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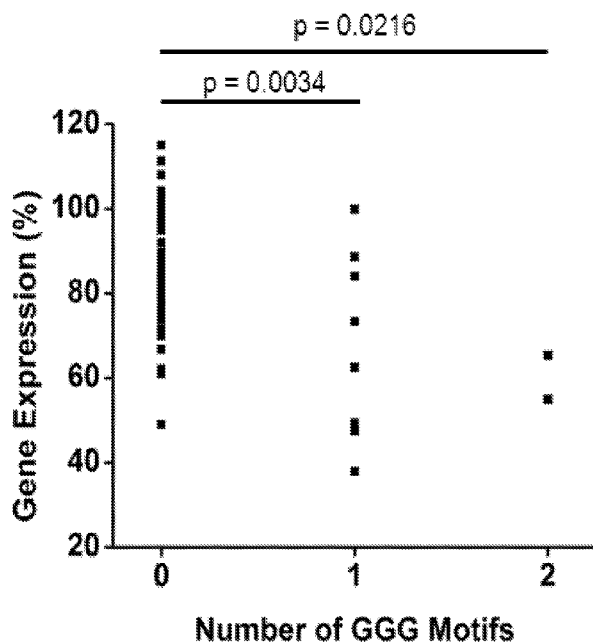
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(54) Title: NUCLEIC ACID NANOSTRUCTURES WITH CORE MOTIFS



(57) Abstract: Optimized inhibitory nucleic acids are provided. The nucleic acids have sequences which include an optimal inhibitory motif, such as a GGG. Related methods are also described.

FIG. 1



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NUCLEIC ACID NANOSTRUCTURES WITH CORE MOTIFS

RELATED APPLICATIONS

This application claims priority under 35 U.S.C. § 119(e) to U.S. Provisional
5 Application Serial No. 62/103,303, entitled “NUCLEIC ACID NANOSTRUCTURES
WITH CORE MOTIFS” filed on January 14, 2015, which is herein incorporated by
reference in its entirety.

BACKGROUND OF THE INVENTION

10 Inhibitory nucleic acids downregulate gene expression through a variety of
mechanisms. Antisense oligonucleotides, for instance, are typically single strands of
DNA or RNA that are at least partially complementary to a chosen target sequence and
function by preventing protein translation of specific messenger RNA strands. Double-
stranded RNA (dsRNA) is another type of inhibitory nucleic acid that can induce
15 sequence-specific posttranscriptional gene silencing in many organisms by a process
known as RNA interference (RNAi). These functional RNAs include at least two types
of small RNA molecules (1) siRNA molecules that induce mRNA degradation, and (2)
miRNAs (microRNAs) that induce translational inhibition. Other small RNAs work at
the transcriptional level by affecting DNA and histone methylation.

20

SUMMARY OF THE INVENTION

In some aspects the invention is a spherical nucleic acid (SNA) having a dense
configuration of oligonucleotides radially positioned around a lipidated structure,
wherein the oligonucleotides have a length of 8-200 nucleotides and include at least one
25 GGG.

In some embodiments the oligonucleotides have the following structure: 5'
X₁GGGX₂ 3' wherein X₁ and X₂ are independently of one another any nucleotide and
optionally wherein X₁ is selected from the group consisting of G and A. In other
embodiments 5' X₁GGGX₂ 3' is selected from the group consisting of GGGG, GGGT,
30 AGGG and GGGC. In other embodiments the at least one GGG is positioned at the 5'
end of the oligonucleotide within the first 10 nucleotides. In yet other embodiments at
least one GGG is positioned at the 3' end of the oligonucleotide within the 10

nucleotides at the 3' end or the at least one GGG is positioned in the center of the oligonucleotide. In other embodiments the oligonucleotides include 2-5 GGG motifs.

In another embodiment the oligonucleotides comprise 2-10,000 oligonucleotides. In other embodiments the oligonucleotides comprise 100-10,000, 500-10,000, 1,000-
5 10,000, 5,000-10,000, 6,000-10,000, 7,000-10,000, 8,000-10,000, 9,000-10,000 or 9,500-10,000 oligonucleotides.

The SNA in some embodiments is not a dendrimer.

In some embodiments the oligonucleotides are antisense oligonucleotides. In other embodiments the oligonucleotides are nucleolipids. In yet other embodiments the
10 oligonucleotides are siRNAs.

In some embodiments the oligonucleotides are comprised of single-stranded or double-stranded DNA oligonucleotides. In other embodiments the oligonucleotides are comprised of single-stranded or double-stranded RNA oligonucleotides. In other
15 embodiments the oligonucleotides are comprised of chimeric RNA-DNA oligonucleotides. In another embodiment the oligonucleotides are comprised of RNA-DNA or DNA-RNA oligonucleotide heteroduplexes. In another embodiment the oligonucleotides are comprised of combinations of single-stranded or double-stranded DNA, RNA, or chimeric RNA-DNA oligonucleotides. In some embodiments the oligonucleotides are double stranded and do not have an overhang. In other embodiments
20 the oligonucleotides are linear.

In another embodiment the oligonucleotides have structurally and nucleotide sequence identical oligonucleotides. In some embodiments the oligonucleotides have at least two structurally and nucleotide sequence different oligonucleotides.

In other embodiments the oligonucleotides have 2-10 different nucleotide
25 sequences.

In an embodiment at least one of the oligonucleotides is a modified oligonucleotide. In some embodiments at least 50% of the oligonucleotides are modified oligonucleotides. In yet other embodiments all of the oligonucleotides are modified oligonucleotides. In some embodiments the oligonucleotides have at least one
30 phosphorothioate linkage. In other embodiments the oligonucleotides do not have a phosphorothioate linkage.

In another embodiment the nanostructure comprises a liposomal core having a lipid bilayer.

In some embodiments at least one oligonucleotide has its 5'-terminus exposed to the outside surface of the nanostructure. In other embodiments all of the oligonucleotides have their 5'-terminus exposed to the outside surface of the nanostructure. In other
5 embodiments at least one oligonucleotide has its 3'-terminus exposed to the outside surface of the nanostructure. All of the oligonucleotides have their 3'-terminus exposed to the outside surface of the nanostructure in other embodiments.

In another embodiment the oligonucleotides are directly linked to the core. In
10 some embodiments the oligonucleotides are indirectly linked to the core through a linker. In other embodiments the oligonucleotides are indirectly linked to the core through more than one linker.

In other embodiments the oligonucleotides are reversibly or irreversibly coupled to the core.

15 In some embodiments the oligonucleotides are linked to the core through a linker. The linker in some embodiments is a chemical structure containing one or more thiol groups, including various chain length alkane thiols, cyclic dithiol, lipoic acid, PEG-thiol, and other thiol group containing linkers. Optionally the oligonucleotides are linked to a liposomal core and the linker is one or more of the following linkers: tocopherols,
20 sphingolipids such as sphingosine, sphingosine phosphate, methylated sphingosines and sphinganine, ceramides, ceramide phosphates, 1-0 acyl ceramides, dihydroceramides, 2-hydroxy ceramides, sphingomyelin, glycosylated sphingolipids, sulfatides, gangliosides, phosphosphingolipids, and phytosphingosines of various lengths and saturation states and their derivatives, phospholipids such as phosphatidylcholines,
25 lysophosphatidylcholines, phosphatidic acids, lysophosphatidic acids, cyclic LPA, phosphatidylethanolamines, lysophosphatidylethanolamines, phosphatidylglycerols, lysophosphatidylglycerols, phosphatidylserines, lysophosphatidylserines, phosphatidylinositols, inositol phosphates, LPI, cardiolipins, lysocardiolipins, bis(monoacylglycero) phosphates, (diacylglycero) phosphates, ether lipids, diphytanyl
30 ether lipids, and plasmalogens of various lengths, saturation states, and their derivatives, sterols such as cholesterol, desmosterol, stigmasterol, lanosterol, lathosterol, diosgenin, sitosterol, zymosterol, zymostenol, 14-demethyl-lanosterol, cholesterol sulfate, DHEA,

DHEA sulfate, 14-demethyl-14-dehydranosterol, sitostanol, campesterol, ether anionic lipids, ether cationic lipids, lanthanide chelating lipids, A-ring substituted oxysterols, B-ring substituted oxysterols, D-ring substituted oxysterols, side-chain substituted oxysterols, double substituted oxysterols, cholestanoic acid derivatives, fluorinated
 5 sterols, fluorescent sterols, sulfonated sterols, phosphorylated sterols, and polyunsaturated sterols of different lengths, saturation states and derivatives thereof.

The core in some embodiments is a solid or hollow core and may be inert, paramagnetic or supramagnetic. In embodiments the solid core is comprised of noble metals, including gold and silver, transition metals including iron and cobalt, metal
 10 oxides including silica, polymers or combinations thereof. In other embodiments the core is a polymeric core and wherein the polymeric core is comprised of amphiphilic block copolymers, hydrophobic polymers including polystyrene, poly(lactic acid), poly(lactic co-glycolic acid), poly(glycolic acid), poly(caprolactone) and other biocompatible polymers.

15 In another embodiment the core is a liposomal core and is comprised of one type of lipid or alternatively is comprised of 2-10 different lipids. The liposomal core in some embodiments is comprised of one or more lipids selected from: sphingolipids such as sphingosine, sphingosine phosphate, methylated sphingosines and sphingamines, ceramides, ceramide phosphates, 1-0 acyl ceramides, dihydroceramides, 2-hydroxy
 20 ceramides, sphingomyelin, glycosylated sphingolipids, sulfatides, gangliosides, phosphosphingolipids, and phytosphingosines of various lengths and saturation states and their derivatives, phospholipids such as phosphatidylcholines, lysophosphatidylcholines, phosphatidic acids, lysophosphatidic acids, cyclic LPA, phosphatidylethanolamines, lysophosphatidylethanolamines, phosphatidylglycerols,
 25 lysophosphatidylglycerols, phosphatidylserines, lysophosphatidylserines, phosphatidylinositols, inositol phosphates, LPI, cardiolipins, lysocardiolipins, bis(monoacylglycero) phosphates, (diacylglycero) phosphates, ether lipids, diphytanyl ether lipids, and plasmalogens of various lengths, saturation states, and their derivatives, sterols such as cholesterol, desmosterol, stigmasterol, lanosterol, lathosterol, diosgenin,
 30 sitosterol, zymosterol, zymostenol, 14-demethyl-lanosterol, cholesterol sulfate, DHEA, DHEA sulfate, 14-demethyl-14-dehydranosterol, sitostanol, campesterol, ether anionic lipids, ether cationic lipids, lanthanide chelating lipids, A-ring substituted oxysterols, B-

ring substituted oxysterols, D-ring substituted oxysterols, side-chain substituted oxysterols, double substituted oxysterols, cholestanoic acid derivatives, fluorinated sterols, fluorescent sterols, sulfonated sterols, phosphorylated sterols, and polyunsaturated sterols of different lengths, saturation states, and derivatives thereof.

5 In another embodiment the SNA further comprises an active agent. In some embodiments the active agent is mixed together with the SNA. In other embodiments the active agent is linked directly to the oligonucleotide shell. In some embodiments the active agent is linked indirectly to the oligonucleotide shell through a linker. In other
10 embodiments the active agent is linked directly to the core. In yet another embodiment the active agent is linked indirectly to the core through a linker. In another embodiment an active agent -oligonucleotide conjugate is linked to the core through oligonucleotide hybridization. In some embodiments the active agent is associated with the core by being embedded within the core, optionally the liposomal core. In some embodiments the active agent is encapsulated within the liposomal core in an inner aqueous layer.

15 In some embodiments the SNA is a self-assembling nanostructure.

 A method for reducing gene expression by contacting a cell with a nanostructure comprising a nucleotide amphiphile having an inhibitory oligonucleotide having at least one GGG motif, wherein gene expression is reduced to a greater extent than when the cell is contacted with free inhibitory oligonucleotide is provided in other aspects of the
20 invention. The nucleotide amphiphile may be a spherical nucleic acid (SNA), as described herein.

 In some embodiments the inhibitory oligonucleotide is an antisense oligonucleotide. In other embodiments the inhibitory oligonucleotide has the following structure: 5' X₁GGGX₂ 3' wherein X₁ and X₂ are independently of one another any
25 nucleotide, wherein X₁ optionally is selected from the group consisting of G and A. In some embodiments 5' X₁GGGX₂ 3' is selected from the group consisting of GGGG, GGGT, AGGG and GGGC.

