

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
4 September 2003 (04.09.2003)

PCT

(10) International Publication Number
WO 03/072067 A2

(51) International Patent Classification⁷: **A61K**

(21) International Application Number: PCT/US03/06691

(22) International Filing Date: 27 February 2003 (27.02.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/082,998 27 February 2002 (27.02.2002) US

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(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,

CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designation US
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designation US
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designation US
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designation US
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designation US
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designation US
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designation US

Published:

- without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: COMPOSITIONS AND METHODS FOR TREATING EPITHELIAL AND RETINAL TISSUE DISEASES

(57) Abstract: The present invention relates to mononucleoside phosphate compounds that have the benefits of a dinucleotide pharmaceutical. These mononucleoside phosphates can be made from a mononucleotide that has been modified by attaching a degradation resistant substituent on the terminal phosphate of apolyphosphate mononucleotide. By attaching this degradation resistant substituent, the stability from degradation matches or exceeds those of certain dinucleotides.



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COMPOSITIONS AND METHODS FOR TREATING EPITHELIAL AND RETINAL TISSUE DISEASES

TECHNICAL FIELD

5 The present invention relates to compounds and the methods of using such compounds in the diagnosis, prevention or treatment of epithelial and retinal tissue diseases or conditions of humans and other mammals. Such diseases or conditions requiring diagnosis, prevention, or treatment of epithelial tissue diseases include respiratory diseases, eye diseases, vaginal and/or cervical dryness, gastrointestinal tract diseases, and
10 inflammatory and allergic diseases.

BACKGROUND OF THE INVENTION

Epithelial tissues comprise a layer or layers of cells that cover free and enclosed surfaces throughout the body, including cutaneous, mucous, luminal, serous, and glandular
15 spaces. All epithelial layers contain two specialized domains: an apical domain that faces the mucosal (or luminal) space and a basolateral membrane that faces the serosal (or abluminal) space. Thus an important function of all epithelia is to provide an appropriate barrier function to separate and to control many physiological processes between these two spaces. In the lung, for example, the airways epithelia serve many functions, including
20 providing a barrier between the lung mucosa and blood supply, to coordinate the hydration of the airways, to regulate blood-borne immune responses in the airway mucosa, and to clear the airways of toxins and pathogens. Epithelial cells are ubiquitous throughout the body, and are found in the entire respiratory and digestive tract, reproductive system and sensory organs (eye, ear, nose and skin). Epithelial cells have evolved to serve many homeostatic
25 functions that are specific to their location throughout the body. One such specific function is found in the mucociliary clearance (MCC) system. Mucous secretions are normally removed via the MCC. MCC relies on the integrated action of three components: 1) mucus secretion by goblet cells and submucosal glands; 2) the movement of cilia on epithelial cells which propels the mucus across the luminal surface; and 3) ion transport into and out of
30 luminal epithelial cells which concomitantly controls the flow of water into the mucus. It is now known that nucleoside phosphates such as uridine 5'-triphosphate (UTP) modulate all of the components of the MCC system. First, UTP has been shown to increase both the rate and total amount of mucin secretion by goblet cells *in vitro* (M. Lethem, et al., *Am J. Respir.*

Cell Mol. Biol. 9, 315-22 (1993)). Second, UTP has been shown to increase cilia beat frequency in human airway epithelial cells *in vitro* (D. Drutz, et al., *Drug Dev. Res.* 37(3), 185 (1996)). And third, UTP has been shown to increase Cl⁻ secretion, and hence, water secretion from airway epithelial cells *in vitro* (S. Mason, et al., *Br. J. Pharmacol.* 103, 1649-56 (1991)). In addition, it is thought that the release of surfactant from Type II alveolar cells in response to UTP (Gobran, *Am. J. Physiol.* 267, L625-L633 (1994)) contributes to optimal functioning of the lungs and may assist in maximizing MCC. UTP has been shown to increase intracellular Ca⁺⁺ due to stimulation of phospholipase C by the P2Y₂ receptor (H. Brown, et al., *Mol. Pharmacol.* 40, 648-55 (1991)).

The retinal pigment epithelium (RPE) lies in the back of the vertebrate eye and forms a barrier that separates the retina from the choroidal blood supply. Although anatomically an epithelial tissue, the RPE also functions in a glial-like capacity in maintaining homeostatic retinal function. For example, a critical function of the RPE is to maintain and regulate the hydration of the subretinal space, the extracellular volume that exists between the retina and the RPE. (Marmor, pp. 3-12, in *The Retinal Pigment Epithelium*, Eds. M.F. Marmor and T.J. Wolfensberger, Oxford University Press, New York, (1998)) This function is achieved by the regulated transport of fluid, ions, and metabolites between the subretinal space and the choroidal blood supply. (Marmor, pp. 420-438, in *The Retinal Pigment Epithelium*, Eds. M.F. Marmor and T.J. Wolfensberger, Oxford University Press, New York, (1998); Pederson, pp. 1955-1968, in *Retina*, Ed. S.J. Ryan, Mosby, St. Louis, (1994)). Like all epithelia, the RPE contains two functionally and anatomically distinct membranes: an apical membrane that faces the retina, and a basolateral membrane that faces the choroidal blood supply. In the normal retina, fluid is absorbed across the RPE in the direction of the subretinal space to the choroid. This active absorption of fluid by the RPE, often referred to as the "RPE pump," plays a critical role in maintaining proper attachment of photoreceptors to the apical membrane of the RPE by pumping fluid out of the retinal spaces. (Marmor, pp. 1931-1954, in *Retina*, Ed. S. J. Ryan, Mosby, St. Louis, (1994); Hughes, *et al.*, pp. xvii, 745, in *The Retinal Pigment Epithelium*, Eds. M.F. Marmor and T.J. Wolfensberger, Oxford University Press, New York, (1998)).

Glaucoma is a disease complex characterized primarily by an increase in intraocular pressure. Sufficiently high and persistent intraocular pressure may result in damage to the optic disc at the juncture of the optic nerve and retina, resulting in irreversible blindness.

There are three types of glaucoma: primary, secondary, and congenital. Primary glaucoma is subdivided into narrow angle (acute congestive) and wide-angle (chronic simple) types, depending on the configuration of the angle of the anterior chamber where re-absorption of the aqueous humor occurs. Effects on the volumes of the various intraocular vascular beds, such as those of the iris and ciliary body and on the rate of secretion of the aqueous humor into the posterior chamber may contribute secondarily to the lowering of the pressure or, conversely, may produce a rise in pressure preceding the fall. In narrow angle glaucoma, the aqueous outflow is enhanced by freeing of the entrance to the trabecular space at the canal of Schlemm from blockade by the iris, as a result of the drug-induced contraction of the sphincter muscle of the iris. (Taylor, pp. 123-125, in *The Pharmacological Basis of Therapeutics*, 7th Ed, Eds., A.G. Gilman, L.S. Goodman, T.W. Rall, and F. Murad, MacMillan Publishing Company, New York, (1985))

In wide-angle, or chronic simple, glaucoma, the entry to the trabeculae is not physically obstructed; the trabeculae, a meshwork of pores of small diameter, lose their patency. Contraction of the sphincter muscle of the iris and the ciliary muscle enhances tone and alignment of the trabecular network to improve re-absorption and outflow of aqueous humor through the network to the canal of Schlemm (Watson, *Br. J. Ophthalmol.* 56: 145-318 (1972); Schwartz, *N. Engl. J. Med.*, 290: 182-186 (1978); Kaufman, *et al.*, *Handbook of Experimental Pharmacology* 69: 149-192 (1984)).

Human joints are lubricated by fluid secreted from synovial membranes, which line internal, non-articular joint surfaces. The lubricating properties of synovial fluid have been attributed to a surfactant consisting of surface active phospholipid (SAPL), the mucinous glycoprotein lubricin, hyaluronic acid (hyaluronan), and water. Hyaluronan is a critical constituent component of normal synovial fluid and an important contributor to joint homeostasis. Hyaluronan imparts anti-inflammatory and antinociceptive properties to normal synovial fluid and contributes to joint lubrication, buffering load transmission across articular surfaces and providing a continually replenished source of hyaluronan to articular tissues. Joint lubrication is compromised in osteoarthritis (OA).

Studies suggest that activation of P2Y receptors by extracellular nucleotides elicit responses from inflammatory cells (such as mast cells, eosinophil, leukocytes, neutrophils) consistent with a pro-inflammatory effect. Extracellular nucleotide-induced stimulation of leukocytes and subsequent adhesion to endothelium has been shown to play an important

role in inflammatory diseases. Extracellular nucleotides stimulate P2Y receptor on human polymorphonuclear neutrophils (PMN) with the pharmacological profile of the P2Y₂ receptor.

Allergy is a state of hypersensitivity caused by exposure to a specific antigen (allergen) resulting in harmful immunologic reactions or subsequent exposures. The first encounter with an allergen sensitizes the body via the lymphocytes, resulting in IgE coating of mast cells and basophils. Subsequent exposure results in the development of the “early phase” of the allergic reaction and occurs within seconds or minutes of exposure to an allergen. The early phase is also known as the immediate hypersensitivity reaction. In the allergic reaction, hypersensitivity is a condition in a previously exposed person, in which tissue inflammation is caused by an immune reaction upon re-exposure to an allergen sensitizer. In half of occurrences, the allergic reaction develops into a “late phase,” which occurs about 4 to 6 hours after the exposure. In the late phase reaction, tissues become red and swollen due to the collection of eosinophils, neutrophils, lymphocytes, and other cells. Preferably the nucleotide receptor is a P2Y purinergic receptor, such as the P2Y₂ receptor. Activation of such receptors by P2Y agonists trigger the elevation of intracellular calcium levels and activation of signaling pathways leading to prevention and / or reversal of the symptoms and manifestations of early and late phases of allergic reactions and inflammatory diseases. Previous work has demonstrated the presence of P2Y receptors in glial and neuronal cells of the mature nervous system (Abbracchio and Burnstock, Jpn J. Pharmacol, 78:113-45, 1998). P2Y receptors belong to a class of G-protein coupled receptors (GPCR) that activate a variety of intracellular signaling pathways. Although features of P2Y receptor signaling in many cell types are well known, the physiological roles of P2Y receptors in the nervous system are not well-characterized. In central, peripheral and sensory nervous systems, P2Y receptor activation profoundly affect glia, a cell type that plays important roles in nervous system development, function, and survival. Previous work has suggested a role for P2Y receptors in neurotransmission, neuronal-to-glial cell-cell signaling, alterations of gene expression, neuritogenesis, and interactions with growth factors in an additive or synergistic manner (Abbracchio and Burnstock, Jpn J Pharmacol, 78:113-45, 1998).

There is an unmet medical need for new therapeutic nucleotides that have good storage stability and/or *in vivo* stability that can be used for the treatment of epithelial and

retinal diseases with minimal side effects. Nucleotides, defined here as a nucleoside base with one or more phosphate groups attached at the furanosyl primary hydroxyl group, can act via receptors (e.g. P2Y), and ion channels (e.g. P2X). The therapeutic utility of nucleotides arises from their actions as either agonists or antagonists of receptor (P2)

function. Two classes of therapeutic nucleotides have emerged recently—mononucleotides (e.g. nucleoside tri- and diphosphates) and dinucleotides (dinucleoside polyphosphates). Mononucleotides, such as uridine triphosphate and adenosine triphosphate (UTP and ATP) are potent ligands of P2 receptors (see U.S. Patent Nos. 5,292,498 and 5,628,984).

However these mononucleotides have poor chemical and metabolic stability making them less attractive as drug candidates due to required refrigeration and short *in vivo* half-life.

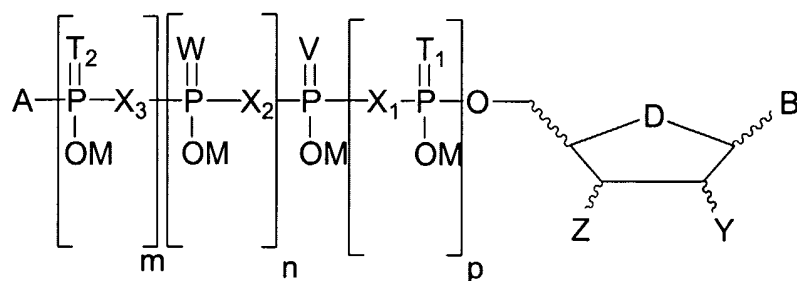
Dinucleotides, such as diuridine tetraphosphate and diadenosine tetraphosphate (Up₄U and Ap₄A), show an improvement in chemical and metabolic stability while retaining activity at various P2 receptors (see U.S. Patent Nos. 5,635,160; 5,837,861; 5,900,407; 6,319,908; and 6,323,187).

Despite the therapeutic improvements made by the use of dinucleotides and their *in vivo* and storage stability, the difficulty and expense of their synthesis requires further improvement for use in the treatment of epithelial and retinal diseases with minimal side effects.

SUMMARY OF THE INVENTION

The present invention comprises compounds of mononucleoside phosphates of the general Formula I, or pharmaceutically acceptable salts thereof:

Formula I



wherein;

A has a molecular weight of no more than about 1000 and is OR_1 , SR_1 , NR_1R_2 , or $CR_1R_2R_3$ such that R_1 , R_2 , and R_3 are each independently hydrogen, alkyl, cycloalkyl, aryl, arylalkyl, phosphonate, or acylthioalkyl, with or without substituents or heteroatoms; or taken together to form a cycloalkyl or aryl ring, with or without substituents or heteroatoms, with the

- 5 exception of OR_1 and SR_1 not being OH or SH; or A is a natural or non-natural amino acid, peptide, polypeptide, or other oligomer, or natural or non-natural steroid:

X_1 , X_2 , and X_3 are independently oxygen, methylene, monochloromethylene, dichloromethylene, monofluoromethylene, difluoromethylene, or imido;

T_1 , T_2 , W, and V are independently oxygen or sulfur;

- 10 $m = 0, 1$ or 2 ;

$n = 0$ or 1 ;

$p = 0, 1$, or 2 ;

where the sum of $m+n+p$ is from 0 to 5;

M = H or a pharmaceutically-acceptable inorganic or organic counter ion;

- 15 $D = O$ or CH_2 ;

B is a purine or a pyrimidine residue according to general Formulae IV and V which is linked to the 1' position of the furanose or carbocycle via the 9- or 1- position of the base, respectively;

$Y = H$, OH, or OR_4 ;

- 20 $Z = H$, OH, or OR_5 ; with the proviso that Y and Z are not both H;

R_4 and R_5 are residues which are linked directly to the 2' and /or 3' oxygens of the furanose or carbocycle via a carbon atom according to Formula II, or linked directly to the two 2' and 3' oxygens of the furanose or carbocycle via a common carbon atom according to Formula III.

25

The present invention is also directed to a method of preventing, diagnosing or treating epithelial diseases or conditions; such diseases include respiratory diseases, eye diseases, vaginal and cervical dryness, gastrointestinal tract diseases, inflammatory and allergic diseases, such as chronic bronchitis, cystic fibrosis, sinusitis, lung cancer, otitis media, retinal detachment, retinal edema, dry mouth, gastroesophageal reflux disease (GERD), constipation, glaucoma associated with elevated intraocular pressure, retinal degenerative diseases, corneal edema, allergic conjunctivitis, ocular surface inflammation, allergic rhinitis. A further aspect of the present invention is directed to a method of preventing or treating diseases of the joint; such diseases include osteoarthritis and rheumatoid arthritis. Yet a further aspect of the present invention is directed to a method of preventing or treating diseases associated with platelet aggregation and thrombosis in humans and other mammals.

The method comprises administering to a subject a pharmaceutical composition comprising a therapeutically effective amount of a nucleotide of Formula I, wherein said amount is effective to diagnose, prevent, or treat such epithelial tissue diseases.

The present invention is also directed to a method of preventing or treating epithelial tissue diseases or conditions associated therewith, the method comprises:

- (a) identifying a mammal at risk for epithelial tissue diseases; and
- (b) applying a composition comprising a compound of Formula I in an amount effective to prevent or treat epithelial tissue diseases or conditions associated here within.

The present invention is also directed to a method of preventing epithelial tissue diseases or conditions associated therewith, the method comprises:

- (a) applying to a mammal at risk for epithelial tissue diseases a composition comprising a compound of Formula I in an amount effective to prevent the incidence of epithelial tissue diseases.
- (b) determining whether such disease or condition developed.

The invention also provides novel pharmaceutical compositions comprising compounds of Formula I in a pharmaceutically acceptable carrier.

DETAILED DESCRIPTION OF THE INVENTION

The applicants have unexpectedly discovered that the benefits of a dinucleotide pharmaceutical can be achieved by a mononucleotide that has been modified by attaching a degradation resistant substituent A on the terminal phosphate of a nucleoside

5 polyphosphate. The pharmacological activity of the mononucleotide is unexpectedly maintained, and in some instances enhanced, when this degradation resistant substituent is present. Further, by attaching this degradation resistant substituent, the stability from degradation matches or exceeds those of certain dinucleotides. The applicants have unexpectedly discovered that certain benefits of a dinucleotide can be obtained even when
10 one end of a dinucleotide is replaced by degradation resistant substituent that does not have the activity of a nucleotide. In the worst case, this new mononucleotide molecule will only have half of the efficacy of the comparable dinucleotide, but in many instances that lower efficacy is completely acceptable, particularly when viewing the benefits of the new molecule.

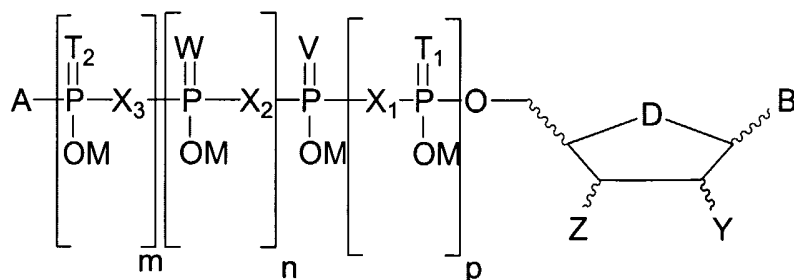
15 In many instances the degradation resistant substituent can have its own pharmacological activity, different from those of nucleotides. Further, these new molecules, due to the degradation resistant substituent A, in many instances have the benefits of 1) ease in manufacture, e.g. superior physical chemical characteristics which lend to simplified purification schemes; 2) reduced costs, as nearly all of the substituents described as A are
20 less costly than nucleosides; 3) fewer stereochemistry concerns as few substituents are as stereochemically complex as nucleosides; 4) enhanced pharmacokinetic properties as non-nucleoside substituents can possess a myriad of differing characteristics; and/or 5) enhanced chemical stability as nucleosides are inherently less stable than most organic molecules.

