MULTIPLE OLIGONUCLEOTIDE MOIETIES ON PEPTIDE CARRIER

CROSS-REFERENCE TO RELATED APPLICATION

[001] This application claims the benefit of priority to U.S. Provisional Patent Application No. 62/002,296, filed May 23, 2014, which is hereby incorporated by reference in its entirety.

DESCRIPTION OF THE INVENTION

Field of the Invention

[002] The present disclosure relates to antisense oligonucleotides (AONs), such as, but not limited to, phosphorodiamidate morpholino oligonucleotides (PMOs). The present disclosure further relates to the conjugation of multiple PMOs to cationic cell penetrating peptides (CPPs) to enhance the uptake of PMOs into tissues of interest, such as skeletal and cardiac muscle cells. The present disclosure encompasses such conjugates, as well as methods of their use, including for example, using them to modulate gene expression. The present disclosure further includes methods of treating various disease states by administering to a human or animal in need thereof said multiple PMO-CPP conjugates.

Summary of the Invention

[003] AONs have been shown to successfully modulate gene expression both *in vitro* and *in vivo* in various disease states, including for example Duchenne muscular dystropy (DMD). In particular, PMOs designed to target and remove the in-frame exon 23 have been successful at restoring dystrophin function in the *mdx* mouse model of DMD.

[004] However, AONs have also been shown to exhibit a poor uptake profile in skeletal and cardiac muscle cells, which hampers their ability to affect

mRNA transcription and translation. (WO 2009/147368) In particular, PMOs, 2-O-methyl oligonucleotides, and peptide nucleic acids (PNAs) do not appreciably accumulate in skeletal muscle and their uptake in heart muscle is negligible.

[005] Cell penetrating peptides (CPPs) were discovered in the late 1980s. [Frankel and Pabo Cell 1988; Green and Loewenstein Cell 1988] These compounds help transport different moieties across cell membranes that would otherwise have difficulty crossing the cell membrane on their own. About 20 years after the discovery of CPPs, several research studies showed that CPPs named "K" (RXRRXRRXRRXRXB, SEQ ID NO.: 43) and "B" (RXRRBRRXRRBRXB, SEQ ID NO.: 44) tethered to a single PMO designed to skip exon 23 (PMO23) of the mRNA encoding for dystrophin greatly increased exon skipping in skeletal and heart muscle using the *mdx* mouse model. [Jearawiriyapaisarn et al Mol Therapy 2008] The results of these studies demonstrated that a single PMO-CPP conjugate exhibited >85% skipping of exon 23 in skeletal muscle, whereas the naked PMO compound resulted <15% exon skipping. A modest effect was also observed in cardiac muscle (~60%) in comparison to the naked PMO, which does not effect exon 23 skipping in cardiac muscle. [Op. Cit.]

[006] WO 2009/144481 relates to a construct comprising a cell delivery peptide in a complex with a biologically active compound, such as an AON, including for example a PMO. WO 2004/097017 (US 2004/0265879 and US 2009/0082547) relates to method for enhancing delivery of molecules, including disclosing a conjugate of a biological agent, such as a PMO, and a peptide transporter. WO 2009/147368 discloses novel CPPs, which may be conjugated to for example PNAs and PMOs. US 2010/0130591 discloses PMOs capable of binding to a selected target site in the human dystrophin gene that may be conjugated to a CPP.

[007] Despite the enhanced efficacy observed with single PMO-CPP conjugates, the conjugates possess an increased toxicity compared to the naked PMOs. [cite] For example, the maximum tolerated dose for the mdx mouse exon 23 skipping studies using CPP-PMO23B or CPP-PMO23K was shown to be 30 mg/kg. At amounts of 60 mg/kg, the mice lost weight and doses of 150 mg/kg were lethal. [Amantana et al Bioconjugate Chem 2007] In contrast, the naked PMO23 could be administered in amounts as high as 250 mg/kg without any noticeable toxic effects [Op. Cit.]. WO 2009/005793 discloses that CPPs having below four X (6-aminohexanoic acid) residues, including CPP "B" exhibited lower toxicity than previously identified CPPs. As shown above, however, these CPPs coupled to a single PMO still exhibit unacceptable toxicity compared to the naked PMOs [Op Cit. and Moulton and Moulton Biochemica et Biophysica Acta 2010].

[008] It is accordingly a primary object of the present disclosure to overcome the problems of poor uptake of naked PMOs and the increased toxicity associated with single PMO-CPP constructs. Multiple conjugation sites on the CPP are introduced by adding glutamic acid in the D- or L- enantiomeric position to reduce stearic hindrance of multiple PMOs in close proximity at the termini of the CPP. The use of a peptidase cleavage site with the amino acids Phenylalanine-Lysine at the P1, - P1 positions is introduced between the CPP and the PMO. Cleavage of the peptidase cleavage site releases the PMO from the CPP. For example, the CPP may be attached to the PMO via a maleimide esterized linker with an enzyme cleavage site Phenylalanine-Lysine or Valine-Citruline that could be introduced at a cysteine position. The CPP may also be attached via an amide bond.

[009] Internalization into the cell using the peptide may result in an intracellular protease, including a lysosomal enzyme, cleaving the cleavage site and

the free PMO would have lower stearic hindrance from the peptide bound conjugate. This lower stearic constraint could increase exon skipping efficiency with less toxicity to the nucleus and cytosol.

[010] In at least one aspect this is achieved by the discovery of multiple PMO-CPP conjugates as further described herein. The present disclosure also contemplates a method for increasing the safety margin of a single PMO-CPP conjugate by substituting conjugates according to the present disclosure. The present disclosure further includes methods of modulating gene expression, such as those encoding for glycogen synthase (GYS1 or GYS2), transforming growth factor (TGFβ), matrix metallopeptidase (MMP2 or MMP9), osteopontin, myotonic dystrophy protein kinase (DMPK), Elav-Like Family Member 2 (also known as CUG Triplet Repeat RNA-Binding Protein or CUGBP), double homeobox 4 (DUX4), and/or (Frzl). The following genes: glycogen synthase (GYS1 or GYS2), transforming growth factor (TGFβ), matrix metallopeptidase (MMP2 or MMP9), osteopontin, myotonic dystrophy protein kinase (DMPK), Elav-Like Family Member 2 (also known as CUG Triplet Repeat RNA-Binding Protein or CUGBP), double homeobox 4 (DUX4), and/or (Frzl) may be targeted via the PMO-CPP conjugates of the present invention to mediate exon skipping to create a frame shift mutation. Any frame shift mutation could result in the functional reduction in the amount of mRNA targeted by the AON sequence. The present disclosure also includes within its scope the use of multiple PMO-CPP conjugates for the suppression of microRNAs in various disease states. In another aspect, the present disclosure includes methods of treating various diseases and/or conditions, such as those associated with the genes and microRNAs mentioned above.

[011] Additional objects and advantages of the present disclosure will be set forth in part in the description which follows, and in part will naturally flow from the description, or may be learned by practice of the disclosed embodiments. The objects and advantages of the present disclosure will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

[012] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

[013] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate one (several) embodiment(s) of the invention and together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[014] Figure 1 is a schematic of the configurations of the multiple AONs attached to a single CPP.

[015] Figure 2 is a schematic of the various antisense oligonucleotide subunits that could be oligomerized and used in a multiple AON configuration of the instant invention.

[016] Figure 3 is depicts the effects of some of the CPP-PMO conjugates on exon 23 skipping in wild-type mice.

