

DESCRIPTION

CATIONIC LIPIDS

5 Technical Field

[0001]

The present invention relates to a cationic lipid that enables introduction of nucleic acids as an active ingredient into many types of cells, tissues, or organs. The present
10 invention further relates to a lipid particle containing the cationic lipid, and a composition containing the lipid particle and a nucleic acid.

[0002]

15 [Background of Invention]

Intensive research and development of nucleic acid drugs, which contain a nucleic acid as an active ingredient, have been made in recent years. For example, a number of studies have been conducted for nucleic acid drugs having
20 decomposition effect or function-inhibitory effect on target mRNAs including nucleic acids such as siRNAs, miRNAs, miRNA mimics, and antisense nucleic acids. In addition, studies have been carried out for nucleic acid drugs containing an mRNA or the like encoding a protein of interest to express

the protein of interest in cells. In relation to such research and development, techniques to introduce nucleic acids into cells, tissues, or organs with high efficiency have been developed as drug delivery system (DDS) techniques.

5 [0003]

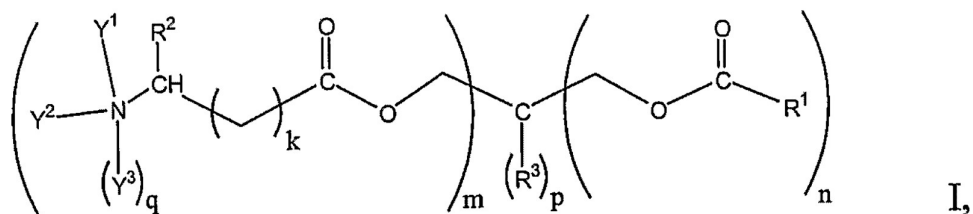
Conventionally known as such a DDS technique is such a technique that a nucleic acid and a lipid are mixed to form a complex and cells are allowed to incorporate the nucleic acid via the complex. Conventionally known as lipids for use in formation of the complex are cationic lipids, hydrophilic polymer lipids, helper lipids, and so on. As such cationic lipids, for example, compounds described in prior art documents, as shown below, are known.

[0004]

15 Patent Literature 1 describes a compound represented by the following formula or a salt thereof, and so on.

[0005]

[Formula 1]



20 It is specified for the formula that R¹ is independently selected from the group consisting of

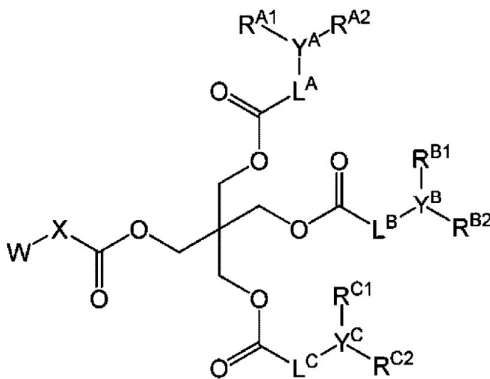
optionally substituted C₈-C₂₄ alkyl and optionally substituted
C₈-C₂₄ alkenyl; each R² and R³ is independently selected from
the group consisting of hydrogen, optionally substituted C₁-C₈
alkyl, optionally substituted arylalkyl, and so on; each Y¹
5 and Y² is independently selected from the group consisting of
hydrogen, optionally substituted C₁-C₆ alkyl, optionally
substituted arylalkyl, and so on; each Y³, if present, is
independently selected from the group consisting of hydrogen,
optionally substituted C₁-C₈ alkyl, optionally substituted
10 arylalkyl, and so on; m is any integer of 1 to 4; n is any
integer of 0 to 3; p is 0 or 1; the sum of m, n, and p is 4;
k is any integer of 1 to 5; and q is 0 or 1.

[0006]

Patent Literature 2 describes a compound represented
15 by the following formula or a salt thereof, and so on.

[0007]

[Formula 2]



In the formula, W denotes formula $-NR^1R^2$ or formula $-N^+R^3R^4R^5(Z^-)$; R^1 and R^2 denote, each independently, a C_{1-4} alkyl group or hydrogen atom; R^3 , R^4 , and R^5 denote, each independently, a C_{1-4} alkyl group; Z^- denotes a negative ion;

5 X denotes a C_{1-6} alkylene group which may be substituted; Y^A , Y^B , and Y^C denote, each independently, a methine group which may be substituted; L^A , L^B , and L^C denote, each independently, a methylene group which may be substituted or a bond; R^{A1} , R^{A2} , R^{B1} , R^{B2} , R^{C1} , and R^{C2} denote, each independently, a C_{4-10}

10 alkyl group which may be substituted.

Citation List

Patent Literature

[0008]

15 Patent Literature 1: International Publication No. WO
2003/102150

Patent Literature 2: International Publication No. WO
2016/021683

20 Summary of Invention

Technical Problem

[0009]

Cationic lipids that enable introduction of nucleic acids into cells with high efficiency are expected to

contribute to creation of nucleic acid drugs that are superior in terms of manifestation of drug action, safety (low toxicity), and so on and exhibit therapeutically superior effect. Cationic lipids that enable introduction of nucleic acids into various cells are expected to enable creation of nucleic acid drugs for diseases that occur in various tissues. Currently, however, no cationic lipid that sufficiently satisfies those requirements has been found.

[0010]

An object of the present invention is to provide a technique that enables introduction of nucleic acids into cells with superior efficiency; and cationic lipids, etc., for use in the technique. An object of the present invention from another viewpoint is to provide a technique that enables introduction of nucleic acids into various cells; and compounds, etc., for use in the technique.

Solution to Problem

[0011]

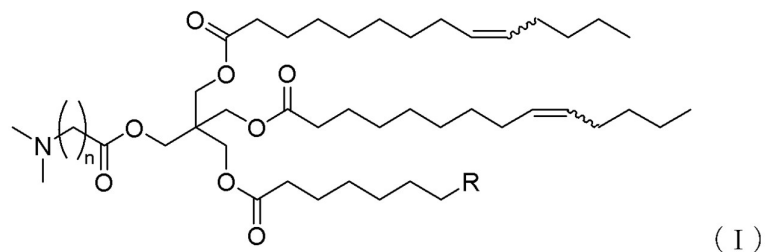
The present inventors have diligently examined to solve the problem and found that the problem is successfully solved by using a compound represented by the formula below or a salt thereof, thus completing the present invention.

[0012]

Specifically, the present invention relates at least to the followings.

[1] A compound represented by formula (I):

[Formula 3]



5

wherein

n represents an integer of 2 to 5,

R represents a linear C₁₋₅ alkyl group, a linear C₇₋₁₁ alkenyl group, or a linear C₁₁ alkadienyl group, and

10 wavy lines each independently represent a cis-bond or a trans-bond,
or a salt thereof.

[2] 3-((4-(Dimethylamino)butanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-
15 enoate or a salt thereof.

[3] 3-((5-(Dimethylamino)pentanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-
enoate or a salt thereof.

[4] 3-((6-(Dimethylamino)hexanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate or a salt thereof.

[5] A lipid particle containing the compound or a
5 salt thereof according to item 1.

[6] A composition for nucleic acid introduction containing a nucleic acid and the lipid particle according to item 5.

[7] The composition according to item 6, wherein the
10 nucleic acid is an RNA.

[7a] The composition according to item 6, wherein the nucleic acid is a DNA.

[8] The composition according to item 7, wherein the RNA is an mRNA or an siRNA.

15 [0013]

Herein, "the compound represented by formula (I)" is occasionally referred to as "compound (I)". "The compound represented by formula (I) or a salt thereof" is occasionally called "the compound of the present invention". A "lipid
20 particle containing the compound represented by formula (I) or a salt thereof (the compound of the present invention)" is occasionally called "the lipid particle of the present invention". A "composition for nucleic acid introduction containing a nucleic acid and the lipid particle of the

present invention" is occasionally called "the composition of the present invention".

Advantageous Effects of Invention

5 [0014]

The present invention enables introduction of nucleic acids into cells, tissues, or organs with superior efficiency. The present invention enables introduction of nucleic acids into various types of cells, tissues, or organs
10 (e.g., cancer cells). The present invention enables acquisition of drugs or reagents for research to introduce a nucleic acid into various types of cells, tissues, or organs. Moreover, if a nucleic acid is introduced into cells, a tissue, or an organ through the present invention, the
15 efficiency of manifestation of the activity (e.g., drug action) possessed by the nucleic acid is high.

[0015]

(Detailed Description of Invention)

20 [0016]

Now, definitions of substituents used herein will be described in detail. Substituents have the following definitions, unless otherwise specified.

[0017]

Examples of the "linear C₁₋₅ alkyl group" herein include methyl, ethyl, propyl, butyl, and pentyl.

[0018]

Examples of the " linear C₇₋₁₁ alkenyl group" herein
5 include 1-heptenyl, 2-heptenyl, 3-heptenyl, 4-heptenyl, 5-heptenyl, 6-heptenyl, 1-octenyl, 2-octenyl, 3-octenyl, 4-octenyl, 5-octenyl, 6-octenyl, 7-octenyl, 1-nonenyl, 2-nonenyl, 3-nonenyl, 4-nonenyl, 5-nonenyl, 6-nonenyl, 7-nonenyl, 8-nonenyl, 1-decenyl, 2-decenyl, 3-decenyl, 4-
10 decenyl, 5-decenyl, 6-decenyl, 7-decenyl, 8-decenyl, 9-decenyl, 1-undecenyl, 2-undecenyl, 3-undecenyl, 4-undecenyl, 5-undecenyl, 6-undecenyl, 7-undecenyl, 8-undecenyl, 9-undecenyl, and 10-undecenyl. While each of these linear C₇₋₁₁ alkenyl groups has one carbon-carbon double bond, and hence
15 the carbon-carbon double bond can form a cis-structure and a trans-structure, the carbon-carbon double bond may form any of the structures.

[0019]

Examples of the " linear C₁₁ alkadienyl group" herein
20 include 1,3-undecadienyl, 1,4-undecadienyl, 1,5-undecadienyl, 1,6-undecadienyl, 1,7-undecadienyl, 1,8-undecadienyl, 1,9-undecadienyl, 1,10-undecadienyl, 2,4-undecadienyl, 2,5-undecadienyl, 2,6-undecadienyl, 2,7-undecadienyl, 2,8-undecadienyl, 2,9-undecadienyl, 2,10-undecadienyl, 3,5-

undecadienyl, 3,6-undecadienyl, 3,7-undecadienyl, 3,8-undecadienyl, 3,9-undecadienyl, 3,10-undecadienyl, 4,6-undecadienyl, 4,7-undecadienyl, 4,8-undecadienyl, 4,9-undecadienyl, 4,10-undecadienyl, 5,7-undecadienyl, 5,8-undecadienyl, 5,9-undecadienyl, 5,10-undecadienyl, 6,8-undecadienyl, 6,9-undecadienyl, 6,10-undecadienyl, 7,9-undecadienyl, 7,10-undecadienyl, and 8,10-undecadienyl.

While each of these linear C₁₁ alkadienyl groups has two carbon-carbon double bonds, and hence the carbon-carbon double bonds can each independently form a cis-structure and a trans-structure, each carbon-carbon double bond may form any of the structures.

[0020]

Preferred examples of n and the wavy lines in formula (I) are as follows.

n is preferably an integer of 3 to 5, and more preferably 3.

The wave lines are preferably each a cis-bond.

[0021]

Specific preferred examples of compound (I) are as follows.

Compound (A): such a compound that n is an integer of 3 to 5, R is a linear C₇₋₁₁ alkenyl group in a cis-structure, and the wavy lines are each a cis-bond.

Compound (B): such a compound that n is 4, R is a linear C₁₁ alkadienyl group in which two carbon-carbon double bonds each form a cis-structure, and the wavy lines are each a cis-bond.

5 Compound (C): such a compound that n is 2 or 3, R is a linear C₁₋₅ alkyl group, and the wavy lines are each a cis-bond.

[0022]

Specific, more preferred examples of compound (I) are
10 as follows.

Compound (A1): such a compound that n is an integer of 3 to 5, R is 5-heptenyl, 7-nonenyl, or 9-undecenyl in the cis-structure, and the wavy lines are each a cis-bond.

Compound (B1): such a compound that n is 4, R is 2,5-
15 undecadienyl in which two carbon-carbon double bonds each form a cis-structure, and the wavy lines are each a cis-bond.

Compound (C1): such a compound that n is 2 or 3, R is methyl, propyl, or pentyl, and the wavy lines are each a cis-bond.

20 [0023]

The salt of compound (I) is preferably a pharmacologically acceptable salt, and examples thereof include salts with an inorganic base, salts with an organic

base, salts with an inorganic acid, salts with an organic acid, and salts with a basic or acidic amino acid.

[0024]

Preferred examples of salts with an inorganic base
5 include alkali metal salts such as sodium salts and potassium salts; alkali earth metal salts such as calcium salts and magnesium salts; aluminum salts; and ammonium salts.

Preferred are sodium salts, potassium salts, calcium salts, and magnesium salts, and more preferred are sodium salts and
10 potassium salts.

[0025]

Preferred examples of salts with an organic base include salts with trimethylamine, triethylamine, pyridine, picoline, ethanolamine, diethanolamine, triethanolamine,
15 tromethamine[tris(hydroxymethyl)methylamine], tert-butylamine, cyclohexylamine, benzylamine, dicyclohexylamine, and N,N-dibenzylethylenediamine.

[0026]

Preferred examples of salts with an inorganic acid
20 include salts with hydrofluoric acid, hydrochloric acid, hydrobromic acid, hydroiodic acid, nitric acid, sulfuric acid, and phosphoric acid. Preferred are salts with hydrochloric acid and salts with phosphoric acid.

[0027]

Preferred examples of salts with an organic acid include salts with formic acid, acetic acid, trifluoroacetic acid, phthalic acid, fumaric acid, oxalic acid, tartaric acid, maleic acid, citric acid, succinic acid, malic acid, 5 methanesulfonic acid, benzenesulfonic acid, and p-toluenesulfonic acid.

[0028]

Preferred examples of salts with a basic amino acid include salts with arginine, lysine, and ornithine.

10 [0029]

Preferred examples of salts with an acidic amino acid include salts with aspartic acid and glutamic acid.

[0030]

In the present invention, the compound of the present 15 invention may be used as a cationic lipid. The cationic lipid can form a complex with a plurality of molecules in a solvent or dispersion medium. The complex may contain an additional component in addition to the compound of the present invention. Examples of the additional component 20 include an additional lipid component and a nucleic acid.