 In some embodiments the inhibitory oligonucleotide is complementary to a target sequence selected from the group consisting of TNF, Bcl-2, EGFR, mdm2, MyD88,
30 PCSK9, survivin, VEGF, developmental genes (e.g. adhesion molecules, cyclin kinase inhibitors, Wnt family members, Pax family members, Winged helix family members, Hox family members, cytokines/lymphokines and their receptors, growth or

differentiation factors and their receptors, neurotransmitters and their receptors),
 oncogenes (e.g. ABLI, BLC1, BCL6, CBFA1, CBL, CSFIR, ERBA, ERBB, EBRB2,
 ETS1, ETS1, ETV6, FGR, FOX, FYN, HCR, HRAS, JUN, KRAS, LCK, LYN, MDM2,
 MLL, MYB, MYC, MYCL1, MYCN, NRAS, PIM1, PML, RET, SRC, TAL1, TCL3
 5 and YES), tumor suppresser genes (e.g. APC, BRCA1, BRCA2, MADH4, MCC, NF1,
 NF2, RB1, TP53 and WT1), enzymes (e.g. ACP desaturases and hycroxyases, ADP-
 glucose pyrophorylases, ATPases, alcohol dehydrogenases, amylases,
 amyloglucosidases, catalases, cellulases, cyclooxygenases, decarboxylases, dextrinases,
 esterases, DNA and RNA polymerases, galactosidases, glucanases, glucose oxidases,
 10 GTPases, helicases, hemicellulases, integrases, invertases, isomerasases, kinases, lactases,
 lipases, lipoxygenases, lysozymes, pectinesterases, peroxidases, phosphatases,
 phospholipases, phosphorylases, polygalacturonases, proteinases and peptideases,
 pullanases, recombinases, reverse transcriptases, topoisomerases, xylanases), and a TLR
 (e.g. TLR2, TLR3, TLR4, TLR5, TLR6, TLR7, TLR8 and TLR9).

15 The inhibitory oligonucleotide may be a therapeutic agent selected from the
 group consisting of anti-viral agents, anti-tumor agents, and agents for treating inherited
 disorders.

 The method, in some embodiments, is a method for treating a disorder selected
 from the group consisting of an autoimmune disease, an infectious disease, transplant
 20 rejection or graft-versus-host disease, malignancy, a pulmonary disorder, an intestinal
 disorder, a cardiac disorder, sepsis, a spondyloarthropathy, a metabolic disorder, anemia,
 pain, a hepatic disorder, a skin disorder, a nail disorder, rheumatoid arthritis, psoriasis,
 psoriasis in combination with psoriatic arthritis, ulcerative colitis, Crohn's disease,
 vasculitis, Behcet's disease, ankylosing spondylitis, asthma, chronic obstructive
 25 pulmonary disorder (COPD), idiopathic pulmonary fibrosis (IPF), restenosis, diabetes,
 anemia, pain, a Crohn's disease-related disorder, juvenile rheumatoid arthritis (JRA), a
 hepatitis C virus infection, psoriatic arthritis, and chronic plaque psoriasis.

 In another aspect a composition for use in the treatment of disease comprises the
 SNA and embodiments thereof.

30 Each of the limitations of the invention can encompass various embodiments of
 the invention. It is, therefore, anticipated that each of the limitations of the invention
 involving any one element or combinations of elements can be included in each aspect of

the invention. This invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. The details of one or more
5 embodiments of the invention are set forth in the accompanying Detailed Description, Examples, Claims, and Figures. Other features, objects, and advantages of the invention will be apparent from the description and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

10 The accompanying drawings are not intended to be drawn to scale. In the drawings, each identical or nearly identical component that is illustrated in various figures is represented by a like numeral. For purposes of clarity, not every component may be labeled in every drawing. In the drawings:

15 FIG. 1 is a graph depicting data that shows that the presence of a GGG motif in SNA-formulated oligonucleotides correlates with a greater gene knockdown in human keratinocytes. There are statistically significant differences between zero GGG motifs and both one motif ($p = 0.0034$) and two motifs ($p = 0.0216$).

DETAILED DESCRIPTION

20 Methods and products for inhibiting gene expression are provided herein. Optimal sequence motifs for inhibiting gene expression using inhibitory nucleic acids have been discovered herein. In particular it has been discovered that oligonucleotides including at least one GGG motif are more effective at reducing gene expression than similar oligonucleotides that lack the GGG motif.

25 The inhibitory oligonucleotides or inhibitory nucleic acids of the invention preferably have the following structure:



wherein X_1 and X_2 are independently of one another any nucleotide. In some embodiments X_1 is G, A or T. In other embodiments $5' \text{ X}_1\text{GGGX}_2 \text{ 3'}$ is selected from the
30 group consisting of GGGG, GGGT, AGGG and GGGC.

The oligonucleotides may have a single GGG motif or multiple GGG motifs. In some instances the oligonucleotides include 2-10 GGG motifs and/or GGGG, GGGT, AGGG and GGGC GGGG, GGGT, AGGG or GGGC motifs in any combination.

5 The at least one GGG may be positioned anywhere in the oligonucleotide. For instance it may be positioned at the 5' end of the oligonucleotide within the first 10 nucleotides. Alternatively it may be positioned at the 3' end of the oligonucleotide within the 10 nucleotides at the 3' end. The at least one GGG may also be positioned in the center of the oligonucleotide.

10 An oligonucleotide, as used herein, refers to any nucleic acid containing molecule. The terms "oligonucleotide" and "nucleic acid" are used interchangeably to mean multiple nucleotides (i.e., molecules comprising a sugar (e.g., ribose or deoxyribose) linked to a phosphate group and to an exchangeable organic base, which is either a substituted pyrimidine (e.g., cytosine (C), thymidine (T) or uracil (U)) or a substituted purine (e.g., adenine (A) or guanine (G)). The terms shall also include
15 oligonucleosides (i.e., a oligonucleotide minus the phosphate) and any other organic base containing polymer.

The nucleic acid may be DNA, RNA, PNA, LNA, ENA, nucleolipids or combinations or modifications thereof. It may also be single, double or triple stranded. Thus the oligonucleotide may be a wide variety of molecules including but not limited
20 to: single-stranded deoxyribonucleotides, ribonucleotides, and other single-stranded oligonucleotides incorporating one or a multiplicity of modifications known to those skilled in the art, double-stranded deoxyribonucleotides, ribonucleotides, and other double-stranded oligonucleotides incorporating one or a multiplicity of modifications known to those skilled in the art.

25 The inhibitory oligonucleotides, also referred to herein as inhibitory nucleic acids, include but are not limited to antisense nucleic acids (single or double stranded), RNAi oligonucleotides, ribozymes, peptides, DNazymes, peptide nucleic acids (PNAs), triple helix forming oligonucleotides, and aptamers and modified form(s) thereof directed to target sequences in genes, RNA transcripts, or proteins.

30 Antisense nucleic acids include modified or unmodified RNA, DNA, or mixed polymer nucleic acids, and primarily function by specifically binding to matching sequences resulting in modulation of peptide synthesis. Antisense nucleic acid binds to

target RNA by Watson Crick base-pairing and blocks gene expression by preventing ribosomal translation of the bound sequences either by steric blocking or by activating RNase H enzyme. Antisense molecules may also alter protein synthesis by interfering with RNA processing or transport from the nucleus into the cytoplasm.

5 As used herein, the term “antisense nucleic acid” or “antisense oligonucleotide” describes a nucleic acid that is an oligoribonucleotide, oligodeoxyribonucleotide, modified oligoribonucleotide, or modified oligodeoxyribonucleotide which hybridizes under physiological conditions to DNA comprising a particular gene or to an mRNA transcript of that gene and, thereby, inhibits the transcription of that gene and/or the
10 translation of that mRNA. The antisense molecules are designed so as to interfere with transcription or translation of a target gene upon hybridization with the target gene or transcript. Those skilled in the art will recognize that the exact length of the antisense oligonucleotide and its degree of complementarity with its target will depend upon the specific target selected, including the sequence of the target and the particular bases
15 which comprise that sequence.

 Inhibitory oligonucleotides also include a broad range of RNAi-based modalities useful for inhibiting expression of a gene in a cell, such as siRNA-based oligonucleotides and/or altered siRNA-based oligonucleotides. Altered siRNA based oligonucleotides are those modified to alter potency, target affinity, safety profile and/or stability, for
20 example, to render them resistant or partially resistant to intracellular degradation. Modifications, such as phosphorothioates, for example, can be made to oligonucleotides to increase resistance to nuclease degradation, binding affinity and/or uptake. In addition, modification of siRNAs at the 2'-sugar position and phosphodiester linkage confers improved serum stability without loss of efficacy.

25 Ribozymes have also been proposed as a means of both inhibiting gene expression of a mutant gene and of correcting the mutant by targeted trans-splicing. Ribozyme activity may be augmented by the use of, for example, non-specific nucleic acid binding proteins or facilitator oligonucleotides. Multitarget ribozymes (connected or shotgun) have been suggested as a means of improving efficiency of ribozymes for
30 gene suppression. Triple helix approaches have also been investigated for sequence-specific gene suppression. Triple helix forming oligonucleotides have been found in some cases to bind in a sequence-specific manner. Similarly, peptide nucleic acids have

been shown to inhibit gene expression (Hanvey et al., *Antisense Res. Dev.* 1(4):307-17, 1991; Knudsen and Nielson *Nucleic Acids Res.* 24(3):494-500, 1996; Taylor et al., *Arch. Surg.* 132(11):1177-83, 1997). Minor-groove binding polyamides can bind in a sequence-specific manner to DNA targets and hence may represent useful small molecules for suppression at the DNA level. The diverse array of suppression strategies that can be employed includes the use of DNA and/or RNA aptamers that can be selected to target a protein of interest.

In some embodiments the inhibitory oligonucleotide is 100% identical to the nucleic acid target. In other embodiments it is at least 99%, 95%, 90%, 85%, 80%, 75%, 70%, or 50% identical to the nucleic acid target. The term "percent identical" refers to sequence identity between two nucleotide sequences. Percent identity can be determined by comparing a position in each sequence which may be aligned for purposes of comparison. Expression as a percentage of identity refers to a function of the number of identical amino acids or nucleic acids at positions shared by the compared sequences.

Various alignment algorithms and/or programs may be used, including FASTA, BLAST, or ENTREZ-FASTA and BLAST are available as a part of the GCG sequence analysis package (University of Wisconsin, Madison, Wis.), and can be used with, e.g., default settings. ENTREZ is available through the National Center for Biotechnology Information, National Library of Medicine, National Institutes of Health, Bethesda, Md.

Other techniques for alignment are described in *Methods in Enzymology*, vol. 266: *Computer Methods for Macromolecular Sequence Analysis* (1996), ed. Doolittle, Academic Press, Inc., a division of Harcourt Brace & Co., San Diego, Calif., USA. Preferably, an alignment program that permits gaps in the sequence is utilized to align the sequences. The Smith-Waterman is one type of algorithm that permits gaps in sequence alignments. See *Meth. Mol. Biol.* 70: 173-187 (1997). Also, the GAP program using the Needleman and Wunsch alignment method can be utilized to align sequences. An alternative search strategy uses MPSRCH software, which runs on a MASPAR computer. MPSRCH uses a Smith-Waterman algorithm to score sequences on a massively parallel computer. This approach improves ability to pick up distantly related matches, and is especially tolerant of small gaps and nucleotide sequence errors. Nucleic acid-encoded amino acid sequences can be used to search both protein and DNA databases.

An inhibitory oligonucleotide may be designed to have partial or complete complementarity with one or more target genes. Depending on the particular target gene, the nature of the inhibitory oligonucleotide and the level of expression of inhibitory oligonucleotide (e.g. depending on copy number, promoter strength) the procedure may provide partial or complete loss of function for the target gene. Quantitation of gene expression in a cell may show similar amounts of inhibition at the level of accumulation of target mRNA or translation of target protein.

“Inhibition of gene expression” refers to the absence or observable decrease in the level of protein and/or mRNA product from a target gene. “Specificity” refers to the ability to inhibit the target gene without manifest effects on other genes of the cell. The consequences of inhibition can be confirmed by examination of the outward properties of the cell or organism or by biochemical techniques such as RNA solution hybridization, nuclease protection, Northern hybridization, reverse transcription, gene expression monitoring with a microarray, antibody binding, enzyme linked immunosorbent assay (ELISA), Western blotting, radioimmunoassay (RIA), other immunoassays, and fluorescence activated cell analysis (FACS). Depending on the assay, quantitation of the amount of gene expression allows one to determine a degree of inhibition which is greater than 10%, 33%, 50%, 90%, 95% or 99% as compared to a cell not treated according to the present invention. As an example, the efficiency of inhibition may be determined by assessing the amount of gene product in the cell.

In some instances the inhibitory oligonucleotide is a peptide nucleic acid (PNA). PNA oligomers have greater binding strength and specificity in the formation of a PNA/DNA duplex or PNA/DNA/PNA triplex as compared to a DNA/DNA duplex. PNAs also have increased stability to nucleases and proteases over a wide pH range, which makes them resistant to enzymatic degradation.

The oligonucleotides may be a duplex. As used herein, “duplex” includes a double-stranded nucleic acid molecule(s) in which complementary sequences or partially complementary sequences are hydrogen bonded to each other. The complementary sequences can include a sense strand and an antisense strand. A double-stranded oligonucleotide can be double-stranded over its entire length, meaning it has no overhanging single-stranded sequences and is thus blunt-ended. In other embodiments, the two strands of the double-stranded oligonucleotide can have different lengths

producing one or more single-stranded overhangs. A double-stranded oligonucleotide of the invention can contain mismatches and/or loops or bulges. In some embodiments, it is double-stranded over at least about 70%, 80%, 90%, 95%, 96%, 97%, 98% or 99% of the length of the oligonucleotide. In some embodiments, the double-stranded

5 oligonucleotide of the invention contains at least or up to 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, or 15 mismatches.