DESCRIPTION OF THE EMBODIMENTS/ DETAILED DESCRIPTION OF THE INVENTION

[017] As mentioned above, it is one object of the present disclosure to improve the safety profile of single PMO-CPP conjugates without compromising the conjugate's uptake into a target cell. It is generally preferable to have at least a 10-

fold safety margin between the efficacious dose and the no adverse effect level (NOAEL). In the mdx/exon 23 experiments described above, the efficacious dose was found to be 30 mg/kg and the NOAEL was also 30 mg/kg. As a result, there was little or no safety margin. In at least one embodiment of the present disclosure, the multiple PMO-CPP conjugate has a safety margin that is better than the mdx/exon 23 experiments described above, such as better than 2-fold, such as better than 5-fold, such as better than 6-fold, such as better than 10-fold. A 10-fold safety margin means that the efficacious dose is 10 times lower than the NOAEL. Thus, when tested in the appropriate model, the multiple PMO-CPP conjugates according to the present disclosure may have a safety margin of at least 2-fold better than the corresponding single PMO-CPP conjugate. The present invention comprises multiple AON, including PMO AON, attached to a single CPP.

[018] In at least one embodiment of the present disclosure the multiple AON-CPP conjugate further comprises a cleavable linker. In some embodiments, the linker is a sequence that contains a cleavage motif. In some embodiments, the cleavage motif can be cleaved by any hydrolytic enzyme. In some embodiments, the cleavage motif can be cleaved by a peptidase or protease such as cathepsin or trypsin. In some embodiments, the linker can be designed to include a cleavage motif recognized by a particular serine protease, threonine protease, cysteine protease, aspartate protease, glutamic acid protease, or metalloprotease, or a group of more than one peptidase. In some embodiments, the linker may include two or more cleavage motifs that are overlapping or nonoverlapping. In some embodiments, the linker may contain no cleavage motifs. In some embodiments, the linker may be designed so that less than 100%, less than 75%, less than 50%, or

less than 10% of the linkers are cleaved. In some embodiments, the linker is designed so that greater than 90% or 99% of the linkers are cleaved.

[019] In at least one embodiment of the present disclosure the multiple AON-CPP conjugate further comprises a cleavable linker, such as FK at the P1/P1' position or in another embodiment, FX at the P1/P1' position where X is any naturally occurring amino acid. The cleavable linker, wherein said linker is cleavable by a hydrolytic enzyme such as for example cathepsin, can occur in between the AON and the CPP or it can occur in a sequence such as AON-cleavable linker-AON-cleavable linker-CPP. In another embodiment, the multiple PMO-CPP conjugate further comprises a cleavable linker, such as cathepsin, or FK at the P1/P1' position or in another embodiment, FX at the P1/P1' position where X is any naturally occurring amino acid. The cleavable linker can occur in between the PMO and the CPP or it can occur in a sequence such as PMO-cleavable linker-PMO-cleavable linker-CPP, e.g. as PMO-cathepsin linker-PMO-cathepsin linker-CPP. The present disclosure does not limit the order of the AONs (including PMOs), cleavable linkers, and CPP, and one skilled in the art will be able to design a suitable multiple AON-CPP conjugate having at least one cathepsin cleavage site according to the claims using the information disclosed herein.

[020] It was surprisingly found that multiple PMO-CPP conjugates with cleavable linker sites according to the present disclosure in some instances exhibited even better efficacy than multiple PMO-CPP conjugates without them. This result was unexpected because it has been shown that single PMO-CPP conjugates are taken up into the lysosome and can remain trapped there if the peptide moiety is degraded too rapidly. In other words, if the CPP part of the single PMO-CPP conjugate is degraded quickly, the PMO becomes trapped in the lysosome and

cannot reach its cellular target, thus decreasing efficacy. (Youngblood et al. 2007) As a result of this phenomenon, it would have been expected that adding a cleavable linker site in the conjugate would facilitate the CPP's degradation, leading to a decrease in efficacy. This was not the case; however, in certain multiple PMO-CPP conjugates with cleavable linker sites according to the present invention as will be described in the specific examples below. Thus, in at least one embodiment of the present disclosure a multiple PMO-CPP conjugate has at least one cleavable linker site. In at least another embodiment of the present disclosure a multiple PMO-CPP conjugate has at least one cathepsin cleavable linker site.

[021] The present disclosure further includes methods of modulating gene expression, such as those encoding for glycogen synthase (GYS1 or GYS2), transforming growth factor (TGFβ), matrix metallopeptidase (MMP2 or MMP9), osteopontin, myotonic dystrophy protein kinase (DMPK), Elav-Like Family Member 2 (also known as CUG Triplet Repeat RNA-Binding Protein or CUGBP), double homeobox 4 (DUX4), and/or (Frzl), wherein the multiple AON-CPP conjugates of the present invention to mediate exon skipping to create a frame shift mutation. Any frame shift mutation could result in the knock-down of mRNA targeted. The present disclosure also includes within its scope the use of multiple PMO-CPP conjugates for the suppression of microRNAs in various disease states. In at least one embodiment, the present disclosure includes methods of treating various diseases and/or conditions, such as those associated with the genes and microRNAs mentioned above. The multiple CPP-PMO conjugates of the present disclosure may be administered to a human or animal in need thereof by any suitable means. Administration to a human or animal subject may be selected from parenteral, intramuscular, intracerebral, intravasulcar, subcutaneous, or transdermal. In at least

one embodiment, the route of administration is by injection, such as intravenously or intramuscularly. A treating physician will be able to determine the appropriate route of administration.

[022] When employed as pharmaceuticals, the multiple CPP-PMO conjugates antisense oligonucleotides disclosed herein can be formulated with a pharmaceutically acceptable excipient or carriers to be formulated into a pharmaceutical composition.

[023] When employed as pharmaceuticals, the multiple CPP-PMO conjugates antisense oligonucleotides can be administered in the form of pharmaceutical compositions. These compounds can be administered by a variety of routes including oral, rectal, transdermal, subcutaneous, intravenous, intramuscular, and intranasal. These compounds are effective as both injectable and oral compositions. Such compositions are prepared in a manner well known in the pharmaceutical art and comprise at least one active compound.

[024] This invention also includes pharmaceutical compositions which contain, as the active ingredient, one or more of the multiple CPP-PMO conjugates antisense oligonucleotides associated with one or more pharmaceutically acceptable excipients or carriers. In making the compositions of this invention, the active ingredient is usually mixed with an excipient or carrier, diluted by an excipient or carrier or enclosed within such an excipient or carrier which can be in the form of a capsule, sachet, paper or other container. When the excipient or carrier serves as a diluent, it can be a solid, semi-solid, or liquid material, which acts as a vehicle, carrier or medium for the active ingredient. Thus, the compositions can be in the form of tablets, pills, powders, lozenges, sachets, cachets, elixirs, suspensions, emulsions, solutions, syrups, aerosols (as a solid or in a liquid medium), ointments containing,

for example, up to 10% by weight of the active compound, soft and hard gelatin capsules, suppositories, sterile injectable solutions, and sterile packaged powders.

[025] In preparing a formulation, it may be necessary to mill the active compound to provide the appropriate particle size prior to combining with the other ingredients. If the active compound is substantially insoluble, it ordinarily is milled to a particle size of less than 200 mesh. If the active compound is substantially water soluble, the particle size is normally adjusted by milling to provide a substantially uniform distribution in the formulation, *e.g.* about 40 mesh.

[026] Some examples of suitable excipients or carriers include lactose, dextrose, sucrose, sorbitol, mannitol, starches, gum acacia, calcium phosphate, alginates, tragacanth, gelatin, calcium silicate, microcrystalline cellulose, polyvinylpyrrolidone, cellulose, sterile water, syrup, and methyl cellulose. The formulations can additionally include: lubricating agents such as talc, magnesium stearate, and mineral oil; wetting agents; emulsifying and suspending agents; preserving agents such as methyl- and propylhydroxy-benzoates; sweetening agents; and flavoring agents. The compositions of the invention can be formulated so as to provide quick, sustained or delayed release of the active ingredient after administration to the patient by employing procedures known in the art.