Important criteria for these new molecules are stability and that the degradation
25 resistant substituent does not interfere with the activity of the nucleotide. This means that the degradation resistant substituent is no larger than 1000 Daltons, preferably less than 500, and that the substituent does not adversely affect pharmacological activity or toxicity or alternatively is beneficial. Further, this degradation resistant substituent on the nucleotide must not react with other nucleotide molecules or with other components of the
30 pharmaceutical formulation in ways that would detrimentally modify the nucleotide's pharmacological activity. This means that this degradation resistant substituent must be reasonably stable within a pharmaceutical formulation.

The present invention provides compounds of Formula I as well as methods of preventing, diagnosing or treating epithelial and retinal tissue diseases or conditions. The method comprises administering to a subject a pharmaceutical composition comprising a therapeutically effective amount of the compound of general Formula I and

5 pharmaceutically acceptable salts thereof:

Formula I



wherein:

- 10 A is a covalently bound degradation resistant substituent that has a molecular weight of no more than about 1000 and is OR_1 , SR_1 , NR_1R_2 , or $CR_1R_2R_3$ such that R_1 , R_2 , and R_3 are independently hydrogen, alkyl, cycloalkyl, aryl, arylalkyl, phosphonate, or acylthioalkyl, with or without substituents or heteroatoms, or taken together to form a cycloalkyl or aryl ring, with or without substituents or heteroatoms, with the exception of OR_1 and SR_1 not
- 15 being OH or SH; or A is a natural or non-natural amino acid, peptide, polypeptide, oligonucleotide, or natural or non-natural steroid. A is preferably a hydroxylated alkyl group (e.g. glycerol, cholesterol); an amino acid (e.g. phenylalanine, serine, tyrosine) having 3 to 50 carbon atoms; an amino or mono- or disubstituted amino, where the substituents are alkyl, cycloalkyl, aralkyl, aryl, substituted aralkyl, or substituted aryl having
- 20 3 to 50 carbon atoms and which may also contain heteroatoms (e.g. S, N, O). X_1 , X_2 , and X_3 are independently oxygen, methylene, monochloromethylene, dichloromethylene, monofluoromethylene, difluoromethylene, or imido; T_1 , T_2 , W , and V are independently oxygen or sulfur;
- $m = 0, 1$ or 2 ;
- 25 $n = 0$ or 1 ;
- $p = 0, 1$, or 2 ;
- where the sum of $m+n+p$ is from 0 to 5 (preferably 2 or 3);

M = H or a pharmaceutically-acceptable inorganic or organic counter ion;

D = O or CH₂;

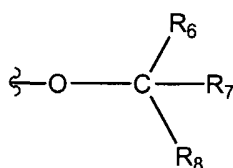
B is a purine or a pyrimidine residue according to general Formulae IV and V which is linked to the 1' position of the furanose or carbocycle via the 9- or 1- position of the base, respectively;

Y = H, OH, or OR₄;

Z = H, OH, or OR₅; with the proviso that Y and Z are not both H;

R₄ and R₅ are residues which are linked directly to the 2' and /or 3' oxygens of the furanose or carbocycle via a carbon atom according to Formula II, or linked directly to the two 2' and 3' oxygens of the furanose or carbocycle via a common carbon atom according to Formula III;

Formula II



wherein:

O is the corresponding 2' and/or 3' oxygen of the furanose or carbocycle;

R₆, R₇, and R₈ are H, an alkyl, cycloalkyl, aralkyl, aryl, substituted aralkyl, or substituted aryl, such that the moiety defined according to Formula II is an ether; or

R₆ and R₇ are H, an alkyl, cycloalkyl, aralkyl, aryl, substituted aralkyl, or substituted aryl, and R₈ is alkoxy, cycloalkoxy, aralkyloxy, aryloxy, substituted aralkyloxy, or substituted aryloxy such that the moiety defined according to formula II is an acyclic acetal or ketal; or

R₆ and R₇ are taken together as oxygen or sulfur doubly bonded to C, and R₈ is alkyl, cycloalkyl, aralkyl, aryl, substituted aralkyl, or substituted aryl, such that the moiety defined according to Formula II is an ester or thioester; or

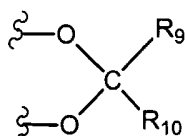
R₆ and R₇ are taken together as oxygen or sulfur doubly bonded to C, and R₈ is amino or mono- or disubstituted amino, where the substituents are alkyl, cycloalkyl, aralkyl, aryl, substituted aralkyl, or substituted aryl, such that the moiety according to Formula II is a carbamate or thiocarbamate; or

R₆ and R₇ are taken together as oxygen or sulfur doubly bonded to C, and R₈ is alkoxy, cycloalkoxy, aralkyloxy, aryloxy, substituted aralkyloxy, or substituted aryloxy, such that the moiety according to Formula II is a carbonate or thiocarbonate; or

- 5 R₈ is not present and R₆ and R₇ are taken together as oxygen or sulfur doubly bonded to C and both the 2' and 3' oxygens of the furanose are directly bound to C to form a cyclical carbonate or thiocarbonate;

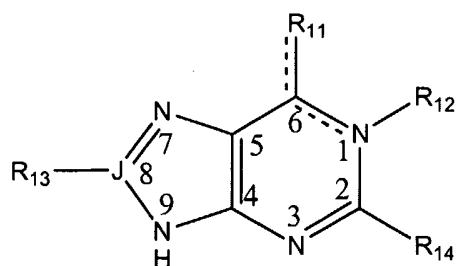
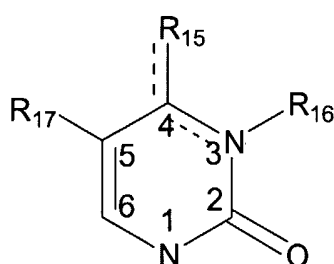
Formula III

10



wherein:

- O is the 2' and 3' oxygens of the furanose or carbocycle; and the 2' and 3' oxygens of the furanose or carbocycle are linked by a common carbon atom (C) to form a cyclical acetal, cyclical ketal, or cyclical orthoester;
- 15 for cyclical acetals and ketals, R₉ and R₁₀ are independently hydrogen, alkyl, cycloalkyl, aralkyl, aryl, substituted aralkyl, substituted aryl or can be joined together to form a homocyclic or heterocyclic ring composed of 3 to 8 atoms, preferably 3 to 6 atoms; for
- 20 cyclical orthoesters, R₉ is hydrogen, alkyl, cycloalkyl, aralkyl, aryl, substituted aralkyl, or substituted aryl, R₁₀ is alkyloxy, cycloalkyloxy, aralkyloxy, aryloxy, substituted aralkyloxy, or substituted aryloxy ;

Formula IV**Formula V**

wherein:

R₁₁ and R₁₅ are hydroxy, oxo, amino, mercapto, alkylthio, arylthio, alkyloxy, aryloxy, alkylamino, cycloalkylamino, aralkylamino, arylamino, diaralkylamino, diarylamino, or dialkylamino, where the alkyl groups are optionally linked to form a heterocycle; or

R₁₁ and R₁₅ are acylamino, provided that they incorporate an amino residue from the C-6 position of the purine or the C-4 position of the pyrimidine; or

when R₁₁ in a purine or R₁₅ in a pyrimidine has as its first atom nitrogen, R₁₁ and R₁₂ or R₁₅ and R₁₆ are taken together to form a 5-membered fused imidazole ring (etheno compounds),

optionally substituted on the etheno ring with alkyl, cycloalkyl, aralkyl, or aryl moieties, as described for R₆-R₁₀ above; or

when R₁₅ in a pyrimidine has as its first atom oxygen, R₁₅ and R₁₇ are taken together to form a 5-membered dihydrofuran ring, optionally substituted on the dihydrofuran ring with alkyl, cycloalkyl, aralkyl, or aryl moieties, as described for R₆-R₁₀ above;

J is carbon or nitrogen, with the provision that when nitrogen, R₁₃ is not present;

R₁₂ is hydrogen, O (adenine 1-oxide derivatives) or is absent (adenine derivatives);

R₁₆ is hydrogen, or acyl (e.g. acetyl, benzoyl, phenylacetyl, with or without substituents);

R₁₃ is hydrogen, alkyl, bromo, azido, alkylamino, arylamino or aralkylamino, alkoxy, aryloxy or aralkyloxy, alkylthio, arylthio or aralkylthio, or ω -E(C₁₋₆ alkyl)G-, wherein E and G are independently amino, mercapto, hydroxy or carboxyl;

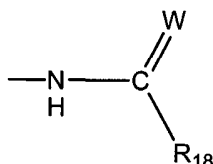
R₁₄ is hydrogen, halo, amino, monosubstituted amino, disubstituted amino, alkylthio,

5 arylthio, or aralkylthio, where the substituent on sulfur contains up to a maximum of 20 carbon atoms, with or without unsaturation;

R₁₇ is hydrogen, methyl, alkyl, halo, alkyl, alkenyl, substituted alkenyl, alkynyl, or substituted alkynyl.

10 Compounds according to Formulae IV and V where R₁₁ or R₁₅ is acylamino for the most part fall within the scope of Formula VI:

Formula VI



15 wherein:

NH is the amino residue at the C-6 position in a purine or the amino residue at the C-4 position in a pyrimidine;

W is oxygen or sulfur;

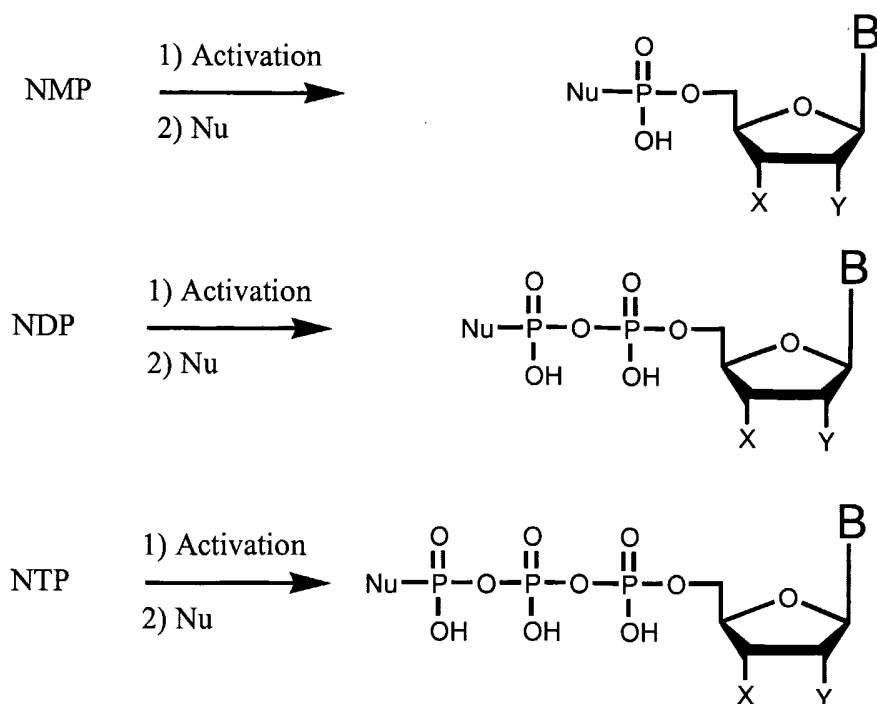
20 R₁₈ is amino or mono- or disubstituted amino such that the moiety according to Formula VI is a urea or thiourea; or R₁₈ is alkoxy, aralkyloxy, aryloxy, substituted aralkyloxy, or substituted aryloxy, such that the moiety according to Formula VI is a carbamate or thiocarbamate; or

25 R₁₈ is alkyl, cycloalkyl, aralkyl, or aryl, with or without substituents or heteroatoms, such that the moiety according to Formula VI is an amide; with definitions of alkyl, cycloalkyl, aralkyl, or aryl groups as previously defined for comparable groups in R₆ to R₁₀.

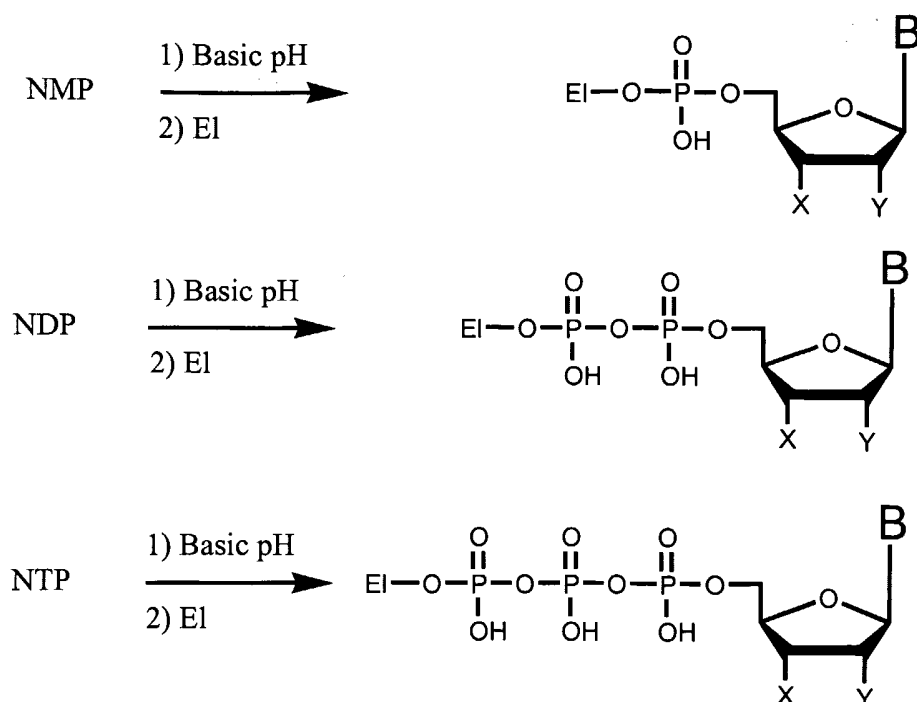
The following applies to all of the R groups above: The number of carbon atoms for the alkyl substituent preferably ranges from 1 to 50 carbons, however, the more preferred alkyl range is 2 to 25 carbons, even more preferred is 3 to 15 carbons, and most preferred is 4 to 10 carbons. The number of carbon atoms for the cycloalkyl substituent preferably

ranges from 5 to 30 carbons, however, the more preferred cycloalkyl range is 7 to 30 carbons, even more preferred is 7 to 20 carbons, and most preferred is 8 to 15 carbons. The preferred aralkyl range is 7 to 30 carbons, more preferred is 7 to 20 carbons, and most preferred is 8 to 15 carbons. The preferred aryl range is 7 to 30 carbons, more preferred is 7 to 20 carbons, and most preferred is 8 to 15 carbons. The preferred alkoxy range is 1 to 25 carbons, more preferred is 1 to 18 carbons, and most preferred is 1 to 10 carbons. The preferred cycloalkoxy range is 6 to 30 carbons, more preferred is 6 to 20 carbons, and most preferred is 6 to 15 carbons. The preferred aralkyloxy range is 7 to 30 carbons, more preferred is 7 to 20 carbons, and most preferred is 8 to 15 carbons. The preferred aryloxy range is 6 to 30 carbons, more preferred is 6 to 20 carbons, and most preferred is 8 to 15 carbons. The preferred alkylthio range is 1 to 25 carbons, more preferred is 1 to 18 carbons, and most preferred is 1 to 10 carbons. The preferred aralkylthio range is 7 to 30 carbons, more preferred is 7 to 20 carbons, and most preferred is 8 to 15 carbons. The preferred arylthio range is 6 to 30 carbons, more preferred is 6 to 20 carbons, and most preferred is 8 to 15 carbons. The preferred alkenyl range is 2 to 25 carbons, more preferred is 2 to 20 carbons, and most preferred is 3 to 15 carbons. The preferred alkynyl range is 3 to 25 carbons, more preferred is 3 to 15 carbons, and most preferred is 4 to 12 carbons. The heteroatoms are sulfur, oxygen, nitrogen, phosphorous, boron, and silicon; the halogens are fluorine, chlorine, bromine, and iodine; and the amino acids include, but are not limited to, both D- and L- forms of alanine, arginine, aspartic acid, cysteine, cystine, glutamic acid, glutamine, glycine, histidine, isoleucine, leucine, lysine, methionine, ornithine, phenylalanine, proline, serine, threonine, tryptophan, tyrosine, and valine.

One general synthetic scheme for the synthesis of compounds of the invention employs activation of a nucleoside mon-, di-, or triphosphate with an activating agent such as carbonyldiimidazole, phosphorous oxychloride, etc. and subsequent reaction with a nucleophile, Nu (e.g. R_1OH , R_1SH , NHR_1R_2 , etc.), to the activated terminal phosphate moiety. B is any purine or pyrimidine, natural or synthetic. The product is shown as a ribofuranosyl sugar in the β -D configuration for illustration purposes only, and is not intended to be limiting in scope.



Alternatively, compounds of the invention can be made according to the scheme below in which a nucleoside mono-, di-, or triphosphate is added to an electrophile, El (e.g. activated sugar, activated carboxylic acid, activated carbon, activated amino acid, etc.). B is any purine or pyrimidine, natural or synthetic. The product is shown as a ribofuranosyl sugar in the β -D configuration for illustration purposes only, and is not intended to be limiting in scope.



The compounds of the present invention can be conveniently synthesized by those skilled in the art using well-known chemical procedures. 5'-nucleoside mono-, di-, tri-, and tetraphosphates can be obtained from commercial sources or can be synthesized from the nucleoside using a variety of phosphorylation reactions, which can be found in the chemical literature. Nucleoside mono- and diphosphates so obtained can be reacted with carbonyldiimidazole, dicyclohexylcarbodiimide or other suitable activating reagents, and coupled with a variety of nucleophiles to install unique substituents on the terminal phosphate. Activation of nucleoside triphosphates with dicyclohexylcarbodiimide gives a cyclical trimetaphosphate as the activated species, which can be advantageously ring opened with nucleophiles, to give substituents on the terminal (γ) phosphate of the triphosphate. If the cyclical trimetaphosphate is opened with reagents containing phosphate as the nucleophile, nucleoside 5'- tetraphosphates are produced with novel moieties on the terminal (δ) phosphate. Alternately, these same phosphate nucleophiles can be reacted with the previously described activated nucleoside mono- and diphosphates, giving di- and triphosphates (respectively) that fall within the scope of the present invention.