Oligonucleotides associated with the invention can be modified such as at the sugar moiety, the phosphodiester linkage, and/or the base. As used herein, "sugar moieties" includes natural, unmodified sugars, including pentose, ribose and
10 deoxyribose, modified sugars and sugar analogs. Modifications of sugar moieties can include replacement of a hydroxyl group with a halogen, a heteroatom, or an aliphatic group, and can include functionalization of the hydroxyl group as, for example, an ether, amine or thiol.

Modification of sugar moieties can include 2'-O-methyl nucleotides, which are
15 referred to as "methylated." In some instances, oligonucleotides associated with the invention may only contain modified or unmodified sugar moieties, while in other instances, oligonucleotides contain some sugar moieties that are modified and some that are not.

In some instances, modified nucleomonomers include sugar- or backbone-
20 modified ribonucleotides. Modified ribonucleotides can contain a non-naturally occurring base such as uridines or cytidines modified at the 5'-position, *e.g.*, 5'-(2-amino)propyl uridine and 5'-bromo uridine; adenosines and guanosines modified at the 8-position, *e.g.*, 8-bromo guanosine; deaza nucleotides, *e.g.*, 7-deaza-adenosine; and N-alkylated nucleotides, *e.g.*, N6-methyl adenosine. Also, sugar-modified ribonucleotides
25 can have the 2'-OH group replaced by an H, alkoxy (or OR), R or alkyl, halogen, SH, SR, amino (such as NH₂, NHR, NR₂), or CN group, wherein R is lower alkyl, alkenyl, or alkynyl. In some embodiments, modified ribonucleotides can have the phosphodiester group connecting to adjacent ribonucleotides replaced by a modified group, such as a phosphorothioate group.

30 In some aspects, 2'-O-methyl modifications can be beneficial for reducing undesirable cellular stress responses, such as the interferon response to double-stranded nucleic acids. Modified sugars can include D-ribose, 2'-O-alkyl (including 2'-O-methyl

and 2'-O-ethyl), *i.e.*, 2'-alkoxy, 2'-amino, 2'-S-alkyl, 2'-halo (including 2'-fluoro), 2'-methoxyethoxy, 2'-allyloxy ($-\text{OCH}_2\text{CH}=\text{CH}_2$), 2'-propargyl, 2'-propyl, ethynyl, ethenyl, propenyl, and cyano and the like. The sugar moiety can also be a hexose.

The term "alkyl" includes saturated aliphatic groups, including straight-chain
5 alkyl groups (*e.g.*, methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, *etc.*), branched-chain alkyl groups (isopropyl, tert-butyl, isobutyl, *etc.*), cycloalkyl (alicyclic) groups (cyclopropyl, cyclopentyl, cyclohexyl, cycloheptyl, cyclooctyl), alkyl substituted cycloalkyl groups, and cycloalkyl substituted alkyl groups. In some
10 embodiments, a straight chain or branched chain alkyl has 6 or fewer carbon atoms in its backbone (*e.g.*, C₁-C₆ for straight chain, C₃-C₆ for branched chain), and more preferably 4 or fewer. Likewise, preferred cycloalkyls have from 3-8 carbon atoms in their ring structure, and more preferably have 5 or 6 carbons in the ring structure. The term C₁-C₆ includes alkyl groups containing 1 to 6 carbon atoms.

Unless otherwise specified, the term alkyl includes both "unsubstituted alkyls"
15 and "substituted alkyls," the latter of which refers to alkyl moieties having independently selected substituents replacing a hydrogen on one or more carbons of the hydrocarbon backbone. The term "alkenyl" includes unsaturated aliphatic groups analogous in length and possible substitution to the alkyls described above, but that contain at least one double bond. Unless otherwise specified, the term alkenyl includes both "unsubstituted
20 alkenyls" and "substituted alkenyls," the latter of which refers to alkenyl moieties having independently selected substituents replacing a hydrogen on one or more carbons of the hydrocarbon backbone.

The term "base" includes the known purine and pyrimidine heterocyclic bases, deazapurines, and analogs (including heterocyclic substituted analogs, *e.g.*,
25 aminoethoxy phenoxazine), derivatives (*e.g.*, 1-alkyl-, 1-alkenyl-, heteroaromatic- and 1-alkynyl derivatives) and tautomers thereof. Examples of purines include adenine, guanine, inosine, diaminopurine, and xanthine and analogs (*e.g.*, 8-oxo-N⁶-methyladenine or 7-diazaxanthine) and derivatives thereof. Pyrimidines include, for example, thymine, uracil, and cytosine, and their analogs (*e.g.*, 5-methylcytosine, 5-
30 methyluracil, 5-(1-propynyl)uracil, 5-(1-propynyl)cytosine and 4,4-ethanocytosine). Other examples of suitable bases include non-purinyl and non-pyrimidinyl bases such as 2-aminopyridine and triazines.

The term “nucleoside” includes bases which are covalently attached to a sugar moiety, preferably ribose or deoxyribose. Examples of preferred nucleosides include ribonucleosides and deoxyribonucleosides. Nucleosides also include bases linked to amino acids or amino acid analogs which may comprise free carboxyl groups, free amino groups, or protecting groups. Suitable protecting groups are well known in the art (see P. G. M. Wuts and T. W. Greene, “Protective Groups in Organic Synthesis”, 2nd Ed., Wiley-Interscience, New York, 1999).

As used herein, the term “linkage” used in the context of an internucleotide linkage includes a naturally occurring, unmodified phosphodiester moiety (-O-(PO²⁻)-O-) that covalently couples adjacent nucleomonomers. As used herein, the term “substitute linkage” or “modified linkage” or modified internucleotide linkage” includes any analog or derivative of the native phosphodiester group that covalently couples adjacent nucleomonomers. Substitute linkages include phosphodiester analogs, *e.g.*, phosphorothioate, phosphorodithioate, and P-ethoxyphosphodiester, P-ethoxyphosphodiester, P-alkyloxyphosphotriester, methylphosphonate, and nonphosphorus containing linkages, *e.g.*, acetals and amides. Such substitute linkages are known in the art (*e.g.*, Bjergarde *et al.* 1991. Nucleic Acids Res. 19:5843; Caruthers *et al.* 1991. Nucleosides Nucleotides. 10:47). In certain embodiments, non-hydrolyzable linkages are preferred, such as phosphorothioate linkages.

In some aspects, oligonucleotides of the invention comprise 3' and 5' termini (except for circular oligonucleotides). The 3' and 5' termini of a oligonucleotide can be substantially protected from nucleases, for example, by modifying the 3' or 5' linkages (*e.g.*, U.S. Pat. No. 5,849,902 and WO 98/13526). Oligonucleotides can be made resistant by the inclusion of a “blocking group.” The term “blocking group” as used herein refers to substituents (*e.g.*, other than OH groups) that can be attached to oligonucleotides or nucleomonomers, either as protecting groups or coupling groups for synthesis (*e.g.*, FITC, propyl (CH₂-CH₂-CH₃), glycol (-O-CH₂-CH₂-O-) phosphate (PO₃²⁻), hydrogen phosphonate, or phosphoramidite). “Blocking groups” also include “end blocking groups” or “exonuclease blocking groups” which protect the 5' and 3' termini of the oligonucleotide, including modified nucleotides and non-nucleotide exonuclease resistant structures.

Exemplary end-blocking groups include cap structures (*e.g.*, a 7-methylguanosine cap), inverted nucleomonomers, *e.g.*, with 3'-3' or 5'-5' end inversions (see, *e.g.*, Ortiagao *et al.* 1992. *Antisense Res. Dev.* 2:129), methylphosphonate, phosphoramidite, non-nucleotide groups (*e.g.*, non-nucleotide linkers, amino linkers, conjugates) and the like. The 3' terminal nucleomonomer can comprise a modified sugar moiety. The 3' terminal nucleomonomer comprises a 3'-O that can optionally be substituted by a blocking group that prevents 3'-exonuclease degradation of the oligonucleotide. For example, the 3'-hydroxyl can be esterified to a nucleotide through a 3'→3' internucleotide linkage. For example, the alkyloxy radical can be methoxy, ethoxy, or isopropoxy, and preferably, ethoxy. Optionally, the 3'→3'linked nucleotide at the 3' terminus can be linked by a substitute linkage. To reduce nuclease degradation, the 5' most 3'→5' linkage can be a modified linkage, *e.g.*, a phosphorothioate or a P-alkyloxyphosphotriester linkage. Preferably, the two 5' most 3'→5' linkages are modified linkages. Optionally, the 5' terminal hydroxy moiety can be esterified with a phosphorus containing moiety, *e.g.*, phosphate, phosphorothioate, or P-ethoxyphosphate.

In some aspects, oligonucleotides can be chimeric RNA-DNA oligonucleotides which include both DNA and RNA or DNA-RNA or RNA-DNA duplexes.

The oligonucleotides are preferably in the range of 2 to 1000, 2-500, 2-100, 5-500, 5-100, 10-500, 10-100, 8-100, 8-200, 10-50, 15-500, 15-100, 15-50, 20-500, 20-100, 20-50, or 20-40 bases or nucleotides in length. However, nucleic acids of other sizes are useful.

In some embodiments the oligonucleotides have a modified backbone such as a phosphorothioate (PS) backbone. In other embodiments the oligonucleotides have a phosphodiester (PO) backbone. In yet other embodiments oligonucleotides have a mixed or chimeric PO and PS backbone.

The inhibitory nucleic acids of the invention may be formulated as a nanostructure. The nanostructure typically is a spherical nucleic acid (SNA). An SNA, as used herein, refers to a dense configuration of oligonucleotides radially positioned around a lipidated structure. In some aspects, the invention is an SNA which is composed of a dense configuration of oligonucleotides radially positioned around a lipidated structure, wherein the oligonucleotides have a length of 8 -200 nucleotides and include at least one GGG.

A lipidated structure is a spherical structure composed at least partially of lipids. In some instances the lipidated structure is composed entirely of lipids. The lipids may be arranged, for instance, in a lipid monolayer or a lipid bilayer. The lipids may be arranged around a hollow center, and thus form a hollow core. Alternatively the lipids
5 may be arranged around a non-lipid material that forms a core. The core may be hollow or solid (including porous cores). A hollow core may be, for instance, an empty space surrounded by lipids i.e. a liposomal core or a hollow space surrounded by a non-lipid material. A solid core is a spherical shaped material that does not have a hollow center. Solid cores include porous or other materials having one or more breaks therein.

10 The term spherical as used herein refers to a general shape and does not imply or is not limited to a perfect sphere or round shape. It may include imperfections.

Solid cores can be constructed from a wide variety of materials known to those skilled in the art including but not limited to: noble metals (gold, silver), transition metals (iron, cobalt) and metal oxides (silica). In addition, these cores may be inert,
15 paramagnetic, or supramagnetic. These solid cores can be constructed from either pure compositions of described materials, or in combinations of mixtures of any number of materials, or in layered compositions of materials. In addition, solid cores can be composed of a polymeric core such as amphiphilic block copolymers, hydrophobic polymers such as polystyrene, poly(lactic acid), poly(lactic co-glycolic acid),
20 poly(glycolic acid), poly(caprolactone) and other biocompatible polymers known to those skilled in the art.

The core may alternatively be a hollow core, which has at least some space in the center region of a shell material. Hollow cores include liposomal cores. A liposomal core as used herein refers to a centrally located core compartment formed by a component of
25 the lipids or phospholipids that form a lipid bilayer. "Liposomes" are artificial, self closed vesicular structure of various sizes and structures, where one or several membranes encapsulate an aqueous core. Most typically liposome membranes are formed from lipid bilayers membranes, where the hydrophilic head groups are oriented towards the aqueous environment and the lipid chains are embedded in the lipophilic
30 core. Liposomes can be formed as well from other amphiphilic monomeric and polymeric molecules, such as polymers, like block copolymers, or polypeptides or lipid monolayers. Unilamellar vesicles are liposomes defined by a single membrane enclosing

an aqueous space. In contrast, oligo- or multilamellar vesicles are built up of several membranes. Typically, the membranes are roughly 4 nm thick and are composed of amphiphilic lipids, such as phospholipids, of natural or synthetic origin. Optionally, the membrane properties can be modified by the incorporation of other lipids such as sterols or cholic acid derivatives.

A lipid bilayer is composed of two layers of lipid molecules and a lipid monolayer is composed of one layer of lipid molecules. Each lipid molecule in a layer is oriented substantially parallel to adjacent lipid bilayers, and two layers that form a bilayer have the polar ends of their molecules exposed to the aqueous phase and the non-polar ends adjacent to each other. The central aqueous region of the liposomal core may be empty or filled fully or partially with water, an aqueous emulsion, oligonucleotides, or other therapeutic or diagnostic agent.

