THERAPEUTIC NANOPARTICLES AND RELATED COMPOSITIONS, METHODS, AND SYSTEMS

STATEMENT REGARDING GOVERNMENT RIGHTS

[0001] This invention was made with government support under Contract No. HHSN261201300030C awarded by the National Institutes of Health. Thus, the government has certain rights in the invention.

SEQUENCE LISTING

[0002] The instant application contains a Sequence Listing, which has been submitted electronically in ASCII format and is hereby incorporated by reference in its entirety. Said ASCII copy, created on September 1, 2015, is named 0269.13PCT_SL.txt and is 9,822 bytes in size.

BACKGROUND

[0003] Effective delivery of agents of interest to cells, tissues, organs, and organisms has been a challenge in biomedicine, imaging, and other fields where delivery of molecules of various sizes and dimensions to a predetermined target is desirable. Whether for pathological examination, therapeutic treatment, or fundamental biology studies, several methods are known and used for delivering various classes of biomaterials and biomolecules, which are typically associated with a biological and/or chemical activity of interest. As the number of molecules suitable to be used as chemical or biological agents (*e.g.*, drugs, biologics, therapeutic or imaging agents) increases, development of a delivery system suitable for use with compounds of varied complexity, dimensions, and chemical nature has proven to be particularly challenging.

[0004] Nanoparticles are structures useful as carriers for delivering agents with various methods of delivery. Several nanoparticle delivery systems exist, which utilize an array of different strategies to package, transport, and deliver an agent to specific targets. However, a need exists for nanoparticle therapeutics (and methods of making such nanoparticles) that are capable of delivering therapeutic levels of drug to cellular and molecular targets to improve treatment of diseases.

[0005] Polynucleotides have important therapeutic applications in medicine. Polynucleotides can be used to modulate (increase or decrease) the expression of genes that are responsible for a particular disease. Gene silencing technology employs polynucleotides that

hybridize to a target nucleic acid and modulate gene expression activities or function, such as transcription or translation. Importantly, gene-silencing agents are a promising alternative to traditional small organic compounds that inhibit the function of a protein linked to a disease. RNAseH, small interfering RNAs (siRNAs), microRNAs (miRNAs), and small hairpin RNAs (shRNAs) are examples of gene silencing compounds and mechanisms that prevent the formation of proteins by gene silencing.

[0006] A need persists for delivery systems and therapeutic agents that are capable of specifically modulating gene expression to improve treatment of diseases.

BRIEF SUMMARY OF THE INVENTION

[0007] Provided herein are non-viral nanoparticles and related compositions, methods, and systems that can be used for carrying and delivering a wide range of molecules of various sizes, dimensions, and chemical natures, including to predetermined targets. One having skill in the art, once armed with this disclosure, will be able, without undue experimentation, to identify, prepare, and exploit non-viral nanoparticles for these and other uses.

[0008] In one aspect, the invention provides a system for the delivery of therapeutics, vaccines, and/or diagnostic agents to a desired target. When nanoparticles are formulated with sterile water, such as in the course of developing or manufacturing a pharmaceutically acceptable therapeutic nanoparticle, and a lithium dopant that has been pre-treated with cesium, significant benefits and unexpected advantages are achieved. Such significant benefits and unexpected advantages include, but are not limited to, greater stability of the nanoparticles, including increased capabilities for reliable transport of the nanoparticles, more flexibility and efficiency in employing the disclosed nanoparticles in drug development, such as manufacturing at multiple sites, and other advantages evident to the person of ordinary skill in the art.

[0009] The compositions and methods disclosed herein demonstrate the flexibility of the inventive nanoparticles to successfully accommodate ligands and cargoes of choice. In one embodiment, the nanoparticle comprises a core comprised of a bioactive agent including, for example, a drug, vaccine, and/or diagnostic agent, with an optional condensing agent; a surfactant substantially surrounding the core to form a surfactant-coated complex, wherein the surfactant has an hydrophile-lipophile balance (HLB) value of less than about 6.0 units; and a shell that non-covalently adheres to and substantially surrounds the surfactant-coated complex, wherein the shell comprises a targeting moiety (ligand), wherein the shell has been formed

with a cationic agent comprising lithium pre-treated with cesium. The mean diameter of the nanoparticle is less than about 50 nanometers (*i.e.*, a sub-50 nm particle).

[0010] Also disclosed herein are DNA/RNA chimeric single-stranded polynucleotides of up to about 50 nucleotides in length and capable of specifically hybridizing to the corresponding RNA nucleic acid sequence of Casein Kinase 2 (CK2) alpha and DNA/RNA chimeric single-stranded polynucleotides of up to about 50 nucleotides in length and capable of specifically hybridizing to the corresponding RNA sequence of CK2 alpha prime, as well as methods of preparing and using a combination ("mix") of said polynucleotides comprising different sequences to decrease or inhibit expression of CK2 alpha and CK2 alpha prime and inhibit the growth of solid tumors. Non-limiting examples of such polynucleotides include SEQ ID NO:8 against CK2 alpha and SEQ ID NO:9 against CK2 alpha prime.

[0011] Additionally disclosed herein are CK2-targeted polynucleotides with backbones modified to substitute the number 2 position from the 5'end to a 2' O-Methylated (2' O-Me) RNA nucleotide. Non-limiting examples of such backbone-modified polynucleotides are provided in Table 2, below.

[0012] In another aspect of the invention, combining and incorporating a mix of thus modified, CK2-targeted polynucleotides in a tumor-targeted sub-50 nanometer capsule results in a therapeutic composition of nanoparticles that, upon administration to a subject, significantly reduces or inhibits tumor growth, tumor cell proliferation, and/or inflammation.

[0013] Thus, in one aspect, the invention provides a composition comprising nanoparticles, wherein the nanoparticles comprise: at least one bioactive agent, a surfactant having an HLB value of less than 6.0 units, a ligand, and Li^+ and Cs^+, wherein: i) the at least one bioactive agent and the surfactant form a surfactant micelle core, ii) the ligand forms a shell, and iii) the nanoparticles have an average diameter of less than 50 nanometers. In one embodiment, the ligand forms an exterior shell. In another embodiment, the nanoparticles are prepared using sterile water.

[0014] In still another embodiment, the at least one bioactive agent is a polynucleotide. In still another embodiment, the at least one bioactive agent is a plasmid DNA. In yet another embodiment, the Li^+ is pre-treated with Cs^+.

[0015] In another aspect, the invention provides a system for delivering at least one bioactive agent to a target, the system comprising at least one bioactive agent, a surfactant having an HLB value of less than 6.0 units, a ligand, and Li^+ pre-treated with Cs^+, to be assembled in a nanoparticle to be used to deliver the at least one bioactive agent to the target.

In one embodiment, the bioactive agent is a polynucleotide. In another embodiment, the target is a cell within the body of a mammal.

[0016] In a further aspect, the invention provides a method of administering at least one bioactive agent to a subject, the method comprising administering to the subject a composition comprising nanoparticles according to the invention.

[0017] In still a further aspect, the invention provides a system for administering at least one bioactive agent to a subject, the system comprising at least one bioactive agent, a surfactant having an HLB value of less than 6.0 units, a ligand, and Li^+ pre-treated with Cs^+, to be assembled in a nanoparticle to be administered to the subject.

[0018] In one embodiment of a composition according to the invention, i): the nanoparticles comprise a plurality of polynucleotides, each comprising a 3' RNA portion and a 5' primarily DNA portion, wherein the number 2 position from the 5' end of each polynucleotide is a 2'-OMe-modified RNA, wherein the sequence of more than about 45% and less than about 55%, of more than about 40% and less than about 60%, or of more than about 30% and less than about 70% of the plurality of polynucleotides on average for the composition of nanoparticles comprises SEQ ID NO: 8, and the sequence of the remainder of the plurality of polynucleotides comprises SEQ ID NO: 9, and ii) the ligand is a protein targeting a tenascin receptor. In another embodiment, the ligand targeting a tenascin receptor is tenfibgen.

[0019] The phrase "composition comprising nanoparticles" or a similar phrase as used herein refers, without limitation, to a dose, a sample, a formulation, a manufacturing lot, and other compositions of matter comprising the inventive nanoparticles.

[0020] In one aspect, the invention provides a polynucleotide comprising a 3' RNA portion and a 5' primarily DNA portion, wherein the number 2 position from the 5' end is a 2'-OMe modified RNA, wherein the polynucleotide comprises up to about 50 consecutive nucleotides of SEQ ID NO:11 and comprises a portion of at least 8 consecutive nucleotides of SEQ ID NO: 8. In another embodiment, the polynucleotide is about 20 nucleotides in length and comprises SEQ ID NO:8.

[0021] In another aspect, the invention provides a polynucleotide comprising a 3' RNA portion and a 5' primarily DNA portion, wherein the number 2 position from the 5' end is a 2'-OMe modified RNA, wherein the polynucleotide comprises up to about 50 consecutive nucleotides of SEQ ID NO:12 and comprises a portion of at least 8 consecutive nucleotides of SEQ ID NO: 9. In another embodiment, the polynucleotide is about 20 nucleotides in length and comprises SEQ ID NO:9.

[0022] In one aspect, the invention provides a method for treating a patient, comprising administering to the subject a therapeutically effective amount of a composition according to the invention, wherein the patient has been diagnosed with a solid tumor cancer.

[0023] In another aspect, the invention provides a method for treating a patient diagnosed with a solid tumor cancer, comprising administering to the patient a therapeutically effective amount of the composition according to the invention, wherein the nanoparticles comprise a plurality of polynucleotides, wherein each of the plurality of polynucleotides comprises a 3' RNA portion and a 5' primarily DNA portion, wherein the number 2 position from the 5' end of the each of the plurality of polynucleotides is a 2'-OMe modified RNA, wherein the sequence of the plurality of polynucleotides comprises either SEQ ID NO: 8 or SEQ ID NO: 9, wherein the percentage of nanoparticles comprising polynucleotides comprising SEQ ID NO: 8 is at least about 10%, about 20%, about 30%, about 40%, about 50%, about 60%, about 70%, about 80%, or about 90%, and the remainder of the nanoparticles comprise polynucleotides comprising SEQ ID NO: 9, wherein the ligand is a protein targeting a tenascin receptor.

[0024] In one embodiment, the percentages are determined based upon the relative levels of CK2 alpha enzymes and CK2 alpha prime enyzmes measured in tumor tissue from one or more subjects, optionally compared to relative levels of CK2 alpha and CK2 alpha prime enzymes in a reference tissue and/or cell culture. In another embodiment, the percentages are about 50% nanoparticles comprising SEQ ID NO: 8 and about 50% comprising SEQ ID NO: 9.

[0025] In one aspect, the invention provides a method for preparing a composition according to the invention, the method comprising: i) complexing a bioactive agent with a condensing agent to form a condensed bioactive agent; ii) dispersing the condensed bioactive agent into a water-miscible solvent comprising a surfactant with an HLB of less than 6.0 to form a surfactant micelle; iii) adsorbing a ligand to the exterior surface of the surfactant micelle to form a ligand-stabilized particle (a.k.a., ligand particle); and iv) mixing and incubating the ligand particle with Li^+ pretreated with Cs^+, and sterile water, to form the composition.

[0026] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. While suitable methods and materials to practice or test the present invention are provided below, the artisan will recognize that other methods and materials similar or equivalent to those described herein can be used in the practice or testing of the

present invention. In addition, the materials, methods, and examples iterated herein are illustrative only and not intended to be limiting.

DETAILED DESCRIPTION OF THE INVENTION

[0027] *Nanoparticles*

[0028] In one aspect, the invention provides stable nanoparticles for the targeted delivery of bioactive agents to specific tissues and cells. The inventive nanoparticles have a ligand coating or shell and an average diameter of less than 50 nanometers, enabling the delivery of bioactive agent cargo through the biologic barriers of the body and/or to and into a cell or tissue of interest.

[0029] As used herein, "sub-50 nm nanoparticles" are generally referred to in the context of a composition of nanoparticles, wherein said nanoparticles comprise (i) a surfactant micelle comprising a bioactive agent and a hydrophobic surfactant and (ii) a shell comprising a ligand, and having an average diameter of less than about 50 nanometers. In certain embodiments, the nanoparticles of a composition according to the present invention have an average diameter of between about 5 and about 50 nanometers, between about 5 and about 40 nanometers, between about 5 and about 30 nanometers, between about 5 and about 20 nanometers, between about 10 and 40 nanometers, between about 10 and 30 nanometers, or between about 10 and 20 nanometers.

[0030] As used herein, the term "shell" generally refers to the exterior or outer shell of the nanoparticle and comprises a layer or coating or corona, which surrounds at least a portion of the outer surface of the core surfactant micelle. In one embodiment, the shell comprises one or more ligands. For a given formulation or composition (used interchangeably herein) of nanoparticles, incorporation of insufficient weight of ligand will typically result in non-uniform particles manifested, for example, by irregular drug-aggregates or fused micelles, while excessive weight of ligand will typically result in large masses or loss of spherical or cubical shape manifested, for example, by elongated structures, as determined by analysis, for example, of TEM or AFM micrographs. One having skill in the art, once armed with the instant disclosure, will be able, without undue experimentation, to identify, prepare, and exploit the use of ligands for incorporation in the inventive nanoparticles.

[0031] In one aspect, the invention provides a composition comprising nanoparticles comprising a bioactive agent. The artisan will understand that the phrase "a composition comprising nanoparticles comprising (a certain feature, property, etc.)" indicates that a plurality of the nanoparticles of the composition comprise the certain feature, property, etc.

[0032] In one embodiment, the nanoparticles are prepared using sterile water. The terms "prepared," "synthesized," "made", "manufactured", and the like are used interchangeably herein. The phrase "nanoparticles (are) prepared using sterile water", as used herein, means that the salt receiving solution used in the synthesis of the inventive nanoparticles is prepared with sterile water. The artisan will understand that the volume of sterile water added at any step or steps in the preparation of the final salt receiving solution comprises, in total, at least 80%, 90%, 95%, 96%, 97%, 98%, 99%, 99.5%, 99.6%, 99.7%, 99.8%, or 99.9% of the total water volume of the final salt receiving solution. In this context, "final salt receiving solution" refers to the solution prior to the addition of ligand-stabilized nanoparticles. Within this framework, other grades of water may be used, for example, as stock solutions for excipients added to the salt receiving solution. It is understood that the phrases "nanoparticles prepared using sterile water" and "salt receiving solution comprising sterile water" contemplate that sterile water accounts for between about 80% and 100% of the total water volume of the final salt receiving solution. "Sterile water", as used in the context of "nanoparticles prepared using sterile water" and "salt receiving solution comprising sterile water" refers to water in which the level of the following metals is no more than about 0.2 parts per million in sum total: aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, magnanese, nickel, rubinium, sulfur, vanadium, and zinc. In one embodiment, the "sterile water" refers to water in which the level of the following metals is no more than about 0.1 parts per million in sum total: aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, magnanese, nickel, rubinium, sulfur, vanadium, and zinc. In this framework, levels of each metal and the sum of the metals are based on results reported down to the Method Detection Limit (MDL). Metal testing can be performed according to available methods, such as, for example, U.S. Environmental Protection Agency methods 6010 and 6020.

[0033] In some embodiments, the use of water of high purity, such as sterile water, is required to meet regulatory standards for pharmaceutical products. In some embodiments, the use of sterile water is desirable to improve control of manufacturing of nanoparticles by reducing levels of contaminants that can alter characteristics of the nanoparticle such as size, shape, stability, and functionality, as determined by, for example, transmission electron microscopy (TEM) or atomic force microscopy (AFM). In some embodiments, the use of sterile water is desirable to improve control of manufacturing nanoparticles by providing a consistent base to which ingredients such as excipients can be added to improve nanoparticle characteristics such as size, shape, stability, and functionality. The ordinarily skilled artisan will also understand that methods and guidelines are available with respect to tests, grades, and

uses of water in pharmaceutical research, development, and manufacturing, such as those produced by United States Pharmacopeia and similar organizations.