[027] The compositions are preferably formulated in a unit dosage form, each dosage containing from about 5 mg to about 100 mg or more, such as any of about 5 mg to about 10 mg, about 5 mg to about 20 mg, about 5 mg to about 30 mg, about 5 mg to about 40 mg, about 5 mg to about 50 mg, about 5 mg to about 60 mg, about 5 mg to about 70 mg, about 5 mg to about 80 mg, or about 5 mg to about 90 mg, inclusive, including any range in between these values, of the active ingredient. The term "unit dosage forms" refers to physically discrete units suitable as unitary

dosages for individuals, each unit containing a predetermined quantity of active material calculated to produce the desired therapeutic effect, in association with a suitable pharmaceutical excipient or carrier.

[028] The multiple CPP-PMO conjugates antisense oligonucleotides are effective over a wide dosage range and are generally administered in a therapeutically effective amount. It will be understood, however, that the amount of the multiple CPP-PMO conjugates antisense oligonucleotides actually administered will be determined by a physician, in the light of the relevant circumstances, including the condition to be treated, the chosen route of administration, the actual compound administered, the age, weight, and response of the individual patient, the severity of the patient's symptoms, and the like.

[029] For preparing solid compositions such as tablets, the principal active ingredient/multiple CPP-PMO conjugates antisense oligonucleotide is mixed with a pharmaceutical excipient or carrier to form a solid preformulation composition containing a homogeneous mixture of a compound of the present invention. When referring to these preformulation compositions as homogeneous, it is meant that the active ingredient is dispersed evenly throughout the composition so that the composition may be readily subdivided into equally effective unit dosage forms such as tablets, pills and capsules.

[030] The tablets or pills of the present invention may be coated or otherwise compounded to provide a dosage form affording the advantage of prolonged action. For example, the tablet or pill can comprise an inner dosage and an outer dosage component, the latter being in the form of an envelope over the former. The two components can be separated by an enteric layer which serves to resist disintegration in the stomach and permit the inner component to pass intact

into the duodenum or to be delayed in release. A variety of materials can be used for such enteric layers or coatings, such materials including a number of polymeric acids and mixtures of polymeric acids with such materials as shellac, cetyl alcohol, and cellulose acetate.

[031] The liquid forms in which the novel compositions of the present invention may be incorporated for administration orally or by injection include aqueous solutions, suitably flavored syrups, aqueous or oil suspensions, and flavored emulsions with edible oils such as corn oil, cottonseed oil, sesame oil, coconut oil, or peanut oil, as well as elixirs and similar pharmaceutical vehicles.

[032] Compositions for inhalation or insufflation include solutions and suspensions in pharmaceutically acceptable, aqueous or organic solvents, or mixtures thereof, and powders. The liquid or solid compositions may contain suitable pharmaceutically acceptable excipients as described supra. The compositions can be administered by the oral or nasal respiratory route for local or systemic effect. Compositions in pharmaceutically acceptable solvents may be nebulized by use of inert gases. Nebulized solutions may be inhaled directly from the nebulizing device or the nebulizing device may be attached to a face mask tent, or intermittent positive pressure breathing machine. Solution, suspension, or powder compositions may also be administered, orally or nasally, from devices which deliver the formulation in an appropriate manner.

[033] The multiple CPP-AON, including CPP-PMO, conjugates according to the present disclosure may be administered in a daily dose ranging from 1- 200__ mg/kg, such as from 10_-50 mg/kg. The CPP-AON conjugate, including CPP-PMO, may be administered in bolus form or over a prolonged injection period. For

example, the daily dosage can be administered in one bolus dose. Alternatively, the daily dosage can be administered via injection, such as intravenously, or subcutaneously. In another embodiment the daily dosage can be divided into several administrations, such as two times, three times, or four times a day. Dosing may be repeated daily as needed as determined by the treating physician. Treatment may be short-term, such as for less than 6 months. In another embodiment, treatment may be long-term, such as greater than 6 months, such as greater than 1 year, such as greater than 10 years, such as over the lifetime of the human or animal in need of treatment.

[034] The multiple AON conjugate, including PMO-CPP, conjugates of the present disclosure specifically hybridize with one or more of pre-mRNA, mRNA, and/or microRNA or long non-coding RNA transcribed from a target gene or locus. As used herein, a multiple PMO-CPP conjugate specifically hybridizes to a target polynucleotide, such as pre-mRNA or mRNA, when the multiple PMO-CPP conjugate hybridizes to the target under physiological conditions. In the context of the present disclosure, hybridization occurs via hydrogen bonding, which may be Watson-Crick, Hoogsteen or reversed Hoogsteen hydrogen bonding, between complementary purine and pyrimidine bases. For example, adenine (A) and thymine (T) are complementary nucleobases which pair through the formation of hydrogen bonds. According to the present disclosure the PMO portion of the multiple PMO-CPP conjugate specifically hybridizes to the target nucleotide. The CPP moiety can remain tethered to the multiple PMO-CPP conjugate or it can be cleaved prior to hybridization, such as for example at a cathepsin cleavage site.

[035] PMO compounds of the present disclosure are complementary to a target polynucleotide, such as pre-mRNA, mRNA, or microRNA, or long non-coding

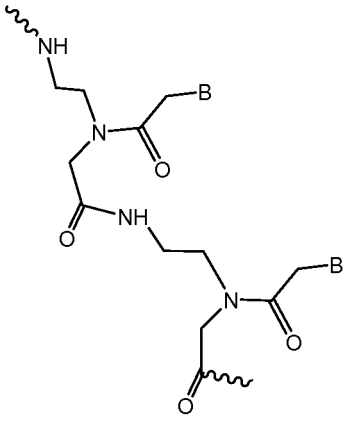
RNA when hybridization occurs according to generally accepted base-pairing rules, e.g., adenine (A)-thymine (T), cytosine (C)-guanine (G), adenine (A)-uracil (U). In particular, "complementary" as used herein refers to the capacity for precise pairing between two nucleobases. For example, if a base (B) at a certain position of a PMO compound is capable of hydrogen binding with a nucleotide at the same position of a pre-mRNA or mRNA molecule, then the PMO and the target polynucleotide molecule are considered to be complementary to each other at that position. The PMO compound and target polynucleotide molecule are complementary to each other when a sufficient number of corresponding positions in each molecule are occupied by bases that can hydrogen bond with each other. Thus, "specifically hybridizable" and "complementary" are terms which are used to indicate a sufficient degree of complementarity or precise pairing such that stable and specific binding occurs between the PMO and the polynuclelotide target. Absolute complementarity, i.e., a 100% complementary base pair match, is not necessary as long as the heteroduplex formed between the target polynucleotide molecule and the PMO has the desired stability sufficient to provoke the desired effect. According to the present disclosure, a PMO is specifically hybridizable when binding of the PMO compound to the target polynucleotide molecule changes the normal function of the target polynucleotide molecule, and there is a sufficient degree of complementarity to avoid undesirable non-specific binding of the PMO to a non-target sequence under conditions in which specific binding is desired, for example under physiological conditions for in vivo applications or under conditions in which assays are performed for in vitro applications.

