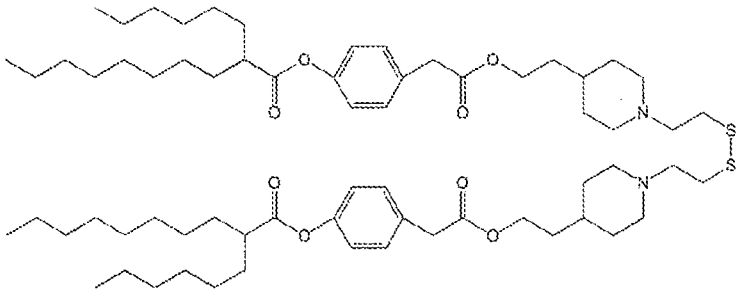
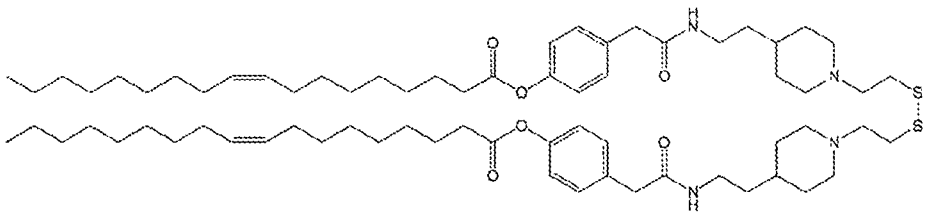
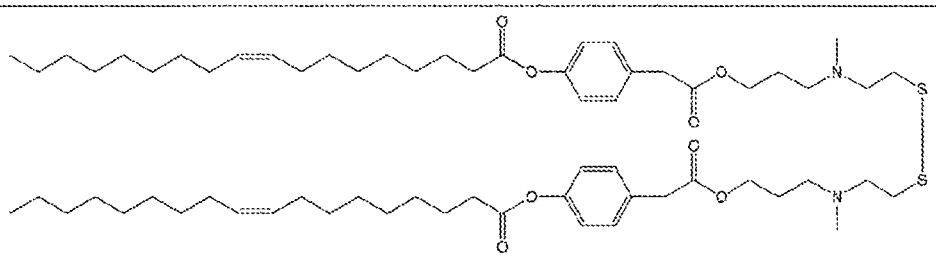
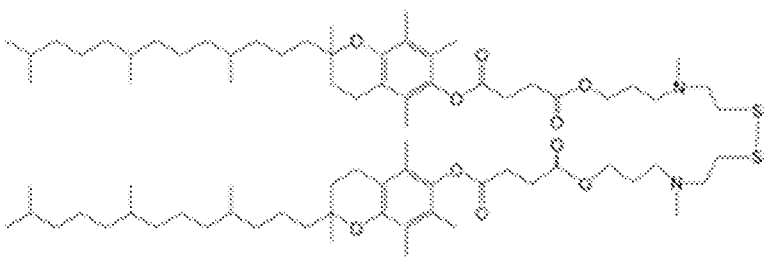
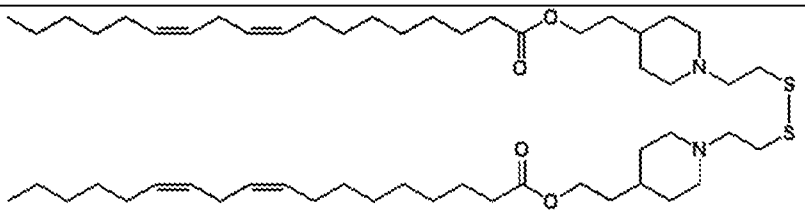
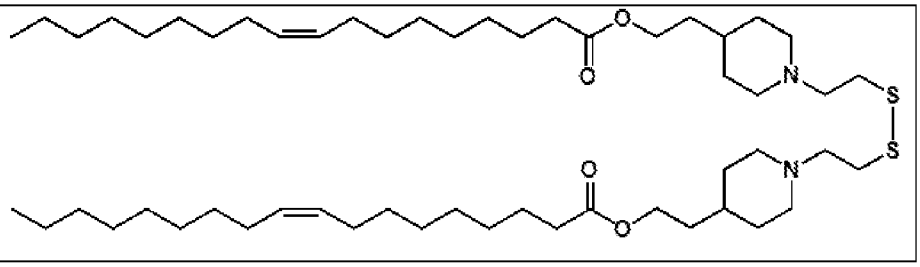
L-Ph-P4C2	
HD-Ph-P4C2	
O-Ph-amide-P4C2	
O-Ph-C3M	

Table 4: Ionizable lipids

α-D-Tocopherolsuccinoyl	
Linoleoyl	

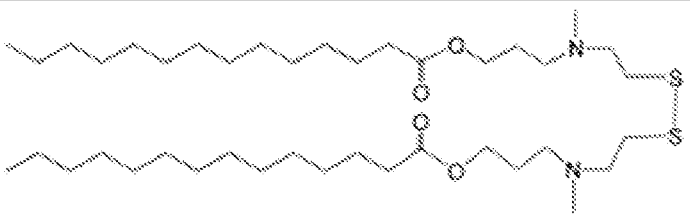
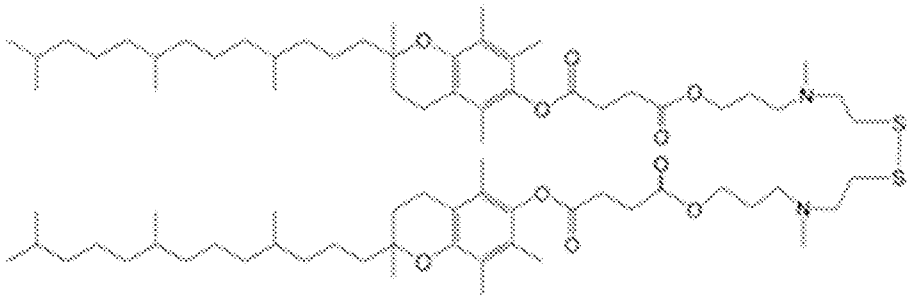
Oleoyl	

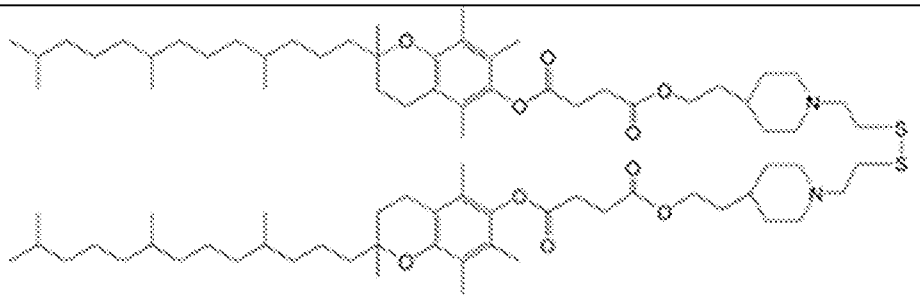
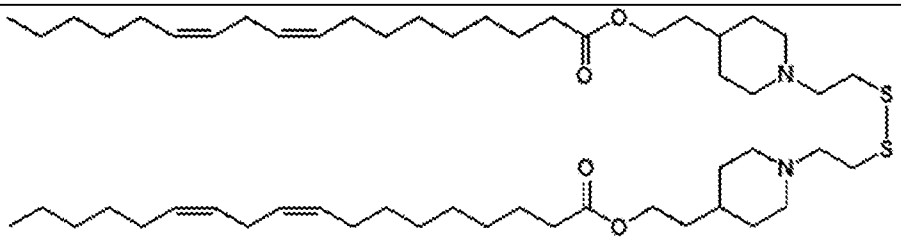
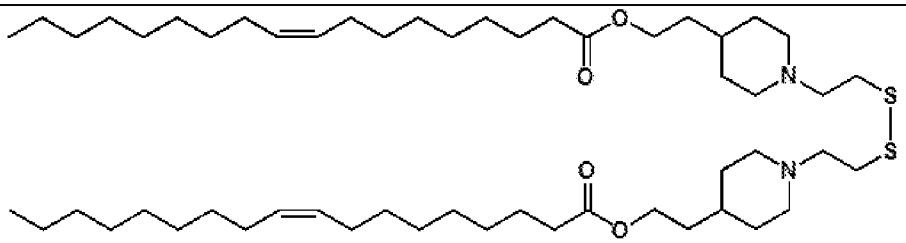
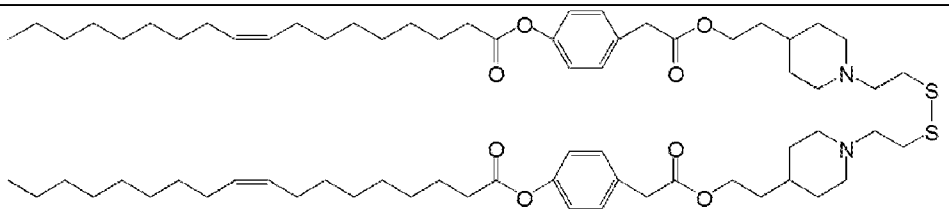
[0216] In some embodiments, the delivery vehicle is an LNP capable of transfecting at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, or at least 95% of a population of lung cells wherein the ionizable lipid is at least 10%, at least 20%, at least 30%, at least 40%, at least 50%, at least 60%, at least 70%, or at least 80% of the molar percentage of the LNP.

[0217] In some embodiments, the ionizable lipid is no more than 20%, no more than 30%, no more than 40%, no more than 50%, no more than 60%, no more than 70%, or no more than 90% of the molar percentage of the LNP. Example ionizable lipids include, but are not limited to: (15Z,18Z)—N,N-dimethyl-6-(9Z,12Z)-octadeca-9,12-dien-1-yl)tetracosa-15,18-dien-1-amine (HGT5000), (15Z,18Z)—N,N-dimethyl-6-((9Z,12Z)-octadeca-9,12-dien-1-yl)tetracosa-4,15,18-trien-1-amine (HGT5001), and (15Z,18Z)—N,N-dimethyl-6-((9Z,12Z)-octadeca-9,12-dien-1-yl)tetracosa-5,15,18-trien-1-amine (HGT5002).

[0218] Lipids having the structure of Formula I are shown in Table 5 below. For example, SS-OP is also named 0-Ph-P4C2. The term "SS-OP analog" as used herein refers to a compound of Formula I.

Table 5: Nomenclature of Lipids

Name	Structure
SS-M	
SS-E	

SS-EC	
SS-LC	
SS-OC	
SS-OP	

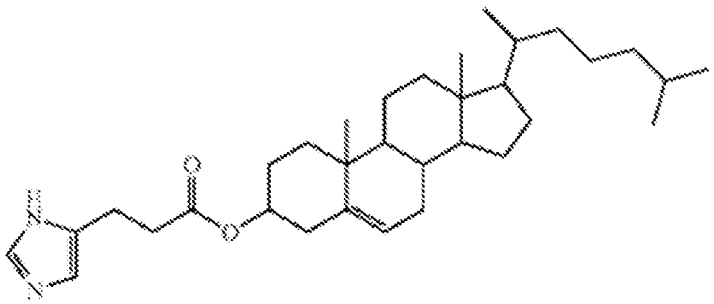
Cationic Lipids

[0219] In some embodiments, a lipid nanoparticle (LNP) of the disclosure comprises a cationic lipid, *e.g.* DOTAP or variations thereof. The cationic lipid may be a "permanent cationic lipid." The term cationic lipid may be cationic in pH ranges found in mammalian physiological environments such as blood or interstitial fluids. Cationic lipids may be composed of a cationic amine moiety and a lipid moiety, and the cationic amine moiety and a polyanion nucleic acid may interact to form a positively charged liposome or lipid membrane structure. Thus, uptake into cells may be promoted and nucleic acids delivered into cells.

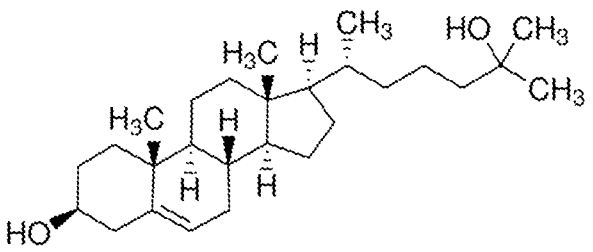
[0220] In some embodiments, the cationic lipid may selected from one or more of 1,2-dioleoyl-3-trimethylammonium-propane (DOTAP), N,N-distearyl-N,N-dimethylarnmonium bromide (DABB), or 1,2-dimyristoyl-sn-glycero-3-ethylphosphocholine (EPC). In some embodiments, an LNP comprises a ionizable lipid wherein the ionizable lipid is one or more of N-[l-(2,3-dioleyloxy)propyl]-N,N,N-trimethylammonium chloride (DOTMA), 5-

carboxyspermylglycinedioctadecylamide (DOGS), 2,3-dioleyloxy-N-[2(spermine-carboxamido)ethyl]-N,N-dimethyl-1-propanaminium (DOSPA), 1,2-Dioleoyl-3-Dimethylammonium-Propane (DODAP), 11,2-distearyloxy-N,N-dimethyl-3-aminopropane (DSDMA), 1,2-dioleyloxy-N,N-dimethyl-3-aminopropane (DODMA), 1,2-dilinoleyloxy-N,N-dimethyl-3-aminopropane (DLinDMA), dimethyldioctadecylammonium (DDA), 1,2-dilinolenyloxy-N,N-dimethyl-3-aminopropane (DLenDMA), N-dioleyl-N,N-dimethylammonium chloride (DODAC), N,N-distearyl-N,N-dimethylammonium bromide (DDAB), N-(1,2-dimyristyloxyprop-3-yl)-N,N-dimethyl-N-hydroxyethyl ammonium bromide (DMRIE), 3-dimethylamino-2-(cholest-5-en-3-beta-oxybutan-4-oxy)-1-(cis,cis-9,12-octadecadienoxy)propane (CLinDMA), 2-[5′-(cholest-5-en-3-beta-oxy)-3′-oxapentoxy)-3-dimethy 1-1-(cis,cis-9′,1-2′-octadecadienoxy)propane (CpLinDMA), N,N-dimethyl-3,4-dioleyloxybenzylamine (DMOBA), 1,2-N,N′-dioleylcarbamyl-3-dimethylaminopropane (DOcarbDAP), 2,3-Dilinoleoyloxy-N,N-dimethylpropylamine (DLinDAP), 1,2-N,N′-Dilinoleylcarbamyl-3-dimethylaminopropane (DLincarbDAP), 1,2-Dilinoleoylcarbamyl-3-dimethylaminopropane or (DLinCDAP), 2,2-dilinoleyl-4-dimethylaminomethyl-[1,3]-dioxolane (DLin-K-DMA), 2,2-dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (DLin-K-XTC2-DMA), and mixtures thereof.

[0221] In some embodiments, a cationic lipid refers to a cationic cholesterol lipid. In some embodiments of the disclosure an LNP comprises imidazole cholesterol ester (ICE). In some embodiments, an ICE structure is substantially similar to:

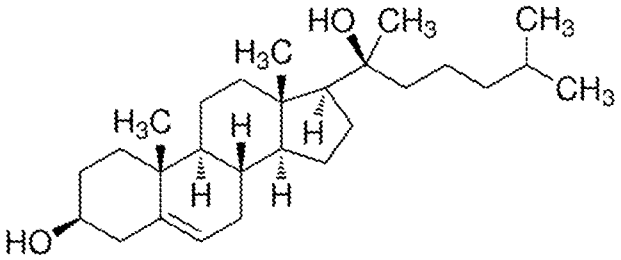


[0222] In some embodiments of the disclosure an LNP comprises 25-Hydroxycholesterol (25 OH Chol). In some embodiments, 25 OH Chol structure is substantially similar to:

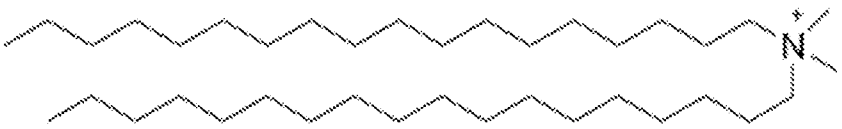


[0223] In some embodiments of the disclosure an LNP comprises 20α-hydroxycholesterol 5-cholestene-3α.

[0224] In some embodiments, the 20α-hydroxycholesterol 5-cholestene-3α (also known as 20α-diol or 20α chol structure) is substantially similar to:



[0225] In some embodiments, a cationic lipid refers to dimethyldioctadecylammonium bromide (DDAB). In some embodiments of the disclosure an LNP comprises dimethyldioctadecylammonium bromide (DDAB). In some embodiments, a dimethyldioctadecylammonium bromide (DDAB) structure is substantially similar to:



Structural Lipids

[0226] In some embodiments, the LNP comprises a structural lipid. As used herein, structural lipids are lipids that contribute a physical or chemical property to the LNP that is in addition to, or independent of, electrical charge. As an example, structural lipids may tend to have a shape, size, rigidity, hydrophobicity, or other property that increases the therapeutic utility of the LNP, such as, for example, by increasing its stability, half-life, deformability, transfection efficiency, tropism, thermostability, resistance to aggregation, membrane fluidity, or other parameter. In some embodiments, structural lipids are neutral in charge, either due to

lacking charged moieties, or due to being zwitterionic with balanced charges summing to zero net charge.

[0227] In some embodiments, an LNP may comprise a structural lipid selected from one more of: 1,2-di-(9Z-octadecenoyl)-sn-glycero-3-phosphoethanolamine (DOPE), glycerol-monooleate (GMO), distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG), dioleoylphosphatidylethanolamine (DOPE), palmitoyloleoylphosphatidylcholine (POPC), palmitoyloleoyl-phosphatidylethanolamine (POPE), dioleoyl-phosphatidylethanolamine 4-(N-maleimidomethyl)-cyclohexane-l-carboxylate (DOPE-mal), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidyl- ethanolamine (DSPE), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1-trans PE, l-stearoyl-2- oleoyl-phosphatidyethanolamine (SOPE), or variants thereof.

[0228] In some embodiments, an LNP may include one or more phosphatidyl lipids, for example, the phosphatidyl compounds (*e.g.*, phosphatidylglycerol, phosphatidylcholine, phosphatidylserine and phosphatidylethanolamine). In some embodiments, an LNP may comprise sphingolipids, for example but not limited to, sphingosine, ceramide, sphingomyelin, cerebroside and ganglioside. In some embodiments, the aforementioned "structural" lipids contribute to the stability and/or specificity of the LNP composition.

Cholesterol-based Lipids

[0229] In some embodiments, an LNP may comprise one or more cholesterol-based lipids. A cholesterol-based lipid may include but is not limited to: PEGylated cholesterol, DC-Choi (N,N-dimethyl-N-ethylcarboxamidocholesterol), 1,4-bis(3-N-oleylamino-propyl)piperazine.

PEGylated Lipids

[0230] In some embodiments of the disclosure, an LNP may comprise one or more PEGylated lipids. For example, the use of polyethylene glycol (PEG)-modified phospholipids and derivatized lipids such as derivatized ceramides (PEG-CER), including N-Octanoyl-Sphingosine-l-[Succinyl(Methoxy Polyethylene Glycol)-2000] (C8 PEG-2000 ceramide) is contemplated by the present disclosure in combination with one or more of the ionizable and/or other lipids. In some embodiments, PEGylated lipids comprise PEG-ceramides having shorter acyl chains (*e.g.*, C14 or C18). In some embodiments, the PEGylated lipid DSPE-PEG-Maleimide-Lectin may be used. Other contemplated PEG-modified lipids include, but are not

limited to, a polyethylene glycol chain of up to 5 kDa in length covalently attached to a lipid with alkyl chain(s) of C6-C2o length. Without wishing to be bound by a particular theory, it is contemplated that the addition of PEGylated lipids may prevent complex aggregation and increase circulation lifetime to facilitate the delivery of the liposome encapsulated mRNA to the target cell.

[0231] In some embodiments, a lipid nanoparticle formulation may comprise, consist essentially of or consist of any of those described in U.S. Patent Nos. 11,185,595; 9,868,693; 10,195,156; 9,877,919; 9,738,593; 10,399,937; 10,106,490; 9,738,593; 10,821,186; or 8,058,069, each of which is incorporated by reference herein in its entirety; or described in U.S. Patent Application Publication Nos. US20180085474A1, US20210259980A1, US20200206362A1, US20210267895A1, US20200283372A1, or US20200163878A1, each of which is incorporated by reference herein in its entirety.

Lipid nanoparticle (LNP) compositions

The following example LNP formulations are not intended to be limiting.

[0232] In some embodiments of the disclosure, an LNP may comprise an ionizable lipid, *e.g.* an SS-OP or SS-OP analog in a molar percentage of about 20, about 25, about 30, about 35, about 40, about 45, about 55, or about 60 relative to the total lipid; and a cationic lipid, *e.g.* DOTAP, ICE, DDAB or a cationic cholesterol lipid, in a molar percentage of about 15, about 20, about 25, about 30, about 35, about 40, about 45, or about 50 relative to the total lipid.

[0233] In some embodiments of the disclosure, the LNP comprises the cationic lipid at a molar percentage of between about 25% and about 35%. In some embodiments, the LNP comprises the cationic lipid at a molar percentage of about 30%.

[0234] In some embodiments of the disclosure, the LNP comprises a structural lipid. In some embodiments, the structural lipid is DOPC. In some embodiments, the LNP comprises DOPC in a molar ration of about 1%, about 2%, about 3%, about 4%, or about 5% of the total lipid.

[0235] In some embodiments of the disclosure, the LNP is substantially free of structural lipids and/or comprises at most 1% structural lipids.

[0236] In some embodiments of the disclosure, the LNP comprises cholesterol. In some embodiments, the LNP comprises a molar percentage of about 20% to about 40% cholesterol relative to the total lipid. In some embodiments, the LNP is substantially free of cholesterol.

[0237] In some embodiments of the disclosure, the LNP comprises an insulator lipid. In some embodiments, the LNP comprises an insulator lipid in a molar ratio of about 0.1% to

about 2%. In some embodiments, the LNP comprises an insulator lipid in a molar ratio of about 0.5% to about 1.5%. In some embodiments, the LNP is substantially free of insulator lipids.

Polymer nanoparticles

[0238] In some embodiments, a suitable delivery vehicle is formulated using a polymer as a carrier, alone or in combination with other carriers including various lipids described herein. Thus, in some embodiments, liposomal delivery vehicles, as used herein, also encompass polymer containing nanoparticles. Suitable polymers may include, for example, polyacrylates, polyalkycyanoacrylates, polylactide, polylactide-polyglycolide copolymers, polycaprolactones, dextran, albumin, gelatin, alginate, collagen, chitosan, cyclodextrins, protamine, polyethylene glycol (PEG)-modified (PEGylated) protamine, poly-D-lysine (PLL), PEGylated PLL and polyethylenimine (PEI). When PEI is present, it may be linear or branched PEI of a molecular weight ranging from 10 to 40 kDA, *e.g.,* 25 kDa branched PEI (Sigma #408727). In some embodiments the PEGylated lipid is 14:0 PEG2000 PE and/or DMG-PEG2000.

Lung targeting

[0239] The delivery vehicles disclosed herein preferentially target the lung. In various embodiments, the delivery vehicles may deliver and/or transfect a polynucleotide, *e.g.* an mRNA to lung cells 10, 10^2, 10^3, 10^4, 10^5, 10^6, 10^7, 10^8, 10^9, or 10^{10}-fold more effectively compared to the liver. LNP compositions as provided herein preferentially deliver to and/or transfects a polynucleotide, *e.g.* an RNA, to the lung compared to liver.

[0240] However, it will be understood that some level of delivery to non-target cells/organs may be tolerated without decreasing the effectiveness in the target organ/cell. In some embodiments, the lipid composition of a delivery vehicle enhances delivery to the lung relative to other lipid compositions known in the art. In other embodiments, the lipid composition of a delivery vehicle enhances delivery to the lung relative to other lipid compositions. In some embodiments, the presence or level of cholesterol enhances delivery of a delivery vehicle, *e.g.* an LNP or extracellular vesicle to the lung. In some embodiments, a delivery vehicle comprises an organ-specific targeting ligand to enhance delivery to a particular organ, *e.g.* the lung

III. Formulation of mRNA and nanoparticle delivery vehicle compositions

[0241] The methods of synthesis of mRNA and lipid nanoparticles (LNPs) are well established. Synthetic mRNAs, *e.g.,* comprising a 5′ cap, 5′ and 3′ UTRs coding sequence, and

a poly-A tail, may be synthesized from modified and unmodified nucleotides by in vitro transcription of a DNA template using an RNA polymerase, for example T7 RNA polymerase. The DNA template may be generated, for example, by PCR or plasmid amplification and restriction digest, followed by purification.

[0242] Lipid nanoparticles (LNPs), liposomes, or polymer nanoparticle delivery vehicles carrying mRNA may be produced, for example, by mixing the lipids or polymers in an organic solvent, *e.g.*, ethanol, with one or more mRNAs in an aqueous buffer, and then subject to buffer exchange and concentration. In some embodiments, the LNP, liposome, or polymer nanoparticle delivery vehicle may be produced using a microfluidic device to rapidly mix reagents and form monodisperse particles of controlled size. For example, the microfluidic mixer could be a staggered herringbone mixer (SHM). For example, the microfluidic mixer could be produce by the NanoAsssemblr made by Precision Nanosystems (PNI). In other embodiments, the LNP, liposome, or polymer nanoparticle delivery vehicle may be produced by a T-mixer. In some embodiments, the LNP, liposome, or polymer nanoparticle may encapsulate an mRNA and/or associate with one or more mRNAs through electrostatic interactions. The buffer exchange and concentration of the LNP, liposome, or polymer nanoparticle may be performed by tangential flow filtration. In other embodiments, the buffer exchange and concentration of the LNP, liposome, or polymer nanoparticle may be performed by centrifugal ultrafiltration using a membrane with a nominal molecule weight cutoff of <= 500,000 Da, for example 100,000 Da.

[0243] In some embodiments, the lipid nanoparticle particles (LNP) formulations provided herein are capable of transfecting at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, or at least 95% of a population of lung cells.

[0244] The form of the lipid membrane structure of the present disclosure is not particularly limited. For example, as a form in which the lipid of the present disclosure is dispersed in an aqueous solvent, liposomes (for example, monolayer liposomes, multilamellar liposomes, etc.), spherical micelles, string micelles, lipid nanoparticles (LNPs) or unspecified layered structures.

[0245] The lipid membrane structure of the present disclosure may further contain other component. Examples of the other components include lipids (phospholipids (such as phosphatidylinositol, phosphatidylethanolamine, phosphatidylserine, phosphatidic acid, phosphatidylglycerol, phosphatidylcholine), glycolipids, peptide lipids, cholesterol, ionizable lipids, cationic lipids, PEGylated lipids, etc.), surfactants (eg 3-[(3-cholamidopropyl) dimethylammonio] propane sulfonate, cholic acid sodium salt, octyl glycoside, ND-gluco -N-methylalkanamides), polyethylene glycol, proteins and the like. The content of the other

constituents in the lipid membrane structure of the present disclosure is usually 5 to 95 mol%, optionally 10 to 90 mol%, or 30 to 80 mol%.

[0246] The lipid membrane structure of the present disclosure is prepared by dispersing the lipids of the present disclosure and other components (lipids, etc.) in a suitable solvent or dispersion medium, for example, an aqueous solvent or an alcoholic solvent, and if necessary, tissue It can be prepared by performing an operation that induces crystallization.

[0247] Examples of the "operation for inducing organization" include an ethanol dilution method using a microchannel or a vortex, a simple hydration method, an ultrasonic treatment, a heating, a vortex, an ether injection method, a French press method, and a cholic acid method. Examples thereof include, but are not limited to, methods known per se such as Ca 2+ fusion method, freeze-thaw method, and reverse phase evaporation method.

[0248] The nucleic acid can be introduced into the cell in vivo and / or in vitro by encapsulating the nucleic acid in the lipid membrane structure containing the ionizable lipid of the present disclosure and bringing it into contact with the cell. Therefore, the present disclosure provides a nucleic acid introduction agent comprising the ionizable lipid or lipid membrane structure of the present disclosure.

[0249] The nucleic acid introduction agent of the present disclosure can introduce any nucleic acid into cells. Examples of the nucleic acid include, but are not limited to, DNA, RNA, RNA chimeric nucleic acid, DNA / RNA hybrid, and the like. The nucleic acid can be any one of 1 to 3 strands, but is optionally single strand or double strand. Nucleic acids may be other types of nucleotides that are N-glycosides of purine or pyrimidine bases, or other oligomers having a non-nucleotide backbone (*e.g.*, commercially available peptide nucleic acids (PNA), etc.) or other oligomers with special linkages. The oligomer may contain nucleotides having a configuration that allows base pairing or base attachment as found in DNA or RNA. In addition, the nucleic acid may be substituted with, for example, a known modified nucleic acid, a labeled nucleic acid, a capped nucleic acid, a methylated nucleic acid, or one or more natural nucleotides known in the art, intramolecular nucleotide modified nucleic acids, nucleic acids with uncharged bonds (*e.g.*, methyl sulfonate, phosphotriester, phosphoramidate, carbamate, etc.), charged bonds or sulfur containing bonds (eg phosphorothioate), side chain groups such as proteins (*e.g.*, nucleases, nuclease inhibitors, toxins, antibodies, signal peptides, poly-L-lysine, etc.) and sugars (eg, monosaccharides), nucleic acids and nucleic acids with intercurrent compounds (eg, acridine, psoralen, etc.), nucleic acids containing chelate compounds (eg, metals, radioactive metals, boron, oxidizing metals, etc.), nucleic acids containing alkylating agents, and nucleic acids with modified bonds (eg, alpha anomeric nucleic acids, etc.)

[0250] The type of DNA that can be used in the present disclosure is not particularly limited, and can be appropriately selected depending on the purpose of use. Examples include plasmid DNA, cDNA, antisense DNA, chromosomal DNA, PAC, BAC, and CpG oligo, optionally plasmid DNA, cDNA, and antisense DNA, or plasmid DNA. Circular DNA such as plasmid DNA can be appropriately digested with a restriction enzyme or the like and used as linear DNA.

[0251] The type of RNA that can be used in the present disclosure is not particularly limited, and can be appropriately selected depending on the purpose of use. For example, siRNA, miRNA, shRNA, antisense RNA, messenger RNA (mRNA), single-stranded RNA genome, double-stranded RNA genome, RNA replicon, transfer RNA, ribosomal RNA, etc., optionally siRNA, miRNA, shRNA, mRNA, antisense RNA, RNA replicon.

[0252] The nucleic acid used in the present disclosure is optionally purified by a method commonly used by those skilled in the art.

[0253] The nucleic acid-introducing agent of the present disclosure encapsulating nucleic acid can be administered in vivo for the purpose of, for example, prevention and / or treatment of diseases. Accordingly, the nucleic acid used in the present disclosure is optionally a nucleic acid having preventive and / or therapeutic activity against a given disease (prophylactic / therapeutic nucleic acid). Examples of such nucleic acids include nucleic acids used for so-called gene therapy.

[0254] In order to introduce a nucleic acid into a cell using the nucleic acid introduction agent of the present disclosure, the nucleic acid was encapsulated by coexisting the target nucleic acid when forming the lipid membrane structure of the present disclosure. The lipid membrane structure of the present disclosure is formed. For example, when liposomes are formed by the ethanol dilution method, the aqueous solution of nucleic acid and the ethanol solution of the components of the lipid membrane structure of the present disclosure (lipids, etc.) are vigorously mixed by vortex or microchannel, etc. Is diluted with an appropriate buffer. When liposomes are formed by the simple hydration method, the components (lipids, etc.) of the lipid membrane structure of the present disclosure are dissolved in an appropriate organic solvent, the solution is placed in a glass container, and the solvent is retained by drying under reduced pressure and left to obtain a lipid film. Here, an aqueous solution of nucleic acid is added and hydrated, followed by sonication with a sonicator. The present disclosure also provides the above lipid membrane structure in which such a nucleic acid is encapsulated.

[0255] An example of a lipid membrane structure in which a nucleic acid is encapsulated is LNP encapsulated in a nucleic acid by forming an electrostatic complex between the nucleic

acid and a ionizable lipid. This LNP can be used as a drug delivery system for selectively delivering a nucleic acid or the like into a specific cell. For example, a DNA vaccine by introducing an antigen gene into a dendritic cell, a gene therapy drug for a tumor, RNA It is useful for nucleic acid drugs that suppress the expression of target genes using interference.

[0256] The particle diameter of the lipid membrane structure of the present disclosure encapsulating nucleic acid is not particularly limited, but is optionally 10 nm to 500 nm, or 20 nm to 200 nm. The particle diameter can be measured using a particle size distribution measuring apparatus such as Zetasizer Nano (Malvern). The particle diameter of the lipid membrane structure can be appropriately adjusted according to the method for preparing the lipid membrane structure.

[0257] The surface potential (zeta potential) of the lipid membrane structure of the present disclosure encapsulating nucleic acid is not particularly limited, but may be −60 to +60 mV, −45 to 45 mV, −30 to +30 mV, −15 to +15 mV, or −10 to +10 mV. The zeta potential of the lipid membrane structure may be positive (>0 mV), +5mV to + 60mV, +30mM to + 45mV, or +10mV to + 45mV. In conventional gene transfer, particles having a positive surface potential have been mainly used. While this is useful as a method to promote electrostatic interaction with negatively charged cell surface heparin sulfate and promote cellular uptake, positive surface charge is delivered intracellularly. There is a possibility that the nucleic acid release from the carrier due to the interaction with the nucleic acid is suppressed, and the protein synthesis due to the interaction between the mRNA and the delivery nucleic acid is suppressed. By adjusting the surface charge within the above range, this problem can be solved. The surface charge can be measured by using a zeta potential measuring device such as Zetasizer Nano. The surface charge of the lipid membrane structure can be adjusted by the composition of the components of the lipid membrane structure.