[0034] In one embodiment, the sterile water used is pharmaceutical grade water. In another embodiment, the sterile water is used to prepare pharmaceutically acceptable therapeutic nanoparticles. The phrase "pharmaceutically acceptable" is employed herein to refer to those compounds, materials, compositions, and/or dosage forms that are, within the scope of sound medical judgment, suitable for use in contact with the tissues of subjects without excessive toxicity, irritation, allergic response, or other problem or complication, commensurate with a reasonable benefit/risk ratio. In one embodiment, the sterile water is also used in other steps in the nanoparticle preparation process, such as the solution preparation of any reagent used in assembling the salt receiving solution or in preparing one or more components of the nanoparticles prior to their addition to the salt receiving solution.

[0035] In one embodiment, the nanoparticles comprise the ions lithium (Li^+) and cesium (Cs^+). In another embodiment, the nanoparticles comprise Li^+ that has been pre-treated with Cs^+. The phrase "Li^+ pretreated with Cs^+" and similar phrases, as used herein, refer to the pre-mixing or contacting of the Li^+ and Cs^+ ions prior to associating said pre-mixed or contacted ions with the sterile water volume that has been or will be used to prepare the salt receiving solution. The concentration of Li^+ in the pretreatment step should typically be at least 1M. In one embodiment, the concentration is 2M. In one embodiment, the concentration is 3M. In one embodiment, the concentration is between 3M and 5M. In one embodiment, the concentration is 4M. In one embodiment, the concentration is 5M. In one embodiment, the pretreatment of Li^+ with ions prior to addition of the Li^+ to the salt receiving bath used to form the nanoparticles is limited to the ion Cs^+. In said embodiment, it is understood that the limitation of pretreatment ions to Cs^+ is contemplated to specifically exclude other ions being added to the premix but is not contemplated to exclude other ions that may be present in the water source used to pretreat Li^+ with Cs^+. The pre-mixing or contacting of Li^+ and Cs^+ ions, for the purposes disclosed and contemplated herein, can be readily performed according to methods for combining ions and similar molecules known to the artisan, including simply mixing the ions in desired concentrations in water, for example, sterile water. In one embodiment, Cs^+ at about 0.1 µg/1 ml is added to about 4M Li^+, at about 2.5 ppb Cs^+ to Li^+ by weight, in sterile water in a 50 ml tube, and rotated for about 2 minutes. The artisan will understand that the ratio of Cs^+ to Li^+ used and/or the concentration of the combined ions in, for example, the sterile water in a 50 ml tube, can be routinely varied to manipulate the

morphology or stability or some other characteristic of the nanoparticles subsequently produced.

[0036] In another embodiment, Cs^+ is pre-mixed with Li^+ at a ratio of between about 0.1 and about 100 parts per billion (ppb). In yet another embodiment, the pre-mix ratio is between about 0.1 and about 5 ppb. In still another embodiment, the pre-mix ratio is between about 1 and about 4 ppb. Each of these ranges include sub-ranges within that range. For example, between about 1 and about 4 ppb includes such ranges as: between about 1.2 and about 2.5 ppb, and between about 2 and about 4 ppb, and the like. Surprisingly, for nanoparticles prepared using sterile water, those particles formulated with Cs^+ pre-mixed with Li^+ formed desirable spherical, cuboid, or elliptical sub-50 nanometer nanoparticles, while those particles formulated with Cs^+ and Li^+ that were simply commingled in the salt receiving solution and not pre-mixed, generally formed unwound, long rod-like compositions unsuitable for use. One having skill in the art, once armed with this disclosure, will be able, through routine experimentation, to identify, prepare, and exploit the use of Cs^+ and Li^+ pre-mixtures for the targeted nanoparticles.

[0037] The disclosed nanoparticles provide a modular targeting component that can be readily synthesized for a given target, for example, a given tissue or cellular target, without the steps of chelating, conjugating, or covalently attaching the targeting moiety to the nanoparticle. One having skill in the art will understand that, with judicious selection of a targeting moiety based upon the intended target and methods and compositions known in the art, the inventive nanoparticles are capable of delivering bioactive agents to predetermined target tissue and cells.

[0038] In one embodiment, the shell comprises a ligand. The term “ligand”, as used herein, refers to a substance that binds to a target receptor. In some embodiments, the ligand comprises a protein, a peptide, a polypeptide, a carbohydrate, polyvinylpyrrolidone (PVP), an antibody, or a biocompatible polymer, or fragments thereof, or a small molecule. In one embodiment, the sub-50 nm nanoparticles are coated with at least one tissue- or cell-specific ligand. A "coated nanoparticle” refers to a nanoparticle wherein the ligand is bound to the core surfactant micelle via a non-covalent association. The flexibility of ligand options for the inventive nanoparticles is enabled, in part, by the absence of such complex steps as attaching the ligand to the nanoparticle via chelation, conjugation, or covalent attachment, employing, instead, a straight-forward step of adsorbing the ligand to the hydrophobic micelle surface, and, subsequently, stabilizing the targeted particle in a salt crystallization solution. Thus for example, adsorption of the ligand to the core surfactant micelle allows for more efficient

incorporation of larger ligands than nanoparticles where ligands are conjugated or chelated to the core particle. Diverse ligands including, for example, tenfibgen, hyaluronan, and synthetic polymers such as PVP, may be utilized as ligands in formulating the inventive Cs^+-treated nanoparticles. For example, a particle comprising PVP would be formulated similarly to Formula J (Examples, below) for a 5.5 kb plasmid except using 4 µl of 25 kD PEI as a condenser, 3.3 µg of 10 kD PVP as a ligand adsorbed to the core micelle, and modifying the receiving bath to 1.5 nM Mg^{2+} and 1.88 nM Sr^{2+}, all other ions the same.

[0039] In one embodiment, the ligand targets cells with tenascin receptors. In another embodiment, the ligand is tenfibgen.

[0040] In still another embodiment, the ligand is hyaluronan.

[0041] In one aspect, the invention provides a system to deliver a bioactive agent to a target or to administer a bioactive agent to a subject. In one embodiment, the system comprises at least one bioactive agent, for example, a polynucleotide, a surfactant having an HLB value of less than 6.0 units, a ligand, and Li^+ and Cs^+, to be assembled in a sub-50 nanometer nanoparticle to be used to deliver the at least one bioactive agent to the target or administer the at least one bioactive agent to a subject. The term "system", as used herein, refers to a formulation or composition that enables the introduction of a bioactive agent in the body of a subject and improves its efficacy or performance.

[0042] In one embodiment, the instant nanoparticles incorporate a bioactive agent or agents useful for modulating gene expression, to increase or decrease the production of specific gene products (*e.g.*, proteins or RNA). In another embodiment, the bioactive agent or agents engage(s) mechanisms of action such as RNaseH, RNAi, and dsRNA enzymes, as well as other modulating mechanisms based on target degradation or target occupancy.

[0043] *Bioactive agents*

[0044] Cs-treated nanoparticles of the present invention can be used to carry and deliver bioactive agents to targeted tissues and cells. The phrase "bioactive agent" or "bioactive agents", as used herein, refers to one or more agents that, when administered or delivered to a cell, tissue, or organism, mimics, alters, or modulates one or more physiological, biochemical, or pathological processes of the cell, tissue, or organism. Preferably, the alteration or modulation is a medically desirable alteration or modulation. More specifically, a bioactive agent can be any one or more of a number of different compounds or molecules for purposes comprising imaging or monitoring or therapeutic or prophylactic uses including, but not limited to, a bioactive agent such as an oligonucleotide, a polynucleotide, a plasmid DNA, any nucleic acid-based molecule including but not limited to DNA, RNA, siRNA, mRNA,

miRNA, shRNA, aptamers, antisense molecules, or ribozymes, as well as a protein, a polypeptide, a peptide, a carbohydrate, an antibody or a small molecule.

[0045] Without wishing to be bound by theory, the flexiblity of bioactive agent options is enabled, in part, by the partitioning and condensing features of the hydrophobic-surfactant-coated micelle that forms the core of the nanoparticle. The artisan would recognize these features as being suitable and functional for the purposes of formulating the inventive nanoparticles with oligonucleotides, polynucleotides, plasmid DNA, any nucleic acid-based molecule including DNA, RNA, siRNA, miRNA, shRNA, aptamers, antisense molecules, or ribozymes, proteins, polypeptides, peptides, carbohydrates, antibodies, or other cargos, more preferably, but not exclusively, hydrophilic and/or negatively or approximately neutrally charged cargos. This flexibilty of the inventive nanoparticles for incorporating a range of bioactive agents in different formulations is demonstrated, for example, by the formulation of a 10.5 kb plasmid DNA and hyaluronan nanoparticle shell with a resulting average diameter of 22.7 nanometers and charge of -6.4 mev, and the formulation of a 6800 dalton single strand oligonucleotide and tenfibgen nanoparticle shell with a resulting diameter of 19.5 nanometers and charge of -5.8 mev (see Examples).

[0046] Thus, other diverse bioactive agents can be incorporated in the cesium-pretreated nanoparticles through routine experimentation. For example, the small molecule erythritol (MW, 122) would be formulated similar to Formula A (Examples), except that 500 µg of erythritol without any condenser would be micellized with 8.75 µg of surfactant, coated with 5.5 mcg of TBG, and atomized into a receiving bath modified with 6.25 nM of Mg^{2+} and 9.38 nM of Sr2+, all other ions the same. Resulting nanoparticle size would be approximately 25 nm in diameter, and surface charge would be approximatly -12 mev.

[0047] The phrase "hydrophobic surfactant-coated", as used herein, refers to the coating or layer of hydrophobic surfactant used to form the surfactant micelle, and which surrounds at least a portion of the bioactive agent and optional condensing agent. For a given formulation, incorporation of insufficient surfactant will typically result in irregular drug aggregates, while excessive surfactant will typically result in surfactant globules, as determined by analysis for example of TEM or AFM micrographs. In certain embodiments, the bioactive agent is a single-stranded chimeric oligonucleotide. Bioactive agents including oligonucleotides can generally be prepared using techniques well known in the art but can also be obtained from commercial manufacturers.

[0048] In one embodiment, the bioactive agent is a plurality of bioactive agents against a molecular target. In another embodiment, the bioactive agent comprises a mix of two or more bioactive agents with different molecular targets and/or mechanisms of action.

[0049] In some embodiments, the bioactive agent is condensed with a cationic condensing agent comprising polyethyleneimine, polyornithine, polyarginine, spermine, or other cationic condensing agent or agents well known in the art.

[0050] "Specifically hybridizable" and "complementary" are terms that are used to indicate a sufficient degree of complementarity such that stable and specific binding occurs between a polynucleotide of the present invention and a target RNA molecule. It is understood in the art that the sequence of a polynucleotide need not be 100% complementary to that of its target RNA molecule to be specifically hybridizable. One of ordinary skill in the art would recognize that the compounds provided herein are at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98%, at least 99% or 100% complementary to a target nucleic acid. A polynucleotide is specifically hybridizable when (a) binding of the polynucleotide to the target RNA molecule interferes with the normal function of the target RNA molecule, and (b) there is sufficient complementarity so that binding of the polynucleotide to the target RNA molecule is highly selective and largely avoids non-specific binding of the polynucleotide to non-target sequences under conditions in which specific binding is desired, *i.e.*, under conditions in which *in vitro* assays are performed or under physiological conditions for *in vivo* assays or therapeutic uses. Examples of methods for designing oligonucleotides that are sufficiently complementary to be useful in the present invention and such design skills are within the purview of one of skill in the art.

[0051] The term "RNA" or "RNA molecule" or "ribonucleic acid molecule" refers to a polymer of ribonucleotides. "Target RNA" refers to any RNA that can hybridize with a sufficiently complementary polynucleotide of the present invention. Target RNA can include, without limitation, pre-mRNA, pre-miRNA, pri-miRNA, mRNA, miRNA, small nuclear or cytosolic non-coding regulatory RNAs, ribosomal RNA, transfer RNAs, hnRNA at any stage in the mRNA processing pathway, or mitochondrial RNAs. "mRNA" or "messenger RNA" is single-stranded RNA that specifies the amino acid sequence of one or more polypeptide chains. In one embodiment, the target mRNA of the invention specifies the amino acid sequence of a cellular protein (*e.g.*, a nuclear, cytoplasmic, mitochondrial, transmembrane, or membrane-associated protein). In another embodiment, the target mRNA of the invention specifies the amino acid sequence of an extracellular protein (*e.g.*, an extracellular matrix protein or secreted

protein). The term "DNA" or "DNA molecule" or “deoxyribonucleic acid molecule" refers to a polymer of deoxyribonucleotides.

[0052] The term "nucleic acid molecule" or “polynucleotide” refers to any nucleic acid-containing molecule, including, but not limited to, DNA and/or RNA of more than 1 nucleotide in either single chain, duplex, or multiple chain form. The terms encompass sequences that include any of the known base analogs of DNA and RNA. The term "polynucleotide" is also meant to encompass polydeoxyribonucleotides containing 2'-deoxy-D-ribose or modified forms thereof, RNA and any other type of polynucleotide that is an N-glycoside or C-glycoside of a purine or pyrimidine base, or modified purine or pyrimidine base or basic nucleotide. The polynucleotide, in some embodiments, may encode promoter regions, operator regions, structural regions, termination regions, combinations thereof, or any other genetically relevant material that regulates or modifies chromatin or other polynucleotides. Similarly, the term "genetic" as used herein, refers to any material capable of modifying gene expression.

[0053] The term "oligonucleotide" refers to a short length of single-stranded polynucleotide chain. Oligonucleotides are typically less than 200 residues long (*e.g.*, between about 8 and 100). The terms “polynucleotide” and “oligonucleotide” are used interchangeably herein.

[0054] As used herein, “gene silencing,” “gene silencing molecule,” "gene silencing compound", and the like refer to a polynucleotide, at least a portion of which is at least partially complementary to a target nucleic acid to which it hybridizes. In certain embodiments, a gene silencing compound modulates (for example, decreases) expression or amount of a target nucleic acid. In certain embodiments, a gene silencing compound alters splicing of a target pre-mRNA, resulting in a different splice variant. In certain embodiments, an antisense compound modulates expression of one or more different target proteins. Gene silencing mechanisms contemplated herein include, but are not limited to, RNase H mechanisms, RNAi mechanisms, splicing modulation, translational arrest, altering RNA processing, inhibiting microRNA function, and mimicking microRNA function, as well as additional mechanisms identifiable by the artisan upon reading of the present disclosure.

[0055] The term "small interfering RNA" ("siRNA") (also referred to in the art as "short interfering RNAs") refers to an RNA (or RNA analog) comprising between about 10-50 nucleotides (or nucleotide analogs) capable of directing or mediating RNA interference. As used herein, the term "RNA interference" ("RNAi") refers to a selective intracellular

degradation of RNA. In some embodiments, the bioactive agent is a double-stranded siRNA polynucleotide.

[0056] As used herein, "expression" refers to the process by which a gene ultimately results in a protein. Expression includes, but is not limited to, transcription, splicing, post-transcriptional modification, and translation.

[0057] The term "gene" refers to a nucleic acid (*e.g.*, DNA) sequence that comprises coding sequences necessary for the production of a polypeptide, precursor, or RNA (e.g., rRNA, tRNA, and other ncRNAs). The polypeptide can be encoded by a full length coding sequence or by any portion of the coding sequence, so long as the desired activity or functional properties (*e.g.*, enzymatic activity, ligand binding, signal transduction, immunogenicity, etc.) of the full-length or fragment is retained.