[0031]

Examples of the additional lipid component include structural lipids capable of constituting a lipid particle. For such a structural lipid, for example, at least one

selected from the group consisting of the following may be used:

sterols (e.g., cholesterol, cholesteryl ester, cholesteryl hemisuccinate);

5 phospholipids (e.g., phosphatidylcholine (e.g.,
dipalmitoylphosphatidylcholine,
distearoylphosphatidylcholine, lysophosphatidylcholine,
dioleoylphosphatidylcholine,
palmitoyloleoylphosphatidylcholine,
10 dilinolenoylphosphatidylcholine, MC-1010 (NOF CORPORATION),
MC-2020 (NOF CORPORATION), MC-4040 (NOF CORPORATION)),
phosphatidylserine (e.g., dipalmitoylphosphatidylserine,
distearoylphosphatidylserine, dioleoylphosphatidylserine,
palmitoyloleoylphosphatidylserine), phosphatidylethanolamine
15 (e.g., dipalmitoylphosphatidylethanolamine,
distearoylphosphatidylethanolamine,
dioleoylphosphatidylethanolamine,
palmitoyloleoylphosphatidylethanolamine,
lysophosphatidylethanolamine), phosphatidylinositol,
20 phosphatidic acid); and
polyethylene glycol lipids (PEG lipids) (e.g., PEG-DAA, PEG-DAG, PEG-phospholipid conjugate, PEG-Cer, PEG-cholesterol, PEG-C-DOMG, 2KPEG-CMG, GM-020 (NOF CORPORATION), GS-020 (NOF CORPORATION), GS-050 (NOF CORPORATION)). In the present

invention, it is preferred to use all of the three, namely, a sterol (in particular, cholesterol), a phospholipid (in particular, phosphatidylcholine), and a polyethylene glycol lipid, as the structural lipid.

5 [0032]

The ratio between the compound of the present invention and the structural lipid in the mixed lipid component constituting the lipid particle of the present invention may be appropriately controlled according to the
10 purpose or use. For example, the ratio of the structural lipid is typically 0.008 to 4 mol and preferably 0.4 to 1.5 mol per mole of the compound of the present invention. In another definition of ratios in the mixed lipid component, the amount of the compound of the present invention is
15 typically 1 to 4 mol, that of the sterol is typically 0 to 3 mol, that of the phospholipid is typically 0 to 2 mol, and that of the polyethylene glycol lipid is typically 0 to 1 mol. In a more preferred embodiment with use of a mixture of the compound of the present invention and additional lipid
20 components, with respect to ratios, the amount of the compound of the present invention is 1 to 1.5 mol, that of the sterol is 0 to 1.25 mol, that of the phospholipid is 0 to 0.5 mol, and that of the polyethylene glycol lipid is 0 to 0.125 mol.

[0033]

The compound of the present invention may be used for producing the lipid particle of the present invention. The lipid particle of the present invention refers to the complex described above but containing no nucleic acid. The shape of the lipid particle of the present invention is not limited to a particular shape, and the scope includes a complex in which the compound of the present invention and so on assemble to form a sphere; a complex in which the compound of the present invention and so on assemble without forming a particular shape; a complex in which the compound of the present invention and so on dissolve in a solvent; and a complex in which the compound of the present invention and so on homogeneously or heterogeneously disperse in a dispersion medium.

[0034]

The lipid particle of the present invention (e.g., a lipid particle composed of the compound of the present invention and structural lipids other than the compound) may be used, for example, for producing the composition of the present invention containing the lipid particle and a nucleic acid (in particular, a nucleic acid as a substance useful for pharmaceutical applications or applications for research). The composition of the present invention may be used as a

drug or a reagent. It is preferred for the composition of the present invention that the lipid particle encapsulate a nucleic acid in a ratio as high as possible (i.e., in a high encapsulation ratio).

5 [0035]

The "nucleic acid" may be any molecule in which molecules of nucleotide or molecules having functions equivalent to those of the nucleotide are polymerized, and examples thereof include RNA, which is a polymer of
10 ribonucleotide; DNA, which is a polymer of deoxyribonucleotide; a polymer of a mixture of ribonucleotide and deoxyribonucleotide; and a nucleotide polymer including a nucleotide analog. Further, the nucleic acid may be a nucleotide polymer including a nucleic acid derivative. The
15 nucleic acid may be a single-stranded nucleic acid or a double-stranded nucleic acid. The concept of the double-stranded nucleic acid encompasses a double-stranded nucleic acid such that one strand hybridizes with the other strand under stringent conditions.

20 [0036]

The nucleotide analog may be any molecule obtained by modifying ribonucleotide, deoxyribonucleotide, RNA, or DNA to improve nuclease resistance, to stabilize, to enhance affinity with a complementary-strand nucleic acid or to

enhance cell permeability as compared with RNA or DNA, or for
visualization. The nucleotide analog may be a naturally-
occurring molecule or a non-natural molecule, and examples
thereof include a sugar-modified nucleotide analog and a
5 phosphodiester bond-modified nucleotide analog.

[0037]

The sugar-modified nucleotide analog may be any one
obtained by addition of or substitution with a substance
having an arbitrary chemical structure for a part or the
10 whole of the chemical structure of the sugar of a nucleotide.
Specific examples thereof include a nucleotide analog
substituted with 2'-O-methylribose, a nucleotide analog
substituted with 2'-O-propylribose, a nucleotide analog
substituted with 2'-methoxyethoxyribose, a nucleotide analog
15 substituted with 2'-O-methoxyethylribose, a nucleotide analog
substituted with 2'-O-[2-(guanidinium)ethyl]ribose, a
nucleotide analog substituted with 2'-O-fluororibose, a
crosslinked artificial nucleic acid provided with two cyclic
structures by introducing a crosslinked structure to the
20 sugar moiety (Bridged Nucleic Acid) (BNA), more specifically,
a locked artificial nucleic acid in which the oxygen atom at
position 2' and the carbon atom at position 4' are
crosslinked via methylene (Locked Nucleic Acid) (LNA) and an
ethylene-crosslinked artificial nucleic acid (Ethylene

bridged nucleic acid) (ENA) [Nucleic Acid Research, 32, e175
(2004)], further, a peptide nucleic acid (PNA) [Acc. Chem.
Res., 32, 624 (1999)], an oxypeptide nucleic acid (OPNA) [J.
Am. Chem. Soc., 123, 4653 (2001)], and a peptide ribonucleic
5 acid (PRNA) [J. Am. Chem. Soc., 122, 6900 (2000)].
[0038]

The phosphodiester bond-modified nucleotide analog may
be any one obtained by addition of or substitution with an
arbitrary chemical substance for a part or the whole of the
10 chemical structure of the phosphodiester bond of a
nucleotide. Specific examples thereof include a nucleotide
analog substituted with a phosphorothioate bond and a
nucleotide analog substituted with an N3'-P5' phosphoramidate
bond [Saibo Kogaku (in Japanese, translated title: Cell
15 Engineering), 16, 1463-1473 (1997)] [RNAi and Antisense
Strategies, KODANSHA LTD. (2005)].
[0039]

The nucleic acid derivative may be any molecule
obtained by adding to a nucleic acid another chemical
20 substance to improve nuclease resistance, to stabilize, to
enhance affinity with a complementary-strand nucleic acid, or
to enhance cell permeability as compared with the nucleic
acid, or for visualization. Specific examples thereof
include a derivative with 5'-polyamine added, a derivative

with cholesterol added, a derivative with steroid added, a
derivative with bile acid added, a derivative with vitamin
added, a derivative with Cy5 added, a derivative with Cy3
added, a derivative with 6-FAM added, and a derivative with
5 biotin added.

[0040]

The nucleic acid in the present invention is not
limited to a particular nucleic acid, and may be a nucleic
acid, for example, for the purpose of ameliorating a disease,
10 a symptom, a disorder, or sickness, and mitigating a disease,
a symptom, a disorder, or pathological condition or
preventing the onset thereof (herein, occasionally referred
to as "treatment or the like of a disease"), or a nucleic
acid for regulating expression of a desired protein that is
15 useful for research, even though the protein does not
contribute to treatment or the like of a disease.

[0041]

Genes or polynucleotides related to diseases (herein,
occasionally referred to as "disease-related genes") are
20 available, for example, from McKusick-Nathans Institute of
Genetic Medicine, Johns Hopkins University (Baltimore, Md.)
and National Center for Biotechnology Information, National
Library of Medicine (Bethesda, Md.).

[0042]

Specific examples of the nucleic acid in the present invention include siRNAs, shRNAs, miRNAs, miRNA mimics, antisense nucleic acids, ribozymes, mRNAs, decoy nucleic acids, aptamers, plasmid DNAs, Cosmid DNAs, and BAC DNAs.

5 The nucleic acid is preferably an RNA such as an siRNA and an mRNA or an analog or derivative obtained by artificially modifying an RNA.

[0043]

In the present invention, the "siRNA" refers to a
10 double-stranded RNA or relative thereof consisting of 10 to 30 nucleotides, preferably of 15 to 25 nucleotides, and including complementary sequences. The siRNA includes protruding nucleotides preferably of one to three nucleotides, more preferably of two nucleotides, at the 3'-
15 end. The moiety of complementary sequences may be completely complementary or include non-complementary nucleotides, but preferably are completely complementary.

[0044]

The siRNA in the present invention is not limited to a
20 particular siRNA, and, for example, an siRNA for knockdown of gene expression against a disease-related gene may be used. A disease-related gene refers to any gene or polynucleotide generating a transcription or translation product at an abnormal level or in an abnormal form in cells derived from

tissue of a patient, as compared with tissue or cells from a disease-free control. For the siRNA in the present invention, an siRNA to regulate expression of a desired protein useful for research may be used.

5 [0045]

In the present invention, the "mRNA" refers to an RNA including a nucleotide sequence that can be translated into a protein. The mRNA in the present invention is not limited to a particular mRNA and may be any mRNA capable of expressing a
10 desired protein in cells. The mRNA is preferably an mRNA useful for pharmaceutical applications (e.g., applications of disease treatment) and/or applications for research, and examples of such mRNAs include an mRNA to express a marker protein such as luciferase in cells.

15 [0046]

The disease is not limited to a particular disease, and examples of the disease include diseases listed below. Contents in each "()" are examples of the corresponding disease-related gene, except for the case that specific
20 disease examples are listed. Another example of the nucleic acid in the present invention is a nucleic acid that regulates the expression level of any of those disease-related genes (or a protein encoded by the disease-related gene).

(1) Diseases of blood system [anaemia (CDAN1, CDA1, RPS19, DBA, PKLR, PK1, NT5C3, UMPH1, PSN1, RHAG, RH50A, NRAMP2, SPTB, ALAS2, ANH1, ASB, ABCB7, ABC7, ASAT), bare lymphocyte syndrome (TAPBP, TPSN, TAP2, ABCB3, PSF2, RING11, MHC2TA, C2TA, RFX5), hemorrhagic diseases (TBXA2R, P2RX1, P2X1), factor H and factor H-like 1 deficiencies (HF1, CFH, HUS), factor V and factor VIII deficiencies (MCFD2), factor VII deficiency (F7), factor X deficiency (F10), factor XI deficiency (F11), factor XII deficiency (F12, HAF), factor XIII A deficiency (F13A1, F13A), factor XIII B deficiency (F13B), Fanconi's anaemia (FANCA, FACA, FA1, FA, FAA, FAAP95, FAAP90, FLJ34064, FANCB, FANCC, FACC, BRCA2, FANCD1, FANCD2, FANCD, FACD, FAD, FACE, FANCF, XRCC9, FANCG, BRIP1, BACH1, FANCI, PHF9, FANCL, FANCM, KIAA1596), haemophagocytic lymphohistiocytosis (PRF1, HPLH2, UNC13D, MUNC13-4, HPLH3, HLH3, FHL3), haemophilia A (F8, F8C, HEMA), haemophilia B (F9, HEMB), hemorrhagic disorders (PI, ATT, F5), leucocyte deficiency (ITGB2, CD18, LCAMB, LAD, EIF2B1, EIF2BA, EIF2B2, EIF2B3, EIF2B5, LVWM, CACH, CLE, EIF2B4), sickle cell anaemia (HBB), thalassaemia (HBA2, HBB, HBD, LCRB, HBA1), and so on];

(2) inflammatory/immunologic diseases [AIDS (KIR3DL1, NKAT3, NKB1, AMB11, KIR3DS1, IFNG, CXCL12, SDF1), autoimmune lymphoproliferative syndrome (TNFRSF6, APT1, FAS, CD95, ALPS1A), combined immunodeficiency (IL2RG, SCIDX1, SCIDX,

IMD4), HIV infection (CCL5, SCYA5, D17S135E, TCP228, IL10, CSIF, CMKBR2, CCR2, DMKBR5, CCKR5, CCR5), immunodeficiency (CD3E, CD3G, AICDA, AID, HIGM2, TNFRSF5, CD40, UNG, DGU, HIGM4, TNFSF5, CD40LG, HIGM1, IGM, FOXP3, IPEX, AIID, XPID, 5 PIDX, TNFRSF14B, TACI), inflammation (IL10, IL-1, IL-13, IL-17, IL-23, CTLA4), severe combined immunodeficiency (JAK3, JAKL, DCLRE1C, ATREMIS, SCIDA, RAG1, RAG2, ADA, PTPRC, CD45, LCA, IL7R, CD3D, T3D, IL2RG, SCIDX1, SCIDX, IMD4), rheumatoid arthritis, psoriasis, inflammatory bowel diseases (e.g., 10 Crohn's disease, ulcerative colitis), Sjogren's syndrome, Behcet's disease, multiple sclerosis, systemic lupus erythematosus, lupus nephritis, discoid lupus erythematosus, Castleman's disease, ankylosing spondylitis, polymyositis, dermatomyositis, polyarteritis nodosa, mixed connective 15 tissue disease, dermatosclerosis, lupus profundus, chronic thyroiditis, Graves' disease, autoimmune gastritis, type I and type II diabetes mellitus, autoimmune haemolytic anaemia, autoimmune neutropenia, thrombocytopenia, atopic dermatitis, chronic active hepatitis, myasthenia gravis, graft-versus- 20 host disease, Addison's disease, abnormal immune response, arthritis, dermatitis, radiodermatitis, primary biliary cirrhosis, and so on];

(3) metabolic/liver/kidney diseases [amyloid neuropathy (TTR, PALB), amyloidosis (APOA1, APP, AAA, CVAP, AD1, GSN, FGA,