[0258] The lipid membrane surface pKa (hereinafter referred to as Liposomal pKa) of the lipid membrane structure of the present disclosure is not particularly limited, but may have a pKa of 5.5 to 7.2, or a pKa of 6.0. to 6.8. Liposomal pKa is used as an index indicating that the lipid membrane structure taken up by endocytosis is susceptible to protonation of the lipid membrane structure in a weakly acidic environment within the endosome. Liposomal pKa can be adjusted by the composition of the components of the lipid membrane structure.

[0259] The hemolysis activity (membrane fusion ability) of a lipid membrane structure of the present disclosure is not particularly limited, but may have no hemolysis activity (less than 5%) at physiological pH (pH 7.4), and may be endosomal. The higher the hemolysis activity, the more efficiently the nucleic acid can be delivered into the cytoplasm. However, if the

hemolysis activity is present at physiological pH, the nucleic acid will be delivered to unintended cells during residence in the blood, resulting in decreased target-directedness and toxicity. Therefore, it is preferable to have hemolysis activity only in the endosomal environment as described above. The hemolysis activity can be adjusted by the composition of the components of the lipid membrane structure.

[0260] By bringing the lipid membrane structure of the present disclosure in which nucleic acid is encapsulated into contact with the cell, the encapsulated nucleic acid can be introduced into the cell. The cell may be a cultured cell line containing cancer cells, a cell isolated from an individual or tissue, or a tissue or tissue piece of cell. Further, the cells may be adherent cells or non-adherent cells.

[0261] The step of bringing the lipid membrane structure of the present disclosure encapsulating nucleic acid into contact with cells in vitro will be specifically described below.

[0262] Cells are suspended in an appropriate medium several days before contact with the lipid membrane structure and cultured under appropriate conditions. Upon contact with the lipid membrane structure, the cell may or may not be in the growth phase.

[0263] The culture medium at the time of the contact may be a serum-containing medium or a serum-free medium, but the serum concentration in the medium may be 30% by weight or less, more may be 20% by weight or less. If the medium contains excessive protein such as serum, the contact between the lipid membrane structure and the cell may be inhibited.

[0264] The cell density at the time of the contact is not particularly limited and can be appropriately set in consideration of the cell type, but is usually in the range of 1×10^4 to 1×10^7 cells/mL.

[0265] For example, a suspension of the lipid membrane structure of the present disclosure in which the above-described nucleic acid is encapsulated is added to the cells thus prepared. The addition amount of the suspension is not particularly limited, and can be appropriately set in consideration of the number of cells and the like. The concentration of the lipid membrane structure at the time of contacting the cell is not particularly limited as long as the introduction of the target nucleic acid into the cell can be achieved, but the lipid concentration is usually 1 to 100 nmol / mL, and may be 0.1 to 10 μg / mL.

[0266] After adding the above suspension to the cells, the cells are cultured. The culture temperature, humidity, CO_2 concentration, etc. are appropriately set in consideration of the cell type. When the cells are mammalian cells, the temperature is usually about 37 ° C., the humidity is about 95%, and the CO_2 concentration is about 5%. In addition, the culture time can be appropriately set in consideration of conditions such as the type of cells used, but may

be in the range of 0.1 to 76 hours, or in the range of 0.2 to 24 hours, and may be 0. .5-12 hours. If the culture time is too short, the nucleic acid is not sufficiently introduced into the cells, and if the culture time is too long, the cells may be weakened.

[0267] The nucleic acid is introduced into the cells by the above-described culture. The medium may be replaced with a fresh medium, or the fresh medium is added to the medium and the cultivation is further continued. If the cells are mammalian cells, the fresh medium may contain serum or nutrient factors.

[0268] The lipid membrane structure of the present disclosure may further contain other components in addition to the ionizable lipid of the present disclosure. Examples of the other components include lipids (phospholipids (such as phosphatidylinositol, phosphatidylethanolamine, phosphatidylserine, phosphatidic acid, phosphatidylglycerol, phosphatidylcholine), glycolipids, peptide lipids, cholesterol, ionizable lipids other than cationic lipids, PEG lipids, etc.), surfactants (eg 3-[(3-cholamidopropyl) dimethylammonio] propane sulfonate, cholic acid sodium salt, octyl glycoside, ND-gluco -N-methylalkanamides), polyethylene glycol, proteins and the like.

[0269] The lipid membrane structure of the present disclosure is prepared by dispersing the ionizable lipid of the present disclosure and other components (lipids, etc.) in a suitable solvent or dispersion medium, for example, an aqueous solvent or an alcoholic solvent, and if necessary, tissue. It can be prepared by performing an operation that induces crystallization.

[0270] Examples of the "operation for inducing organization" include an ethanol dilution method using a microchannel or a vortex, a simple hydration method, an ultrasonic treatment, a heating, a vortex, an ether injection method, a French press method, and a cholic acid method. Examples thereof include, but are not limited to, methods known per se such as Ca 2+ fusion method, freeze-thaw method, and reverse phase evaporation method.

[0271] The nucleic acid can be introduced into the cell in vivo and / or in vitro by encapsulating the nucleic acid in the lipid membrane structure containing the ionizable lipid of the present disclosure and bringing it into contact with the cell. Therefore, the present disclosure provides a nucleic acid introduction agent comprising the ionizable lipid or lipid membrane structure of the present disclosure.

[0272] The nucleic acid introduction agent of the present disclosure can introduce any nucleic acid into cells. Examples of the nucleic acid include, but are not limited to, DNA, RNA, RNA chimeric nucleic acid, DNA / RNA hybrid, and the like. The nucleic acid can be any one of 1 to 3 strands, but may be single strand or double strand. Nucleic acids may be other types of nucleotides that are N-glycosides of purine or pyrimidine bases, or other oligomers having

a non-nucleotide backbone (eg, commercially available peptide nucleic acids (PNA), etc.) or other oligomers with special linkages. The oligomer may contain nucleotides having a configuration that allows base pairing or base attachment as found in DNA or RNA.

[0273] The type of RNA that can be used in the present disclosure is not particularly limited, and can be appropriately selected depending on the purpose of use. For example, siRNA, miRNA, shRNA, antisense RNA, messenger RNA (mRNA), single-stranded RNA genome, double-stranded RNA genome, RNA replicon, transfer RNA, ribosomal RNA, etc., or siRNA, miRNA, shRNA, mRNA, antisense RNA, or an RNA replicon.

[0274] The nucleic acid used in the present disclosure may be purified by a method commonly used by those skilled in the art.

[0275] The nucleic acid-introducing agent of the present disclosure encapsulating nucleic acid can be administered in vivo for the purpose of, for example, prevention and / or treatment of diseases. Accordingly, the nucleic acid used in the present disclosure may be a nucleic acid having preventive andat/or therapeutic activity against a given disease (prophylactic / therapeutic nucleic acid). Examples of such nucleic acids include nucleic acids used for so-called gene therapy.

IV. Methods of treatment

[0276] Methods of treatment as described herein refer to the treatment of fibrotic disease and/or lung disease and/or lung fibrosis in a subject in need thereof by administration of a composition comprising one or more TERT mRNA sequences. Compositions and methods of the disclosure may be used for the treatment of fibrotic conditions, including fibrosis. In some embodiments, compositions and/or methods of use of compositions of the disclosure intended for treatment of fibrotic conditions, including fibrosis, induce TERT expression or increase TERT activity in a lung cell. In some embodiments, compositions and/or methods of use of compositions of the disclosure intended for treatment of fibrotic conditions, including fibrosis, do not induce cellular, tissue or systemic toxicity. Compositions may be administered systemically, *e.g.*, intravenously.

Dosage and timing of telomerase reverse transcriptase (TERT) mRNA

[0277] In the compositions and methods described herein, in some embodiments, a TERT mRNA is administered in a dose of about 0.001 mg/kg per the subject's body weight to about 2.0 mg/kg per the subject's body weight to a subject in need thereof. In some embodiments, a TERT mRNA is administered to a subject in need thereof in a dose of about 0.01 mg/kg; in some embodiments in a dose of about 0.025 mg/kg; in some embodiments in a dose of about

0.05 mg/kg; in some embodiments in a dose of about 0.075 mg/kg; in some embodiments in a dose of about 0.1 mg/kg; in some embodiments in a dose of about 0.125 mg/kg; in some embodiments in a dose of about 0.150 mg/kg; in some embodiments in a dose of about 0.175 mg/kg; in some embodiments in a dose of about 0.2 mg/kg; in some embodiments in a dose of about 0.5 mg/kg; in some embodiments in a dose of about 0.75 mg/kg; in some embodiments in a dose of about 1.0 mg/kg; in some embodiments, in a dose of about 1.25 mg/kg; in some embodiment in a dose of about 1.5 mg/kg; or in some embodiment in a dose of about 2.0 mg/kg. In some embodiments the TERT mRNA is administered to a subject in need thereof in a dose of 0.1 mg/kg. In some embodiments the TERT mRNA is administered to a subject in need thereof in a dose of 0.125 mg/kg.

[0278] In some embodiments the TERT mRNA is administered to a subject in need thereof in a single dose. In some embodiments the TERT mRNA is administered to a subject in need thereof two, three, four, or five or more times. In some embodiments, the TERT mRNA is administered twice a week, every week, every two weeks, every four weeks, every six weeks, every twelve weeks, or every fifteen weeks. In some embodiments, the TERT mRNA is administered every month, every two months, every three months, every six months, once a year, on an ongoing basis, or as determined by their physician.

TERT mRNA co-therapies

[0279] In some embodiments, co-administration of a TERT mRNA may be combined with other anti-fibrotic drugs used in the treatment of fibrotic diseases and/or lung diseases. Drugs that may be used include, but are not limited to nintedanib, pirfenidone, prednisone, azathioprine, cyclophosphamide, mycophenolate mofetil, Pamrevlumab, and N-acetylcysteine.

Routes of Administration

[0280] In some embodiments, a TERT mRNA may be delivered orally, subcutaneously, intravenously, intranasally, intradermally, transdermally, intraperitoneally, intramuscularly, intrapulmonarily, vaginally, rectally, or intraocularly. In example embodiments a TERT mRNA may be administered intravenously or through inhalation.

Subjects and Treatment

[0281] The methods of treatment described herein are useful for the treatment of lung disease and/or lung fibrosis in a subject in need thereof. Lung and lung fibrotic diseases may include, but are not limited to pulmonary fibrosis, lung cancer, familial pulmonary fibrosis,

idiopathic pulmonary fibrosis, pulmonary fibrosis associated with dyskeratosis congenita, an interstitial lung disease (ILD), pneumonia, interstitial pneumonia, tuberculosis, bronchitis, emphysema, lung cancer, chronic obstructive pulmonary disease (COPD), aging-associated fibrosis, pulmonary hypertension, asthma, and cystic fibrosis.

[0282] In some embodiments, a subject in need of the combination treatments described herein is a subject with a genetic disorder or mutation in telomerase reverse transcriptase (TERT). In some embodiments the subject has no symptoms of fibrosis. In other embodiments, the subject has symptoms and the treatment completely or partially ameliorates the symptoms. In other embodiments, the treatment slows progression of the symptoms.

[0283] In some embodiments, a subject in need of treatments described herein is a subject with a genetic disorder or mutation in telomerase reverse transcriptase (TERT). In some embodiments the subject has no symptoms of lung disease and/or lung fibrosis. In other embodiments, the subject has symptoms and the treatment completely or partially ameliorates the symptoms. In other embodiments, the treatment slows progression of the symptoms.

[0284] In some embodiments, the subject is human.

[0285] In some embodiments, efficacy of the treatment may be measured by lung or pulmonary function may be performed by methods including not limited to: spirometry, body plethysmography, methacholine inhalation challenge, six-minute walk test, exhaled nitric oxide test, arterial blood gas test, lung volume test, lung diffusion capacity, cardiopulmonary exercise test, oximetry with ambulation, respiratory muscle strength test, altitude simulation tests, exercise challenge (with spirometry before and after), shunt study (100% O_2), forced expiratory volume (FEV1), forced vital capacity (FVC), and maximal voluntary volume (MVV).

[0286] In some embodiments, administration of a TERT mRNA reduces fibrotic tissue in a subject by at least 5%, at least 10%, at least 20%, at least 30%, at least 40%, at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, at least 95%, at least 99%, or at least 100% over the treatment period and/or after the treatment period.

[0287] In some embodiments, administration of a TERT mRNA stops or slows the increase in fibrotic tissue over time relative to a subject without treatment. In some embodiments, the administration of a TERT mRNA slows the increase in amount of fibrotic tissue in a subject by at least 5%, at least 10%, at least 20%, at least 30%, at least 40%, at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, at least 95%, at least 99%, or at least 100% over the treatment period and/or after the treatment period.

[0288] In some embodiments, administration of a TERT mRNA increases lung function relative to a subject without treatment. In some embodiments, the administration of a TERT mRNA increases lung function in a subject by at least 5%, at least 10%, at least 20%, at least 30%, at least 40%, or at least 50% over the treatment period and/or after the treatment period.

[0289] In some embodiments, administration of a TERT mRNA extends survival relative to a subject without treatment. In some embodiments, administration of a TERT mRNA extends lung transplant-free survival relative to a subject without treatment. In some embodiments, the administration of a TERT mRNA extends survival of a subject by at least 5%, at least 10%, at least 20%, at least 30%, at least 40%, at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, at least 95%, at least 99%, at least 100%, at least 200%, at least 300%, at least 400%, at least 500%, at least 1000%, over the treatment period and/or after the treatment period. In some embodiments, administration of a TERT mRNA reduces hospitalization time and/or number of hospitalization visits to treat the lung disease and/or lung fibrosis. In some embodiments, administration of a TERT mRNA delays time to lung transplant.

V. Pharmaceutical Combinations

[0290] In some embodiments, a composition comprising a TERT mRNA includes an excipient, or carrier, *e.g.*, an aqueous carrier. A variety of aqueous carriers can be used, *e.g.*, buffered saline. The compositions may contain pharmaceutically acceptable auxiliary substances as those required to approximate physiological conditions such as pH and buffering agents, toxicity countering agents, *e.g.*, sodium acetate, sodium chloride, sodium citrate, potassium chloride, calcium chloride, and sodium lactate. In some embodiments, the pharmaceutical composition comprises 10 mM sodium citrate buffered to pH 6.4. The composition may contain a cryoprotectant, *e.g.*, glycerol, ethylene glycol, sucrose, propylene glycol, or dimethylsulfoxide (DMSO). The concentration of active agent in these formulations can vary and are selected based on fluid volumes, viscosities, and body weight in accordance with the particular mode of administration selected and the patient's needs (*e.g.*, Remington's Pharmaceutical Science (15th ed., 1980) and Goodman & Gillman, The Pharmacological Basis of Therapeutics (Hardman et al., eds., 1996)).

VI. Methods of Extending Telomeres

[0291] In another aspect, the instant disclosure provides methods of extending telomeres, comprising the step of administering any of the above-described compounds or compositions

to a cell with shortened telomeres, wherein telomeres are extended within the cell. The instant disclosure also provides methods of treatment, comprising the step of administering any of the above-described compounds or compositions to an animal subject in need of, or that may benefit from, telomere extension.

[0292] In some embodiments, the compounds or compositions are administered to a cell, wherein the cell is an isolated cell or is part of a cell culture, an isolated tissue culture, an isolated organ, or the like (i.e., the administration is in vitro).

[0293] In other embodiments, the compounds or compositions are administered without isolating the cell or cells, the tissue, or the organ from the subject (i.e., the administration is in vivo). In some of these embodiments, the compound or composition is delivered to all, or almost all, cells in the subject's body. In some embodiments, the compound or composition is delivered to a specific cell, cell type, tissue, or organ in the subject's body.

[0294] Administration of the compounds or compositions of the instant disclosure may result in the transient expression of a telomerase activity in the cell. The increased activity may be measured by various assays, such as, for example, the telomerase repeat amplification protocol (TRAP) assay. Commercial versions of the TRAP assay are available, for example the Trapeze® telomerase detection kit (Millipore), which provides a sensitive detection and quantitation of telomerase activity, although other measurement techniques are also possible.

[0295] As previously noted, one of the advantages of the instant techniques is that the expression of telomerase activity is transient in the treated cells. In particular, such transient expression is in contrast to previous techniques where a telomerase reverse transcriptase gene persists in an episomal DNA moiety, or is inserted into the genomic sequence of the cell or otherwise permanently modifies the genetic make-up of the targeted cell and results in constitutive activity of the nucleic acid sequence.

[0296] FIG. 1 graphically illustrates some of the advantages of the compounds, compositions, and methods disclosed herein. In particular, the speed of telomere extension made possible with these compounds, compositions, and methods enables telomere maintenance by very infrequent delivery of TERT mRNA. The expressed telomerase activity rapidly extends telomeres in a brief period, before being turned over, thus allowing the protective anti-cancer mechanism of telomere-shortening to function most of the time. Between treatments, normal telomerase activity and telomere shortening is present, and therefore the anti-cancer safety mechanism of telomere shortening to prevent out-of-control proliferation remains intact, while the risk of short telomere-related disease remains low. In contrast, small

molecule treatments for extending telomeres may require chronic delivery, and thus present a chronic cancer risk, with minimal therapeutic benefit.

[0297] In some embodiments of the instant methods, the transient expression is independent of cell cycle.

[0298] As noted above, the transient expression of telomerase reverse transcriptase results in the extension of shortened telomeres in treated cells. Telomere length can be measured using techniques such as terminal restriction fragment (TRF) length analysis, qPCR, MMqPCR, TeSLA, flow FISH, and Q-FISH, as would be understood by one of ordinary skill in the art. In some embodiments, the instant methods increase average telomere length in treated cells by at least 0.1 kb, at least 0.2 kb, at least 0.3 kb, at least 0.4 kb, at least 0.5 kb, at least 1 kb, at least 2 kb, at least 3 kb, at least 4 kb, at least 5 kb, or even more. In some embodiments, the instant methods reduce the percentage of telomeres with lengths below a certain length, for example 1 kb, 2 kb, 3 kb, 4 kb, 5 kb, or more.

[0299] One of the advantages of the instant compounds, compositions, and methods, is the rapidity of extension of telomeres achieved by these techniques. The techniques allow treatments to be brief, and thus the interval between treatments can be long, and thus the treatments can be safe because the normal protective telomere shortening mechanism remains intact for most of the time i.e. between treatments.

[0300] The transient expression of telomerase reverse transcriptase also results in an increased replicative capacity in treated cells. Increased replicative capacity is readily monitored in cells that are approaching replicative senescence by measuring additional population doublings in such cells. Senescent cells do not divide in response to many conditions that cause normal cells to divide, for example passage in culture or treatment with serum. Senescent cells are further often characterized by the expression of pH-dependent β-galactosidase activity, expression of cell cycle inhibitors p53 and p19, and other altered patterns of gene expression, and an enlarged cell size. It is known in the art that, absent treatment with TERT mRNA, certain types of cells (*e.g.*, human lung fibroblast cells) typically double 50-60 times after birth before senescing; with TERT mRNA treatments, however, these cells achieve an additional 16-28 population doublings. If treated again several weeks later, additional proliferative capacity is conferred again. This process of intermittent treatments to periodically re-extend telomeres may be applied additional times, with the interval between treatments depending on factors such as the rate of telomere shortening, the rate of cell divisions, and the amount of telomere extension provided by the treatment. Likewise, human microvascular dermal endothelial cells from an aged individual, absent treatment with the instant

compositions, may achieve only 1-2 population doublings, whereas treated cells may achieve 3, 4, or even more population doublings.

[0301] Accordingly, in some embodiments, the instant treatment methods increase the number of population doublings of treated cells.

[0302] Compositions of the disclosure may treat genetic diseases resulting from mutations in genes not involved directly in telomere maintenance, but resulting in shortened telomeres. Such diseases include, for example, dyskeratosis congenita (DC) and forms of pulmonary fibrosis, lung disease, bone marrow failure, and aplastic anemia.

[0303] In addition, various types of cancer may be prevented or delayed by treatment with compounds of the present disclosure, and indeed chromosome-chromosome fusions caused by critically short telomeres are believed to be a cause of cancer.

VII. Therapeutic kits

[0304] Therapeutic kits comprising a pharmaceutical composition of a TERT mRNA, or sequences thereof (including complementary sequences), and instructions for use are also contemplated herein. In some embodiments, the therapeutic kit comprises devices for administration, including but not limited to syringes, inhalers, nebulizers, and vials or containers.

[0305] In another aspect, the instant disclosure provides ready-to-use kits for use in extending telomeres in a mammalian cell. The kits comprise any of the above-described compounds or compositions, together with instructions for their use. In some embodiments, the kits further comprise packaging materials. In some embodiments, the packaging materials are air-tight. In these embodiments, the packaging materials may optionally be filled with an inert gas, such as, for example, nitrogen, argon, or the like. In some embodiments, the packaging materials comprise a metal foil container, such as, for example, a sealed aluminum pouch or the like. Such packaging materials are well known by those of ordinary skill in the art. The kit may also comprise a delivery vehicle, such as a lipid as described herein. In some embodiments, one or more components of the formulation are provided frozen with a cryoprotectant, or lyophilized.

[0306] In some embodiments, the kit may further comprise a desiccant, a culture medium, an RNase inhibitor, or other such components. In some embodiments, the kit may further comprise a combination of more than one of these additional components. In some kit embodiments, the composition of the kit is sterile.

ENUMERATED EMBODIMENTS

[0307] The disclosure may be defined by reference to the following enumerated, illustrative embodiments.

Embodiments I

[0308] Embodiment I-1. A composition comprising a (i) a ribonucleic acid (RNA) encoding telomerase reverse transcriptase (TERT) and (ii) a delivery vehicle, wherein the RNA of (i) comprises one or more modified nucleotides and wherein the delivery vehicle of (ii) is operably-linked to the RNA of (i).

[0309] Embodiment I-2. The composition of embodiment I-1, wherein the delivery vehicle comprises one or more of a nanoparticle, a liposome, a cationic lipid, an ionizable lipid, an exosome, a lipid nanoparticle, a natural lipoprotein particle and an artificial lipoprotein particle.

[0310] Embodiment I-3. The composition of embodiment I-1, wherein the delivery vehicle comprises a lipid nanoparticle.

[0311] Embodiment I-4. The composition of embodiment I-1, wherein the delivery vehicle comprises a ionizable lipid nanoparticle.

[0312] Embodiment I-5. The composition of any one of embodiments I-1 to I-4, wherein the delivery vehicle comprises a targeting lipid.

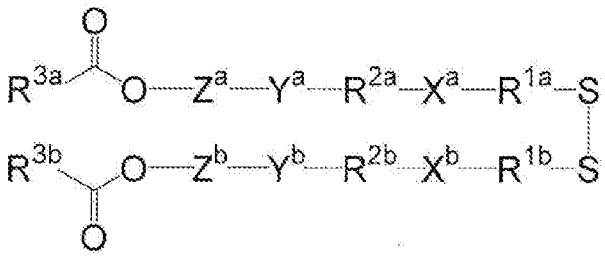
[0313] Embodiment I-6. The composition of embodiment I-5, wherein the targeting lipid specifically or selectively interacts with a liver cell.

[0314] Embodiment I-7. The composition of embodiment I-6, wherein the targeting lipid comprises cholesterol.

[0315] Embodiment I-8. The composition of embodiment I-5, wherein the targeting lipid specifically or selectively interacts with a lung cell.

[0316] Embodiment I-9. The composition of embodiment I-8, wherein the targeting lipid comprises 1,2-dioleoyl-3-trimethylammonium-propane (DOTAP), N,N-distearyl-N,N-dimethylarnmonium bromide (DABB), or 1,2-dimyristoyl-*sn*-glycero-3-ethylphosphocholine (EPC).

[0317] Embodiment I-10. The composition of any one of embodiments I-1 to I-9, wherein the delivery vehicle comprises a compound of Formula I:



(1)

,

[0318] wherein R^{1a} and R^{1b} each independently represents an alkylene group having 1 to 6 carbon atoms,

wherein X^a and X^b are each independently an acyclic alkyl tertiary amino group having 1 to 6 carbon atoms and 1 tertiary amino group, or 2 to 5 carbon atoms, and A cyclic alkylene tertiary amino group having 1 to 2 tertiary amino groups,

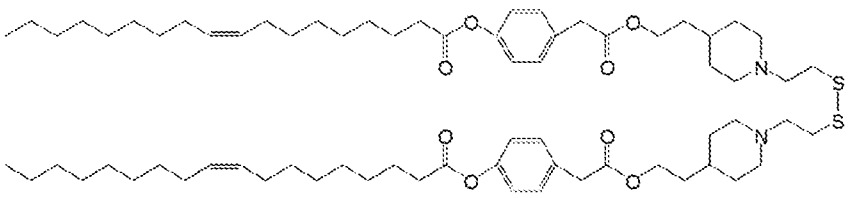
[0319] wherein R^{2a} and R^{2b} each independently represent an alkylene group having 8 or less carbon atoms or an oxydialkylene group,

[0320] wherein Y^a and Y^b each independently represent an ester bond, an amide bond, a carbamate bond, an ether bond or a urea bond;

[0321] wherein Z^a and Z^b are each independently a divalent group derived from an aromatic compound having 3 to 16 carbon atoms, having at least one aromatic ring, and optionally having a hetero atom, and

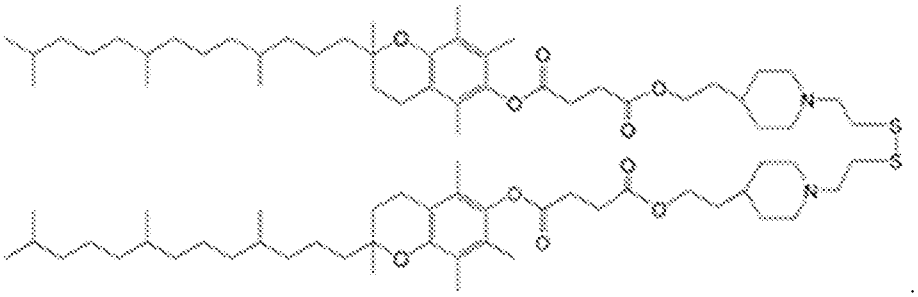
[0322] wherein R^{3a} and R^{3b} each independently represent a residue derived from a reaction product of a fat-soluble vitamin having a hydroxyl group and succinic anhydride or glutaric anhydride, or a sterol derivative having a hydroxyl group and succinic anhydride or a residue derived from a reaction product with glutaric anhydride or an aliphatic hydrocarbon group having 12 to 22 carbon atoms.

[0323] Embodiment I-11. The composition of embodiment I-10, wherein the compound of Formula I is:

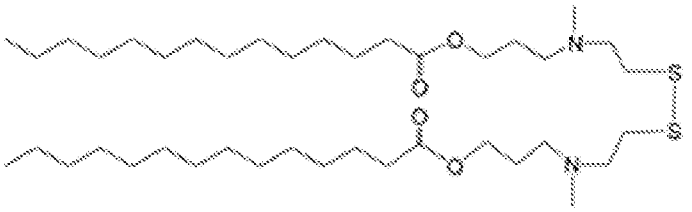


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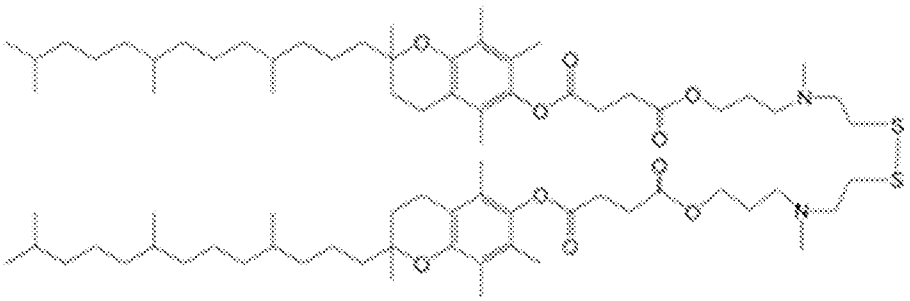
[0324] Embodiment I-12. The composition of embodiment I-10, wherein the compound of Formula I is:



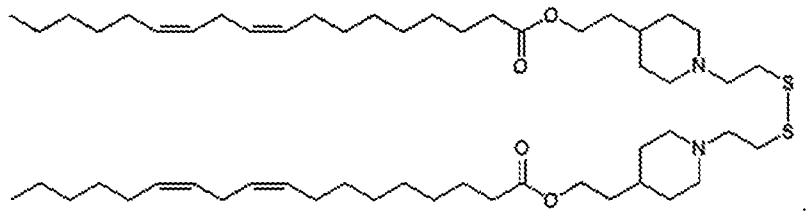
[0325] Embodiment I-13. The composition of embodiment I-10, wherein the compound of Formula I is:



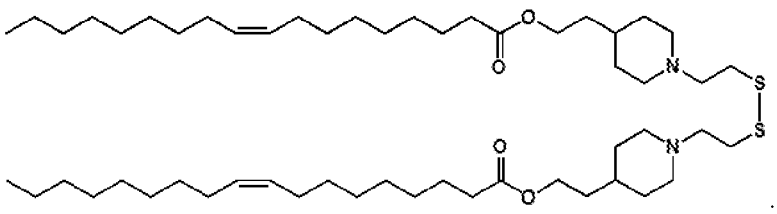
[0326] Embodiment I-14. The composition of embodiment I-10, wherein the compound of Formula I is:



[0327] Embodiment I-15. The composition of embodiment I-10, wherein the compound of Formula I is:



[0328] Embodiment I-16. The composition of embodiment I-10, wherein the compound of Formula I is:



[0329] Embodiment I-17. The composition of any one of embodiments I-1 to I-16, wherein the RNA comprises a human sequence of SEQ ID NO: 3 or 4 or a sequence at least 70% identical to the sequence of SEQ ID NO: 3 or 4.

[0330] Embodiment I-18. The composition of embodiment I-17, wherein the RNA comprises a 5′ cap.

[0331] Embodiment I-19. The composition of embodiment I-18, wherein the 5′cap comprises an anti-reverse cap analog (ARCA).

[0332] Embodiment I-20. The composition of embodiment I-19, wherein the ARCA comprises an 3′-O-Me-m7G(5′)ppp(5′)G structure.

[0333] Embodiment I-21. The composition of embodiment I-18, wherein the 5′ cap comprises m7G(5′)ppp(5′)(2′OMeA)pG.

[0334] Embodiment I-22. The composition of any one of embodiments I-1 to I-21, wherein the RNA further comprises at least one untranslated region (UTR).

[0335] Embodiment I-23. The composition of embodiment I-22, wherein the at least one UTR is positioned 5′ to the RNA of (i).

[0336] Embodiment I-24. The composition of embodiment I-22, wherein the at least one UTR is positioned 3′ to the RNA of (i).

[0337] Embodiment I-25. The composition of any one of embodiments I-22 to I-24, wherein the UTR comprises a human sequence.

[0338] Embodiment I-26. The composition of any one of embodiments I-22 to I-24, wherein the UTR comprises a non-human sequence.

[0339] Embodiment I-27. The composition of any one of embodiments I-22 to I-26, wherein the UTR comprises a chimeric sequence.

[0340] Embodiment I-28. The composition of embodiment I-27, wherine the chimeric sequence increases stability, increases a transcription rate or decreases a time until initiation of transcription of the RNA of (i).

[0341] Embodiment I-29. The composition of any one of embodiments I-22 to I-28, wherein the UTR comprises a sequence having at least 70% identity to a UTR sequence isolated or derived from one or more of α-globin, β-globin, c-fos, and a tobacco etch virus.

[0342] Embodiment I-30. The composition of any one of embodiments I-1 to I-29, wherein the one or more modified nucleotides of the RNA of (i) comprise one or more of a modified adenine or analog thereof, a modified cytidine or analog thereof, a modified guanosine or analog thereof, and a modified uridine or analog thereof.

[0343] Embodiment I-31. The composition of any one of embodiments I-1 to I-30, wherein the one or more modified nucleotides of the RNA of (i) comprise one or more of 1-methylpseudouridine, pseudouridine, 2-thiouridine, and 5-methylcytidine.

[0344] Embodiment I-32. The composition of any one of embodiments I-1 to I-31, wherein the one or more modified nucleotides of the RNA of (i) comprise 5-methoxyuridine (5-moU).