[0058] The term "gene expression" refers to the process of converting genetic information encoded in a gene into RNA (*e.g.*, mRNA, rRNA, tRNA, or snRNA) through "transcription" of the gene (*i.e.*, via the enzymatic action of an RNA polymerase), and for protein encoding genes, into protein through "translation" of mRNA. Gene expression can be regulated at many stages in the process. "Up-regulation" or "activation" refers to regulation that increases the production of gene expression products (*i.e.*, RNA or protein), while "down-regulation" or "repression" refers to regulation that decrease production. Molecules (*e.g.*, transcription factors) that are involved in up-regulation or down-regulation are often called "activators" and "repressors," respectively.

[0059] The term "inhibition of gene expression" refers to conditions where a polynucleotide of the present invention hybridizes to a target RNA and provides partial or complete loss of function of said gene. It is understood that a polynucleotide need not be 100% complementary to its target RNA sequence to be specifically hybridizable. In certain embodiments, a reduction of target gene expression by at least about 10%, 25%, 50%, 60%, 70%, 80%, 90%, 95%, or 99% is desired relative to the level of expression in the absence of the bifunctional chimeric single stranded polynucleotides of the present invention. The present invention is not limited to the inhibition of expression of a particular gene.

[0060] The term "nucleoside" refers to a molecule having a purine or pyrimidine base covalently linked to a ribose or deoxyribose sugar. Exemplary nucleosides include adenosine, guanosine, cytidine, uridine and thymidine. The term "nucleotide" refers to a nucleoside having one or more phosphate groups joined in ester linkages to the sugar moiety. Exemplary nucleotides include nucleoside monophosphates, diphosphates and triphosphates. The terms "polynucleotide" and "nucleic acid molecule" are used interchangeably herein and refer to a

polymer of nucleotides, and in one embodiment of the present invention, are joined together by a phosphodiester linkage between 5' and 3' carbon atoms of the sugar moiety.

[0061] The term "nucleotide analog" or "altered nucleotide" or "modified nucleotide" refers to a less commonly occurring nucleotide, including natural and non-naturally occurring ribonucleotides or deoxyribonucleotides. Nucleotide analogs may be modified at any position so as to alter certain chemical properties of the nucleotide yet retain the ability of the nucleotide analog to perform its intended function. Nucleotide analogs may also comprise modifications to the sugar portion of the nucleotides. The phosphate group of the nucleotide may also be modified, *e.g.*, by substituting one or more of the oxygens of the phosphate group with sulfur (*e.g.*, phosphorothioates), or by making other substitutions which allow the nucleotide to perform its intended function.

[0062] For use in preparing the nucleoside structural subunits of the compounds of the invention, suitable nucleobases for incorporation in these nucleoside subunits include purines and pyrimidines such as adenine, guanine, cytosine, uridine, and thymine, as well as other synthetic and natural nucleobases such as xanthine, hypoxanthine, 2-aminoadenine, 6-methyl and other alkyl derivatives of adenine and guanine, 2-propyl and other alkyl derivatives of adenine and guanine, 5-halouracil and cytosine, 5-propynyl uracil and cytosine, 6-azo uracil, cytosine and thymine, 5-uracil (pseudouracil), 4-thiouracil, 8-halo, amino, thiol, thioalkyl, hydroxyl and other 8-substituted adenines and guanines, 5-trifluoromethyl and other 5-substituted uracils and cytosines, 7-methylguanine. Further purines and pyrimidines include those disclosed in U.S. Pat. No. 3,687,808, those disclosed in the Concise Encyclopedia Of Polymer Science And Engineering, pages 858-859, Kroschwitz, J. I., ed. John Wiley & Sons, 1990, and those disclosed by Englisch, *et al.* 1991 *Angewandte Chemie*, International Edition 30:613, all incorporated herein by reference.

[0063] "Phosphodiester" refers to a polynucleotide with an oxygen atom linking consecutive nucleotides. "Phosphorothiate" refers to a polynucleotide in which the oxygen atom normally linking two consecutive nucleotides has been replaced with sulfur and which resists degradation by cellular enzymes. Polynucleotides of the present invention have their nucleoside subunits connected by phosphorus linkages from a list including phosphodiester, phosphorothioate, 3'-(or -5')deoxy-3'-(or -5')thio-phosphorothioate, phosphorodithioate, phosphoroselenates, 3'-(or -5')deoxy phosphinates, borano phosphates, 3'-(or -5')deoxy-3'-(or 5'-) amino phosphoramidates, hydrogen phosphonates, borano phosphate esters, phosphoramidates, alkyl or aryl phosphonates and phosphotriester phosphorus linkages. Phosphorothioate modification of nucleoside linkages for increased stability has been reported

to minimally effect silencing activity (2007 *Nat Rev Mol Cell Biol* 8:23-6). In one embodiment, a backbone comprising PS/2-*O*-Me may be of value in situations where PO/2-*O*-Me seems limited.

[0064] The term "phosphorylated" means that at least one phosphate group is attached to a chemical (*e.g.*, organic) compound. Phosphate groups can be attached, for example, to proteins or to sugar moieties via the following reaction: free hydroxyl group + phosphate →donor phosphate ester linkage. Also intended to be included within the scope of the instant invention are phosphate group analogs, which function in the same or similar manner as the mono-, di-, or triphosphate groups found in nature. In one embodiment, the chimeric polynucleotides disclosed herein comprise extrinsic 5' phosphorylation. In another embodiment, the chimeric polynucleotides disclosed herein do not comprise extrinsic 5' phosphorylation. The term "extrinsic 5' phosphorylation" generally refers to phosphorylation carried out through synthetic methods and not natural biological processes.

[0065] "Chimeric" refers, but is not limited, to a molecule that is composed of both RNA and DNA moieties that are naturally occurring or nucleotide analogs, linked by phosphodiester, phosphorothioate, and/or any other naturally occurring or synthetic linkage that permits the nucleotides or analogs to retain their intended function. The oligonucleotide or polynucleotide can be referred to as having at least two segments. One segment is defined as the portion beginning at the 3' end of the polynucleotide and is the ribonucleic acid segment and should include at least about three consecutive ribonucleotides, and the second segment is defined as the portion ending at the 5' end of the polynucleotide and is the primarily deoxyribonucleic acid portion, and comprises at least about 6, 7, 8, 9, or 10 deoxyribonucleotides, wherein a total of zero, one, two, or three ribonucleotides may be placed between the at least about 6, 7, 8, 9, or 10 deoxyribonucleotides. In one embodiment, the second section comprises at least 5 consecutive deoxyribonucleotides. In one embodiment, the number 2 position from the 5' end is a 2'-OMe modified RNA.

[0066] Preferred single stranded chimeric polynucleotides in accordance with this invention preferably comprise from about 8 to about 50 nucleoside subunits. In the context of this invention, it is understood that this encompasses non-naturally occurring oligomers as hereinbefore described, having 8 to 50 nucleoside subunits. It is more preferred that the single stranded chimeric polynucleotides of the present invention comprise from about 15 to about 25 nucleoside subunits. Accordingly, single stranded chimeric polynucleotides can be 8 nucleotides in length, 9 nucleotides in length, 10 nucleotides in length, 11 nucleotides in length, 12 nucleotides in length, 13 nucleotides in length, 14 nucleotides in length, 15

nucleotides in length, 16 nucleotides in length, 17 nucleotides in length, 18 nucleotides in length, 19 nucleotides in length, 20 nucleotides in length, 21 nucleotides in length, 22 nucleotides in length, 23 nucleotides in length, 24 nucleotides in length, 25 nucleotides in length, 26 nucleotides in length, 27 nucleotides in length, 28 nucleotides in length, 29 nucleotides in length, 30 nucleotides in length, 31 nucleotides in length, 32 nucleotides in length, 33 nucleotides in length, 34 nucleotides in length, 35 nucleotides in length, 36 nucleotides in length, 37 nucleotides in length, 38 nucleotides in length, 39 nucleotides in length, 40 nucleotides in length, 41 nucleotides in length, 42 nucleotides in length, 43 nucleotides in length, 44 nucleotides in length, 45 nucleotides in length, 46 nucleotides in length, 47 nucleotides in length, 48 nucleotides in length, 49 nucleotides in length, or 50 nucleotides in length. As will be appreciated, a "nucleoside subunit" is a nucleobase and sugar or sugar surrogate combination suitably bound to adjacent subunits through phosphorus linkages in oligoribonucleotides and through non-phosphorus linkages in oligoribonucleosides. In this context, the term "nucleoside subunit" is used interchangeably with the term "nucleoside unit" or "nucleoside." More preferably, the chimeric oligonucleotides of the invention will have nucleosides linked by naturally occurring phosphodiester linkages.

[0067] In certain embodiments, the bioactive agent is a single-stranded polynucleotide, and the polynucleotide is a guide strand, garnered from standard optimization siRNA techniques. A discussion of conventional siRNA sequence selection is included herein.

[0068] The target RNA cleavage reaction guided by siRNAs is highly sequence-specific. In general, siRNA containing a nucleotide sequence identical to a nucleotide sequence or a portion of a nucleotide sequence of the target gene is preferred for inhibition. However, 100% sequence identity between the siRNA and the target gene is not required to practice the present invention. Thus, the invention has the advantage of being able to tolerate sequence variations that might be expected due to genetic mutation, strain polymorphism, or evolutionary divergence. For example, siRNA sequences with insertions, deletions, and single point mutations relative to the target sequence have also been found to be effective for inhibition. Alternatively, siRNA sequences with nucleotide analog substitutions or insertions can be effective for inhibition.

[0069] Moreover, not all positions of the siRNA contribute equally to target recognition. Mismatches in the center of the siRNA are most critical and essentially abolish target RNA cleavage. In contrast, the 3' nucleotides of the siRNA do not contribute significantly to specificity of target recognition. In particular, residues 3' of the siRNA

sequence, which is complementary to the target RNA (*e.g.*, the guide sequence), are not critical for target RNA cleavage.

[0070] Sequence identity may be determined by sequence comparison and alignment algorithms known in the art. To determine the percent identity of two nucleic acid sequences (or of two amino acid sequences), the sequences are aligned for optimal comparison purposes (*e.g.*, gaps can be introduced in the first sequence or second sequence for optimal alignment). The nucleotides (or amino acid residues) at corresponding nucleotide (or amino acid) positions are then compared. When a position in the first sequence is occupied by the same residue as the corresponding position in the second sequence, then the molecules are identical at that position. The percent identity between the two sequences is a function of the number of identical positions shared by the sequences (*i.e.*, % homology= # of identical positions/total # of positions x 100), optionally penalizing the score for the number of gaps introduced and/or length of gaps introduced.

[0071] The comparison of sequences and determination of percent identity between two sequences can be accomplished using a mathematical algorithm. In one embodiment, the alignment is generated over a certain portion of the sequence aligned having sufficient identity, but not over portions having low degree of identity (*i.e.*, a local alignment). A preferred, non-limiting example of a local alignment algorithm utilized for the comparison of sequences is the algorithm of Karlin and Altschul ((1990) Proc. Natl. Acad. Sci. USA 87:2264-68, modified as in Karlin and Altschul (1993) Proc. Natl. Acad. Sci. USA 90:5873-77, incorporated herein by reference. Such an algorithm is incorporated into the BLAST programs (version 2.0) of Altschul, et al. (1990) J. Mol. Biol. 215:403-10), incorporated herein by reference.

[0072] In another embodiment, the alignment is optimized by introducing appropriate gaps, and percent identity is determined over the length of the aligned sequences (*i.e.*, a gapped alignment). To obtain gapped alignments for comparison purposes, Gapped BLAST can be utilized as described in Altschul, *et al.*, ((1997) Nucleic Acids Res. 25(17):3389-3402). In still another embodiment, the alignment is optimized by introducing appropriate gaps, and percent identity is determined over the entire length of the sequences aligned (*i.e.*, a global alignment). A preferred, non-limiting example of a mathematical algorithm utilized for the global comparison of sequences is the algorithm of Myers and Miller, CABIOS (1989). Such an algorithm is incorporated into the ALIGN program (version 2.0), which is part of the GCG sequence alignment software package. When utilizing the ALIGN program for comparing amino acid sequences, a PAM120 weight residue table, a gap length penalty of 12, and a gap penalty of 4 can be used.

[0073] Sequence identity of at least about 80%, at least about 85%, at least about 90%, at least about 95%, at least about 96%, at least about 97%, at least about 98%, at least about 99% or about 100% between the siRNA and a portion of the target gene is preferred. Alternatively, the siRNA may be defined functionally as a nucleotide sequence (or oligonucleotide sequence) that is capable of hybridizing with a portion of the target gene transcript (*e.g.*, 400 mM NaCl, 40 mM PIPES pH 6.4, 1 mM EDTA, 50°C or 70°C hybridization for 12-16 hours; followed by washing). Additional exemplary hybridization conditions include hybridization at 70°C in 1 x SSC or 50 °C in 1xSSC, 50% formamide followed by washing at 70°C in 0.3xSSC or hybridization at 70°C in 4 x SSC or 50°C in 4xSSC, 50% formamide followed by washing at 67°C in 1xSSC. The hybridization temperature for hybrids anticipated to be less than 50 base pairs in length should be 5-10°C less than the melting temperature (Tm) of the hybrid, where Tm is determined according to the following equations. For hybrids less than 18 base pairs in length, Tm(°C)=2(# of A+T bases)+4(# of G+C bases). For hybrids between 18 and 49 base pairs in length, Tm((°C)=81.5+16.6(log10[Na+])+0.41(% G+C)-(600/N), where N is the number of bases in the hybrid, and [Na+] is the concentration of sodium ions in the hybridization buffer ([Na+] for 1xSSC=0.165 M). Additional examples of stringency conditions for polynucleotide hybridization are provided in Sambrook, J., E. F. Fritsch, and T. Maniatis, 1989, Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y., chapters 9 and 11, and Current Protocols in Molecular Biology, 1995, F. M. Ausubel et al., eds., John Wiley & Sons, Inc., sections 2.10 and 6.3-6.4, incorporated herein by reference. The length of the identical nucleotide sequences may be at least about 10, 12, 15, 17, 20, 22, 25, 27, 30, 32, 35, 37, 40, 42, 45, 47 or 50 bases.

[0074] *Treatment methods*

[0075] In one aspect, the invention provides a method of inhibiting the expression of casein kinase 2 in a solid tumor. This inventive method comprises administering targeted nanoparticles delivering polynucleotides to the tumor, wherein the polynucleotides hybridize to casein kinase 2 nucleic acid sequences and reduce or inhibit the expression thereof.

[0076] In one aspect, the invention provides a method of modulating activity of downstream targets of casein kinase 2 in a solid tumor. In some embodiments, downstream targets of casein kinase 2 include, without limitation, NF-κB p65, Cdc37, and AKT. This inventive method comprises administering targeted nanoparticles delivering polynucleotides to the tumor, wherein the polynucleotides hybridize to casein kinase 2 nucleic acid sequences and

reduce or inhibit the activity of downstream targets, and/or downstream markers of casein kinase 2 activity, including, for example, Ki-67.

[0077] In another aspect, the invention provides a method of reducing the size of a solid tumor or inhibiting or stabilizing the growth of a solid tumor in a subject. This inventive method comprises administering targeted nanoparticles delivering polynucleotides to the tumor, wherein the polynucleotides hybridize to casein kinase 2 nucleic acid sequences and reduce or inhibit the expression thereof. In certain embodiments, targeted nanoparticles delivering polynucleotides to the tumor result in reduction in size or stabilization or inhibition of growth of the solid tumor.