[036] Such hybridization between a PMO and a target polynucleotide molecule, such as mRNA or pre-mRNA, interferes with their normal functions, such

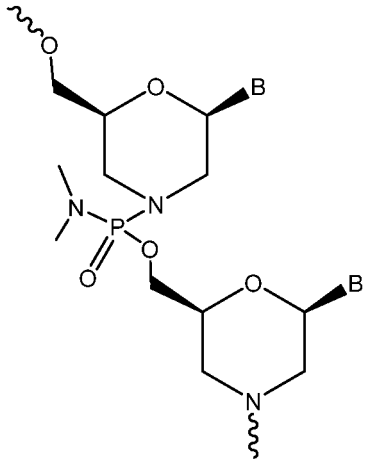
as translation of protein from the mRNA and splicing of the pre-mRNA to yield one or more mRNA species. In at least one embodiment of the present disclosure, the hybridization between the PMO and pre-mRNA affects the splicing of the pre-mRNA to form RNA. In another embodiment the hybridization affects the translation of a protein from mRNA. In another embodiment of the present disclosure, the hybridization of the multiple CPP-AON conjugate to a micro RNA binding site on a pre-mRNA or mRNA can relieve the target pre-mRNA or mRNA from subsequent regulation by the micro RNA. In this case the effect could be to enhance expression of the gene product encoded by the pre mRNA or mRNA. In contrast, if the multiple CPP-AON, for example, a multiple-CPP PMO, were to be targeted to sequences within the micro RNA such that the biological activity of the microRNA were impeded, the effect would probably be to enhance expression of a variety of gene products under repression by that particular micro RNA.

[037] The overall effect of such interference with a target polynucleotide is selective modulation of the expression of a gene. In the context of the present disclosure, “modulation” means either an increase (stimulation) or a decrease (inhibition) in the expression of a gene.

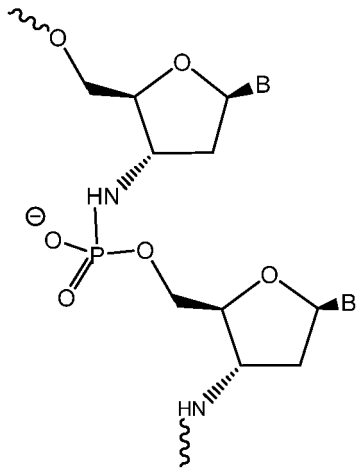
[038] AONs according to the present disclosure include PMO compounds as well as PNA compounds, phosphoramidate compounds, methylene methylimino (“MMI”) compounds, 2-O-methyl compounds and 2-methoxy ethyl compounds, wherein the oligonucleobase of each subunit are set forth in Figure 1. The oligonucleotide compounds are synthetic analogs of natural nucleic acids. In particular, instead of deoxyribose rings and phosphate-linkages, the oligonucleotide compounds comprise subunits comprised of the respective oligonucleotide subunits shown below:



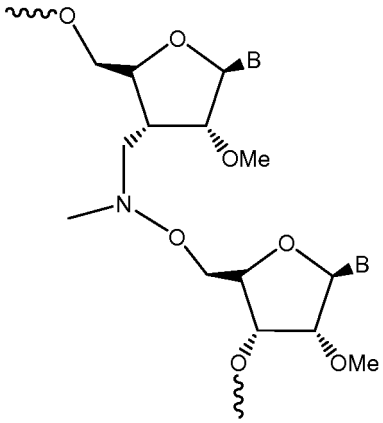
[039] PNA Formula I



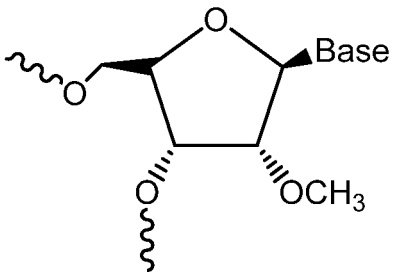
[040] Morpholino Formula II



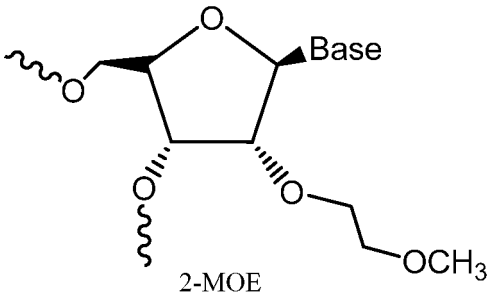
[041] Phosphoramidate Formula III



[042] MMI Formula IV



[043] 2-OMe Formula V

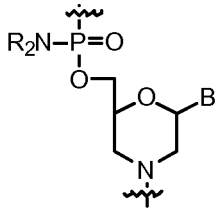


[044] 2-MOE Formula VI

[045] In the case of each of Formula 1-VI, B is a nucleotide base. The primary nucleobases are cytosine (DNA and RNA), guanine (DNA and RNA), adenine (DNA and RNA), thymine (DNA) and uracil (RNA), abbreviated as C, G, A, T, and U, respectively. A, G, C, and T appear in DNA, these molecules are called DNA-bases; A, G, C, and U are called RNA-bases. Uracil replaces thymine in RNA. These two bases are identical except that uracil lacks the 5' methyl group. Adenine

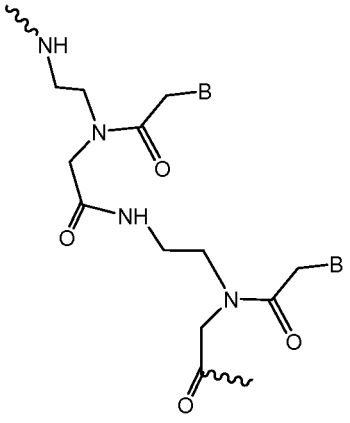
and guanine belong to the double-ringed class of molecules called purines (abbreviated as R). Cytosine, thymine, and uracil are all pyrimidines (abbreviated as Y).

[046] PMO compounds possess subunits comprised of morpholine rings and phosphorodiamidate-linking groups, respectively. For example, the present disclosure includes a PMO compound comprising from 15 to 30 subunits of Formula (II):



wherein R is an alkyl group and B is a naturally occurring purine or pyrimidine nucleotide base selected from cytosine (C), guanine (G), adenine (A), or thymine (T).

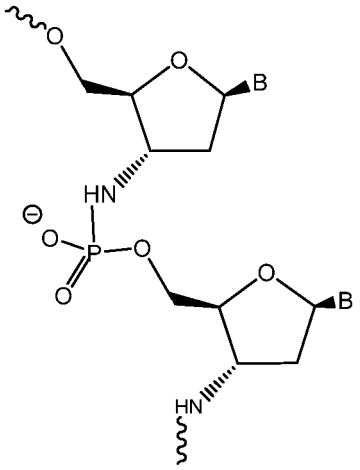
[047] PNA compounds possess subunits comprised of subunits of Formula I. For the present disclosure includes a PMO compound comprising from 15 to 30 subunits of Formula I:



[048] PNA Formula I

[049] wherein B is a purine or pyrimidine nucleotide base selected from cytosine (C), guanine (G), adenine (A), or thymine (T).

[050] Phosphoramidate compounds possess subunits comprised of subunits of Formula III. For the present disclosure includes a phosphoramidate compound comprising from 15 to 30 subunits of Formula III:

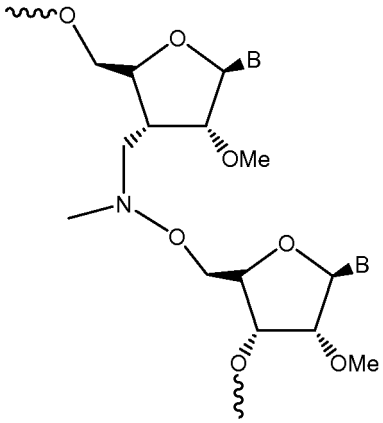


[051] Phosphoramidate Formula III

[052] wherein B is a purine or pyrimidine nucleotide base selected from cytosine (C), guanine (G), adenine (A), or thymine (T).

[053] MMI compounds possess subunits comprised of the subunits of Formula IV. For example, the present disclosure includes an MMI compound comprising from 15 to 30 subunits of Formula (IV):

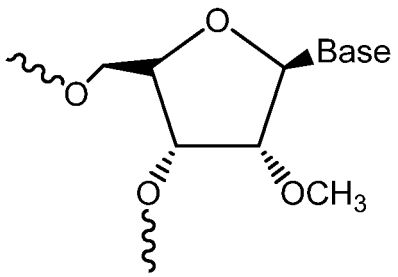
[054]



[055] MMI Formula IV

[056] wherein B is a purine or pyrimidine nucleotide base selected from cytosine (C), guanine (G), adenine (A), or thymine (T).