[0345] Embodiment I-33. The composition of any one of embodiments I-1 to I-32, wherein the one or more modified nucleotides of the RNA of (i) comprise one or more of m1A 1-methyladenosine, m6A N6-methyladenosine, Am 2′-O-methyladenosine, i6A N6-isopentenyladenosine, io6A N6-(cis-hydroxyisopentenyl)adenosine, ms2io6A 2-methylthio-N6-(cis-hydroxyisopentenyl) adenosine, g6A N6-glycinylcarbamoyladenosine, t6A N6-threonylcarbamoyladenosine, ms2t6A 2-methylthio-N6-threonyl carbamoyladenosine, Ar(p) 2′-O-ribosyladenosine (phosphate), m6 2A N6,N6-dimethyladenosine, m6Am N6,2′-O-dimethyladenosine, m6 2Am N6,N6,2′-O-trimethyladenosine, m1Am 1,2′-O-dimethyladenosine, m3C 3-methylcytidine, m5C 5-methylcytidine, Cm 2′-O-methylcytidine, ac4C N4-acetylcytidine, f5C 5-formylcytidine, m4C N4-methylcytidine, hm5C 5-hydroxymethylcytidine, f5Cm 5-formyl-2′-O-methylcytidine, m1G 1-methylguanosine, m2G N2-methylguanosine, m7G 7-methylguanosine, Gm 2′-O-methylguanosine, m2 2G N2,N2-dimethylguanosine, Gr(p) 2′-O-ribosylguanosine (phosphate), yW wybutosine, o2yW peroxywybutosine, OHyW hydroxywybutosine, OHyW* undermodified hydroxywybutosine, imG wyosine, m2,7G N2,7-dimethylguanosine, m2,2,7G N2,N2,7-trimethylguanosine I inosine, m1I 1-methylinosine, Im 2′-O-methylinosine, Q queuosine, galQ galactosyl-queuosine, manQ mannosyl-queuosine, Ψ pseudouridine, D dihydrouridine, m5U 5-methyluridine, Um 2′-O-methyluridine, m5Um 5,2′-O-dimethyluridine, m1Ψ 1-methylpseudouridine, Ψm 2′-O-methylpseudouridine, s2U 2-thiouridine, ho5U 5-hydroxyuridine, chm5U 5-(carboxyhydroxymethyl)uridine, mchm5U 5-(carboxyhydroxymethyl)uridine, methyl ester mcm5U 5-methoxycarbonylmethyluridine, mcm5Um 5-methoxycarbonylmethyl-2′-O-methyluridine, mcm5s2U 5-methoxycarbonylmethyl-2-thiouridine, ncm5U 5-carbamoylmethyluridine, ncm5Um 5-carbamoylmethyl-2′-O-methyluridine, cmnm5U 5-carboxymethylaminomethyluridine, m3U 3-methyluridine, m1acp3Ψ 1-methyl-3-(3-amino-3-carboxypropyl) pseudouridine, cm5U 5-carboxymethyluridine, m3Um 3,2′-O-dimethyluridine, m5D 5-methyldihydrouridine, τm5U 5-taurinomethyluridine, τm5s2U 5-taurinomethyl-2-thiouridine, 2-Aminoadenosine, 2-Amino-6-chloropurineriboside, 8-Azaadenosine, 6-Chloropurineriboside, 5-Iodocytidine, 5-Iodouridine, Inosine, 2′-O-Methylinosine, Xanthosine, 4-Thiouridine, O6-Methylguanosine,

5,6-Dihydrouridine, 2-Thiocytidine, 6-Azacytidine, 6-Azauridine, 2′-O-Methyl-2-aminoadenosine, 2′-O-Methylpseudouridine, N1-Methyladenosine, 2′-O-Methyl-5-methyluridine, 7-Deazaguanosine, 8-Azidoadenosine, 5-Bromocytidine, 5-Bromouridine, 7-Deazaadenosine, 5-Aminoallyluridine, 5-Aminoallylcytidine, 8-Oxoguanosine, 2-Aminopurine-riboside, Pseudoisocytidine, N1-Methylpseudouridine, 5,6-Dihydro-5-Methyluridine, N6-Methyl-2-Aminoadenosine, 5-Carboxycytidine, 5-Hydroxymethyluridine, Thienoguanosine, 5-Hydroxycytidine, 5-Formyluridine, 5-Carboxyuridine, 5-Methoxyuridine, 5-Methoxycytidine, Thienouridine, 5-Carboxymethylesteruridine, Thienocytidine, 8-Oxoadenoosine, Isoguanosine, N1-Ethylpseudouridine, N1-Methyl-2′-O-Methylpseudouridine, N1-Methoxymethylpseudouridine, N1-Propylpseudouridine, 2′-O-Methyl-N6-Methyladenosine, 2-Amino-6-Cl-purine-2′-deoxyriboside, 2-Amino-2′-deoxyadenosine, 2-Aminopurine-2′-deoxyriboside, 5-Bromo-2′-deoxycytidine, 5-Bromo-2′-deoxyuridine, 6-Chloropurine-2′-deoxyriboside, 7-Deaza-2′-deoxyadenosine, 7-Deaza-2′-deoxyguanosine, 2′-Deoxyinosine, 5-Propynyl-2′-deoxycytidine, 5-Propynyl-2′-deoxyuridine, 5-Fluoro-2′-deoxyuridine, 5-Iodo-2′-deoxycytidine, 5-Iodo-2′-deoxyuridine, N6-Methyl-2′-deoxyadenosine, 5-Methyl-2′-deoxycytidine, O6-Methyl-2′-deoxyguanosine, N2-Methyl-2′-deoxyguanosine, 8-Oxo-2′-deoxyadenosine, 8-Oxo-2′-deoxyguanosine, 2-Thiothymidine, 2′-Deoxy-P-nucleoside, 5-Hydroxy-2′-deoxycytidine, 4-Thiothymidine, 2-Thio-2′-deoxycytidine, 6-Aza-2′-deoxyuridine, 6-Thio-2′-deoxyguanosine, 8-Chloro-2′-deoxyadenosine, 5-Aminoallyl-2′-deoxycytidine, 5-Aminoallyl-2′-deoxyuridine, N4-Methyl-2′-deoxycytidine, 2′-Deoxyzebularine, 5-Hydroxymethyl-2′-deoxyuridine, 5-Hydroxymethyl-2′-deoxycytidine, 5-Propargylamino-2′-deoxycytidine, 5-Propargylamino-2′-deoxyuridine, 5-Carboxy-2′-deoxycytidine, 5-Formyl-2′-deoxycytidine, 5-[(3-Indolyl)propionamide-N-allyl]-2′-deoxyuridine, 5-Carboxy-2′-deoxyuridine, 5-Formyl-2′-deoxyuridine, 7-Deaza-7-Propargylamino-2′-deoxyadenosine, 7-Deaza-7-Propargylamino-2′-deoxyguanosine, Biotin-16-Aminoallyl-2′-dUTP, Biotin-16-Aminoallyl-2′-dCTP, Biotin-16-Aminoallylcytidine, N4-Biotin-OBEA-2′-deoxycytidine, Biotin-16-Aminoallyluridine, Dabcyl-5-3-Aminoallyl-2′-dUTP, Desthiobiotin-6-Aminoallyl-2′-deoxycytidine, Desthiobiotin-16-Aminoallyl-Uridine, Biotin-16-7-Deaza-7-Propargylamino-2′-deoxyguanosine, Cyanine 3-5-Propargylamino-2′-deoxycytidine, Cyanine 3-6-Propargylamino-2′-deoxyuridine, Cyanine 5-6-Propargylamino-2′-deoxycytidine, Cyanine 5-6-Propargylamino-2′-deoxyuridine, Cyanine 3-Aminoallylcytidine, Cyanine 3-Aminoallyluridine, Cyanine 5-Aminoallylcytidine, Cyanine 5-Aminoallyluridine, Cyanine 7-Aminoallyluridine, 2′-Fluoro-2′-deoxyadenosine, 2′-Fluoro-2′-deoxycytidine, 2′-Fluoro-2′-deoxyguanosine, 2′-Fluoro-2′-deoxyuridine, 2′-O-

Methyladenosine, 2′-O-Methylcytidine, 2′-O-Methylguanosine, 2′-O-Methyluridine, Puromycin, 2′-Amino-2′-deoxycytidine, 2′-Amino-2′-deoxyuridine, 2′-Azido-2′-deoxycytidine, 2′-Azido-2′-deoxyuridine, Aracytidine, Arauridine, 2′-Azido-2′-deoxyadenosine, 2′-Amino-2′-deoxyadenosine, Araadenosine, 2′-Fluoro-thymidine, 3′-O-Methyladenosine, 3′-O-Methylcytidine, 3′-O-Methylguanosine, 3′-O-Methyluridine, 2′-Azido-2′-deoxyguanosine, Araguanosine, 2′-Deoxyuridine, 3′-O-(2-nitrobenzyl)-2′-Deoxyadenosine, 3′-O-(2-nitrobenzyl)-2′-Deoxyinosine, 3′-Deoxyadenosine, 3′-Deoxyguanosine, 3′-Deoxycytidine, 3′-Deoxy-5-Methyluridine, 3′-Deoxyuridine, 2′,3′-Dideoxyadenosine, 2′,3′-Dideoxyguanosine, 2′,3′-Dideoxyuridine, 2′,3′-Dideoxythymidine, 2′,3′-Dideoxycytidine, 3′-Azido-2′,3′-dideoxyadenosine, 3′-Azido-2′,3′-dideoxythymidine, 3′-Amino-2′,3′-dideoxyadenosine, 3′-Amino-2′,3′-dideoxycytidine, 3′-Amino-2′,3′-dideoxyguanosine, 3′-Amino-2′,3′-dideoxythymidine, 3′-Azido-2′,3′-dideoxycytidine, 3′-Azido-2′,3′-dideoxyuridine, 5-Bromo-2′,3′-dideoxyuridine, 2′,3′-Dideoxyinosine, 2′-Deoxyadenosine-5′-O-(1-Thiotriphosphate), 2′-Deoxycytidine-5′-O-(1-Thiotriphosphate), 2′-Deoxyguanosine-5′-O-(1-Thiotriphosphate), 2′-Deoxythymidine-5′-O-(1-Thiotriphosphate), Adenosine-5′-O-(1-Thiotriphosphate), Cytidine-5′-O-(1-Thiotriphosphate), Guanosine-5′-O-(1-Thiotriphosphate), Uridine-5′-O-(1-Thiotriphosphate), 2′,3′-Dideoxyadenosine-5′-O-(1-Thiotriphosphate), 2′,3′-Dideoxycytidine-5′-O-(1-Thiotriphosphate), 2′,3′-Dideoxyguanosine-5′-O-(1-Thiotriphosphate), 3′-Deoxythymidine-5′-O-(1-Thiotriphosphate), 3′-Azido-2′,3′-dideoxythymidine-5′-O-(1-Thiotriphosphate), 2′,3′-Dideoxyuridine-5′-O-(1-Thiotriphosphate), 2′-Deoxyadenosine-5′-O-(1-Boranotriphosphate), 2′-Deoxycytidine-5′-O-(1-Boranotriphosphate), 2′-Deoxyguanosine-5′-O-(1-Boranotriphosphate), and 2′-Deoxythymidine-5′-O-(1-Boranotriphosphate).

[0346] Embodiment I-34. The composition of any one of embodiments I-1 to I-33, wherein the composition further comprises a ribonucleic acid (RNA) encoding TElomerase RNA Component (TERC).

[0347] Embodiment I-35. The composition of any one of embodiments I-1 to I-34, wherein the delivery vehicle comprises the RNA encoding TERT.

[0348] Embodiment I-36. The composition of embodiment I-35, wherein one or more of a surface, a layer or a volume of the delivery vehicle comprises the RNA encoding TERT.

[0349] Embodiment I-37. The composition of embodiment I-36, wherein the surface comprises an outer surface or an inner surface.

[0350] Embodiment I-38. The composition of embodiment I-36, wherein the layer comprises a lipid monolayer or lipid bi-layer.

[0351] Embodiment I-39. The composition of embodiment I-36, wherein the volume comprises an internal volume.

[0352] Embodiment I-40. The composition of any one of embodiments I-1 to I-39, wherein the delivery vehicle is operably-linked to a ribonucleic acid (RNA) encoding TElomerase RNA Component (TERC).

[0353] Embodiment I-41. The composition of embodiment I-40, wherein the delivery vehicle comprises the RNA encoding TERC.

[0354] Embodiment I-42. The composition of embodiment I-35, wherein one or more of a surface, a layer or a volume of the delivery vehicle comprises the RNA encoding TERC.

[0355] Embodiment I-43. The composition of embodiment I-42, wherein the surface comprises an outer surface or an inner surface.

[0356] Embodiment I-44. The composition of embodiment I-42, wherein the layer comprises a lipid monolayer or lipid bi-layer.

[0357] Embodiment I-45. The composition of embodiment I-42, wherein the volume comprises an internal volume.

[0358] Embodiment I-46. A method of increasing telomerase activity in a cell, the method comprising contacting the cell and the composition of any one of embodiments I-1 to I-45.

[0359] Embodiment I-47. A method of extending telomeres in a cell, the method comprising contacting the cell and the composition of any one of embodiments I-1 to I-45.

[0360] Embodiment I-48. The method of embodiment I-46 or I-47, wherein the cell is in vivo, ex vivo or in vitro.

[0361] Embodiment I-49. A cell comprising the composition of any one of embodiments I-1 to I-45.

[0362] Embodiment I-50. A formulation comprising the cell of embodiment I-49.

[0363] Embodiment I-51. The formulation of embodiment I-50, wherein a plurality of cells comprises the cell of embodiment I-49.

[0364] Embodiment I-52. The formulation of embodiment I-51, wherein each cell of the plurality is a cell according to embodiment I-49.

[0365] Embodiment I-53. A method of treating a disease or disorder comprising administering to a subject an effective amount of a composition according to any one of embodiments I-1 to I-45.

[0366] Embodiment I-54. A method of treating a disease or disorder comprising administering to a subject an effective amount of a cell according to embodiment I-49.

[0367] Embodiment I-55. A method of treating a disease or disorder comprising administering to a subject an effective amount of a formulation according to any one of embodiments I-50 to I-52.

[0368] Embodiment I-56. A method of delaying the onset of a disease comprising administering to a subject an effective amount of a composition according to any one of embodiments I-1 to I-45.

[0369] Embodiment I-57. A method of delaying the onset of a disease comprising administering to a subject an effective amount of a cell according to embodiment I-49.

[0370] Embodiment I-58. A method of delaying the onset of a disease comprising administering to a subject an effective amount of a formulation according to any one of embodiments I-50 to I-52.

[0371] Embodiment I-59. The composition of any one of embodiments I-1 to I-45, wherein the composition is capable of transfecting at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, or at least 95% of a population of lung cells.

[0372] Embodiment I-60. A composition comprising a lipid nanoparticle particle (LNP) capable of transfecting at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, or at least 95% of a population of lung cells.

[0373] Embodiment I-61. The composition of embodiment I-60, comprising a polynucleotide.

[0374] Embodiment I-62. The composition of embodiment I-61, wherein the polynucleotide is an RNA.

[0375] Embodiment I-63. The composition of embodiment I-62, wherein the RNA is an mRNA.

[0376] Embodiment I-64. The composition of any one of embodiments I-60 to I-63, wherein the LNP is capable of transfecting about 50%-99%, about 60%-99%, about 70%-99%, about 80%-99%, or about 90%-99% of the population of lung cells.

[0377] Embodiment I-65. The composition of any one of embodiments I-60 to I-63, wherein the LNP is capable of transfecting 50%-95%, about 60%-95%, about 70%-95%, about 80%-95%, or about 90%-95% of the population of lung cells.

[0378] Embodiment I-66. The composition of any one of embodiments I-60 to I-65, wherein the population of lung cells comprises lung endothelial cells.

[0379] Embodiment I-67. The composition of embodiment I-66, wherein the lung endothelial cells comprise vascular endothelial cells.

[0380] Embodiment I-68. The composition of embodiment I-66, wherein the lung endothelial cells comprise alveolar endothelial cells.

[0381] Embodiment I-69. The composition of any one of embodiments I-60 to I-68, wherein the population of lung cells comprises lung epithelial cells.

[0382] Embodiment I-70. The composition of embodiment I-69, wherein the lung epithelial cells comprise lung alveolar epithelial cells.

[0383] Embodiment I-71. The composition of embodiment I-70, wherein the lung alveolar epithelial cells comprise alveolar type 1 (AT1) cells.

[0384] Embodiment I-72. The composition of embodiment I-70, wherein the lung alveolar epithelial cells comprise alveolar type 2 (AT2) cells.

[0385] Embodiment I-73. The composition of any one of embodiments I-60 to I-72, wherein the lung cells comprise any one or more of macrophages, mast cells, club cells, brush cells, neuroepithelial cells, and goblet cells.

[0386] Embodiment I-74. The composition of any one of embodiments I-60 to I-73, wherein the lung cells comprise one or more of fibroblasts, myofibroblasts, lipofibroblasts, and fibromyocytes.

[0387] Embodiment I-75. The composition of any one of embodiments I-60 to I-74, wherein the population of lung cells comprise bronchial cells.

[0388] Embodiment I-76. The composition of any one of embodiments I-60 to I-75, wherein the population of lung cells comprises bronchioalveolar stem cells.

[0389] Embodiment I-77. The composition of any one of embodiments I-60 to I-76, wherein the population of lung cells comprises lung immune cells.

[0390] Embodiment I-78. The composition of any one of embodiments I-60 to I-77, wherein the population of lung cells comprises lung fibroblasts.

[0391] Embodiment I-79. The composition of any one of embodiments I-60 to I-78, wherein the population of lung cells comprises one or more of lung precancerous and cancer cells.

[0392] Embodiment I-80. The composition of any one of embodiments I-60 to I-79, wherein the population of lung cells comprise lung alveolar endothelial cells and lung alveolar epithelial cells, and at least 60%, at least 70%, at least 80%, or at least 90% of the lung endothelial cells are transfected, and at least 60%, at least 70%, at least 80%, or at least 90% of the lung epithelial cells are transfected.

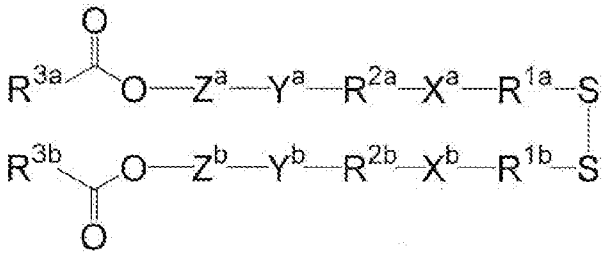
[0393] Embodiment I-81. The composition of any one of any one of embodiments I-60 to I-80, wherein the lung cells are transfected when administered to a subject by intravenous injection.

[0394] Embodiment I-82. The composition of any one of embodiments I-60 to I-80, the lung cells are transfected when administered to a subject by one or more of aerosol injection, aerosolization, inhalation, nebulization or instillation.

[0395] Embodiment I-83. The composition of any one of embodiments I-60 to I-82, wherein the composition comprises an ionizable lipid.

[0396] Embodiment I-84. The composition of embodiment I-83, wherein the ionizable lipid is about 40-60% of the molar percentage of the LNP.

[0397] Embodiment I-85. The composition of any one of embodiments I-60 to I-84, wherein the composition comprises a compound of Formula I:



(1)

,

[0398] wherein R^{1a} and R^{1b} each independently represents an alkylene group having 1 to 6 carbon atoms,
wherein X^a and X^b are each independently an acyclic alkyl tertiary amino group having 1 to 6 carbon atoms and 1 tertiary amino group, or 2 to 5 carbon atoms, and A cyclic alkylene tertiary amino group having 1 to 2 tertiary amino groups,

[0399] wherein R^{2a} and R^{2b} each independently represent an alkylene group having 8 or less carbon atoms or an oxydialkylene group,

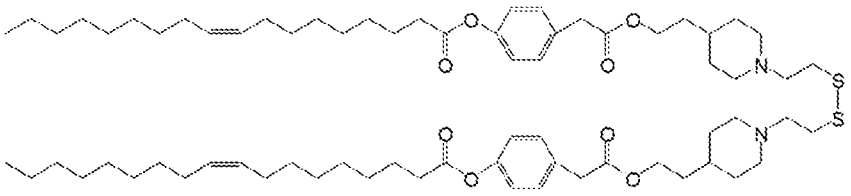
[0400] wherein Y^a and Y^b each independently represent an ester bond, an amide bond, a carbamate bond, an ether bond or a urea bond;

[0401] wherein Z^a and Z^b are each independently a divalent group derived from an aromatic compound having 3 to 16 carbon atoms, having at least one aromatic ring, and optionally having a hetero atom, and

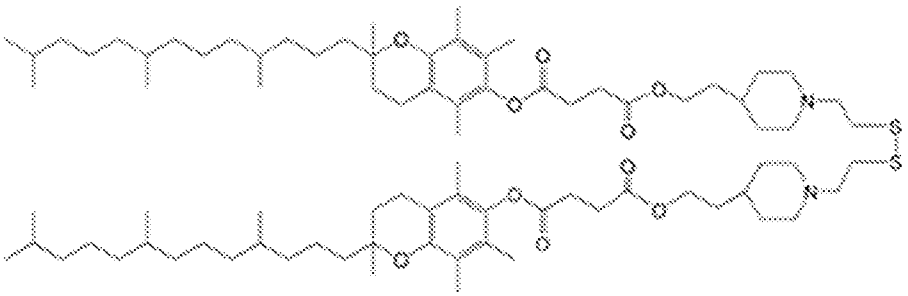
[0402] wherein R^{3a} and R^{3b} each independently represent a residue derived from a reaction product of a fat-soluble vitamin having a hydroxyl group and succinic anhydride or glutaric anhydride, or a sterol derivative having a hydroxyl group and succinic anhydride or a residue

derived from a reaction product with glutaric anhydride or an aliphatic hydrocarbon group having 12 to 22 carbon atoms.

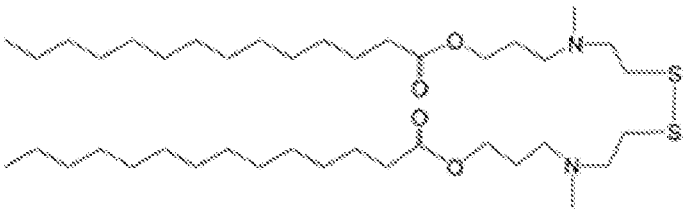
[0403] Embodiment I-86. The composition of embodiment I-84, wherein the compound of Formula I is:



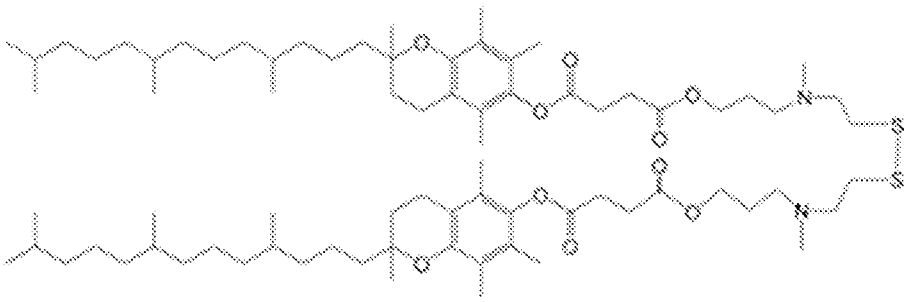
[0404] Embodiment I-87. The composition of embodiment I-84, wherein the compound of Formula I is:



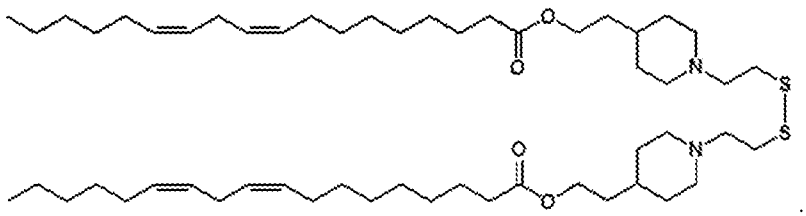
[0405] Embodiment I-88. The composition of embodiment I-84, wherein the compound of Formula I is:



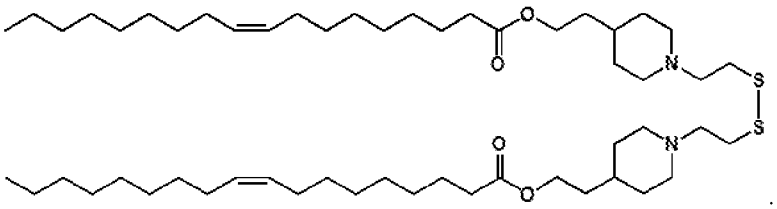
[0406] Embodiment I-89. The composition of embodiment I-84, wherein the compound of Formula I is:



[0407] Embodiment I-90. The composition of embodiment I-84, wherein the compound of Formula I is:



[0408] Embodiment I-91. The composition of embodiment I-84, wherein the compound of Formula I is:



[0409] Embodiment I-92. The composition of any one of embodiments I-60 to I-91, wherein the compound of Formula I comprises a carbon chain having between 8 and 24 carbon atoms.

[0410] Embodiment I-93. The composition of any one of embodiments I-60 to I-92, wherein the LNP comprises a mixture of two or more ionizable lipids.

[0411] Embodiment I-94. The composition of any one of embodiments I-82 to I-92, wherein the cationic lipid is an ionizable lipid and a targeting lipid.

[0412] Embodiment I-95. The composition of any one of embodiments I-60 to I-93, wherein the LNP comprises a sterol.

[0413] Embodiment I-96. The composition of embodiment I-94, wherein the sterol is a cholesterol.

[0414] Embodiment I-97. The composition of any one of embodiments I-94 to I-96, wherein the sterol is about 10-30% of the molar percentage of the LNP.

[0415] Embodiment I-98. The composition of any one of embodiments I-1 to I-97, wherein the LNP comprises an insulator lipid.

[0416] Embodiment I-99. The composition of embodiment I-98, wherein the insulator lipid is a PEGylated lipid.

[0417] Embodiment I-100. The composition of any one of embodiments I-98 to I-99, wherein the PEGylated lipid is linear.

[0418] Embodiment I-101. The composition of any one of embodiments I-98 to I-99, wherein the PEGylated lipid is branched.

[0419] Embodiment I-102. The composition of any one of embodiments I-98 to I-101, wherein the PEGylated lipid comprises a carbon chain having between 8 and 24 carbon atoms.

[0420] Embodiment I-103. The composition of any one of embodiments I-98 to I-102, wherein the insulator lipid is conjugated to a blood protein or a peptide sequence of a blood protein, wherein the blood protein is albumin or a globulin.

[0421] Embodiment I-104. The composition of any one of embodiments I-98 to I-101, wherein the insulator lipid is at least 0.25-5% of the molar percentage of the LNP.

[0422] Embodiment I-105. The composition of any one of embodiments I-1 to I-104, wherein the LNP comprises a cationic lipid.

[0423] Embodiment I-106. The composition of embodiment I-105, wherein the cationic lipid is any one or more of 1,2-dioleoyl-3-trimethylammonium-propane (DOTAP), and a DOTAP analog.

[0424] Embodiment I-107. The composition of embodiment I-105, wherein the cationic lipid is any one or more of N-[1-(2,3-dioleyloxy)propyl]-N,N,N-trimethylammonium chloride (DOTMA), 5-carboxyspermylglycinedioctadecylamide (DOGS), 2,3-dioleyloxy-N-[2(spermine-carboxamido)ethyl]-N,N-dimethyl-1-propanaminium (DOSPA), 1,2-Dioleoyl-3-Dimethylammonium-Propane (DODAP), 1,2-Dioleoyl-3-Trimethylammonium-Propane (DOTAP), 1,2-distearyloxy-N,N-dimethyl-3-aminopropane (DSDMA), 1,2-dioleyloxy-N,N-dimethyl-3-aminopropane (DODMA), 1,2-dilinoleyloxy-N,N-dimethyl-3-aminopropane (DLinDMA), dimethyldioctadecylammonium (DDA), 1,2-dilinolenyloxy-N,N-dimethyl-3-aminopropane (DLenDMA), N-dioleyl-N,N-dimethylammonium chloride (DODAC), N,N-distearyl-N,N-dimethylammonium bromide (DDAB), N-(1,2-dimyristyloxyprop-3-yl)-N,N-dimethyl-N-hydroxyethyl ammonium bromide (DMRIE), 3-dimethylamino-2-(cholest-5-en-3-beta-oxybutan-4-oxy)-1-(cis,cis-9,12-oc-tadecadienoxy)propane (CLinDMA), 2-[5′-(cholest-5-en-3-beta-oxy)-3′-oxapentoxy)-3-dimethy 1-1-(cis,cis-9′,1-2′-octadecadienoxy)propane (CpLinDMA), N,N-dimethyl-3,4-dioleyloxybenzylamine (DMOBA), 1,2-N,N′-dioleylcarbamyl-3-dimethylaminopropane (DOcarbDAP), 2,3-Dilinoleoyloxy-N,N-dimethylpropylamine (DLinDAP), 1,2-N,N′-Dilinoleylcarbamyl-3-dimethylaminopropane (DLincarbDAP), 1,2-Dilinoleoylcarbamyl-3-dimethylaminopropane or (DLinCDAP), 2,2-dilinoleyl-4-dimethylaminomethyl-[1,3]-dioxolane (DLin-K-DMA), 2,2-dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (DLin-K-XTC2-DMA), and mixtures thereof.

[0425] Embodiment I-108. The composition of any one of embodiments I-1 to I-107, wherein the LNP comprises a structural lipid.

[0426] Embodiment I-109. The composition of embodiment I-108, wherein the structural lipid is any one or more of 1,2-di-(9Z-octadecenoyl)-sn-glycero-3-phosphoethanolamine (DOPE), glycerol-monooleate (GMO), distearoylphosphatidylcholine (DSPC),

dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG), dioleoylphosphatidylethanolamine (DOPE), palmitoyloleoylphosphatidylcholine (POPC), palmitoyloleoyl-phosphatidylethanolamine (POPE), dioleoyl-phosphatidylethanolamine 4-(N-maleimidomethyl)-cyclohexane-1-carboxylate (DOPE-mal), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidyl-ethanolamine (DSPE), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1-trans PE, 1-stearoyl-2-oleoyl-phosphatidyethanolamine (SOPE), cholesterol or another sterol, and mixtures thereof.

[0427] Embodiment I-110. The composition of any one of embodiments I-1 to I-109, wherein the LNP comprises at least a first component, a second component, and a third component, wherein:

[0428] the first component is an ionizable lipid;

[0429] the second component is a cationic lipid; and

[0430] the third component is a structural lipid.

[0431] Embodiment I-111. The composition of embodiment I-110, further comprising a sterol.

[0432] Embodiment I-112. The composition of any one of embodiments I-110 to I-111, comprising an insulator lipid selected from: 14:0 PEG2000 PE and a DMG-PEGylated lipid., and a lipid conjugated to a blood protein or a peptide sequence of a blood protein, wherein the blood protein is albumin or a globulin.

[0433] Embodiment I-113. The composition of any one of embodiments I-1 to I-112, wherein the LNP comprises SS-OP or an SS-OP analog, DOPC, a cholesterol, DMG-PEG2000, and DOTAP.

[0434] Embodiment I-114. The composition of embodiment I-113, wherein the LNP comprises 45-55% cationic lipid and SS-OP or an analog thereof at between 20-40%.

[0435] Embodiment I-115. The composition of embodiment I-114, wherein the LNP comprise 45-55% DOTAP.

[0436] Embodiment I-116. The LNP of embodiment I-113, wherein the LNP comprises SS-OP, DOPC, a cholesterol, DMG-PEG2000, and DOTAP.

[0437] Embodiment I-117. The composition of embodiment I-114, wherein the LNP comprises 25-29% of SS-OP; 1-3% DOPC; 15-35% cholesterol; 0.8-1.6% DMG-PEG2000; and 45-55% DOTAP.

[0438] Embodiment I-118. The composition of embodiment I-114, wherein the LNP comprises 27% of SS-OP; 2.5% DOPC; 20% cholesterol; 1.2% DMG-PEG2000; and 50% DOTAP.

[0439] Embodiment I-119. The composition of any one of embodiments I-60 to I-118, wherein the LNP comprises cKK-E12 or a cKK-E12 analog, DOPE, a cholesterol, PEG2000 PE, and DOTAP.

[0440] Embodiment I-120. A method of delivering a cargo to a population of lung cells in a subject in a subject in need thereof, comprising administering the composition of any one of embodiments I-1 to I-45 or embodiments I-1 to I-119 to the subject.

[0441] Embodiment I-121. A method of treating a lung disease or disorder in a subject in need thereof, comprising administering the composition of any one of embodiments I-1 to I-45 or embodiments I-60 to I-119 to the subject.

[0442] Embodiment I-122. The method of any one of embodiments I-120 to I-121, the method comprising administering the composition by intravenous injection.

[0443] Embodiment I-123. The method of any one of embodiments I-120 to I-121, the method comprising administering the LNP by one or more of aerosol injection, aerosolization, inhalation, nebulization or instillation.

[0444] Embodiment I-124. The method of any one of embodiments I-120 to I-123, wherein the cargo comprises a polynucleotide.

[0445] Embodiment I-125. The method of embodiment I-124, wherein the polynucleotide is an RNA.

[0446] Embodiment I-126. The method of embodiment I-125, wherein the RNA is an mRNA.

[0447] Embodiment I-127. The method of embodiment I-126, wherein the mRNA encodes one or more of TERT, a Cystic Fibrosis Transmembrane Conductance Regulator (CFTR) protein, a growth factor, a transcription factor, and a gene-editing protein.

[0448] Embodiment I-128. The method of any one of embodiments I-120 to I-127, wherein at least 50%, at least 60%, at least 70%, at least 80%, or at least 90% of a population of lung cells of the subject are transfected.

[0449] Embodiment I-129. The method of any one of embodiments I-120 to I-128, wherein about 50%-99%, about 60%-99%, about 70%-99%, about 80%-99%, or about 90%-99% of a population of lung cells of the subject are transfected.

[0450] Embodiment I-130. The method of any one of embodiments I-120 to I-129, wherein about 50%-95%, about 60%-95%, about 70%-95%, about 80%-95%, or about 90%-95% of a population of lung cells of the subject are transfected.

[0451] Embodiment I-131. The method of any one of embodiments I-120 to I-130, wherein the lung disease or disorder is selected from: pulmonary fibrosis, idiopathic pulmonary fibrosis, emphysema, interstitial lung diseases, chronic obstructive pulmonary disease (COPD), a lung infection, pneumonia, tuberculosis, gastric reflux, lung cancer, cystic fibrosis, dyskeratosis congenita, Alpha-1 antitrypsin deficiency, and other genetic diseases of the lung.