[0078] As used herein, the term "subject" refers to any animal (*e.g.*, a mammal), including, but not limited to, humans, non-human primates, vertebrate animals, rodents, and the like, which is to be the recipient of a particular treatment. The terms "subject", "patient", and "individual" are used interchangeably herein.

[0079] In some embodiments, the target is an *in vitro* biological system such as *in vitro* tissues or cells, and the method comprises contacting the target with the nanoparticles herein described.

[0080] In one embodiment, oligonucleotides for binding to casein kinase 2 have the sequence shown in SEQ ID NO:8 (for the target casein kinase 2 alpha), or SEQ ID NO:9 (for the target casein kinase 2 alpha prime). In one embodiment of a composition of nanoparticles according to the invention, the nanoparticles comprise a plurality of polynucleotides, wherein the percentage of the plurality of polynucleotides that comprises SEQ ID NO: 8 is, on average, more than about 1% and less than about 100%, more than about 30% and less than 70%, more than about 40% and less than about 60%, more than about 45% and less than about 55%, more than about 48% and less than about 52%, more than about 49% and less than about 51%, or is about 50%, and the remainder of the plurality of polynucleotides comprises SEQ ID NO:9. Factors influencing the percentages of each polynucleotide sequence include, for example, the relative volume of each polynucleotide incorporated upon formulating the nanoparticles or the relative encapsulation percentage of each polynucleotide. The polynucleotide makeup of the composition can be determined using sampling methods known in the art, such as hybridization assays and functional cell assays.

[0081] In one embodiment of a composition of nanoparticles according to the invention, a mix of nanoparticles comprises polynucleotides comprising either SEQ ID NO: 8 or SEQ ID NO: 9. In another embodiment of a nanoparticle composition according to the invention, the percentage of nanoparticles that comprise polynucleotides comprising SEQ ID

NO: 8 is about 10%, about 20%, about 30%, about 40%, about 50%, about 60%, about 70%, about 80%, or about 90%, with the remainder of nanoparticles of the composition comprising polynucleotides comprising SEQ ID NO: 9.

[0082] Representative tumors contemplated for treatment by methods of the invention include those associated with certain cancers, and include, without limitation, breast cancer, lung cancer (including non-small cell lung carcinoma), prostate cancer, colorectal cancer, brain cancer, esophageal cancer, kidney cancer, bladder cancer, pancreatic cancer, cervical cancer, head and neck cancer, skin cancers, nasopharyngeal carcinoma, liposarcoma, epithelial carcinoma, renal cell carcinoma, gallbladder adenocarcinoma, parotid adenocarcinoma, ovarian cancer, melanoma, lymphoma, glioma, and endometrial sarcoma.

[0083] In one embodiment, treatment by methods of the invention includes administration to patients diagnosed with a solid tumor cancer. "Solid tumor", as used herein, refers to an abnormal mass of tissue that results from the proliferation of cells. Solid tumors can arise in any part of the body and may be benign (not cancerous) or malignant (cancerous). Most types of cancer other than leukemias can form solid tumors. Solid tumors include, without limitation, adenocarcinomas, carcinomas, hemangiomas, liposarcomas, lymphomas, melanomas, and sarcomas. The phrase “solid tumor” can also be used to refer to conditions such as endometriosis, *i.e.*, conditions caused by uncontrolled proliferation of cells.

[0084] Tenascin is a large glycoprotein shown to be overexpressed in the microenvironment of solid tumors (Brellier , *et al.* 2011 *J Cell Molec Med* 16: 32-40). Receptors for tenascin are found on tumor cells, representing an attractive target for treating solid tumor cancers by employing therapeutic nanoparticles with tenascin-directed ligands. Non-limiting examples of receptors for tenascin found on tumor cells include integrin alpha V, alpha 2, beta 1, and beta 3. One having skill in the art, once armed with this disclosure, will be able, without undue experimentation, to identify, prepare, and exploit tenascin-directed ligand nanoparticles to solid tumors for the purposes of targeting and delivering bioactive agents to solid tumors. Non-limiting examples of such tenascin-directed ligands include tenascin-C, tenascin-W, and fragments thereof, including, but not limited to, tenfibgen.

[0085] In one embodiment, the inventive nanoparticle compositions are useful for treating any condition in which inhibiting expression of a target gene is potentially of use. In another embodiment, the compositions may be used for treating a subject suffering from a proliferative disease. By "proliferative disease" is meant any human or animal disease or disorder affecting any one or any combination of organs, cavities, or body parts, which is

characterized by single or multiple local abnormal proliferations of cells, groups of cells, or tissues, whether benign or malignant.

[0086] The terms "treatment", "treating", and the like are intended to mean administering a therapeutic, vaccine, or diagnostic on one or more occasions for the purpose of obtaining or assessing a desired pharmacologic and/or physiologic effect in a subject. The effect may be prophylactic in terms of completely or partially preventing a disease or symptom thereof and/or may be therapeutic in terms of a partial or complete cure for a disease and/or adverse effect (symptom) attributable to the disease. "Treatment", as used herein, covers any treatment of a disease in a subject and includes, without limitation: (a) preventing a disease or condition from occurring in an individual who may be predisposed to the disease but has not yet been diagnosed as having it; (b) eliminating or inhibiting the disease, (*e.g.*, arresting its development); or (c) relieving the disease (*e.g.*, reducing or eliminating symptoms associated with the disease).

[0087] In another aspect, the invention provides a single-stranded (ss) oligonucleotide of up to about 50 nucleotides in length that includes a portion of at least 8 consecutive nucleotides of SEQ ID NO: 8, wherein the ss oligonucleotide inhibits the expression of human casein kinase 2 alpha. In another aspect, the invention provides a ss oligonucleotide of up to about 50 nucleotides in length that includes a portion of at least 8 consecutive nucleotides of SEQ ID NO: 9, wherein the ss oligonucleotide inhibits the expression of human casein kinase 2 alpha prime.

[0088] *Administration*

[0089] The formulation of therapeutic compositions of the present invention and their subsequent administration are described herein and can be practiced by those of ordinary skill in the art. In general, for therapeutics, a patient in need of therapy is provided a composition in accordance with the invention, in dosages and novel regimen strategies as described elsewhere herein. In some embodiments of the present invention, administration is determined based upon one or more of the patient's body weight or surface area, age, and severity of the disease or disorder being treated.

[0090] In one embodiment, the subject is treated with the nanoparticle composition, for example, comprising polynucleotides, at a dose/in an amount sufficient to reduce, stabilize, or inhibit expression of a target gene against a suitable control. In another embodiment, the subject is treated with the single-stranded polynucleotide at a dose/in an amount sufficient to reduce, stabilize, or inhibit the target lesion against a suitable control. In another embodiment, the bioactive agent (for example, polynucleotide) dose is of equal to or less than about 20

mg/kg body weight, less than about 10 mg/kg body weight, or less than about 5 mg/kg body weight. In other embodiments, the bioactive agent, for example, a single-stranded chimeric polynucleotide, is delivered at a dose of less than about 4 mg/kg body weight, less than about 3 mg/kg body weight, less than about 2 mg/kg body weight, less than about 1 mg/kg body weight, less than about 100 µg/kg body weight, less than about 100 nanogram(ng)/kg body weight, less than about 10 ng/kg body weight, less than about 1 ng/kg body weight, less than about 100 picogram(pg)/kg body weight, less than about 10 pg/kg body weight, less than about 1 pg/kg body weight, less than about 100 femtogram(fg)/kg body weight, less than about 10 fg/kg body weight, less than about 1 fg/kg body weight, less than about 100 attogram(ag)/kg body weight, less than about 10 ag/kg body weight, or less than about 1 ag/kg body weight. Similar dosage ranges can be developed and used based upon for example the body surface area of the subject.

[0091] The treatment regimen may last for a period of time that will vary depending upon the nature of the particular disease, its severity, and the overall condition of the patient, and may extend from once daily to once every 30 years. Following treatment, the patient may be monitored for changes in his/her condition and for alleviation of the symptoms of the disease or disorder state. The dosage of the bioactive agent may either be increased in the event that the patient does not respond significantly to current dosage levels, or the dosage may be decreased if an alleviation of the symptoms of the disease or disorder is observed, or if the disease or disorder has been ablated.

[0092] Dosing is dependent on severity and responsiveness of the disease condition to be treated, with the course of treatment lasting from several days to several months, or until a cure is effected or a diminution of disease or disorder is achieved. Optimal dosing schedules can be calculated, for example, from measurements of bioactive agent accumulation in the body of the patient. Persons of ordinary skill can readily determine optimum dosages, dosing methodologies, and repetition rates. Optimum dosages may vary depending on the relative potency of individual compounds, and can generally be estimated, for example, based on EC50 found to be effective in *in vitro* and *in vivo* animal models. Dosages may be given, for example, once or more daily, weekly, monthly or yearly, or even once every 2 to 30 years.

[0093] In some embodiments, methods of the invention include a step that involves comparing a value, level, feature, characteristic, property, etc. to a "suitable control", referred to interchangeably herein as an "appropriate control". A "suitable control" or "appropriate control" is any control or standard familiar to one of ordinary skill in the art useful for comparison purposes. In one embodiment, a "suitable control" or "appropriate control" is a

value, level, feature, characteristic, property, etc. determined prior to administering a composition of nanoparticles as described herein. For example, a transcription rate, mRNA level, translation rate, protein level, biological activity, lesion size, cellular characteristic or property, genotype, phenotype, etc. can be determined prior to introducing a composition of nanoparticles of the invention into a cell or organism. In another embodiment, a "suitable control" or "appropriate control" is a value, level, feature, characteristic, property, etc. determined in a cell or organism, *e.g.*, a control or normal cell or organism, exhibiting, for example, normal traits. In yet another embodiment, a "suitable control" or "appropriate control" is a predefined value, level, feature, characteristic, property, etc.

[0094] In another aspect, the invention provides methods of treatment comprising administering to a subject in need thereof a therapeutically effective amount of a bioactive agent in a formulated composition of nanoparticles according to the invention. By the term "therapeutically effective amount", for example, of a bioactive agent, is meant such amount as is capable of obtaining the desired phenotype or performing the desired therapeutic function such as stabilizing, slowing, reducing, eliminating, or preventing a disease or disorder (or a symptom of such disease or disorder). The exact amount required will vary, depending on known variables, such as the bioactive agent employed, the condition of the subject, and the parameters of the therapeutic regimen. Thus, it is neither necessarily possible nor required to specify an exact "therapeutically effective amount." Rather, the appropriate effective amount may be determined by one of ordinary skill in the art using routine experimentation.

[0095] The compositions of the present invention may be administered via a number of routes, depending upon whether local or systemic treatment is desired and upon the area to be treated. Administration may be topical (including ophthalmic, vaginal, rectal, intranasal, transdermal), oral, or parenteral. Parenteral administration includes, but is not limited to, intravenous, subcutaneous, intraperitoneal or intramuscular injection, intratumoral, or intrathecal or intraventricular administration. Without wishing to be bound by theory, the flexibility of particle (composition) administration options is enabled, in part, by the small size and low surface charge of the highly stable nanoparticles of the inventive composition, allowing the particle and its drug cargo to traverse biologic barriers and size-limited structures such as the bloodstream wall, lymphatic channels, and the skin to reach cellular and molecular targets.

[0096] "Low surface charge" of the nanoparticles of the inventive compositions generally means an average surface charge of between about -20 and about +4 milli-electron volts (mev), although one skilled in the art will understand that the inventive nanoparticles

having an average surface charge outside of this range can still be exploited for therapeutic purposes, if the nanoparticles retain their spherical or elliptical shape, sub-50 nanometer size, and crystallized form.

[0097] In one embodiment, the invention provides a method of treating a disease or disorder in a subject, for the purpose of obtaining a desired phenotype or performing a desired function such as stabilizing, slowing, reducing, or eliminating such disease or disorder (or a symptom of such disease or disorder), such as, without limitation, proliferative disease, such as, without limitation, cancer, comprising administering to a subject under conditions suitable for the treatment of the disease or disorder, a therapeutically effective amount of a nanoparticle composition, wherein the nanoparticles comprise a micelle core comprising bioactive agents comprising a mix of SEQ ID NO: 8 and SEQ ID NO: 9, a surfactant with an HLB value of less than or equal to about 6.0, a shell adsorbed to the micelle core and comprising tenfibgen, Li^+ and Cs^+, and having a mean diameter of less than about 50 nanometers, wherein the nanoparticles are administered via one or more of the routes described above. In another embodiment, the inventive method comprises pre-treatment of the Li^+ with Cs^+.In one embodiment, the polynucleotide of the present invention may be introduced in an amount which allows delivery of at least about 1, 5, 10, 50, 100, 500, or 5000 polynucleotides per target cell.

[0098] The following illustrates some of the benefits and advantages of the instant invention based on work described in the examples, below. Stable tenfibgen-shell sub-50 nanometer nanoparticles made with sterile water and Cs+ pre-mixed with Li+, and encapsulating a mix of oligonucleotides comprising 2R-modified anti-CK2 SEQ ID NO: 8 and SEQ ID NO: 9, significantly inhibited tumor growth in mice over a 30-day period (Table 3, below). An analysis of the tumors treated with the mix also showed significant inhibition of Ki-67, a marker of cell proliferation, and NF-kB, a marker of inflammation. Under similar experimental conditions, mice treated with only nanoencapsulated 2R-modified SEQ ID NO: 8 showed reductions in tumor weight and NF-kB vs. controls, but the changes were not significant, and the Ki-67 index for the treated group increased vs. controls. Similarly, mice treated with only a nanoencapsulated, unmodified oligonucleotide mix (SEQ ID NO: 5 and SEQ ID NO: 6) showed an increase in tumor weight, with small changes in Ki-67 and NF-kB.

[0099] *Preparation of nanoparticles*

[00100] The following description of methods that can be used to make targeted sub-50 nanoparticles is meant to be representative only and is not meant to be limiting. U.S. Patent No. 6,632,671, U.S. Patent No. 7,741,304, and U.S. Patent Publication No. 2013/0267577,

incorporated herein by reference, disclose the preparation of unmodified nanoparticles. Briefly, a negatively-charged bioactive agent such as a nucleic acid that is to be targeted and delivered to, for example, a tumor cell, can be complexed with a polycationic polymer to condense or reduce its size to about 50 nm or less. A number of different polycationic polymers (also known as "condensing" agents or proteins) can be used and are well-known in the art (Rolland 1998, Crit. Rev. Therapeutic Drug Carr. Syst., 15:143-198). For example, enough polycationic condensing protein can be complexed with the negatively-charged cargo moiety to neutralize at least about 75% (*e.g.*, about 80%, 85%, 90%, 95%, 99% or 100%) of the negatively-charged cargo moiety, which, for nucleic acids, can be measured by ethidium dye exclusion (see, for example, (1998, J. Controlled Release, 53:289-99)). Simply by way of example, 125 µg of 10 kD polyornithine can be used to condense 500 µg of a 20-mer oligonucleotide, or 87.5 µg of spermine may be used to condense 250 µg of a 14 kD siRNA oligo. For cargo moieties lacking a negative charge or bearing a positive charge, a condensing polycationic polymer may not be necessary.

[00101] An aqueous solution of the complexed or uncomplexed cargo moiety can be encapsulated by first dispersing the cargo moiety into a biocompatible, water-miscible solvent using a biocompatible, water-insoluble surfactant system suitable for preparation of an inverted or reverse micelle. Suitable surfactant systems are well-known in the formulation arts as amphiphilic materials that are essentially hydrophobic and characterized by a hydrophile-lipophile balance (HLB) of less than about 6, a critical micelle concentration (CMC) of less than about 200 µM, or a critical packing diameter greater than 1. In some embodiments, the HLB is less than about 5. Hydrophobic surfactants and hydrophobic, water-miscible solvents suitable for preparing reverse micelles are described in Pashley & Karaman (2004, In Applied Colloid and Surface Chemistry, John Wiley, pp. 60-85), Rosen (2004, in Surfactants and Interfacial Phenomena, John Wiley), The Handbook of Industrial Surfactants (1993, Ash, ed., Gower Pub), and Perry's Chemical Engineer's Handbook (1997, Perry & Green, 7th Ed., McGraw-Hill Professional), incorporated herein by reference.