As mentioned above, the role of the phosphate chain can be reversed such that the terminal phosphate of the chain can serve as a nucleophile towards electrophilic reagents. Examples of electrophilic reagents include alkyl and aralkyl halides and sulfonates, activated acyl compounds, activated phosphorous compounds, and the like.

5 For the compounds of the present invention which are modified on the nucleic acid base or furanose in addition to the phosphate chain, the modifications can be made at the level of the nucleoside, followed by phosphorylation and condensation with nucleophiles as previously described, or the reactions can be carried out directly on the preassembled nucleotide. In general Formula I, the substituents at Y and Z can be ethers, esters, acyclic
10 acetals and ketals, carbamates, or carbonates, which are generally described by Formula II. Ethers can be prepared by reacting a hydroxyl group in a nucleoside or nucleotide with an activated form of an appropriate alkyl or aralkyl, such as an alkyl/aralkyl halide, alkyl/aralkyl sulfonate and the like, usually in the presence of an organic or inorganic base. Esters can be readily prepared by reacting a hydroxyl group in a nucleoside or nucleotide
15 with an activated form of an appropriate organic acid, such as an acid halide or acid anhydride in the presence of an organic or inorganic base. Alternately, use of a suitable coupling reagent such as dicyclohexylcarbodiimide, 1,1'-carbonyldiimidazole and the like to activate the organic acid can be used to achieve the same result. Acyclic acetals and ketals can be prepared by the reaction between a single hydroxyl in a nucleoside or
20 nucleotide with aldehydes or ketones (respectively) or their chemical equivalents, under acidic conditions.

Carbamates or thiocarbamates can be most conveniently prepared by reaction of a hydroxyl group in a nucleoside or nucleotide with any of a number of commercially available isocyanates or isothiocyanates, respectively, in an inert solvent. Carbonates or
25 thiocarbonates can be synthesized by reacting the hydroxyl groups in a nucleoside or nucleotide with an appropriate haloformate in the presence of an organic or inorganic base.

In the general Formula I, the substituents at Y and Z, when taken together, can be taken to mean acetals, ketals or orthoesters, as described by Formula III. Acetals and ketals can be readily prepared by reaction of the neighboring 2' and 3' hydroxyl groups in an
30 appropriate nucleoside or nucleotide with an aldehyde or ketone, respectively, or their chemical equivalents, in the presence of an acid catalyst. Typical acids include trichloroacetic, p-toluenesulfonic, and methanesulfonic employed in catalytic amounts, in

conjunction with inert solvents. Alternately, weaker organic acids such as formic can be used as both the catalyst and solvent for the reaction.

Cyclical orthoesters can be prepared by reaction of the neighboring 2' and 3' hydroxyl groups in a nucleoside or nucleotide with an acyclic orthoester, in the presence of an acid.

When the nucleoside or nucleotide to be derivatized is a purine that contains a 6-amino functionality or is a pyrimidine that contains a 4-amino functionality, it can be converted to the respective urea or thiourea, as described by general formula VI. This can be accomplished by treatment with isocyanates or isothiocyanates, respectively, as was previously described for carbamates or thiocarbamates of the 2' or 3' hydroxyls. Reactions of these amino groups with isocyanates or isothiocyanates can be carried out in the presence of the unprotected hydroxyl groups, by appropriate manipulation of the stoichiometry of the reaction.

Those skilled in the art will recognize various synthetic methodologies which can be employed to prepare non-toxic pharmaceutically acceptable salts and acylated prodrugs of the compounds of the present invention. Methods of preparing these from the compound of Formula I include passing an aqueous solution through a column of ion exchange resin in the desired cation form, thus converting the compound to the desired salt form. If the desired end product is a sodium salt, such as A on uridine tetrphosphate tetrasodium salt, the starting material (an ammonium or other salt) is passed through a DOW 50 H⁺ column to protonate the compound and generate the free acid. This protonated compound is collected in an aqueous solution of sodium hydroxide which forms the sodium salt.

As is typical for nucleotide chemistry, the reactions which give rise to compounds of the present invention usually end with several products being formed, owing to multiple reactive sites in these molecules. When multiple products are obtained, these can be separated by the use of preparative reverse phase high performance liquid chromatography (HPLC). Particularly advantageous is the use of C18 or phenyl reverse phase columns, in conjunction with gradients that start with ammonium acetate buffer and end with methanol. Following chromatography, the products are isolated by evaporation of the solvent, followed by lyophilization.

While separation of multiple products can be done by HPLC, another strategy is to use nucleosides or nucleotides which contain only a single functionality which is reactive

under the conditions being employed. This can be accomplished by the use of protecting groups to block side reactions at other positions in the molecule. This can be done at the level of the nucleoside prior to phosphorylation and coupling of the phosphate chain with a nucleophile, or at the level of the nucleotide.

5 The second aspect of the present invention provides methods of preventing, diagnosing or treating epithelial and retinal tissue diseases or conditions. The method comprises administering to a subject a pharmaceutical composition comprising a therapeutically effective amount of the compound of general Formula I and pharmaceutically acceptable salts thereof.

10 The present invention is also directed to a method of preventing or treating diseases or conditions associated with enhancing clearance of secretions in the respiratory tract by increasing the hydration of retained mucus secretions, stimulating the production of mucins, and increasing ciliary beat frequency. Prevention or treatment of diseases that could benefit from enhancing clearance of secretions by increasing the hydration of retained mucus
15 secretions, stimulating the production of mucins, and increasing ciliary beat frequency are chronic obstructive pulmonary diseases such as chronic bronchitis, acute bronchitis, acute exacerbations of chronic bronchitis, PCD, cystic fibrosis, as well as prevention of pneumonia due to immobility. Furthermore, because of their general ability to clear retained mucus secretions and stimulate ciliary beat frequency, the compounds of the
20 present invention are also useful in the treatment of acute and chronic sinusitis and otitis media in mammals, including humans. By enhancing secretion clearance, the compounds are useful as protection before or after exposure to inhaled biological warfare agents. They can also be used to enhance lung imaging by clearing secretions from the lungs prior to obtaining the image, for detection of lung disease through an increase in sputum production.
25 The method comprises administering to a subject a pharmaceutical composition comprising a therapeutic effective amount of a nucleotide, wherein said amount is effective to hydrate the mucosal membranes of the respiratory tract.

Still further indications where the compounds of the invention are useful are for a method of stimulating cervical and vaginal secretions in a subject in need of such treatment.

30 The method of the present invention can be used to increase cervical and vaginal secretions for any reason, including, but not limited to, treatment of vaginal dryness and/or treatment of vulvar pain. Vaginal dryness is associated with but not limited to menopause, childbirth,

breastfeeding, chemotherapy or radiotherapy, diabetes mellitus, Sjögren's syndrome, Ehlers-Danlos syndrome, systemic sclerosis and other systemic autoimmune diseases, hysterectomy, urogenital surgery, psychosomatic disorders, anxiety, psychosexual problems, and pharmacological drug-related side effects. The method comprises administering to a
5 subject a pharmaceutical composition comprising a therapeutic effective amount of a nucleotide, wherein said amount is effective to hydrate the mucosal membranes in the vaginal and cervical tracts.

Still further indications where the compounds of the invention are useful are for a method of regulating mucus secretions and fluid transport in the gastrointestinal system of a
10 mammal, including humans. There are many situations where it is therapeutically desirable to increase the amount of mucin secretion, bicarbonate secretions, and/or degree of hydration in gastrointestinal systems. When the mucosal barrier is impaired in the digestive tract, it results in diseases such as dry mouth, gastro-esophageal reflux disease, peptic ulcer, inflammatory bowel disease, etc. Abnormal fluid and electrolytic transport in the lower
15 gastrointestinal tract results in disorders such as constipation and diarrhea. Proper regulation of fluid and electrolytic absorption and secretion at appropriate regions along the gastrointestinal system is required for normal digestive function. The invention provides a method of regulating mucus/mucin secretions, and fluid transport in the gastrointestinal tract. The invention provides a method for treating gastrointestinal disease in which the
20 mucosal barrier of the gastrointestinal system is impaired. Gastrointestinal diseases suitable for treatment by this invention include diseases or disorders affecting the buccal cavity (primary salivary), esophagus, stomach, small intestine, large intestine, rectum and ancillary organs such as pancreas, liver and gall bladder. The invention additionally provides a method for correcting disorders of fluid secretion or absorption in the gastrointestinal. For
25 example, dry mouth, mouth ulcer, gum disease, esophageal reflux disease, peptic ulcer, inflammatory bowel disease (ulcerative colitis and Crohn's disease), diarrhea and constipation can be treated by the present method. In addition, gastrointestinal problems associated with cystic fibrosis diseases such as dry mucin and decreased absorption of nutrient by epithelial cells in the gastrointestinal tract can also be treated by the present
30 method. In addition, gastrointestinal problems caused by cancer and chemotherapy can also be treated by this method. The method comprises administering to a subject a pharmaceutical composition comprising a therapeutic effective amount of a compound of

Formula I or a pharmaceutically acceptable salt thereof, wherein said amount is effective to hydrate the mucosal membranes of the gastrointestinal tract.

The present invention is also directed to a method of preventing or treating diseases or conditions associated with the ocular surface. Such conditions of the ocular surface include, but not limited to, dry eye disease and ocular surface inflammation. This method for treatment of the causes of dry eye disease is through stimulating tear secretions from conjunctival tissues. The present invention is also directed to a method of preventing or treating ocular surface inflammation as well as other eye related conditions such as keratoconjunctivitis sicca (KCS), age-related dry eye, Stevens-Johnson syndrome, Sjögren syndrome; ocular cicatrical, pemphigoid; blepharitis; corneal injury; infection; Reilly-Day syndrome; congenital alacrima; nutritional disorders; pharmacologic side-effects; eye stress and glandular and tissue; smog exposure; smoke exposure; dry air caused by insufficient hydration of the ocular surface.

Still further indications where the compounds of the invention are useful are for the treatment of other diseases or conditions associated with the mammalian eye. Degenerative retinopathies generally affect two neuronal cell populations in the retina: the photoreceptors and ganglion cells. Glial cells in the mature nervous systems provide trophic support to neurons and are therefore a viable cellular target to effect neuronal preservation and survival in a variety of neurodegenerative conditions. This invention is also directed to a method for treating diseases or conditions associated with retinal degeneration, removal of fluid in retinal detachment and retinal edema as well as treatment of ocular hypertension. Retinal degeneration is often an endpoint of a variety of ocular and systemic diseases and environmental conditions, such as macular degeneration, glaucoma, retinitis pigmentosa, optic nerve degeneration, optic neuritis, chronic metabolic diseases (diabetic retinopathy) neurotoxins, ischemia and physical trauma.

The methods and compositions disclosed in the present invention can be used to stimulate removal of extraneous intra-retinal or subretinal fluid for any reason, including, but not limited to, primary and adjunctive treatments of rhegmatogenous retinal detachment, serous retinal detachment, all forms of cystoid macular edema (uveitis, post-surgical, central and branch vein occlusion, and inherited retinal diseases such as retinitis pigmentosa), and all forms of retinal and macular edema (proliferative and non-proliferative, exudative age-related macular degeneration, and retinopathy of prematurity). The method comprises

administering to a subject a pharmaceutical composition comprising a therapeutic effective amount of a compound of Formula I or a pharmaceutically acceptable salt thereof, wherein said amount is effective in said treatment.

5 Still further indications where the compounds of the invention are useful in the management and/or treatment of primary glaucoma, which consists of two types: narrow angle or acute congestive and wide angle or chronic simple glaucoma. Yet another embodiment of the present invention is the management of secondary glaucoma.

10 The present invention provides a method of treating and/or managing glaucoma, by facilitating the outflow of fluid from the eye and thereby reduce the accumulation of said fluid contributing to increased intraocular pressure characteristic of glaucoma. The method comprises co-administration to a subject, an effective dose of a pharmaceutical composition comprising a purinergic receptor ligand, with or without therapeutic and adjuvant agents commonly used to treat or manage glaucoma.

15 The present invention is also directed to a method of stimulating the secretion of synovial fluid, mucins, hyaluronic acid, and/or surface active phospholipids, and thereby enhancing joint lubrication, using a nucleotide in patients in need of such treatment. This is also a method of enhancing joint lubrication comprising: administering to a subject in need of such treatment a purinergic receptor agonist in an amount therapeutically effective to enhance joint lubrication. A method of treating osteoarthritis comprising a therapeutic
20 effective amount of a P2Y receptor agonist ligand, in an appropriate pharmaceutical composition, administering to a subject in need of enhancing joint lubrication in an amount therapeutically effective to treat osteoarthritis.

25 The present invention is also directed to a method preventing and/or reversing the symptoms and manifestations of inflammatory diseases, and hence a method of treating inflammation.

Still further indications where the compounds of the invention are useful are for a method of preventing and/or reversing the symptoms and manifestations of allergic reactions and thus a method of treating allergies.

30 This method comprises administering to a subject in need thereof a pharmacological composition comprising a compound of Formula I or a pharmaceutically acceptable salt thereof in an amount effective to treat, prevent, and/or reverse the symptoms and

manifestations of inflammatory diseases, together with a pharmaceutically acceptable carrier.

The present invention is also directed to a method of preventing or treating diseases or conditions associated with platelet aggregation. The method is also directed to a method of treating thrombosis in humans and other mammals. An intravascular thrombus results from a pathological disturbance of hemostasis. Platelet adhesion and aggregation are critical events in intravascular thrombosis. There is a need in the area of cardiovascular and cerebrovascular therapeutics for an agent that can be used in the prevention and treatment of thrombi, with minimal side effects, such as unwanted prolongation of bleeding in other parts of the circulation, while preventing or treating target thrombi. This invention is also directed to a method of preventing or treating diseases associated with platelet aggregation. Such related diseases are, but not restricted to, thrombosis, primary arterial thrombotic complications of atherosclerotic disease; thrombotic complications of surgical or mechanical damage; mechanically induced platelet aggregation; shunt occlusion; thrombosis secondary to vascular damage and inflammation; indications with a diffuse thrombotic/platelet composition component; venous thrombosis; coronary arterial thrombosis; pathological effects of atherosclerosis and arterial sclerosis, chronic or acute states of hyper-aggregability, reocclusion of an artery or vein following fibrinolytic therapy, platelet adhesion associated with extracorporeal circulation, thrombotic complications associated with thrombolytic therapy, thrombotic complications associated with coronary and other angioplasty, and thrombotic complications associated with coronary artery bypass procedures, venous thrombosis, thrombophlebitis, arterial embolism, coronary and cerebral arterial thrombosis, unstable angina, coronary angioplasty, myocardial infarction, cerebral embolism, kidney embolisms and pulmonary embolisms. The method wherein said primary arterial thrombotic complications of atherosclerotic disease are angioplasty, endarterectomy, stent placement, coronary and other vascular graft surgery. The method wherein said thrombotic complications of surgical or mechanical damage are tissue salvage following surgical or accidental trauma, reconstructive surgery including skin flaps, and “reductive” surgery such as breast reduction. The method wherein said mechanically – induced platelet activation is caused by cardiopulmonary bypass resulting in microthromboembolism and storage of blood products. The method wherein said shunt occlusion is renal dialysis and plasmapheresis. The method wherein said thromboses

secondary to vascular damage and inflammation are vasculitis, arteritis, glomerulonephritis and organ graft rejection. The method wherein said indications with a diffuse thrombotic/platelet consumption component are disseminated intravascular coagulation, thrombotic thrombocytopenic purpura, hemolytic uremic syndrome, heparin-induced thrombocytopenia, and pre-eclampsia/eclampsia. The method wherein said venous thrombosis are deep vein thrombosis, veno-occlusive disease, hematological conditions, and migraine. The method wherein said hematological conditions are thrombocythemia and polycythemia. The method wherein said coronary arterial thrombosis is associated with unstable angina, coronary angioplasty and acute myocardial infarction. The method wherein pathological effects of atherosclerosis and arteriosclerosis are arteriosclerosis, acute myocardial infarction, chronic stable angina, unstable angina, transient ischemic attacks, and strokes, peripheral vascular disease, arterial thrombosis, preeclampsia, embolism, restenosis or abrupt closure following angioplasty, carotid endarterectomy, and anastomosis of vascular grafts. The method wherein said chronic or acute states of hyper-aggregability is caused by DIC, septicemia, surgical or infectious shock, post-operative and post-partum trauma, cardiopulmonary bypass surgery, incompatible blood transfusion, abruptio placenta, thrombotic thrombocytopenic purpura, snake venom and immune diseases. The method wherein said reocclusion of an artery or vein following fibrinolytic therapy is inhibited by internal administration of said compound with a fibrinolytic agent. The method wherein said fibrinolytic agent is selected from the group consisting of natural or synthetic products, which directly or indirectly cause lysis of a fibrin clot. The method wherein said fibrinolytic agent is a plasminogen activator selected from a group consisting of anistreplase, urokinase (UK), pro-urokinase (PUK), streptokinase (SK), tissue plasminogen activator (tPA) and mutants, or variants thereof, which retain plasminogen activator activity. The method wherein said variants are selected from a group consisting of variants which have been chemically modified, variants which one or more amino acids have been added, deleted or substituted or variants with one or more modified functional domains. The method wherein said modified functional domains are added, deleted or altered by combining the active site of one plasminogen activator or fibrin binding domain of another plasminogen activator or fibrin binding molecule. Still further indications where the compounds of the invention are useful are for the prevention of platelet aggregation and clot formation in blood and blood products during storage.

The compounds of the present invention also encompass their non-toxic pharmaceutically acceptable salts, such as, but not limited to, an alkali metal salt such as lithium, sodium or potassium; an alkaline earth metal salt such magnesium or calcium; or an ammonium or tetraalkyl ammonium salt, i.e., NX_4^+ (wherein X is C_{1-4}). Pharmaceutically acceptable salts are salts that retain the desired biological activity of the parent compound and do not impart undesired toxicological effects.