[057] 2-OMe compounds possess subunits comprised of Formula V. For example, the present disclosure includes a 2-OMe compound comprising from 15 to 30 subunits of Formula (V):



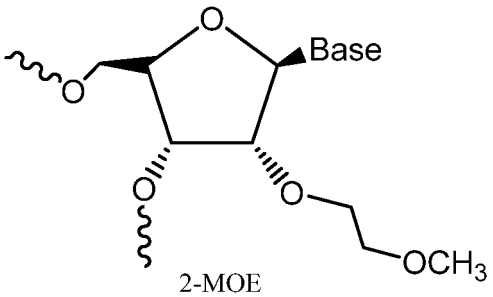
2-OMe Formula V

wherein B is a purine or pyrimidine nucleotide base selected from cytosine (C), guanine (G), adenine (A), or thymine (T).

[058] 2-MOE compounds possess subunits comprised of Formula VI. For example, the present disclosure includes a 2MOE compound comprising from 15 to 30 subunits of Formula (VI):

[059]

[060]



2-MOE Formula VI

wherein B is a purine or pyrimidine nucleotide base selected from cytosine (C), guanine (G), adenine (A), or thymine (T).

[061] The above description of each class of AON can each be substituted where AON-CPP is set forth in the description, e.g. 2MOE-CPP, MMI-CPP, 2-OMe-CPP, PNA-CPP, and Phosphoramidate-CPP.

[062] In at least one embodiment, the AON compound has from 15-25 subunits of formula (I), (II), (III), (IV), (V), or (VI). In another embodiment, the AON compound has from 20-25 subunits of formula (I), (II), (III), (IV), (V), or (VI). In yet another embodiment, the AON compound has about 25 subunits of formula (I), (II), (III), (IV), (V), or (VI), such as from 24-26 subunits.

[063] According to the present disclosure, the multiple PMO-CPP conjugates have less than 60% of PMO subunits where the nucleobase (B) is C or G. In at least one embodiment, the multiple PMO-CPP conjugate has less than 50% of PMO subunits where the nucleobase is C or G.

[064] According to the present disclosure, the multiple AON-CPP conjugates have less than 60% of AON (of formula (I), (II), (III), (IV), (V), or (VI)) subunits where the nucleobase (B) is C or G. In at least one embodiment, the multiple AON-CPP conjugate has less than 50% of AON subunits where the nucleobase is C or G.

[065] The multiple PMO-CPP conjugates of the present disclosure have at least two PMO compounds having from 0 to 3 repeating subunits where the nucleobase is G. In at least one embodiment, the multiple PMO-CPP conjugate has 0 repeating subunits where B is G. In another embodiment the multiple PMO-CPP conjugate has 1, 2, or 3 repeating subunits where B is G. Multiple conjugation sites on the CPP are introduced by adding glutamic acid in the D- or L- enantiomeric

position to reduce stearic hindrance of multiple PMOs in close proximity at the termini of the CPP. The use of a peptidase cleavage site with the amino acids Phenylalanine-Lysine at the P1, - P1 positions is introduced between the CPP and the PMO. Cleavage of the peptidase cleavage site releases the PMO from the CPP. For example, the CPP may be attached to the PMO via a maleimide esterized linker with an enzyme cleavage site Phenylalanine-Lysine or Valine-Citruline that could be introduced at a cysteine position. The CPP may be attached by an amide linkage.

[066] The multiple AON-CPP conjugates of the present disclosure have at least two AON compounds having from 0 to 3 repeating subunits where the nucleobase is G. In at least one embodiment, the multiple AON-CPP conjugate has 0 repeating subunits where B is G. In another embodiment the multiple AON-CPP conjugate has 1, 2, or 3 repeating subunits where B is G. Multiple conjugation sites on the CPP are introduced by adding glutamic acid in the D- or L- enantiomeric position to reduce stearic hindrance of multiple AONs in close proximity at the termini of the CPP. The use of a peptidase cleavage site with the amino acids Phenylalanine-Lysine at the P1, - P1 positions is introduced between the CPP and the AON. Cleavage of the peptidase cleavage site releases the AON from the CPP. For example, the CPP may be attached to the AON via a maleimide esterized linker with an enzyme cleavage site Phenylalanine-Lysine or Valine-Citruline that could be introduced at a cysteine position. The CPP may be attached by an amide linkage.

[067] Internalization into the cell using the peptide may result in an intracellular protease, including for example a lysosomal enzyme, cleaving the cleavage site and the free PMO, or AON, would have lower stearic hindrance from

the peptide bound conjugate. This lower stearic constraint could increase exon skipping efficiency with less toxicity to the nucleus and cytosol.

[068] According to the present disclosure, the CPP component of the multiple PMO-CPP conjugate can be selected from known CPPs, such as those named A-N, having the sequences in Tables 1, 2, Figure 1 or the K Series or B series CPPs described herein.

[069] According to the present disclosure, the CPP component of the multiple AON-CPP conjugate can be selected from known CPPs, such as those named A-N, having the sequences in Tables 1, 2, Figure 1 or the K Series or B series CPPs described herein.

[070] In at least one embodiment the CPP component is peptide K: RXRRXRRXRRXRXB (SEQ ID NO: 43), where R is D-arginine, X is 6-aminohexanoic acid and B is β-alanine. In another embodiment the CPP component is peptide B: RXRRBRRXRRBRXB (SEQ ID NO: 44), wherein R, X, and B are hereinabove defined.

[071] The CPP component of the multiple PMO-CPP, or AON-CPP, conjugates of the present disclosure may also be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl. In some embodiments, the linker is a sequence that contains a cleavage motif. In some embodiments, the cleavage motif can be cleaved by any hydrolytic enzyme. In some embodiments, the cleavage motif can be cleaved by a peptidase or protease such as cathepsin or trypsin. In some

embodiments, the linker can be designed to include a cleavage motif recognized by a particular serine protease, threonine protease, cysteine protease, aspartate protease, glutamic acid protease, or metalloprotease, or a group of more than one peptidase. In some embodiments, the linker may include two or more cleavage motifs that are overlapping or nonoverlapping. In some embodiments, the linker may contain no cleavage motifs. In some embodiments, the linker may be designed so that less than 100%, less than 75%, less than 50%, or less than 10% of the linkers are cleaved. In some embodiments, the linker is designed so that greater than 90% or 99% of the linkers are cleaved.

[072] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the variable sequence comprises an α-, β-, ɣ-, or δ-amino acid, or a cycloalkane structure.

[073] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the variable sequence causes the compound to be targeted to the nucleus.

[074] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-

aminocyclopentane-1-carbonyl; and wherein the variable sequence causes the compound to be targeted to the cytosol.

[075] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the variable sequence causes the compound to be targeted to the mitochondria.

[076] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the spacer comprises an aminohexanoic acid (Ahx).

[077] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the spacer comprises (Ahx)B, wherein B is selected from β-alanine or β-glycine.

[078] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the linker comprises a cleavage motif.

[079] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; wherein the linker comprises a cleavage motif; and wherein the cleavage motif is cleavable by a hydrolytic enzyme.

[080] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the linker comprises FS.

[081] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the linker comprises FSQ.

[082] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the linker comprises FSQK.

[083] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-

aminocyclopentane-1-carbonyl; and wherein the linker comprises FxyB, x is any amino acid, y is selected from glutamic acid (E), aspartic acid (D), lysine (K), serine (S), and threonine (T) , and B is β-alanine.

[084] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the linker comprises FxyB, x is any amino acid, y is selected from glutamic acid (E), aspartic acid (D), lysine (K), serine (S), and threonine (T) , and B is β-alanine; and wherein y is a non-natural analog of glutamic acid.