[00102] In some embodiments, the surfactant component may be 2,4,7,9-tetramethyl-5-decyn-4,7-diol(TM-diol), blends of 2,4,7,9-tetramethyl-5-decyn-4,7-diol(TM-diol), molecules having one or more acetylenic diol groups, cetyl alcohol, or any combination of any of these. In some embodiments, water-miscible solvents comprising food or USP grade oils, such as DMSO, DMF, castor oil, or any combination thereof, may be used. In one embodiment, a hydrophobic surfactant can be 2,4,7,9-tetramethyl-5-decyn-4,7-diol (TM-diol) or preparations thereof, such as SE-30 (Air Products), used in a concentration of up to about 0.5% by weight

of surfactant micelle volume, and a water-miscible solvent can be DMSO. The concentration of surfactant selected should be sufficient to prepare an optically clear nanoemulsion, but not so much as to induce aggregation, since aggregation can lead to overly large nanoparticles.

[00103] The micelles carrying the cargo moieties (*i.e.*, the surfactant micelles) can be coated with tumor-targeting moieties (*e.g.*, tenfibgen) by mixing one or more targeting moieties with an aqueous dilution of the nanoparticles. In some embodiments, targeting moieties can be mixed with nanoparticles in a ratio (by weight) of about 1:500 to about 1:0.1 of targeting moiety to bioactive agent, depending upon factors including the targeting moiety and the rate at which the nanoparticle is desired to dissolve or disassemble. In one embodiment, the weight ratio is about 1:90 (that is, $1/90^{th}$) of targeting moiety to bioactive agent. In one embodiment, the weight ratio is about 1:40 of targeting moiety to bioactive agent.

[00104] Nanoparticle ligands may be modified by processes designed to enhance final nanoparticle function. As a non-limiting example, coating ligands may be readily modified with pharmaceutically acceptable heavy metals by re-precipitating protein in saturated ammonium sulfate solutions prepared with known levels of heavy metals. Incubation of about a 0.1-1 mg/ml solution of protein ligand at a ratio of 1:1 with a saturated ammonium sulfate solution is most expeditiously executed for about 4-36 hours before recovering metal-modified coating ligand by centrifugation. Metal concentrations in the ultrapure ammonium sulfate may range from, for example, 1 part per thousand to 1 part per trillion. As a further non-limiting example, tenascin polypeptides may be precipitated from cell culture supernatants using metal-containing ammonium sulfate, such that metals known to promote oxidative stress are adsorbed onto coating ligands preceding nanoparticles preparation.

[00105] To stabilize the ligand-adsorbed nanoparticle, the aqueous suspension of nanoparticles coated with one or more ligands can be mixed into an aqueous solution of metal ions (*i.e.*, a "stabilization solution") capable of precipitating, crystallizing, or iontophoretic exchange with the coated nanoparticles. Representative, non-limiting examples of solutes that can be used to form coated nanoparticles include ionic species derived from elements listed in the periodic table. Ions may be included in the aqueous stabilization composition in a range from about, for example, 0.1 part per trillion to about 1 Molar (M). An adequate amount of ion should be included, such that the coated nanoparticles are sufficiently contacted with ions, but not so much that aggregation occurs, which can lead to overly large nanoparticles.

[00106] In one embodiment, a stabilization (or crystallization or receiving) solution can comprise about 10 millimolar (mM) Ca^{2+} and about 126 mM Li^{+}. If ultrapure reagents are

used in the stabilization solution, very small amounts (*e.g.*, less than about 1 mM) of ions such as Ba, Fe, Mg, Sr, Pb and Zn may be added to optimize stabilization of the coated nanoparticles. In one embodiment, when the nanoparticles are prepared with sterile water, 126 mM of Li^+ is pre-treated with 2.5 ppb of CS^+ for increased stability. In one embodiment, a stabilization solution includes 10 mM Ca^2+, 126 mM Li+ (pre-mixed with 2.5 ppb Cs^+), 0.042 mM Ba^{2+} with 14 nM Sr^{2+}, 6.25 nM Mg^{2+} (all ultrapure, all prepared as stock solutions with sterile water, except Sr^{2+} and Mg^{2+}, which are prepared with laboratory grade water, all metals are used as chloride salts, total bath volume approximately 30 ml). Flexibility of the system is demonstrated by nanoparticles showing high levels of cellular uptake that have been synthesized at lithium levels about 10-fold lower than those described here (data not shown). The artisan will understand that a variety of counter-ions can be used with these metals in the stabilization solution, such as chloride, sulfate, and nitrate.

[00107] The term "ultrapure", as used in reference to salts and metals, refers to salts and metals that are about or greater than 99% pure or of the highest purity available. The artisan will understand that ultrapure salts and metals are generally commercially available, and that, if required, altering effects of variations in content of such ultrapure materials on nanoparticle formulation can be addressed without undue experimentation by, for example, adjusting the baseline levels of other salts and metals that were used in previous formulations. Reducing the level of barium in a formulation can, for example, offset increases in the levels of impurities in calcium chloride dihydrate, to maintain size, shape, and/or function of formulated nanoparticles. As used herein, "laboratory grade" salts and metals refers to salts and metals that are not ultrapure. In order to maintain consistency of nanoparticle size, shape, and/or function for a given line of formulation, it is recommended that use of laboratory grade salts and metals be minimized, such as less than 25%, 20%, 15%, 10%, or 5% of the total weight of salts and metals added to the final salt receiving solution.

[00108] In one embodiment, the Cesium (Cs)-pretreated lithium nanoparticles comprise a polymorphic form that is differentiated from nanoparticles not pre-treated with Cs. This differentiation is evidenced by, for example, the substantive differences in melting point and FTIR spectra between Cs and non-CS nanoparticles presented in Table 1, below. As used herein, the terms "polymorph" and "polymorphic form" refer to solid crystalline-ordered forms of a compound or complex.

[00109] One or more solid state forms of a compound of interest such as a nanoparticle may be generated by crystallization. One or more solid state forms may also be generated by cocrystallization of a chemical substance with different guest molecules (*i.e.*, components that

are not the principal component of the crystal lattice). One or more solid forms may also be generated by inclusion of an element or element-combination into a supramolecular assembly or addition of a new element or element-combination to generate a new supramolecular assembly.

[00110] Among the phenomena in crystallization are the processes of nucleation and growth. Crystal nucleation is the formation of an ordered solid phase from liquids, supersaturated solutions, saturated vapors, or amorphous phases. Growth is the enlargement of crystals caused by deposition of molecules upon an existing surface. Nucleation may be induced by the presence of "seed" crystals. Some solid particle is present to provide a catalytic effect and reduce the energy barrier to formation of a new phase. Crystals may originate, for example, on a minute trace of a foreign substance (*e.g.*, either impurities or scratches on container walls) acting as a nucleation site. Nucleation may also be promoted by external or nonchemical means, such as stirring the crystallization environment, or by applying both an initiating surface, together with physical energy, such as could be observed by the process of atomizing ultra-small nanoscale micelles into a salt solution.

[00111] Practically, polymorphic and novel forms of a compound such as a nanoparticle are known in the pharmaceutical arts to affect, for example, the solubility, stability, flowability, fractability, and compressibility of the compound, (Knapman, K. 2000 *Modern Drug Discovery* 3: 53-58). Therefore, the discovery of either new polymorphs of a nanoparticle drug or highly-related structural forms can provide a variety of advantages.

[00112] Polymorphs can be detected, identified, classified, and characterized using well-known techniques, such as, but not limited to, differential scanning calorimetry (DSC), thermogravimetry (TGA), X-ray powder diffractometry (XRPD), single crystal X-ray diffractometry, vibrational spectroscopy, solution calorimetry, solid state nuclear magnetic resonance (NMR), infrared (IR) spectroscopy, Fourier-transform infared spectroscopy (FTIR), Raman spectroscopy, hot stage optical microscopy, scanning electron microscopy (SEM), transmission electron microscopy (TEM), electron crystallography and quantitative analysis, particle size analysis (PSA), surface area analysis, solubility, and rate of dissolution.

[00113] As used herein, in reference to the spectra or data originally generated in graphical form (*e.g.*, XRPD, IR, FTIR, Raman and NMR spectra), and unless otherwise indicated, the term "peak" refers to a peak or other special feature that one skilled in the art would recognize as not attributable to background noise. Some limited variance in interpreting or reading peak positioning can occur due to machine and/or algorithm variability in peak detection.

[00114] While not wishing to be bound by theory, the material science data presented in Table 1, below, indicate the addition of trace amounts of cesium (in the form of the element combination, *i.e.*, cesium-treated lithium) surprisingly induced significant changes in the melting point and FTIR spectra of the inventive nanoparticles as compared to non-cesium nanoparticles. Changes in melting point indicates a new polymorphic form that corresponds with changes in physical state. The data presented in Table 1 link the measured changes in melting point with increases in nanoparticle stability, as manifested by improved shipping performance and extended Burton-derived *in vitro* release times.

[00115] As discussed elsewhere herein, nanoparticles formulated with cesium-treated lithium formed suitable nanoparticles with respect to size and shape (sub-50 nm spheroid, cuboid, or elliptical), while nanoparticles formulated with cesium simply commingled with lithium in the salt receiving bath did not. This supports the observation that it is the introduction of the element combination, *i.e.*, cesium-treated lithium, and not simply the addition of cesium, which induced the significant changes in melting point and concomitant improved stability described above.

[00116] In one embodiment, the Cs-pretreated lithium sub-50 nanometer nanoparticles with a hydrophobic micelle core, ligand shell and an encapsulated bioactive agent comprise a novel polymorphic form of a supramolecular assembly (referred to herein as a Cs polymorph nanoparticle) of apparent molecular weight greater than 10,000 daltons, greater than 20,000 daltons, or greater than 30,000 daltons. The artisan can determine apparent molecular weight by standard methods such as for example, ultra high resolution aqueous size exclusion chromatography, using, for example, a Yarra 3u SEC-2000, 30 cm x 7.8 mm column and UV detection together with a mobile phase of 0.3M NaCl in 0.1M phosphate buffer, pH 7.

[00117] In one embodiment, the element combination of cesium and lithium yields Cs polymorph nanoparticles that are/can be formed, used, and/or stored in an aqueous environment.

[00118] In another embodiment, the ligand shell of the Cs polymorph nanoparticle comprises tenfibgen. In still another embodiment, the ligand shell of the Cs polymorph nanoparticle comprises hyaluronan.

[00119] Nanoparticles that have a low surface charge, preferably as close to neutral as possible or even slightly negative, and/or that have the morphology of a compact or roughly spheroidal, cuboid, or elliptical shape, exemplify optimized stability. Additionally, any other components that are capable of increasing the stability of the nanoparticles can be included as part of the stabilization solution, such that the final mean diameter of the nanoparticles is

between a range of about, for example, 5-50 nm. In certain embodiments, nanoparticles of a composition according to the invention have an average diameter of between about 5 and about 50 nanometers, between about 5 and about 40 nanometers, between about 5 and about 30 nanometers, or between about 5 and about 20 nanometers.

[00120] Particle size can be manipulated through routine variation of parameters, including, for example, the length of incubation time after crystallization in the salt receiving solution. In one embodiment, the nanoparticles are measured by atomic force microscopy (AFM). In another embodiment, the nanoparticles are measured by transmission electron microscopy (TEM). In another embodiment, the nanoparticles are measured by dynamic light scattering (DLS). In another embodiment, the nanoparticles are measured by size exclusion chromatography (SEC). In another embodiment, the nanoparticles are measured in dry state by methods known in the art. Unless otherwise stated, average diameter is expressed herein as the average of the major and minor axes of the nanoparticles as measured in dry state. Generally, formulations or compositions of nanoparticles with average major-to-minor -dimension ratios of greater than about about 10:1, about 5:1, or about 3:1 are not suitable for uses intended herein.

[00121] For a more consistent size of nanoparticles, the nanoparticles can optionally be atomized into a receiving solution through a nozzle. Atomization should be sufficient to apply a shear force capable of breaking up flocculated aggregates without so much force as to induce hard aggregates. Those skilled in the art will understand that a particular nozzle diameter will lead to range of feed pressures suitable for atomizing the nanoparticles to a suitable and consistent size. In one embodiment, a nozzle diameter of about 250 microns or smaller with feed pressure of less than about 10 psi produces suitable nanoparticles.

[00122] The stabilized nanoparticles can be incubated at varying times and temperatures depending upon the amount of time required or desired for particle dissolution or disassembly in end use. Incubation times can vary from about 8 hours to about 7 days. In some embodiments, nanoparticles are incubated in round bottom tubes with nominal rotation at 4°C for between 36 and 48 hours. Without wishing to be bound by theory, longer incubation times result in higher crystallization that increases both size and stability of the particle. After atomizing and/or incubating the nanoparticles in a stabilization solution, the nanoparticles can be filtered, centrifuged and/or dried to obtain a composition comprising separate and discrete sub-50 nm nanoparticles. In one embodiment, nanoparticles are centrifuged at 20,000xg at 4°C for 2 hours and sterile-filtered through a 0.2 μm filter. The resultant nanoparticles can be

frozen at about -20°C or dried and reconstituted for later use. Sequences manufactured as chimeric polynucleotides are optionally propyl 3' end-blocked.

[00123] In one embodiment, the nanoparticles are prepared without polyethylene glycol (PEG) and similar species typically used to stabilize nanoparticles. In another embodiment, nanoparticles can be lyophilized and resuspended at lower, same, or higher concentrations, using standard methods known in the art.

[00124] Although the invention has been particularly shown and described with reference to a number of embodiments, it is understood by those skilled in the art that changes in the form and details may be made to the various embodiments disclosed herein without departing from the spirit and scope of the invention, and that the various embodiments disclosed herein are not intended to limit the scope of the claims.

[00125] The invention will be further described in the following examples, which likewise are not intended to limit the scope of the invention described in the claims.

EXAMPLES

[00126] Example 1 – Formulation of targeted therapeutic nanoparticles.

[00127] Illustrative nanoparticles comprising diverse cargos and targeting moieties were generated as follows.

[00128] *Formula A*: In a 2 mL conical tube, 500 µg of chimeric oligo (SEQ ID NO: 5) polynucleotide against CK2 (phosphodiester 3' and propylendblocked – 2'-OMe RNA chimeric, "LCK-6", (US Patent No. 7,741304, incorporated herein in its entirety by reference)) in sterile water (HPLC grade, Fisher) at a concentraton of 1 mg/ml was briefly vortexed, then complexed with 200 µg of 10 kD polyornithine (Sigma), and dispersed into 150 µl of sterile water using a water-insoluble surfactant system (TM-diol blend (SE-30, Air Product), 10 µg in 10 µg DMSO. Following emulsification with a water-miscible solvent (DMSO), by adding 150 µl of DMSO, vortexing, and subsequently placing in bath sonicator for 5 minutes, the complexes were then inverted and diluted by the addition of 700 µl of PBS.