LYZ, TTR, PALB), non-alcoholic steatohepatitis and hepatic
fibrosis (COL1A1), cirrhosis (KRT18, KRT8, CIRH1A, NAIC,
TEX292, KIAA1988), cystic fibrosis (CFTR, ABCC7, CF, MRP7),
glycogen storage disease (SLC2A2, GLUT2, G6PC, G6PT, G6PT1,
5 GAA, LAMP2, LAMPB, AGL, GDE, GBE1, GYS2, PYGL, PFKM),
hepatocellular adenoma (TCF1, HFN1A, MODY3), hepatic failure
(SCOD1, SCO1), hepatic lipase deficiency (LIPC),
hepatoblastoma (CTNNB1, PDGRL, PDGRL, PRLTS, AXIN1, AXIN,
TP53, P53, LFS1, IGF2R, MPRI, MET, CASP8, MCH5), medullary
10 cystic kidney disease (UMOD, HNFJ, FJHN, MCKD2, ADMCKD2),
phenylketonuria (PAH, PKU1, QDPR, DHPR, PTS), multicystic
kidney and liver diseases (FCYT, PKHD1, APRKD, PDK1, PDK2,
PDK4, PDKTS, PRKCSH, G19P1, PCLD, SEC63), and so on];
(4) nervous system diseases [ALS (SOD1, ALS2, STEX, FUS,
15 TARDBP, VEGF), Alzheimer's disease (APP, AAA, CVAP, AD1,
APOE, AD2, PSEN2, AD4, STM2, APBB2, FE65L1, NOS3, PLA2, URK,
ACE, DCP1, ACE1, MPO, PACIP1, PAXIP1L, PTIP, A2M, BLMH, BMH,
PSEN1, AD3), autism (BZRAP1, MDGA2, GLO1, MECP2, RTT, PPMX,
MRX16, MRX79, NLGN3, NLGN4, KIAA1260, AUTSX2), fragile X
20 syndrome (FMR2, FXR1, FXR2, mGLUR5), Huntington's disease
(HD, IT15, PRNP, PRIP, JPH3, JP3, HDL2, TBP, SCA17),
Parkinson's disease (NR4A2, NURR1, NOT, TINUR, SNCAIP, TBP,
SCA17, SNCA, NACP, PARK1, PARK4, DJ1, DBH, NDUFV2), Rett
syndrome (MECP2, RTT, PPMX, MRX16, MRX79, CDKL5, STK9),

schizophrenia (GSK3, 5-HTT, COMT, DRD, SLC6A3, DAOA, DTNBP1),
secretase-related disorder (APH-1), and so on];

(5) eye diseases [age-related macular degeneration (Abcr,
Ccl2, cp, Timp3, cathepsin D, Vldlr, Ccr2), cataract (CRYAA,
5 CRYA1, CRYBB2, CRYB2, PITX3, BFSP2, CP49, CP47, PAX6, AN2,
MGDA, CRYBA1, CRYB1, CRYGC, CRYG3, CCL, LIM2, MP19, CRYGD,
CRYG4, BSFP2, CP49, CP47, HSF4, CTM, MIP, AQP0, CRYAB, CRYA2,
CTPP2, CRYBB1, CRYGD, CRYG4, CRYA1, GJA8, CX50, CAE1, GJA3,
CX46, CZP3, CAE3, CCM1, CAM, KRIT1), corneal opacity (APOA1,
10 TGFB1, CSD2, CDGG1, CSD, BIGH3, CDG2, TASTD2, TROP2, M1S1,
VSX1, RINX, PPCD, PPD, KTCN, COL8A2, FECD, PPCD2, PIP5K3,
CFD), congenital hereditary corneal plana (KERA, CNA2),
glaucoma (MYOC, TIGR, GLC1A, JOAG, GPOA, OPTN, GLC1E, FIP2,
HYPL, NRP, CYP1B1, GLC3A, OPA1, NTG, NPG, CYP1B1, GLC3A),
15 Leber's congenital amaurosis (CRB1, RP12, CRX, CORD2, CRD,
RPGRIPI1, LCA6, CORD9, RPE65, RP20, AIPL1, LCA4, GUCY2D,
GUC2D, LCA1, CORD6, RDH12, LCA3), macular dystrophy (ELOVL4,
ADMD, STGD2, STGD3, RDS, RP7, PRPH2, PRPH, AVMD, AOFMD,
VMD2), and so on]; and
20 (6) neoplastic diseases [malignant tumor, neovascular
glaucoma, infantile hemangioma, multiple myeloma, chronic
sarcoma, metastatic melanoma, Kaposi's sarcoma,
angioproliferation, cachexia, metastasis or the like of
breast cancer, cancer (e.g., colorectal cancer (e.g.,

familial colorectal cancer, hereditary nonpolyposis
colorectal cancer, gastrointestinal stromal tumor), lung
cancer (e.g., non-small cell lung cancer, small cell lung
cancer, malignant mesothelioma), mesothelioma, pancreatic
5 cancer (e.g., pancreatic ductal carcinoma), gastric cancer
(e.g., papillary adenocarcinoma, mucinous adenocarcinoma,
adenosquamous cell carcinoma), breast cancer (e.g., invasive
ductal breast carcinoma, noninvasive ductal breast carcinoma,
inflammatory breast carcinoma), ovarian cancer (e.g.,
10 epithelial ovarian cancer, extragonadal germ cell tumor,
ovarian germ cell tumor, low-grade ovarian tumor), prostate
cancer (e.g., hormone-dependent prostate cancer, hormone-
independent prostate cancer), liver cancer (e.g., primary
liver cancer, extrahepatic bile duct cancer), thyroid cancer
15 (e.g., medullary thyroid cancer), kidney cancer (e.g., renal
cell carcinoma, transitional cell carcinoma of renal pelvis
and ureter), uterine cancer, brain tumor (e.g., pineal
astrocytoma, pilocytic astrocytoma, diffuse astrocytoma,
anaplastic astrocytoma), melanoma, sarcoma, bladder cancer,
20 hematological cancer or the like including multiple myeloma,
pituitary adenoma, glioma, acoustic neurinoma, retinal
sarcoma, pharyngeal cancer, laryngeal cancer, tongue cancer,
thymoma, esophageal carcinoma, duodenal cancer, colon cancer,
rectal cancer, hepatocellular carcinoma, pancreatic endocrine

tumor, bile duct cancer, gallbladder cancer, penile cancer,
ureteric cancer, testicular tumor, vulvar carcinoma, cervix
cancer, corpus uteri carcinoma, uterine sarcoma,
trophoblastic disease, vaginal cancer, skin cancer, mycosis
5 fungoides, basalioma, soft part sarcoma, malignant lymphoma,
Hodgkin's disease, myelodysplastic syndrome, adult T-cell
leukemia, chronic myeloproliferative disease, pancreatic
endocrine tumor, fibrous histiocyoma, leiomyosarcoma,
rhabdomyosarcoma, carcinoma of unknown primary), leukaemia
10 (e.g., acute leukaemia (e.g., acute lymphocytic leukaemia,
acute myeloid leukaemia), chronic leukaemia (e.g., chronic
lymphocytic leukaemia, chronic myeloid leukaemia),
myelodysplastic syndrome), uterine sarcoma (e.g., uterine
mesodermal mixed tumor, uterine leiomyosarcoma, endometrial
15 stromal tumor), myelofibrosis, and so on].

[0047]

The composition of the present invention as a drug may
be produced by using a method known in the art of drug
formulation with a pharmaceutically acceptable carrier.
20 Examples of the dosage form of the drug include formulations
for parenteral administration (e.g., a liquid such as an
injection) blended with a conventional auxiliary such as a
buffering agent and/or a stabilizer; and formulations for
topical administration, such as an ointment, a cream, a

liquid, and a plaster, blended with a conventional pharmaceutical carrier.

[0048]

The composition of the present invention may be used
5 for introduction of an active ingredient into various types
of cells, tissues, or organs. Examples of cells to which the
composition of the present invention may be applied include
mesenchymal stem cells, neural stem cells, skin stem cells,
splenocytes, nerve cells, glial cells, pancreatic B cells,
10 bone marrow cells, mesangial cells, Langerhans cells,
epidermal cells, epithelial cells, endothelial cells,
fibroblasts, fiber cells, muscle cells (e.g., skeletal muscle
cells, cardiac muscle cells, myoblasts, muscle satellite
cells, smooth muscle cells), fat cells, blood cells (e.g.,
15 macrophages, T cells, B cells, natural killer cells, mast
cells, leukocytes, neutrophils, basophils, eosinophils,
monocytes, megakaryocytes, hematopoietic stem cells),
synoviocytes, chondrocytes, osteocytes, osteoblasts,
osteoclasts, mammary cells, hepatocytes or stromal cells,
20 ova, spermatids, or precursor cells capable of inducing
differentiation into these cells, stem cells (e.g., including
induced pluripotent stem cells (iPS cells), embryonic stem
cells (ES cells)), primordial germ cells, oocytes, and
fertilized ova. Examples of tissues or organs to which the

composition of the present invention may be applied include all tissues or organs in which the above cells are present, for example, brain, sites of brain (e.g., olfactory bulb, amygdala, basal ganglion, hippocampus, thalamus, hypothalamus, subthalamic nucleus, cerebral cortex, medulla oblongata, cerebellum, occipital lobe, frontal lobe, temporal lobe, putamen, caudate nucleus, callosum, substantia nigra), spinal cord, pituitary gland, stomach, pancreas, kidney, liver, gonad, thyroid, gallbladder, bone marrow, adrenal gland, skin, lung, digestive tract (e.g., large intestine, small intestine), blood vessel, heart, thymus, spleen, submandibular gland, peripheral blood, peripheral blood cells, prostate, placenta, uterus, bones, joints, and muscles (e.g., skeletal muscle, smooth muscle, cardiac muscle). Those cells, tissues, or organs may be cancer cells, cancer tissues, or the like that have undergone canceration.

[0049]

The composition of the present invention is particularly superior in efficiency to introduce a nucleic acid into cancer cells.

[0050]

The compound, the lipid particle, and the composition of the present invention are stable and have low toxicity and can be safely used. In using the composition of the present

invention in vivo, or using the composition as a drug, the composition is suitably administered to a subject (e.g., a human or a non-human mammal (preferably, a human)) so that an effective amount of the nucleic acid can be delivered to
5 targeted cells.

[0051]

In using the composition of the present invention in vivo, or using the composition as a drug, the composition can be orally or parenterally (e.g., local, rectal, or
10 intravenous administration) administered in a safe manner in the form of a pharmaceutical formulation such as tablets (including sugar-coated tablets, film-coated tablets, sublingual tablets, orally disintegrating tablets), powders, granules, capsules (including soft capsules, microcapsules),
15 liquids, troches, syrups, emulsions, suspensions, injections (e.g., subcutaneous injections, intravenous injections, intramuscular injections, intraperitoneal injections), topical formulations (e.g., formulations for nasal administration, transdermal formulations, ointments),
20 suppositories (e.g., rectal suppositories, vaginal suppositories), pellets, nasal formulations, pulmonary formulations (inhalations), and infusions. Each formulation may be a controlled-release formulation such as a fast-

release formulation and a sustained-release formulation
(e.g., a sustained-release microcapsule).

[0052]

Now, a method for producing the compound of the
5 present invention will be described.

[0053]

Raw materials and reagents used in each step of the
production method below, and the resulting compound may each
form a salt. Examples of such salts are the same as the
10 above-mentioned salts for the compound of the present
invention.

[0054]

When a compound obtained in each step is a free
compound, the compound may be converted into an intended salt
15 by using a known method. Conversely, when a compound
obtained in each step is a salt, the compound may be
converted into a free form or another intended salt by using
a known method.

[0055]

20 A compound obtained in each step may be used for the
subsequent reaction directly as a reaction solution, or a
crude product may be obtained therefrom and used for the
subsequent reaction. Alternatively, a compound obtained in
each step may be isolated and/or purified from a reaction

mixture according to a conventional method using a separation means such as concentration, crystallization, recrystallization, distillation, solvent extraction, fractional distillation, and chromatography.

5 [0056]

If a compound as a raw material or reagent in each step is commercially available, the commercially available product may be directly used.

[0057]

10 Reaction time for reaction in each step, which may vary depending on reagents and solvents to be used, is typically 1 minute to 48 hours, and preferably 10 minutes to 8 hours, unless otherwise specified.

[0058]

15 Reaction temperature for reaction in each step, which may vary depending on reagents and solvents to be used, is typically -78°C to 300°C, and preferably -78°C to 150°C, unless otherwise specified.

[0059]

20 Pressure for reaction in each step, which may vary depending on reagents and solvents to be used, is typically 1 atm to 20 atm, and preferably 1 atm to 3 atm, unless otherwise specified.

[0060]

A microwave synthesis apparatus such as an Initiator produced by Biotage is occasionally used in reaction in a step. The reaction temperature, which may vary depending on reagents and solvents to be used, is typically room
5 temperature to 300°C, preferably room temperature to 250°C, and more preferably 50°C to 250°C, unless otherwise specified. The reaction time, which may vary depending on reagents and solvents to be used, is typically 1 minute to 48 hours, and preferably 1 minute to 8 hours, unless otherwise specified.

10 [0061]

In reaction in each step, a reagent is used in an amount of 0.5 equivalents to 20 equivalents, preferably in an amount of 0.8 equivalents to 5 equivalents, to the amount of a substrate, unless otherwise specified. When a reagent is
15 used as a catalyst, the reagent is used in an amount of 0.001 equivalents to 1 equivalent, preferably in an amount of 0.01 equivalents to 0.2 equivalents, to the amount of a substrate, unless otherwise specified. If a reagent serves as a reaction solvent in combination with its own role, the
20 reagent is used in an amount as solvent.

[0062]

In reaction in each step, the reaction is performed without solvent, or in an appropriate solvent dissolving or suspending reactants therein, unless otherwise specified.

Examples of the solvent include solvents described in
Examples and the following solvents.

[0063]

Alcohols: methanol, ethanol, isopropanol, isobutanol,
5 tert-butyl alcohol, 2-methoxyethanol, and so on;

ethers: diethyl ether, diisopropyl ether, diphenyl
ether, tetrahydrofuran, 1,2-dimethoxyethane, and so on;

aromatic hydrocarbons: chlorobenzene, toluene, xylene,
and so on;

10 saturated hydrocarbons: cyclohexane, hexane, heptane,
and so on;

amides: N,N-dimethylformamide, N-methylpyrrolidone,
and so on;

halogenated hydrocarbons: dichloromethane, carbon
15 tetrachloride, and so on;

nitriles: acetonitrile and so on;

sulfoxides: dimethylsulfoxide and so on;

aromatic organic bases: pyridine and so on;

acid anhydride: acetic anhydride and so on;

20 organic acids: formic acid, acetic acid,

trifluoroacetic acid, and so on;

inorganic acids: hydrochloric acid, sulfuric acid, and
so on;

esters: ethyl acetate, isopropyl acetate, and so on;

ketones: acetone, methyl ethyl ketone, and so on; and water.