[0452] Embodiment I-132. The method of any one of embodiments I-120 to I-131, wherein the LNP is administered to the subject as a single dose.

[0453] Embodiment I-133. The method of any one of embodiments I-120 to I-131, wherein the LNP is administered to the subject as multiple doses, wherein the multiple doses comprise at least two doses.

[0454] Embodiment I-134. The method of any one of embodiments I-120 to I-133, wherein a dose of the LNP is administered to the subject is at least 0.01, 0.1, 1, 2, 5, 10, 20, 30, 40, 50, 60, 70, or 80 mg/kg by weight of the subject.

[0455] Embodiment I-135. The method of any one of embodiments I-120 to I-134, wherein the cargo is an mRNA, and the mRNA is administered to the subject at a dose of about 0.1, about 0.2, about 0.3, about 0.4, about 0.5, about 0.6, about 0.7, about 0.8, about 0.9, about 1, about 1.5, about 2, or about 2.5 mg/kg by weight of the subject.

[0456] Embodiment I-136. The method of any one of embodiments I-120 to I-135, wherein the subject is human.

Embodiments II

[0457] Embodiment II-1. A method of delivering a polynucleotide to the lung of a subject, comprising administering, by intravenous injection, a polynucleotide encapsulated in a lipid nanoparticle (LNP) comprising:

[0458] (i) a cationic lipid in a molar percentage of between about 20% and about 50%,

[0459] (ii) a SS-OP or an SS-OP analog at a molar percentage of between about 20% and about 60%.

[0460] Embodiment II-2. The method of embodiment II-1, wherein the SS-OP analog is any one or more of SS-M, SS-E, SS-EC, SS-LC, and SS-OC.

[0461] Embodiment II-3. The method of embodiment II-1 or II-2, wherein the cationic lipid is is any one or more of 2-Dioleoyl-3-Trimethylammonium-Propane (DOTAP), Dimethyldioctadecylammonium bromide (DDAB), Imidazole Cholesterol Ester (ICE), 25-Hydroxycholesterol (25 OH Chol), 20α-hydroxycholesterol 5-cholestene-3α, 20α-diol (20α Chol), N-[1-(2,3-dioleyloxy)propyl]-N,N,N-trimethylammonium chloride (DOTMA), 5-carboxyspermylglycinedioctadecylamide (DOGS), 2,3-dioleyloxy-N-[2(spermine-carboxamido)ethyl]-N,N-dimethyl-1-propanaminium (DOSPA), 1,2-Dioleoyl-3-Dimethylammonium-Propane (DODAP), 11,2-distearyloxy-N,N-dimethyl-3-aminopropane (DSDMA), 1,2-dioleyloxy-N,N-dimethyl-3-aminopropane (DODMA), 1,2-dilinoleyloxy-N,N-dimethyl-3-aminopropane (DLinDMA), dimethyldioctadecylammonium (DDA), 1,2-dilinolenyloxy-N,N-dimethyl-3-aminopropane (DLenDMA), N-dioleyl-N,N-dimethylammonium chloride (DODAC), N,N-distearyl-N,N-dimethylammonium bromide (DDAB), N-(1,2-dimyristyloxyprop-3-yl)-N,N-dimethyl-N-hydroxyethyl ammonium bromide (DMRIE), 3-dimethylamino-2-(cholest-5-en-3-beta-oxybutan-4-oxy)-1-(cis,cis-9,12-octadecadienoxy)propane (CLinDMA), 2-[5′-(cholest-5-en-3-beta-oxy)-3′-oxapentoxy)-3-dimethy 1-1-(cis,cis-9′,1-2′-octadecadienoxy)propane (CpLinDMA), N,N-dimethyl-3,4-dioleyloxybenzylamine (DMOBA), 1,2-N,N′-dioleylcarbamyl-3-dimethylaminopropane (DOcarbDAP), 2,3-Dilinoleoyloxy-N,N-dimethylpropylamine (DLinDAP), 1,2-N,N′-Dilinoleylcarbamyl-3-dimethylaminopropane (DLincarbDAP), 1,2-Dilinoleoylcarbamyl-3-dimethylaminopropane or (DLinCDAP), 2,2-dilinoleyl-4-dimethylaminomethyl-[1,3]-dioxolane (DLin-K-DMA), 2,2-dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (DLin-K-XTC2-DMA), and mixtures thereof.

[0462] Embodiment II-4. The method of embodiment II-4, wherein the cationic lipid is DOTAP.

[0463] Embodiment II-5. The method of any one of embodiments II-1 to II-4, wherein the LNP comprises the cationic lipid at a molar percentage of between about 25% and about 35%.

[0464] Embodiment II-6. The method of any one of embodiments II-1 to II-4, wherein the LNP comprises the cationic lipid at a molar percentage of about 30%.

[0465] Embodiment II-7. The method of any one of embodiments II-1 to II-6, wherein the LNP comprises a structural lipid.

[0466] Embodiment II-8. The method of embodiment II-7, wherein the structural lipid is any one or more of 1,2-di-(9Z-octadecenoyl)-sn-glycero-3-phosphoethanolamine (DOPE), glycerol-monooleate (GMO), distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG), dioleoylphosphatidylethanolamine (DOPE), palmitoyloleoylphosphatidylcholine (POPC), palmitoyloleoyl-phosphatidylethanolamine (POPE), dioleoyl-phosphatidylethanolamine 4-(N-maleimidomethyl)-cyclohexane-1-carboxylate (DOPE-mal), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidyl-ethanolamine (DSPE), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1-trans PE, 1-stearoyl-2-oleoyl-phosphatidyethanolamine (SOPE), cholesterol or another sterol, and mixtures thereof.

[0467] Embodiment II-9. The method of embodiment II-7, wherein the structural lipid is DOPC.

[0468] Embodiment II-10. The method of embodiment II-9, wherein the LNP comprises between about 1% and about 5% DOPC.

[0469] Embodiment II-11. The method of any one of embodiments II-1 to II-6, wherein the LNP is substantially free of structural lipids and/or comprises at most 1% structural lipids.

[0470] Embodiment II-12. The method of any one of embodiments II-1 to II-11, wherein the LNP comprises between about 20% and about 40% cholesterol.

[0471] Embodiment II-13. The method of any one of embodiments II-1 to II-11, wherein the LNP is substantially free of cholesterol.

[0472] Embodiment II-14. The method of any one of embodiments II-1 to II-13, wherein the LNP comprises an insulator lipid.

[0473] Embodiment II-15. The method of any one of embodiments II-1 to II-13, wherein the LNP is substantially free of insulator lipids.

[0474] Embodiment II-16. The method of any one of embodiments II-1 to II-15, wherein the LNP preferentially delivers to and/or transfects the lung compared to liver.

[0475] Embodiment II-17. The method of any one of embodiments II-1 to II-16, wherein the polynucleotide is a synthetic ribonucleic acid (RNA).

[0476] Embodiment II-18. The method of embodiment II-17, wherein the synthetic ribonucleic acid (RNA) encodes telomerase reverse transcriptase (TERT).

[0477] Embodiment II-19. A method of treating a lung fibrosis in a subject in need thereof, comprising administering an effective amount of a composition comprising a delivery vehicle comprising a synthetic ribonucleic acid (RNA) encoding telomerase reverse transcriptase (TERT).

[0478] Embodiment II-20. The method of embodiment II-19, wherein the delivery vehicle is a lipid nanoparticle (LNP).

[0479] Embodiment II-21. The method of embodiment II-20, wherein the LNP comprises a cationic lipid at a molar percentage of between about 20% and about 50%, a SS-OP or an SS-OP analog at a molar percentage of between about 20% and 60%, and optionally one or more of a structural lipid, an insulator lipid, and a cholesterol.

[0480] Embodiment II-22. The method of any one of embodiments II-19 to II-21, wherein the TERT synthetic mRNA comprises at least one modified nucleoside from the list in Table 2.

[0481] Embodiment II-23. The method of embodiment II-22, wherein the modified nucleoside is pseudouridine or a pseudouridine analog.

[0482] Embodiment II-24. The method of embodiment II-22, wherein the pseudouridine analog is N-1-methylpseudouridine.

[0483] Embodiment II-25. The method of any one of embodiments II-19 to II-24, wherein the TERT synthetic mRNA comprises an untranslated region (UTR).

[0484] Embodiment II-26. The method of any one of embodiments II-19 to II-25, wherein the TERT synthetic mRNA comprises a 5′ cap structure, wherein the 5′ cap structure is m7(3′OMeG)(5′)ppp(5′)(2′OMeA)pG, IRES, Cap0, Capl, ARCA, inosine, Nl-methyl-guanosine, 2′fluoro-guanosine, 7-deaza-guanosine, CleanCapTM, 8-oxo-guanosine, 2-amino-guanosine, LNA-guanosine, 2-azido-guanosine, Cap2, Cap4, CAP-003, or CAP-225.

[0485] Embodiment II-27. The method of any one of embodiments II-19 to II-26, wherein the TERT synthetic mRNA comprises a poly-adenosine (poly-A) nucleotide sequence 3′ to the encoding region.

[0486] Embodiment II-28. The method of any one of embodiments II-19 to II-27, wherein the TERT synthetic mRNA comprises a chain terminating nucleotide, wherein the nucleotide is 3′-deoxyadenosine (cordycepin), 3′-deoxyuridine, 3′-deoxycytosine, 3′-deoxyguanosine, 3′-

deoxythymine, 2′,3′-dideoxynucleosides, 2′,3′-dideoxyadenosine, 2′,3′-dideoxyuridine, 2′,3′-dideoxycytosine, 2′,3′- dideoxyguanosine, 2′,3′-dideoxythymine, a 2′-deoxynucleoside, or -O-methylnucleoside.

[0487] Embodiment II-29. The method of any one of embodiments II-19 to II-28, wherein the TERT synthetic mRNA is codon optimized.

[0488] Embodiment II-30. The method of any one of embodiments II-19 to II-28, wherein the lung fibrosis is associated with a lung disease.

[0489] Embodiment II-31. The method of embodiment II-30, wherein the lung disease is pulmonary fibrosis, familial pulmonary fibrosis, idiopathic pulmonary fibrosis, pulmonary fibrosis associated with dyskeratosis congenita, an interstitial lung disease, pneumonia, interstitial pneumonia, emphysema, or lung cancer.

[0490] Embodiment II-32. The method of any one of embodiments II-19 to II-31, wherein the lung fibrosis is associated with a TERT mutation.

[0491] Embodiment II-33. The method of any one of embodiments II-19 to II-32, wherein the subject is human.

[0492] Embodiment II-34. The method of any one of embodiments II-19 to II-33, wherein the composition is administered to the subject via intravenous injection.

[0493] Embodiment II-35. The method of any one of embodiments II-19 to II-33, wherein the composition is administered to the subject via inhalation.

[0494] Embodiment II-36. A composition, comprising a polynucleotide encapsulated in a lipid nanoparticle (LNP) comprising:

[0495] (i) a cationic lipid in a molar percentage of between about 20% and about 50%,

[0496] (ii) a SS-OP or an SS-OP analog at a molar percentage of between about 20% and about 60%.

[0497] Embodiment II-37. The composition of embodiment II-36, wherein the SS-OP analog is any one or more of SS-M, SS-E, SS-EC, SS-LC, and SS-OC.

[0498] Embodiment II-38. The composition of embodiment II-36, wherein the cationic lipid is is any one or more of 2-Dioleoyl-3-Trimethylammonium-Propane (DOTAP), Dimethyldioctadecylammonium bromide (DDAB), Imidazole Cholesterol Ester (ICE), 25-Hydroxycholesterol (25 OH Chol), 20α-hydroxycholesterol 5-cholestene-3α, 20α-diol (20α Chol), N-[1-(2,3-dioleyloxy)propyl]-N,N,N-trimethylammonium chloride (DOTMA), 5-carboxyspermylglycinedioctadecylamide (DOGS), 2,3-dioleyloxy-N-[2(spermine-carboxamido)ethyl]-N,N-dimethyl-1-propanaminium (DOSPA), 1,2-Dioleoyl-3-Dimethylammonium-Propane (DODAP), 11,2-distearyloxy-N,N-dimethyl-3-aminopropane

(DSDMA), 1,2-dioleyloxy-N,N-dimethyl-3-aminopropane (DODMA), 1,2-dilinoleyloxy-N,N-dimethyl-3-aminopropane (DLinDMA), dimethyldioctadecylammonium (DDA), 1,2-dilinolenyloxy-N,N-dimethyl-3-aminopropane (DLenDMA), N-dioleyl-N,N-dimethylammonium chloride (DODAC), N,N-distearyl-N,N-dimethylammonium bromide (DDAB), N-(1,2-dimyristyloxyprop-3-yl)-N,N-dimethyl-N-hydroxyethyl ammonium bromide (DMRIE), 3-dimethylamino-2-(cholest-5-en-3-beta-oxybutan-4-oxy)-1-(cis,cis-9,12-octadecadienoxy)propane (CLinDMA), 2-[5′-(cholest-5-en-3-beta-oxy)-3′-oxapentoxy)-3-dimethy 1-1-(cis,cis-9′,1-2′-octadecadienoxy)propane (CpLinDMA), N,N-dimethyl-3,4-dioleyloxybenzylamine (DMOBA), 1,2-N,N′-dioleylcarbamyl-3-dimethylaminopropane (DOcarbDAP), 2,3-Dilinoleoyloxy-N,N-dimethylpropylamine (DLinDAP), 1,2-N,N′-Dilinoleylcarbamyl-3-dimethylaminopropane (DLincarbDAP), 1,2-Dilinoleoylcarbamyl-3-dimethylaminopropane or (DLinCDAP), 2,2-dilinoleyl-4-dimethylaminomethyl-[1,3]-dioxolane (DLin-K-DMA), 2,2-dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (DLin-K-XTC2-DMA), and mixtures thereof.

[0499] Embodiment II-39. The composition of embodiment II-38, wherein the cationic lipid is DOTAP.

[0500] Embodiment II-40. The composition of any one of embodiments II-36 to II-39, wherein the LNP comprises the cationic lipid at a molar percentage of between about 25% and about 35%.

[0501] Embodiment II-41. The composition of any one of embodiments II-36 to II-39, wherein the LNP comprises the cationic lipid at a molar percentage of about 30%.

[0502] Embodiment II-42. The composition of any one of embodiments II-36 to II-41, wherein the LNP comprises a structural lipid.

[0503] Embodiment II-43. The composition of embodiment II-42, wherein the structural lipid is any one or more of 1,2-di-(9Z-octadecenoyl)-sn-glycero-3-phosphoethanolamine (DOPE), glycerol-monooleate (GMO), distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG), dioleoylphosphatidylethanolamine (DOPE), palmitoyloleoylphosphatidylcholine (POPC), palmitoyloleoyl-phosphatidylethanolamine (POPE), dioleoyl-phosphatidylethanolamine 4-(N-maleimidomethyl)-cyclohexane-1-carboxylate (DOPE-mal), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidyl-ethanolamine (DSPE), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1-trans PE, 1-stearoyl-2-oleoyl-phosphatidyethanolamine (SOPE), cholesterol or another sterol, and mixtures thereof.

[0504] Embodiment II-44. The composition of embodiment II-43, wherein the structural lipid is DOPC.

[0505] Embodiment II-45. The composition of embodiment II-44, wherein the LNP comprises between about 1% and about 5% DOPC.

[0506] Embodiment II-46. The compositon of any one of embodiments II-36 to II-45, wherein the LNP is substantially free of structural lipids and/or comprises at most 1% structural lipids.

[0507] Embodiment II-47. The composition of any one of embodiments II-36 to II-46, wherein the LNP comprises between about 20% and about 40% cholesterol.

[0508] Embodiment II-48. The composition of any one of embodiments II-36 to II-46, wherein the LNP is substantially free of cholesterol.

[0509] Embodiment II-49. The composition of any one of embodiments II-36 to II-48, wherein the LNP comprises an insulator lipid.

[0510] Embodiment II-50. The composition of any one of embodiments II-36 to II-48, wherein the LNP is substantially free of insulator lipids.

[0511] Embodiment II-51. The composition of any one of embodiments II-36 to II-50, wherein the LNP preferentially delivers to and/or transfects the lung compared to liver.

[0512] Embodiment II-52. The composition of any one of embodiments II-36 to II-51, wherein the polynucleotide is a synthetic ribonucleic acid (RNA).

[0513] Embodiment II-53. The composition of embodiment II-52, wherein the synthetic ribonucleic acid (RNA) encodes telomerase reverse transcriptase (TERT).

[0514] Embodiment II-54. The composition of embodiment II-53, wherein the TERT synthetic RNA comprises at least one modified nucleoside from the list in Table 2.

[0515] Embodiment II-55. The composition of embodiment II-54, wherein the modified nucleoside is pseudouridine or a pseudouridine analog.

[0516] Embodiment II-56. The composition of embodiment II-54, wherein the pseudouridine analog is N-1-methylpseudouridine.

[0517] Embodiment II-57. The composition of embodiments II-53 to II-56, wherein the TERT synthetic RNA comprises an untranslated region (UTR).

[0518] Embodiment II-58. The composition of any one of embodiments II-53 to II-57, wherein the wherein the TERT synthetic RNA comprises a 5′ cap structure, wherein the 5′ cap structure ism7(3′OMeG)(5′)ppp(5′)(2′OMeA)pG, IRES, Cap0, Capl, ARCA, inosine, Nl-methyl-guanosine, 2′fluoro-guanosine, 7-deaza-guanosine, CleanCapTM, 8-oxo-guanosine, 2-amino-guanosine, LNA-guanosine, 2-azido-guanosine, Cap2, Cap4, CAP-003, or CAP-225.

[0519] Embodiment II-59. The composition of any one of embodiments II-53 to II-58, wherein the TERT synthetic RNA comprises a poly-adenosine (poly-A) nucleotide sequence 3′ to the encoding region.

[0520] Embodiment II-60. The composition of any one of embodiments II-53 to II-59, wherein the TERT synthetic RNA comprises a chain terminating nucleotide, wherein the nucleotide is 3′-deoxyadenosine (cordycepin), 3′-deoxyuridine, 3′-deoxycytosine, 3′-deoxyguanosine, 3′-deoxythymine, 2′,3′-dideoxynucleosides, 2′,3′-dideoxyadenosine, 2′,3′-dideoxyuridine, 2′,3′-dideoxycytosine, 2′,3′- dideoxyguanosine, 2′,3′-dideoxythymine, a 2′-deoxynucleoside, or -O- methylnucleoside.

[0521] Embodiment II-61. The composition of any one of embodiments II-53 to II-60, wherein the TERT synthetic RNA is codon optimized.

[0522] Embodiment II-62. Use of the composition of any one of embodiments II-36 to II-61, for the treatment of lung fibrosis in a subject in need thereof.

[0523] Embodiment II-63. Use of the composition according to embodiment II-62, wherein the lung fibrosis is associated with a lung disease, and wherein the lung disease is pulmonary fibrosis, familial pulmonary fibrosis, idiopathic pulmonary fibrosis, pulmonary fibrosis associated with dyskeratosis congenita, an interstitial lung disease, pneumonia, interstitial pneumonia, emphysema, or lung cancer.

[0524] Embodiment II-64. Use of the composition according to embodiment II-62 or II-63, wherein the lung fibrosis is associated with a TERT mutation in the subject.

[0525] Embodiment II-65. Use of the composition according to any of embodiments II-62 to II-64, wherein the composition is administered to the subject via intravenous injection.

[0526] Embodiment II-66. A pharmaceutical composition comprising:

[0527] (i) a delivery vehicle comprising a ribonucleic acid (RNA) encoding telomerase reverse transcriptase (TERT); and

[0528] (ii) and a pharmaceuticaly acceptable solvent or excipient;

[0529] wherein the delivery vehicle is capable of preferentially delivering to and/or transfecting lung cells.

[0530] Embodiment II-67. The pharmaceutical composition of embodiment II-66, wherein the delivery vehicle is an LNP.

[0531] Embodiment II-68. The pharmaceutical composition of embodiment II-67, wherein the LNP comprises:

[0532] (i) a cationic lipid in a molar percentage of between about 20% and about 50%; and

[0533] (ii) a SS-OP or an SS-OP analog at a molar percentage of between about 20% and about 60%.

[0534] Embodiment II-69. The pharmaceutical composition of embodiment II-68, wherein the SS-OP analog is any one or more of SS-M, SS-E, SS-EC, SS-LC, and SS-OC.

[0535] Embodiment II-70. The pharmaceutical composition of embodiment II-68 or II-69, wherein the cationic lipid is is any one or more of 2-Dioleoyl-3-Trimethylammonium-Propane (DOTAP), Dimethyldioctadecylammonium bromide (DDAB), Imidazole Cholesterol Ester (ICE), 25-Hydroxycholesterol (25 OH Chol), 20α-hydroxycholesterol 5-cholestene-3α, 20α-diol (20α Chol), N-[1-(2,3-dioleyloxy)propyl]-N,N,N-trimethylammonium chloride (DOTMA), 5-carboxyspermylglycinedioctadecylamide (DOGS), 2,3-dioleyloxy-N-[2(spermine-carboxamido)ethyl]-N,N-dimethyl-1-propanaminium (DOSPA), 1,2-Dioleoyl-3-Dimethylammonium-Propane (DODAP), 11,2-distearyloxy-N,N-dimethyl-3-aminopropane (DSDMA), 1,2-dioleyloxy-N,N-dimethyl-3-aminopropane (DODMA), 1,2-dilinoleyloxy-N,N-dimethyl-3-aminopropane (DLinDMA), dimethyldioctadecylammonium (DDA), 1,2-dilinolenyloxy-N,N-dimethyl-3-aminopropane (DLenDMA), N-dioleyl-N,N-dimethylammonium chloride (DODAC), N,N-distearyl-N,N-dimethylammonium bromide (DDAB), N-(1,2-dimyristyloxyprop-3-yl)-N,N-dimethyl-N-hydroxyethyl ammonium bromide (DMRIE), 3-dimethylamino-2-(cholest-5-en-3-beta-oxybutan-4-oxy)-1-(cis,cis-9,12-octadecadienoxy)propane (CLinDMA), 2-[5′-(cholest-5-en-3-beta-oxy)-3′-oxapentoxy)-3-dimethy 1-1-(cis,cis-9′,1-2′-octadecadienoxy)propane (CpLinDMA), N,N-dimethyl-3,4-dioleyloxybenzylamine (DMOBA), 1,2-N,N′-dioleylcarbamyl-3-dimethylaminopropane (DOcarbDAP), 2,3-Dilinoleoyloxy-N,N-dimethylpropylamine (DLinDAP), 1,2-N,N′-Dilinoleylcarbamyl-3-dimethylaminopropane (DLincarbDAP), 1,2-Dilinoleoylcarbamyl-3-dimethylaminopropane or (DLinCDAP), 2,2-dilinoleyl-4-dimethylaminomethyl-[1,3]-dioxolane (DLin-K-DMA), 2,2-dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (DLin-K-XTC2-DMA), and mixtures thereof.

[0536] Embodiment II-71. The pharmaceutical composition of embodiment II-70, wherein the cationic lipid is DOTAP.

[0537] Embodiment II-72. The pharmaceutical composition of any one of embodiments II-68 to II-71, wherein the LNP comprises the cationic lipid at a molar percentage of between about 25% and about 35%.

[0538] Embodiment II-73. The pharmaceutical composition of any one of embodiments II-68 to II-71, wherein the LNP comprises the cationic lipid at a molar percentage of about 30%.

[0539] Embodiment II-74. The pharmaceutical composition of any one of embodiments II-68 to II-73, wherein the LNP comprises a structural lipid.

[0540] Embodiment II-75. The pharmaceutical composition of embodiment II-74, wherein the structural lipid is any one or more of 1,2-di-(9Z-octadecenoyl)-sn-glycero-3-phosphoethanolamine (DOPE), glycerol-monooleate (GMO), distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG), dioleoylphosphatidylethanolamine (DOPE), palmitoyloleoylphosphatidylcholine (POPC), palmitoyloleoyl-phosphatidylethanolamine (POPE), dioleoyl-phosphatidylethanolamine 4-(N-maleimidomethyl)-cyclohexane-1-carboxylate (DOPE-mal), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidyl-ethanolamine (DSPE), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1-trans PE, 1-stearoyl-2-oleoyl-phosphatidyethanolamine (SOPE), cholesterol or another sterol, and mixtures thereof.

[0541] Embodiment II-76. The pharmaceutical composition of embodiment II-75, wherein the structural lipid is DOPC.

[0542] Embodiment II-77. The pharmaceutical composition of embodiment II-76, wherein the LNP comprises between about 1% and about 5% DOPC.

[0543] Embodiment II-78. The pharmaceutical compositon of any one of embodiments II-68 to II-77, wherein the LNP is substantially free of structural lipids and/or comprises at most 1% structural lipids.

[0544] Embodiment II-79. The pharmaceutical composition of any one of embodiments II-68 to II-78, wherein the LNP comprises between about 20% and about 40% cholesterol.

[0545] Embodiment II-80. The pharmaceutical composition of any one of embodiments II-68 to II-78, wherein the LNP is substantially free of cholesterol.

[0546] Embodiment II-81. The pharmaceutical composition of any one of embodiments II-68 to II-80, wherein the LNP comprises an insulator lipid.

[0547] Embodiment II-82. The pharmaceutical composition of any one of embodiments II-68 to II-80, wherein the LNP is substantially free of insulator lipids.

[0548] Embodiment II-83. The pharmaceutical composition of any one of embodiments II-68 to II-82, wherein the LNP preferentially delivers to and/or transfects the lung compared to liver.

[0549] Embodiment II-84. The pharmaceutical composition of any one of embodiments II-66 to II-83, wherein the TERT synthetic RNA comprises at least one modified nucleoside from the list in Table 2.

[0550] Embodiment II-85. The pharmaceutical composition of embodiment II-84, wherein the modified nucleoside is pseudouridine or a pseudouridine analog.

[0551] Embodiment II-86. The pharmaceutical composition of embodiment II-85, wherein the pseudouridine analog is N-1-methylpseudouridine.

[0552] Embodiment II-87. The pharmaceutical composition of embodiments II-66 to II-86, wherein the TERT synthetic RNA comprises an untranslated region (UTR).

[0553] Embodiment II-88. The pharmaceutical composition of any one of embodiments II-66 to II-87, wherein the wherein the TERT synthetic RNA comprises a 5′ cap structure, wherein the 5′ cap structure is m7(3′OMeG)(5′)ppp(5′)(2′OMeA)pG, IRES, Cap0, Capl, ARCA, inosine, Nl-methyl-guanosine, 2′fluoro-guanosine, 7-deaza-guanosine, CleanCapTM, 8-oxo-guanosine, 2-amino-guanosine, LNA-guanosine, 2-azido-guanosine, Cap2, Cap4, CAP-003, or CAP-225.

[0554] Embodiment II-89. The pharmaceutical composition of any one of embodiments II-66 to II-88, wherein the TERT synthetic RNA comprises a poly-adenosine (poly-A) nucleotide sequence 3′ to the encoding region.

[0555] Embodiment II-90. The pharmaceutical composition of any one of embodiments II-66 to II-89, wherein the TERT synthetic RNA comprises a chain terminating nucleotide, wherein the nucleotide is 3′-deoxyadenosine (cordycepin), 3′-deoxyuridine, 3′-deoxycytosine, 3′-deoxyguanosine, 3′-deoxythymine, 2′,3′-dideoxynucleosides, 2′,3′-dideoxyadenosine, 2′,3′-dideoxyuridine, 2′,3′-dideoxycytosine, 2′,3′- dideoxyguanosine, 2′,3′-dideoxythymine, a 2′-deoxynucleoside, or -O- methylnucleoside.

[0556] Embodiment II-91. The pharmaceutical composition of any one of embodiments II-66 to II-90, wherein the TERT synthetic RNA is codon optimized.

[0557] Embodiment II-92. Use of the pharmaceutical composition of any one of embodiments II-66 to II-91, for the treatment of lung fibrosis in a subject in need thereof.

[0558] Embodiment II-93. Use of the pharmaceutical composition according to embodiment II-92, wherein the lung fibrosis is associated with a lung disease, and wherein the lung disease is pulmonary fibrosis, familial pulmonary fibrosis, idiopathic pulmonary fibrosis, pulmonary fibrosis associated with dyskeratosis congenita, an interstitial lung disease, pneumonia, interstitial pneumonia, emphysema, or lung cancer.

[0559] Embodiment II-94. Use of the pharmaceutical composition according to embodiment II-92 or II-93, wherein the lung fibrosis is associated with a TERT mutation in the subject.

[0560] Embodiment II-95. Use of the pharmaceutical composition according to any of embodiments II-92 to II-94, wherein the composition is administered to the subject via intravenous injection.

EXAMPLES

[0561] The following examples are included for illustrative purposes and are not intended to limit the scope of the disclosure.

Example 1: Lipid Nanoparticle Formulations

[0562] Compositions and methods of the disclosure may be used for delivery of cargo, such as a polynucleotide, by a delivery vehicle to lung cells. In some embodiments, the delivery vehicle is a lipid nanoparticle (LNP) as disclosed herein. In some embodiments, the LNPs disclosed herein are used for delivery of an mRNA to a population of lung cells.

[0563] Tables 6A-6B below show exemplary formulations for an LNP that can be used as a delivery vehicle, and Table 6C below shows example ranges of molar percentages for an LNP with classes of lipids that can be used as a delivery vehicle.

[0564] FIG. 2 depicts a representative dynamic light scattering (DLS) plot of the mRNA-LNPs made using the exemplary lipid components shown in Table 6A.

Table 6A

Compound		pK	Molar Ratio	Molar Percentage
SS-OP	Ionizable lipid	~6.4	55	27.2%
DOPC			5	2.5%
Cholesterol			40	19.8%
DMG-PEG2000			2.5	1.2%
DOTAP	Cationic lipid		100	49.4%

Table 6B

Compound	Molar Ratio	Molar Percentage
cKK-E12	35	17.5%
DOPE	16	8.0%
Cholesterol	46.5	23.3%
14:0 PEG2000 PE	2.5	1.3%
DOTAP	100	50.0%

Table 6C

Compound	Molar Percentage
Ionizable lipid	10-50%
Structural lipid	0-15%
Cholesterol	0-40%
Insulator lipid	0.2-6%
Cationic lipid	20-80%

Example 2: Intravenous Injection of mRNA-LNPs in Mice

[0565] FIG. 3 depicts bioluminescent imaging of whole organs in mice that were injected with mRNA-LNPs. mRNA-LNPs were prepared by formulated using microfluidic mixing, and were next processed by concentration and buffer exchange prior to injection. The organs were harvested and imaged 26 hours after the mice were dosed intravenously with Luciferase mRNA-LNPs at 0.6mg/kg of total mRNA to body weight. The bioluminescent imaging

demonstrates that the LNP delivery vehicles were capable of delivering mRNA cargo to the lung.

Example 3: mRNA Translation from Intravenous Injection in Mice

[0566] FIGS. 4A-4B depict immunohistochemistry staining for tdTomato in lung cells from a mouse treated with an mRNA reporter, and an untreated control mouse, respectively. tdTomato fl/fl mice were dosed intravenously with Cre mRNA LNPs at 0.6mg/kg or saline. Lungs were harvested 4 days later. These figures demonstrate that in cells successfully targeted by Cre mRNA-LNP, Cre mRNA was translated and Cre recombinase excised the STOP codon allowing for tdTomato expression under the CAG promoter in the Rosa26 locus. In FIGS. 4A-4B, the scale bar is 50μM.

Example 4: Telomerase Activity Measurements in Mouse Lung After TERT mRNA-LNA Delivery

[0567] FIGS. 5A-5B depict measurements of telomerase activity in mouse lung after delivery of TERT mRNA-LNP, and in mouse lung of an untreated control, respectively. TERT knockout (KO) mice were dosed intravenously with TERT mRNA LNPs at 2.0 mg/kg and lungs were harvested 19 hours later. As a control, lungs were also harvested from an untreated TERT KO mouse. The telomere repeat amplification protocol (TRAP) was run on lung lysates. The banding pattern observed in the lung lysate of the TERT mRNA LNP treated mouse demonstrates that telomerase activity was present.

[0568] The TRAP assay was performed as follows. Protein lysate from cells or tissues was incubated with an artificial telomere (DNA oligonucleotide). If active telomerase is present, it extends the artificial telomere 6 bp at a time, producing a ladder pattern. This extension reaction is then amplified by PCR and run on a gel (Agilent bioanalyzer, using a microfluidic agarose gel). The presence of a ladder in 6 bp increments indicates telomerase activity.

Example 5: Transfection Efficiency of Lung Delivery Vehicle Formulation

[0569] FIG. 6A is a bar graph depicting the transfection efficiency of an exemplary lung delivery vehicle formulation, as a function of Cre dose, number of doses, and genotype in mice. Cre mRNA complexed with the LNP lung vehicle of the Table 6A was delivered at the indicated doses via tail vein injection to mice carring a tdTomato reporter gene that requires Cre to turn on. Lungs were harvested for histological analysis by immunostaining of the

reporter gene. FIG. 6A demonstrates that the Cre mRNA LNPs formulation transfected the cells of the lung and turned on the reporter gene in a dose-dependent manner.

[0570] FIGS. 6B-6F depict representative images of lung sections harvested from the mice as described above, with the reporter protein shown as a darkened stain. Lung cells were harvested after treatment with saline control (FIG. 6B), 0.1 mg/kg (FIG. 6C), 0.3 mg/kg (FIG. 6D), 0.6 mg/kg (FIG. 6E), or 2.0 mg/kg (FIG. 6F) by body weight dose of the mRNA.