“Lipid” is a generic term encompassing fats, lipids, alcohol-ether-soluble constituents of protoplasm, which are insoluble in water. Lipids usually consist of a hydrophilic and a hydrophobic moiety. In water lipids can self organize to form bilayers membranes, where the hydrophilic moieties (head groups) are oriented towards the aqueous phase, and the lipophilic moieties (acyl chains) are embedded in the bilayers core. Lipids can comprise as well two hydrophilic moieties (bola amphiphiles). In that case, membranes may be formed from a single lipid layer, and not a bilayer. Typical examples for lipids in the current context are fats, fatty oils, essential oils, waxes, steroid, sterols, phospholipids, glycolipids, sulpholipids, aminolipids, chromolipids, and fatty acids. The term encompasses both naturally occurring and synthetic lipids. Preferred lipids in connection with the present invention are: steroids and sterol, particularly cholesterol, phospholipids, including phosphatidyl, phosphatidylcholines and phosphatidylethanolamines and sphingomyelins. Where there are fatty acids, they could be about 12-24 carbon chains in length, containing up to 6 double bonds. The fatty acids are linked to the backbone, which may be derived from glycerol. The fatty acids within one lipid can be different (asymmetric), or there may be only 1 fatty acid chain present, e.g. lysolecithins. Mixed formulations are also possible, particularly when the non-cationic lipids are derived from natural sources, such as lecithins (phosphatidylcholines) purified from egg yolk, bovine heart, brain, liver or soybean.

The liposomal core can be constructed from one or more lipids known to those in the art including but not limited to: sphingolipids such as sphingosine, sphingosine phosphate, methylated sphingosines and sphinganine, ceramides, ceramide phosphates, 1-0 acyl ceramides, dihydroceramides, 2-hydroxy ceramides, sphingomyelin, glycosylated sphingolipids, sulfatides, gangliosides, phosphosphingolipids, and phytosphingosines of various lengths and saturation states and their derivatives, phospholipids such as phosphatidylcholines, lysophosphatidylcholines, phosphatidic acids, lysophosphatidic acids, cyclic LPA, phosphatidylethanolamines, lysophosphatidylethanolamines, phosphatidylglycerols, lysophosphatidylglycerols, phosphatidylserines, lysophosphatidylserines, phosphatidylinositols, inositol phosphates, LPI, cardiolipins, lysocardiolipins, bis(monoacylglycero) phosphates, (diacylglycero) phosphates, ether lipids, diphytanyl ether lipids, and plasmalogens of various lengths, saturation states, and their derivatives, sterols such as cholesterol, desmosterol, stigmasterol, lanosterol, lathosterol, diosgenin, sitosterol, zymosterol, zymostenol, 14-demethyl-lanosterol, cholesterol sulfate, DHEA, DHEA sulfate, 14-demethyl-14-dehydrlanosterol, sitostanol, campesterol, ether anionic lipids, ether cationic lipids, lanthanide chelating lipids, A-ring substituted oxysterols, B-ring substituted oxysterols, D-ring substituted oxysterols, side-chain substituted oxysterols, double substituted oxysterols, cholestanoic acid derivatives, fluorinated sterols, fluorescent sterols, sulfonated sterols, phosphorylated sterols, and polyunsaturated sterols of different lengths, saturation states, and their derivatives.

The oligonucleotides are positioned on or coupled to the exterior of the lipidated structure. Coupled may be direct or indirect or reversible or irreversible. Reversibly coupled compounds are associated with one another using a susceptible linkage. A susceptible linkage is one which is susceptible to separation under physiological conditions. For instance Watson crick base pairing is a susceptible linkage. Cleavable linkers are also susceptible linkages.

A dense configuration of oligonucleotides is a collection of oligonucleotides situated in close proximity to one another. At least two oligonucleotides are positioned on the exterior of the lipidated structure. In some embodiments at least 25, 50, 75, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1,000, 2,000, 3,000, 4,000, 5,000, 6,000, 7,000, 8,000, 9,000 or 10,000 oligonucleotides or any range combination thereof are on the

exterior of the lipidated structure. In some embodiments, 1-1000, 2-10,000, 10-500, 50-250, 50-300, 1,000-10,000, 2,000-10,000, 3,000-10,000, 4,000-10,000, 5,000-10,000, 6,000-10,000, 7,000-10,000, 8,000-10,000, 9,000-10,000, or 9,500-10,000 oligonucleotides are present on the surface.

5 In some instances the inhibitory oligonucleotides form an oligonucleotide shell. An oligonucleotide shell is formed when at least 50% of the available surface area of the exterior surface of the lipidated structure includes an oligonucleotide. In some embodiments at least 60%, 70%, 80%, 90%, 95%, 96%, 97% 98% or 99% of the available surface area of the exterior surface of the lipidated structure includes an
10 oligonucleotide.

 The oligonucleotides of the oligonucleotide shell may be oriented in a variety of directions. In some embodiments the oligonucleotides are oriented radially outwards. The orientation of these oligonucleotides can be either 5' distal/3' terminal in relation to the core, or 3' distal/5' terminal in relation to the core. In one embodiment one or a
15 multiplicity of different oligonucleotides are present on the same surface of a single SNA. In all cases, at least 1 oligonucleotide is present on the surface but up to 10,000 can be present.

 The oligonucleotides may be linked to the core or to one another and/or to other molecules such as active agents either directly or indirectly through a linker. The
20 oligonucleotides may be conjugated to a linker via the 5' end or the 3' end, e.g. [Sequence, 5'-3']-Linker or Linker-[Sequence, 5'-3']. Some or all of the oligonucleotides of the nanostructure may be linked to one another either directly or indirectly through a covalent or non-covalent linkage. The linkage of one oligonucleotide to another oligonucleotide may be in addition to or alternatively to the
25 linkage of that oligonucleotide to liposomal core. One or more of the oligonucleotides may also be linked to other molecules such as an alternative therapeutic agent. The oligonucleotides may be linked to the therapeutic either directly or indirectly through a covalent or non-covalent linkage.

 The oligonucleotide shell formed of at least inhibitory oligonucleotide may be
30 anchored to the surface of the lipidated structure or core through one or multiple of linker molecules, including but not limited to: any chemical structure containing one or

multiple thiols, such as the various chain length alkane thiols, cyclic dithiol, lipoic acid, or other thiol linkers known to those skilled in the art.

In an embodiment containing a liposomal core, the oligonucleotide shell may be anchored to the surface of the liposomal core through conjugation to one or a multiplicity of linker molecules including but not limited to: tocopherols, sphingolipids such as sphingosine, sphingosine phosphate, methylated sphingosines and sphingamines, ceramides, ceramide phosphates, 1-0 acyl ceramides, dihydroceramides, 2-hydroxy ceramides, sphingomyelin, glycosylated sphingolipids, sulfatides, gangliosides, phosphosphingolipids, and phytosphingosines of various lengths and saturation states and their derivatives, phospholipids such as phosphatidylcholines, lysophosphatidylcholines, phosphatidic acids, lysophosphatidic acids, cyclic LPA, phosphatidylethanolamines, lysophosphatidylethanolamines, phosphatidylglycerols, lysophosphatidylglycerols, phosphatidylserines, lysophosphatidylserines, phosphatidylinositols, inositol phosphates, LPI, cardiolipins, lysocardiolipins, bis(monoacylglycero) phosphates, (diacylglycero) phosphates, ether lipids, diphytanyl ether lipids, and plasmalogens of various lengths, saturation states, and their derivatives, sterols such as cholesterol, desmosterol, stigmasterol, lanosterol, lathosterol, diosgenin, sitosterol, zymosterol, zymostenol, 14-demethyl-lanosterol, cholesterol sulfate, DHEA, DHEA sulfate, 14-demethyl-14-dehydranosterol, sitostanol, campesterol, ether anionic lipids, ether cationic lipids, lanthanide chelating lipids, A-ring substituted oxysterols, B-ring substituted oxysterols, D-ring substituted oxysterols, side-chain substituted oxysterols, double substituted oxysterols, cholestanoic acid derivatives, fluorinated sterols, fluorescent sterols, sulfonated sterols, phosphorylated sterols, and polyunsaturated sterols of different lengths, saturation states, and their derivatives.

In some embodiments, PEG of different sizes is incorporated into the structure to alter the in vivo properties including but not limited to sizes from 1,000 Da to 40,000 Da.

The nanostructure may also include an active agent. An active agent as used herein is a molecule capable of providing some therapeutic or diagnostic advantage to a cell or subject. Active agents can be attached to the structures by the externally-facing oligonucleotides through covalent or non-covalent, e.g. Watson/Crick hybridization. Alternatively or additionally the active agents may be incorporated into a liposomal

bilayer via conjugation to a hydrophobic moiety. In yet another embodiment, active agent may be incorporated inside the inner aqueous layer of the liposome.

In one embodiment, active agent is conjugated to the liposomal nanostructure via interactions with the oligonucleotide shell. In some instances the active agent –

5 oligonucleotide conjugate is linked to the core through oligonucleotide hybridization. In other words the oligonucleotide is hybridized to a complementary or partially complementary oligonucleotide to form a duplex or partial duplex. One or both of the oligonucleotides of the duplex is linked directly to the core and the active agent which is external facing (on the outside of the lipid bilayer) or which is internal (in the inner

10 aqueous layer) and not directly linked to the core is linked to one or both of the oligonucleotides in the duplex. In another embodiment, active agent is conjugated to the liposomal nanostructure via direct interactions with the core. The active agent can be anchored to the surface of the liposomal core through conjugation to one or a multiplicity of linker molecules including but not limited to: tocopherols, sphingolipids such as

15 sphingosine, sphingosine phosphate, methylated sphingosines and sphingamines, ceramides, ceramide phosphates, 1-0 acyl ceramides, dihydroceramides, 2-hydroxy ceramides, sphingomyelin, glycosylated sphingolipids, sulfatides, gangliosides, phosphosphingolipids, and phytosphingosines of various lengths and saturation states and their derivatives, phospholipids such as phosphatidylcholines,

20 lysophosphatidylcholines, phosphatidic acids, lysophosphatidic acids, cyclic LPA, phosphatidylethanolamines, lysophosphatidylethanolamines, phosphatidylglycerols, lysophosphatidylglycerols, phosphatidylserines, lysophosphatidylserines, phosphatidylinositols, inositol phosphates, LPI, cardiolipins, lysocardiolipins, bis(monoacylglycero) phosphates, (diacylglycero) phosphates, ether lipids, diphytanyl

25 ether lipids, and plasmalogens of various lengths, saturation states, and their derivatives, sterols such as cholesterol, desmosterol, stigmasterol, lanosterol, lathosterol, diosgenin, sitosterol, zymosterol, zymostenol, 14-demethyl-lanosterol, cholesterol sulfate, DHEA, DHEA sulfate, 14-demethyl-14-dehydranosterol, sitostanol, campesterol, ether anionic lipids, ether cationic lipids, lanthanide chelating lipids, A-ring substituted oxysterols, B-

30 ring substituted oxysterols, D-ring substituted oxysterols, side-chain substituted oxysterols, double substituted oxysterols, cholestanoic acid derivatives, fluorinated

sterols, fluorescent sterols, sulfonated sterols, phosphorylated sterols, and polyunsaturated sterols of different lengths, saturation states, and their derivatives.

The invention also encompasses the use of the inhibitory oligonucleotides for reducing gene expression in a cell. The method is achieved by contacting the cell with
5 any of the inhibitory oligonucleotides or nanostructures described herein in order to reduce gene expression. For instance, a nanostructure comprising a nucleotide amphiphile having an inhibitory oligonucleotide having at least one GGG motif may be delivered to a cell to reduce gene expression

A nucleotide amphiphile, as used herein, is a supramolecular structure comprised
10 minimally of inhibitory oligonucleotides and lipids associated with one another through interactions including weak noncovalent chemical bonds. The lipids may be assembled into a liposomal structure which captures an end of the oligonucleotide. In some embodiments the nucleotide amphiphile is a spherical nucleic acid (SNA) as described herein.

The nucleotide amphiphile may be composed, in whole or in part, of nucleolipids. Nucleolipids possessing both nucleic acid components and lipophilic chains components are useful as building blocks for constructing these supramolecular structures because they include a diversity of functional groups capable of cooperative non-covalent interactions combined with specific base-base recognition. Nucleolipids may possess a
20 polar head derived from either a purine base (adenine or guanine) or a pyrimidine base (cytosine, thymine or uracil). These bases can interact through π -stacking and hydrogen bonding, each base-base motif displaying different binding characteristics. The base pairs present in nucleic acids are adenine-thymine and guanine-cytosine in DNA double strands or adenine-uracil and guanine-cytosine in RNA double strands. Each strand of
25 DNA (or RNA) is coupled through H-bonding to the other strand formed by the complementary bases sequence.

Gene expression may be reduced to a greater extent by when the cell is contacted with an inhibitory oligonucleotide in the form of a nanostructure than when the cell is contacted with free inhibitory oligonucleotide. The relative level of gene expression may
30 be assessed using any methods known in the art. For instance, several methods are described herein. The skilled artisan is aware of other methods.