[00129] The resultant hydrophobic micelles were coated (non-covalently) by the addition of 5.5 µg of recombinant fibrinogen fragment of tenascin (TBG), prepared by the method of Aukhill, *et al.* (*J. Biol Chem.*, 268:2542-53 (1993)), with modifications as described herein, placed in a bath sonicator for 15 minutes, transferred to a 5 ml polypropylene tube, and diluted up to 3 ml with PBS, then atomized with a manual actuator using an approximately 250 µm diameter orifice with feed pressure of less than about 10 psi into a salt receiving solution of sterile water containing primarily Li^+ (126 mM Li^+ (premixed with 2.5 ppb Cs^+ on Li^+), 10

mM Ca^{2+}, 0.042 mM Ba^{2+} with 14 nM Sr^{2+}, 6.25 nM Mg^{2+} (all ultrapure, all prepared as stock solutions with sterile water except Sr^{2+} and Mg^{2+} prepared with laboratory grade water, all metals were used as chloride salts, total bath volume approximately 30 ml). The total reaction volume was 36 ml. The level of the following metals tested for in the sterile water used to prepare the stabilization solution was determined to be less than 0.1 parts per million in sum total: aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, magnanese, nickel, rubinium, sulfur, vanadium, and zinc.

[00130] The premixing step comprised adding Cs^+ at about 0.1 µg/1 ml to about 4M Li^+, at about 2.5 ppm Cs^+ to Li^+ by weight, in sterile water in a 50 ml tube, and rotating for about 2 minutes. Following cold-room incubation (4°C) with nominal rotation in 40 ml round-bottomed tubes for 48 hours, which further stabilized the coated micelles in the salt solution, the sub-50 nm nanoparticles were recovered by centrifugation at 20,000xg at 4°C for 2 hrs and resuspended in PBS + 10% lactitol (at a concentration of 1 µg/µl), transferred to a 2 ml conical, and spun down at maximum speed for 5 minutes at 4°C, washed by resuspending pellet in PBS/10% lactitol, sterilized through a 0.2 µm filter, and frozen at -20°C.

[00131] In all formulations described in the instant example, a small amount (1% of coating weight) of Syrian Hamster IgG was "spiked" into the ligand coat to enable immunodetection of nanoparticle uptake by anti-Syrian Hamster antibodies. Average particle size was less than 50 nm, as measured by tapping mode atomic force microscopy using elliptical diameters of a 1 $e^{(-27)}$ g/ml sample dried down on a mica sheet. Average particle size is stated as the average of the major and minor axes of the measured nanoparticles. AFM measurements were further supported by TEM negative staining, where 1 ng/ml suspensions were spotted onto carbon grids. NIH Image J is used to calculate mean particle diameters. Most typically, the average particle size ranged from about 8 nanometers to about 30 nanometers. Formula A had an average particle diameter of 16 ± 2.3 nm by TEM with a surface charge of -2.4 ± 2.3 mev, as measured by a Zetasizer 4 dynamic light scattering device at a potential of 20 volts with a 2-minute pause between measurements in 1 mM KCl at 2 µg/ml.

[00132] *Tenascin-based ligands:* Tenascin has been implicated in cancer activities and also as being specific for smooth muscle cells; furthermore, peptidic domains of tenascin have been identified, *e.g.*, as in U.S. Pat. No. 6,124,260, and are known in the art. In one embodiment, tenascin suitable for the present invention is *H. sapiens* tenascin C, Genbank Accession No. NM_002160. Moreover, tenascin peptides and domains for adhesion with particular cell types, as well as functional and structural aspects of tenascin, have been

disclosed and are known in the art, *e.g.*, Aukhill, *et al.* 1993 *J Biol Chem* 268:2542-2553. Tenascin and/or any of its domains are suitable as ligands for the present invention. In one embodiment, the fibrinogen fragment of tenascin (also referred to herein as Fbg-L domain of tenascin-C or tenfibgen or TBG; nucleotide sequence of tenfibgen used in one embodiment of this invention as follows
(atgattggactcctgtacccctttccccaaggactgctcccaagcaatgctgaatggagacacgacctctggcctctacaccatttatctga
atggtgataaggctcaggcgctggaagtcttctgtgacatgacctctgatgggggtggatggattgtgttcctgagacgcaaaaacggac
gcgagaacttctaccaaaactggaaggcatatgctgctggatttggggaccgcagagaagaattctggcttgggctggacaacctgaac
aaaatcacagcccaggggcagtacgagctccgggtggacctgcgggaccatggggagacagcctttgctgtctatgacaagttcagcg
tgggagatgccaagactcgctacaagctgaaggtggaggggtacagtgggacagcaggtgactccatggcctaccacaatggcagat
ccttctccacctttgacaaggacacagattcagccatcaccaactgtgctctgtcctacaaaggggctttctggtacaggaactgtcaccgt
gtcaacctgatggggagatatggggacaataaccacagtcagggcgttaactggttccactggaagggccacgaacactcaatccagtt
tgctgagatgaagctgagaccaagcaacttcagaaatcttgaaggcaggcgtaagcgggcataa) (SEQ ID NO:10)
is used as the ligand. Tenascin, its subdomains, or any other biocompatible polymer ligand may be expressed or produced by methods known in the art or methods which the artisan can readily adapt. For illustration purposes, a method for producing TBG is provided below.

[00133] *Tenfibgen (TBG) preparation:* For all TBG formulas, unless otherwise noted, TBG was prepared by the method of Aukhil (*J Biol Chem* (268): 2542-2553 (1993)) with modifications, *i.e.* TBG was isolated and refolded from bacterial lysate by washing the insoluble pellet once with lysis buffer (50 mM Tris-HCl, 1.0 mM EDTA, 0.1 M NaCl, 0.2 mg/ml lysozyme, 0.1% Triton X-100, 0.1 mM PMSF, pH 8.0) containing 2 M urea and resuspending in 4M GuCL, 5 mM DTT in 0.02 M Tris-HCI, pH 8.0. After additional centrifugation, the clarified TBG solution was diluted with 2 M Guanidine-HCl, 20 mM Tris-HCl, pH 8.0 to make a final OD280 of about 1 and diluted dropwise about10-fold into N_2-sparged, 20 mM Tris-HCl, 0.2 M NaCl, 0.5 M Arginine-HCl for overnight stirred incubation (4°C). After diafiltration against 20 mM Tris-HCl, pH 8.0 with an approximate 4-5 fold reduction in concentration and 0.45 μM filtration, a final purification was performed on heparan sepharose in 20 mM Tris-HCl, pH 8.0, with elution by bringing the NaCl concentration to 0.6 M. Endotoxin was removed in an anion exchange chromatography step by applying pH 10.5 Tenfibgen to Q Fast Flow resin, equillibrated with 20mM NaH_2CO_3, 0.2M NaCl, pH=10.5, then readjusting pH to 7 with H_3PO_4 before final 0.2um filtration. In therapeutic tumor-targeting formulations, TBG was reprecipitated in ultra-pure 40% ammonium sulfate containing 250 ppb As^{+3}, 25 ppm Se^{+4}, 2.5 ppm Hg^{+2} and 25 ppm Mo^{+5} for about 16 hours.

[00134] *Formula B*: sub-50 nm nanoparticles coated with TBG were generated as described in Formula A, except that 6.3 mcg of TBG was added to 500 mcg of 2R-modified chimeric oligo (SEQ ID NO: 8), condensed with 125 mcg of 10 kD polyornithine (Sigma). When generating these nanoparticles, the TBG-coated micelles were atomized into the salt receiving solution of Formula A except for the following modified concentrations: 4.5 nM Sr^{2+}, 2.25 nM Mg^{2+}. Average particle diameter was less than 50 nm (17.8 ± 3.1 nm), as measured by negative staining TEM using elliptical diameters of a 1 ng/ml sample spotted onto a carbon grid, with a surface charge of -7.7 ± 4.2 mev, as measured by a Zetasizer 4 dynamic light scattering device at a potential of 20 volts with a 2-minute pause between measurements in 1 mM KCl at 2 µg/ml.

[00135] *Formula C*: sub-50 nm nanoparticles coated with TBG were generated as described in Formula A, except that 2.6 mcg of TBG was added to 250 mcg of chimeric oligos (SEQ ID NOs:5 and 6, 1:1 by weight) condensed with 100 mcg of 10 kD polyornithine (Sigma) and micellized using 7.5 ug surfactant. When generating these nanoparticles, the TBG-coated micelles were atomized into the salt receiving solution of Formula A modified for the following concentrations: 3.75 nM Sr^{2+}, 4.68 nM Mg^{2+}. Average particle diameter was less than 50 nm (17.8 ± 1.5 nm), as measured by negative staining TEM using elliptical diameters of a 1 ng/ml sample spotted onto a carbon grid, with a surface charge of -12.3 ± 3.5 mev, as measured by a Zetasizer 4 dynamic light scattering device at a potential of 20 volts with a 2-minute pause between measurements in 1 mM KCl at 2 µg/ml.

[00136] *Formula D*: sub-50 nm nanoparticles coated with TBG were generated as described in Formula C, except the oligonucleotide mix consisted of SEQ ID NOs: 5 and 7 (1:1 by weight). Average particle diameter was less than 50 nm (17 ± 1.6 nm), as measured by negative staining TEM using elliptical diameters of a 1 ng/ml sample spotted onto a carbon grid, with a surface charge of -7.1 ± 5.4 mev, as measured by a Zetasizer 4 dynamic light scattering device at a potential of 20 volts with a 2-minute pause between measurements in 1 mM KCl at 2 µg/ml.

[00137] *Formula E*: sub-50 nm nanoparticles coated with TBG were generated as described in Formula A, except that 3.1 mcg of TBG was added to 250 mcg of 2R-modified chimeric oligos (SEQ ID NOs: 8 and 9, 1:1 by weight) condensed with 62.5 mcg of 10 kD polyornithine (Sigma) and micellized using 7.5 ug TM-diol. When generating these nanoparticles, the TBG-coated micelles were atomized into the salt receiving solution of Formula A modified for the following concentrations: 2.5 nM Sr^{2+}, 0.25 nM Mg^{2+}. Average particle diameter was less than 50 nm (19.5 ± 1.5 nm), as measured by negative staining TEM

using elliptical diameters of a 1 ng/ml sample spotted onto a carbon grid, with a surface charge of -5.8 ± 3.9 mev, as measured by a Zetasizer 4 dynamic light scattering device at a potential of 20 volts with a 2-minute pause between measurements in 1 mM KCl at 2 µg/ml. Lithium content was assessed as 5.39 ng of Li^+ per µg of oligo by ICP-AES. (It is noted that for an analogous formulation, lithium content of 292 pg/ug of oligo was measured by the more senstive ICP-MS method.)

[00138] *Formula F*: sub-50 nm control nanoparticles coated with TBG were generated as described in Formula A, except that 6.3 mcg of TBG was added to 500 mcg of a 2R-modified chimeric oligo (anti-coagulation Factor VII, as reported in Akinc, *et al.* 2008 *Nat Biotechnol* 26:5(561-9)) condensed with 125 mcg of 10 kD polyornthine (Sigma) and micellized using 5 ug TM-diol. When generating these nanoparticles, the TBG-coated micelles were atomized into the salt receiving solution of Formula A modified for the following concentrations: 1.17 nM Sr2+, 4.68 nM Mg2+. Average particle diameter was less than 50 nm (24.7 ± 3 nm), as measured by negative staining TEM using elliptical diameters of a 1 ng/ml sample spotted onto a carbon grid, with a surface charge of -7.6 ± 2.4 mev, as measured by a Zetasizer 4 dynamic light scattering device at a potential of 20 volts with a 2-minute pause between measurements in 1 mM KCl at 2 µg/ml.

[00139] *Formula G*: sub-50 nm nanoparticles coated with TBG were generated as described in Formula A, except that the stabilization solution was comprised of non-sterile, laboratory-grade water, and the Lithium Chloride stock was not pretreated with cesium or any other ion. The level of the following metals tested for in the water used to prepare the stabilization solution was determined to be about 0.9 parts per million in sum total: aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, magnanese, nickel, rubinium, sulfur, vanadium, and zinc. Nanoparticles were resuspended following centrifugation in PBS + 10% Lactitol. Average particle diameter was less than 50 nm (21.8 ± 4 nm), as measured by negative staining TEM using elliptical diameters of a 1 ng/ml sample spotted onto a carbon grid, with a surface charge of -9.6 ± 3.8 mev, as measured by a Zetasizer 4 dynamic light scattering device at a potential of 20 volts with a 2-minute pause between measurements in 1 mM KCl at 2 µg/ml.

[00140] *Formula H*: sub-50 nm nanoparticles coated with TBG were generated as described in Formula A using the same LCK oligo. When generating these nanoparticles, the TBG-coated micelles were atomized into the salt receiving solution of Formula A based on Lithium Nitrate, rather than Lithium Chloride and modified for the following concentrations: 7.5 nM Sr^{2+}, 5.0 nM Mg^{2+}. Average particle diameter was less than 50 nm (21.5 ± 2 nm), as

measured by negative staining TEM using elliptical diameters of a 1 ng/ml sample spotted onto a carbon grid with a surface charge of -12.4 ± 4 mev, as measured by a Zetasizer 4 dynamic light scattering device at a potential of 20 volts with a 2-minute pause between measurements in 1 mM KCl at 2 µg/ml.

[00141] *Formula I:* sub-50 nm nanoparticles coated with 20 kD MW hyaluronan (Sodium Hyaluronate powder resuspended in HPLC water, Lifecore Biomedical, Lha, low molecular-weight hyaluronan) were generated as described in Formula G, except that 3.1 mcg of HA (substituted for TBG) was added to 125 mcg of plasmid DNA (pVivoßgal, Invivogen Corp., 10.5 kb) (substituted for oligonucleotides), first complexed with 19.4 µg of 25 kDa polyethyleneimine (PEI; Sigma Chemical Co., St. Louis, MO), a branched cationic polymer, then micellized with 6.25 ug of TM-diol. When generating these nanoparticles, the Lha-coated micelles were atomized into the salt receiving solution of Formula G modified for the following concentrations and additions: 2 nM Sr^{2+}, 0.5 nM Mg^{2+}, 0.54 Bi^{2+} µM, and addition of 0.40 mM Ni^{2+} (ultrapure, basis of 40 ml total volume) . Average particle diameter was less than 50 nm (20.4 ± 2), as measured by negative staining TEM using elliptical diameters of a 1 ng/ml sample spotted onto a carbon grid with an average surface charge of -8.1 ± 4.7 mev, as measured by a Zetasizer 4 dynamic light scattering device at a potential of 20 volts with a 2-minute pause between measurements in 1 mM KCl at 2 µg/ml.

[00142] *Formula J:* sub-50 nm nanoparticles coated with 20 kD MW hyaluronan (Sodium Hyaluronate powder resuspended in HPLC water, Lifecore Biomedical, Lha, low molecular-weight hyaluronan) were generated as described in Formula A, except that 3.1 mcg of HA (substituted for TBG) was added to 125 mcg of plasmid DNA (pVivoßgal, Invivogen Corp., 10.5 kb) (substituted for oligonucleotides), first complexed with 19.4 µg of 25 kDa polyethyleneimine (PEI; Sigma Chemical Co., St. Louis, MO), a branched cationic polymer, then micellized with 6.25 µg of TM-diol. When generating these nanoparticles, the Lha-coated micelles were atomized into the salt receiving solution of Formula A modified for the following concentrations and additions: 2 nM Sr^{2+}, 0.5 nM Mg^{2+}, 0.54 Bi^{2+} uM and addition of 0.40 mM Ni^{2+} (ultrapure, basis of 40 ml total volume). Average particle diameter was less than 50 nm (22.7 ± 5 nm), as measured by negative staining TEM using elliptical diameters of a 1 ng/ml sample spotted onto a carbon grid with an average surface charge of -6.4 ± 4.2 mev, as measured by a Zetasizer 4 dynamic light scattering device at a potential of 20 volts with a 2-minute pause between measurements in 1 mM KCl at 2 µg/ml. Li+ content of between 8.1 - 13.1 ng/µg of plasmid have been measured in similar formulations by ICP (data not shown).