Example 6: Lung Fibrosis Treatment in Mice with TERT mRNA LNPs

[0571] FIGS. 7A-7C depict computed tomography (CT) X-ray scans of mouse lungs tested for lung fibrosis. Mice were instilled intratracheally with 1 U/kg of bleomycin on day 0 and injected intravenously with 0.6 mg/kg TERT mRNA LNPs or saline on days 4, 7, and 11. CT images were acquired two weeks later. FIG. 7A depicts a control with no bleomycin treatment, and FIGS. 7B-7C depict use of 1 U/kg bleomycin for inducing lung fibrosis. FIGS. 7B-7C were treated with saline and TERT mRNA LNPs, respectively. Healthy lung tissue appears darker, and fibrotic lung tissue appears lighter. Less fibrosis is shown in the TERT mRNA LNP-treated mouse than in the saline-treated control. These figures demonstrate the effect of treatment with TERT mRNA LNPs on fibrosis reduction in the bleomycin mouse model of pulmonary fibrosis.

Example 7: Reduction of Toxicity with Use of SS-OP DOTAP in Mice

[0572] FIG. 8 depicts a graph showing the mortality of mice dosed with various formulations of lung-targeted LNPs. The C57Bl/6 mice were dosed with formulations of lung-targeted LNPs containing SS-OP and DOTAP, according to the exemplary formulation of Table 6A (N=2-12 per time point), or formulations of lung-targeted LNPs containing cKK DOTAP (N=2-4 per time point), according to the exemplary formulation of Table 6B. Mortality is shown as percent of mice that survived the acute treatment. Mice were dosed based on mg/kg of total reporter mRNA. These results demonstrate the improved tolerability and reduced toxicity rate of the exemplary formulation of Table 6A using SS-OP and DOTAP.

Example 8: Delivery of mRNA to Alveolar Cells in Mouse Fibrosis Model

[0573] FIGS. 9A-9D depict various lung samples from mice treated with bleomycin for inducing lung fibrosis, and treated with CRE mRNA or saline to show delivery of the mRNA to alveolar cells. Briefly, Ai14 (ROSA26 Lox-stop-lox tdTomato) mice were given 1 U/kg bleomycin via oral aspiration (OA) to induce fibrosis. On day 21 post-bleomycin, mice were

dosed with saline or 2 mg/kg Cre mRNA, translation of which allows for tdTomato expression. At 3 days post-dosing (day 24), mice were sacrificed and the lungs were fixed by inflation with PFA. Lung sections were stained with anti-tdTomato antibody and trichrome. These results demonstrate that the Cre mRNA can be successfully delivered to alveolar cells even in mice with lung fibrosis, which can address the question of whether shunting of the LNP in a disease context affects mRNA delivery.

Example 9: Lung delivery of mRNA by SS-OP DOTAP IV and OA routes

[0574] To compare intravenous and oral administration of SS-OP DOTAP LNP formulations, lipid nanoparticles (LNP) compositions encapsulating firefly luciferase (Luc) mRNA were formulated according to Tables 2A and 2B. The lipid to mRNA ratios (wt/wt) used in these experiments were 75:1 and 40:1. C57Bl/6 mice were dosed with the LNP-mRNAs at 0.5 mg/kg via intravenous injection (IV) or 0.2 mg/kg via oropharyngeal aspiration (OA). Lungs were imaged *ex vivo* 24 hours later. FIG. 10 shows the mean radiance of luciferase in the lung (photons/s/cm2/sr). Intravenous administration of the SS-OP DOTAP formulation provided significantly higher lung transfection (FIGS. 10 and 11) than through oral administration. Further, SS-OP DOTAP LNPs with a lipid: RNA ratio of either 75:1 or 40:1 lipid: RNA exhibited similar transfection efficiencies when dosed intravenously.

Example 10: Positively charged lipids targeted mRNA to the lung

[0575] To compare SS-OP LNP formulations with other cationic lipids, Tomato fl/fl mice were dosed with various LNP formulations encapsulating Cre mRNA, delivered intravenously in a range of 0.1 – 0.5 mg/kg, as shown in FIG. 12. The lipid to mRNA ratio for the SS-OP DOTAP formulation, the SS-OP 20α Chol formulation, the SS-OP DDAB formulation, and the 25 OH Chol was 80 μmol lipid: 1 mg mRNA. The lipid to mRNA ratio for SS-OP ICE was 50:1. The lipid to mRNA ratio for the SS-OP DOTAP ICE formulation was 70: 1. Lungs were harvested 3 days later and processed via formalin fixation and paraffin embedding. Positive cells were labeled with anti-tdTomato antibody. FIG. 12 shows the percent positive Tomato cells in the lung parenchyma.

[0576] The results of the transfection are shown in FIG.12 Notably, other cationic lipids with a net positive charge at physiological pH (7.4) may be substituted for DOTAP, including positively charged forms of cholesterol (ICE) in an SS-OP LNP formulation. The tested LNP formulations are shown below in Tables 7-12.

Table 7: SS-OP DOTAP

Compound	Molar Ratio	Percent
SS-OP	55	27.2
DOPC	5	2.5
Cholesterol	40	19.8
DMG-PEG2000	2.5	1.2
DOTAP	100	49.4

Table 8: SS-OP ICE

Compound	Molar Ratio	Percent
SS-OP	55	54.2
DOPC	5	4.9
Cholesterol	0	0
ICE	40	39.4
DMG-PEG2000	1.5	1.5

Table 9: SS-OP 20α Chol

Compound	Molar Ratio	Percent
SS-OP	55	27.2
DOPC	5	2.5
20α Chol	40	19.8
DMG-PEG2000	2.5	1.2
DOTAP	100	49.4

Table 10: SS-OP DDAB

Compound	Molar Ratio	Percent
SS-OP	55	27.2
DOPC	5	2.5
Cholesterol	40	19.8
DMG-PEG2000	2.5	1.2
DDAB	100	49.4

Table 11: SS-OP 25 OH Chol

Compound	Molar Ratio	Percent
SS-OP	55	27.2
DOPC	5	2.5
25 OH Chol	40	19.8
DMG-PEG2000	2.5	1.2
DOTAP	100	49.4

Table 12: SS-OP DOTAP ICE

Compound	Molar Ratio	Percent
SS-OP	55	30.2
DOPC	5	2.7
ICE	40	22
Cholesterol	20	11
DMG-PEG2000	2.2	1.2
DOTAP	60	32.9

Example 11: Different flow rates for formulation of mRNA LNP for lung delivery

[0577] To compare flow rates for formulation of the SS-OP DOTAP LNP (Table 6A) encapsulation of mRNA, SS-OP DOTAP LNPs encapsulating luciferase mRNA were formulated per the ratios in Table 6A. The lipid:mRNA wt/wt ratio was 50:1. The aqueous (mRNA) to ethanol (lipid) flow ratio was 3: 1. The overall flow rate was varied as shown in FIG. 13. C57Bl/6 mice were dosed at 0.1mg/kg via intravenous injection, and lungs were imaged ex vivo 20 hours later. Shown is mean radiance of the lungs (photons/s/cm2/sr). The highest signal for SS OP DOTAP formulation was found with 8 ml/minute flow rate for LNP mRNA encapsulation (FIG. 13). Table 13 compares the flow rate to particle size, zeta potential and encapsulation efficiency of the SS OP DOTAP formulation of Table 6A.

Table 13: Flow rate versus particle size, zeta potential and encapsulation efficiency

Flow rate	Particle size	Zeta potential	Encapsulation
1ml/min	69	41.8	95
4ml/min	73	30.8	96
8ml/min	52	17.3	95
12ml/min	54	-2.6	94

Example 12: DOPC and Cholesterol were not required for SS-OP DOTAP LNP mRNA delivery

[0578] To determine the components of the SS-OP DOTAP LNPs necessary to transfect the lung, the SS-OP DOTAP LNP formulation of Table 6A was varied according to the formulas presented in Table 14 below. C57Bl/6 mice were dosed with the LNP formulations of Table 14, comprising luciferase mRNA, via intravenous injection, and lungs were imaged *ex vivo* 16 hours later. FIG. 14 shows the mean radiance of Luciferase activity in the lungs (photons/s/cm^2/sr) per the formulation. Notably, neither a neutral lipid, *e.g.*, DOPC nor cholesterol were required for lung transfection with an SS-OP DOTAP LNP formulation. Table 14 shows the tested SS-OP DOTAP formulations, with and without DOPC and/or cholesterol.

Table 14: SS-OP DOTAP formulations without DOPC and/or cholesterol

Mix No.	SS-OP	DOPC	Cholesterol	DMG-PEG2000	DOTAP	Name	DOTAP %	PEG %
1	55	5	40	2.5	100	SSOP DOTAP	49.4%	1.2%
2	55	0	40	2.5	95	no DOPC	49.4%	1.3%
3	55	0	20	2.5	75	no DOPC, less Chol	49.2%	1.6%
4	55	0	0	2.5	55	no DOPC, no Chol	48.9%	2.2%
5	55	0	40	4	95	no DOPC, 2% PEG	49.0%	2.1%

Example 13: Varying mRNA:lipid ratio showed differential activity

[0579] To determine the association of mRNA delivery with the ratio of mRNA to lipids, SS-OP DOTAP LNPs according to the formulation of Table 6A, and comprising the luciferase

mRNA in an mRNA:lipid ratio (wt/wt) of 1:62, 1:45, and 1:30 were dosed intravenously in C57Bl/6 mice. Mice were dosed via intravenous injection at 1.5mg/kg, and lungs were imaged ex vivo 26 hours later. FIG. 15 shows that mRNA:lipid ratios of 1:30 through 1:62 were the best performing mRNA:lipid ratios, with 1:30 exhibiting the highest bioluminescence.

[0580] SS-OP DOTAP LNPs without DOPC and comprising firefly luciferase (Luc) mRNA at varied ratios were injected intravenously in C57Bl/6 mice at a dose of 1.5mg/kg. Lungs were imaged ex vivo 26 hours later. Shown is mean radiance of the lungs (photons/s/cm2/sr).

[0581] LNPs were not formed with an mRNA:lipid ratio of 1:5 (N.D. refers to not dosed). In these SS-OP DOTAP LNP formulations without DOPC, the mRNA:lipid ratio of 1:62 exhibited the highest luciferase signal (FIG. 16).

Example 14: Varying PEGylated lipid percent showed differential activity

[0582] To determine the effects of the percent PEGylated lipid on SS-OP DOTAP LNPs delivery of mRNA, LNPs were formulated per the ratios in Table 15 below with luciferase mRNA and were administered intravenously to C57Bl/6 mice in a dose of 1.5mg/kg. Lungs were imaged ex vivo 19 hours later. FIGS. 17A and 17B show the mean radiance of the lungs (photons/s/cm^2/sr). It was observed that the bioluminescence signal decreased as PEG signal increased.

[0583] The optimal PEGylated lipid range for SS-OP DOTAP LNPw was found to be 0-3%, with 0.5% providing the best LNP delivery of mRNA (FIGS. 17A and 17B). Table 15 shows the SS-OP DOTAP formulations with varied percentage of PEGylated lipid.

Table 15: SS-OP DOTAP formulations with varied percentage of PEGylated lipid

Name	SS-OP	DOPC	Cholesterol	DMG-PEG2000	DOTAP	DOTAP %	PEG %	Lipid:mRNA wt/wt
0.5% PEG	55	5	40	1.0	100	50%	0.5%	62
1.2% PEG	55	5	40	2.5	100	49%	1.2%	62
3.5% PEG	55	5	40	7.3	100	48%	3.5%	63
6% PEG	55	5	40	12.8	100	47%	6.0%	65
7% PEG	55	5	40	15.0	100	47%	7.0%	66

Example 16: PEGylated lipid is not required for lung targeting

To determine whether PEGylated lipids were even required for SS-OP DOTAP LNP mRNA delivery, LNPs were formulated per the ratios in Table 16 below with luciferase mRNA. C57Bl/6 mice were dosed via intravenous injection and lungs were imaged ex vivo 21 hours later. The LNP-mRNA dose was 1.5mg of mRNA per kg of animal mass for the 1.2% PEG and 0.1% PEG conditions. The lipid to mRNA ratio was 63. For the 0% PEG condition, the mice were dosed at 0.2mg/kg. FIGS. 18A and 18B show the mean radiance of the lungs (photons/s/cm2/sr). These results demonstrate that SS-OP DOTAP LNP formulation containing 0.1-1.2% of a PEGylated may be optimal. However, LNP formulation without a PEGylated lipid successfully delivered mRNA to the lung. Table 16 shows the low and no PEGylated lipid SS-OP DOTAP formulations.

Table 16: Low and no PEGylated lipid SS-OP DOTAP formulations

Lipid Mix	SSOP %	DOPC %	Cholesterol %	DMG-PEG2000 %	DOTAP %
1.2% PEG	38%	3%	27%	1.2%	30%
0.1% PEG	38%	3%	28%	0.1%	30%
0% PEG	38%	3%	28%	0.0%	30%

Example 15: Varying DOTAP percentage shows differential lung activity

[0584] To determine the effects of varying DOTAP percentage on SS-OP DOTAP LNPs, SS-OP DOTAP LNPs were formulated with firefly luciferase (Luc) mRNA per the ratios in Table 17. C57Bl/6 mice were dosed via intravenous injection at 1.5mg/kg, and lungs were imaged ex vivo 19 hours later. FIG. 19 shows the mean radiance of the lungs (photons/s/cm^2/sr) relative to the percentage of DOTAP in the LNP. The most effective delivery of SS-OP DOTAP LNPs to the lung, among the formulas in Table 17, was 30% DOTAP. Minimum liver targeting was observed for LNPs have 20% or greater DOTAP; whereas strong liver signal was seen with 10% DOTAP (FIGS. 20A and 20B). Table 17 shows the SS-OP DOTAP formulations with varied DOTAP percentage.

Table 17: SS-OP DOTAP formulations with varied DOTAP percentage

Name	SS-OP	DOPC	Cholesterol	DMG-PEG2000	DOTAP	DOTAP %	PEG %	Lipid:mRNA wt/wt
49% DOTAP	55	5	40	2.5	100	49%	1.2%	62
40% DOTAP	55	5	40	2.5	69	40%	1.5%	53
30% DOTAP	55	5	40	2.5	44	30%	1.7%	45
20% DOTAP	55	5	40	2.5	26	20%	1.9%	39
10% DOTAP	55	5	40	2.5	11	10%	2.2%	35

Example 17: Delivery of LNP-mRNAs to the lung transfects alveolar epithelial cells

[0585] To observe the cell types transfected by SS-OP DOTAP LNP per the formula of Table 6A, LNPs were formulated with Cre mRNA and administered to tomato fl/fl mice at 2.0

mg/kg (FIG. 21A). FIG. 21B shows a PBS negative control. Lungs were harvested 3 days later and processed via formalin fixation and paraffin embedding. 4 μm sections were stained with:

[0586] Anti-IGFBP2, a marker of AT1 alveolar epithelial lung cells, Anti-Prosurfactant Protein C (SPC) a marker of AT2 alveolar epithelial lung stem cells, Anti-tdTomato, and DAPI as a marker of DNA to identify cells. Cells positive for both SPC and tdTomato demonstrated that the LNP formulation successfully transfected lung AT2 alveolar epithelial stem cells. Cells positive for both IGFBP2 and tdTomato demonstrated that the LNP formulation successfully transfected lung AT1 alveolar epithelial cells. Absence of tdTomato staining in the control showed that the anti-tdTomato staining was specific.

Example 18: TERT mRNA delivery in KO mice with SS-OP DOTAP

[0587] To determine SS-OP DOTAP delivery of therapeutic mRNA as a disease treatment, SS-OP DOTAP LNPs encapsulating TERT mRNA were administered to a lung fibrosis model mouse. The timeline of the mouse lung fibrosis model lung and treatment are shown in FIG. 22. Lung fibrosis was induced in third generation (G3) TERT knock-out (KO) mice, which have telomere lengths that are similar to those of humans. Bleomycin was administered continuously via subcutaneously implanted osmotic minipump. Total dose delivered was 100U/kg. TERT mRNA encapsulated in the SS-OP DOTAP LNP formulation of Table 6A, was administered intravenously four times beginning on day 10, as shown. Relative to the control, which was firefly Luciferase mRNA, delivery of the TERT mRNA extended the survival rate of the mouse by 210% at the endpoint.

[0588] While preferred embodiments of the instant disclosure have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the disclosure. It should be understood that various alternatives to the embodiments of the disclosure described herein may be employed in practicing the disclosure. It is intended that the following claims define the scope of the disclosure and that methods and structures within the scope of these claims and their equivalents be covered thereby.

Claims

1. A method of delivering a polynucleotide to the lung of a subject, comprising administering, by intravenous injection, a polynucleotide encapsulated in a lipid nanoparticle (LNP) comprising:

(i) a cationic lipid in a molar percentage of between about 20% and about 50%,

(ii) a SS-OP or an SS-OP analog at a molar percentage of between about 20% and about 60%.

2. The method of claim 1, wherein the LNP comprises SS-OP at a molar percentage of between about 20% and 60%.

3. The method of claims 1 or 2, wherein the cationic lipid is any one or more of 2-Dioleoyl-3-Trimethylammonium-Propane (DOTAP), Dimethyldioctadecylammonium bromide (DDAB), Imidazole Cholesterol Ester (ICE), 25-Hydroxycholesterol (25 OH Chol), 20α-hydroxycholesterol 5-cholestene-3α, 20α-diol (20α Chol), N-[1-(2,3-dioleyloxy)propyl]-N,N,N-trimethylammonium chloride (DOTMA), 5-carboxyspermylglycinedioctadecylamide (DOGS), 2,3-dioleyloxy-N-[2(spermine-carboxamido)ethyl]-N,N-dimethyl-1-propanaminium (DOSPA), 1,2-Dioleoyl-3-Dimethylammonium-Propane (DODAP), 11,2-distearyloxy-N,N-dimethyl-3-aminopropane (DSDMA), 1,2-dioleyloxy-N,N-dimethyl-3-aminopropane (DODMA), 1,2-dilinoleyloxy-N,N-dimethyl-3-aminopropane (DLinDMA), dimethyldioctadecylammonium (DDA), 1,2-dilinolenyloxy-N,N-dimethyl-3-aminopropane (DLenDMA), N-dioleyl-N,N-dimethylammonium chloride (DODAC), N,N-distearyl-N,N-dimethylammonium bromide (DDAB), N-(1,2-dimyristyloxyprop-3-yl)-N,N-dimethyl-N-hydroxyethyl ammonium bromide (DMRIE), 3-dimethylamino-2-(cholest-5-en-3-beta-oxybutan-4-oxy)-1-(cis,cis-9,12-oc-tadecadienoxy)propane (CLinDMA), 2-[5′-(cholest-5-en-3-beta-oxy)-3′-oxapentoxy)-3-dimethy 1-1-(cis,cis-9′,1-2′-octadecadienoxy)propane (CpLinDMA), N,N-dimethyl-3,4-dioleyloxybenzylamine (DMOBA), 1,2-N,N′-dioleylcarbamyl-3-dimethylaminopropane (DOcarbDAP), 2,3-Dilinoleoyloxy-N,N-dimethylpropylamine (DLinDAP), 1,2-N,N′-Dilinoleylcarbamyl-3-dimethylaminopropane (DLincarbDAP), 1,2-Dilinoleoylcarbamyl-3-dimethylaminopropane or (DLinCDAP), 2,2-dilinoleyl-4-dimethylaminomethyl-[1,3]-dioxolane (DLin-K-DMA), 2,2-dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (DLin-K-XTC2-DMA), and mixtures thereof.

4. The method of claim 3, wherein the cationic lipid is DOTAP.

5. The method of any one of claims 1-4, wherein the LNP comprises the cationic lipid at a molar percentage of between about 25% and about 35%.

6. The method of any one of claims 1-4, wherein the LNP comprises the cationic lipid at a molar percentage of about 30%.

7. The method of any one of claims 1-6, wherein the LNP comprises a structural lipid.

8. The method of claim 7, wherein the structural lipid is any one or more of 1,2-di-(9Z-octadecenoyl)-sn-glycero-3-phosphoethanolamine (DOPE), glycerol-monooleate (GMO), distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG), dioleoylphosphatidylethanolamine (DOPE), palmitoyloleoylphosphatidylcholine (POPC), palmitoyloleoyl-phosphatidylethanolamine (POPE), dioleoyl-phosphatidylethanolamine 4-(N-maleimidomethyl)-cyclohexane-1-carboxylate (DOPE-mal), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidyl-ethanolamine (DSPE), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1-trans PE, 1-stearoyl-2-oleoyl-phosphatidyethanolamine (SOPE), cholesterol or another sterol, and mixtures thereof.

9. The method of claim 7, wherein the structural lipid is DOPC.

10. The method of claim 9, wherein the LNP comprises between about 1% and about 5% DOPC.

11. The method of any one of claims 1-6, wherein the LNP is substantially free of structural lipids and/or comprises at most 1% structural lipids.

12. The method of any one of claims 1-11, wherein the LNP comprises between about 20% and about 40% cholesterol.

13. The method of any one of claims 1-11, wherein the LNP is substantially free of cholesterol.

14. The method of any one of claims 1-13, wherein the LNP comprises an insulator lipid.

15. The method of any one of claims 1-13, wherein the LNP is substantially free of insulator lipids.

16. The method of any one of claims 1-15, wherein the LNP preferentially delivers to and/or transfects the lung compared to liver.

17. The method of any one of claims 1-16, wherein the polynucleotide is a synthetic ribonucleic acid (RNA).

18. The method of claim 17, wherein the synthetic ribonucleic acid (RNA) encodes telomerase reverse transcriptase (TERT), wherein optionally the TERT mRNA comprises a nucleic acid sequence at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 91%, at least 92%, at least 93%, at

least 94%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical to any one of SEQ ID NOS: 38-40 .

19. A method of treating a lung disease and/or lung fibrosis in a subject in need thereof, comprising administering an effective amount of a composition comprising a delivery vehicle comprising a synthetic ribonucleic acid (RNA) encoding telomerase reverse transcriptase (TERT), wherein the delivery vehicle is a lipid nanoparticle (LNP) comprising SS-OP or an SS-OP analog, wherein optionally the TERT mRNA comprises a nucleic acid sequence at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 91%, at least 92%, at least 93%, at least 94%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical to any one of SEQ ID NOS: 38-40.

20. The method of claim 19, wherein the delivery vehicle is a lipid nanoparticle (LNP) comprising SS-OP at a molar percentage of between about 20% and 60%.

21. The method of claim 20, wherein the LNP comprises a cationic lipid at a molar percentage of between about 20% and about 50%, SS-OP at a molar percentage of between about 20% and 60%, and optionally one or more of a structural lipid, an insulator lipid, and a cholesterol.

22. The method of any one of claims 19-21, wherein the TERT synthetic mRNA comprises at least one modified nucleoside from the list in Table 2.

23. The method of claim 22, wherein the modified nucleoside is pseudouridine or a pseudouridine analog.

24. The method of claim 22, wherein the pseudouridine analog is N-1-methylpseudouridine.

25. The method of any one of claims 19-24, wherein the TERT synthetic mRNA comprises an untranslated region (UTR).

26. The method of any one of claims 19-25, wherein the TERT synthetic mRNA comprises a 5′ cap structure, wherein the 5′ cap structure is m7(3′OMeG)(5′)ppp(5′)(2′OMeA)pG, IRES, Cap0, Capl, ARCA, inosine, Nl-methyl-guanosine, 2′fluoro-guanosine, 7-deaza-guanosine, CleanCapTM, 8-oxo-guanosine, 2-amino-guanosine, LNA-guanosine, 2-azido-guanosine, Cap2, Cap4, CAP-003, or CAP-225.

27. The method of any one of claims 19-26, wherein the TERT synthetic mRNA comprises a poly-adenosine (poly-A) nucleotide sequence 3′ to the encoding region.

28. The method of any one of claims 19-27, wherein the TERT synthetic mRNA comprises a chain terminating nucleotide, wherein the nucleotide is 3′-deoxyadenosine

(cordycepin), 3′-deoxyuridine, 3′-deoxycytosine, 3′-deoxyguanosine, 3′-deoxythymine, 2′,3′-dideoxynucleosides, 2′,3′-dideoxyadenosine, 2′,3′-dideoxyuridine, 2′,3′-dideoxycytosine, 2′,3′- dideoxyguanosine, 2′,3′-dideoxythymine, a 2′-deoxynucleoside, or -O-methylnucleoside.

29. The method of any one of claims 19-28, wherein the TERT synthetic mRNA is codon optimized.

30. The method of any one of claims 19-28, wherein the lung disease is associated with lung fibrosis.

31. The method of claim 30, wherein the lung disease is pulmonary fibrosis, familial pulmonary fibrosis, idiopathic pulmonary fibrosis, pulmonary fibrosis associated with dyskeratosis congenita, an interstitial lung disease, pneumonia, interstitial pneumonia, emphysema, chronic obstructive pulmonary disease, cystic fibrosis, an infectious disease, a coronavirus disease, or lung cancer.

32. The method of any one of claims 19-31, wherein the lung fibrosis is associated with a TERT mutation.

33. The method of any one of claims 19-32, wherein the subject is human.

34. The method of any one of claims 19-33, wherein the composition is administered to the subject via intravenous injection.

35. The method of any one of claims 19-33, wherein the composition is administered to the subject via inhalation.

36. A composition, comprising a polynucleotide encapsulated in a lipid nanoparticle (LNP) comprising:

(i) a cationic lipid in a molar percentage of between about 20% and about 50%,

(ii) an SS-OP or an SS-OP analog at a molar percentage of between about 20% and about 60%.

37. The composition of claim 36, wherein the LNP comprises SS-OP at a molar percentage of between about 20% and 60%.

38. The composition of claim 36, wherein the cationic lipid is any one or more of 2-Dioleoyl-3-Trimethylammonium-Propane (DOTAP), Dimethyldioctadecylammonium bromide (DDAB), Imidazole Cholesterol Ester (ICE), 25-Hydroxycholesterol (25 OH Chol), 20α-hydroxycholesterol 5-cholestene-3α, 20α-diol (20α Chol), N-[1-(2,3-dioleyloxy)propyl]-N,N,N-trimethylammonium chloride (DOTMA), 5-carboxyspermylglycinedioctadecylamide (DOGS), 2,3-dioleyloxy-N-[2(spermine-carboxamido)ethyl]-N,N-dimethyl-1-propanaminium (DOSPA), 1,2-Dioleoyl-3-Dimethylammonium-Propane (DODAP), 11,2-distearyloxy-N,N-

dimethyl-3-aminopropane (DSDMA), 1,2-dioleyloxy-N,N-dimethyl-3-aminopropane (DODMA), 1,2-dilinoleyloxy-N,N-dimethyl-3-aminopropane (DLinDMA), dimethyldioctadecylammonium (DDA), 1,2-dilinolenyloxy-N,N-dimethyl-3-aminopropane (DLenDMA), N-dioleyl-N,N-dimethylammonium chloride (DODAC), N,N-distearyl-N,N-dimethylammonium bromide (DDAB), N-(1,2-dimyristyloxyprop-3-yl)-N,N-dimethyl-N-hydroxyethyl ammonium bromide (DMRIE), 3-dimethylamino-2-(cholest-5-en-3-beta-oxybutan-4-oxy)-1-(cis,cis-9,12-oc-tadecadienoxy)propane (CLinDMA), 2-[5′-(cholest-5-en-3-beta-oxy)-3′-oxapentoxy)-3-dimethy 1-1-(cis,cis-9′,1-2′-octadecadienoxy)propane (CpLinDMA), N,N-dimethyl-3,4-dioleyloxybenzylamine (DMOBA), 1,2-N,N′-dioleylcarbamyl-3-dimethylaminopropane (DOcarbDAP), 2,3-Dilinoleoyloxy-N,N-dimethylpropylamine (DLinDAP), 1,2-N,N′-Dilinoleylcarbamyl-3-dimethylaminopropane (DLincarbDAP), 1,2-Dilinoleoylcarbamyl-3-dimethylaminopropane or (DLinCDAP), 2,2-dilinoleyl-4-dimethylaminomethyl-[1,3]-dioxolane (DLin-K-DMA), 2,2-dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (DLin-K-XTC2-DMA), and mixtures thereof.

39. The composition of claim 38, wherein the cationic lipid is DOTAP.

40. The composition of any one of claims 36-39, wherein the LNP comprises the cationic lipid at a molar percentage of between about 25% and about 35%.

41. The composition of any one of claims 36-39, wherein the LNP comprises the cationic lipid at a molar percentage of about 30%.

42. The composition of any one of claims 36-41, wherein the LNP comprises a structural lipid.

43. The composition of claim 42, wherein the structural lipid is any one or more of 1,2-di-(9Z-octadecenoyl)-sn-glycero-3-phosphoethanolamine (DOPE), glycerol-monooleate (GMO), distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG), dioleoylphosphatidylethanolamine (DOPE), palmitoyloleoylphosphatidylcholine (POPC), palmitoyloleoyl-phosphatidylethanolamine (POPE), dioleoyl-phosphatidylethanolamine 4-(N-maleimidomethyl)-cyclohexane-1-carboxylate (DOPE-mal), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidyl-ethanolamine (DSPE), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1-trans PE, 1-stearoyl-2-oleoyl-phosphatidyethanolamine (SOPE), cholesterol or another sterol, and mixtures thereof.

44. The composition of claim 43, wherein the structural lipid is DOPC.

45. The composition of claim 44, wherein the LNP comprises between about 1% and about 5% DOPC.

46. The composition of any one of claims 36-45, wherein the LNP is substantially free of structural lipids and/or comprises at most 1% structural lipids.

47. The composition of any one of claims 36-46, wherein the LNP comprises between about 20% and about 40% cholesterol.

48. The composition of any one of claims 36-46, wherein the LNP is substantially free of cholesterol.

49. The composition of any one of claims 36-48, wherein the LNP comprises an insulator lipid.

50. The composition of any one of claims 36-48, wherein the LNP is substantially free of insulator lipids.

51. The composition of any one of claims 36-50, wherein the LNP preferentially delivers to and/or transfects the lung compared to liver.

52. The composition of any one of claims 36-51, wherein the polynucleotide is a synthetic ribonucleic acid (RNA).

53. The composition of claim 52, wherein the synthetic ribonucleic acid (RNA) encodes telomerase reverse transcriptase (TERT), wherein optionally the TERT RNA comprises a nucleic acid sequence at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 91%, at least 92%, at least 93%, at least 94%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical to any one of SEQ ID NOS: 38-40.

54. The composition of claim 53, wherein the TERT RNA comprises at least one modified nucleoside from the list in Table 2.

55. The composition of claim 54, wherein the modified nucleoside is pseudouridine or a pseudouridine analog.

56. The composition of claim 54, wherein the pseudouridine analog is N-1-methylpseudouridine.

57. The composition of claims 53-56, wherein the TERT RNA comprises an untranslated region (UTR).

58. The composition of any one of claims 53-57, wherein the wherein the TERT RNA comprises a 5′ cap structure, wherein the 5′ cap structure is m7(3′OMeG)(5′)ppp(5′)(2′OMeA)pG, IRES, Cap0, Capl, ARCA, inosine, Nl-methyl-

guanosine, 2′fluoro-guanosine, 7-deaza-guanosine, CleanCapTM, 8-oxo-guanosine, 2-amino-guanosine, LNA-guanosine, 2-azido-guanosine, Cap2, Cap4, CAP-003, or CAP-225.

59. The composition of any one of claims 53-58, wherein the TERT RNA comprises a poly-adenosine (poly-A) nucleotide sequence 3′ to the encoding region.

60. The composition of any one of claims 53-59, wherein the TERT RNA comprises a chain terminating nucleotide, wherein the nucleotide is 3′-deoxyadenosine (cordycepin), 3′-deoxyuridine, 3′-deoxycytosine, 3′-deoxyguanosine, 3′-deoxythymine, 2′,3′-dideoxynucleosides, 2′,3′-dideoxyadenosine, 2′,3′-dideoxyuridine, 2′,3′-dideoxycytosine, 2′,3′- dideoxyguanosine, 2′,3′-dideoxythymine, a 2′-deoxynucleoside, or -O-methylnucleoside.

61. The composition of any one of claims 53-60, wherein the TERT RNA is codon optimized.

62. Use of the composition of any one of claims 36-61, for the treatment of a lung disease in a subject in need thereof.

63. Use of the composition according to claim 62, wherein the lung disease is pulmonary fibrosis, familial pulmonary fibrosis, idiopathic pulmonary fibrosis, pulmonary fibrosis associated with dyskeratosis congenita, an interstitial lung disease, pneumonia, interstitial pneumonia, emphysema, chronic obstructive pulmonary disease, cystic fibrosis, an infectious disease, a coronavirus disease, or lung cancer.

64. Use of the composition according to claims 62 or 63, wherein the lung disease is associated with a TERT mutation in the subject.

65. Use of the composition according to any of claims 62-64, wherein the composition is administered to the subject via intravenous injection or intravenous infusion.

66. A pharmaceutical composition comprising:

(i) a delivery vehicle comprising a ribonucleic acid (RNA) encoding telomerase reverse transcriptase (TERT), wherein optionally the TERT mRNA comprises a nucleic acid sequence at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 91%, at least 92%, at least 93%, at least 94%, at least 95%, at least 96%, at least 97%, at least 98%, or at least 99% identical to any one of SEQ ID NOS: 38-40; and

(ii) a pharmaceuticaly acceptable solvent or excipient;

wherein the delivery vehicle is an LNP comprising SS-OP or an SS-OP analog, and is capable of preferentially delivering to and/or transfecting lung cells.