The inhibitory oligonucleotide is complementary to a target sequence. Numerous targets are available and known. In some embodiments the target is selected from the group consisting of TNF, Bcl-2, EGFR, mdm2, MyD88, PCSK9, survivin, VEGF, developmental genes (e.g. adhesion molecules, cyclin kinase inhibitors, Wnt family members, Pax family members, Winged helix family members, Hox family members, cytokines/lymphokines and their receptors, growth or differentiation factors and their receptors, neurotransmitters and their receptors), oncogenes (e.g. ABLI, BLC1, BCL6, CBFA1, CBL, CSFIR, ERBA, ERBB, EBRB2, ETS1, ETS1, ETV6, FGR, FOX, FYN, HCR, HRAS, JUN, KRAS, LCK, LYN, MDM2, MLL, MYB, MYC, MYCL1, MYCN, NRAS, PIM1, PML, RET, SRC, TAL1, TCL3 and YES), tumor suppresser genes (e.g. APC, BRCA1, BRCA2, MADH4, MCC, NF1, NF2, RB1, TP53 and WT1), enzymes (e.g. ACP desaturases and hycroxyases, ADP-glucose pyrophorylases, ATPases, alcohol dehydrogenases, amylases, amyloglucosidases, catalases, cellulases, cyclooxygenases, decarboxylases, dextrinases, esterases, DNA and RNA polymerases, galactosidases, glucanases, glucose oxidases, GTPases, helicases, hemicellulases, integrases, invertases, isomersases, kinases, lactases, lipases, lipoxygenases, lysozymes, pectinesterases, peroxidases, phosphatases, phospholipases, phosphorylases, polygalacturonases, proteinases and peptideases, pullanases, recombinases, reverse transcriptases, topoisomerases, xylanases), and a TLR (e.g. TLR2, TLR3, TLR4, TLR5, TLR6, TLR7, TLR8 and TLR9). In some embodiments the inhibitory oligonucleotide is a therapeutic agent selected from the group consisting of anti-viral agents, anti-tumor agents, and agents for treating inherited disorders.

A nanostructure comprised of an inhibitory oligonucleotide may include multiple copies of the same oligonucleotide. Alternatively the structure may include multiple inhibitory oligonucleotides having different sequences. These different inhibitory oligonucleotides may be directed to the same or different targets, depending on the goal of the study or the therapy.

The invention also encompasses methods for the treatment of a subject having a condition or disease. The disorder may be, for instance, an autoimmune disease, an infectious disease, transplant rejection or graft-versus-host disease, malignancy, a pulmonary disorder, an intestinal disorder, a cardiac disorder, sepsis, a spondyloarthropathy, a metabolic disorder, anemia, pain, a hepatic disorder, a skin

disorder, a nail disorder, rheumatoid arthritis, psoriasis, psoriasis in combination with psoriatic arthritis, ulcerative colitis, Crohn's disease, vasculitis, Behcet's disease, ankylosing spondylitis, asthma, chronic obstructive pulmonary disorder (COPD), idiopathic pulmonary fibrosis (IPF), restenosis, diabetes, anemia, pain, a Crohn's disease-related disorder, juvenile rheumatoid arthritis (JRA), a hepatitis C virus infection, 5 psoriatic arthritis, and chronic plaque psoriasis.

The nanostructure can be combined with other unlinked therapeutic agents for treating the disorder. The nanostructure and/or other therapeutic agent may be administered simultaneously or sequentially. When the other therapeutic agents are 10 administered simultaneously they can be administered in the same or separate formulations, but are administered at the same time. The other therapeutic agents are administered sequentially with one another and with the nanostructure, when the administration of the other therapeutic agents and the nanostructure and the therapeutic agent is temporally separated. The separation in time between the administration of 15 these compounds may be a matter of minutes or it may be longer, e.g., days, weeks, months.

The term "effective amount" of an inhibitory oligonucleotide or a nanostructure containing the inhibitory oligonucleotide refers to the amount necessary or sufficient to realize a desired biologic effect. For example, an effective amount of an inhibitory 20 oligonucleotide or a nanostructure containing the inhibitory oligonucleotide for treating or preventing disease is that amount necessary to prevent the progression or further worsening of the disease or is that amount necessary to decrease the amount severity or duration of the disease that would otherwise occur in the absence of the inhibitory oligonucleotide or a nanostructure containing the inhibitory oligonucleotide. Combined 25 with the teachings provided herein, by choosing among the various active compounds and weighing factors such as potency, relative bioavailability, patient body weight, severity of adverse side-effects and preferred mode of administration, an effective prophylactic or therapeutic treatment regimen can be planned which does not cause substantial toxicity and yet is entirely effective to treat the particular subject. The 30 effective amount for any particular application can vary depending on such factors as the disease or condition being treated, the particular nanostructure being administered the size of the subject, or the severity of the disease or condition. One of ordinary skill in

the art can empirically determine the effective amount of a particular nanostructure without necessitating undue experimentation.

Subject doses of the compounds described herein typically range from about 0.1 µg to 10,000 mg, more typically from about 1 µg/day to 8000 mg, and most typically
5 from about 10 µg to 100 µg. Stated in terms of subject body weight, typical dosages range from about 0.1 µg to 20 mg/kg/day, more typically from about 1 to 10 mg/kg/day, and most typically from about 1 to 5 mg/kg/day.

The inhibitory oligonucleotides or nanostructures containing the inhibitory oligonucleotides of the invention (referred to collectively as SNA) may be delivered to a
10 subject *in vivo* or *ex vivo* for therapeutic and/or diagnostic use or may be used *in vitro*, *ex vivo* or *in vivo* for research purposes. The SNAs may be administered alone or in any appropriate pharmaceutical carrier, such as a liquid, for example saline, or a powder, for administration *in vivo*. They can also be co-delivered with larger carrier particles or within administration devices. The SNAs may be formulated or unformulated. The
15 formulations of the invention can be administered in pharmaceutically acceptable solutions, which may routinely contain pharmaceutically acceptable concentrations of salt, buffering agents, preservatives, compatible carriers, adjuvants, and optionally other therapeutic ingredients. In some embodiments, SNAs are mixed with a substance such as a lotion (for example, aquaphor) and are administered to the skin of a subject,
20 whereby the SNAs are delivered through the skin of the subject. The SNAs may also be sterile.

In other embodiments of the invention, the SNA is administered on a routine schedule. A "routine schedule" as used herein, refers to a predetermined designated period of time. The routine schedule may encompass periods of time which are identical
25 or which differ in length, as long as the schedule is predetermined. For instance, the routine schedule may involve administration of the SNA on a daily basis, every two days, every three days, every four days, every five days, every six days, a weekly basis, a monthly basis or any set number of days or weeks there-between, every two months, three months, four months, five months, six months, seven months, eight months, nine
30 months, ten months, eleven months, twelve months, etc. Alternatively, the predetermined routine schedule may involve administration of the SNA on a daily basis for the first week, followed by a monthly basis for several months, and then every three

months after that. Any particular combination would be covered by the routine schedule as long as it is determined ahead of time that the appropriate schedule involves administration on a certain day.

For use in therapy, an effective amount of the SNAs can be administered to a subject by any mode that delivers the SNAs to the desired cell. Administering pharmaceutical compositions may be accomplished by any means known to the skilled artisan. Routes of administration include but are not limited to oral, parenteral, intramuscular, intravenous, subcutaneous, mucosal, intranasal, sublingual, intratracheal, inhalation, ocular, vaginal, dermal, rectal, and by direct injection.

A subject shall mean a human or vertebrate animal including but not limited to a dog, cat, horse, cow, pig, sheep, goat, turkey, chicken, primate, e.g., monkey, and fish (aquaculture species), e.g. salmon. Thus, the invention can also be used to treat disease in non-human subjects.

As used herein, the term treat, treated, or treating when used with respect to an disorder refers to a prophylactic treatment which increases the resistance of a subject to development of the disease or, in other words, decreases the likelihood that the subject will develop the disease as well as a treatment after the subject has developed the disease in order to fight the disease or prevent the disease from becoming worse.

In another aspect, the present invention is directed to a kit including one or more of the compositions previously discussed. A “kit,” as used herein, typically defines a package or an assembly including one or more of the compositions of the invention, and/or other compositions associated with the invention, for example, as previously described. Each of the compositions of the kit, if present, may be provided in liquid form (e.g., in solution), or in solid form (e.g., a dried powder). In certain cases, some of the compositions may be constitutable or otherwise processable (e.g., to an active form), for example, by the addition of a suitable solvent or other species, which may or may not be provided with the kit. Examples of other compositions that may be associated with the invention include, but are not limited to, solvents, surfactants, diluents, salts, buffers, emulsifiers, chelating agents, fillers, antioxidants, binding agents, bulking agents, preservatives, drying agents, antimicrobials, needles, syringes, packaging materials, tubes, bottles, flasks, beakers, dishes, frits, filters, rings, clamps, wraps, patches, containers, tapes, adhesives, and the like, for example, for using, administering,

modifying, assembling, storing, packaging, preparing, mixing, diluting, and/or preserving the compositions components for a particular use, for example, to a sample and/or a subject.

In some embodiments, a kit associated with the invention includes one or more components of the SNA. For instance the kit may include liposomes for forming a
5 liposome core or a metal for forming a solid core, and or inhibitory oligonucleotides for the exterior of the nanostructure. A kit can also include one or more other therapeutic agents.

A kit of the invention may, in some cases, include instructions in any form that
10 are provided in connection with the compositions of the invention in such a manner that one of ordinary skill in the art would recognize that the instructions are to be associated with the compositions of the invention. For instance, the instructions may include instructions for the use, modification, mixing, diluting, preserving, administering, assembly, storage, packaging, and/or preparation of the compositions and/or other
15 compositions associated with the kit. In some cases, the instructions may also include instructions for the use of the compositions, for example, for a particular use, e.g., to a sample. The instructions may be provided in any form recognizable by one of ordinary skill in the art as a suitable vehicle for containing such instructions, for example, written or published, verbal, audible (e.g., telephonic), digital, optical, visual (e.g., videotape,
20 DVD, etc.) or electronic communications (including Internet or web-based communications), provided in any manner.

The present invention is further illustrated by the following Examples, which in no way should be construed as further limiting. The entire contents of all of the references (including literature references, issued patents, published patent applications,
25 and co-pending patent applications) cited throughout this application are hereby expressly incorporated by reference.

EQUIVALENTS

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

All references, including patent documents, disclosed herein are incorporated by reference in their entirety.

In order that the invention described herein may be more fully understood, the following examples are set forth. The examples described in this application are offered to illustrate the compounds, pharmaceutical compositions, and methods provided herein and are not to be construed in any way as limiting their scope.

EXAMPLES

Example 1: Correlation of Sequence Features with Antisense SNA Potency

Methods

I. Liposomal spherical nucleic acid synthesis

Diioleoylphosphatidylcholine (DOPC) liposomes, approximately 50 nm in diameter, were synthesized via extrusion. Under RNase-free and sterile conditions, the active and negative control antisense oligonucleotides were added liposomes and allowed to stand overnight. The lipids at the 3' end of the oligonucleotides insert into the DOPC bilayer, resulting in an external nucleic acid functionalization of liposome. These SNAs were functionalized with a final loading of 100 antisense strands per liposome. Liposomal SNAs have been found to incorporate nucleic acids essentially quantitatively. SNAs were stored at 4 °C until the day of transfection when they were warmed to room temperature prior to use.

II. Cell culture and transfections

Primary human fetal keratinocytes (HFKs) were maintained in Medium 154 (Life Technologies, M-154CF-500) supplemented with 70 µM calcium chloride and 1% human keratinocyte growth supplement (HKGS, Life Technologies, S-001-K). Primary neonatal human epidermal melanocytes (HEMn) were maintained in Medium 254 (Life Technologies, M-254-500) supplemented with 1% human melanocyte growth supplement (HMGS, Life Technologies, S-002-5). For HFK experiments, cells were seeded at passage 5 at a density of 15,000 cells per well in 96-well tissue culture treated plates. For HEMn experiments, cells were seeded between passages 7-12 in a similar manner to that of the HFKs. HFK cells were treated in quadruplicate with inhibitory SNAs targeting nuclear factor-kappa B1 (NF-κB1), interleukin-22 receptor A1 (IL-

22RA1), interleukin-17 receptor A1 (IL-17RA1), or receptor for advanced glycation end-products (RAGE) and a non-targeting control SNA. In all experiments, the SNA concentration was 5 nM (the corresponding antisense concentration was 500 nM) in fresh maintenance media. HEMn cells were treated in quadruplicate with inhibitory
 5 SNAs targeting tyrosinase (TYR) and a non-targeting control SNA at a final SNA concentration of 5 nM (antisense concentration of 500 nM) in fresh maintenance media. The SNAs were incubated with the cells for 24 hours.

III. *RNA isolation and real-time PCR*

10 Cells were lysed in RLT Buffer (Qiagen) after the 24 hr SNA transfection. RNA was isolated from lysates using the RNEasy 96-well kit (Qiagen) according to the manufacturer's instructions. cDNA was then synthesized from the RNA isolates using a cDNA high capacity reverse transcription kit (Life Technologies). RNA isolates were treated on a thermocycler at 25 °C for 10 minutes, 37 °C for 90 minutes, 85 °C for 5
 15 minutes with a 4° C hold to generate cDNA. RT-PCR was performed using a mixture containing 6 µL of the synthesized cDNA, 4.66 µL LightCycler480 probes master mix (Roche), 0.47 µL of gene specific FAM-labeled probes and primers, and 0.37 µL human glyceraldehyde-3-phosphate dehydrogenase (GAPDH) specific HEX-labeled probe and primers per reaction well of a 384-well optical reaction plate (Roche). The primer and
 20 probe sets for NF-κB1, IL22RA, IL17RA, RAGE, TYR and GAPDH were designed using the known human genome sequence (NCBI reference sequences NM_003998.3 , NM_021258.3, NM_014339.6, NM_001136.4, NM_000372.4 and NM_002046.4 , respectively) and were found to be specific by "blastn" analysis (NCBI). The oligonucleotide probes and primers used can be found in the table below. RT-PCR
 25 reactions, in duplicate, were carried out on the Roche Lightcycler 480 with the following cycle programming: initial denaturation at 95 °C for 10 minutes and then 50 cycles of denaturation at 95 °C for 10 seconds, annealing at 60 °C for 30 seconds and extension at 72 °C for 1 second. Cp values were obtained by analysis with the 2nd derivative method. Relative gene expression was determined by normalization with the housekeeping gene
 30 (GAPDH) and the ΔΔ-Cp method. Each active SNA was compared to its control SNA.