[085] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the linker comprises FxyB, x is any amino acid, y is selected from glutamic acid (E), aspartic acid (D), lysine (K), serine (S), and threonine (T) , and B is β-alanine; and wherein y is a non-natural analog of aspartic acid.

[086] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the linker comprises FxyB, x is any amino acid, y is selected from glutamic acid (E), aspartic acid (D), lysine (K), serine

(S), and threonine (T) , and B is β-alanine; and wherein y is a non-natural analog of lysine.

[087] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the linker comprises FxyB, x is any amino acid, y is selected from glutamic acid (E), aspartic acid (D), lysine (K), serine (S), and threonine (T) , and B is β-alanine; and wherein y is a non-natural analog of serine.

[088] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the linker comprises FxyB, x is any amino acid, y is selected from glutamic acid (E), aspartic acid (D), lysine (K), serine (S), and threonine (T) , and B is β-alanine; and wherein y is a non-natural analog of E, D, K, S or T

[089] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the spacer comprises an aminohexanoic acid (Ahx); and wherein the linker comprises FSQG-OH.

[090] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl; and wherein the linker comprises FxyB, x is any amino acid, y is selected from glutamic acid (E), aspartic acid (D), lysine (K), serine (S), and threonine (T) , and B is β-alanine; and wherein y is a non-natural analog of threonine; and wherein n is 7, and the spacer is (Ahx).

[091] In some embodiments, the CPP may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl, wherein the variable sequence, the spacer, and the linker comprise a sequence selected from: SEQ ID NOs: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11.

[092] In some embodiments, the CPP-PMO, or CPP-AON, may be a comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl, further comprising a cargo conjugated to the linker, wherein the cargo comprises a phosphorodiamidate morpholino oligomer (PMO).

[093] In some embodiments, the CPP-PMO, or CPP-AON, may be a compound comprising the formula variable sequence – spacer - linker, wherein the variable sequence is Ac-R(O)nR, wherein n ≥ 7; wherein O is a sequence of

residues selected from R, X, and Z; wherein R is L-arginine, X is 3-cis-aminocyclohexane, and Z is cis-2-aminocyclopentane-1-carbonyl, further comprising a cargo conjugated to the linker, wherein the cargo further comprises one or more additional PMOs.

[094] In some embodiments, the CPP may include a variable sequence – spacer – linker according to any of the sequences of Table 1:

Table 1:

Hit	Sequence	Localization	SEQ ID NO:
2C4	Ac-RXXXXXRRR(Ahx)FSQG-OH	Nucleus	1
4G9	Ac-RXXXXXXRR(Ahx)FSQG-OH	Nucleus	2
9F5	Ac-RXXXRXRXR(Ahx)FSQG-OH	Nucleus	3
12G4	Ac-RRXXZXXXR(Ahx)FSQG-OH	Nucleus	4
12D10	Ac-RRRXXXXXR(Ahx)FSQG-OH	Nucleus	5
12D11	Ac-RXRXXXXXR(Ahx)FSQG-OH	Nucleus	6
12E4	Ac-RRZXXXXXR(Ahx)FSQG-OH	Nucleus	7
21A5	Ac-RXXXXZXZR(Ahx)FSQG-OH	Nucleus	8
11G1	Ac-RXXZXRXXR(Ahx)FSQG-OH	Cytosol	9
12D4	Ac-RRXRXXXXR(Ahx)FSQG-OH	Cytosol	10
13D2	Ac-RRZXXZXXR(Ahx)FSQG-OH	Cytosol	11

[095] In some embodiments, the CPP may include the following sequences set forth in Table 2

Table 2:

Hit	Sequence	SEQ ID NO:
9H8	Ac-RXXXXXRXR(Ahx)	12
9H9	Ac-RZXXXXRXR(Ahx)	13
9H11	Ac-RXZXXXRXR(Ahx)	14
1A2	Ac-RRRRRRRRR(Ahx)	15
12D12	Ac-RZRXXXXXR(Ahx)	16
13D3	Ac-RXZXXZXXR(Ahx)	17
12D10	Ac-RRRXXXXXR(Ahx)	18
2C4	Ac-RXXXXXRRR(Ahx)	19
4G9	Ac-RXXXXXXRR(Ahx)	20
11F4	Ac-RXXXXRXXR(Ahx)	21
9F5	Ac-RXXXRXRXR(Ahx)	22
12D11	Ac-RXRXXXXXR(Ahx)	23
20B7	Ac-RXXXXXXZR(Ahx)	24
20C4	Ac-RXXZXXXZR(Ahx)	25
5D4	Ac-RXXXRZXRR(Ahx)	26
9H7	Ac-RRXXXXRXR(Ahx)	27
5B1	Ac-RXXXZXXRR(Ahx)	28
4H6	Ac-RXXZXXXRR(Ahx)	29
12D4	Ac-RRXRXXXXR(Ahx)	30
15A8	Ac-RXXXXXZXR(Ahx)	31
12D8	Ac-RXZRXXXXR(Ahx)	32
12E3	Ac-RZXXXXXXR(Ahx)	33
12H2	Ac-RXXZZXXXR(Ahx)	34
4G10	Ac-RZXXXXXRR(Ahx)	35
15H5	Ac-RXXXXZZXR(Ahx)	36
11F1	Ac-RXRXXRXXR(Ahx)	37
21C7	Ac-RRXXZZXZR(Ahx)	38
12E2	Ac-RXXXXXXXR(Ahx)	39
12E4	Ac-RRZXXXXXR(Ahx)	40
12G4	Ac-RRXXZXXXR(Ahx)	41
21A5	Ac-RXXXXZXZR(Ahx)	42

[096] One of ordinary skill in the art will be able to design additional CPP sequences that will achieve the goals of the present disclosure, such as enhanced cellular penetration. As a result, the presently disclosed multiple PMO-CPP and AON-CPP conjugates are not limited to the CPP components disclosed herein.

[097] As used herein, NOAEL means the dosage level where no untoward effects are observed. In other words, the NOAEL is the maximum safe dose.

[098] In some embodiments, the linker is a sequence that contains a cleavage motif. In some embodiments, the cleavage motif can be cleaved by any hydrolytic enzyme. In some embodiments, the cleavage motif can be cleaved by a peptidase or protease such as cathepsin or trypsin. As used herein, cathepsin cleavable linker is synonymous with cathepsin cleavage site. The cleavable linker according to the present disclosure is capable of being cleaved, i.e., chemically degraded, by intracellular enzymes. In some embodiments, the linker can be designed to include a cleavage motif recognized by a particular serine protease, threonine protease, cysteine protease, aspartate protease, glutamic acid protease, or metalloprotease, or a group of more than one peptidase. In some embodiments, the linker may include two or more cleavage motifs that are overlapping or nonoverlapping. In some embodiments, the linker may contain no cleavage motifs. In some embodiments, the linker may be designed so that less than 100%, less than 75%, less than 50%, or less than 10% of the linkers are cleaved. In some embodiments, the linker is designed so that greater than 90% or 99% of the linkers are cleaved.

[099] In some embodiments, the linker includes the sequence FS (SEQ ID NO.:45. In some embodiments, the linker includes the sequence FSQ (SEQ ID NO.: 46) or FSQK (SEQ ID NO.:47). In some embodiments, the linker includes the sequence FxyB (SEQ ID NO.: 48), where x is any amino acid, standard or nonstandard, y is glutamic acid (E), aspartic acid (D), and lysine (K), serine (S), or threonine (T), and B is β-alanine or β-glycine. In some embodiments, suitable cathepsin cleavage sites include FKE (SEQ ID NO.: 49), FAE (SEQ ID NO.: 50), FVE (SEQ ID NO.: 51), FLE (SEQ ID NO.: 52), FSE (SEQ ID NO.: 53), and V[Cit]E (SEQ ID NO.: 54), wherein F is phenylalanine, K is lysine, E is glutamic acid, A is

alanine, V is valine, L is leucine, S is serine, and Cit is citruline. The present disclosure is not limited to the specific cathepsin linkers disclosed herein, but also include additional amino acid sequences capable of being cleaved by intracellular proteases.