Two or more of these solvents may be mixed for use with an appropriate ratio.

5 [0064]

When a base is used in reaction in each step, for example, any of bases listed below or bases described in Examples is used.

[0065]

10 Inorganic bases: sodium hydroxide, potassium hydroxide, magnesium hydroxide, and so on;

basic salts: sodium carbonate, calcium carbonate, sodium hydrogen carbonate, and so on;

organic bases: triethylamine, diethylamine, pyridine,
15 4-dimethylaminopyridine, N,N-dimethylaniline, 1,4-diazabicyclo[2.2.2]octane, 1,8-diazabicyclo[5.4.0]-7-undecene, imidazole, piperidine, and so on;

metal alkoxides: sodium ethoxide, potassium tert-butoxide, sodium tert-butoxide, and so on;

20 alkali metal hydrides: sodium hydride and so on;

metal amides: sodium amide, lithium diisopropylamide, lithium hexamethyldisilazide, and so on; and

organolithiums: n-butyllithium, sec-butyllithium, and so on.

[0066]

When an acid or an acidic catalyst is used in reaction in each step, for example, any of acids and acidic catalysts listed below and acids and acidic catalysts described in
5 Examples is used.

[0067]

Inorganic acids: hydrochloric acid, sulfuric acid, nitric acid, hydrobromic acid, phosphoric acid, and so on;
organic acids: acetic acid, trifluoroacetic acid,
10 citric acid, p-toluenesulfonic acid, 10-camphorsulfonic acid, and so on; and

Lewis acids: boron trifluoride-diethyl ether complex, zinc iodide, anhydrous aluminum chloride, anhydrous zinc chloride, anhydrous iron chloride, and so on.

15 [0068]

Unless otherwise specified, reaction in each step is performed in accordance with a known method such as a method described in The Fifth Series of Experimental Chemistry, Vol. 13 to 19 (The Chemical Society of Japan (ed.)); Shin Jikken
20 Kagaku Koza (in Japanese, translated title: New Experimental Chemistry), Vol. 14 and 15 (The Chemical Society of Japan (ed.)); Seimitsu Yuki Kagaku (in Japanese, translated title: Precise Organic Chemistry, original title: Reaktionen und Synthesen im organisch-chemischen Praktikum und

Forschungslaboratorium) Revised 2nd Edition (L. F. Tietze,
Th. Eicher, Nankodo Co., Ltd.); Organic Name Reaction; The
Reaction Mechanism and Essence Revised Edition (TOGO, Hideo,
KODANSHA LTD.); ORGANIC SYNTHESSES Collective Volume I to VII
5 (John Wiley & Sons Inc.); Modern Organic Synthesis in the
Laboratory A Collection of Standard Experimental Procedures
(Jie Jack Li, Oxford University Press); Comprehensive
Heterocyclic Chemistry III, Vol. 1 to Vol. 14 (Elsevier Japan
K.K.); Strategic Applications of Named Reactions in Organic
10 Synthesis (translation supervisor: TOMIOKA, Kiyoshi,
publisher: Kagaku-Dojin Publishing Company, INC.);
Comprehensive Organic Transformations (VCH Publishers Inc.)
(1989); or the like, or in accordance with a method described
in Examples.

15 [0069]

Protection or deprotection reaction for a functional
group in each step is performed in accordance with a known
method such as a method described in "Protective Groups in
Organic Synthesis, 4th Ed." (Theodora W. Greene, Peter G. M.
20 Wuts) published by Wiley-Interscience Publication, 2007;
"Protecting Groups 3rd Ed." (P. J. Kocienski) published by
Thieme Medical Publishers, 2004; or the like, or in
accordance with a method described in Examples.

[0070]

Examples of protective groups for a hydroxy group of alcohols or the like and phenolic hydroxy groups include ether-type protective groups such as methoxymethyl ether, benzyl ether, p-methoxybenzyl ether, t-butyldimethylsilyl ether, t-butyldiphenylsilyl ether, and tetrahydropyranyl ether; carboxylate-type protective groups such as acetate; sulfonate-type esters such as methanesulfonate; and carbonate-type protective groups such as t-butylcarbonate.

[0071]

Examples of protective groups for a carbonyl group of aldehydes include acetal-type protective groups such as dimethylacetal; and cyclic acetal-type protective groups such as cyclic 1,3-dioxane.

[0072]

Examples of protective groups for a carbonyl group of ketones include ketal-type protective groups such as dimethyl ketal; cyclic ketal-type protective groups such as cyclic 1,3-dioxane; oxime-type protective groups such as O-methyloxime; and hydrazone-type protective groups such as N,N-dimethylhydrazone.

[0073]

Examples of protective groups for a carboxy group include ester-type protective groups such as methyl ester; and amide-type protective groups such as N,N-dimethylamide.

[0074]

Examples of protective groups for thiol include ether-type protective groups such as benzyl thioether; and ester-type protective groups such as thioacetate, thiocarbonate,
5 and thiocarbamate.

[0075]

Examples of protective groups for an amino group and aromatic heterocycles such as imidazole, pyrrole, and indole include carbamate-type protective groups such as
10 benzylcarbamate; amide-type protective groups such as acetamide; alkylamine-type protective groups such as N-triphenylmethylamine; and sulfonamide-type protective groups such as methanesulfonamide.

[0076]

15 Removal of a protective group may be performed by using a known method such as a method using an acid, a base, ultraviolet light, hydrazine, phenylhydrazine, sodium N-methyldithiocarbamate, tetrabutylammonium fluoride, palladium acetate, or trialkylsilyl halide (e.g., trimethylsilyl
20 iodide, trimethylsilyl bromide), or by using a reduction method.

[0077]

Examples of reductants to be used when reduction reaction is performed in each step include metal hydrides

such as lithium aluminium hydride, sodium triacetoxyborohydride, sodium cyanoborohydride, diisobutylaluminium hydride (DIBAL-H), sodium borohydride, and tetramethylammonium triacetoxyborohydride; boranes such as a borane-tetrahydrofuran complex; Raney nickel; Raney cobalt; hydrogen; and formic acid. For example, Raney nickel or Raney cobalt may be used in the presence of hydrogen or formic acid. When a carbon-carbon double bond or triple bond is reduced, a method using a catalyst such as palladium-carbon and Lindlar's catalyst may be used.

[0078]

Examples of oxidants to be used when oxidation reaction is performed in each step include peracids such as m-chloroperbenzoic acid (MCPBA), hydrogen peroxide, and t-butylhydroperoxide; perchlorates such as tetrabutylammonium perchlorate; chlorates such as sodium chlorate; chlorites such as sodium chlorite; periodates such as sodium periodate; hypervalent iodine reagents such as iodosylbenzene; manganese-containing reagents such as manganese dioxide and potassium permanganate; leads such as lead tetraacetate; chromium-containing reagents such as pyridinium chlorochromate (PCC), pyridinium dichromate (PDC), and the Jones reagent; halogen compounds such as N-bromosuccinimide (NBS); oxygen; ozone; a sulfur trioxide-pyridine complex;

osmium tetroxide; selenium dioxide; and 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ).

[0079]

Examples of radical initiators to be used when radical
5 cyclization reaction is performed in each step include azo
compounds such as azobisisobutyronitrile (AIBN); water-
soluble radical initiators such as 4-4'-azobis-4-
cyanopentanoic acid (ACPA); triethylboron in the presence of
air or oxygen; and benzoyl peroxide. Examples of radical
10 reaction reagents to be used include tributylstannane,
tristrimethylsilylsilane, 1,1,2,2-tetraphenyldisilane,
diphenylsilane, and samarium iodide.

[0080]

Examples of Wittig reagents to be used when the Wittig
15 reaction is performed in each step include
alkylidenephosphoranes. Alkylidenephosphoranes may be
prepared by using a known method such as reaction of a
phosphonium salt and a strong base.

[0081]

20 Examples of reagents to be used when the Horner-Emmons
reaction is performed in each step include phosphonoacetates
such as methyl dimethylphosphonoacetate and ethyl
diethylphosphonoacetate; and bases such as alkali metal
hydrides and organolithiums.

[0082]

Examples of reagents to be used when the Friedel-Crafts reaction is performed in each step include a Lewis acid with an acid chloride or an alkylating agent (e.g., a halogenated alkyl, an alcohol, an olefin). Alternatively, an organic acid or an inorganic acid may be used instead of a Lewis acid, and an acid anhydride such as acetic anhydride may be used instead of an acid chloride.

[0083]

When aromatic nucleophilic substitution reaction is performed in each step, a nucleophile (e.g., an amine, imidazole) and a base (e.g., a basic salt, an organic base) are used as reagents.

[0084]

Examples of bases used to generate a carbanion when nucleophilic addition reaction with a carbanion, nucleophilic 1,4-addition reaction with a carbanion (Michael addition reaction), or nucleophilic substitution reaction with a carbanion is performed in each step include organolithiums, metal alkoxides, inorganic bases, and organic bases.

[0085]

Examples of Grignard reagents to be used when the Grignard reaction is performed in each step include arylmagnesium halides such as phenylmagnesium bromide; and

alkylmagnesium halides such as methylmagnesium bromide and isopropylmagnesium bromide. Grignard reagents may be prepared by using a known method such as reaction of a halogenated alkyl or halogenated aryl and metal magnesium in
5 a solvent of an ether or tetrahydrofuran.

[0086]

When the Knoevenagel condensation reaction is performed in each step, an active methylene compound sandwiched between two electron-withdrawing groups (e.g.,
10 malonic acid, diethyl malonate, malononitrile) and a base (e.g., an organic base, a metal alkoxide, an inorganic base) are used as reagents.

[0087]

When the Vilsmeier-Haack reaction is performed in each
15 step, phosphoryl chloride and an amide derivative (e.g., N,N-dimethylformamide) are used as reagents.

[0088]

Examples of azidating agents to be used when azidation reaction is performed for an alcohol, an alkyl halide, or a
20 sulfonate in each step include diphenylphosphorylazide (DPPA), trimethylsilylazide, and sodium azide. When an alcohol is azidated, for example, a method using diphenylphosphorylazide and 1,8-diazabicyclo[5,4,0]undec-7-

ene (DBU) or a method using trimethylsilylazide and a Lewis acid may be used.

[0089]

Examples of reductants to be used when reductive
5 amination reaction is performed in each step include sodium triacetoxymethylborohydride, sodium cyanoborohydride, hydrogen, and formic acid. Examples of carbonyl compounds to be used when the substrate is an amine compound include aldehydes such as paraformaldehyde as well as acetaldehyde, and ketones such as
10 cyclohexanone. Examples of amines to be used when the substrate is a carbonyl compound include ammonia; primary amines such as methyl amine; and secondary amines such as dimethylamine.

[0090]

15 When the Mitsunobu reaction is performed in each step, an azodicarboxylate (e.g., diethyl azodicarboxylate (DEAD), diisopropyl azodicarboxylate (DIAD)) and triphenylphosphine are used as reagents.

[0091]

20 Examples of reagents to be used when esterification reaction, amidation reaction, or urea formation reaction is performed in each step include halogenated acyl forms such as acid chlorides and acid bromides; and activated carboxylic acids such as acid anhydrides, activated ester forms, and

sulfate forms. Examples of activators for carboxylic acids include carbodiimide condensing agents such as 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (WSCD); triazine-based condensing agents such as 4-(4,6-dimethoxy-1,3,5-triazin-2-yl)-4-methylmorpholinium chloride-n-hydrate (DMT-MM); carbonate condensing agents such as 1,1-carbonyldiimidazole (CDI); diphenylphosphoryl azide (DPPA); benzotriazol-1-yloxy-trisdimethylaminophosphonium salt (BOP reagent); 2-chloro-1-methyl-pyridinium iodide (Mukaiyama reagent); thionyl chloride; lower alkyl haloformates such as ethyl chloroformate; O-(7-azabenzotriazol-1-yl)-N,N,N',N'-tetramethyluronium hexafluorophosphate (HATU); sulfuric acid; and any combination of them. When a carbodiimide condensing agent is used, an additive such as 1-hydroxybenzotriazol (HOBt), N-hydroxysuccinimide (HOSu), and dimethylaminopyridine (DMAP) may be further added to the reaction.

[0092]

Examples of metal catalysts to be used when coupling reaction is performed in each step include palladium compounds such as palladium(II) acetate, tetrakis(triphenylphosphine)palladium(0), dichlorobis(triphenylphosphine)palladium(II), dichlorobis(triethylphosphine)palladium(II),

tris(dibenzylideneacetone)dipalladium(0), 1,1'-
bis(diphenylphosphino)ferrocenepalladium(II) chloride, and
palladium(II) acetate; nickel compounds such as
tetrakis(triphenylphosphine)nickel(0); rhodium compounds such
5 as tris(triphenylphosphine)rhodium(III) chloride; cobalt
compounds; copper compounds such as copper oxide and
copper(I) iodide; and platinum compounds. A base may be
further added to the reaction, and examples of the base
include inorganic bases and basic salts.

10 [0093]

When thiocarbonylation reaction is performed in each
step, diphosphorus pentasulfide is typically used as a
thiocarbonylating agent; however, not only diphosphorus
pentasulfide, but also a reagent having 1,3,2,4-
15 dithiadiphosphetane-2,4-disulfide structure such as 2,4-
bis(4-methoxyphenyl)-1,3,2,4-dithiadiphosphetane-2,4-
disulfide (Lowesson reagent) may be used.

[0094]

Examples of halogenating agents to be used when the
20 Wohl-Ziegler reaction is performed in each step include N-
iodosuccinimide, N-bromosuccinimide (NBS), N-
chlorosuccinimide (NCS), bromine, and sulfonyl chloride.
Further, the reaction may be accelerated by addition of heat,

light, or a radical initiator such as benzoyl peroxide and azobisisobutyronitrile.