By routine characterization and TEM, plasmid s50 particles of Formula I and J were found to be similar to TBG-coated oligo particles of Formulas A-H in terms of physical properties and comparable TEM. For example, regardless of nucleic acid cargo, nanoparticle encapsulation yields for the formulas described herein were greater than 95%, as determined by the modified method of Burton (Kren, *et al.*2009 *JCI* 119 :2086-99) (data not shown). This similarity of properties between the nanoparticles comprising an oligonucleotide bioactive agent and protein shell and the nanoparticles comprising a plasmid DNA bioactive agent and carbohydrate shell demonstrates the flexibility of the nanoparticle formulation process and resulting nanoparticle composition to accommodate different bioactive agents, polymers, and ligand moieties.

[00143] Example 2 – Cesium modification of the lithium ion in nanoparticle synthesis improves stability.

[00144] Besides being efficacious, nanoparticle dosage forms must comply with the requirements of pharmaceutical manufacturing and product requirements from regulatory and other entities. For example, a nanoparticle's physical stability is a a key component of its regulatory approval, impacting formulation, manufacturing, and storage protocols. Trace addition of cesium to the nanoparticle synthesis when executed in sterile water, has been found, surprisingly, to result in improved physical stability, as manifested by enhanced shipping performance and Burton-derived stability measures.

[00145] It has been discovered, quite unexpectedly, that 2.5 ppb cesium pre-treatment of the lithium before assembling the receiving solution into which the ligand-stabilized micelles are added quadruples the concentration at which nanoparticles bearing either oliogonucleotides or plasmid DNA may be shipped as liquid formulations by air freight at -4°C. These observations are summarized in Table 1. In these air shipping tests, nanoparticle suspensions were concentrated by lyophilization, shipped, and subsequently examined upon return for changes in particle diameter by TEM microscopy following an air shipping challenge. In TEM, the inventive nanoparticles appear as cubic or fractal supramolecular assemblies surrounded in a visible, but poorly refractive corona, comprised of targeting ligand (data not shown). For example, suspension concentrations of 20 mg/ml are required to aquire light scattering data for (*i.e.*, to detect) the nanoparticles (sized approximately 25 nanometers in diameter) in low power (1 mW) dynamic light scattering (DLS). In contrast, ligand-coated micelles preceding incubation in the cesium-treated lithium salt receiving solution, while similarly small in size (28 nm diameter, Table 1), are readily detected at concentrations of

about 1 mg/ml under similar DLS conditions, suggesting significant change in nanoparticle supramolecular assembly occurs during the incubation/stabilization step (data not shown).

[00146] In shipping and control samples, particle diameters were quantified by image analysis in NIH Image J as the average of ellipitical axes fitted to particles from TEM micrographs. Results are summarized in Table 1 to show that for a non-modified cesium formulation bearing oligo (Formula G), average particle diameter increased 161% from a control formulation to the same formulation air-shipped at 3 mg/ml. A concommitant loss in protein corona surrounding the faceted, birefringent particle was also observed after shipping (data not shown). In contrast, the analogous cesium-modified formulation (Formula A) maintained shape and corona at 4 mg/ml (Table 1, data not shown).

[00147] The same analysis was executed for a pair of formulations bearing a commercial reporter gene plasmid and coated with hyaluronan with a similar result. For Formula J, prepared with cesium pre-treatment of the lithium in the receiving bath, particles could be shipped at an 8-fold increase in concentration (2 vs. 0.25 mg/ml) with less than 15% increase in particle diameter relative to Formula I, prepared without cesium pretreament. A loss in ligand corona was also observed in the non-cesium pretreated particles with increased shipping concentration also (data not shown). The improvement in shipping concentration demonstrated with Formula H, prepared with Lithium Nitrate rather than Lithium Chloride, indicates that multiple salts of lithium may be used in nanoparticle synthesis. While premixing of cesium and lithium prior to their addition to the salt receiving solution resulted in nanoparticles of suitable spherical or cuboid ultra-small (LTE 50 nm dry diameter) morphology, the unmixed addition of cesium and lithium to the salt receiving solution did not (data not shown).

[00148] TABLE 1. Particle and shipping stability with + without cesium modification

Particle/Cargo	Formula	Particle Diameter [1]		In vitro release [2]		DSC Transitions[3]; °C, gt midpoints, et nadirs	FTIR spectrum[7] (wavenumber, cm -1)
		(nm)	% Δ from control	Hrs	% Δ		
PBS + 10% Lactitol						gt 160; sharp et, 186	
TM-Diol surfactant[4]							quad, 2956, 2928, 2873, 2832; singlet, 1733; triplet, 1449, 1370, 1260; group of 5; singlet, 805
Ligand-coated micelle[4]		28.2 ± 1.6				broad et, 98, 105 (45-126)	

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1 mg/ml shipped		27.4 ± 1.4	+ 26*			strong, broad et, 180(172-200)	2921, 2873, 2839; s brd singlet, 1647; md triplet, 1456, 1377, 1260; v st doublet, 1079, 1031; md singlet, 798
2 mg/ml shipped		35.9 ± 1.2	+ 65*				
3 mg/ml shipped		57 ± 3.4	+ 161*				
TBG LCK oligo(+ Cs)	A	24.8 ± 2.5		104	+68	et, 130, 137, 275	v brd, 3377; triplet, 2952, 2925, 2853; doublet, 1740, 1644; md triplet, 1462, 1377, 1260; v st doublet, 1093, 1021; md singlet, 795
2 mg/ml shipped		24.7 ± 1.8	0				
3 mg/ml shipped		25.7 ± 1	+4				
4 mg/ml shipped		21.4± 1.1	-14				
TBG LCK oligo(+ Cs)	H	21.5 ± 0.5		82	+ 33		
3 mg/ml shipped		22.8 ± 0.9	+6				
LhaNi pVivoßgal (- Cs)	I	20.4 ± 0.5	--------	117	------	gt 158; strong, broad et, 178(172-227)[5]	
0.25 mg/ml, shipped		23.4 ± 0.9	+ 15				
0.5 mg/ml, shipped		32.3 ± 1.3	+ 58*				
1 mg/ml, shipped		34.4 ± 2.2	+ 69*				
2 mg/ml, shipped		36 ± 1.6	+76*				
LhaNi pVivoßgal (+ Cs)	J	22.7 ± 1.1		>120[6]	+++	vs gt 150; sharp et, 193, 206, 227°C[5]	
0.25 mg/ml, shipped		21.6 ± 0.7	- 5				
0.5 mg/ml, shipped		21 ± 0.9	- 7				
1 mg/ml, shipped		23.8 ± 1.3	+5				
2 mg/ml, shipped		25.5 ± 1.6	+ 12				

Notes: * = $p < 0.5$, **1**) Particle diameter was measured as average elliptical diameter after drying at 0.1 ng/ml by negative staining TEM at x271,000. Expressed as mean ± SE with 15-20 measurements per analysis. Lots were confirmed to have substantial *in vitro* cellular uptake into tumor cells grown in 3-D culture before use in shipping studies. **2**) *In vitro* release was measured in conjunction with DNA incorporation by a colorimetric, modified Burton assay employing a standard curve. Release is reported as a timepoint interpolated from later timepoints with average Burton yields surrounding 100%. **3**) Thermal transitions were identified from thermograms generated by differential scanning calorimetry (DSC). Suspensions were dried to produce powder for analysis, and 1-2 mg were scanned at 20°C/min from room temperature to about 400°C in crimped aluminum pans. *abbreviations*, gt, glass transition; et, endotherm; vs, very small. **4**) TM-Diol is unformulated hydrophobic surfactant and is presented for analysis reference. Ligand-coated micelles are micelles formulated according to Formula E but were scanned prior to incubation in salt receiving solution. **5**) Hyaluronan-coated ligand particles were similar formulations to shipping samples but comprised 8.5 kb reporter gene plasmids rather than 10.5 kb reporter plasmids. **6)** After about 120 hours in this form of assay, color started to degrade in the standard curve, necessitating, here, the premature termination of the assay. **7)** The FTIR spectra were recorded using a Perkin Elmer Spectrum 65, equipped with a ATR attachment, a mid-infrared source as the excitation source, and a DTGS detector. The spectra were acquired in 32 scans at a resolution of 4 cm^{-1}. Suspension samples were extracted with 3:1 (v/v) of isobutyl to isoamyl alcohol at 4°C to remove residual surfactant and evaporated, dried powder was submitted for analysis. Abbreviations, v, very; s, small; md, moderate; str, strong; brd, broad.

[00149] The impact of cesium pre-treatment of lithium preceding assembly of the receiving solution on particle stability was further investigated by examining formulations for *in vitro* release. *In vitro* release was assessed in conjunction with particle degradation based on a modified colorimetric Burton assay (Kren, *et al.* 2009 *JCI* 119:2086-99). In this assay,

particles are incubated at 56°C in 1M NaOH overnight rather than 6M NaOH. The nanoparticles were then neutralized and the Burton reagents added to create a blue signal upon reaction with released DNA. Percent yield is expressed relative to a theoretical value from a standard curve, so that 100% yield is approached as the nanoparticles are fully degraded to release their contents. *In vitro* release is then expressed as an endpoint interpolated from timepoints surrounding 100% yield. Thus, *in vitro* release time is a measure of the nanoparticle's resistance to degradation, and its increase following Cs-pre-treatment corresponds with the increase in shipping stability observed for Cs-treated vs. non-CS-treated nanoparticles for both oligo and plasmid series (Table 1 *in vitro* release times; Cs vs. non-Cs oligo, 104 hrs. vs. 62 hrs.; Cs vs. non-Cs plasmid DNA, >120 hrs. vs. 117 hrs.).

[00150] To investigate how differences in nanoparticle composition might impact the inventive nanoparticles at a physical (release) and functional (shipping) level, thermal profiles of the dried and crushed powder of the oligo and plasmid-bearing nanoparticles were examined for potential changes in characteristic transitions by differential scanning calorimetry at 10°C per minute over a range from about 25°C to about 400°C (summarized in Table 1, above). In multiple runs, a small transition at 158°C, followed by a strong, broad endotherm (172-200°C) with nadir at 180°C, was observed in the non-Cs-modifed Formula G, while only one strong endotherm at 275°C was observed for Cs-modified Formula A, indicating a change in morphological state. Similarly, for hyaluronan nanoparticles bearing 8.5 kb reporter gene plasmids, in the non-Cs-modified compound (representing Formula I), a small transition at 158°C followed by a stong and broad endotherm with nadir at 178°C (172-227) was observed, compared to the Cs-modified compound, where a very small transition at 150°C, with strong, very sharp endotherms at 193, 206, and 227°C, was observed (representing Formula J), again indicating a change in morphological state. In contrast, a scan of the diluent, PBS + 10% lactitol, a non-reducing sugar, showed a very small transition at about 160°C and a strong, sharp endotherm at 186°C with a degradation endotherm centered around at about 310°C. All nanoparticle compounds showed such an endotherm centered around 307-313°C. A thermal scan of a TBG-coated micelle before atomization and subsequent incubation in the primarily lithium salt solution ("Ligand-coated micelle") showed a broad endotherm with peaks (98, 105°C) centered around 100°C. The observation that this thermogram was markedly different from the nanoparticles scanned post incubation in the cesium-treated lithium solution supports the statement that the cesium-treated lithium solution imparts order and rearrangement to the stabilized micelle and nanoparticle over time to create a unique supramolecular assembly.

[00151] Compound differences upon introducing cesium-pretreatment of lithium into the stabilization bath were further investigated by FTIR spectroscopy. The FTIR spectrum of non-Cs Formula G and Cs-containing Formula A were read from 600-4000 cm-^{1}. Based on peak assignment derived from component and library scans, the capsule scans were generally characterized by a broad, intensive band around 3300, representing the O-H stretching vibration of water at 3390 cm-^{1}, groups of bands attributable to the surfactant (4: at about 2956-2832 cm^{-1}, 3:at about 1449-1260 cm^{-1}) and a strong, intensive band attributable to Li-O and Li-OH vibrations at about 1100 – 1110 cm^{-1}. Major peak differences observed upon cesium-pretreatment of the stabilizing bath (Formula G vs. Formula A) were: 1) the narrowing of a broad peak at about 1647 cm^{-1} into peaks at about 1740, 1640; 2) the modification of a likely surfactant-derived quadruplet at about 2952-2839 into a triplet at about 2952-2853; and 3) a shift in the water vibration band from about 3329 to 3377 cm^{-1}.

[00152] In terms of absorbance shifts, cesium pretreatment resulted in a greater than 50% decrease in the magnitude of the water absorbance, consistent with a possible decrease in the amount of water trapped within a reorganized capsule assembly. Of note, the hydrophobic surfactant was devoid of absorbances in this region. There were also greater than 50% absorbance increases in the surfactant-attributable bands at about 1260 and 795 cm^{-1} nearest to the lithium region, suggesting possible changes in the interactions between these critical components of the assembly. Following atomization of the ligand-coated micelle into the receiving bath comprised of cesium-treated lithium, these components are in intimate contact for a number of hours before the reaction is stopped.

[00153] Significant changes in thermal transitions and IR spectra are important indicators of polymorphic change in crystalline compounds, pharmaceutical compounds, and nanoscale supramolecular assemblies, which are known to undergo, in different morphology states, important phyical and functional change. Without wishing to be be bound by theory, the indicated differences (Table 1) in morphological state for Cs-modified nanoparticles compared with unmodified nanoparticles potentially provides an important mechansim underlying the improved shipping stability and extended Burton-derived *in vitro* stability observed for the Cs-modified nanoparticles.

[00154] This example shows that the inventive nanoparticles substantially increase shipping concentrations and Burton-derived stability for diverse cargos and nanoparticle polymorphs.

[00155] Example 3 – Modified chimeric polynucleotide mix demonstrates surprising efficacy in a mouse tumor model.

[00156] The cesium-modified nanoparticles comprising TBG ligands and anti-CK2 chimeric polynucleotide bioactive agents are directed toward manipulating levels of Casein Kinase 2alpha (Csnk2a1) and Casein Kinase 2alphaprime (Csnk2a2) protein in tumor and tumor stromal cells, as the TBG ligand in the nanoparticle delivery system directs particle and oligo cargo to both tissue types. Casein Kinase 2 (CK2) is a ubiquitous enzyme overdriven by tumor cells to promote survival by multiple pathways, and it accumulates in cell nuclei under conditions of stress and in tumors. Shuttling of CK2 from the nuclear compartment precedes apoptosis, and the inability of the tumor cell to maintain nuclear CK2 precedes tumor death. Oncology therapeutics are often evaluated in human tumors grown in immunocompromised mice (xenograft models). As outlined in Table 2, below, in the regions of the genes targeted with the bifunctional oligos engaging Ago2 and RNAseH (U.S. Patent Publication No. 2013/0267577, incorporated herein in its entirety by reference), up to 3 mismatches can exist between human and mouse (3 between hu Csnk2a1 and mu Csnk2a2). Mismatches to hu Csnk2a1 are highlighted by shading and either bolded underline, outlined, or oversize letters.