EXAMPLES

[0100] Peptide Synthesis

[0101] Peptides were synthesized using a Ranin Symphony automated peptide synthesizer using standard Fmoc-chemistry on pre-loaded CLEAR (Cross-Linked Ethoxylate Acrylate Resin) (Peptides International, Louisville, KY). Amino acids (EMD Biosciences, San Diego, CA or Anaspec, San Jose, CA) were orthogonally protected with tert-butoxycarbonyl (BOC), tert-butyl (tBu) 2,2,4,6,7-pentamethyldihydro-benzofuran-5-sulfonyl (Pbf), or Trityl (Trt) groups. Couplings were performed using an amino acid/HCTU/N-Methylmorpholine/resin molar ration of 5/5/10/1. 20% piperidine, 2% 1,8-diazabicyclo[5.4.0]-undec-7-ene (DBU) in DMF was used to remove Fmoc from the amine terminus during each cycle. N-terminal acetylation was performed on resin using acetic anhydride/NMM/resin in DMF in a molar ratio of 30/8/1. Deprotection/cleavage from resin was performed using a mixture of 15 ml/0.1 mM resin of 2.5% water/2.5% TIS/5% Anisole/90% TFA v/v ratio for 3 hr. Supernatant was precipitated in diethylether (-80ºC) and pelleted at 3000 rpm for 10 min. Ether was decanted and pellet was washed again. Crude peptide was lyophilized and purified using semi-preparative reversed-phase HPLC (XBridge C18, 10 x 250 mm, 5µm particle size). Purification was performed at 5 ml/min with a load gradient of 99% Buffer-A (water, 0.1% TFA) and 1% Buffer-B (Acetonitrile, 0.1% TFA) (gradient slope, 0.3% B/min). Peptide purity >95% was evaluated by reversed-phase analytical HPLC and MALDI-TOF (Waters Synapt). Fractions were pooled,

lyophilized, and redissolved in appropriate conjugation buffers. (All solvents were of HPLC grade purchased from EMD Biosciences, San Diego, Ca or Sigma Aldrich, St. Louis, MO)

[0102] Peptide (CPP)-PMO Conjugation

[0103] PMOs were ordered with a 5'-end primary amine and peptides were synthesized as described above. In single PMO-CPP conjugates, peptide was used in 2-fold molar excess compared to PMO, and in multiple PMO-CPP conjugates, moles of PMOs were calculated using the following equation: (1.2-fold) x (Number of Conjugates) x (moles of peptide). The PMOs were dissolved in DMSO (5 mM) and set aside. Peptides were dissolved in DMF (50 mM) and mixed with a molar equivalent of the aminium-based coupling reagent 2-(6-chloro-1-H-benzotriazole-1-yl)-1,1,3,3-tetramethylaminium hexafluorophosphate. 4-Methylmorpholine (NMM) at 2 molar equivalents was added to the peptide mixture and immediately added to the PMO solution. Reaction proceeded for 1.5 hr at 37°C and was stopped using 4 volume equivalents of water. The mixture was added to a CM sepharose (Sigma Aldrich, St. Louis, MO) column and washed with 10 column volumes to remove unconjugated PMO and reactants. Peptide CPP-PMO conjugates were eluted from the column with 1M guanidium-HCL, 1M NaCl and dialyzed against 100 mM NH_4HCO_3 with 3 buffer exchanges to remove salts and unconjugated peptide. Dialyzed material was lyophilized and analyzed with analytical HPLC.

[0104] The following CPPs were synthesized according to the general peptide synthesis protocol described above: :

- No. 1215 : Ac-$(RXRRBR)_2$XFKEG-OH (SEQ ID NO.: 55)
- No. 1216: Ac-$(RXRRBR)_2$XFD(d-Glu)EG-OH (SEQ ID NO.: 56)
- No. 1217: Ac-E$(RXRRBR)_2$XFKG-amide (SEQ ID NO.: 57)

- No. 1218: Ac-E(RXRRBR)$_2$XFKG-OH (SEQ ID NO.: 58)
- No. 1219: Ac-E(RXRRBR)$_2$XFKEG-OH (SEQ ID NO.: 59)
- No. 1220: Ac-E(RXRRBR)$_2$XFK(d-Glu)EG-OH (SEQ ID NO.: 60)
- No. 1221: Ac-(d-Glu)E(RXRRBR)$_2$xFKG-amide (SEQ ID NO.: 61)
- No. 1222: Ac-(dGlu)E(RXRRBR)$_2$XFKG-OH (SEQ ID NO.: 62)
- No. 1223: Ac-(d-Glu)E(RXRRBR)$_2$XFKEG-OH (SEQ ID NO.: 63)
- No. 1224: Ac-(d-Glu)E(RXRRBR)$_2$XFK((d-Glu)EG-OH (SEQ ID NO.: 64)
- No. 1225-B: Biot-(RXRRBR)$_2$XFKG-OH (SEQ ID NO.: 65)
- No. 1225-F: FITC-(RXRRBR)$_2$XFKG-OH (SEQ ID NO.: 66)
- No. 1226-B: Ac-(RXRRBR)$_2$XFK(Biot)G-OH (SEQ ID NO.: 67)
- No. 1226-F: Ac-(RXRRBR)$_2$XFK(FITC)G-OH (SEQ ID NO.: 68)

wherein Ac is acetyl, R is D-arginine, X is 6-aminohexanoic acid, B is β-alanine, FK is a cathepsin cleavage site, E is glutamic acid, G is glycine, Biot is biotin, and FITC is fluorescein isothiocyanate.

[0105] The CPPs listed above were conjugated with PMO23 to form PMO-CPP conjugates using the synthesis procedure described above. The conjugates formed according to this procedure had the following sequences::

- No. 1215: Ac-(RXRRBR)$_2$XFKE(PMO)G(PMO) (SEQ ID NO.: 69)
- No. 1216: Ac-(RXRRBR)$_2$XFD(d-Glu)(PMO)E(PMO)G(PMO) (SEQ ID NO.: 70)
- No. 1217: Ac-E(PMO)(RXRRBR)$_2$XFKG (SEQ ID NO.: 71)
- No. 1218: Ac-E(PMO)(RXRRBR)$_2$XFKG(PMO) (SEQ ID NO.: 72)

- No. 1219: Ac-E(PMO)$(RXRRBR)_2$XFKE(PMO)G(PMO) (SEQ ID NO.: 73)
- No. 1220: Ac-E(PMO)$(RXRRBR)_2$XFK(d-Glu)(PMO)E(PMO)G(PMO) (SEQ ID NO.: 74)
- No. 1221: Ac-(d-Glu)(PMO)E(PMO)$(RXRRBR)_2$XFKG (SEQ ID NO.: 75)
- No. 1222: Ac-(dGlu)(PMO)E(PMO)$(RXRRBR)_2$XFKG(PMO) (SEQ ID NO.: 76)
- No. 1223: Ac-(d-Glu)(PMO)E(PMO)$(RXRRBR)_2$XFKE(PMO)G(PMO) (SEQ ID NO.: 77)
- No. 1224: Ac-(d-Glu)(PMO)E(PMO)$(RXRRBR)_2$XFK(d-Glu)(PMO)E(PMO)G(PMO) (SEQ ID NO.: 78)
- No. 1225-B: Biot-$(RXRRBR)_2$XFKG(PMO) (SEQ ID NO.: 79)
- No. 1226-B: Ac-$(RXRRBR)_2$XFK(Biot)G(PMO) (SEQ ID NO.: 80)

[0106] The above-referenced CPP-PMO conjugates as well as No. 1120 (Ac-$(RXR)_4$XFKE-($(PEG)_2$-PMO)G-(PMO)) (SEQ ID NO.: 81) and (Ac-$(RXRRBR)_2$XBA-PMO) (SEQ ID NO.: 82) were administered intravenously to wild-type mice at a dose of 2.84 μM/kg.