Compounds of the present invention can be administered systemically to target sites in a subject in need such that a target dose in the range of 10^{-1} to 10^{-6} M is achieved and preferably in the range of 10^{-2} to 10^{-4} M.

For systemic administration such as injection and infusion, the pharmaceutical formulation is prepared in a sterile medium. The active ingredient, depending on the vehicle and concentration used, can either be suspended or dissolved in the vehicle. Adjuvants such as local anesthetics, preservatives and buffering agents can also be dissolved in the vehicle. The sterile indictable preparation can be a sterile indictable solution or suspension in a non-toxic acceptable diligent or solvent. Among the acceptable vehicles and solvents that can be employed are sterile water, saline solution, or Ringer's solution.

Another method of systemic administration of the active compound involves oral administration, in which pharmaceutical compositions containing active compounds are in the form of tablets, lozenges, aqueous or oily suspensions, viscous gels, chewable gums, dispersible powders or granules, emulsion, hard or soft capsules, or syrups or elixirs.

For oral use, an aqueous suspension is prepared by addition of water to dispersible powders and granules with a dispersing or wetting agent, suspending agent one or more preservatives, and other excipients. Suspending agents include, for example, sodium carboxymethylcellulose, methylcellulose and sodium alginate. Dispersing or wetting agents include naturally-occurring phosphatides, condensation products of an allylene oxide with fatty acids, condensation products of ethylene oxide with long chain aliphatic alcohols, condensation products of ethylene oxide with partial esters from fatty acids and a hexitol, and condensation products of ethylene oxide with partial esters derived from fatty acids and hexitol anydrides. Preservatives include, for example, ethyl, and n-propyl p-hydroxybenzoate. Other excipients include sweetening agents (e.g., sucrose, saccharin), flavoring agents and coloring agents. Those skilled in the art will recognize the many specific excipients and wetting agents encompassed by the general description above.

For oral application, tablets are prepared by mixing the active compound with nontoxic pharmaceutically acceptable excipients suitable for the manufacture of tablets. These excipients can be, for example, inert diluents, such as calcium carbonate, sodium carbonate, lactose, calcium phosphate or sodium phosphate; granulating and disintegrating agents, for example, corn starch, or alginic acid; binding agents, for example, starch, gelatin or acacia; and lubricating agents, for example magnesium stearate, stearic acid or talc. The tablets can be uncoated or they can be coated by known techniques to delay disintegration and absorption in the gastrointestinal tract and thereby provide a sustained action over a longer period. For example, a time delay material such as glyceryl monostearate or glyceryl distearate can be employed. Formulations for oral use can also be presented as hard gelatin capsules wherein the active ingredient is mixed with an inert solid diluent, for example, calcium carbonate, calcium phosphate or kaolin, or as soft gelatin capsules wherein the active ingredient is mixed with water or an oil medium, for example, peanut oil, liquid paraffin or olive oil. Formulation for oral use can also be presented as chewable gums by embedding the active ingredient in gums so that the active ingredient is slowly released upon chewing.

Additional means of systemic administration of the active compound to the target platelets of the subject would involve a suppository form of the active compound, such that a therapeutically effective amount of the compound reaches the target sites via systemic absorption and circulation.

For rectal administration, the compositions in the form of suppositories can be prepared by mixing the active ingredient with a suitable non-irritating excipient which is solid at ordinary temperatures but liquid at the rectal temperature and will therefore melt in the rectum to release the compound. Such excipients include cocoa butter and polyethylene glycols.

The active compounds can also be systemically administered to the sites through absorption by the skin using transdermal patches or pads. The active compounds are absorbed into the bloodstream through the skin. Plasma concentration of the active compounds can be controlled by using patches containing different concentrations of active compounds.

One systemic method involves an aerosol suspension of respirable particles comprising the active compound, which the subject inhales. The active compound would be

absorbed into the bloodstream via the lungs, and subsequently contact the target in a pharmaceutically effective amount. The respirable particles can be liquid or solid, with a particle size sufficiently small to pass through the mouth and larynx upon inhalation; in general, particles ranging from about 1 to 10 microns, but more preferably 1-5 microns, in size are considered respirable.

Another method of systemically administering the active compounds to the platelet aggregation sites of the subject involves administering a liquid/liquid suspension in the form of eye drops or eye wash or nasal drops of a liquid formulation, or a nasal spray of respirable particles that the subject inhales. Liquid pharmaceutical compositions of the active compound for producing a nasal spray or nasal or eye drops can be prepared by combining the active compound with a suitable vehicle, such as sterile pyrogen free water or sterile saline by techniques known to those skilled in the art.

Intravitreal delivery can include single or multiple intravitreal injections, or via an implantable intravitreal device that releases the compound in a sustained capacity. Intravitreal delivery can also include delivery during surgical manipulations as either an adjunct to the intraocular irrigation solution or applied directly to the vitreous during the surgical procedure.

For systemic administration, plasma concentrations of active compounds delivered can vary according to compounds; but are generally 1×10^{-6} - 1×10^{-1} moles/liter, and preferably 1×10^{-4} - 1×10^{-2} moles/liter.

The present invention also provides novel formulation compositions of matter. The compositions are pharmaceutically acceptable formulation comprising compounds of Formula I of high purity, and/or in a pharmaceutically acceptable carrier. The pharmaceutically acceptable carrier can be selected by those skilled in the art using conventional criteria. The pharmaceutically acceptable carrier include, but are not limited to, saline and aqueous electrolyte solutions, water polyethers such as polyethylene glycol, polyvinyls such as polyvinyl alcohol and povidone, cellulose derivatives such as methylcellulose and hydroxypropyl methylcellulose, petroleum derivatives such as mineral oil and white petrolatum, animal fats such as lanolin, polymers of acrylic acid such as carboxypolymethylene gel, vegetable fats such as peanut oil and polysaccharides such as dextrans, and glycosaminoglycans such as sodium hyaluronate and salts such as sodium chloride and potassium chloride.

Preferred compounds of the present invention comprise compounds of Formula I wherein A has a molecular weight of no more than about 1000 and is OR₁, SR₁, NR₁R₂, or CR₁R₂R₃ such that R₁, R₂, and R₃ are independently hydrogen, C₁₋₅₀ alkyl, C₅₋₃₅ cycloalkyl, aryl, arylalkyl, phosphonate, or acylthioalkyl, with or without substituents or heteroatoms; or taken together to form a cycloalkyl or aryl ring, with or without substituents or heteroatoms with the exception of OR₁ and SR₁ not being OH or SH; or a natural or non-natural amino acid, peptide, polypeptide, or other oligomer; or natural or non-natural steroid: More preferably A is a hydroxylated alkyl group (e.g. glycerol, cholesterol); is an amino acid (e.g. phenylalanine, serine, tyrosine) having 3 to 50 carbon atoms; is amino or mono- or disubstituted amino, where the substituents are alkyl, cycloalkyl, aralkyl, aryl, substituted aralkyl, or substituted aryl having 3 to 50 carbon atoms and which may also contain heteroatoms (e.g. S, N, O) with 3 to 30 atoms being most preferred.

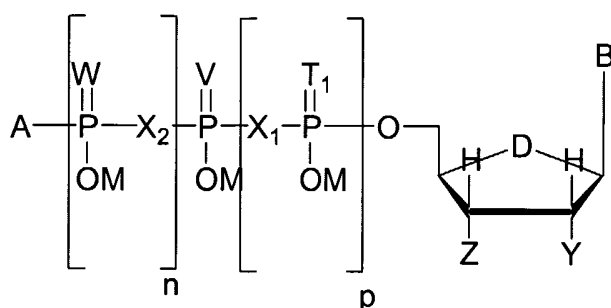
In preferred compounds of the present invention, X₁, X₂, and X₃ of Formula I are independently oxygen, methylene, monochloromethylene, dichloromethylene, monofluoromethylene, difluoromethylene, or imido. More preferably X₁, X₂, and X₃ are oxygen, dichloromethylene or difluoromethylene; with oxygen being most preferred. In preferred compounds of the compositions of the present invention, T₁, T₂, W, and V of Formula I are independently oxygen or sulfur. More preferably T₁ and T₂ are sulfur or oxygen, and W and V oxygen, respectively; with T₁, T₂, W, and V being oxygen being most preferred. In preferred compounds of the compositions of the present invention, the sum of m+n+p of Formula I is from 1 to 4. More preferably, the sum of m+n+p of Formula I is 2 or 3, with 3 being most preferred. In preferred compounds of the present invention, M is lithium, sodium or potassium; an alkaline earth metal salt such as magnesium or calcium; or an ammonium or tetraalkyl ammonium salt, i.e., NX₄⁺ (wherein X is C₁₋₄). More preferably M is sodium, potassium, or tetraalkyl ammonium; with sodium being most preferred. In preferred compounds of the present invention, D is oxygen.

In preferred compounds of the present invention, B is a purine or pyrimidine; with a pyrimidine being most preferred. In preferred compounds of the present invention, Y is H, OH, or OR, and Z is H, OH, or OR; with the proviso that both Y and Z cannot be H at the same time. More preferably both Y and Z are OH. In preferred compounds of the present invention, R₄ is H, R₅ is H, R₆ and R₇ together is oxygen, R₈ is mono- or di-substituted amino, R₉ is H or aralkyl, R₁₀ is aralkyl, R₁₁ is alkylamino, R₁₂ is H, R₁₃ is H or halogen, R₁₄

is H, halogen, thioalkyl, or thioaralkyl, R_{15} is O, S, amino, or substituted amino, R_{16} is H or R_{15} and R_{16} are taken together to form a substituted 5-membered imidazole ring, R_{17} is H, halogen, alkyl, or substituted alkynyl, and R_{18} is aralkyloxy. More preferably R_{13} is H, R_{14} is H or thioalkyl, R_{15} is O, S, or amino or R_{15} and R_{16} taken together to form a substituted 5-membered imidazole ring, and R_{17} is H, halogen, alkyl, or substituted alkynyl; with R_{15} is O and R_{17} is H being most preferred.

A preferred formula for the compound of the present invention is Formula Ia:

Formula Ia



wherein the variable groups have the definitions as above.

A is preferably O-alkyl, O-cycloalkyl, O-aryl, S-alkyl, S-aryl, N-alkyl, N-cycloalkyl, or C-alkyl; more preferably preferably O-alkyl, O-cycloalkyl, or O-aryl, having 3 to 30 carbon atoms;

X_1 , X_2 , and X_3 are preferably oxygen;

T_1 , T_2 , W , and V are preferably oxygen;

preferably the sum of $m+n+p$ is from 1 to 4; more preferably 2 or 3;

20 M is preferably H or an alkali metal; more preferably every M is a sodium or a potassium counter ion;

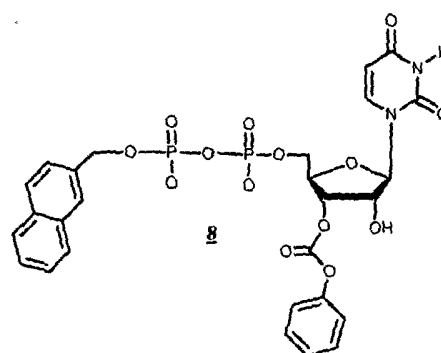
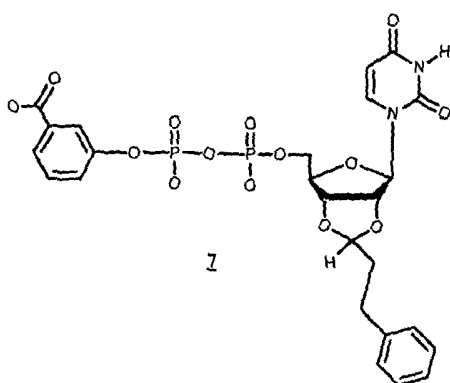
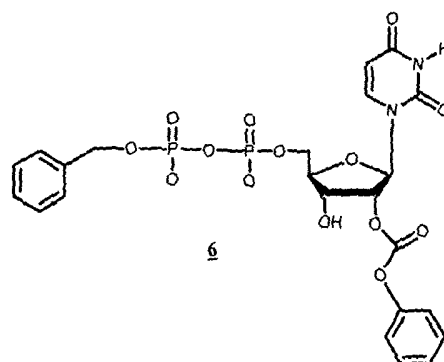
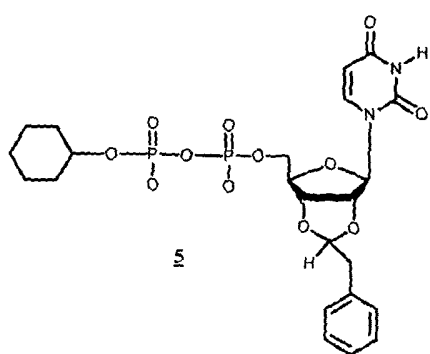
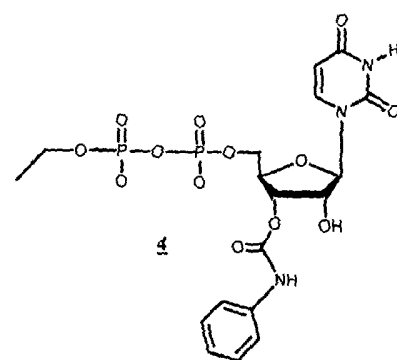
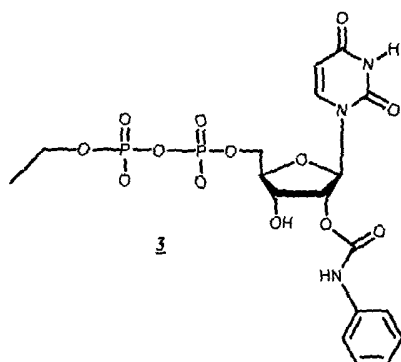
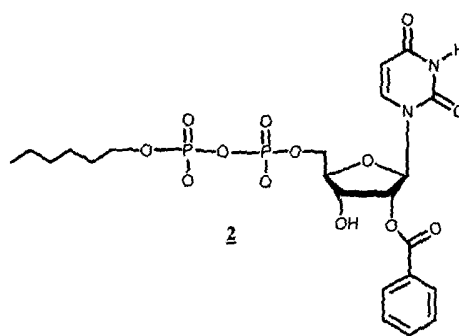
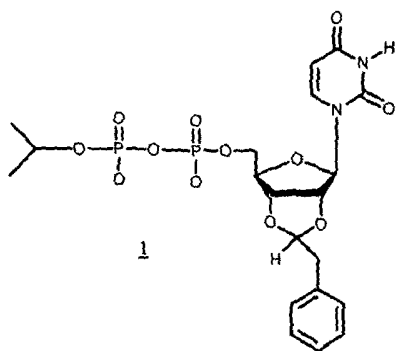
D is preferably oxygen;

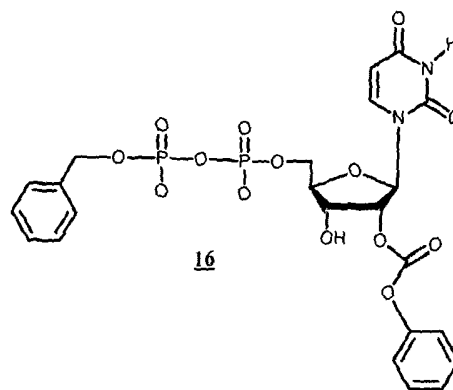
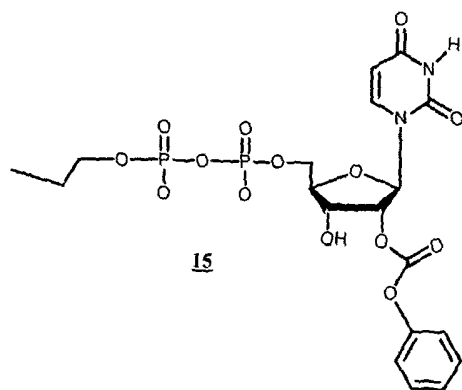
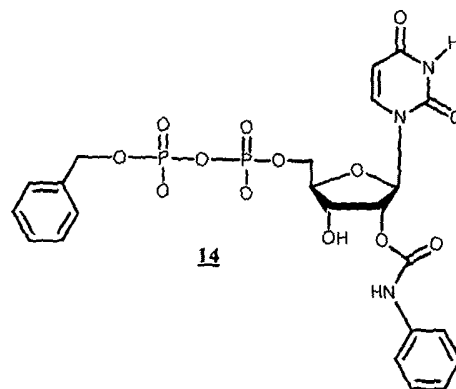
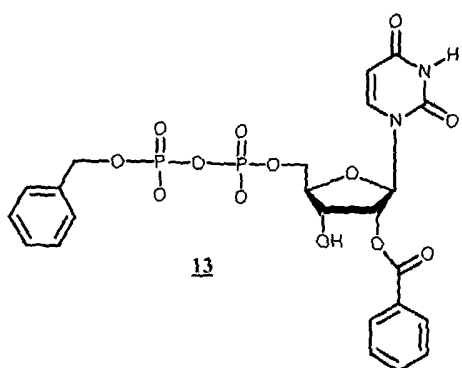
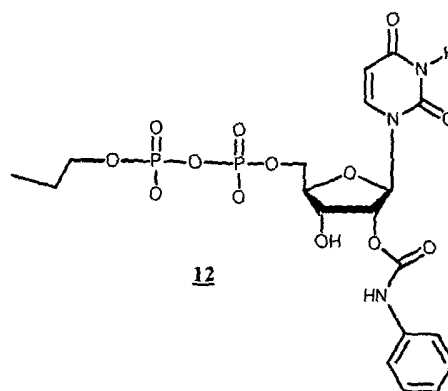
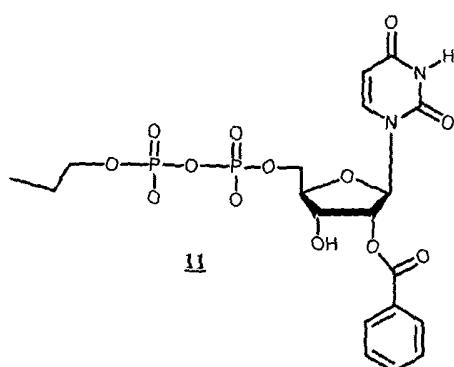
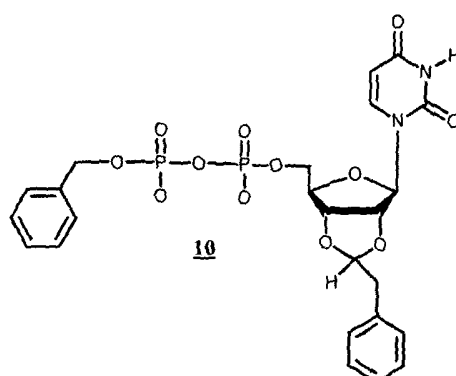
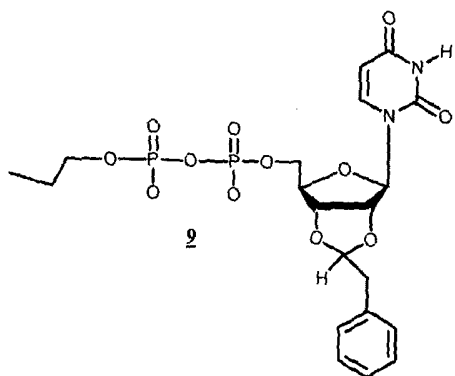
B is preferably selected from the group consisting of uracil, cytosine, thymine, imidazo[1,2-*c*]pyrimidin-5(6H)-one {ethenocytosine}, 2-phenyl-imidazo[1,2-*c*]pyrimidin-5(6H)-one {phenylethenocytosine}, 5-iodouracil, 5-iodocytosine, 4-thiouracil, and 5-phenylethynyluracil;