67. The pharmaceutical composition of claim 66, wherein the LNP comprises

SS-OP at a molar percentage of between about 20% and about 60%.

68. The pharmaceutical composition of claim 67, wherein the LNP comprises:
a cationic lipid in a molar percentage of between about 20% and about 50%.

69. The pharmaceutical composition of claim 66, wherein the LNP comprises an SS-OP analog at a molar percentage of between about 20% and 60%.

70. The pharmaceutical composition of claim 68 or 69, wherein the cationic lipid is any one or more of 2-Dioleoyl-3-Trimethylammonium-Propane (DOTAP), Dimethyldioctadecylammonium bromide (DDAB), Imidazole Cholesterol Ester (ICE), 25-Hydroxycholesterol (25 OH Chol), 20α-hydroxycholesterol 5-cholestene-3α, 20α-diol (20α Chol), N-[1-(2,3-dioleyloxy)propyl]-N,N,N-trimethylammonium chloride (DOTMA), 5-carboxyspermylglycinedioctadecylamide (DOGS), 2,3-dioleyloxy-N-[2(spermine-carboxamido)ethyl]-N,N-dimethyl-1-propanaminium (DOSPA), 1,2-Dioleoyl-3-Dimethylammonium-Propane (DODAP), 11,2-distearyloxy-N,N-dimethyl-3-aminopropane (DSDMA), 1,2-dioleyloxy-N,N-dimethyl-3-aminopropane (DODMA), 1,2-dilinoleyloxy-N,N-dimethyl-3-aminopropane (DLinDMA), dimethyldioctadecylammonium (DDA), 1,2-dilinolenyloxy-N,N-dimethyl-3-aminopropane (DLenDMA), N-dioleyl-N,N-dimethylammonium chloride (DODAC), N,N-distearyl-N,N-dimethylammonium bromide (DDAB), N-(1,2-dimyristyloxyprop-3-yl)-N,N-dimethyl-N-hydroxyethyl ammonium bromide (DMRIE), 3-dimethylamino-2-(cholest-5-en-3-beta-oxybutan-4-oxy)-1-(cis,cis-9,12-oc-tadecadienoxy)propane (CLinDMA), 2-[5′-(cholest-5-en-3-beta-oxy)-3′-oxapentoxy)-3-dimethy 1-1-(cis,cis-9′,1-2′-octadecadienoxy)propane (CpLinDMA), N,N-dimethyl-3,4-dioleyloxybenzylamine (DMOBA), 1,2-N,N′-dioleylcarbamyl-3-dimethylaminopropane (DOcarbDAP), 2,3-Dilinoleoyloxy-N,N-dimethylpropylamine (DLinDAP), 1,2-N,N′-Dilinoleylcarbamyl-3-dimethylaminopropane (DLincarbDAP), 1,2-Dilinoleoylcarbamyl-3-dimethylaminopropane or (DLinCDAP), 2,2-dilinoleyl-4-dimethylaminomethyl-[1,3]-dioxolane (DLin-K-DMA), 2,2-dilinoleyl-4-dimethylaminoethyl-[1,3]-dioxolane (DLin-K-XTC2-DMA), and mixtures thereof.

71. The pharmaceutical composition of claim 70, wherein the cationic lipid is DOTAP.

72. The pharmaceutical composition of any one of claims 68-71, wherein the LNP comprises the cationic lipid at a molar percentage of between about 25% and about 35%.

73. The pharmaceutical composition of any one of claims 68-71, wherein the LNP comprises the cationic lipid at a molar percentage of about 30%.

74. The pharmaceutical composition of any one of claims 68-73, wherein the LNP comprises a structural lipid.

75. The pharmaceutical composition of claim 74, wherein the structural lipid is any one or more of 1,2-di-(9Z-octadecenoyl)-sn-glycero-3-phosphoethanolamine (DOPE), glycerol-monooleate (GMO), distearoylphosphatidylcholine (DSPC), dioleoylphosphatidylcholine (DOPC), dipalmitoylphosphatidylcholine (DPPC), dioleoylphosphatidylglycerol (DOPG), dipalmitoylphosphatidylglycerol (DPPG), dioleoylphosphatidylethanolamine (DOPE), palmitoyloleoylphosphatidylcholine (POPC), palmitoyloleoyl-phosphatidylethanolamine (POPE), dioleoyl-phosphatidylethanolamine 4-(N-maleimidomethyl)-cyclohexane-1-carboxylate (DOPE-mal), dipalmitoyl phosphatidyl ethanolamine (DPPE), dimyristoylphosphoethanolamine (DMPE), distearoyl-phosphatidyl-ethanolamine (DSPE), 16-O-monomethyl PE, 16-O-dimethyl PE, 18-1-trans PE, 1-stearoyl-2-oleoyl-phosphatidyethanolamine (SOPE), cholesterol or another sterol, and mixtures thereof.

76. The pharmaceutical composition of claim 75, wherein the structural lipid is DOPC.

77. The pharmaceutical composition of claim 76, wherein the LNP comprises between about 1% and about 5% DOPC.

78. The pharmaceutical compositon of any one of claims 68-77, wherein the LNP is substantially free of structural lipids and/or comprises at most 1% structural lipids.

79. The pharmaceutical composition of any one of claims 68-78, wherein the LNP comprises between about 20% and about 40% cholesterol.

80. The pharmaceutical composition of any one of claims 68-78, wherein the LNP is substantially free of cholesterol.

81. The pharmaceutical composition of any one of claims 68-80, wherein the LNP comprises an insulator lipid.

82. The pharmaceutical composition of any one of claims 68-80, wherein the LNP is substantially free of insulator lipids.

83. The pharmaceutical composition of any one of claims 68-82, wherein the LNP preferentially delivers to and/or transfects the lung compared to liver.

84. The pharmaceutical composition of any one of claims 66-83, wherein the TERT RNA comprises at least one modified nucleoside from the list in Table 2.

85. The pharmaceutical composition of claim 84, wherein the modified nucleoside is pseudouridine or a pseudouridine analog.

86. The pharmaceutical composition of claim 85, wherein the pseudouridine analog is N-1-methylpseudouridine.

87. The pharmaceutical composition of claims 66-86, wherein the TERT RNA comprises an untranslated region (UTR), optionally a non-naturally occurring UTR.

88. The pharmaceutical composition of any one of claims 66-87, wherein the wherein the TERT RNA comprises a 5′ cap structure, wherein the 5′ cap structure is m7(3′OMeG)(5′)ppp(5′)(2′OMeA)pG, IRES, Cap0, Capl, ARCA, inosine, Nl-methyl-guanosine, 2′fluoro-guanosine, 7-deaza-guanosine, CleanCapTM, 8-oxo-guanosine, 2-amino-guanosine, LNA-guanosine, 2-azido-guanosine, Cap2, Cap4, CAP-003, or CAP-225.

89. The pharmaceutical composition of any one of claims 66-88, wherein the TERT RNA comprises a poly-adenosine (poly-A) nucleotide sequence 3′ to the encoding region.

90. The pharmaceutical composition of any one of claims 66-89, wherein the TERT RNA comprises a chain terminating nucleotide, wherein the nucleotide is 3′-deoxyadenosine (cordycepin), 3′-deoxyuridine, 3′-deoxycytosine, 3′-deoxyguanosine, 3′-deoxythymine, 2′,3′-dideoxynucleosides, 2′,3′-dideoxyadenosine, 2′,3′-dideoxyuridine, 2′,3′-dideoxycytosine, 2′,3′- dideoxyguanosine, 2′,3′-dideoxythymine, a 2′-deoxynucleoside, or -O-methylnucleoside.

91. The pharmaceutical composition of any one of claims 66-90, wherein the TERT RNA is codon optimized.

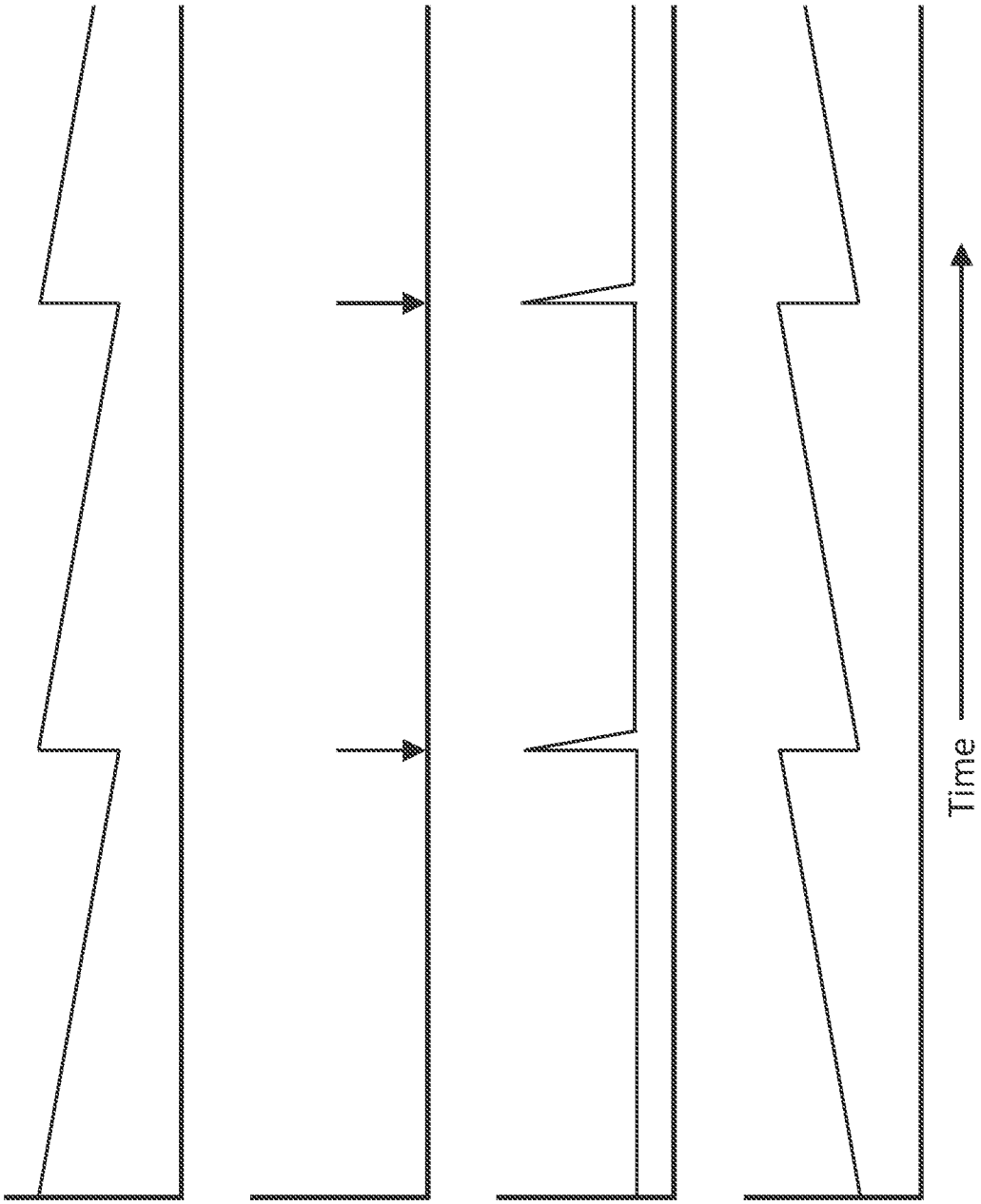
92. Use of the pharmaceutical composition of any one of claims 66-91, for the treatment of lung disease and/or lung fibrosisin a subject in need thereof.

93. Use of the pharmaceutical composition according to claim 92, wherein the lung disease is pulmonary fibrosis, familial pulmonary fibrosis, idiopathic pulmonary fibrosis, pulmonary fibrosis associated with dyskeratosis congenita, an interstitial lung disease, pneumonia, interstitial pneumonia, emphysema, chronic obstructive pulmonary disease, cystic fibrosis, an infectious disease, a coronavirus disease, or lung cancer.

94. Use of the pharmaceutical composition according to claims 92 or 93, wherein the lung fibrosis is associated with a TERT mutation in the subject.

95. Use of the pharmaceutical composition according to any of claims 92-94, wherein the composition is administered to the subject via intravenous injection.

FIG. 1


Telomere length
TERT mRNA doses
Telomere extension rate
Risk of disease
Time

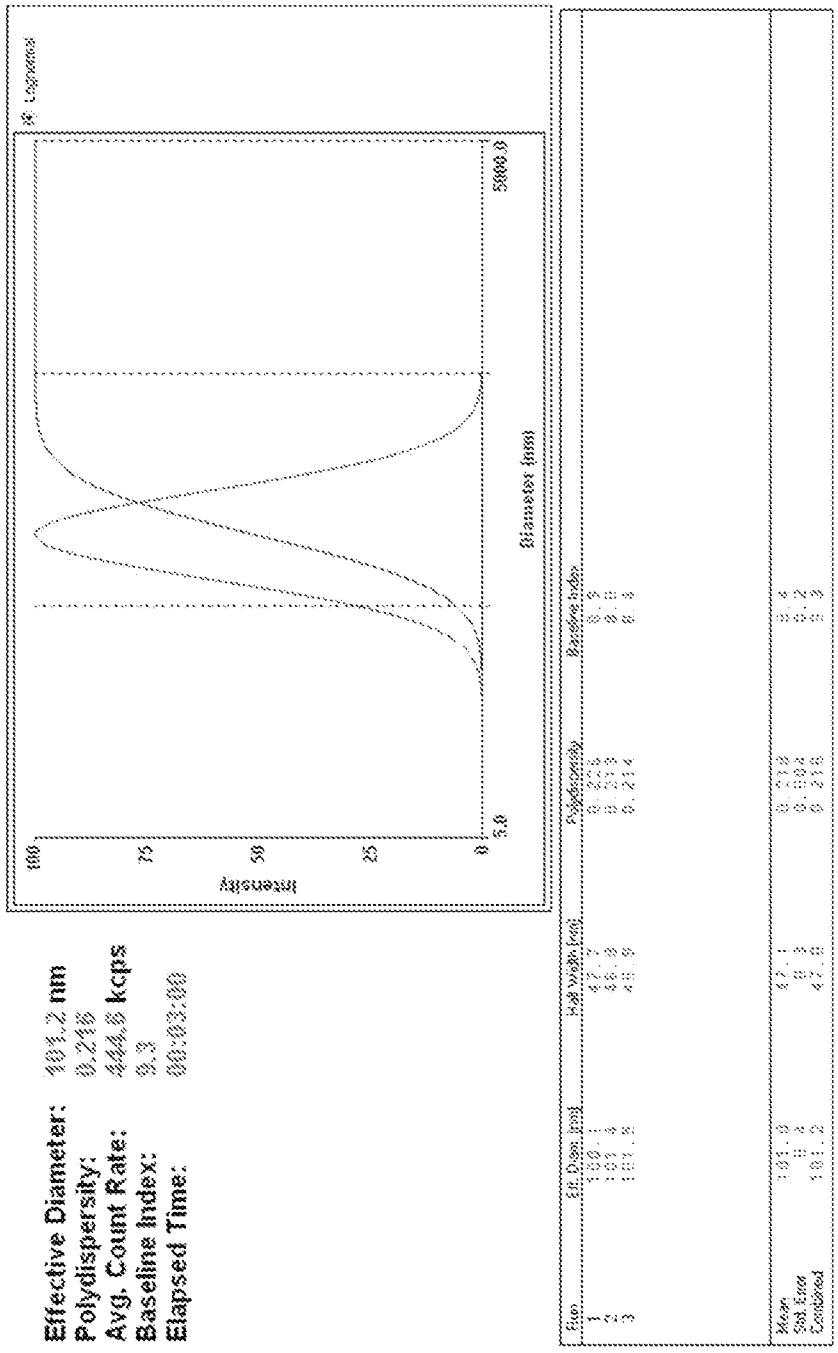

Effective Diameter: 101.2 nm
Polydispersity: 0.216
Avg. Count Rate: 444.8 kcps
Baseline Index: 0.3
Elapsed Time: 00:03:00
Intensity
Diameter (nm)
5000.0
5.0
Run
Eff. Diam. (nm)
Half Width (nm)
Polydispersity
Baseline Index
Mean
Std. Error
Combined

FIG. 2

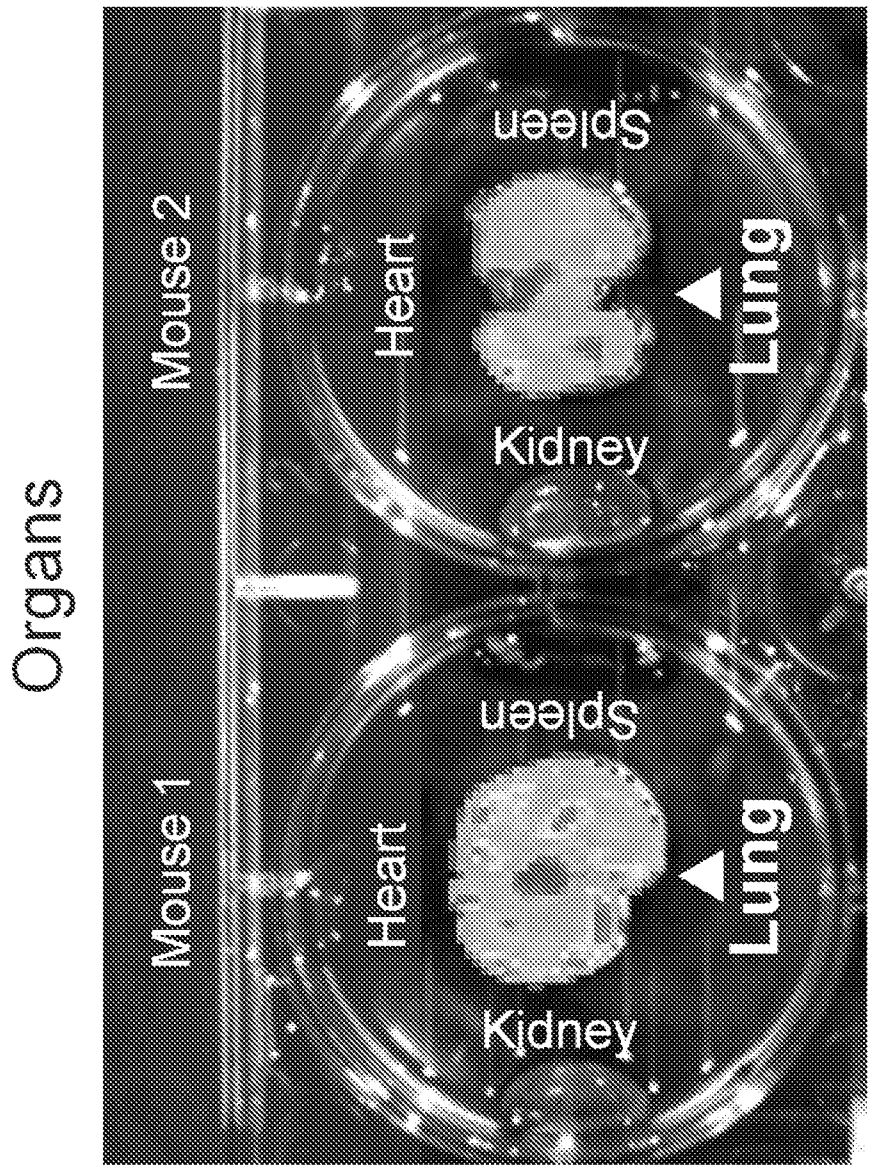

Organs
Mouse 1
Mouse 2
Heart
Lung
Kidney
Spleen
Heart
Lung
Kidney
Spleen

FIG. 3

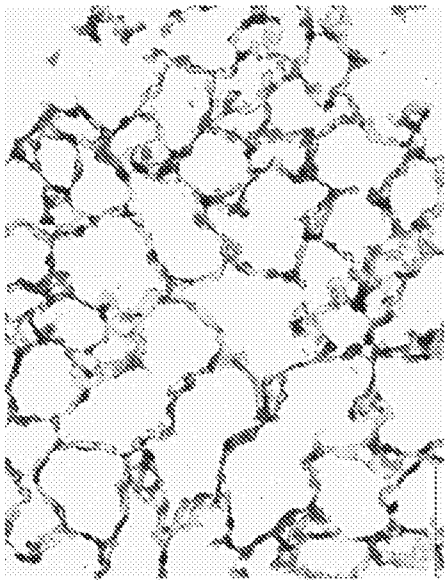


FIG. 4A

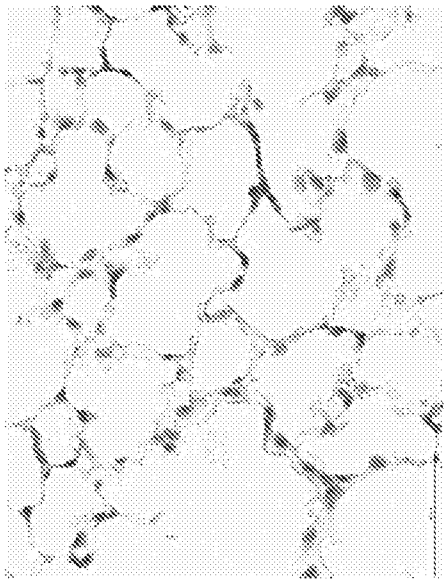


FIG. 4B

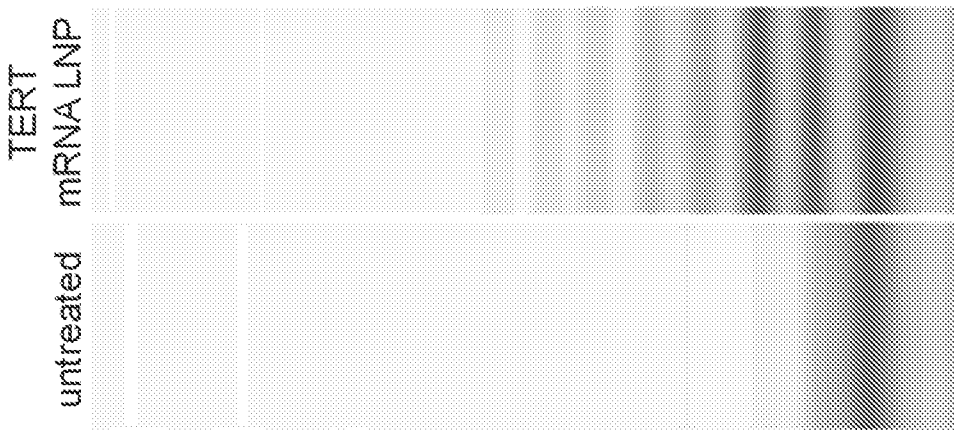


FIG. 5A FIG. 5B

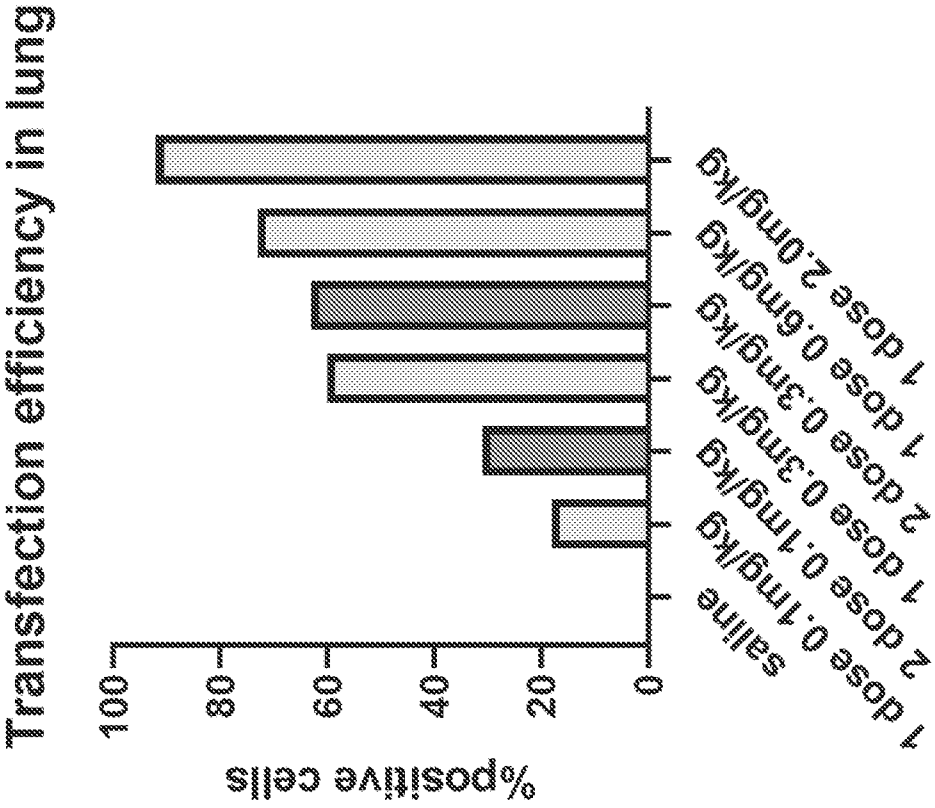
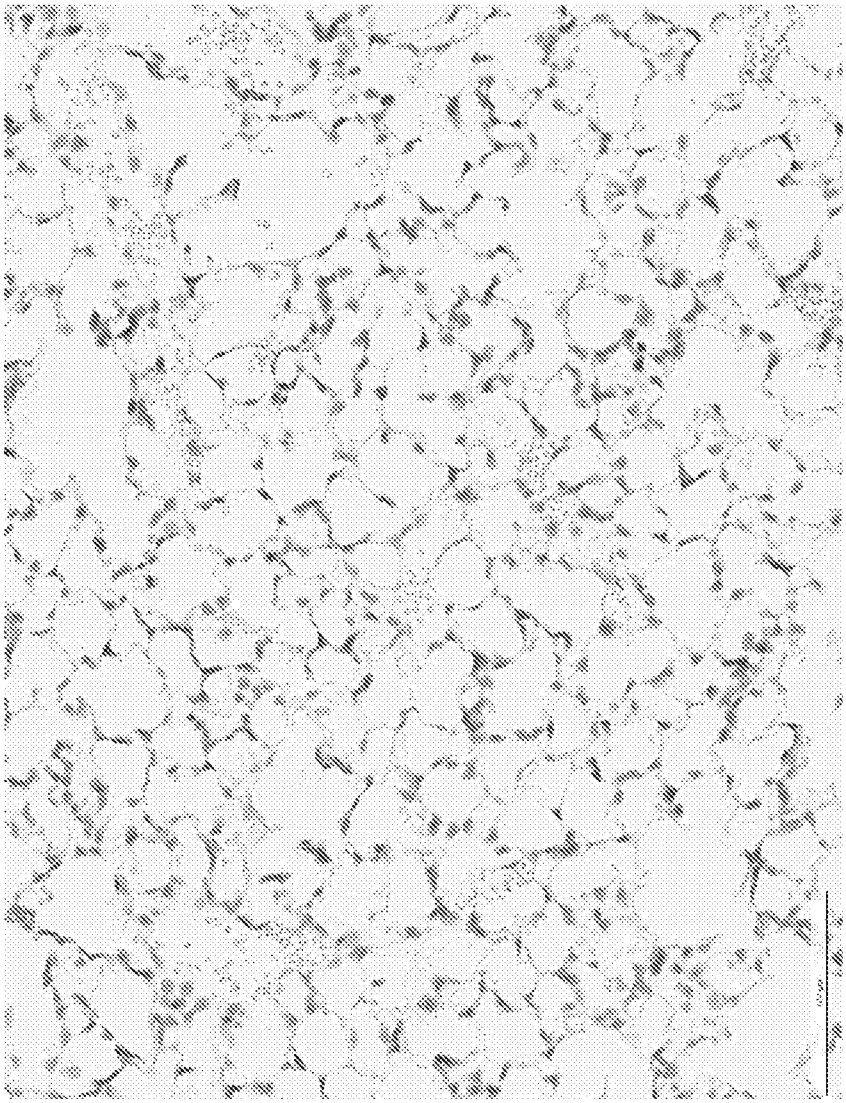
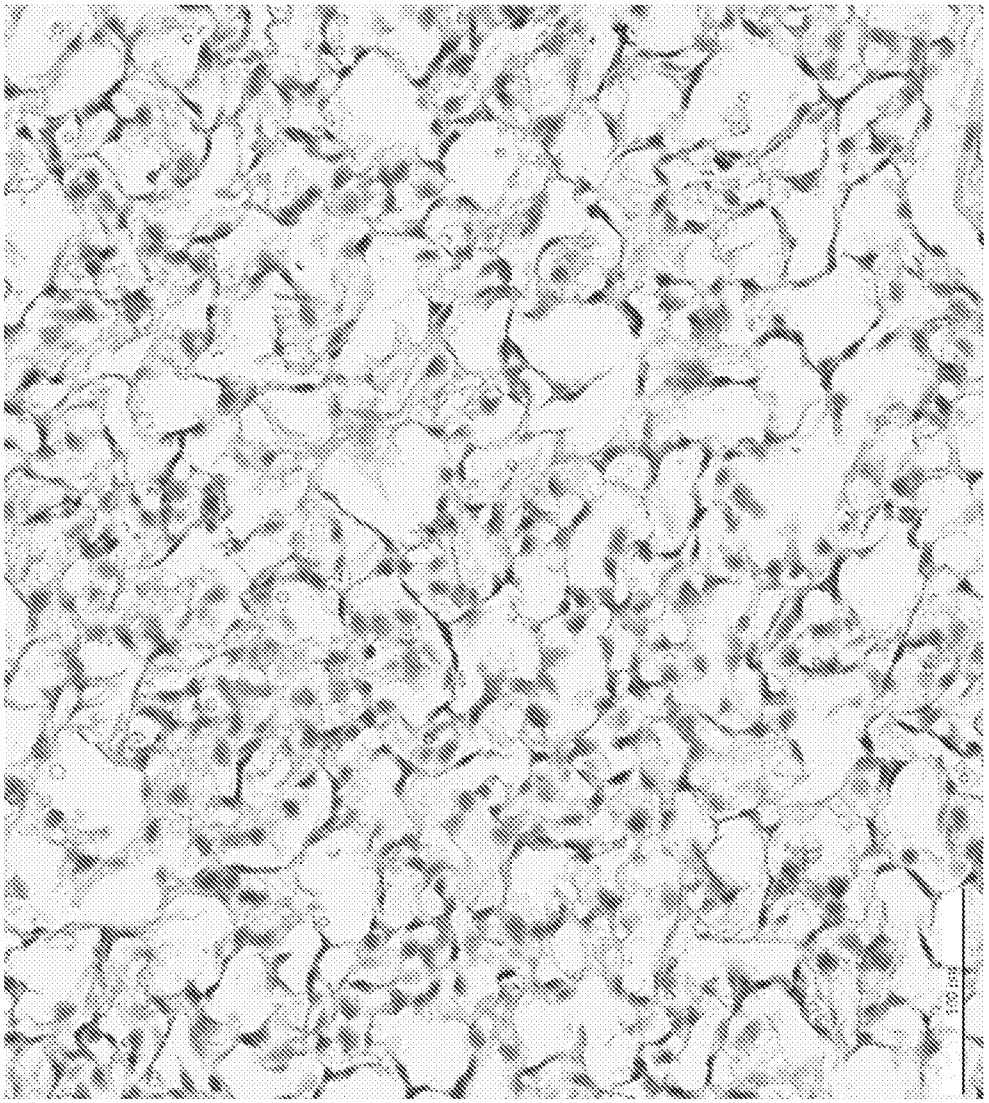

Transfection efficiency in lung
%positive cells
100
80
60
40
20
0
saline
1 dose 0.1mg/kg
2 dose 0.1mg/kg
1 dose 0.3mg/kg
2 dose 0.3mg/kg
1 dose 0.6mg/kg
1 dose 2.0mg/kg