[0107] Following the end of dosing, tissue was harvested under anesthesia and frozen in liquid nitrogen. Frozen heart and quadriceps were processed to isolate RNA. Samples were quantified using a nanodrop ND1000 spectrophotometer. Samples were further diluted to a concentration of 15 ng/μl. Samples were amplified using primers having the following sequences: CAGAATTCTGCCAATTGCTGAG (SEQ ID NO.: 83) and TTCTTCAGCTTGTGTCATCC (SEQ ID NO.: 84). PCR was

conducted with a run sequence of 55°C /30 min.; 94°C/2 min; 94°C/15 s x 30 times; 55°C/30 s; 68°C/1.5 min.

[0108] The percentage of exon 23 skipping for each conjugate is shown in Table 3.

Table 3:

	% Exon 23 Skipping (mean)	
Conjugate	**Quadricep**	**Heart**
PBS Buffer (control)	0	0
1120	48.7	1.3
1204	75.7	33.7
1215	25.5	0.8
1216	69.5	28.5
1217	0	0
1218	4.3	0
1219	36.5	0.8
1220	10.7	0.7
1221	11.3	5
1222	9.5	0
1223	40	0
1224	15	0
1225-B	66.7	6.7
1226-B	39	1.2

[0109] PMOs conjugated to the N-terminus of the CPP did not perform as well as the same number of PMOs conjugated to the C-terminus. Conjugate No. 1212 did not perform as well as the K-peptide conjugate No. 1120. No. 1204, with only one PMO, performed better than conjugate No. 1120, with two PMOs. No. 1225-B performed better than No. 1226-B.

[0110] The following additional CPP-PMO conjugates were synthesized according to the above procedures. The PMO used for the conjugates below is GGCCAAACCTCGGCTTACCTGAAAT (SEQ ID NO.: 85).

K Series (PMO is PMO23):

- No. 1118: Ac-$(RXR)_4$XEG-(PMO) (SEQ ID NO.: 86)

- No. 1119: Ac-$(RXR)_4$XE-$((PEG)_2$-PMO)G-(PMO) (SEQ ID NO.: 87)
- No. 1120: Ac-$(RXR)_4$XFKE-$((PEG)_2$-PMO)G-(PMO) (SEQ ID NO.: 81)
- No. 970-S: Stearyl-$(RXR)_4$XA-PMO (SEQ ID NO.: 88)

B Series (PMO is PMO23):

- No. 1204: Ac-$(RXRRBR)_2$XBA-PMO (SEQ ID NO.: 82)
- E(PMO)$(RXRRBR)_2$XFKG, "n-terminal PPMO-B" (SEQ ID NO.: 89)
- No. 1239: Ac-$(RXRRBR)_2$XE(PMO)G(PMO) (SEQ ID NO.: 90)
- Ac-$(RXRRBR)_2$FKEG-$(PMO)_2$, "Di-PMO-B + FK" (SEQ ID NO.: 91)

wherein Ac is acetyl, R is D-arginine, X is 6-aminohexanoic acid, B is β-alanine, FK is a cathepsin cleavage site, E is glutamic acid, and G is glycine.

[0111] In some embodiments, X can also include other types of residues, such as proline, glycine, or alanine, or additional modified or nonstandard amino acids. In some embodiments, the variable sequence includes alpha, beta, gamma, or delta amino acids, or cycloalkane structures. In some embodiments, the linker includes the sequence FS (SEQ ID NO.: 45). In some embodiments, the linker includes the sequence FSQ (SEQ ID NO.: 46) or FSQK (SEQ ID NO.: 47), wherein F is phenyalanine, S is serine, K is lysine and Q is glutamine. In some embodiments, the linker includes the sequence FxyB (SEQ ID NO.: 48), where x is any amino acid, standard or nonstandard, y is glutamic acid (E), aspartic acid (D), and lysine (K), serine (S), or threonine (T), and B is β-alanine or β-glycine Wild-type mice were intravenously administered conjugate Nos. 1204, 1119, 1120, 1239, and 1215 at a dose of 2.84μM/kg. Tissues were harvested and RNA was isolated as described above. The percentage of exon 23 skipped is shown in Table 4.

Table 4:

	% Exon 23 Skipping (mean)	
Conjugate	**Quadricep**	**Heart**
PBS Buffer (control)	0	0
1204	54.3	0
1119	44.9	0.4
1120	68	16.6
1239	2.6	0
1215	21.3	0

[0112] Figure 3 also depicts the effects of some of the multiple CPP-PMO conjugates on exon 23 skipping in wild-type mice.

[0113] As shown above, efficacy was improved by attaching more than one PMO to a single CPP-K but not CPP-B. A single dose of CPP-B delivered by IV injection, conjugated to 2 PMO exon 23 moieties (No. 1239) was far less effective than CPP-B conjugated to a single PMO exon 23 (No. 1204). Surprisingly, we found that a single dose of CPP-K conjugated to 2 PMOs (No. 1119) in exactly the same chemical fashion was roughly two times as efficacious as a single dose of CPP- K conjugated to a single PMO exon 23 (No. 1118). Interestingly, CPP-PMO23B was more efficacious than CPP-PMO23K as a monomeric construct. In multiple CPP-PMO conjugate studies where three PMOs were tethered to a CPP, three PMO23 moieties conjugated to a single peptide B (No. 1216) doubled the activity compared to the di-PMO B (although tri-PMO23-B was similar to di-PMO23-K in terms of its exon skipping capacity). These results suggest that it cannot be predicted *a priori* which multiple CPP-PMO conjugate will have the desired properties, and therefore, one of ordinary skill in the art will have to conduct preliminary studies using the methods described in the present disclosure to determine the efficacy for each conjugate prepared.

[0114] Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

WHAT IS CLAIMED IS:

1. A peptide conjugated AON compound comprising at least two AON compounds comprising from 15 to 30 subunits of Formulas (I), (II), (III), (IV), (V), or (VI):

wherein B is a naturally occurring purine or pyrimidine nucleotide base selected from C, G, A, or T;

wherein said at least two AON compounds have a nucleotide base sequence that is complementary to at least 75% of the bases of a target pre-mRNA or mRNA;

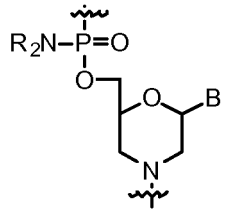
wherein said at least two AON compounds have from 0 to 3 repeating subunits where B is G;

wherein said at least two AON compounds have less than 60% of said subunits where B is C or G;

wherein said at least two AON compounds have a non-self-complimentary sequence; and

wherein said at least two AON compounds are conjugated to a polycationic peptide.

2. A peptide conjugated phosphorodiamidate morpholino compound comprising at least two phosphorodiamidate morpholino compounds comprising from 15 to 30 subunits of Formula (I):



(I)

wherein R is an alkyl group and B is a naturally occurring purine or pyrimidine nucleotide base selected from C, G, A, or T;

wherein said at least two phosphorodiamidate morpholino compounds have a nucleotide base sequence that is complementary to at least 8 contiguous bases of a target pre-mRNA or mRNA;

wherein said at least two phosphorodiamidate morpholino compounds have from 0 to 3 repeating subunits where B is G;

wherein said at least two phosphorodiamidate morpholino compounds have less than 60% of said subunits where B is C or G;

wherein said at least two phosphorodiamidate morpholino compounds have a non-self-complimentary sequence; and

wherein said at least two phosphorodiamidate morpholino compounds are conjugated to a polycationic peptide.