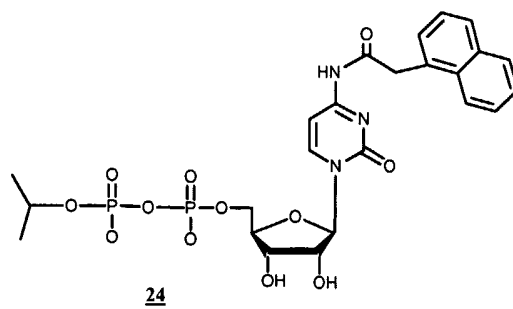
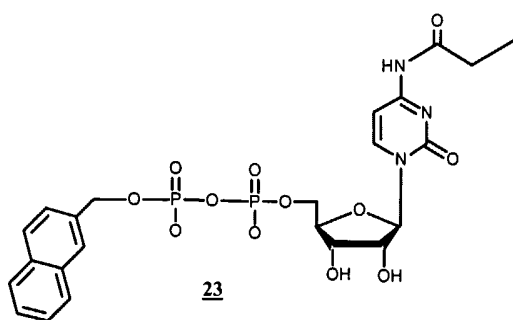
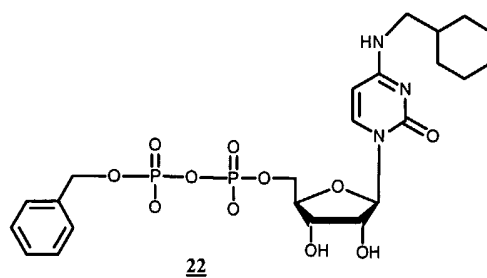
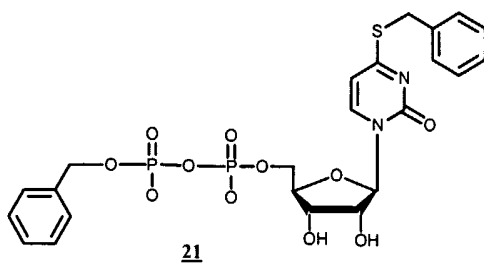
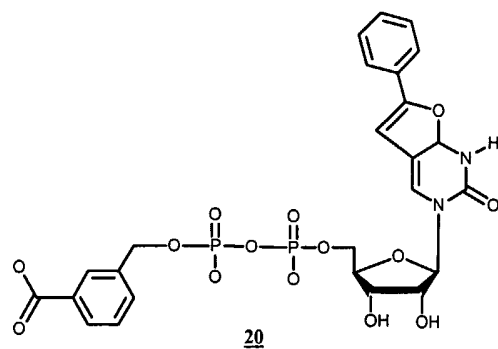
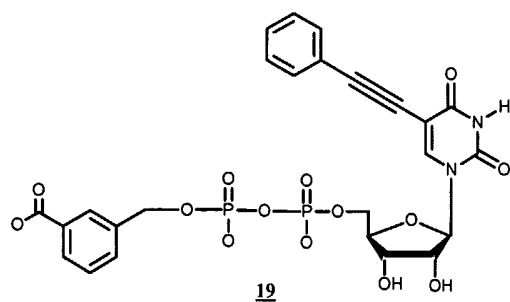
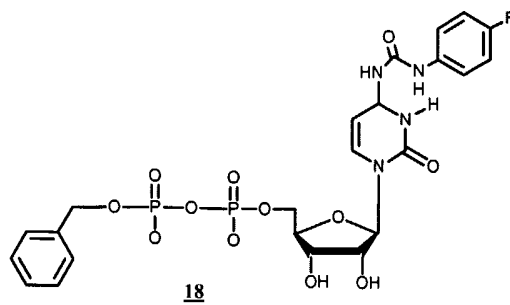
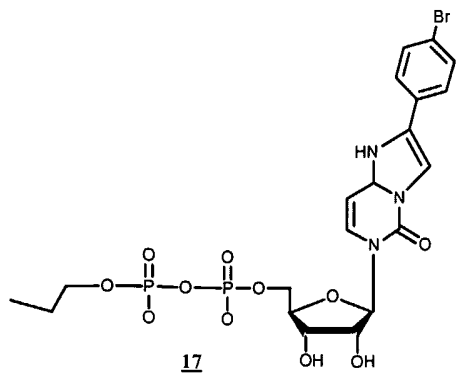
Y and Z are both preferably OH.

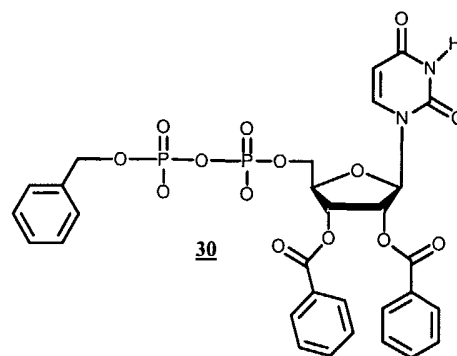
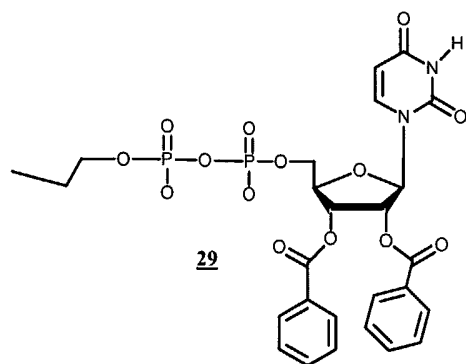
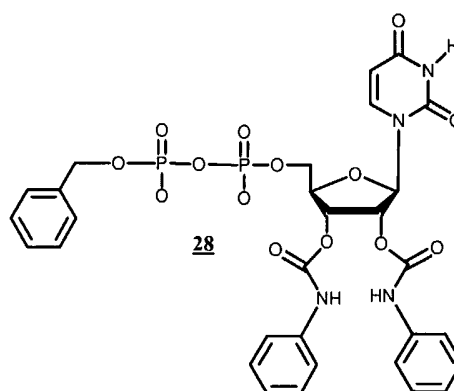
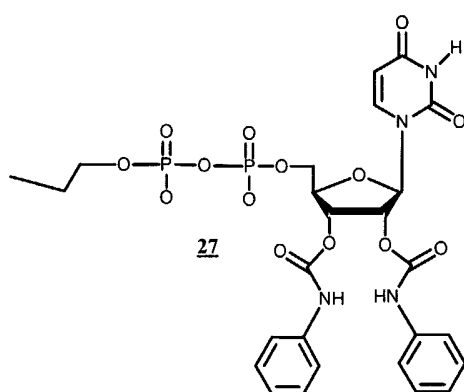
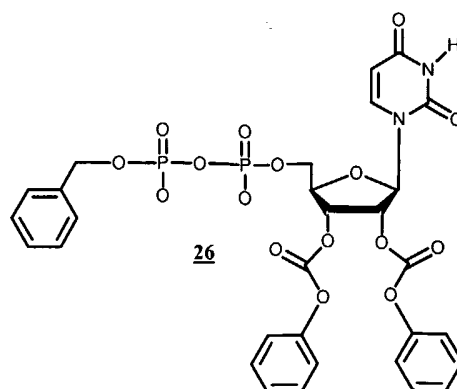
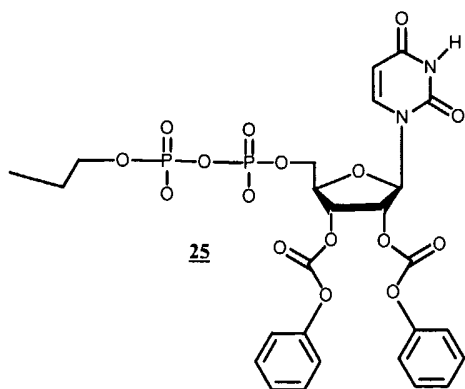
The following compounds, within the scope of the present invention, are deemed particularly useful:

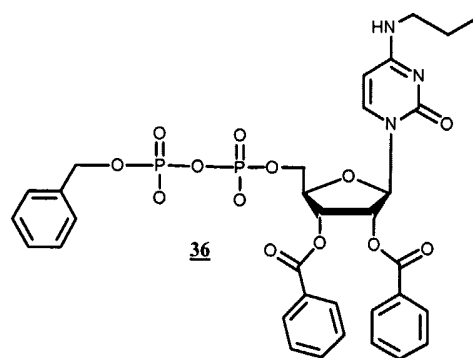
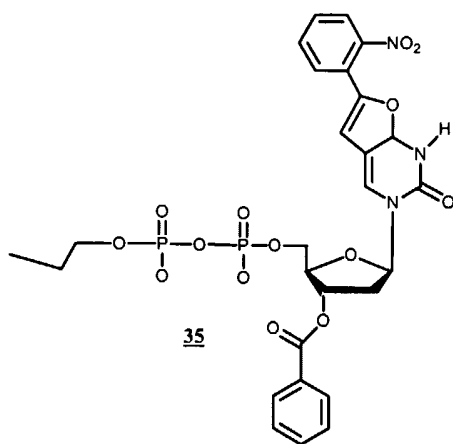
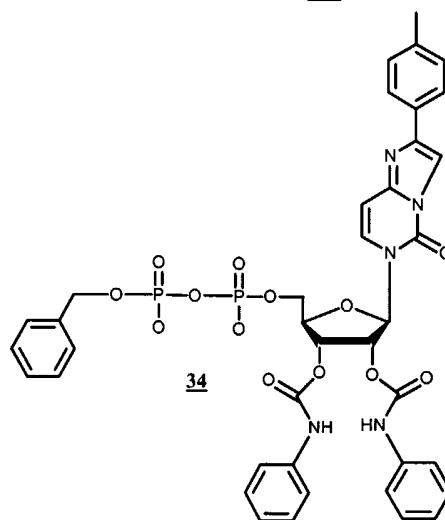
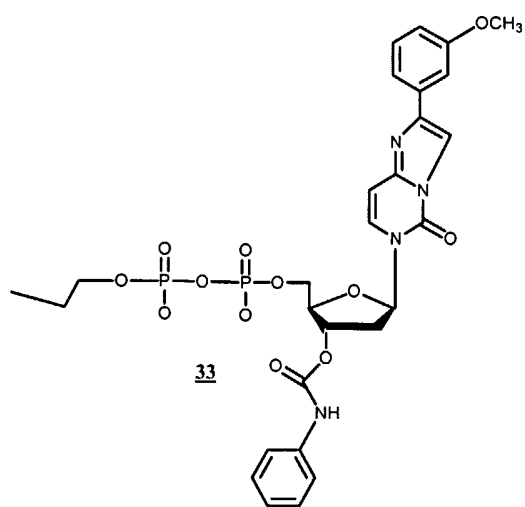
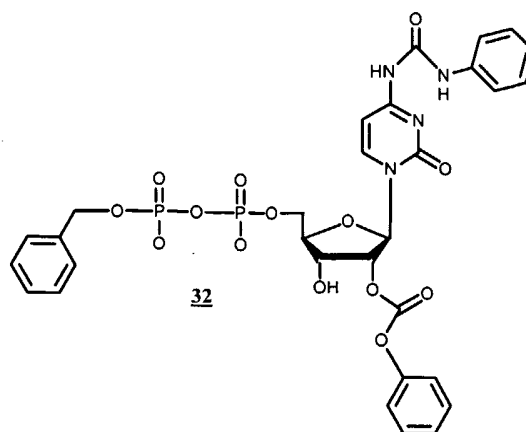
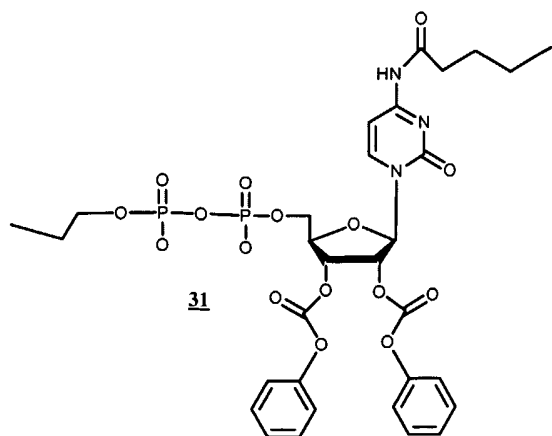
Structures 1-36 exemplify pyrimidine diphosphates where A=OR₁:



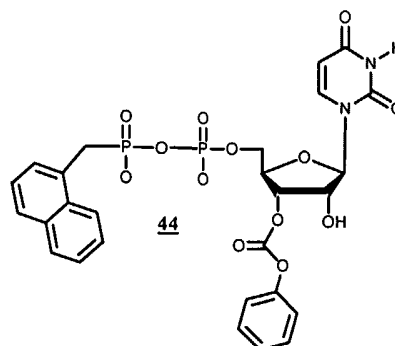
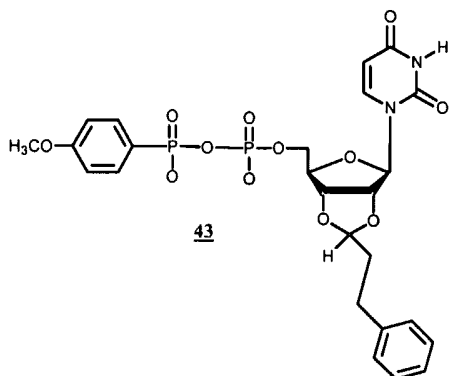
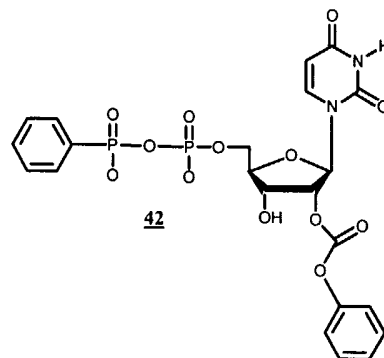
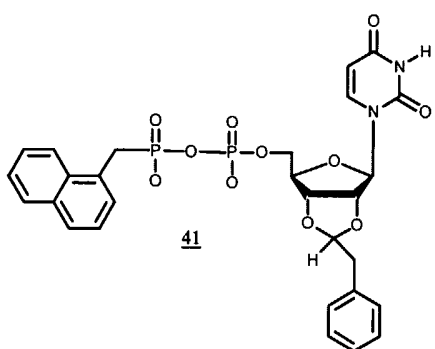
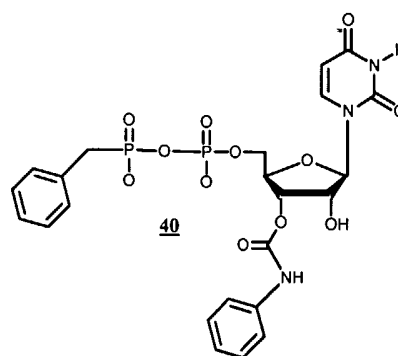
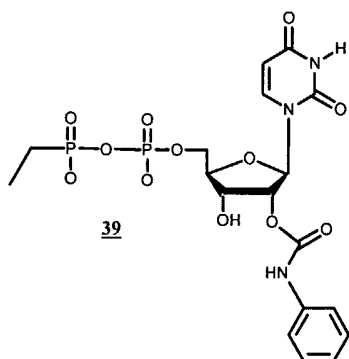
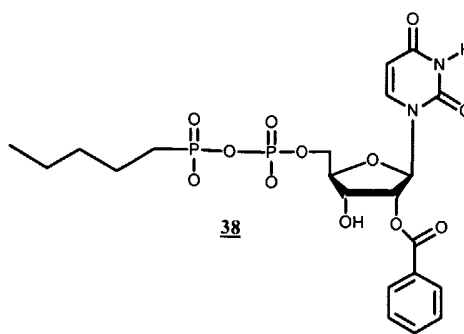
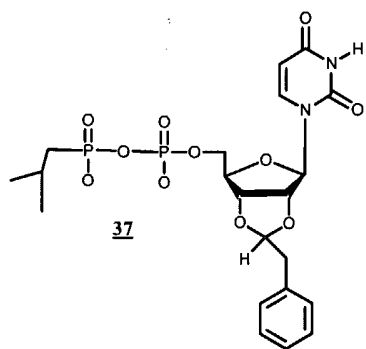