[0095]

Examples of halogenating agents to be used when
5 halogenation reaction is performed for a hydroxy group in
each step include hydrohalic acids and acid halides of
inorganic acids, specifically, hydrochloric acid, thionyl
chloride, phosphorus oxychloride for chlorination, and 48%
hydrobromic acid for bromination. A method may be used in
10 which a halogenated alkyl form is obtained from an alcohol by
the action of triphenylphosphine and carbon tetrachloride,
carbon tetrabromide, or the like. Alternatively, a method
may be used in which a halogenated alkyl form is synthesized
through two-step reaction such that an alcohol is converted
15 into a sulfate and then reacted with lithium bromide, lithium
chloride, or sodium iodide.

[0096]

Examples of reagents to be used when the Arbuzov
reaction is performed in each step include halogenated alkyls
20 such as bromoethyl acetate; and phosphites such as
triethylphosphite and tri(isopropyl)phosphite.

[0097]

Examples of sulfonating agents to be used when
sulfonation reaction is performed in each step include

methanesulfonyl chloride, p-toluenesulfonyl chloride, methanesulfonic anhydride, p-toluenesulfonic anhydride, and trifluoromethanesulfonic anhydride.

[0098]

5 When hydrolysis reaction is performed in each step, an acid or a base is used as a reagent. When acid hydrolysis reaction is performed for a t-butyl ester, formic acid or triethylsilane is added in some cases to reductively trap t-butyl cations produced as byproducts.

10 [0099]

 Examples of dehydrating agents to be used when dehydration reaction is performed in each step include sulfuric acid, diphosphorus pentoxide, phosphorus oxychloride, N,N'-dicyclohexylcarbodiimide, alumina, and
15 polyphosphoric acid.

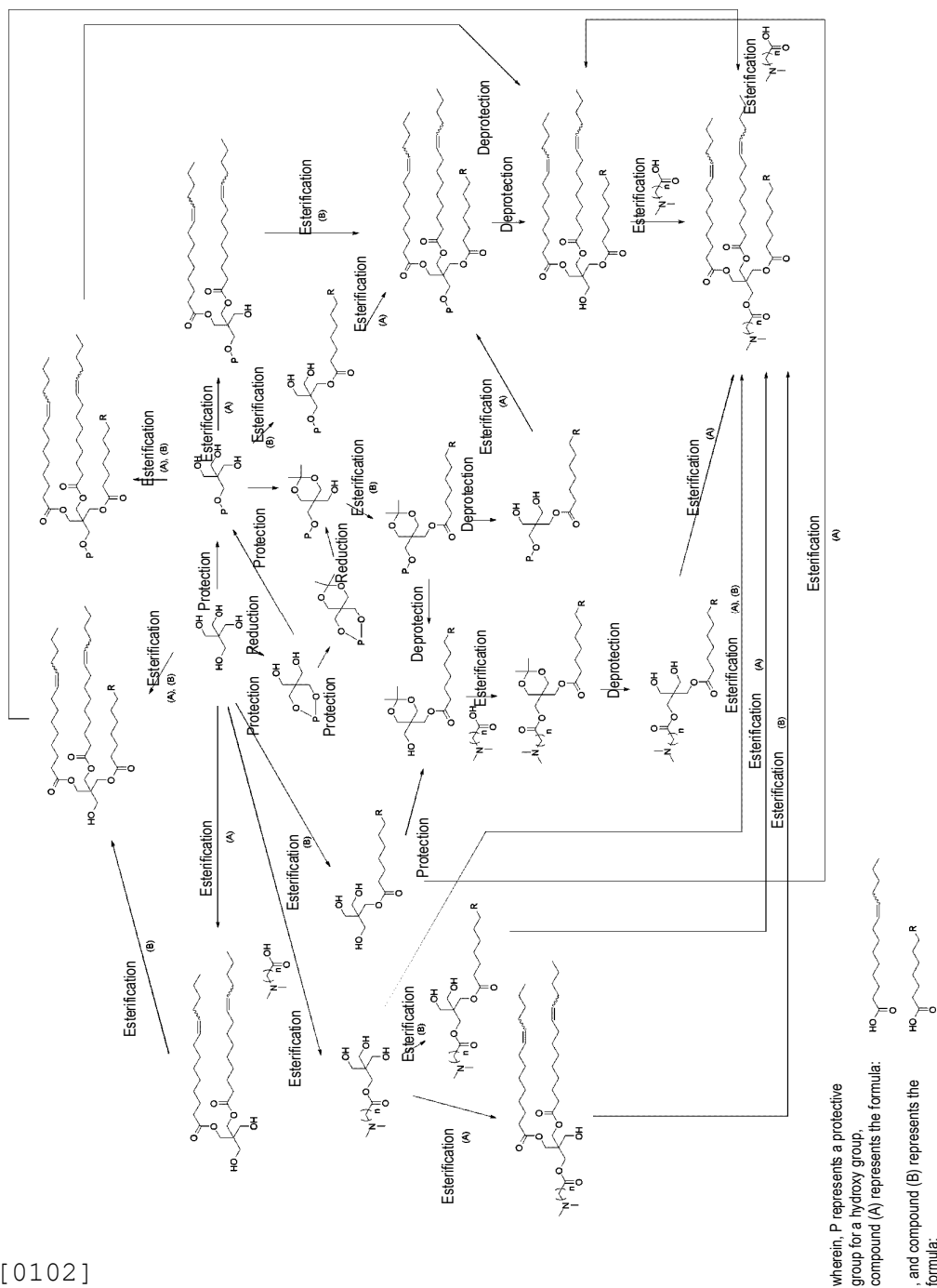
[0100]

 Compound (I) may be produced, for example, by using a production method shown below. Among the compounds (I), a compound in which each of the wavy lines forms a cis-
20 structure and a compound in which one or both of the wave lines forms a trans-structure can be both produced by using the same production method as the production method shown below. In the present invention, compound (I) with a desired structure can be synthesized by using an appropriate raw

material for the intended structure of compound (I)
particularly in esterification. A salt of compound (I) can
be obtained through appropriate mixing with an inorganic
base, an organic base, an organic acid, or a basic or acidic
5 amino acid.

[0101]

[Formula 4]



[0102]

Now, a method for producing a lipid particle

5 containing the compound of the present invention and that for

producing a composition containing the lipid particle and a nucleic acid for nucleic acid introduction will be described.

[0103]

The lipid particle of the present invention can be
5 produced by mixing the compound of the present invention
(cationic lipid) and, as necessary, an additional lipid
component, and then applying a known method to prepare a
lipid particle from a lipid component. For example, the
lipid particle can be produced as a lipid particle dispersion
10 by dissolving the (mixed) lipid component in an organic
solvent and mixing the resulting organic solvent solution
with water or a buffer (e.g., through an emulsifying method).
The mixing may be performed by using a microfluid mixing
system (e.g., the apparatus NanoAssemblr (Precision
15 NanoSystems)). The lipid particle obtained may be subjected
to desalting or dialysis and sterile filtration. As
necessary, pH adjustment or osmotic pressure adjustment may
be performed.

[0104]

20 Compound (I) can form different structures depending
on combination of the definitions of n, R, and the wavy lines
of formula (I). To produce the lipid particle, one compound
having a specific structure may be used alone as compound

(I), and a mixture of a plurality of compounds of different structures may be used as compound (I).

[0105]

Examples of the "additional lipid component" include
5 the above-mentioned structural lipids such as sterols,
phospholipids, and polyethylene glycol lipids. The
"additional lipid component" is used, for example, in an
amount of 0.008 to 4 mol per mole of the compound of the
present invention. The compound of the present invention is
10 preferably used as a mixture with the additional lipid
component (in particular, cholesterol, phosphatidylcholine,
and a polyethylene glycol lipid). In a preferred embodiment
using a mixture of the compound of the present invention and
the additional lipid component, the mixture is a mixture of 1
15 to 4 mol of the compound of the present invention, 0 to 3 mol
of a sterol, 0 to 2 mol of a phospholipid, and 0 to 1 mol of
a polyethylene glycol lipid. In a more preferred embodiment
using a mixture of the compound of the present invention and
the additional lipid component, the mixture is a mixture of 1
20 to 1.5 mol of the compound of the present invention, 0 to
1.25 mol of a sterol, 0 to 0.5 mol of a phospholipid, and 0
to 0.125 mol of a polyethylene glycol lipid.

[0106]

The concentration of the compound of the present invention or the mixture of the compound of the present invention and the additional lipid component in the organic solvent solution is preferably 0.5 to 100 mg/mL.

5 [0107]

Examples of the organic solvent include methanol, ethanol, 1-propanol, 2-propanol, 1-butanol, tert-butanol, acetone, acetonitrile, N,N-dimethylformamide, dimethylsulfoxide, and mixtures of them. The organic solvent
10 may contain 0 to 20% of water or a buffer.

[0108]

Examples of the buffer include acidic buffers (e.g., acetate buffer, citrate buffer, 2-morpholinoethanesulfonate (MES) buffer, phosphate buffer), and neutral buffers (e.g.,
15 4-(2-hydroxyethyl)-1-piperazineethanesulfonate (HEPES) buffer, tris(hydroxymethyl)aminomethane (Tris) buffer, phosphate buffer, phosphate-buffered saline (PBS)).

[0109]

If mixing is performed by using a microfluid mixing
20 system, it is preferred to mix 1 to 5 parts by volume of water or the buffer per part by volume of the organic solvent solution. The flow rate of the mixed solution (mixed solution of the organic solvent solution and water or the

buffer) in the system is preferably 0.1 to 10 mL/min, and the temperature is preferably 15 to 45°C.

[0110]

The composition of the present invention can be
5 produced as a lipid particle dispersion containing an active
ingredient by adding in advance a nucleic acid as an active
ingredient to water or the buffer in production of the lipid
particle or a lipid particle dispersion. The active
ingredient is preferably added so that the active ingredient
10 concentration of water or the buffer reaches 0.05 to 2.0
mg/mL.

[0111]

In addition, the composition of the present invention
can be produced as a lipid particle dispersion containing an
15 active ingredient by admixing the lipid particle or a lipid
particle dispersion and an active ingredient or an aqueous
solution of the active ingredient through a known method.
The lipid particle dispersion can be prepared by dispersing
the lipid particle in an appropriate dispersion medium. The
20 aqueous solution of the active ingredient can be prepared by
dissolving the active ingredient in an appropriate solvent.

[0112]

The content of the compound of the present invention
in the composition of the present invention with the

dispersion medium and solvent excluded is preferably 40 to 70% by weight.

[0113]

The content of the active ingredient in the
5 composition of the present invention with the dispersion medium and solvent excluded is preferably 1 to 20% by weight.

[0114]

The dispersion medium of the lipid particle dispersion or the dispersion containing the composition can be replaced
10 with water or a buffer through dialysis. The dialysis is performed with an ultrafiltration membrane having a molecular weight cutoff of 10 to 20K at 4°C to room temperature. The dialysis may be repeatedly performed. For replacement of the dispersion medium, tangential flow filtration (TFF) may be
15 used. After replacement of the dispersion medium, pH adjustment or osmotic pressure adjustment may be performed, as necessary.

[0115]

Now, methods for analyzing a lipid particle containing
20 the compound of the present invention, and a composition containing the lipid particle and a nucleic acid as an active ingredient will be described.

[0116]

The particle size of the lipid particle (in the composition) can be measured by using a known means. For example, a Zetasizer Nano ZS (Malvern Instruments Limited), a particle size analyzer based on an NIBS (non-invasive backscatter) technique, can be used to calculate the particle size as a z-average particle size through cumulant analysis of the autocorrelation function. The particle size (average particle size) of the lipid particle (in the composition) is preferably 10 to 200 nm.

10 [0117]

The concentration and encapsulation ratio of a nucleic acid (e.g., an siRNA, an mRNA) as an active ingredient in the composition of the present invention can be measured by using a known means. For example, after the nucleic acid is fluorescence-labeled with Quant-iT (TM) RiboGreen (R) (Invitrogen), the concentration and the encapsulation ratio can be determined by measuring the fluorescence intensity. The concentration of the nucleic acid in the composition can be calculated by using a standard curve prepared from aqueous solutions of the nucleic acid with known concentrations, and the encapsulation ratio can be calculated on the basis of difference in fluorescence intensity depending on the presence or absence of addition of Triton-X100 (a surfactant to disintegrate the lipid particle). The concentration of

the nucleic acid in the composition refers to the total concentration of molecules of the nucleic acid encapsulated in the lipid particle and molecules of the nucleic acid not encapsulated in the lipid particle, and the encapsulation
5 ratio refers to the fraction of molecules of the nucleic acid encapsulated in the lipid particle to all the molecules of the nucleic acid in the composition.

Examples

10 [0118]

The present invention will be further described in detail with reference to Examples, Test Examples, and Formulation Examples; however, these do not limit the present invention, and modification may be made without departing
15 from the scope of the present invention.

[0119]

"Room temperature" in Examples below typically indicates approximately 10°C to approximately 35°C. Each ratio shown for mixed solvent indicates a volume ratio,
20 unless otherwise stated. % indicates % by weight, unless otherwise stated.

[0120]

Elution in column chromatography was performed under observation with TLC (thin-layer chromatography), unless

otherwise described. In TLC observation, a 60 F₂₅₄ produced by Merck KGaA was used as a TLC plate, and a solvent used as an elution solvent in column chromatography was used as an eluent. A UV detector was employed for detection, and
5 observation was performed with a TLC coloring reagent, as necessary. In description of silica gel column chromatography, NH indicates that aminopropylsilane-bonded silica gel was used, and Diol indicates that 3-(2,3-dihydroxypropoxy)propylsilane-bonded silica gel was used. In
10 description of preparative HPLC (high-performance liquid chromatography), C18 indicates that octadecyl-bonded silica gel was used. Each ratio shown for elution solvent indicates a volume ratio, unless otherwise stated.

[0121]

15 ¹H NMR was measured by using a Fourier transformation-NMR. The software ACD/SpecManager (product name) and so on were used for ¹H NMR analysis. Description is occasionally omitted for peaks for a hydroxy group, an amino group, and so on with a very broad proton peak.

20 [0122]

MS was measured through an LC/MS and an MALDI/TOFMS. For the ionization method, an ESI method, an APCI method, or an MALDI method was used. CHCA was used for the matrix. Measured values (found) were reported as data. In typical

cases, some molecular ion peaks are observed as fragment ions. In the case of a salt, a molecular ion peak for the free form, or cationic, anionic, or fragment ion peaks are typically observed.

5 [0123]

In Examples below, the following abbreviations are used.