FIG. 6A



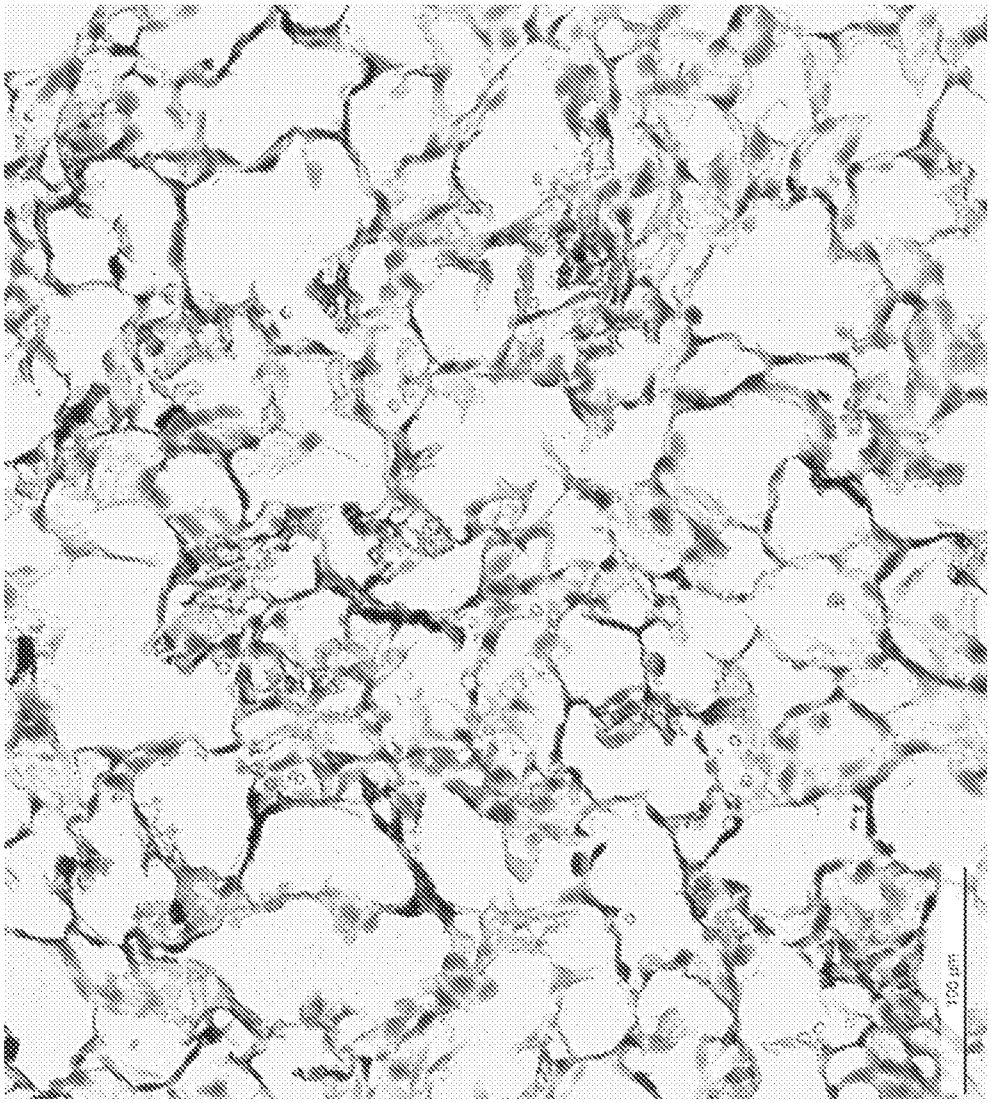
0 mg/kg

FIG. 6B



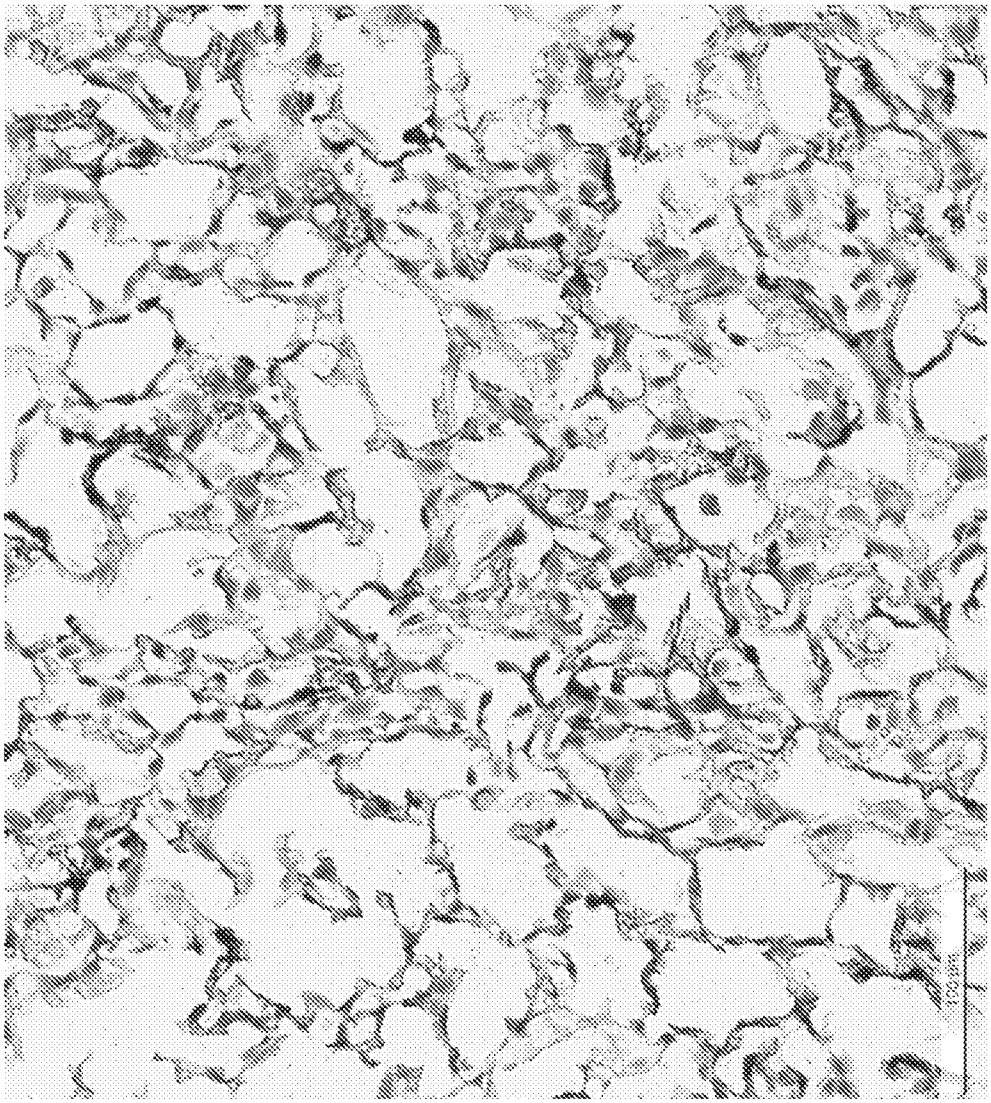
0.1 mg/kg

FIG. 6C



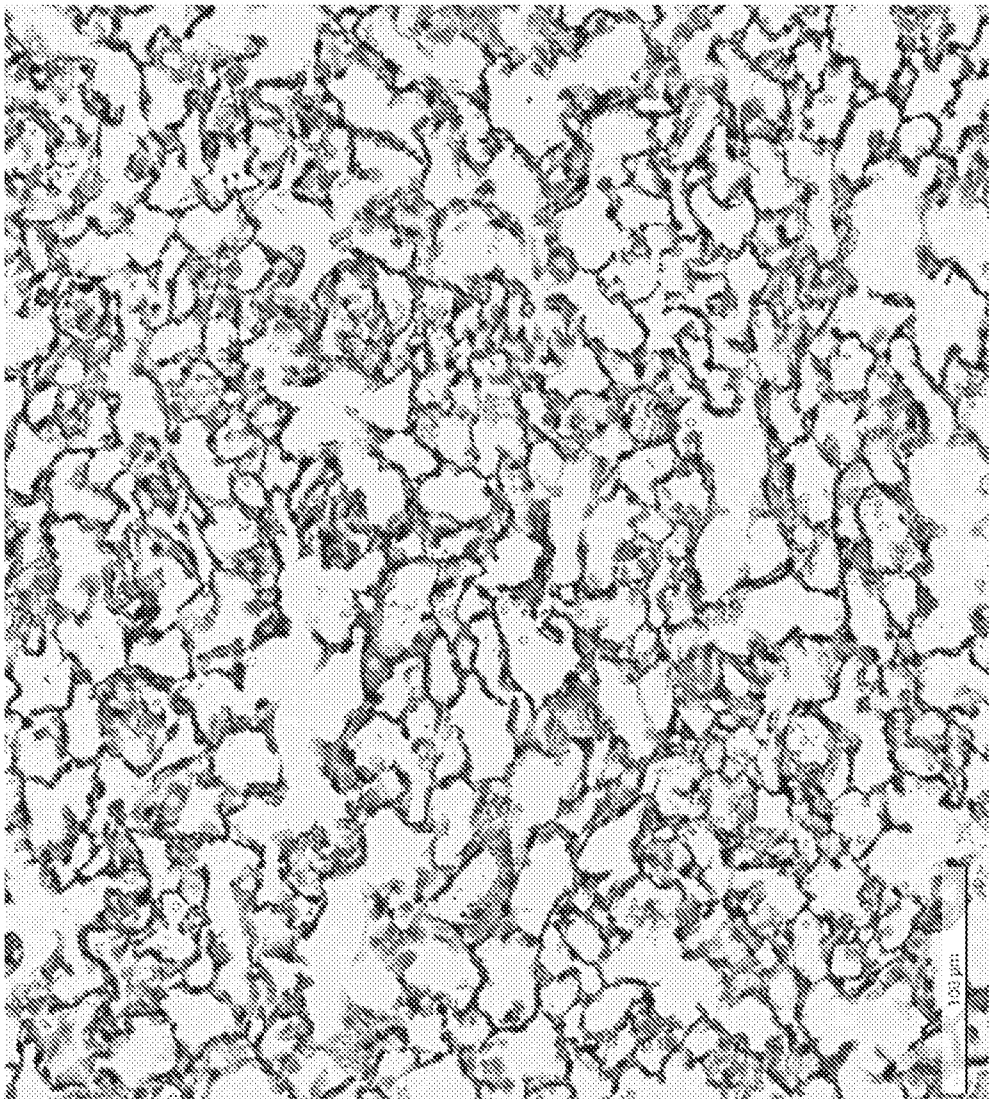
0.3 mg/kg

FIG. 6D



0.6 mg/kg

FIG. 6E



2.0 mg/kg

FIG. 6F

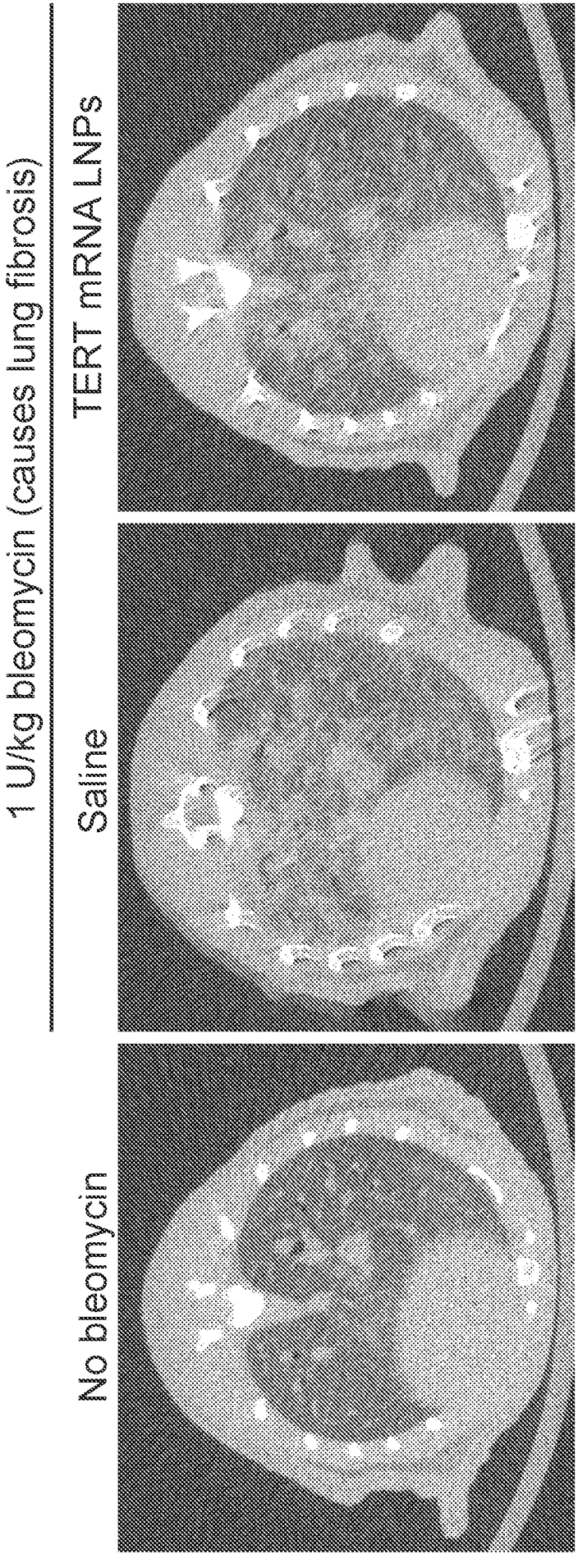


FIG. 7A

FIG. 7B

FIG. 7C

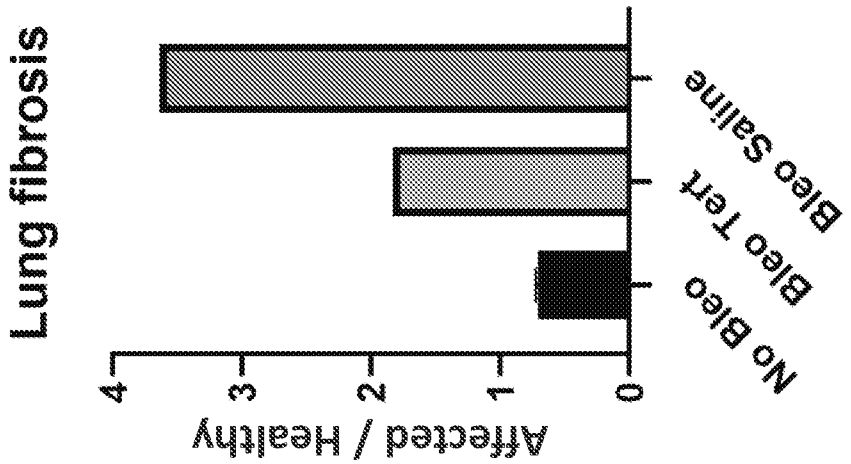

Lung fibrosis
Affected / Healthy
0
1
2
3
4
No Bleo
Bleo Tert
Bleo Saline

FIG. 7D

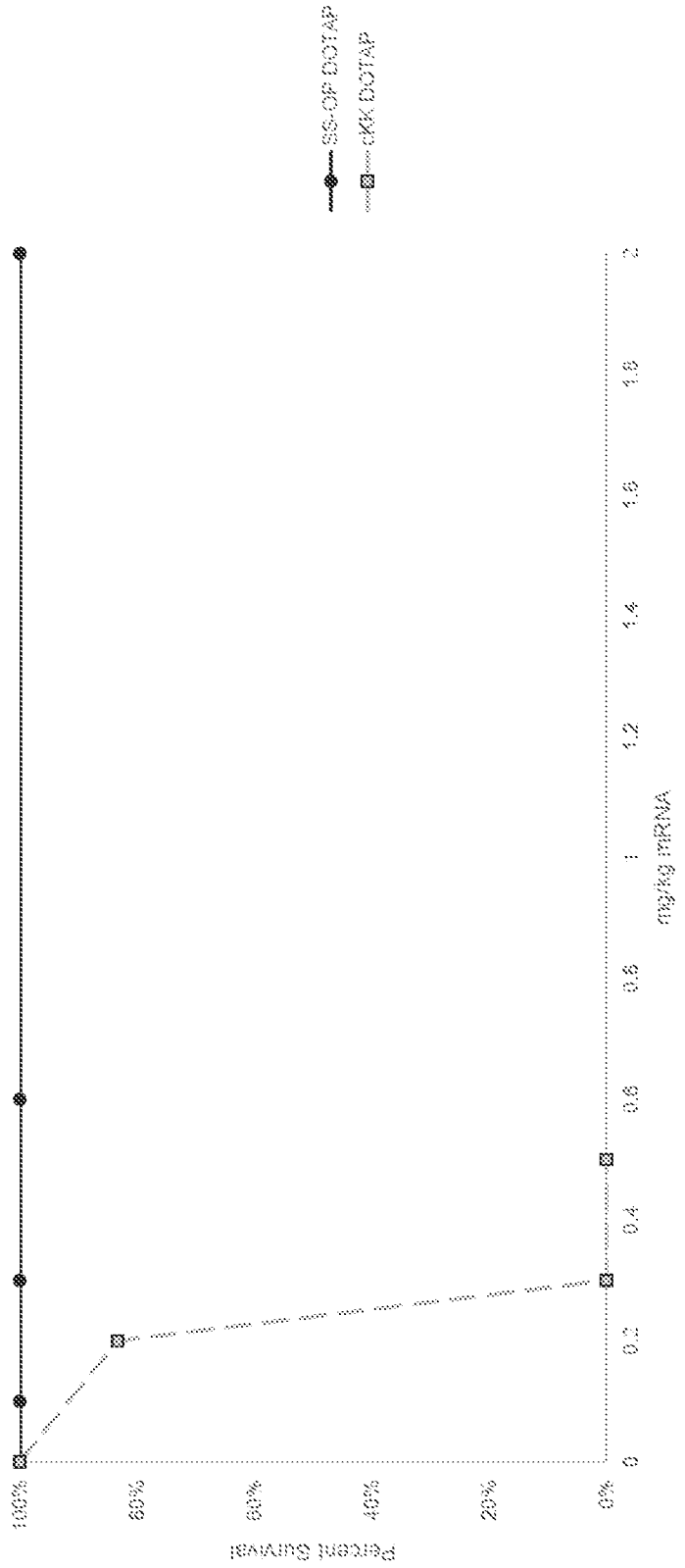

SS-OP DOTAP
cMix DOTAP
Percent Survival
100%
80%
60%
40%
20%
0%
mg/kg mRNA
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

FIG. 8

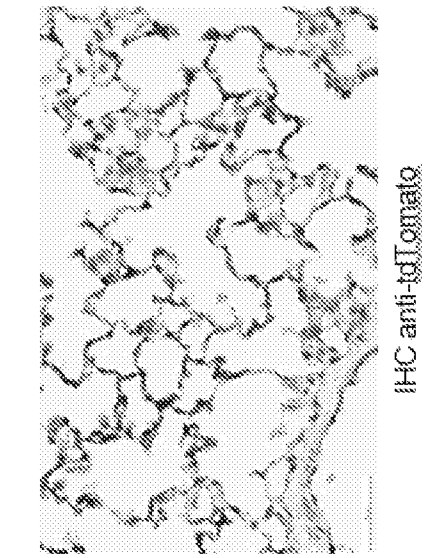


FIG. 9A

FIG. 9B

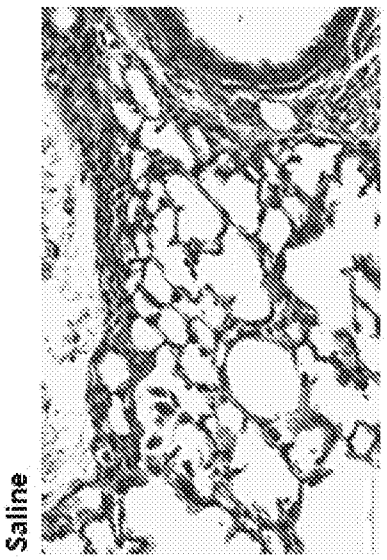


FIG. 9C

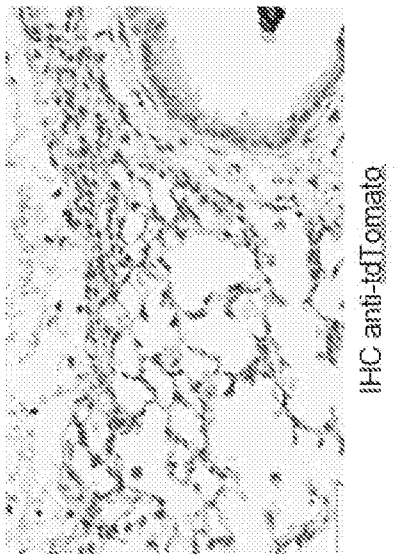


FIG. 9D

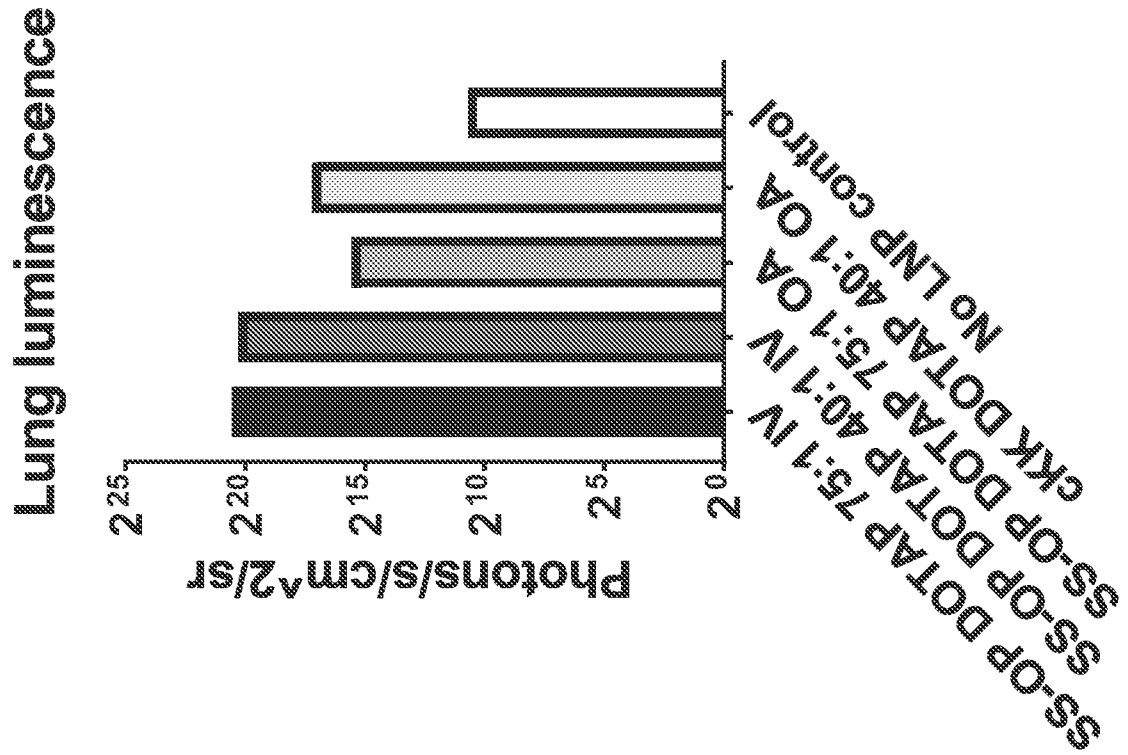

Lung luminescence
Photons/s/cm^2/sr
2^25
2^20
2^15
2^10
2^5
2^0
SS-OP DOTAP 75:1 IV
SS-OP DOTAP 40:1 IV
SS-OP DOTAP 75:1 OA
SS-OP DOTAP 40:1 OA
cKK DOTAP 40:1 OA
No LNP control

FIG. 10

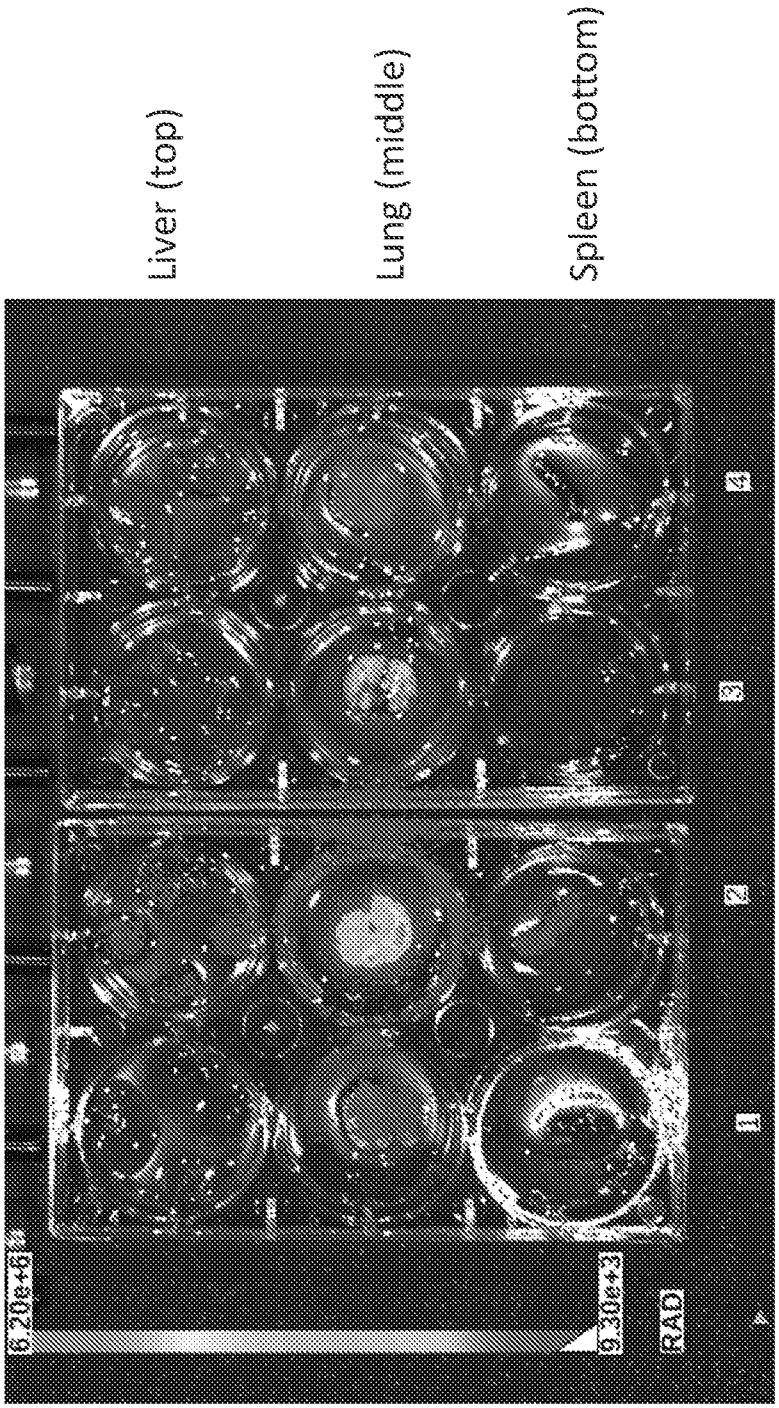


FIG. 11

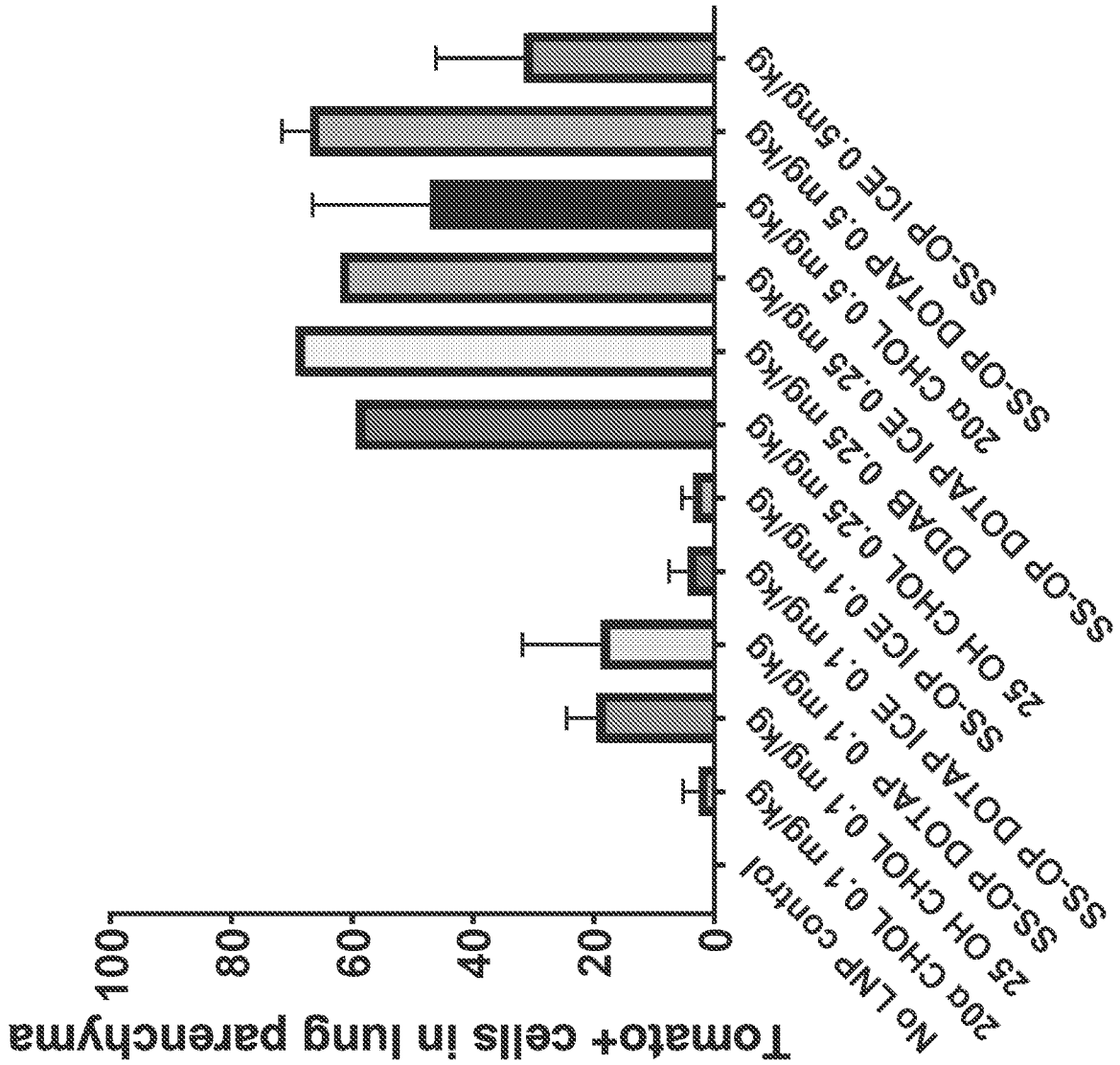

Tomato+ cells in lung parenchyma
0
20
40
60
80
100
No LNP control
20α CHOL 0.1 mg/kg
25 OH CHOL 0.1 mg/kg
SS-OP DOTAP 0.1 mg/kg
SS-OP ICE 0.1 mg/kg
25 OH CHOL 0.25 mg/kg
DDAB 0.25 mg/kg
SS-OP DOTAP ICE 0.25 mg/kg
20α CHOL 0.5 mg/kg
SS-OP DOTAP 0.5 mg/kg
SS-OP ICE 0.5mg/kg

FIG. 12

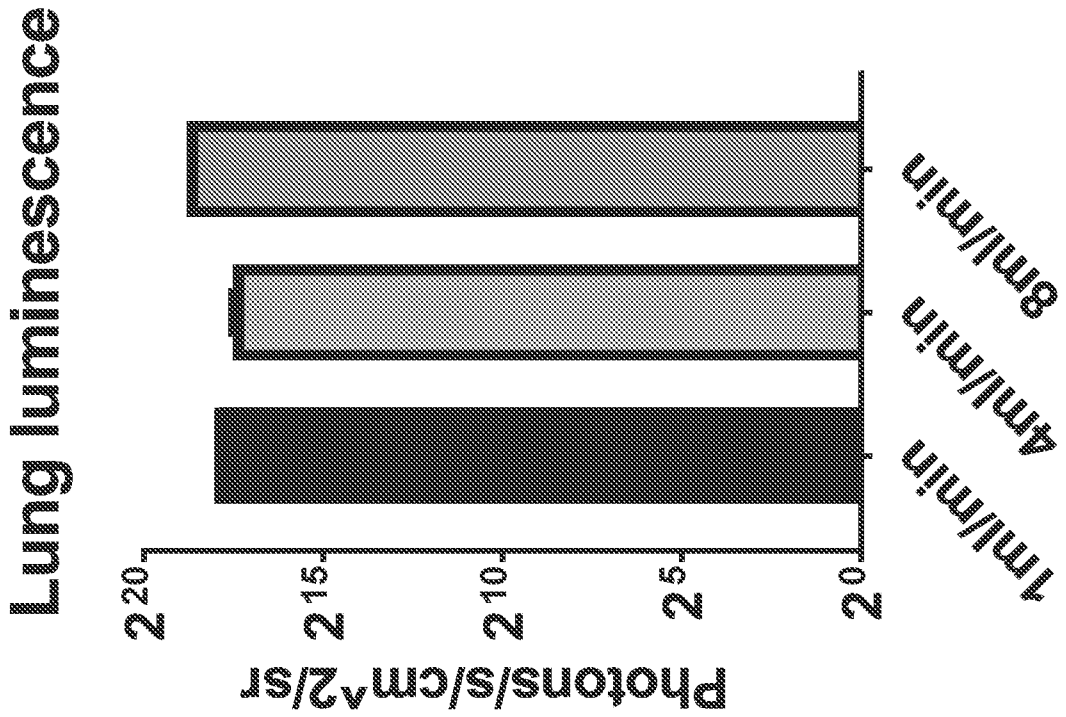

Lung luminescence
Photons/s/cm^2/sr
2^20
2^15
2^10
2^5
2^0
1ml/min
4ml/min
8ml/min