[00157] Upon incorporating a single-nucleotide modification into the single-strand oligo design described herein (SEQ ID NO: 8), as well as into a novel single-strand oligo design directed to Csnk2a2 (SEQ ID NO: 9), and combining these single-strand oligos in TBG-coated s50 particles to form a CK2 anticancer therapeutic mix, significant results in terms of inhibition of tumor growth, cell proliferation, and inflammation were achieved in tumor-bearing mice. The 2R backbone modification consisted of changing a single nucleotide -- the DNA nucleotide at position 2 from the 5'-end to a 2'-O-methyl-modified RNA nucleotide. All backbone linkages in these oligos were phosphodiester. In this experiment, efforts were also made to assess the impact of mismatching analogous murine target regions. Table 2, below, describes the sequences used or referred to in the instant example:

[00158] TABLE 2. Sequences

DNA	**Target – perfect match**	**SEQ ID NO:**	**Sequence**
Hu Csnk2a1		1	*ATGTGG*AGTTTGGGTTGTAT
Hu Csnk2a2		2	*ATGTGG*AGTTTGGG**C**TGTAT
Mu Csnk2a1		3	*ATGTGG*AG**C**TTGGGTTGTAT
Mu Csnk2a2		4	*ATGTGG*AG**C**TTGGG**C**TG**C**AT
Oligos			
LCK	Hu Csnk2a1	5	5'ATACAACCCAAACT ccacau *-propyl-3'*
huCK2prime	Hu Csnk2a2	6	5'ATACA**G**CCCAAACT ccacau *-propyl-3'*
muCK2prime	Mu Csnk2a2	7	5'AT**G**CA**G**CCCAA**G**CT ccacau-*propyl*-3'
Modified Oligos			

2RLCK	Hu Csnk2a1	8	5'AuACAACCCAAACT ccacau *-propyl-3'*
2RhuCK2prime	Hu Csnk2a2	9	5'AuACAGCCCAAACT ccacau *-propyl-3'*

Notes: **1**) All nucleotide linkages are phosphodiester. **2**) Italics in DNA target sequences = 2'O-Methyl RNA region in the 3' end of the corresponding chimeric drug oligo. **3**) Mismatches to Hu Csnk2a1 are shaded and contain either shaded underline, boxed, or oversize underline letters. **4**) For Oligos and Modified Oligos, caps denote DNA, lower case denotes RNA, and all RNA nucleotides are 2' O-Me modified.

[00159] Using two strains of nude mouse (FoxN, Balb/CaNCR (BN)) and one tumor line (FaDu, hypopharyngeal), mice were inoculated intradermally with either $2e^6$ (FoxN) or $2e^5$ (BN) tumor cells in 50% Matrigel, and subcutaneous treatment was initiated 7 days later. Average tumor size at start of treatment was approximately 69 – 86 cu mm. Cohorts of 5 mice were treated at 10 µg/kg twice weekly. In some cases, after approximately 10 days of treatment, 2 mice from a treatment group were sacrificed. After 30 days of treatment (D30), the remaining 3-5 animals per group were sacrificed, and residual viable tumors were weighed.

[00160] To assess molecular changes, cryosections from viable tumor regions from each mouse were assayed for Ki-67 and p65 NF-kB levels by microscopy and quantified as signal area fraction thresholded against background controls using NIH Image J. Duplicate representative fields were collected from viable tumor sections representing all D30 mice. Ki-67 is a common clinical indicator of tumor proliferation rate and is expressed as a fraction or percentage of viable cell nuclei area, and p65 NF-kB is a major signaling and regulatory protein in inflammation and is an important downstream target of CK2. NF-kB is aberrantly activated, and inhibition of NF-kB induces cell death and inhibits tumorigenesis in head and neck squamous cell carcinomas (HNSCC) (Yu, et al. 2006 *Cancer Research* 66:6722-6731). The artisan, thus, appreciates the potency and many of the results of anti-CK2 strategies in tumor models can be understood in terms of anti-NF-kB activity. In terms of cell biology, p65 NF-kB (similar to CK2) localizes to cell nuclei under inflammatory conditions and conditions of stress, and is cytoplasmic or less detectable with increasing reduction in inflammation. Table 3 summarizes treatments and results for the three analyses.

[00161] TABLE 3. Results 30 days after start of treatment in mouse Fadu tumor model

Treatment	**SEQ ID NO:**	**Formula No.[5]**	**Tumor Weight (g)**	**% Δ**	**Ki-67 Index (signal area/ nuclear area)**	**%Δ**	**NF-kB Index (signal/tissue area)**	**% Δ**
Experiment E1 - Effect of 2R modification on starting single-stranded oligo in FoxN mouse model.								
Control			1.03 ± 0.04		0.8 ± 00.13		0.87 ± 0.06	
2RLCK	8	B	0.58 ± 0.19	-43.7	0.87 ± 0.09	+9	0.69 ± 0.06	-20.4
LCK	5	A	1.043 ± 0.22	0	1.1 ± 0.32	+44	0.8 ± 0.1	-7.5
Experiment E2 – Effect of oligo mix perfect match approach without 2R modification in BN mouse model								
Control			0.634 ± 0.17		0.96 ± 0.05		0.78 ± 0.01	

muMix	5 + 7	D	0.8 ± 0.07	+26.2	0.85 ± 0.33	-11	0.31 ± 0.05	-59.7*
huMix	5 + 6	C	0.85 ± 0.06	+34.1*	0.89 ± 0.42	-6.5	0.82 ± 0.12	+5.1
LCK	5	A	1.0 ± 0.39	+57.7	1 ± 0.16	+5.5	0.74 ± 0.01	-5.3
Experiment E3 - Effect of combined 2R modification and oligo mix approach in BN mouse model								
Control			0.68 ± 0.24		0.89 ± 0.11		0.89 ± 0.09	
2R huMix	8 + 9	E	0.29 ± 0.04	-56.1*#	0.24 ± 0.1	-73*	0.0029 ± 0.002	-99.7*

Notes: **1**) N = 3 mice per group, except for huMix which had 5. **2**) Values are reported as mean ± SE. **3**) *= $p<0.05$, Student's t-test. **4**) # = $p<0.05$, Student's t-test, significant against entire BN control pool, 0.66 ± 0.11g. **5**) Formula number for TBG nanoencapsulated sequence as listed under and described in Example 1.

[00162] Of note, despite limited differences between the oligonucleotide components of the experiment groups, the TBG-encapsulated 2R huMix oligo was the only approach that produced significant reductions in all three categories of tumor weight, cell proliferation (Ki-67), and inflammation index (NF-kB) vs. controls 30 days after the start of treatment (Table 2, E3 experiment, Formula E). Neither the encapsulated single-nucleotide 2R modification (E1 experiment, Formula B) nor the encapsulated huMix approach (E2 experiment, Formula C) showed a significant decrease in tumor weight at 30 days post-treatment. Indeed, the huMix-treated group (Formula C) showed a significant increase of 34% in tumor weight relative to control. Conversely, the tumors from mice treated with nanoencapsulated 2RhuMix (Formula E) showed a significant 56% reduction in tumor weight against pooled BN control tumors that corresponded with large and dramatic reductions in cell proliferation and inflammatory index (-73% Ki-67 index, -99.7% p65 NF-kB signal fraction, $p<0.05$). No other treatment group showed significant reduction in both cell proliferation index and p65 NF-kB signal vs. controls, much less those two measures and tumor weight. The muMix treatment in the E2 experiment showed a significant 59.7% reduction in NF-kB signal area fraction vs. controls, but this was accompanied by a 26.2% increase in tumor weight vs. controls, a clearly undesired outcome. Of additional note, in the E3 experiment, there was significant reduction (99.7%) in p65 NF-kB signal in the 2R huMix cohort vs. controls, whereas there was little change in p65 NF-kB signal in the huMix cohort in the E2 experiment, where mismatches to murine sequences were equal to those of the the 2R huMix (Table 2, above).

[00163] Changes in CK2 alpha and CK2 alpha prime protein levels for the mice in the E3 experiment were assessed by microscopy. Consistent with significant decreases in shrinkage, proliferation, and inflammation indices, significant reduction ($p < 0.05$) in CK2 alpha and CK2 alpha prime signal levels (- 52% and - 45%, respectively) was observed in viable tumor sections of treated mice relative to controls (data not shown). No significant

alpha and CK2 alpha prime signal levels (- 52% and - 45%, respectively) was observed in viable tumor sections of treated mice relative to controls (data not shown). No significant changes in CK2 alpha and CK2alpha prime signal fraction were observed in all other treatments in experiments E1 and E2.

[00164] It is noted that the treated mice in E3 experiment showed no significant weight loss or untoward effects during the 30-day observation period (data not shown). Taken together, the observed results show that the combination of limited modifications in oligonucleotide backbone and sequences resulted in significant and surprising changes in phenotypic and molecular markers in tumor-bearing mice.

[00165] Example 4 – Modified chimeric polynucleotide mix demonstrates surprising efficacy in an aggressive, xenograft mouse tumor model.

[00166] To investigate the effect of limited modifications in oligonucleotide backbone and sequences, together with Cs-modification of nanoparticle, in another model, a xenograft tumor model comprising the human tumor line (UM-SCC-47, derived from HPV-(+) tongue tissue) and NIH outbred athymic nude mice were examined. In this experiment, nude mice were inoculated subcutaneously with $2e^6$ cells and held for two weeks, while tumors grew to 60-80 cu. mm. before starting daily SQ treatment at 100 μg/kg. Tumors were collected after 14 days of treatment and examined similarly as in the FaDu experiment described above. Results are summarized below in Table 4.

[00167] In this example, similar to example 3 and using the same methods, the Cs-modified,TBG-encapsulated 2R huMix oligo produced the largest reductions in all three categories of tumor weight, cell proliferation (Ki-67), and inflammation index (p65 NF-kB) vs. controls at 14 days (rather than 30 days) after the start of treatment (Table 4, Formula E). Additional controls, *i.e.*, Cs-modified nanoparticles with control oligo and sugar cargos, were included to illustrate the negative impact of non-specific interventional stress on tumor growth response. In this combination of mouse and cell line, tumors were observed to be immediately metastatic to lymph nodes and grossly invaded the peritoneal cavity in every mouse but those treated with Formula E (data not shown). Thus, tumor weight is reported as a combination of primary tumor with peritoneal extension and major lymph nodes. Taken together, examples 3 and 4 show the advantageous efficacy of the novel combination of 2R modification and Csnk2a1 and Csnk2a2 sequences across different tumor lines and mouse models.

[00168] TABLE 4. Results 14 days after start of treatment in xenograft UM-SCC-47 tumor model

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Treatment	SEQ ID NOS:	Formula No.[4]	Tumor Burden[5] (g)	% Δ from control	Ki-67 Index (signal area/ nuclear area)	%Δ from control	NF-kB Index (signal/tissue area)	% Δ from control
Experiment E1 - Effect of combined 2R modification and oligo mix approach in NIH Athymic nude mouse model								
Control			1.27 ± 0.28	-----	0.58 ± 0.08	-----	0.71 ± 0.13	-----
Control oligo	2RF76	F	1.78 ± 0.51	+ 40	0.66 ± 0.19	+13.8	0.49 ± 0.06	- 31
Sugar cargo	None 7		1.55 ± 0.3	+ 22	0.67 ± 0.06	+15.5	0.66 ± 0.06	- 7
LCK	5	A	1.38 ± 0.23	+ 9	0.70 ± 0.07	+20.7	0.54 ± 0.09	- 24
2RLCK	5	B	1.235 ± 0.09	- 2	0.42 ± 0.02	- 27.5	0.66 ± 0.04	- 7
2R huMix	8 + 9	E	0.89 ± 0.25	- 30	0.07 ± 0.01*	- 89*	0.18 ± 0.03	- 75*

Notes: **1)** N = 3 mice per group. **2)** Values are reported as mean ± SE. **3)** *= $p<0.05$, Student's t test, **4)** Formula number for nanoencapsulated sequence as listed under and described in Example 1. **5)** Tumor burden is reported as cumulative weight of primary tumor with peritoneal extension, brachial, mandibular, and inguinal lymph nodes. Primary and GI tumor were sampled uniformly for microscopy. **6)** Sequence for additional nanoencapsulated control oligo is anti-coagulation Factor VII from Akinc, *et al.* 2008 *Nat Biotechnol* 26(5):561-9. **7)** 'A'Cs-modified nanoparticle formulation bearing erythritol was included and prepared similar to Formula A, except that 500 µg of erythritol without any condenser was micellized with 8.75 µg of surfactant, coated with 5.5 mcg of TBG and atomized into a receiving bath modified with 6.25 nM of Mg^{2+} and 9.38 nM of Sr2+, all other ions the same. Particle diameter were 24 ± 2 nm with a surfact charge of -12 ± 7.8 mev.

[00169] SEQUENCES

[00170] CK2 alpha (*Homo sapiens* chromosome 20, GRCh38 Primary Assembly; NCBI Reference Sequence: NC_000020.11; 70.52kb region from base 473322 to 543838; Intl Hu Genome Seq Consort; 2004 *Nature* 431(7011):931-945)

[00171] CK2 alpha prime (*Homo sapiens* chromosome 16, GRCh38 Primary Assembly; NCBI Reference Sequence: NC_000016.10; 39.97kb region from base 58157907 to 58197878; Martin, *et al.* 2004 *Nature* 432(7011):988-994)

[00172] NM_001896; cDNA sequence for the mRNA sequence of CK2 alpha prime; *Homo sapiens* casein kinase 2, alpha prime polypeptide (CSNK2A2), mRNA (17-March-2008) (SEQ ID NO:11)

[00173] NM_177560; cDNA sequence for the mRNA sequence of CK2 alpha; *Homo sapiens* casein kinase 2, alpha 1 polypeptide (CSNK2A1), transcript variant 3, mRNA (12-March-2008) (SEQ ID NO:12)

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CLAIMS

What is claimed is:

1. A composition comprising nanoparticles, wherein the nanoparticles comprise: at least one bioactive agent, a surfactant having an HLB value of less than 6.0 units, a ligand, and Li^+ and Cs^+, wherein:

i) the at least one bioactive agent and the surfactant form a surfactant micelle core;

ii) the ligand forms a shell;

iii) the Li^+ is pretreated with Cs^+; and

iv) the nanoparticles have an average diameter of less than about 50 nanometers.

2. The composition of claim 1, wherein the nanoparticles are prepared using sterile water.

3. The composition of claim 1, wherein the at least one bioactive agent is a polynucleotide or a plasmid DNA.

4. The composition of claim 1, wherein:

i) the at least one bioactive agent comprises a plurality of polynucleotides, each comprising a 3' RNA portion and a 5' primarily DNA portion, wherein the number 2 position from the 5' end of each polynucleotide is a 2'-OMe modified RNA, wherein the sequence of more than about 40% and less than about 60% of the plurality of polynucleotides on average comprises SEQ ID NO: 8, and the sequence of the remainder of the plurality of polynucleotides on average comprises SEQ ID NO: 9, and

ii) the ligand is a protein targeting a tenascin receptor.

5. The composition of claim 4, wherein the protein is tenfibgen.

6. A method of administering at least one bioactive agent to a subject, the method comprising administering to the subject the composition of claim 1.

7. A method for treating a patient with a solid tumor cancer, comprising administering to the patient a therapeutically effective amount of the composition of claim 1, wherein

i) the at least one bioactive agent comprises a plurality of polynucleotides, each comprising a 3' RNA portion and a 5' primarily DNA portion, wherein the number 2 position from the 5' end of each polynucleotide is a 2'-OMe modified RNA, wherein the sequence of more than about 40% and less than about 60% of the plurality of polynucleotides on average comprises SEQ ID NO: 8, and the sequence of the remainder of the plurality of polynucleotides on average comprises SEQ ID NO: 9, and

ii) the ligand is a protein targeting a tenascin receptor.

8. A method for preparing the composition of claim 1, the method comprising:

i) complexing at least one bioactive agent with a condensing agent to form a condensed bioactive agent;

ii) dispersing the condensed bioactive agent into a water-miscible solvent comprising a surfactant with an HLB of less than 6.0 to form a surfactant micelle;

iii) adsorbing a ligand to the exterior surface of the surfactant micelle to form a ligand particle; and

iv) mixing and incubating the ligand particle with Li^+ pre-treated with Cs^+ and sterile water to form the composition.