MS: Mass spectrum

M: Molar concentration

10 N: Normality

CDCl₃: Deuterated chloroform

DMSO-d₆: Deuterated dimethylsulfoxide

¹H NMR: Proton nuclear magnetic resonance

LC/MS: Liquid chromatograph/mass spectrometer

15 ESI: Electrospray ionization

APCI: Atmospheric pressure chemical ionization

MALDI: Matrix-assisted laser desorption/ionization

TOFMS: Time-of-flight mass spectrometry

CHCA: α -Cyano-4-hydroxycinnamic acid

20 DMF: N,N-dimethylformamide

THF: Tetrahydrofuran

DMAP: 4-Dimethylaminopyridine

TBAF: Tetrabutylammonium fluoride

[0124]

[Example 1] 3-((4-(Dimethylamino)butanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate

A) 2-(((tert-Butyldimethylsilyl)oxy)methyl)-2-(hydroxymethyl)propane-1,3-diol

To a mixture of 2,2-bis(hydroxymethyl)propane-1,3-diol (5.45 g), 1H-imidazole (2.72 g) and DMF (190 mL), a solution of tert-butylchlorodimethylsilane (3.01 g) in DMF (10 mL) was added at room temperature. After stirring for 24 hours, the reaction mixture was concentrated under reduced pressure. The residue was diluted with ethyl acetate, washed three times with water and once with saturated brine, and then dried over anhydrous sodium sulfate, and the solvent was distilled off under reduced pressure. The residue was purified by silica gel column chromatography (ethyl acetate/hexane) to afford the title compound (2.25 g).

¹H NMR (300 MHz, CDCl₃) δ ppm 0.08 (6H, s), 0.90 (9H, s), 2.53 (3H, t, J = 5.5 Hz), 3.66 (2H, s), 3.73 (6H, d, J = 5.5 Hz) [0125]

B) 3-((tert-Butyl(dimethyl)silyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate

To a solution of 2-(((tert-butyldimethylsilyl)oxy)methyl)-2-(hydroxymethyl)propane-1,3-diol (258 mg), (9Z)-tetradec-9-enoic acid (769 mg) and DMAP

(126 mg) in DMF (3 mL), 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (790 mg) was added at room temperature. After stirring for 18 hours, the reaction mixture was diluted with ethyl acetate, washed twice
5 with water and once with saturated brine, and then dried over anhydrous sodium sulfate, and the solvent was distilled off under reduced pressure. The residue was purified by silica gel column chromatography (NH, ethyl acetate/hexane) to afford the title compound (860 mg).

10 ^1H NMR (300 MHz, CDCl_3) δ ppm 0.03 (6H, s), 0.81-0.96 (18H, m), 1.18-1.41 (36H, m), 1.53-1.67 (6H, m), 1.91-2.10 (12H, m), 2.29 (6H, t, $J = 7.6$ Hz), 3.58 (2H, s), 4.08 (6H, s), 5.27-5.43 (6H, m)
[0126]

15 C) 3-Hydroxy-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate

To a solution of 3-((tert-butyl(dimethyl)silyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate (5.91 g) in THF (120 mL), a mixture of a
20 THF solution of TBAF (1 M, 14.85 mL) and acetic acid (4.91 mL) was added at room temperature. After stirring for 3 days, the reaction mixture was concentrated under reduced pressure. The residue was diluted with ethyl acetate, washed once with saturated aqueous solution of sodium hydrogen

carbonate and once with saturated brine, and then dried over anhydrous sodium sulfate, and the solvent was distilled off under reduced pressure. The residue was purified by silica gel column chromatography (ethyl acetate/hexane) to afford
5 the title compound (4.96 g).

^1H NMR (300 MHz, CDCl_3) δ ppm 0.82-0.97 (9H, m), 1.16-1.42 (36H, m), 1.52-1.68 (6H, m), 1.90-2.12 (12H, m), 2.32 (6H, t, $J = 7.6$ Hz), 2.52 (1H, t, $J = 7.0$ Hz), 3.49 (2H, d, $J = 7.0$ Hz), 4.11 (6H, s), 5.26-5.42 (6H, m)

10 [0127]

D) 3-((4-(Dimethylamino)butanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate

To a solution of 3-hydroxy-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate (4.96 g), DMAP
15 (796 mg) and 4-(dimethylamino)butanoic acid hydrochloride (2.19 g) in DMF (20 mL), 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (2.50 g) was added at room temperature. After stirring for 18 hours, the reaction mixture was diluted with ethyl acetate, washed once
20 with saturated aqueous solution of sodium hydrogen carbonate and once with saturated brine, and then dried over anhydrous sodium sulfate, and the solvent was distilled off under reduced pressure. The residue was purified by silica gel

column chromatography (NH, ethyl acetate/hexane) to afford the title compound (5.31 g).

¹H NMR (300 MHz, CDCl₃) δ ppm 0.82-0.94 (9H, m), 1.20-1.42 (36H, m), 1.50-1.66 (6H, m), 1.69-1.83 (2H, m), 1.90-2.10 (12H, m), 2.20 (6H, s), 2.23-2.41 (10H, m), 4.11 (8H, s), 5.23-5.44 (6H, m)

[0128]

[Example 4] 3-((4-(Dimethylamino)butanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enyloxy)methyl)propyl (9Z)-hexadec-9-enoate

A) 2-(((tert-Butyl(diphenyl)silyl)oxy)methyl)-2-(hydroxymethyl)propane-1,3-diol

To a mixture of 2,2-bis(hydroxymethyl)propane-1,3-diol (5.0 g), 1H-imidazole (2.5 g) and DMF (200 mL), a solution of tert-butylchlorodiphenylsilane (5.1 g) in DMF (10 mL) was added at room temperature. After stirring for 18 hours, the reaction mixture was concentrated under reduced pressure. The residue was diluted with ethyl acetate, washed three times with water and once with saturated brine, and dried over anhydrous sodium sulfate, and the solvent was distilled off under reduced pressure. The residue was purified by silica gel column chromatography (ethyl acetate/hexane) to afford the title compound (6.4 g).

¹H NMR (500 MHz, CDCl₃) δ ppm 1.07 (9H, s), 2.34 (3H, t, J = 5.5 Hz), 3.67 (2H, s), 3.74 (6H, d, J = 5.5 Hz), 7.39-7.48 (6H, m), 7.63-7.67 (4H, m)

[0129]

5 B) (5-(((tert-Butyl(diphenyl)silyl)oxy)methyl)-2,2-dimethyl-1,3-dioxan-5-yl)methanol

To a solution of 2-(((tert-butyl(diphenyl)silyl)oxy)methyl)-2-(hydroxymethyl)propane-1,3-diol (3.5 g) and 2,2-dimethoxypropane (1.5 g) in acetone
10 (35 mL), p-toluenesulfonic acid monohydrate (88.9 mg) was added at room temperature. After stirring for 2 hours, diluted aqueous ammonia was added to the reaction mixture to neutralize the reaction mixture, and the solvent was then distilled off under reduced pressure. The residue was
15 purified by silica gel column chromatography (ethyl acetate/hexane) to afford the title compound (2.7 g).

¹H NMR (500 MHz, CDCl₃) δ ppm 1.07 (9H, s), 1.27 (3H, s), 1.41 (3H, s), 2.12-2.18 (1 H, m), 3.69-3.78 (8H, m), 7.38-7.47 (6H, m), 7.65-7.69 (4H, m)

20 [0130]

C) (5-(((tert-Butyl(diphenyl)silyl)oxy)methyl)-2,2-dimethyl-1,3-dioxan-5-yl)methyl (9Z)-hexadec-9-enoate

To a solution of (5-(((tert-butyl(diphenyl)silyl)oxy)methyl)-2,2-dimethyl-1,3-dioxan-5-

yl)methanol (910 mg), DMAP (215 mg) and (9Z)-hexadec-9-enoic acid (838 mg) in DMF (10 mL), 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (757 mg) was added at room temperature. After stirring for 6 hours, ethyl acetate was added to the reaction mixture, the resultant was washed twice with water and once with saturated brine, and then dried over anhydrous sodium sulfate, and the solvent was distilled off under reduced pressure. The residue was purified by silica gel column chromatography (ethyl acetate/hexane) to afford the title compound (1.43 g).

¹H NMR (500 MHz, CDCl₃) δ ppm 0.84 - 0.91 (3 H, m), 1.03 - 1.07 (9 H, m), 1.22 - 1.35 (16 H, m), 1.40 (6 H, d, J = 17.0 Hz), 1.49 - 1.63 (2 H, m), 2.01 (4 H, q, J=6.5 Hz), 2.24 (2 H, t, J=7.6 Hz), 3.65 (2 H, s), 3.73 (2 H, d, J=11.7 Hz), 3.80 (2 H, d, J=12.0 Hz), 4.17 (2 H, s), 5.29 - 5.39 (2 H, m), 7.35 - 7.46 (6 H, m), 7.65 (4 H, d, J=6.9 Hz)

[0131]

D) (5-(Hydroxymethyl)-2,2-dimethyl-1,3-dioxan-5-yl)methyl (9Z)-hexadec-9-enoate

To a solution of (5-(((tert-butyl(diphenyl)silyl)oxy)methyl)-2,2-dimethyl-1,3-dioxan-5-yl)methyl (9Z)-hexadec-9-enoate (1.43 g) in THF (4 mL), a THF solution of TBAF (1 M, 2.64 mL) was added at room temperature. After stirring for 3 hours, the reaction

mixture was concentrated under reduced pressure. The residue was diluted with ethyl acetate, washed once with saturated aqueous solution of sodium hydrogen carbonate and once with saturated brine, and then dried over anhydrous sodium sulfate, and the solvent was distilled off under reduced pressure. The residue was purified by silica gel column chromatography (ethyl acetate/hexane) to afford the title compound (0.82 g).

¹H NMR (500 MHz, CDCl₃) δ ppm 0.85 - 0.91 (3 H, m), 1.24 - 1.36 (16 H, m), 1.42 (6 H, s), 1.58 - 1.66 (2 H, m), 2.01 (4 H, q, J=6.5 Hz), 2.30 (1 H, t, J=6.6 Hz), 2.35 (2 H, t, J=7.6 Hz), 3.48 (2 H, d, J=6.6 Hz), 3.69 - 3.75 (4 H, m), 4.25 (2 H, s), 5.31 - 5.38 (2 H, m)

[0132]

E) (5-(((4-(Dimethylamino)butanoyl)oxy)methyl)-2,2-dimethyl-1,3-dioxan-5-yl)methyl (9Z)-hexadec-9-enoate

To a solution of (5-(hydroxymethyl)-2,2-dimethyl-1,3-dioxan-5-yl)methyl (9Z)-hexadec-9-enoate (410 mg), DMAP (97 mg) and 4-(dimethylamino)butyric acid hydrochloride (250 mg) in DMF (4 mL), 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (343 mg) was added at 50°C. After stirring for 4 hours, ethyl acetate was added to the reaction mixture, the resultant was washed twice with water and once with saturated brine, and then dried over anhydrous sodium sulfate, and the

solvent was then distilled off under reduced pressure. The residue was purified by silica gel column chromatography (NH, ethyl acetate/hexane) to afford the title compound (430 mg).

¹H NMR (500 MHz, CDCl₃) δ ppm 0.86 - 0.91 (3 H, m), 1.24 -
5 1.36 (16 H, m), 1.42 (6 H, s), 1.53 - 1.69 (2 H, m), 1.78 (2 H, m), 1.98 - 2.04 (4 H, m), 2.21 (6 H, s), 2.29 (4 H, m), 2.37 (2 H, t, J=7.6 Hz), 3.74 (4 H, s), 4.11 (4 H, d, J=5.7 Hz), 5.31 - 5.38 (2 H, m)

[0133]

10 F) 3-((4-(Dimethylamino)butanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-hexadec-9-enoate

To (5-((4-(dimethylamino)butanoyl)oxy)methyl)-2,2-dimethyl-1,3-dioxan-5-yl)methyl (9Z)-hexadec-9-enoate (430 mg), acetic acid (2 mL) and water (1 mL) were added, and the
15 resultant was stirred at 75°C for 2 hours, and the solvent was then distilled off under reduced pressure. Ethyl acetate and saturated aqueous solution of sodium hydrogen carbonate were added to the residue, and the resultant was stirred for 2 hours. After washing with water was performed twice, the
20 resultant was dried over anhydrous sodium sulfate, and the solvent was then distilled off under reduced pressure. To a solution of the resulting residue, DMAP (201 mg) and (9Z)-tetradec-9-enoic acid (466 mg) in DMF (4 mL), 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (458 mg) was

added at 50°C. After stirring for 4 hours, ethyl acetate was added to the reaction mixture, the resultant was washed twice with water and once with saturated brine, and then dried over anhydrous sodium sulfate, and the solvent was then distilled
5 off under reduced pressure. The residue was purified by silica gel column chromatography (NH, ethyl acetate/hexane) to afford the title compound (604 mg).

¹H NMR (500 MHz, CDCl₃) δ ppm 0.85 - 0.92 (9 H, m), 1.24 - 1.36 (40 H, m), 1.55 - 1.64 (6 H, m), 1.73 - 1.80 (2 H, m),
10 1.98 - 2.05 (12 H, m), 2.20 (6 H, s), 2.24 - 2.33 (8 H, m), 2.36 (2 H, t, J=7.6 Hz), 4.09 - 4.13 (8 H, m), 5.31 - 5.38 (6 H, m)

[0134]

[Example 8] 2-(((N,N-Dimethyl-β-alanyl)oxy)methyl)-2-
15 ((octanoyloxy)methyl)propane-1,3-diyl (9Z,9'Z)bis-tetradec-9-enoate

A) (2-(4-Methoxyphenyl)-1,3-dioxane-5,5-diyl)dimethanol

A solution of 2,2-bis(hydroxymethyl)propane-1,3-diol
20 (506 g) in water (2.0 L) was stirred at 50°C. Concentrated hydrochloric acid (18 mL) was added thereto, to which p-methoxybenzaldehyde (474 mL) was added dropwise at around 30°C over 3 hours. Thereafter, the temperature of the reaction solution was adjusted to 25°C, and the reaction

solution was stirred for 5 hours. Thereto, 2 N aqueous solution of sodium hydroxide (120 mL) was added, and the resultant was stirred for 1 hour. Crystals were collected through filtration and washed with water, and then
5 recrystallization was performed with ethyl acetate/hexane to afford the title compound (769 g).