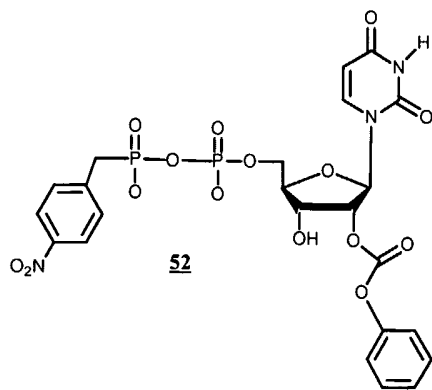
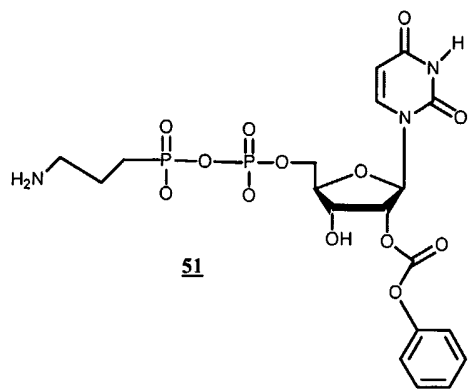
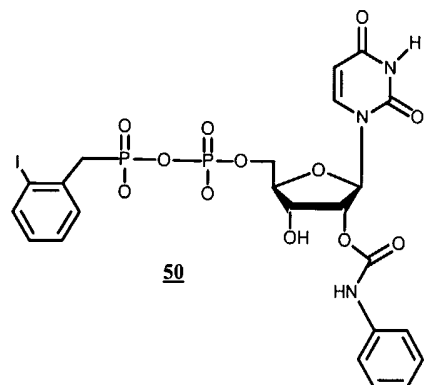
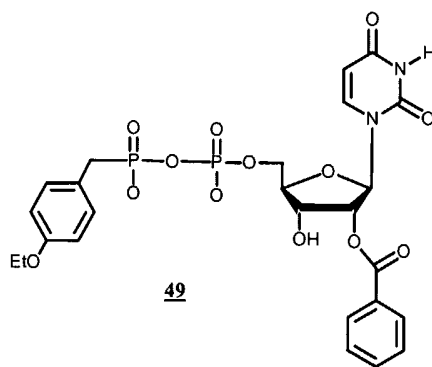
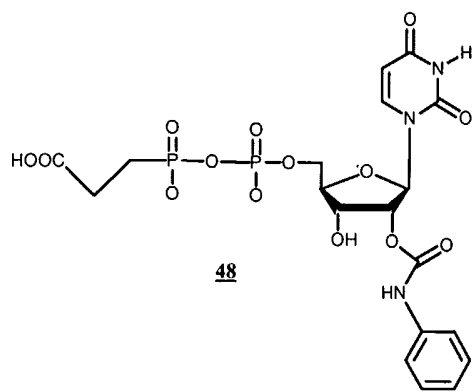
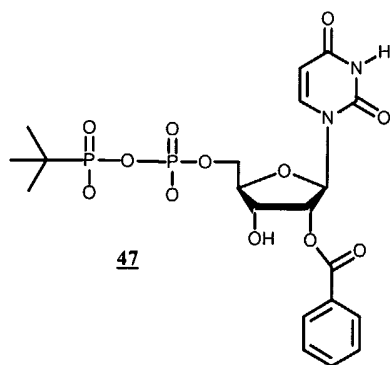
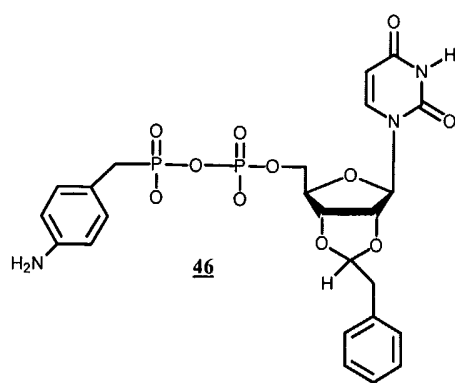
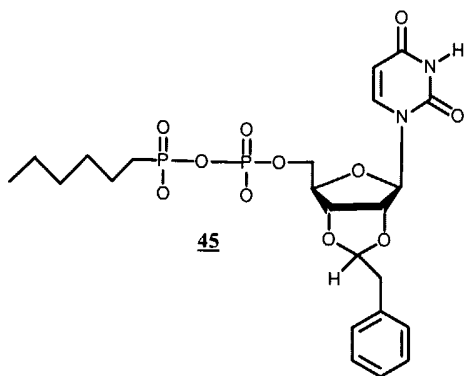


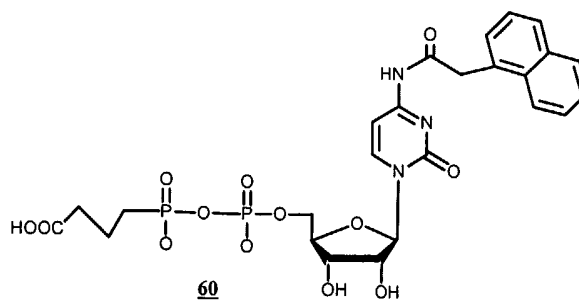
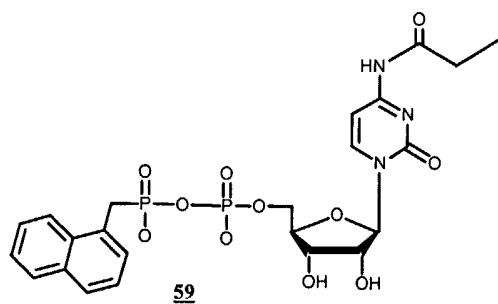
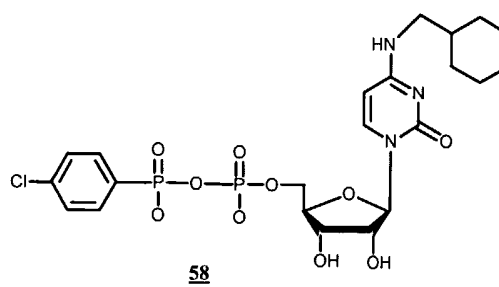
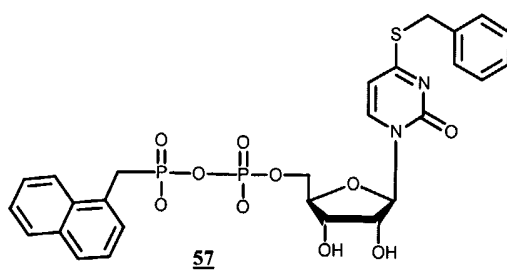
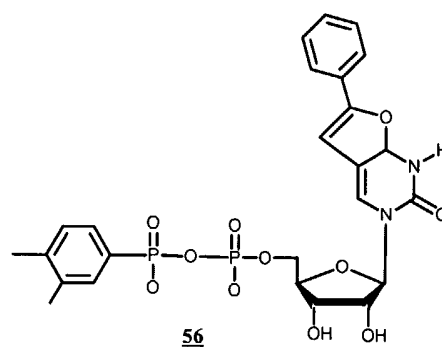
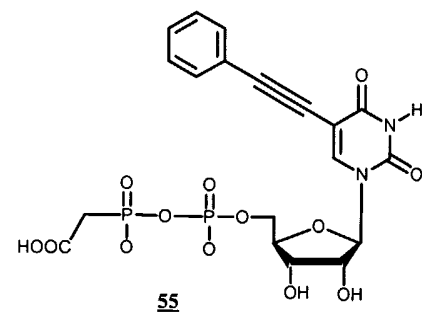
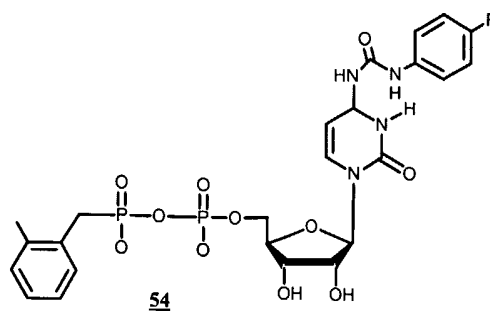
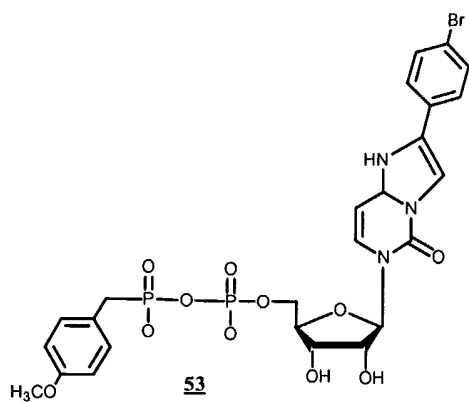


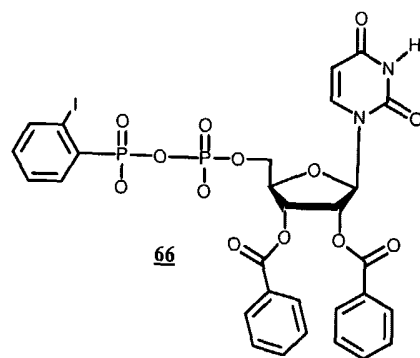
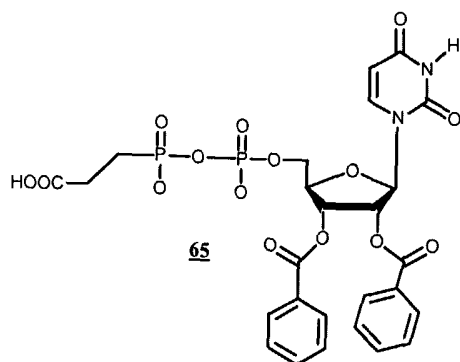
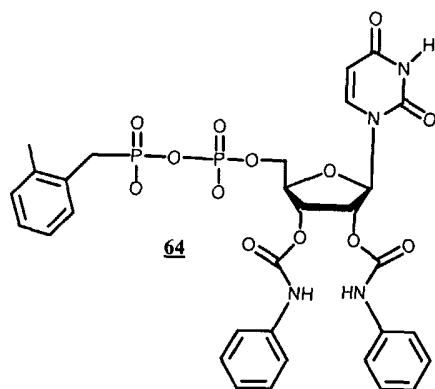
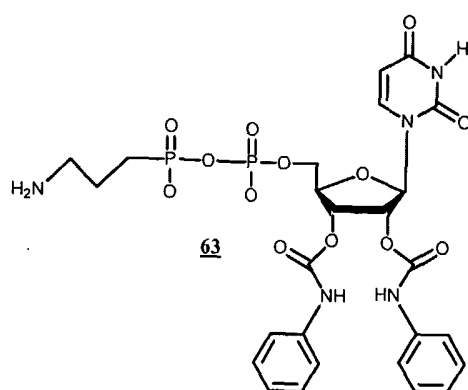
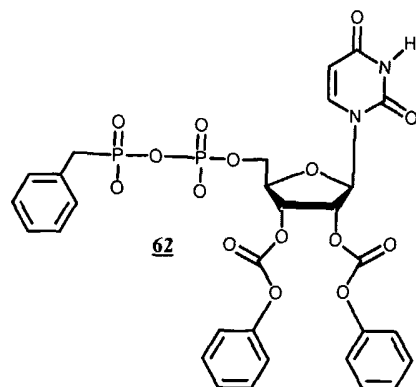
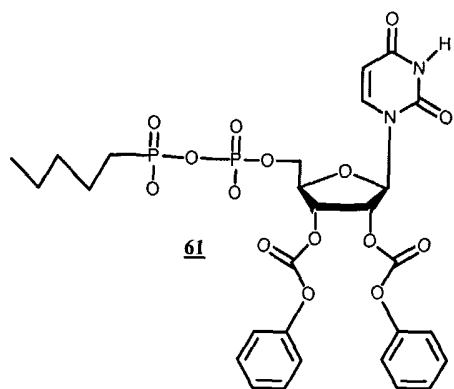


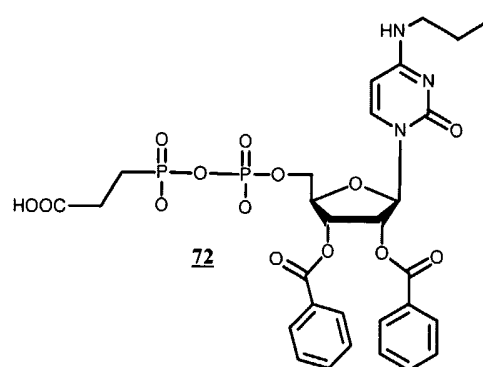
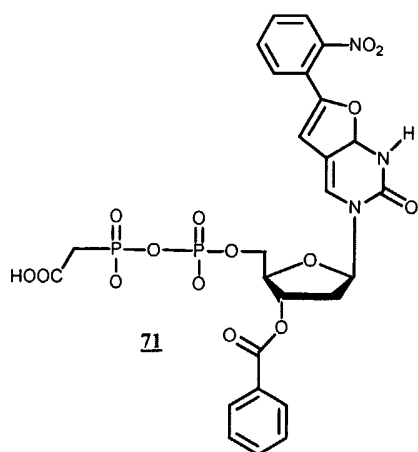
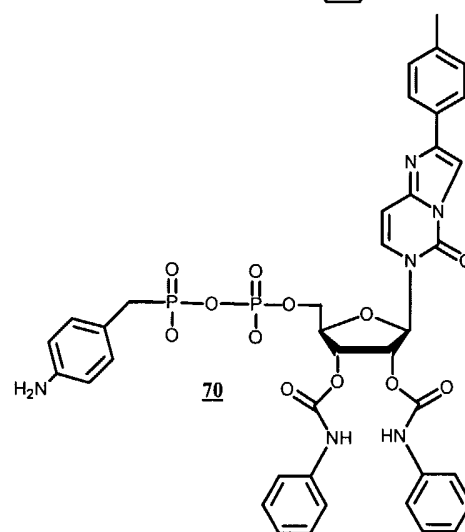
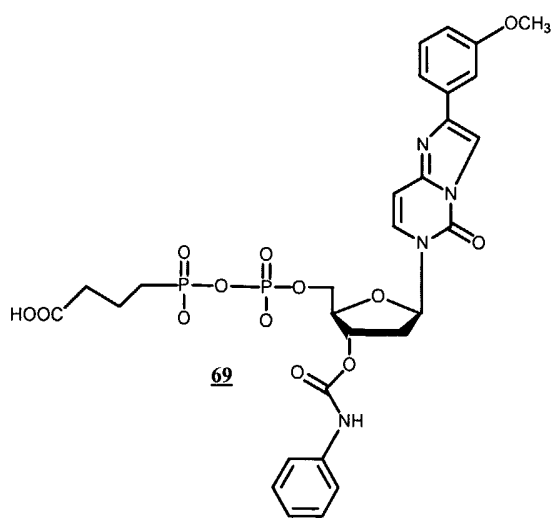
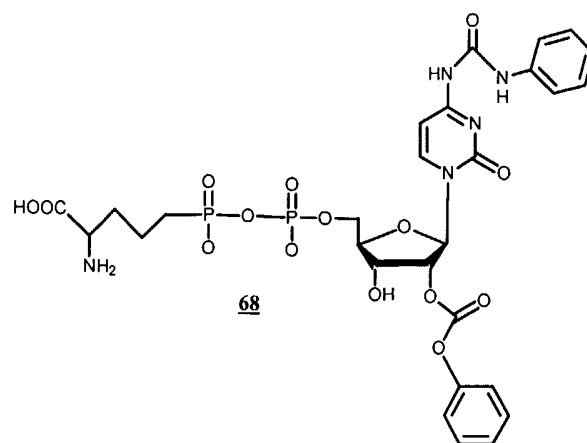
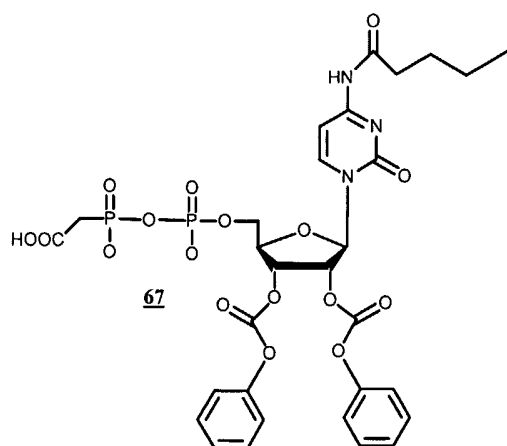
Structures 37-72 exemplify pyrimidine diphosphates where A= CR₁R₂R₃:



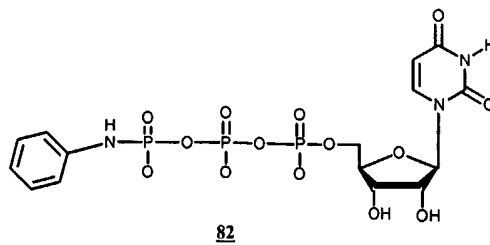
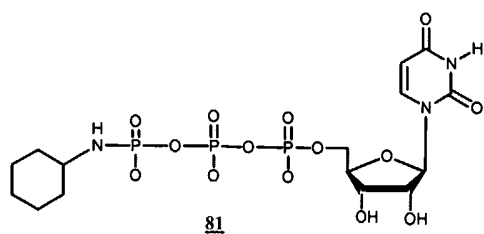
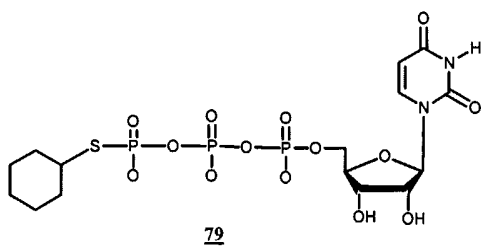
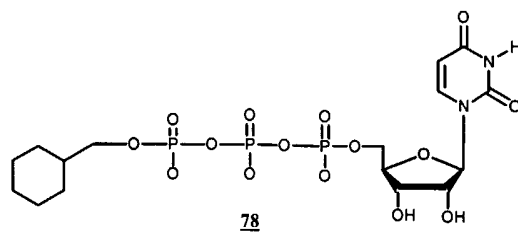
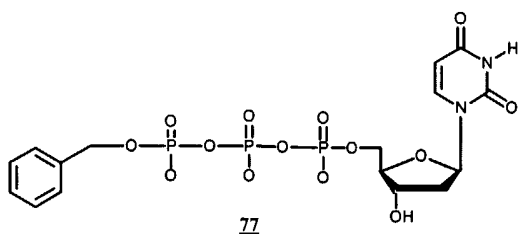
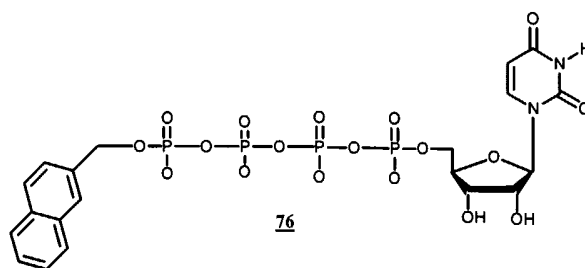
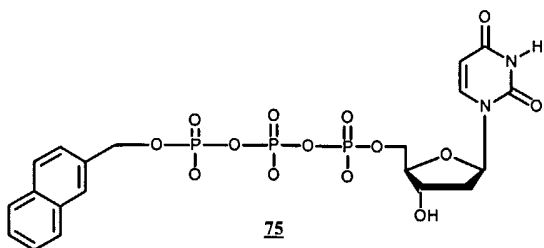
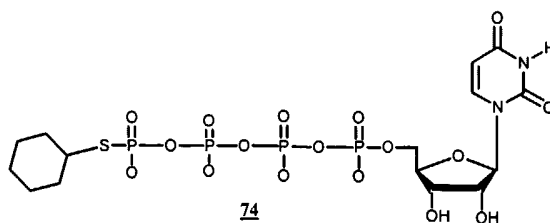
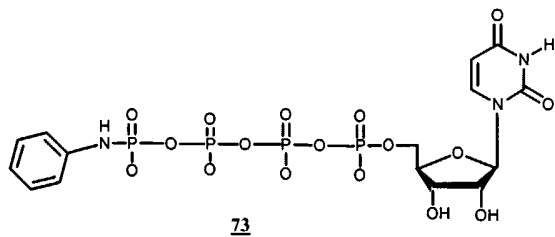