FIG. 13

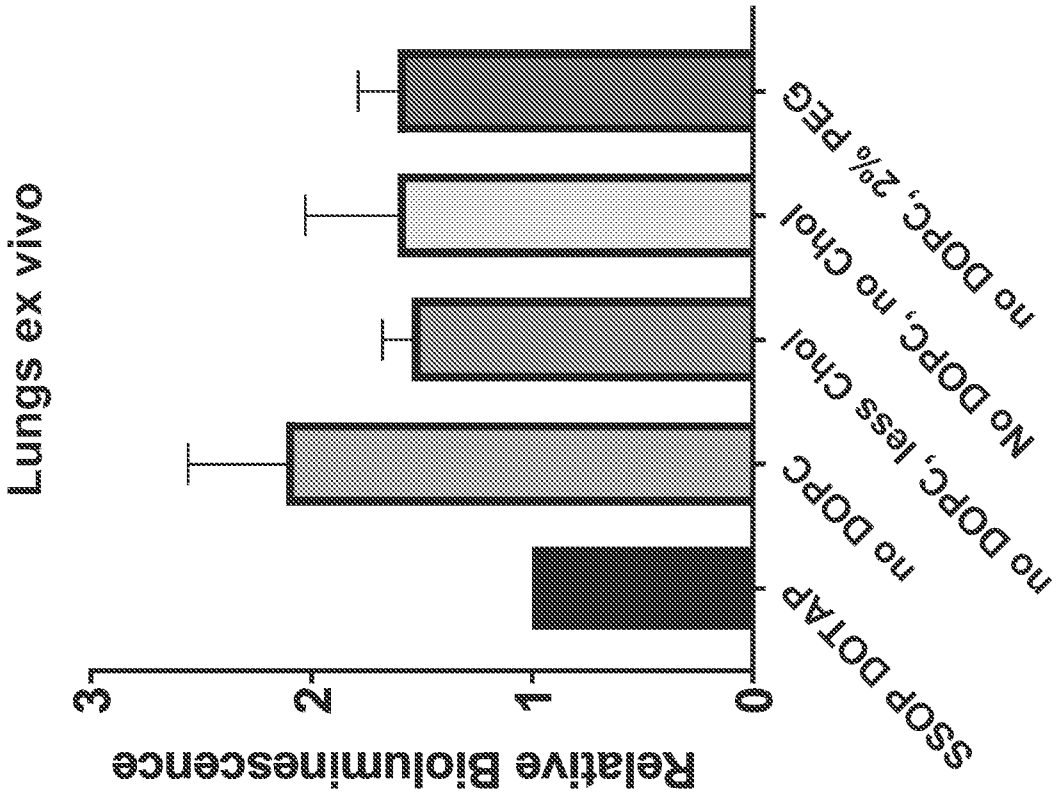

Lungs ex vivo
Relative Bioluminescence
0
1
2
3
SSOP DOTAP
no DOPC
no DOPC, less Chol
No DOPC, no Chol
no DOPC, 2% PEG

FIG. 14

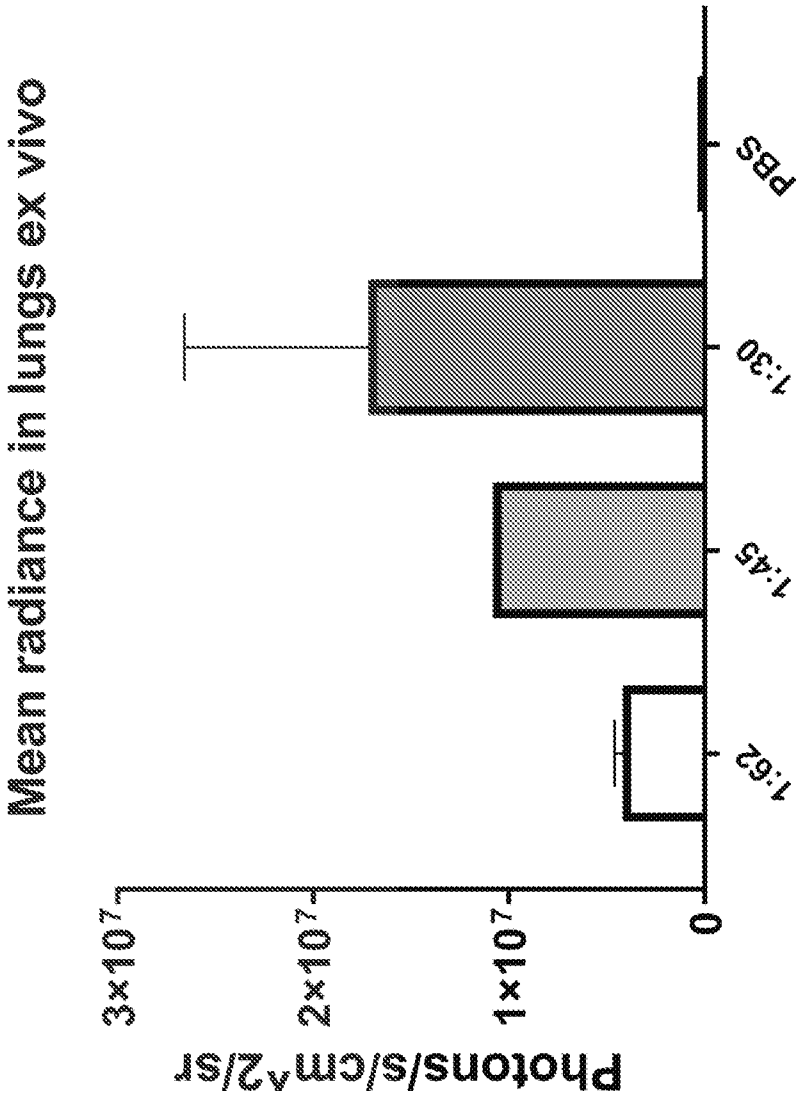

Mean radiance in lungs ex vivo
Photons/s/cm^2/sr
3×10^7
2×10^7
1×10^7
0
1:62
1:45
1:30
PBS

FIG. 15

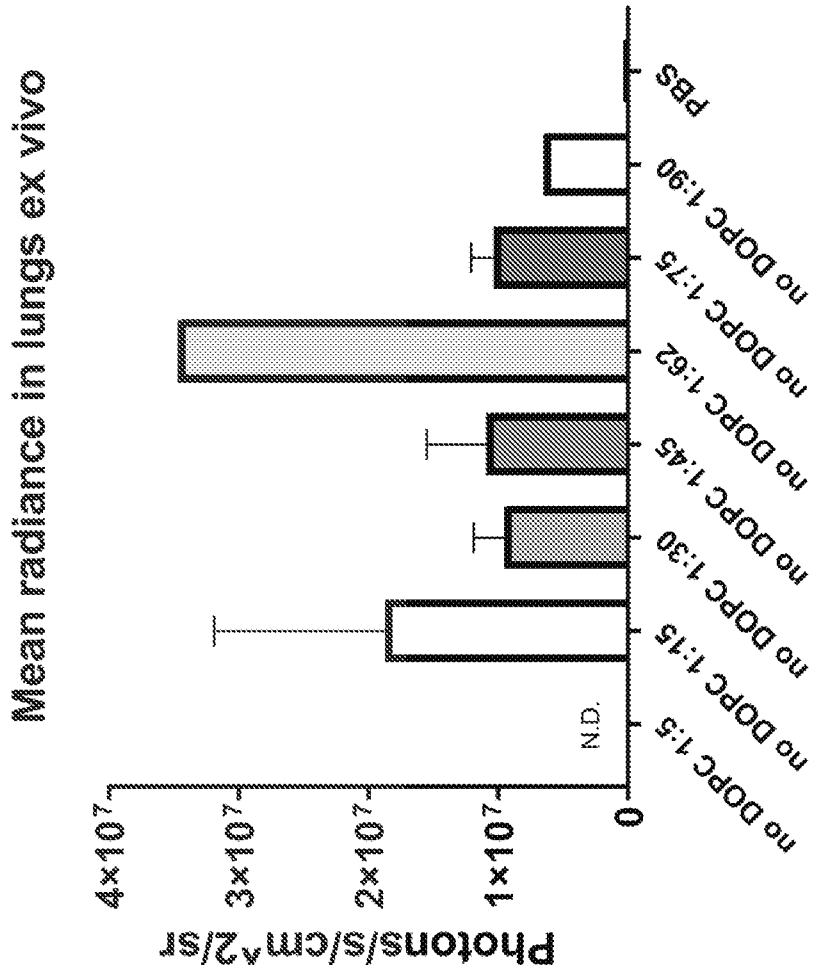

Mean radiance in lungs ex vivo
Photons/s/cm^2/sr
4×10^7
3×10^7
2×10^7
1×10^7
0
N.D.
PBS
no DOPC 1:90
no DOPC 1:75
no DOPC 1:62
no DOPC 1:45
no DOPC 1:30
no DOPC 1:15
no DOPC 1:5

FIG. 16

FIG. 17B

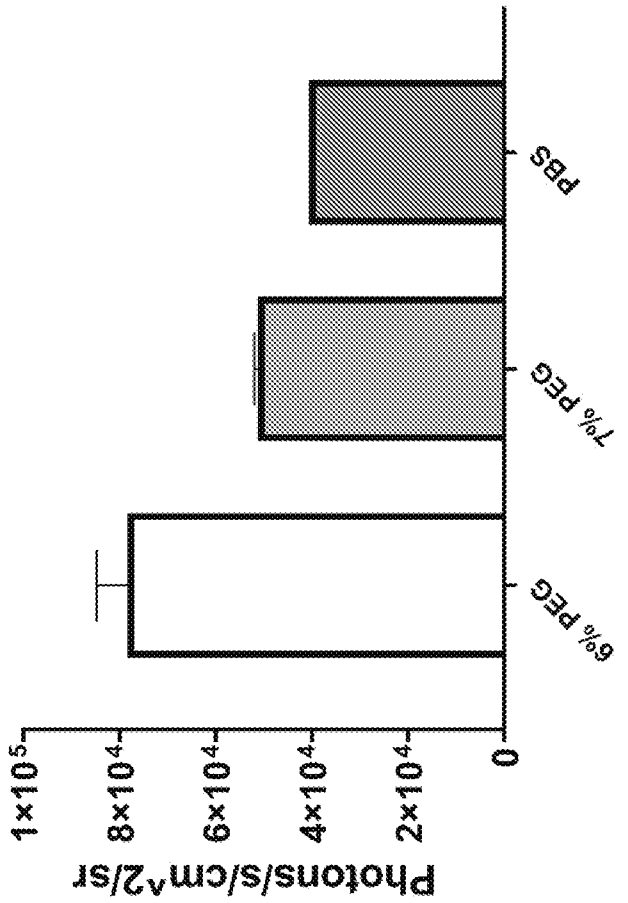


FIG. 17A

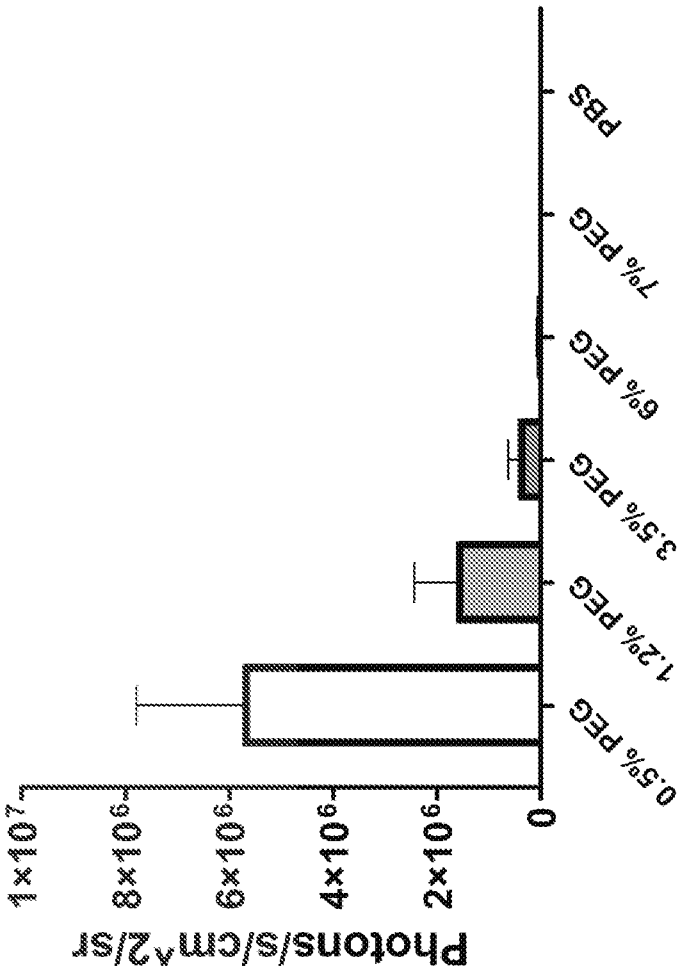


FIG. 18A

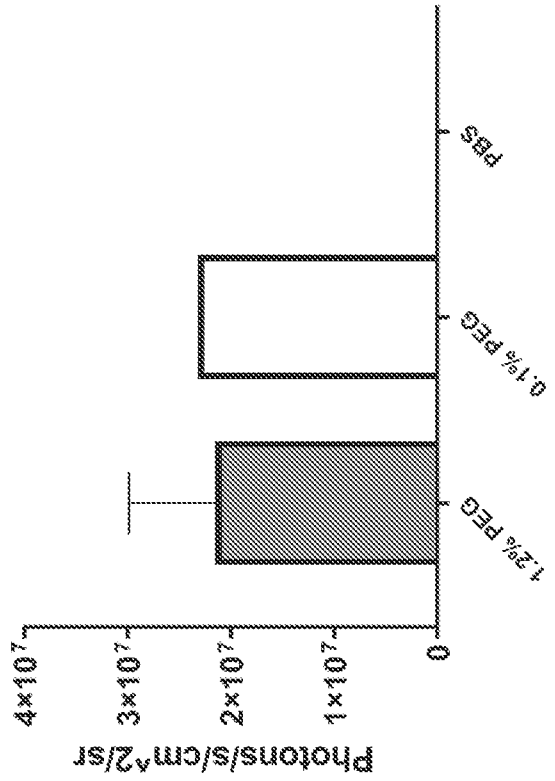
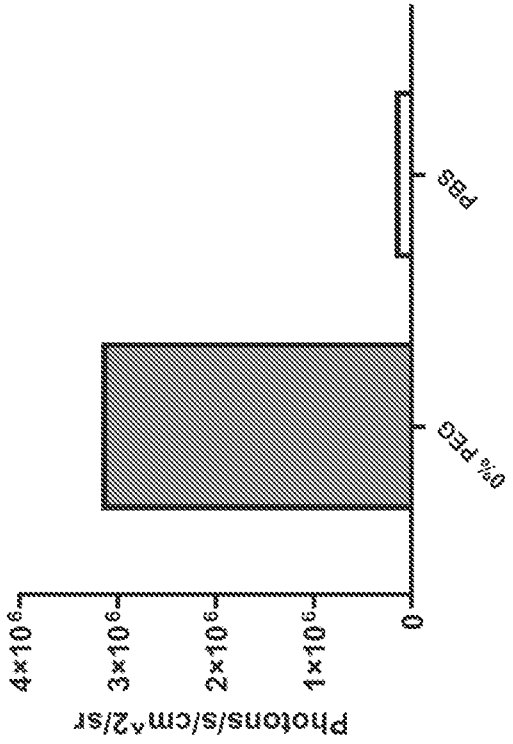


FIG. 18B



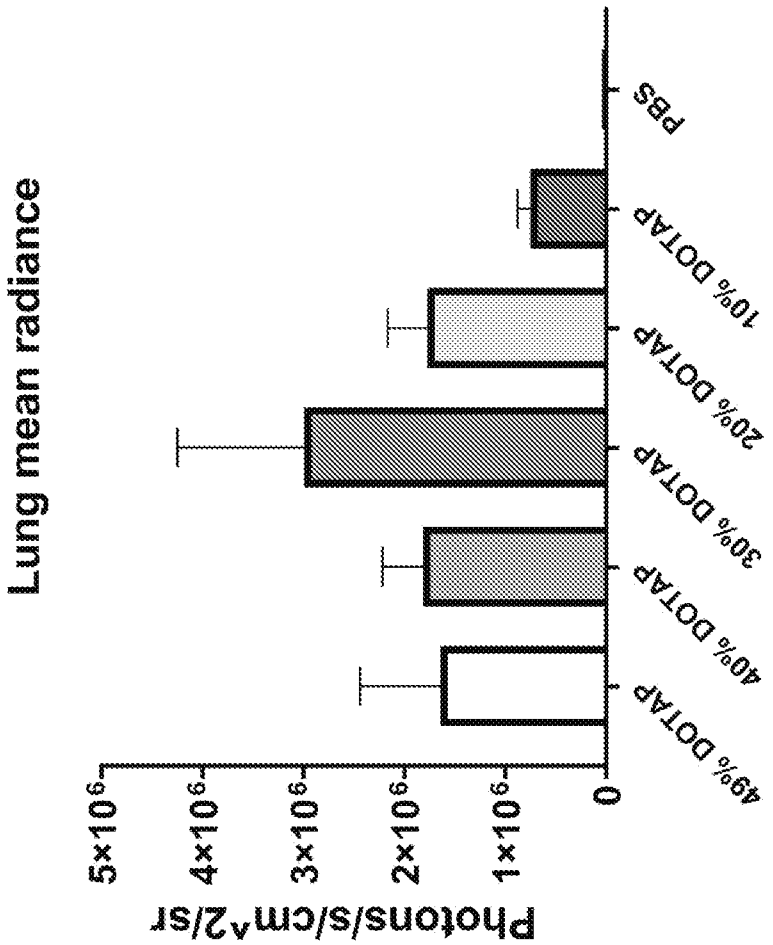

Lung mean radiance
Photons/s/cm^2/sr
5×10^6
4×10^6
3×10^6
2×10^6
1×10^6
0
PBS
10% DOTAP
20% DOTAP
30% DOTAP
40% DOTAP
49% DOTAP

FIG. 19

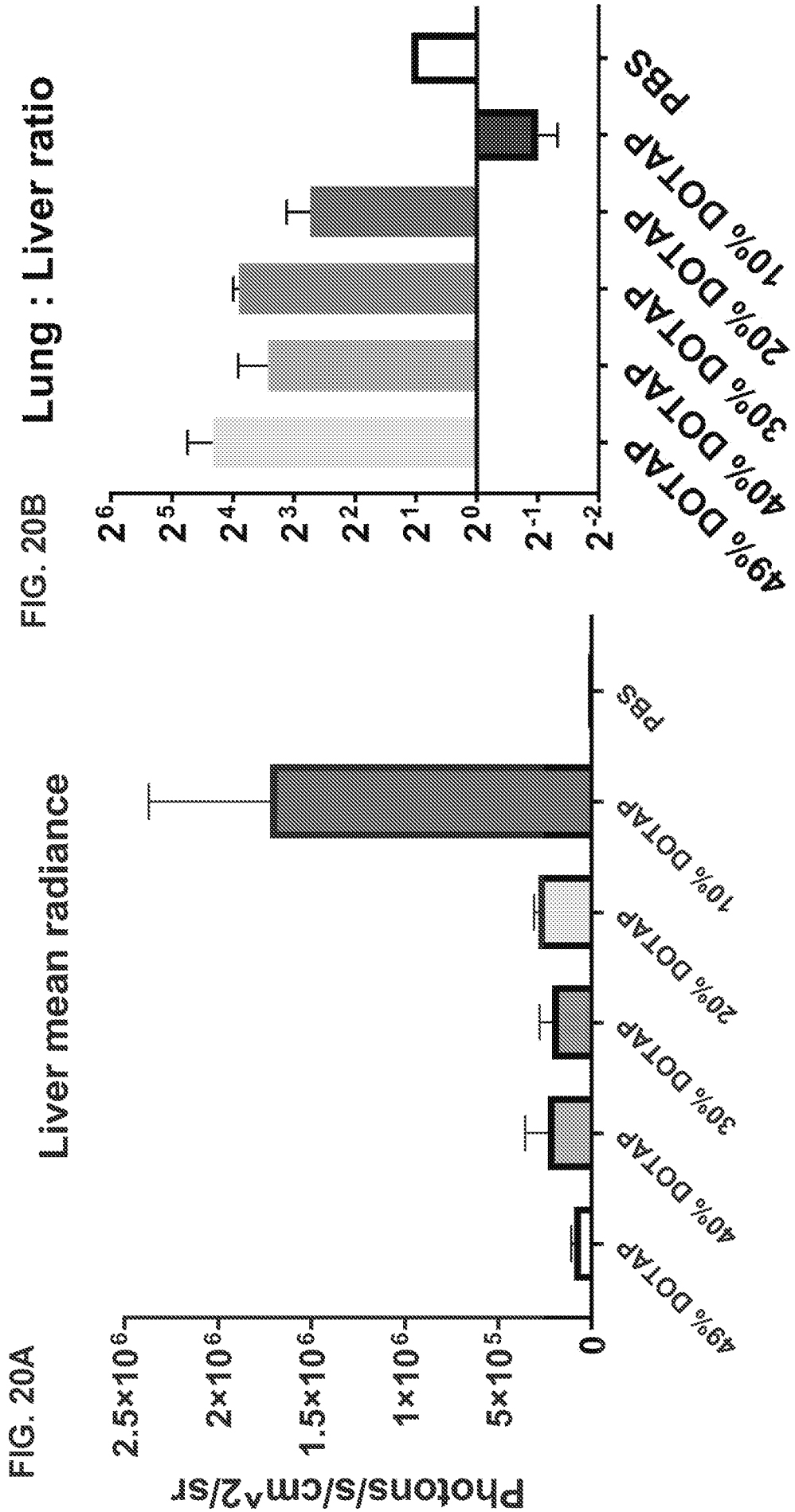

FIG. 20A
Liver mean radiance
Photons/s/cm^2/sr
2.5x10^6
2x10^6
1.5x10^6
1x10^6
5x10^5
0
49% DOTAP
40% DOTAP
30% DOTAP
20% DOTAP
10% DOTAP
PBS
FIG. 20B
Lung : Liver ratio
2^6
2^5
2^4
2^3
2^2
2^1
2^0
2^-1
2^-2
49% DOTAP
40% DOTAP
30% DOTAP
20% DOTAP
10% DOTAP
PBS

FIG. 21A

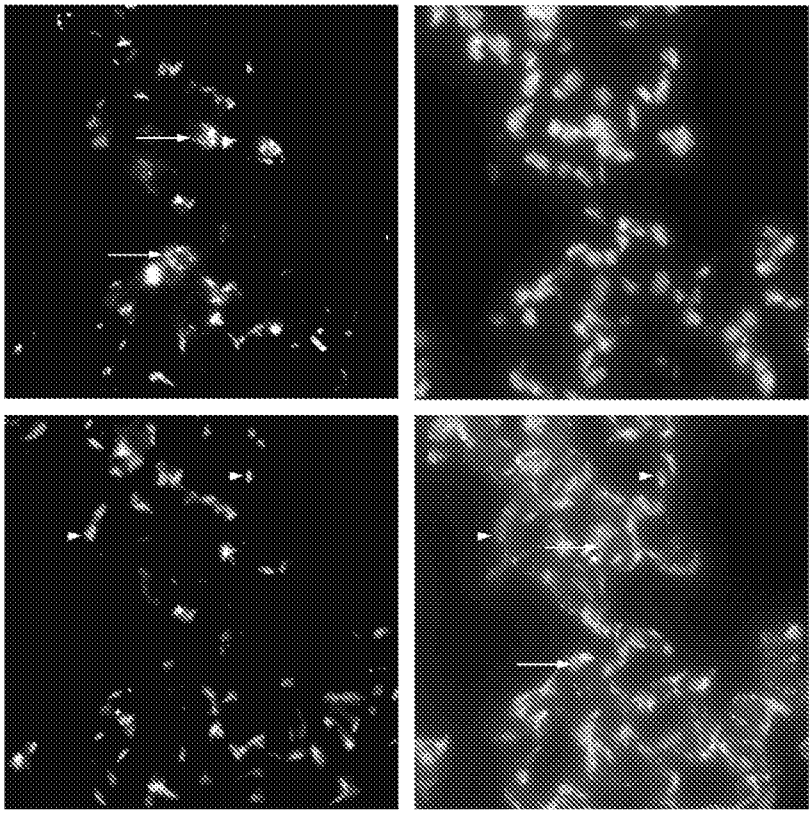
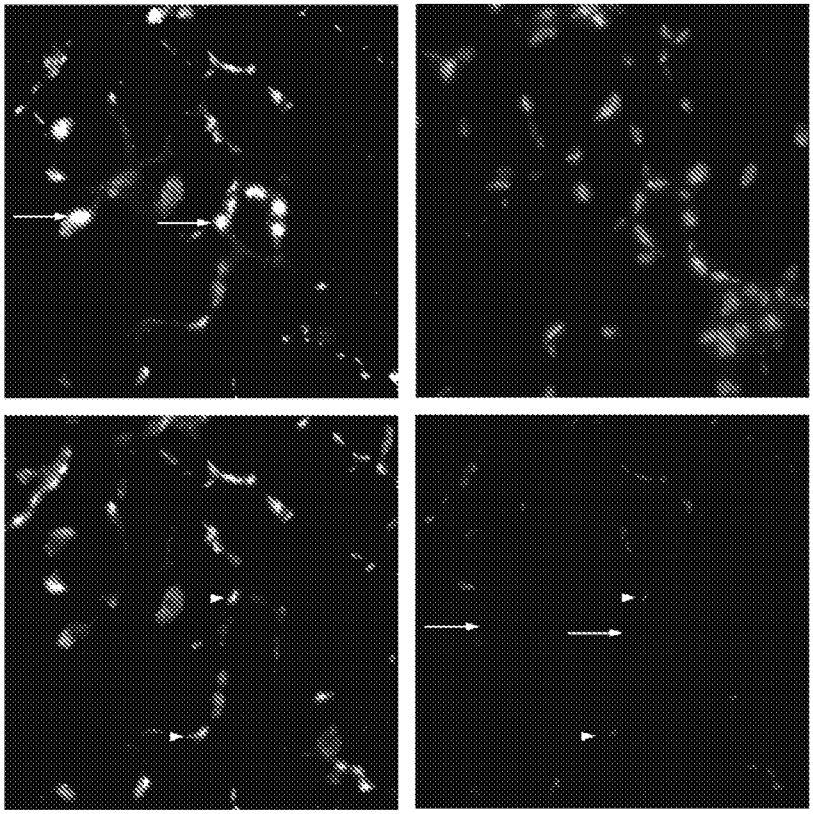


FIG. 21B



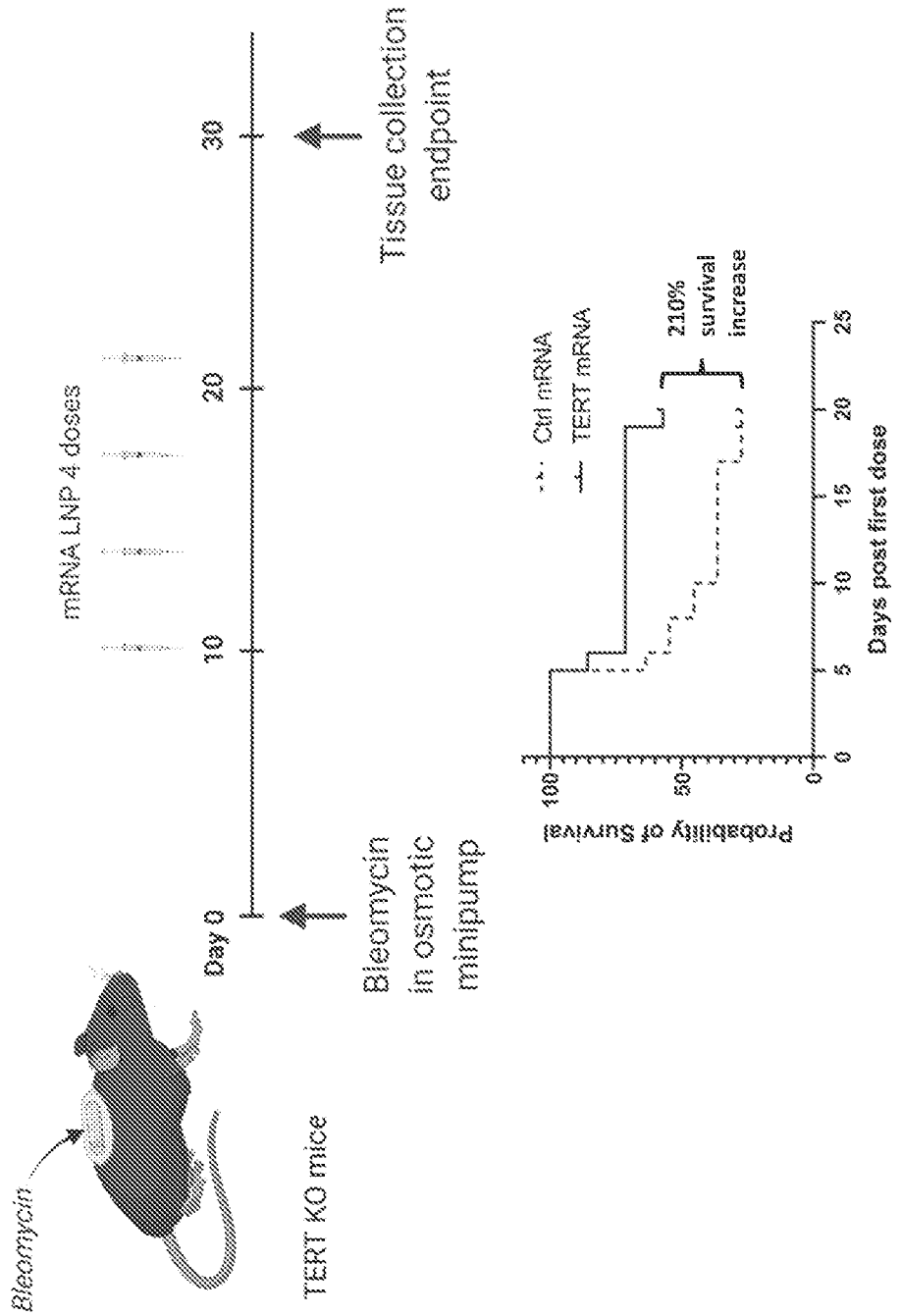

Bleomycin
TERT KO mice
Day 0
Bleomycin in osmotic minipump
mRNA LNP 4 doses
10
20
30
Tissue collection endpoint
Ctrl mRNA
TERT mRNA
210% survival increase
Probability of Survival
100
50
0
0
5
10
15
20
25
Days post first dose

FIG. 22

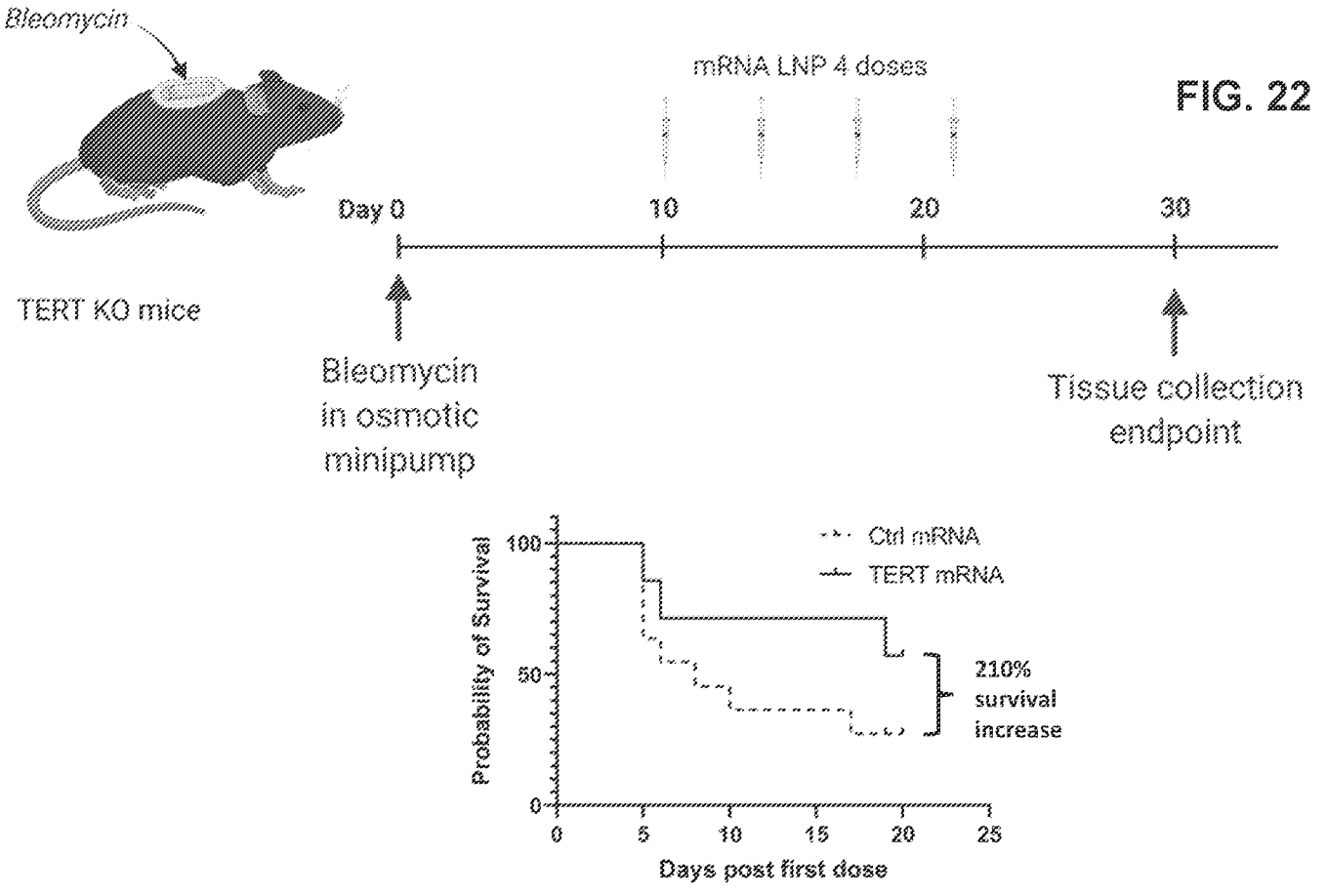

Bleomycin
mRNA LNP 4 doses
Day 0
10
20
30
TERT KO mice
Bleomycin in osmotic minipump
Tissue collection endpoint
Ctrl mRNA
TERT mRNA
210% survival increase
Probability of Survival
100
50
0
0
5
10
15
20
25
Days post first dose

FIG. 22