^1H NMR (500 MHz, DMSO- d_6) δ ppm 3.24 (2H, d, $J = 5.0$ Hz), 3.67 (2H, d, $J = 5.4$ Hz), 3.74 (3H, s), 3.77 (2H, d, $J = 11.3$ Hz), 3.88 (2H, t, $J = 11.3$ Hz), 4.53 (1H, t, $J = 5.4$ Hz), 4.62
10 (1H, t, $J = 5.0$ Hz), 5.34 (1H, s), 6.90 (2H, d, $J = 8.9$ Hz), 7.33 (2H, d, $J = 8.9$ Hz)

[0135]

B-1) 2-(Hydroxymethyl)-2-(((4-methoxybenzyl)oxy)methyl)propane-1,3-diol

15 To a suspension solution of (2-(4-methoxyphenyl)-1,3-dioxane-5,5-diyl)dimethanol (10.0 g) in toluene (100 mL), 1.5 M DIBAL-H solution (105 mL) was added dropwise at room temperature, and the resultant was stirred for 5 hours. Methanol (30 mL) was added thereto, and 2 N hydrochloric acid
20 (20 mL) and 4 N aqueous solution of sodium hydroxide (240 mL) were then added thereto and the resultant was stirred for 2 hours, and thereafter the toluene layer was removed. After the aqueous layer was neutralized with hydrochloric acid, extraction was performed with ethyl acetate, and the extract

was washed twice with saturated brine and filtered through a Celite. The solvent was distilled off under reduced pressure, and the residue was recrystallized with ethyl acetate/hexane to afford the title compound (6.6 g).

5 ^1H NMR (500 MHz, DMSO- d_6) δ ppm 3.32 (2H, s), 3.39 (6H, d, J = 5.4 Hz), 3.74 (3H, s), 4.21 (3H, t, J = 5.4 Hz), 4.36 (2H, s), 6.90 (2H, d like, J = 7.8 Hz), 7.23 (2H, d like, J = 7.8 Hz)

[0136]

10 C-1) (5-(((4-Methoxybenzyl)oxy)methyl)-2,2-dimethyl-1,3-dioxan-5-yl)methanol

To a solution of 2-(hydroxymethyl)-2-(((4-methoxybenzyl)oxy)methyl)propane-1,3-diol (1.00 g) and 2,2-dimethoxypropane (1.22 g) in DMF (5 mL), pyridinium p-
15 toluenesulfonate (10 mg) was added at room temperature. After stirring for 2 hours, ethyl acetate was added to the reaction mixture, the resultant was washed once with saturated aqueous solution of sodium hydrogen carbonate and twice with 5% saline, and then dried over anhydrous sodium
20 sulfate, and the solvent was distilled off under reduced pressure. The residue was purified by silica gel column chromatography (ethyl acetate/hexane) to afford the title compound (426 mg).

¹H NMR (500 MHz, DMSO-d₆) δ ppm 1.29 (3H, s), 1.29 (3H, s),
3.35 (2H, s), 3.39 (2H, d, J = 5.1 Hz), 3.61 (4H, s), 3.74
(3H, s), 4.38 (2H, s), 4.59 (1H, t, J = 5.1 Hz), 6.90 (2H, d
like, J = 7.5 Hz), 7.24 (2H, d like, J = 7.5 Hz)

5 [0137]

B-2) 9-(4-Methoxyphenyl)-3,3-dimethyl-2,4,8,10-
tetraoxaspiro[5.5]undecane

To a solution of (2-(4-methoxyphenyl)-1,3-dioxane-5,5-
diyl)dimethanol (2.00 g) and 2,2-dimethoxypropane (2.46 g) in
10 DMF (8 mL), pyridinium p-toluenesulfonate (20 mg) was added
at room temperature. After stirring for 4 hours, the
reaction mixture was diluted with ethyl acetate, washed twice
with saturated aqueous solution of sodium hydrogen carbonate
and twice with saturated brine, and then dried over anhydrous
15 magnesium sulfate, and the solvent was then distilled off
under reduced pressure. The residue was recrystallized with
ethyl acetate/hexane to afford the title compound (1.62 g).

¹H NMR (500 MHz, DMSO-d₆) δ ppm 1.34 (6H, s), 3.33 (2H, s),
3.63 (2H, d, J = 11.7 Hz), 3.74 (3H, s), 3.99 (2H, s), 4.12
20 (2H, d, J = 11.7 Hz), 5.37 (1H, s), 6.90 (2H, d, J = 8.8 Hz),
7.34 (2H, d, J = 8.8 Hz)

[0138]

C-2) (5-(((4-Methoxybenzyl)oxy)methyl)-2,2-dimethyl-
1,3-dioxan-5-yl)methanol

To a suspension solution of 9-(4-methoxyphenyl)-3,3-dimethyl-2,4,8,10-tetraoxaspiro[5.5]undecane (22.0 g) in toluene (200 mL), 1.5 M DIBAL-H solution (60 mL) was added dropwise at 5 to 20°C, and the resultant was stirred at 15°C
5 for 3 hours. Methanol (22 mL) was added thereto, and 2 N aqueous solution of sodium hydroxide (100 mL) and 4 N aqueous solution of sodium hydroxide (200 mL) were then added dropwise thereto in the order presented. After stirring for 1.5 hours, the toluene layer was separated and washed with 5%
10 saline. The solvent was distilled off under reduced pressure. The residue was purified by silica gel column chromatography (ethyl acetate/hexane) to afford the title compound (14.7 g).

¹H NMR (500 MHz, DMSO-d₆) δ ppm 1.29 (3H, s), 1.29 (3H, s),
15 3.35 (2H, s), 3.39 (2H, d, J = 5.1 Hz), 3.61 (4H, s), 3.74 (3H, s), 4.38 (2H, s), 4.59 (1H, t, J = 5.1 Hz), 6.90 (2H, d like, J = 7.5 Hz), 7.24 (2H, d like, J = 7.5 Hz)

[0139]

D) (5-(((4-Methoxybenzyl)oxy)methyl)-2,2-dimethyl-1,3-dioxan-5-yl)methyl octanoate
20

To a solution of (5-(((4-methoxybenzyl)oxy)methyl)-2,2-dimethyl-1,3-dioxan-5-yl)methanol (2.00 g), DMAP (412 mg) and octanoic acid (1.27 g) in DMF (20 mL), 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (1.94 g) was

added at 50°C. After stirring for 4 hours, ethyl acetate was added to the reaction mixture, the resultant was washed twice with water and once with saturated brine, and then dried over anhydrous sodium sulfate, and the solvent was then distilled off under reduced pressure. The residue was purified by silica gel column chromatography (ethyl acetate/hexane) to afford the title compound (2.78 g).

¹H NMR (500 MHz, CDCl₃) δ 0.84 - 0.91 (3 H, m), 1.22 - 1.33 (8 H, m), 1.40 (6 H, s), 1.53 - 1.61 (2 H, m), 2.26 (2 H, t, J = 7.6 Hz), 3.39 (2 H, s), 3.68 - 3.74 (2 H, m), 3.76 - 3.80 (2 H, m), 3.80 (3 H, s), 4.15 (2 H, s), 4.42 (2 H, s), 6.87 (2 H, d, J = 7.8 Hz), 7.20 - 7.24 (2 H, m)

[0140]

E) (5-(Hydroxymethyl)-2,2-dimethyl-1,3-dioxan-5-yl)methyl octanoate

To a solution of (5-(((4-methoxybenzyl)oxy)methyl)-2,2-dimethyl-1,3-dioxan-5-yl)methyl octanoate (2.78 g) in ethanol (30 mL), Pd-carbon (840 mg) was added at room temperature, and the resultant was stirred under a hydrogen atmosphere for 5 hours. After the reaction, Pd-carbon was removed through filtration, and the solvent was then distilled off under reduced pressure. The residue was purified by silica gel column chromatography (ethyl acetate/hexane) to afford the title compound (1.35 g).

^1H NMR (500 MHz, CDCl_3) δ 0.85 - 0.91 (3 H, m), 1.23 - 1.34 (8 H, m), 1.38 - 1.44 (6 H, m), 1.63 (2 H, m), 2.30 - 2.38 (3 H, m), 3.48 (2 H, d, J = 6.6 Hz), 3.68 - 3.75 (4 H, m), 4.25 (2 H, s)

5 [0141]

F) (5-(((N,N-Dimethyl- β -alanyl)oxy)methyl)-2,2-dimethyl-1,3-dioxan-5-yl)methyl octanoate

To a solution of (5-(hydroxymethyl)-2,2-dimethyl-1,3-dioxan-5-yl)methyl octanoate (400 mg), DMAP (129 mg) and 3-
10 (dimethylamino)propanoic acid hydrochloride (305 mg) in DMF (4 mL), 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride (456 mg) was added at room temperature. After stirring for 4 hours, ethyl acetate was added to the reaction mixture, the resultant was washed twice with water and once
15 with saturated brine, and then dried over anhydrous sodium sulfate, and the solvent was then distilled off under reduced pressure. The residue was purified by silica gel column chromatography (NH, ethyl acetate/hexane) to afford the title compound (320 mg).

20 ^1H NMR (500 MHz, CDCl_3) δ 0.84 - 0.92 (3 H, m), 1.21 - 1.33 (8 H, m), 1.42 (6 H, s), 1.61 (2 H, br), 2.23 (6 H, s), 2.32 (2 H, t, J = 7.6 Hz), 2.47 - 2.51 (2 H, m), 2.57 - 2.61 (2 H, m), 3.75 (4 H, s), 4.13 (4 H, d, J = 11.7 Hz)

[0142]

G) 2-(((N,N-Dimethyl- β -alanyl)oxy)methyl)-2-
((octanoyloxy)methyl)propane-1,3-diyl (9Z,9'Z)bis-tetradec-9-
enoate

To (5-(((N,N-dimethyl- β -alanyl)oxy)methyl)-2,2-
5 dimethyl-1,3-dioxan-5-yl)methyl octanoate (320 mg), acetic
acid (1.6 mL) and water (0.8 mL) were added, and the
resultant was stirred at 65°C for 3.5 hours, and the solvent
was then distilled off under reduced pressure. Ethyl acetate
and saturated aqueous solution of sodium hydrogen carbonate
10 were added to the residue, and the resultant was stirred for
2 hours. After washing was performed twice with water and
once with saturated brine, the resultant was dried over
anhydrous sodium sulfate, and the solvent was then distilled
off under reduced pressure. To a solution of the resulting
15 residue (150 mg), DMAP (101 mg), and (9Z)-tetradec-9-enoic
acid (235 mg) in DMF (4.5 mL), 1-ethyl-3-(3-
dimethylaminopropyl)carbodiimide hydrochloride (231 mg) was
added at 50°C. After stirring for 8 hours, ethyl acetate was
added to the reaction mixture, the resultant was washed twice
20 with water and once with saturated brine, and then dried over
anhydrous sodium sulfate, and the solvent was then distilled
off under reduced pressure. The residue was purified by
silica gel column chromatography (NH, ethyl acetate/hexane)
to afford the title compound (230 mg).

¹H NMR (500 MHz, CDCl₃) δ 0.84 - 0.93 (9 H, m), 1.24 - 1.36
(30 H, m), 1.53 - 1.65 (8 H, m), 1.98 - 2.05 (8 H, m), 2.22
(6 H, s), 2.30 (6 H, t, J = 7.6 Hz), 2.48 (2 H, t, J = 6.9
Hz), 2.58 (2 H, t, J = 6.8 Hz), 4.06 - 4.22 (8 H, m), 5.31 -
5 5.38 (4 H, m)

[0143]

[Example 11] 2-(((4-
(Dimethylamino)butanoyl)oxy)methyl)-2-
((dodecanoyloxy)methyl)propane-1,3-diyl (9Z,9'Z)bis-tetradec-
10 9-enoate

A) 3-Hydroxy-2,2-bis(hydroxymethyl)propyl dodecanoate

To a solution of 2,2-bis(hydroxymethyl)propane-1,3-
diol (5.00 g), DMAP (2.24 g) and lauric acid (3.68 g) in DMF
(150 mL), 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide
15 hydrochloride (7.04 g) was added at room temperature. After
stirring for 20 hours, ethyl acetate was added to the
reaction mixture, the resultant was washed twice with water
and once with saturated brine, and then dried over anhydrous
sodium sulfate, and the solvent was then distilled off under
20 reduced pressure. The residue was purified by silica gel
column chromatography (ethyl acetate/hexane) to afford the
title compound (1.79 g).

¹H NMR (500 MHz, CDCl₃) δ 0.85 - 0.91 (3 H, m), 1.22 - 1.33
(16 H, m), 1.59 - 1.66 (3 H, m), 2.36 (2 H, t, J = 7.6 Hz),

2.51 (2 H, t, J = 5.8 Hz), 3.65 (6 H, d, J = 5.7 Hz), 4.23 (2 H, s)

[0144]

B) 2-((Dodecanoyloxy)methyl)-2-(hydroxymethyl)propane-
5 1,3-diyl (9Z,9'Z)bis-tetradec-9-enoate

To a solution of 3-hydroxy-2,2-bis(hydroxymethyl)propyl dodecanoate (400 mg), DMAP (153 mg) and (9Z)-tetradec-9-enoic acid (569 mg) in DMF (4 mL), 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride
10 (602 mg) was added at room temperature. After stirring for 8 hours, ethyl acetate was added to the reaction mixture, the resultant was washed twice with water and once with saturated brine, and then dried over anhydrous sodium sulfate, and the solvent was then distilled off under reduced pressure. The
15 residue was purified by silica gel column chromatography (ethyl acetate/hexane) to afford the title compound (230 mg).