Gene/ Oligonucleotide Name	SEQ ID NO.	Sequence (5'--> 3')
NF-κB1 Forward Primer	1	ACTCTGGCGCAGAAATTAGG
NF-κB1 Reverse Primer	2	TGTAGCCCATTTGTCTCAGG
NF-κB1 Probe	3	/FAM/ACAACATATGAGGTCTCTGGGGGTAC/BHQ1/
IL22RA Forward Primer	4	GCTGCTGACCATCTTGACTG
IL22RA Reverse Primer	5	GGACTGGAATTTACGTGCTG
IL22RA Probe	6	/FAM/CTGAGGACCCCTCGGATCTGCT/BHQ1/
IL17RA Forward Primer	7	AGAAATGCCAGACACTCCAG
IL17RA Reverse Primer	8	GATGGAGATGCCCGTGATG
IL17RA Probe	9	/FAM/CCAATTCCGGACTACATGCCCCT/BHQ1/
RAGE Forward Primer	10	GTCATCTTGTGGCAAAGGC
RAGE Reverse Primer	11	TGATTCAGTTCTGCACGCTC
RAGE Probe	12	/FAM/CAACGCCGAGGAGAGGAGAGGAAGG/BHQ1/
TYR Forward Primer	13	TCCTAACTTACTCAGCCCAGCATC
TYR Reverse Primer	14	TGGCTGTTGTACTCCTCCAATCG
TYR Probe	15	/FAM/TCTCCTCTTGGCAGATTGTCTGTAGCCGA/BHQ1/
GAPDH Forward Primer	16	CAAGGTCATCCATGACAACTTTG
GAPDH Reverse Primer	17	GGGCCATCCACAGTCTTCT
GAPDH Probe	18	/HEX/ACCACAGTCCATGCCATCACTGCCA/BHQ1/

The SNA knockdown data were analyzed as a function of the following antisense strand features: G content, number of G doublets, triplets, and quadruplets, and strand

self-dimerization ΔG (Table 1). In the analysis, the knockdown data against five different genes (Tables 2-6) were merged together.

Results

- 5 The presence of a GGG motif in the sequences of the dataset gives rise to a statistically significant increase in knockdown versus those sequences without the specific motif.

Table 1: Percent mRNA Expression after Treatment with 5nM Hollow SNA

Internal Code	SEQ ID NO.	Molecule	mRNA Target	#GGG	% mRNA Expression
Oligo 5003	19	mAmGmGmUmGmGC*T*T*G*A*G*mGmGmUmAmGmU/iSp18//iSp18//Chol/	IL22RA	1	47.5
Oligo 5303	20	mAmGmGmUmGmGC*T*T*G*A*G*mGmGmUmAmGmU/iSp18//iSp18//Stearyl/	IL22RA	1	37.9
Oligo 5383	21	T*A*G*A*G*T*G*A*G*G*T*C*A*G*G*C*T*T*/isp18//isp18//Chol/	Tyrosinase	0	101.8
Oligo 5389	22	mUmUmAmGmAG*T*G*A*G*G*T*C*A*G*mGmCmUmUmU/isp18//isp18//Stearyl/	Tyrosinase	0	88.0
Oligo 5390	23	mGmUmUmCmCT*C*A*T*T*A*C*C*A*A*mAmUmAmGmC/isp18//isp18//Stearyl/	Tyrosinase	0	88.0
Oligo 5390	24	mG*mU*mU*mC*mC*T*C*A*T*T*A*C*C*A*A*mA*mU*mA*mG*mC*/isp18//isp18//Stearyl/	Tyrosinase	0	97.0
Oligo 5391	25	mCmUmGmAmGT*G*A*A*A*A*C*A*G*C*mAmAmGmAmC/isp18//isp18//Stearyl/	Tyrosinase	0	96.0
Oligo 5392	26	mCmUmCmUmGmCC*T*G*A*A*A*mGmCmUmGmGmC/isp18//isp18//Stearyl/	Tyrosinase	0	88.8
Oligo 5393	27	mU*mC*mA*mU*mG*G*T*T*T*C*C*A*G*G*A*mU*mU*mA*mC*mG*/isp18//isp18//Stearyl/	Tyrosinase	0	92.1
Oligo	28	mG*mA*mG*mC*mA*C*T*G	Tyrosinase	0	104.2

Internal Code	SEQ ID NO.	Molecule	mRNA Target	#GGG	% mRNA Expression
5394		*G*C*A*G*G*T*C*mC*mU*mA*mU*mU//isp18//isp18//Stearyl/	e		
Oligo 5395	29	mU*mU*mC*mC*mU*mC*A*T*T*A*C*C*mA*mA*mA*mU*mA*mG//isp18//isp18//Stearyl/	Tyrosinase	0	95.0
Oligo 5397	30	mG*mU*mG*mC*mU*mG*A*C*C*T*C*C*C*A*T*mG*mU*mA*mC*mU*mC//iSp18//iSp18//Stearyl/	Tyrosinase	0	80.0
Oligo 5399	31	mA*mC*mA*mC*mA*mG*G*C*T*C*T*A*mG*mG*mG*mA*mA*mA//iSp18//iSp18//Stearyl/	Tyrosinase	1	84.0
Oligo 5400	32	mCmAmUmGmGmUT*T*C*C*A*G*mGmAmUmAmC//isp18//isp18//Stearyl/	Tyrosinase	0	77.0
Oligo 5401	33	mUmUmGmGmAmAG*A*A*G*G*C*mUmAmCmAmCmU//isp18//isp18//Stearyl/	Tyrosinase	0	79.0
Oligo 5402	34	mCmCmUmCmUG*C*C*T*G*A*A*A*G*C*mUmGmGmCmC//isp18//isp18//Stearyl/	Tyrosinase	0	75.7
Oligo 5403	35	mGmGmCmUmGA*G*T*A*A*G*T*T*A*G*mGmAmUmUmU//isp18//isp18//Stearyl/	Tyrosinase	0	70.0
Oligo 5417	36	C*A*C*T*A*G*T*T*T*C*C*A*A*G*T*C*A*G*A*T//iSp18//iSp18//Stearyl/	NFKB	0	104.0
Oligo 5418	37	C*A*C*G*C*T*G*A*G*G*T*C*C*A*T*C*T*C//iSp18//isp18//Stearyl/	NFKB	0	115.0
Oligo 5419	38	C*A*A*C*T*G*C*T*G*T*T*C*C*G*G*C*T*G*C//isp18//isp18//Stearyl/	RAGE	0	85.7
Oligo 5481	39	C*C*A*C*G*C*T*G*A*G*G*T*C*C*A*T*C*T*C*C//iSp18//iSp18//Stearyl/	NFKB	0	108.0
Oligo 5484	40	T*G*C*C*A*G*G*T*G*G*C*G*A*C*C*G*T*G//iSp18//isp18//Stearyl/	NFKB	0	76.6
Oligo 5486	41	A*A*C*T*G*C*T*G*T*T*C*C*G*G*C*T*G*C//isp18//isp18//Stearyl/	RAGE	0	78.0

Internal Code	SEQ ID NO.	Molecule	mRNA Target	#GGG	% mRNA Expression
Oligo 5487	42	A*T*G*C*T*G*A*C*A*G*C *A*C*G*G*C*T*T*T*C*/isp18//isp18//Stearyl/	RAGE	0	88.7
Oligo 5488	43	C*T*C*C*T*T*T*C*C*A*T* T*C*C*T*G*T*T*C*A*/isp18//isp18//Stearyl/	RAGE	0	98.9
Oligo 5489	44	mC*mA*mC*mU*mA*G*T*T *T*C*C*A*A*G*T*mC*mA* mG*mA*mU*/iSp18//iSp18//Stearyl/	NFKB	0	103.0
Oligo 5490	45	mA*mU*mG*mC*mC*A*G* G*T*G*G*C*G*A*C*mC*m G*mU*mG*mA*/iSp18//iSp18//Stearyl/	NFKB	0	77.0
Oligo 5491	46	mA*mC*mU*mA*mG*mU*T *T*C*C*A*A*mG*mU*mC* mA*mG*mA*/iSp18//iSp18//Stearyl/	NFKB	0	86.0
Oligo 5492	47	mU*mG*mC*mC*mA*mG*G *T*G*G*C*G*mA*mC*mC* mG*mU*mG*/iSp18//iSp18//Stearyl/	NFKB	0	81.0
Oligo 5493	48	mC*mA*mA*mC*mU*mG*C *T*G*T*T*C*C*mG*mG*mC* *mU*mG*mC*/isp18//isp18//Stearyl/	RAGE	0	49.0
Oligo 5494	49	A*T*G*C*C*A*G*G*T*G*G *C*G*A*C*C*G*T*G*A*/iSp18//iSp18//Stearyl/	NFKB	0	79.6
Oligo 5495	50	mC*mU*mG*mC*mU*mU*C *C*T*T*C*C*mA*mG*mG* mG*mU*mC*/isp18//isp18//Stearyl/	RAGE	1	62.5
Oligo 5500	51	mC*mU*mU*mC*mC*mC*T* C*C*A*A*G*mG*mU*mG*m C*mA*mU*/iSp18//iSp18//Stearyl/	IL22RA	0	152.4
Oligo 5501	52	mC*mC*mC*mA*mC*mU*G *C*A*C*A*G*mU*mC*mA* mG*mG*mG*/iSp18//iSp18//Stearyl/	IL22RA	1	99.9
Oligo 5502	53	mA*mG*mG*mC*mA*mG*T *T*G*C*C*C*mU*mG*mG* mC*mU*mG*/iSp18//iSp18//Stearyl/	IL22RA	0	101.5

Internal Code	SEQ ID NO.	Molecule	mRNA Target	#GGG	% mRNA Expression
Oligo 5506	54	T*C*C*T*G*C*A*G*A*G*A *A*A*G*G*C*C*A*C*C*/iSp 18//iSp18//Stearyl/	IL22RA	0	86.0
Oligo 5509	55	C*T*T*C*C*C*T*C*C*A*A* G*G*T*G*C*A*T*/iSp18//iSp 18//Stearyl/	IL22RA	0	111.3
Oligo 5511	56	A*G*G*C*T*A*T*G*C*C*G *C*T*G*T*G*G*A*/iSp18//iS p18//Stearyl/	IL22RA	0	83.4
Oligo 5544	57	mU*mA*mG*mG*mG*C*G* T*G*T*G*T*G*G*G*mU*mC *mU*mG*mU*/iSp18//iSp18// Stearyl/	IL17RA	2	65.4
Oligo 5551	58	mC*mU*mC*mA*mC*T*C*C *A*C*T*C*A*C*C*mU*mC* mC*mC*mA*/iSp18//iSp18//St earyl/	IL17RA	0	99.5
Oligo 5552	59	mU*mG*mU*mC*mC*T*G*T *T*T*G*C*T*C*T*mC*mC* mU*mG*mU*/iSp18//iSp18//St earyl/	IL17RA	0	79.8
Oligo 5553	60	mA*mG*mA*mC*mG*A*T* A*A*C*C*A*G*A*C*mC*m G*mC*mU*mG*/iSp18//iSp18/ /Stearyl/	IL17RA	0	66.8
Oligo 5554	61	mU*mA*mA*mC*mU*C*T*G *C*A*C*C*C*T*C*mG*mA* mG*mG*mU*/iSp18//iSp18//St earyl/	IL17RA	0	81.0
Oligo 5559	62	T*G*T*C*C*T*G*T*T*T*G* C*T*C*T*C*C*T*G*T*/iSp18 //iSp18//Stearyl/	IL17RA	0	95.6
Oligo 5562	63	mU*mU*mG*mU*mC*A*T*C *A*C*T*T*T*T*G*mU*mC* mA*mC*mA*/iSp18//iSp18//St earyl/	NFKB	0	71.6
Oligo 5563	64	mC*mC*mA*mC*mG*C*T*G *A*G*G*T*C*C*A*mU*mC* mU*mC*mC*/iSp18//iSp18//St earyl/	NFKB	0	61.1
Oligo 5571	65	mU*mG*mU*mC*mU*mG*T *G*C*A*A*A*mU*mC*mC* mC*mC*mA*/iSp18//iSp18//St earyl/	IL22RA	0	102.7

Internal Code	SEQ ID NO.	Molecule	mRNA Target	#GGG	% mRNA Expression
Oligo 5610	66	mUmAmGmGmGC*G*T*G*T*G*T*G*G*mUmCmUmGmU/iSp18//iSp18//Stearyl/	IL17RA	2	54.9
Oligo 5614	67	mCmCmAmCmAT*A*G*T*A*G*G*T*G*C*mAmCmAmAmU/iSp18//iSp18//Stearyl/	IL17RA	0	89.7
Oligo 5618	68	mCmUmCmAmCT*C*C*A*C*T*C*A*C*C*mUmCmCmCmA/iSp18//iSp18//Stearyl/	IL17RA	0	83.0
Oligo 5619	69	mUmGmUmCmCT*G*T*T*T*G*C*T*C*T*mCmCmUmGmU/iSp18//iSp18//Stearyl/	IL17RA	0	84.5
Oligo 5621	70	mAmGmAmCmGA*T*A*A*C*C*A*G*A*C*mCmGmCmUmG/iSp18//iSp18//Stearyl/	IL17RA	0	73.9
Oligo 5622	71	mUmAmAmCmUC*T*G*C*A*C*C*C*T*C*mGmAmGmGmU/iSp18//iSp18//Stearyl/	IL17RA	0	62.1
Oligo 5623	72	mAmCmUmAmGmUT*T*C*C*A*A*mGmUmCmAmGmA/iSp18//iSp18//Stearyl/	NFKB	0	71.4
Oligo 5624	73	mCmUmGmCmUmUC*C*T*T*C*C*mAmGmGmGmUmC/iSp18//iSp18//Stearyl/	RAGE	1	49.4
Oligo 5630	74	mUmCmCmCmAC*T*G*C*A*C*A*G*T*C*mAmGmGmGmC/iSp18//iSp18//Stearyl/	IL22RA	1	73.3
Oligo 5631	75	mCmAmGmGmCA*G*T*T*G*C*C*C*T*G*mGmCmUmGmG/iSp18//iSp18//Stearyl/	IL22RA	0	75.7
Oligo 5632	76	mCmUmCmCmCT*T*G*G*C*C*T*C*T*A*mCmUmCmUmG/iSp18//iSp18//Stearyl/	IL22RA	0	96.5
Oligo 5636	77	mUmGmUmCmUmGT*G*C*A*A*A*mUmCmCmCmA/iSp18//iSp18//Stearyl/	IL22RA	0	84.0
Oligo 5638	78	mAmGmGmCmAmGT*T*G*C*C*C*mUmGmGmCmUmG/iSp18//iSp18//Stearyl/	IL22RA	0	95.5
Oligo 5646	79	A*G*G*C*A*G*T*T*G*C*C*C*T*G*G*C*T*G*/iSp18//iSp18//Stearyl/	IL22RA	0	87.3
Oligo 5710	80	mUmGmGmUmAA*T*G*G*G*T*A*G*A*T*mUmCmGmUmU/iSp18//iSp18//Stearyl/	IL17RA	1	88.7

Internal Code	SEQ ID NO.	Molecule	mRNA Target	#GGG	% mRNA Expression
Oligo 5909	81	mGmUmUmUmCmAC*C*A* C*C*C*mAmAmUmUmCmC/i Sp18//iSp18//Stearyl/	Control	0	N/A
Oligo 5416	82	mGmUmUmUmCmAC*C*A* C*C*C*mAmAmUmUmCmC/i Sp18//iSp18//Chol/	Control	0	N/A

mN = 2' O-Methyl RNA

* = Phosphorothioate internucleotide linkage

iSp18 = hexa(ethylene glycol) phosphodiester

Stearyl = Octadecyl phosphodiester (www.glenresearch.com/ProductFiles/10-1979.html)

5 Chol = cholesteryl tetra(ethylene glycol) (CLP-2795 from ChemGenes)

Gene	RefSeq	Citation	Comments
IL22RA	NM_021258.3	J. Biol. Chem. 275 (40), 31335-31339 (2000)	The protein encoded by this gene belongs to the class II cytokine receptor family, and has been shown to be a receptor for interleukin 22 (IL22). It is implicated in a variety of inflammatory conditions, including psoriasis.
RAGE/AGER	NM_001136.4	J. Biol. Chem. 267 (21), 14998-15004 (1992)	The advanced glycosylation end product (AGE) receptor encoded by this gene is a member of the immunoglobulin superfamily of cell surface receptors. It is a multiligand receptor, and besides AGE, interacts with other molecules implicated in homeostasis, development, and inflammation, and certain diseases, such as diabetes and Alzheimer's disease. Many alternatively spliced transcript variants encoding different isoforms, as well as non-protein-coding variants, have been described for this gene. It is related to aging and skin care.
Tyrosinase	NM_000372.4	Science 217 (4565), 1163-1165 (1982)	The enzyme encoded by this gene catalyzes the first 2 steps, and at least 1 subsequent step, in the conversion of tyrosine to melanin. The enzyme has both tyrosine hydroxylase and dopa oxidase catalytic activities, and requires copper for function. Mutations in this gene result in oculocutaneous albinism, and nonpathologic polymorphisms result in skin pigmentation variation. The human genome contains a pseudogene similar to the 3' half of this gene.
IL17RA	NM_014339.6	Trends in Pharmacol	Interleukin 17A (IL17A) is a proinflammatory cytokine secreted by activated T-lymphocytes.

Gene	RefSeq	Citation	Comments
		ogical Sciences 30 (2), 95-103 (2009)	It is a potent inducer of the maturation of CD34-positive hematopoietic precursors into neutrophils. The protein encoded by this gene (interleukin 17A receptor; IL17RA) is a ubiquitous type I membrane glycoprotein that binds with low affinity to interleukin 17A. Interleukin 17A and its receptor play a pathogenic role in many inflammatory and autoimmune diseases such as rheumatoid arthritis.
NFkB1	NM_003998.3	Annu. Rev. Immunol. 14: 649–83	NF-KB (nuclear factor kappa-light-chain-enhancer of activated B cells) is a protein complex that controls transcription of DNA. NF-KB is found in almost all animal cell types and is involved in cellular responses to stimuli such as stress, cytokines, free radicals, ultraviolet irradiation, oxidized LDL, and bacterial or viral antigens. NF-KB plays a key role in regulating the immune response to infection (K light chains are critical components of immunoglobulins). Incorrect regulation of NF-KB has been linked to cancer, inflammatory, and autoimmune diseases, septic shock, viral infection, and improper immune development.

This application refers to various issued patents, published patent applications, journal articles, and other publications, all of which are incorporated herein by reference. If there is a conflict between any of the incorporated references and the instant

5 specification, the specification shall control. In addition, any particular embodiment of the present invention that falls within the prior art may be explicitly excluded from any one or more of the claims. Because such embodiments are deemed to be known to one of ordinary skill in the art, they may be excluded even if the exclusion is not set forth explicitly herein. Any particular embodiment of the invention can be excluded from any

10 claim, for any reason, whether or not related to the existence of prior art.

Those skilled in the art will recognize or be able to ascertain using no more than routine experimentation many equivalents to the specific embodiments described herein. The scope of the present embodiments described herein is not intended to be limited to the above Description, but rather is as set forth in the appended claims. Those of

15 ordinary skill in the art will appreciate that various changes and modifications to this

description may be made without departing from the spirit or scope of the present invention, as defined in the following claims.

CLAIMS

We claim:

1. A spherical nucleic acid (SNA) comprising, a dense configuration of oligonucleotides radially positioned around a lipidated structure, wherein the oligonucleotides have a length of 8-200 nucleotides and include at least one GGG.
2. The SNA of claim 1, wherein the oligonucleotides have the following structure:
5' X₁GGGX₂ 3'
wherein X₁ and X₂ are independently of one another any nucleotide.
3. The SNA of claim 2, wherein X₁ is selected from the group consisting of G and A.
4. The SNA of claim 2 or 3, wherein 5' X₁GGGX₂ 3' is selected from the group consisting of GGGG, GGGT, AGGG and GGGC.
5. The SNA of any one of claims 1-4, wherein the oligonucleotides are antisense oligonucleotides.
6. The SNA of any one of claims 1-5, wherein the oligonucleotides include 2-5 GGG motifs.
7. The SNA of any one of claims 1-6, wherein the SNA structure contains 2-10,000 oligonucleotides.
8. The SNA of any one of claims 1-7, wherein the SNA is not a dendrimer.
9. The SNA of any one of claims 1-8, wherein the oligonucleotides are linked to a core.
10. The SNA of claim 9, wherein the core is the lipidated structure and is a liposomal core.
11. The SNA of claim 10, wherein the liposomal core is comprised of one type of lipid.
12. The SNA of claim 10, wherein the liposomal core is comprised of 2-10 different lipids.
13. The SNA of claim 9, wherein the core is a solid or hollow core.
14. The SNA of claim 9, wherein the core is inert, paramagnetic or supramagnetic.
15. The SNA of claim 9, wherein the core is a solid core.

16. The SNA of claim 15, wherein the solid core is comprised of noble metals, including gold and silver, transition metals including iron and cobalt, metal oxides including silica, polymers or combinations thereof.

17. The SNA of claim 16, wherein the core is a polymeric core and wherein the
5 polymeric core is comprised of amphiphilic block copolymers, hydrophobic polymers including polystyrene, poly(lactic acid), poly(lactic co-glycolic acid), poly(glycolic acid), poly(caprolactone) and other biocompatible polymers.

18. The SNA of any one of claims 1-17, wherein the oligonucleotides have 5'-terminus exposed to the outside surface of the SNA.

10 19. The SNA of any one of claims 1-17, wherein the oligonucleotides have 3'-terminus exposed to the outside surface of the SNA.

20. The SNA of any one of claims 1-17, wherein the oligonucleotides are directly linked to the core.

15 21. The SNA of any one of claims 1-17, wherein the oligonucleotides are indirectly linked to the core through a linker.

22. The SNA of any one of claims 1-17, wherein the oligonucleotides are nucleolipids.

23. The SNA of any one of claims 1-4 or 6-17, wherein the oligonucleotides are siRNAs.

20 24. The SNA of any one of claims 1-23, wherein the oligonucleotides are single stranded.

25. The SNA of any one of claims 1-24, wherein the oligonucleotides are linear.

26. The SNA of any one of claims 1-24, wherein the oligonucleotides are double stranded and do not have an overhang.

25 27. The SNA of any one of claims 1-26, wherein the at least one GGG is positioned at the 5' end of the oligonucleotide within the first 10 nucleotides.

28. The SNA of any one of claims 1-26, wherein the at least one GGG is positioned at the 3' end of the oligonucleotide within the 10 nucleotides at the 3' end.

30 29. The SNA of any one of claims 1-26, wherein the at least one GGG is positioned in the center of the oligonucleotide.

30. A method for reducing gene expression, comprising

contacting a cell with a nanostructure comprising a nucleotide amphiphile having an inhibitory oligonucleotide having at least one GGG motif, wherein gene expression is reduced to a greater extent than when the cell is contacted with free inhibitory oligonucleotide.

5 31. The method of claim 30, wherein the nucleotide amphiphile is a spherical nucleic acid (SNA)

32. The method of claim 31, wherein the SNA is an SNA of any of claims 1-29.

33. The method of claim 30 or 31, wherein the inhibitory oligonucleotide is an antisense oligonucleotide.

10 34. The method of claim 30 or 31, wherein the inhibitory oligonucleotide has the following structure:

5' X₁GGGX₂ 3'

wherein X₁ and X₂ are independently of one another any nucleotide.

15 35. The method of claim 34, wherein X₁ is selected from the group consisting of G and A.

36. The method of claim 34 or 35, wherein 5' X₁GGGX₂ 3' is selected from the group consisting of GGGG, GGGT, AGGG and GGGC.

37. The method of any of claims 30-36, wherein the inhibitory oligonucleotide is complementary to a target sequence selected from the group consisting of TNF, Bcl-2, EGFR, mdm2, MyD88, PCSK9, survivin, VEGF, developmental genes (e.g. adhesion molecules, cyclin kinase inhibitors, Wnt family members, Pax family members, Winged helix family members, Hox family members, cytokines/lymphokines and their receptors, growth or differentiation factors and their receptors, neurotransmitters and their receptors), oncogenes (e.g. ABLI, BCL1, BCL6, CBFA1, CBL, CSFIR, ERBA, ERBB, EBRB2, ETS1, ETS1, ETV6, FGR, FOX, FYN, HCR, HRAS, JUN, KRAS, LCK, LYN, MDM2, MLL, MYB, MYC, MYCL1, MYCN, NRAS, PIM1, PML, RET, SRC, TAL1, TCL3 and YES), tumor suppresser genes (e.g. APC, BRCA1, BRCA2, MADH4, MCC, NF1, NF2, RB1, TP53 and WT1), enzymes (e.g. ACP desaturases and hycroxyases, ADP-glucose pyrophorylases, ATPases, alcohol dehycrogenases, amylases, amyloglucosidases, catalases, cellulases, cyclooxygenases, decarboxylases, dextrinases, esterases, DNA and RNA polymerases, galactosidases, glucanases, glucose oxidases, GTPases, helicases, hemicellulases, integrases, invertases, isomersases, kinases, lactases,

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lipases, lipoxygenases, lysozymes, pectinesterases, peroxidases, phosphatases, phospholipases, phosphorylases, polygalacturonases, proteinases and peptidases, pullanases, recombinases, reverse transcriptases, topoisomerases, xylanases), and a TLR (e.g. TLR2, TLR3, TLR4, TLR5, TLR6, TLR7, TLR8 and TLR9).