¹H NMR (500 MHz, CDCl₃) δ 0.85 - 0.93 (9 H, m), 1.22 - 1.36 (40 H, m), 1.58 - 1.65 (6 H, m), 1.99 - 2.05 (8 H, m), 2.32 (6 H, t, J = 7.6 Hz), 2.52 (1 H, t, J = 7.1 Hz), 3.48 (2 H, d, J = 6.9 Hz), 4.09 - 4.14 (6 H, m), 5.31 - 5.38 (4 H, m)

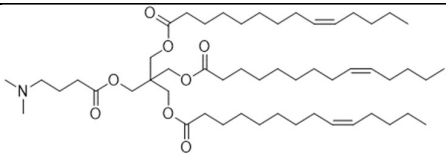
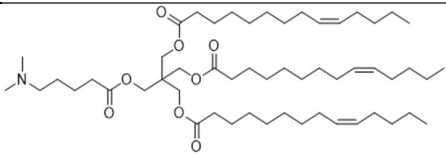
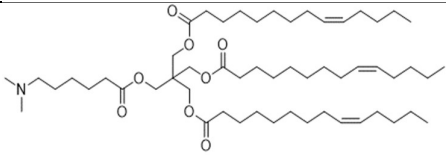
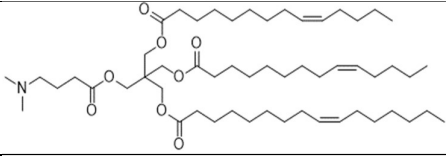
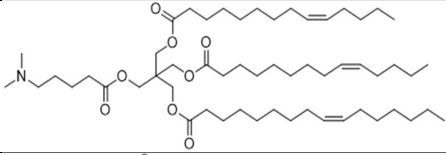
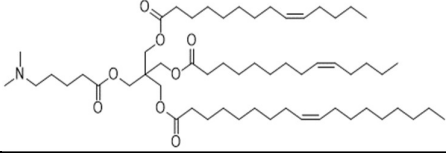
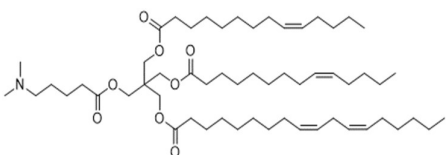
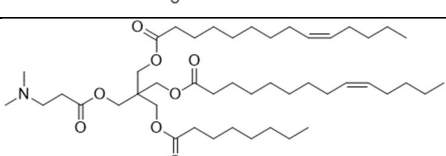
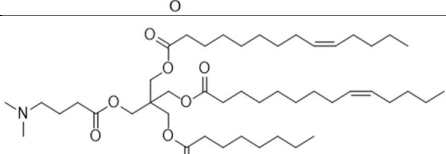
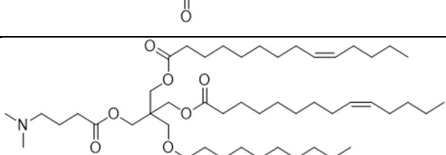
[0145]

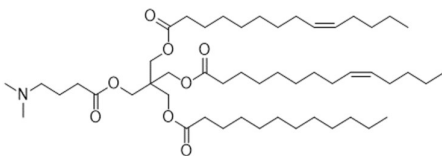
C) 2-(((4-(Dimethylamino)butanoyl)oxy)methyl)-2-((dodecanoyloxy)methyl)propane-1,3-diyl (9Z,9'Z)bis-tetradec-9-enoate

To a solution of 2-((dodecanoyloxy)methyl)-2-(hydroxymethyl)propane-1,3-diyl (9Z,9'Z)bis-tetradec-9-enoate (230 mg), DMAP (38 mg) and 4-(dimethylamino)butyric acid hydrochloride (105 mg) in DMF (4 mL), 1-ethyl-3-(3-
5 dimethylaminopropyl)carbodiimide hydrochloride (150 mg) was added at room temperature. After stirring for 3 hours, ethyl acetate was added to the reaction mixture, the resultant was washed twice with water and once with saturated brine, and then dried over anhydrous sodium sulfate, and the solvent was
10 then distilled off under reduced pressure. The residue was purified by silica gel column chromatography (NH, ethyl acetate/hexane) to afford the title compound (100 mg).
¹H NMR (500 MHz, CDCl₃) δ 0.85 - 0.93 (9 H, m), 1.23 - 1.35 (40 H, m), 1.55 - 1.67 (6 H, m), 1.77 (2 H, m), 1.98 - 2.05
15 (8 H, m), 2.20 (6 H, s), 2.24 - 2.33 (8 H, m), 2.36 (2 H, t, J = 7.6 Hz), 4.09 - 4.13 (8 H, m), 5.31 - 5.38 (4 H, m)
[0146]

Examples 2 and 3, 5 to 7, and 9 and 10 in a table below were produced in accordance with any of the methods
20 shown in Examples above and methods conforming thereto.
Table 1 shows compound names, structures, and mass numbers observed in production (indicated as MS in the table) for those Examples together with Examples 1, 4, 8, and 11.
[0147]

[Table 1]

Example number	IUPAC name	Structural formula	MS:m/z (M+H)
1	3-((4-(dimethylamino)butanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate		874.75
2	3-((5-(dimethylamino)pentanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate		888.73
3	3-((6-(dimethylamino)hexanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate		902.74
4	3-((4-(dimethylamino)butanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-hexadec-9-enoate		902.74
5	3-((5-(dimethylamino)pentanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-hexadec-9-enoate		916.76
6	3-((5-(dimethylamino)pentanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-octadec-9-enoate		944.79
7	3-((5-(dimethylamino)pentanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z,12Z)-octadec-9,12-dienoate		942.77
8	2-(((N,N-dimethyl-β-alanyl)oxy)methyl)-2-[(octanoyloxy)methyl]propane-1,3-diyl (9Z,9'Z)bis-tetradec-9-enoate		778.62
9	2-(((4-(dimethylamino)butanoyl)oxy)methyl)-2-[(octanoyloxy)methyl]propane-1,3-diyl (9Z,9'Z)bis-tetradec-9-enoate		792.63
10	2-((decanoyloxy)methyl)-2-(((4-(dimethylamino)butanoyl)oxy)methyl)propane-1,3-diyl		820.67

	(9Z,9'Z)bis-tetradec-9-enoate		
11	2-(((4-(dimethylamino)butanoyl)oxy)methyl)-2-((dodecanoyloxy)methyl)propane-1,3-diyl (9Z,9'Z)bis-tetradec-9-enoate		848.70

[0148]

[Production Example and Test Example for Composition Containing Lipid Particle of Present Invention and Nucleic Acid for Nucleic Acid Introduction]

5 [Production Example 1]

A lipid mixture (cationic lipid produced in Examples: DPPC:cholesterol:GM-020 = 60:10.6:28:1.4, in mole ratio) was dissolved in 90% EtOH/10% RNase-free water to afford a 8.5 mg/mL lipid solution. Luciferase mRNA (TriLink
10 Bio Technologies) was dissolved in 10 mM 2-morpholinoethanesulfonate (MES) buffer at pH 4.0 to afford a 0.22 mg/mL nucleic acid solution. The lipid solution and nucleic acid solution obtained were mixed by using the apparatus NanoAssemblr (Precision Nanosystems) at room
15 temperature with a flow rate ratio of 3 mL/min:6 mL/min to afford a dispersion containing a lipid particle encapsulating the nucleic acid. By using a Slyde-A-Lyzer (molecular weight cutoff: 20k, Thermo Fisher Scientific), the dispersion obtained was dialyzed with water at room temperature for 1
20 hour and with PBS at 4°C for 48 hours. Subsequently,

filtration was performed with a 0.2 μm syringe filter (IWAKI CO., LTD.) to prepare a composition for nucleic acid introduction, and thereafter the composition was stored at 4°C. The particle size of the lipid particle was measured by using a Zetasizer Nano ZS (Malvern Instruments Limited). The mRNA concentration and encapsulation ratio of the lipid particle were measured by using a Quant-iT (TM) RiboGreen (R) (Invitrogen). Table 2 shows the analysis results.

[0149]

[Table 2]

Cationic lipid	Particle size (nm)	mRNA Concentration ($\mu\text{g/mL}$)	Encapsulation ratio (%)
Example 1	71	136	96
Example 2	90	73	96
Example 3	93	87	96
Example 4	76	113	97
Example 5	91	96	98
Example 8	67	84	94
Example 9	108	129	62
Example 10	92	86	84
Example 11	83	85	92

[0150]

[Test Example 1] Test of mRNA Transfection into Cultured Cells

The human colorectal cancer-derived cell line HCT116 cells were cultured in a 96-well plate at a cell density of 6000 cells/well, and 24 hours thereafter 10 μL of the composition containing 10 ng of luciferase mRNA for nucleic acid introduction (a solution obtained by diluting the

product of Production Example 1 to an mRNA concentration of 10 ng/10 μ L) was added to the medium. The level of luciferase expressed in HCT116 24 hours after the addition of mRNA was measured by using a Picagene LT2.0 kit (TOYOBO CO., LTD.). Tables 3 and 4 show the measurement results.

[0151]

[Table 3]

Cationic lipid	Mean value of luminescence (cps) for 3 wells
PBS Control	560
Example 1	227720
Example 2	570027
Example 3	412187
Example 4	407547
Example 5	545507
Example 8	3853
Example 10	1203467
Example 11	953520

[0152]

[Table 4]

Cationic lipid	Mean value of luminescence (cps) for 3 wells
PBS Control	627
Example 9	549893

[0153]

[Production Example and Test Example for Composition Containing Lipid Particle of Present Invention and Nucleic Acid for Nucleic Acid Introduction]

[Production Example 2]

A lipid mixture (cationic lipid produced in Examples: DPPC:cholesterol:GM-020 = 60:10.6:28:1.4, in mole ratio) was dissolved in 90% EtOH/10% RNase-free water to

afford an approximately 7 mg/mL lipid solution. Equal amounts of an siRNA for Colla1 and an siRNA for Factor VII (FVII) were mixed together, and the mixture was dissolved in 25 mM acetate buffer at pH 4.0 to afford a 0.2 mg/mL nucleic acid solution. Sequence information on the siRNAs are shown in a table below. The lipid solution and nucleic acid solution obtained were mixed by using the apparatus NanoAssemblr (Precision Nanosystems) at room temperature with a flow rate ratio of 3 mL/min:9 mL/min to afford a dispersion containing a lipid particle including the nucleic acids. By using a Slyde-A-Lyzer (molecular weight cutoff: 20k, Thermo Fisher Scientific), the dispersion obtained was dialyzed with water at room temperature for 1 hour and with PBS at 4°C for 48 hours. Subsequently, filtration was performed with a 0.2 μ m syringe filter (IWAKI CO., LTD.) to prepare a composition for nucleic acid introduction, and thereafter the composition was stored at 4°C. The particle size of the lipid particle was measured by using a Zetasizer Nano ZS (Malvern Instruments Limited). The mRNA concentration and encapsulation ratio of the lipid particle were measured by using a Quant-iT (TM) RiboGreen (R) (Invitrogen). Table 6 shows the analysis results.

[0154]

[Table 5]

Colla1 siRNA (cited from Calvente et al. Hepatology 2015, 62:4)

Sense	5' - G[mU][mC][mU]AGA[mC]A[mU]G[mU][mU][mC]AG[mC][mU][mU][ts]t - 3'
Antisense	5' - AAGCUGAA[mC]AUGUC[mU]AGAC[ts]t - 3'

Factor VII siRNA (cited from Landesman et al. Silence 2010, 1:16)

Sense	5' - [mC][mU]A[mC]GAAAG[mC]A[mU][mC][mC][mU][mU][mC]A[mU][ts]t - 3'
Antisense	5' - AUGAAGGAUGCUUUCG[mU]AG[ts]t - 3'

N: RNA

n: DNA

[mN]: 2'-OMe RNA

[ns]: phosphorothioate

[0155]

[Table 6]

Compound	Particle size (nm)	siRNA Concentration (μg/ml)	Encapsulation ratio (%)
Example 2	104	251	98
Example 3	117	196	95
Example 10	88	307	90
Example 11	85	402	91
Example 4	90	355	89
Example 5	103	367	94
Example 6	87	333	98
Example 7	102	320	96

[0156]

[Test Example 2] Test of siRNA Delivery to Hepatic
Stellate Cells in Model Mice with Liver Disorder Caused by
Carbon Tetrachloride

The PBS dispersion of the lipid particle including the
Colla1 siRNA and the FVII siRNA was diluted with PBS to

respective siRNA concentrations of 40 µg/mL and 120 µg/mL, and administered to the orbital sinus of each Balb/c mouse to achieve respective siRNA doses of 0.2 mg/kg and 0.6 mg/kg. Three hours after the administration of the siRNAs, carbon tetrachloride was orally administered to achieve a dose of 0.1 mL/kg. Four days after the administration of carbon tetrachloride, each mouse was euthanized by bleeding under anesthesia with isoflurane, and the liver was removed. From the liver obtained, the total RNA was extracted with an RNeasy Mini Kit (QIAGEN), and the Colla1 mRNA, FVII mRNA, and GAPDH mRNA levels were measured through a quantitative PCR method. The expression reduction rates for Colla1 mRNA and FVII mRNA normalized against the GAPDH mRNA level were calculated with reference to those for mice without siRNA administration, and the following table shows the calculation results.

[0157]

[Table 7]

Compound	COL1A1 Knockdown efficiency (%)	FVII Knockdown efficiency (%)
Example 2	73	0
Example 3	81	0
Example 10	31	0
Example 11	60	0
Example 4	67	19
Example 5	83	14
Example 6	86	27
Example 7	85	24

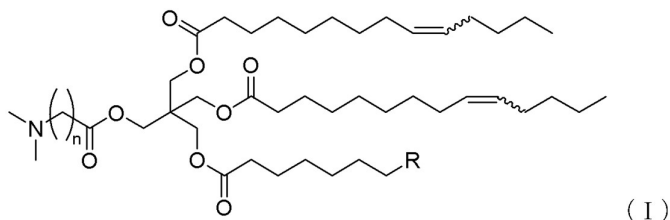
Industrial Applicability

[0158]

The compound, the lipid particle, or the composition of the present invention enables introduction of nucleic acids into various types of cells, tissues, or organs. Accordingly, the compound, the lipid particle, or the composition of the present invention is available as a DDS technique for nucleic acid drugs. In addition, the compound, the lipid particle, or the composition of the present invention is available as a reagent for nucleic acid introduction for research.

CLAIMS

1. A compound represented by formula (I):



5 wherein

n represents an integer of 2 to 5,

R represents a linear C_{1-5} alkyl group, a linear C_{7-11} alkenyl group, or a linear C_{11} alkadienyl group, and

10 wavy lines each independently represent a cis-bond or a trans-bond,
or a salt thereof.

2. 3-((4-(Dimethylamino)butanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate or a
15 salt thereof.

3. 3-((5-(Dimethylamino)pentanoyl)oxy)-2,2-bis(((9Z)-tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate or a
salt thereof.

20

4. 3-((6-(Dimethylamino)hexanoyl)oxy)-2,2-bis(((9Z)-

tetradec-9-enoyloxy)methyl)propyl (9Z)-tetradec-9-enoate or a salt thereof.

5. A lipid particle comprising the compound or a salt
5 thereof according to claim 1.

6. A composition for nucleic acid introduction comprising a nucleic acid and the lipid particle according to claim 5.

10 7. The composition according to claim 6, wherein the nucleic acid is an RNA.

8. The composition according to claim 7, wherein the RNA is an mRNA or an siRNA.