5 38. The method of any of claims 30-36, wherein the inhibitory oligonucleotide is a therapeutic agent selected from the group consisting of anti-viral agents, anti-tumor agents, and agents for treating inherited disorders.

 39. The method of any of claims 30-36, wherein the method is a method for treating a disorder selected from the group consisting of an autoimmune disease, an
10 infectious disease, transplant rejection or graft-versus-host disease, malignancy, a pulmonary disorder, an intestinal disorder, a cardiac disorder, sepsis, a spondyloarthropathy, a metabolic disorder, anemia, pain, a hepatic disorder, a skin disorder, a nail disorder, rheumatoid arthritis, psoriasis, psoriasis in combination with psoriatic arthritis, ulcerative colitis, Crohn's disease, vasculitis, Behcet's disease,
15 ankylosing spondylitis, asthma, chronic obstructive pulmonary disorder (COPD), idiopathic pulmonary fibrosis (IPF), restenosis, diabetes, anemia, pain, a Crohn's disease-related disorder, juvenile rheumatoid arthritis (JRA), a hepatitis C virus infection, psoriatic arthritis, and chronic plaque psoriasis.

 40. An inhibitory oligonucleotide comprising a nucleolipid comprising a lipid
20 linked to an oligonucleotide having a nucleotide sequence that includes at least one GGG, wherein the oligonucleotide has a length of 8 -200 nucleotides and wherein 30%-90% of the nucleotides are modified.

 41. The inhibitory oligonucleotide of claim 40, wherein the oligonucleotide has the following structure:

25 5' X₁GGGX₂ 3'

wherein X₁ and X₂ are independently of one another any nucleotide.

 42. The inhibitory oligonucleotide of claim 41, wherein X₁ is selected from the group consisting of G and A.

 43. The inhibitory oligonucleotide of claim 41 or claim 42, wherein 5'
30 X₁GGGX₂ 3' is selected from the group consisting of GGGG, GGGT, AGGG and GGGC.

44. The inhibitory oligonucleotide of any one of claims 40-43, wherein the oligonucleotide is an antisense oligonucleotide.

45. The inhibitory oligonucleotide of any one of claims 40-44, wherein the oligonucleotide includes 2-5 GGG motifs.

5 46. The inhibitory oligonucleotide of any one of claims 40-45, wherein the lipid is stearyl or cholesterol.

47. The inhibitory oligonucleotide of any one of claims 40-46, wherein the nucleotide modifications are phosphorothioate modifications.

10 48. The inhibitory oligonucleotide of any one of claims 40-46, wherein the nucleotide modifications are 2'O Methyl modifications.

49. The inhibitory oligonucleotide of any one of claims 40-46, wherein 40%-70% of the nucleotides are modified.

50. The inhibitory oligonucleotide of any one of claims 40-49, wherein the oligonucleotide is comprised of at least 40% G.

15 51. The inhibitory oligonucleotide of any one of claims 40-49, wherein the oligonucleotide is comprised of at least 50% G.

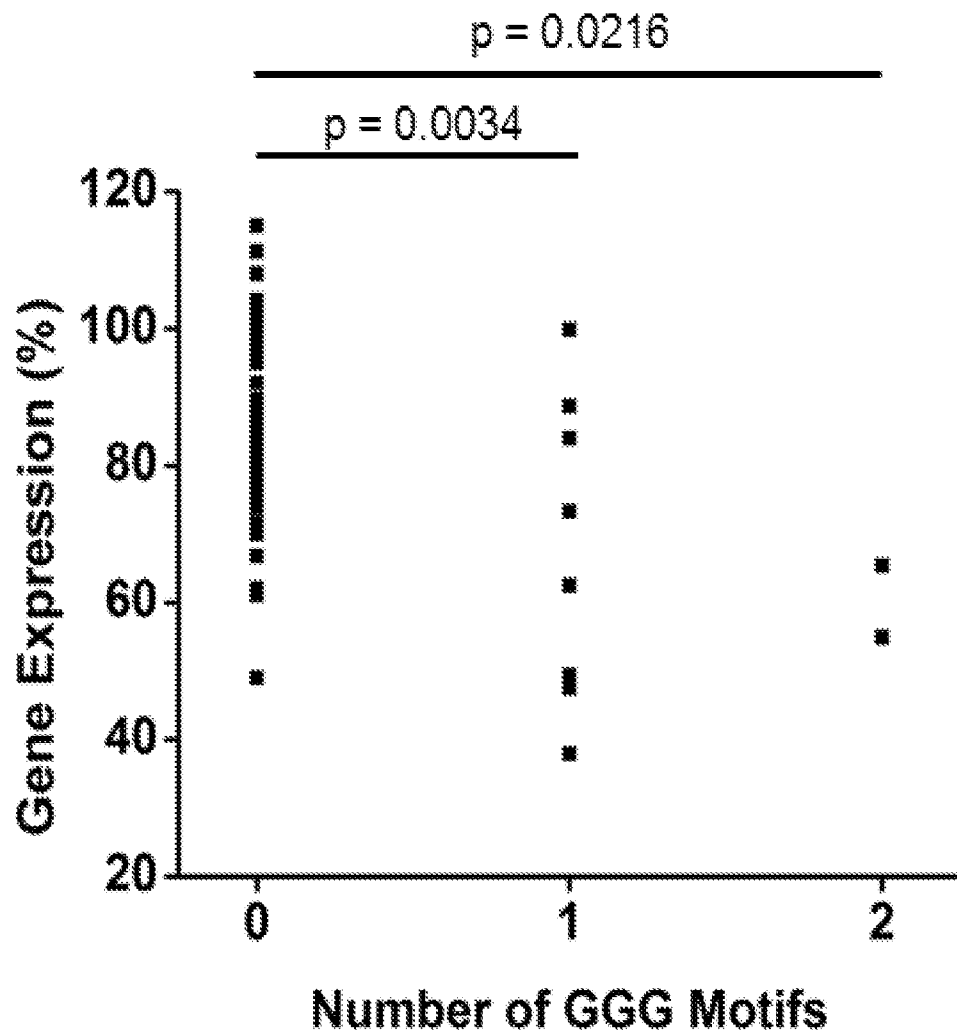


FIG. 1

INTERNATIONAL SEARCH REPORT

 International application No.
PCT/US2016/013365

A. CLASSIFICATION OF SUBJECT MATTER

C12N 15/00 (2006.01) A61K 48/00 (2006.01) A61K 9/51 (2006.01) A61K 47/48 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPIAP, EPODOC, MEDLINE, CAPLUS, BIOSIS & keywords: spherical, microsphere, nanoparticle, oligonucleotide, lipid, nucleolipid, antisense, siRNA and like terms

GOOGLE Scholar: spherical, nucleic acid, particle, lipid, antisense, siRNA and like terms

Auspat, Espacenet, PubMed: Inventor names

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 16 May 2016	Date of mailing of the international search report 16 May 2016
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustalia.gov.au	Authorised officer Alan Brownlee AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61 2 62832943

Box No. I Nucleotide and/or amino acid sequence(s) (Continuation of item 1.c of the first sheet)

1. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of a sequence listing filed or furnished:
 - a. (means)
☐ on paper
☒ in electronic form
 - b. (time)
☐ in the international application as filed
☒ together with the international application in electronic form
☐ subsequently to this Authority for the purposes of search
2. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
3. Additional comments:
There was a sequence listing originally filed but it was not used for the purposes of this search and opinion

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/US2016/013365
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2009/051451 A2 (KOREA ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY) 23 April 2009 para. [49], [76]; Experimental Example 6	1-5, 7, 8, 18, 19, 23-39
X	WO 2014/025795 A1 (TORCHILIN et al.) 13 February 2014 Abstract; Figs 1, 7; paras [0008], [0013], [0014], [0039], [0046], [0049], [0067], [[0079], [0083]-[0085]; Examples 14, 15; claims	1-5, 7, 8, 18, 19, 23-39
X	BANGA, R.J. et al., "Liposomal spherical nucleic acids", Journal of the American Chemical Society. 2014, vol. 136, pages 9866-9869 Abstract; Scheme 1; Supplementary information; Fig. 4D; page 9868, col. 2, para. 1	1-5, 7-51
X	KONG, W.H. et al., "Cationic lipid-coated gold nanoparticles as efficient and non-cytotoxic intracellular siRNA delivery vehicles", Pharmaceutical Research. 2012, vol. 29, pages 362-374 Introduction; Materials; page 368 and Fig. 4	1-5, 7, 8, 18, 19, 23-39
X	US 0295129 A1 (MASSACHUSETTS INSTITUTE OF TECHNOLOGY) 07 November 2013 Figs 1D, 2F, 3A, 7A; Paras [18]-[23], [47]-[48], [0065], [0076]-[0094], [0122]-[0126], [0270]-[0271]	1-51
X	US 2009/0322327 A1 (GAO) 31 December 2009 Abstract; Figs. 1A, 9A; [0016], [0045], [0061], [0070], [0074]-[0075], [0086]-[0091]; Examples 1 and 2	1-5, 7, 8, 18, 19, 23-39
A	WU, Y. et al., "DNA aptamer-micelle as an efficient detection/delivery vehicle toward cancer cells", Proceedings of the National Academy of Sciences, USA. 2010, vol. 107, pages 5-10 Fig. 1; Table 1	
A	WO 2014/088830 A2 (THE REGENTS OF THE UNIVERSITY OF CALIFORNIA) 12 June 2014 Abstract	
A	CHO, Y.-S. et al., "Targeted delivery of siRNA-generating DNA nanocassettes using multifunctional nanoparticles", Small. 2013, vol. 9, pages 1964-1973 Figs 1, 2; Experimental Section	
Form PCT/ISA/210 (fifth sheet) (July 2009)		

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

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

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

See Supplemental Box for Details

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

Remark on Protest

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

Supplemental Box**Continuation of: Box III**

This International Searching Authority has found that there are different inventions as follows:

- Claims 1-29 (completely) are directed to a spherical nucleic acid comprising (inhibitory) oligonucleotides radially positioned around a lipidated structure with a length of 8-200 nucleotides and including at least one GGG. It is considered that *spherical nucleic acids comprising (inhibitory) oligonucleotides positioned around a lipidated structure including at least one GGG* involves a first distinguishing feature. Note that the restriction of claim 1 to the feature of the oligonucleotides being *inhibitory* oligonucleotides is as discussed in Box VIII.
- Claims 30-39 (completely) are directed to a method for reducing gene expression comprising contacting a cell with a nanostructure comprising a nucleotide amphiphile having an inhibitory oligonucleotide having at least one GGG motif. It is considered that the *method for reducing gene expression comprising contacting a cell with a nanostructure comprising a nucleotide amphiphile having an inhibitory oligonucleotide having at least one GGG motif* comprises a second distinguishing feature.
- Claim 40-51 (completely) are directed to an inhibitory oligonucleotide comprising a nucleolipid comprising a lipid linked to an oligonucleotide having a nucleotide sequence that includes at least one GGG, a length of 8-200 nucleotides and wherein 30-90% of the nucleotides are modified. It is considered that *an inhibitory oligonucleotide comprising a nucleolipid comprising a lipid linked to an oligonucleotide having a nucleotide sequence that includes at least one GGG, a length of 8-200 nucleotides and wherein 30-90% of the nucleotides are modified* comprises a third distinguishing feature.

The only feature common to all of the inventions is an inhibitory oligonucleotide including at least one GGG. However this concept is not novel in the light of a substantial body of prior art of which the following is merely representative:

D1: WO 2009/051451 A2 (BALDWIN et al) 23 April 2009

This means that the common feature can not constitute a special technical feature within the meaning of PCT Rule 13.2, second sentence, since it makes no contribution over the prior art *a posteriori*.

While the claims relate to any (inhibitory) nucleotide, the search and examination has been limited to the inhibitory nucleotide being a small antisense oligonucleotide (see Box VIII).

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/US2016/013365	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
WO 2009/051451 A2	23 April 2009	WO 2009051451 A2	23 Apr 2009
		CN 101903018 A	01 Dec 2010
		CN 101903018 B	05 Sep 2012
		EP 2217221 A2	18 Aug 2010
		JP 2011500671 A	06 Jan 2011
		JP 5336500 B2	06 Nov 2013
		KR 20100085079 A	28 Jul 2010
		KR 101198354 B1	14 Mar 2013
		US 2010297242 A1	25 Nov 2010
WO 2014/025795 A1	13 February 2014	WO 2014025795 A1	13 Feb 2014
		US 2015216991 A1	06 Aug 2015
US 0295129 A1	07 November 2013	None	
US 2009/0322327 A1	31 December 2009	US 2009322327 A1	31 Dec 2009
		US 8063131 B2	22 Nov 2011
WO 2014/088830 A2	12 June 2014	WO 2014088830 A2	12 Jun 2014
		EP 2931948 A2	21 Oct 2015
		US 2016130575 A1	12 May 2016
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.			