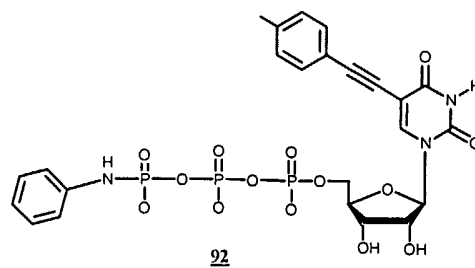
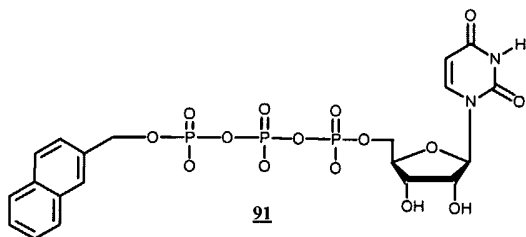
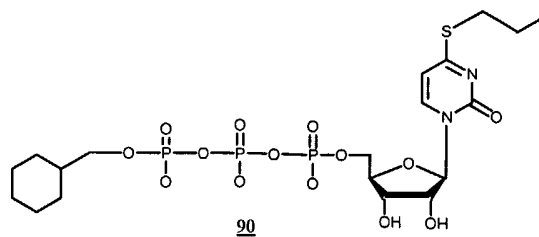
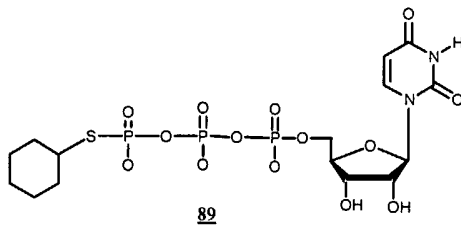
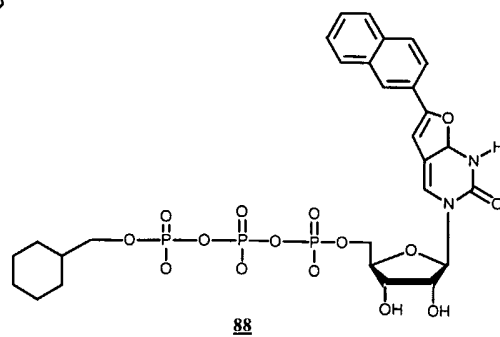
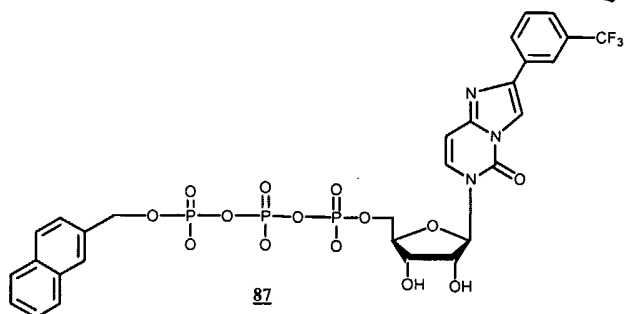
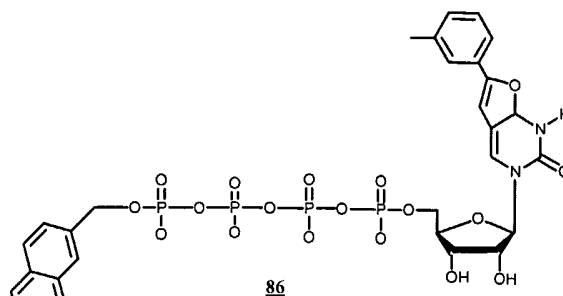
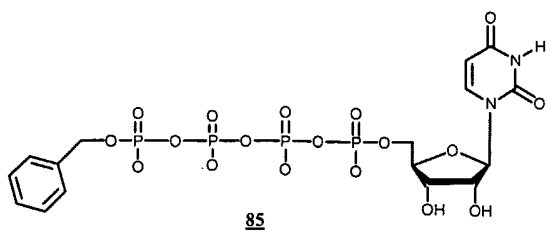
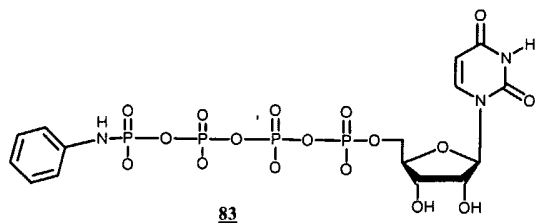


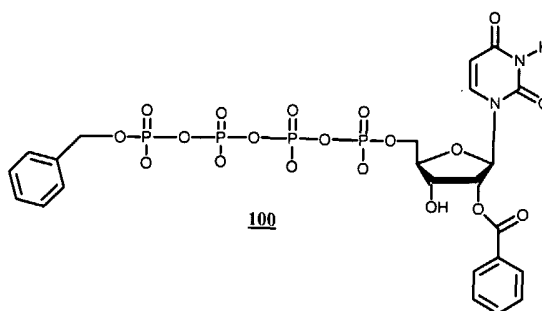
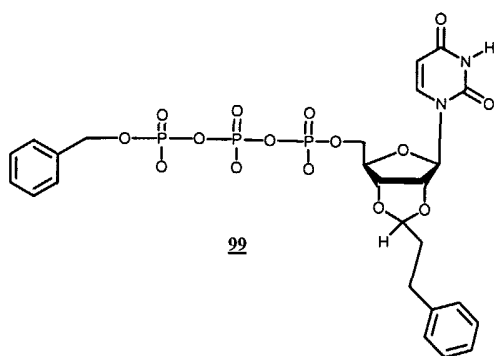
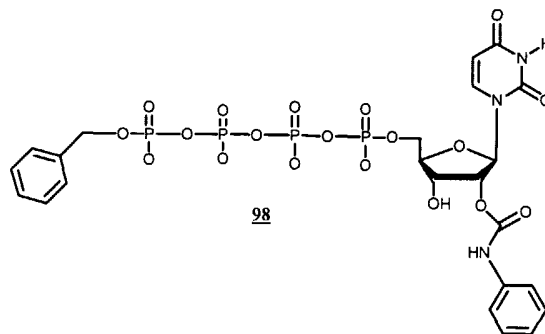
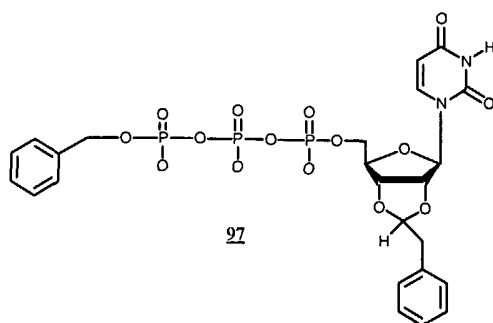
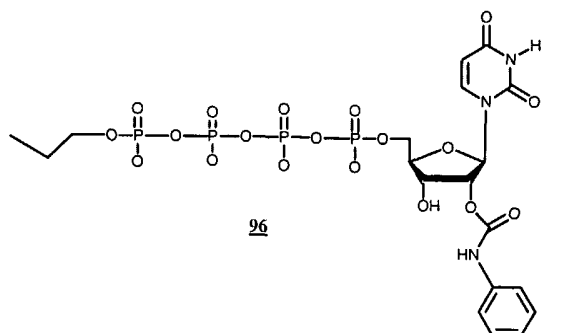
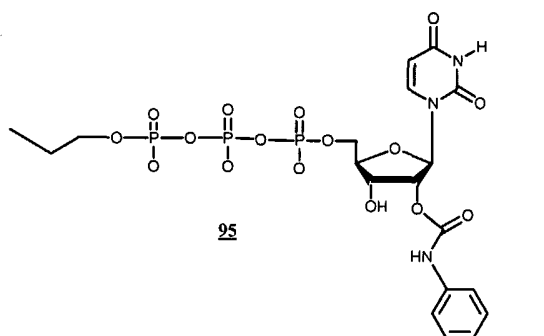
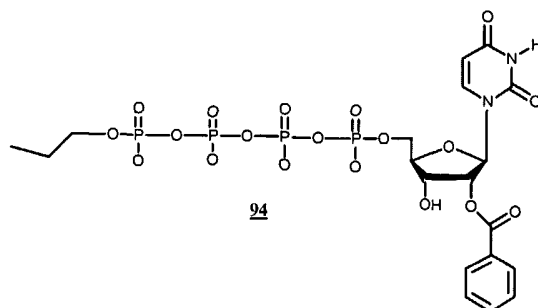
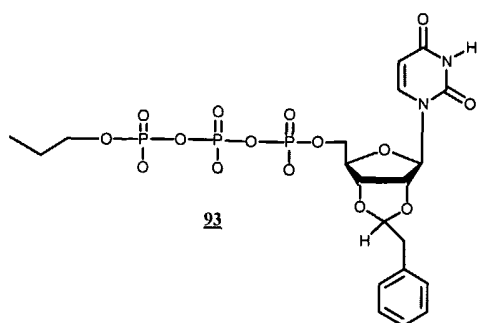


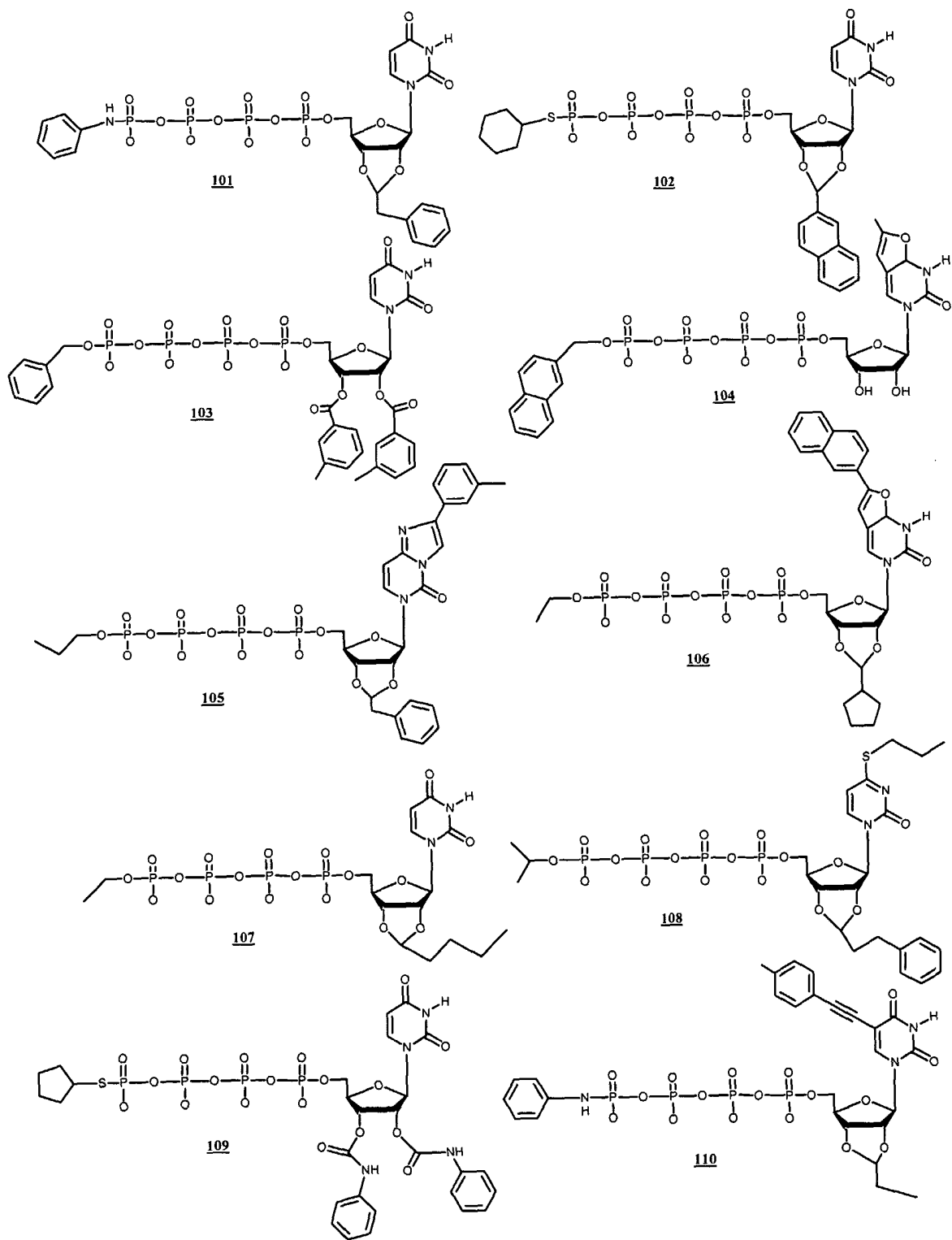


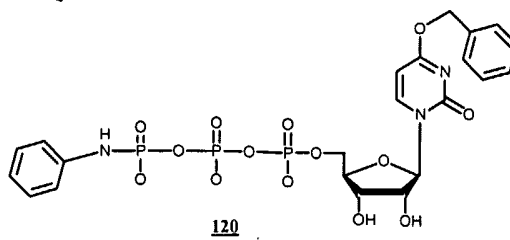
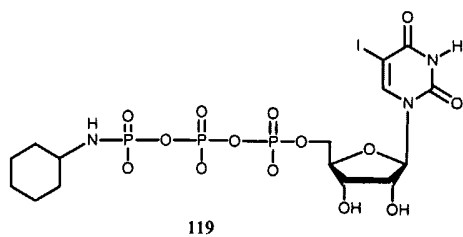
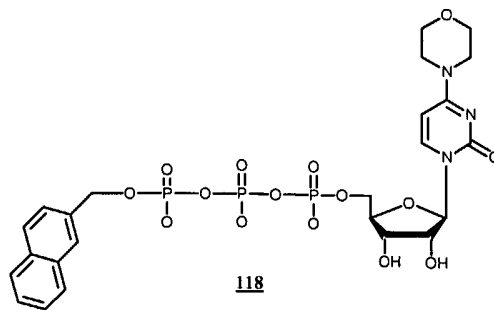
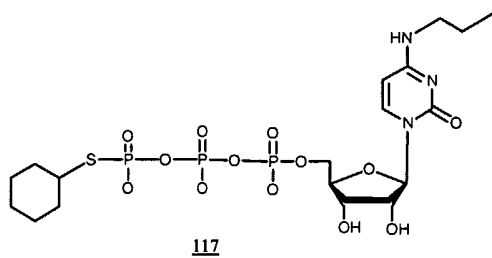
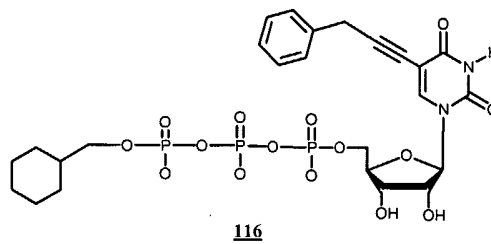
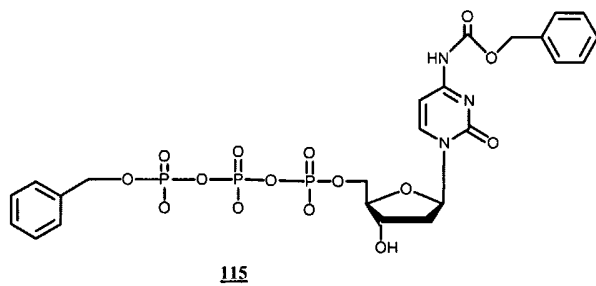
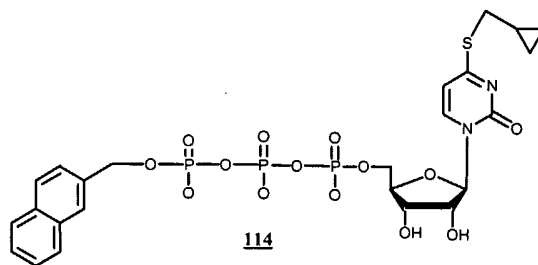
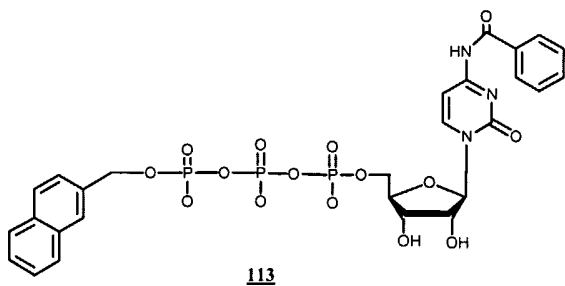
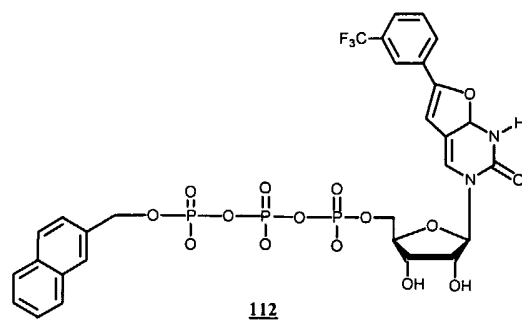
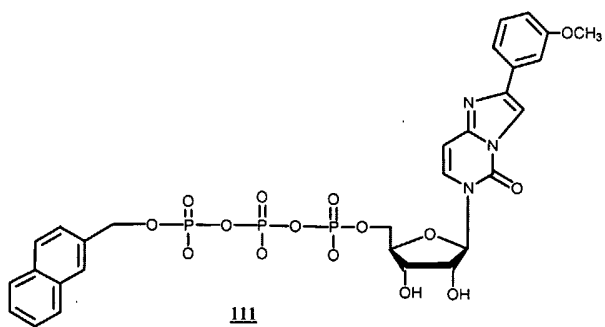
Structures **73-130** exemplify pyrimidine triphosphates and tetraphosphates where A= OR₁, SR₁, or NR₁R₂:

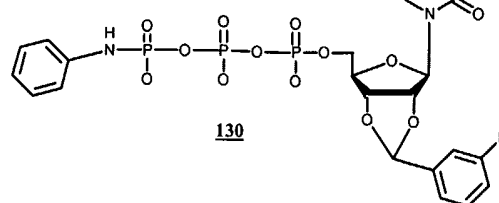
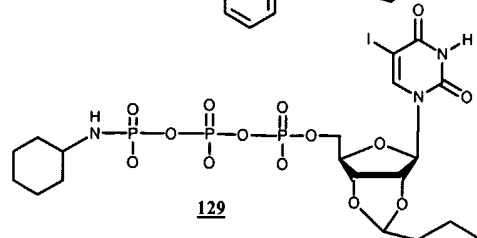
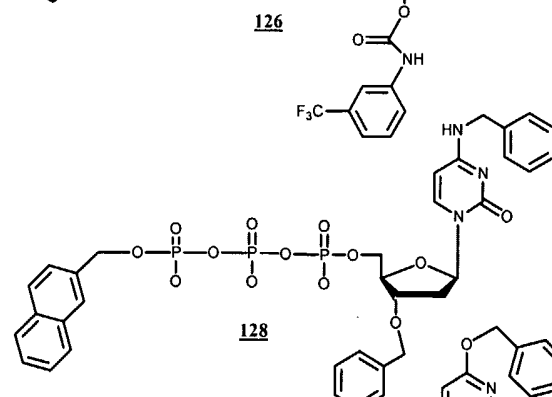
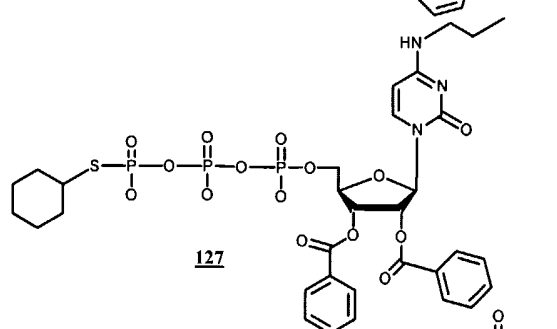
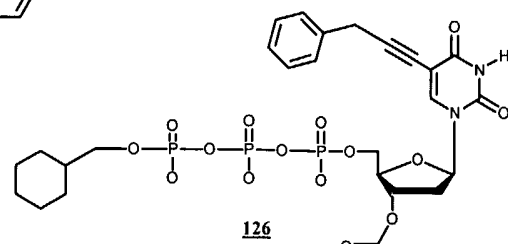
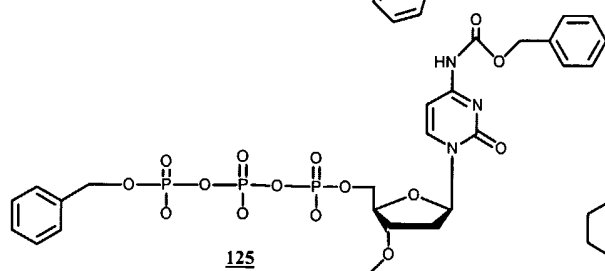
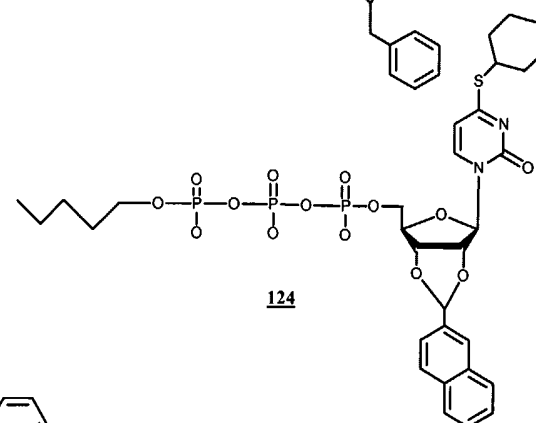
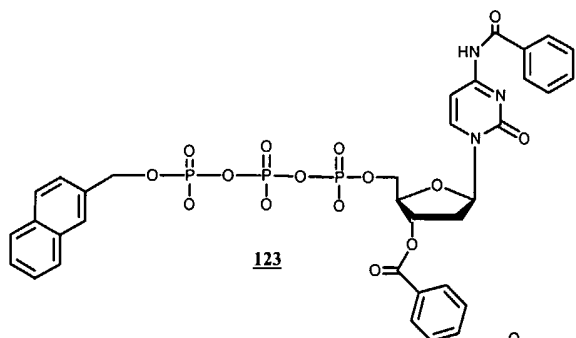
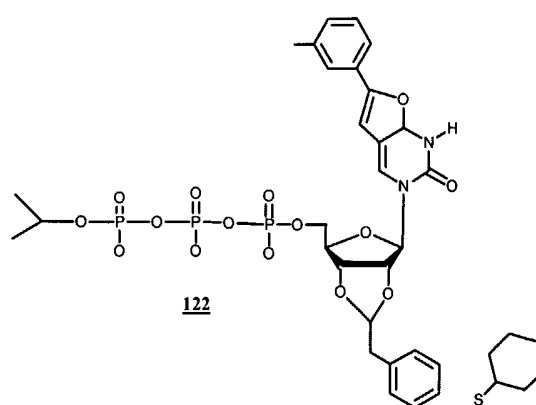
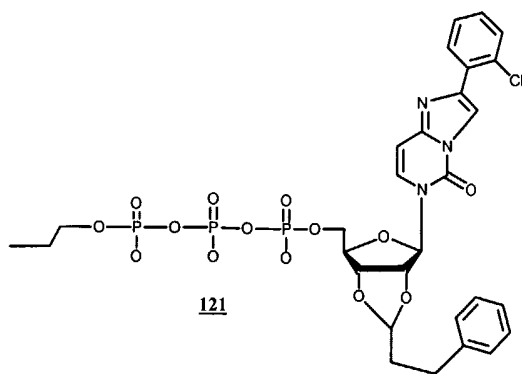




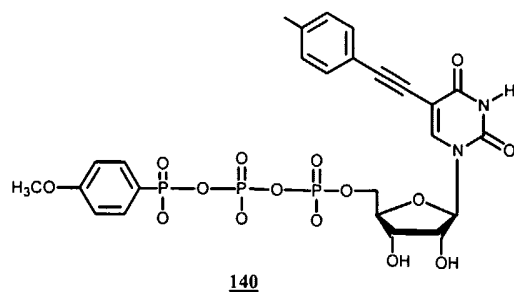
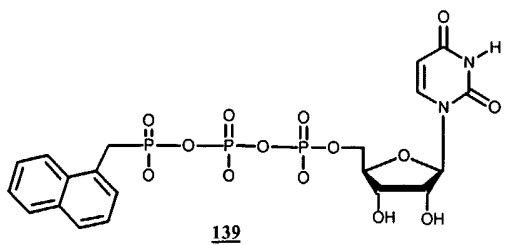
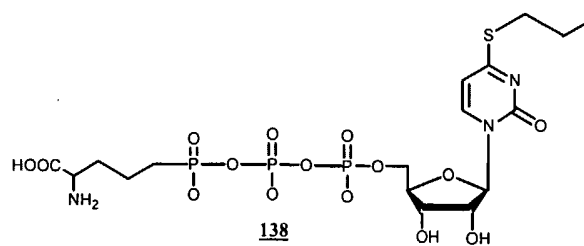
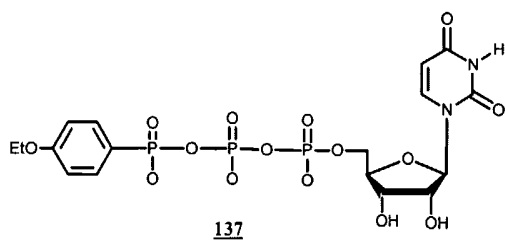
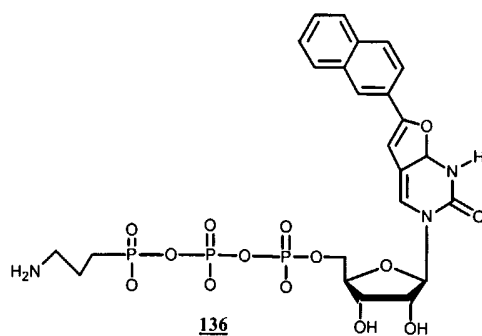
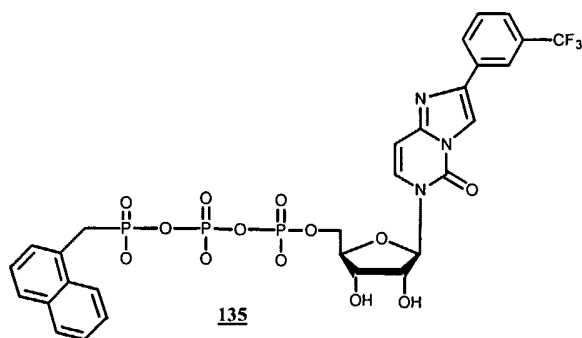
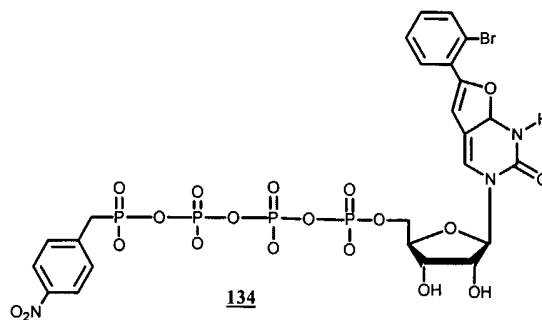
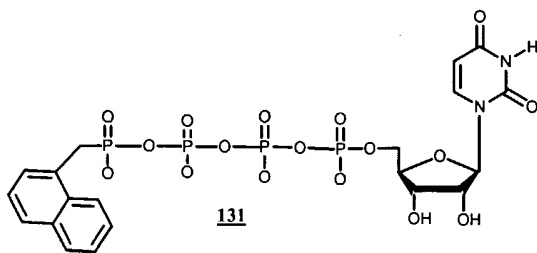


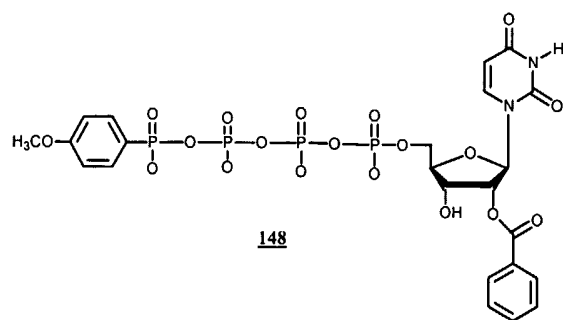
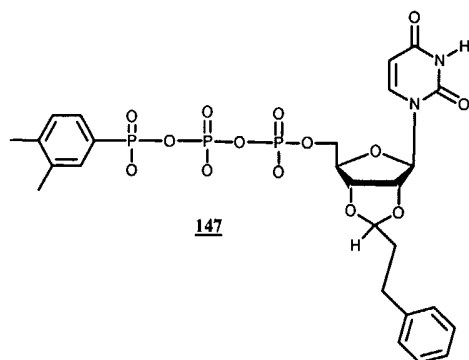
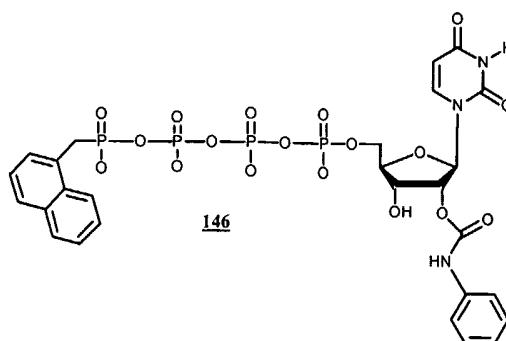
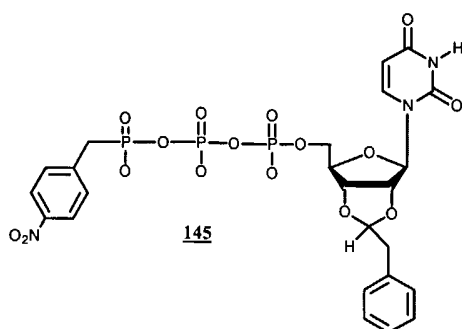
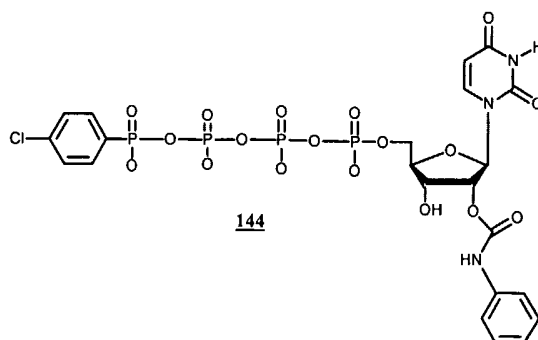
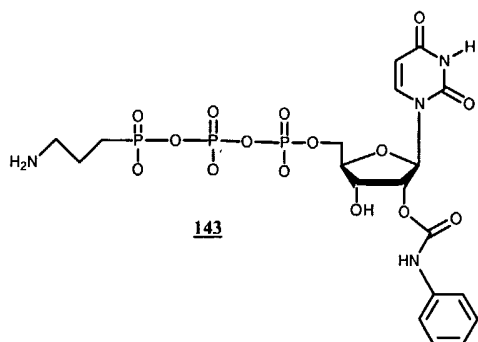
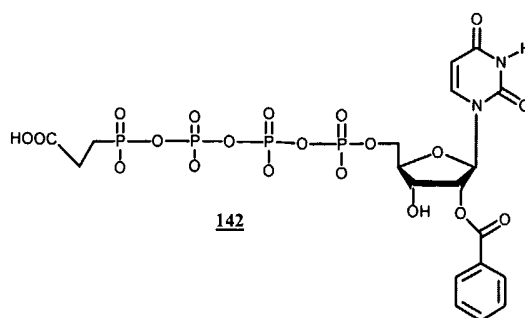
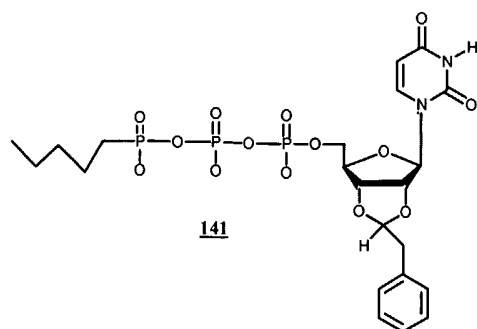


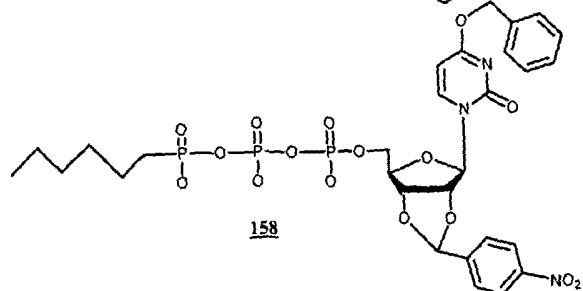
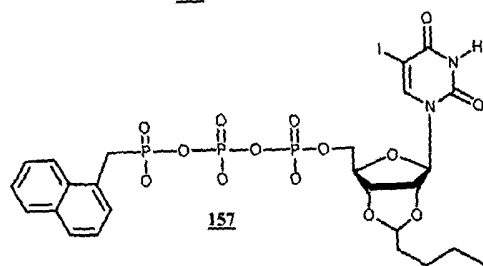
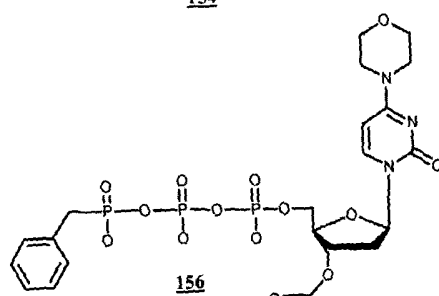
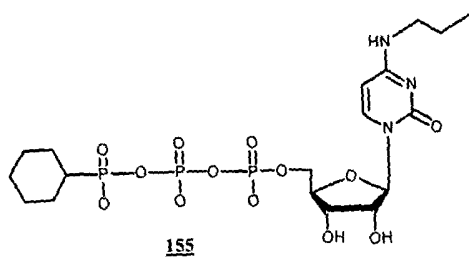
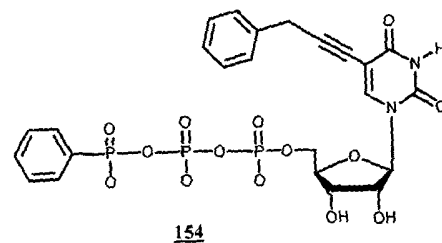
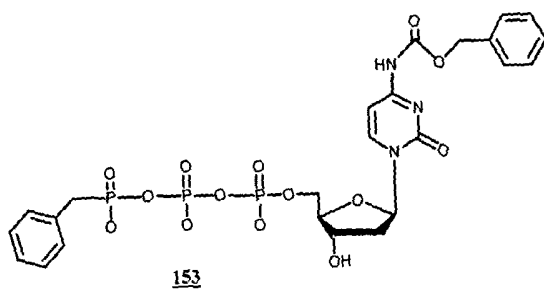
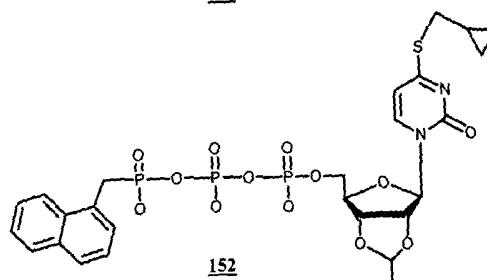
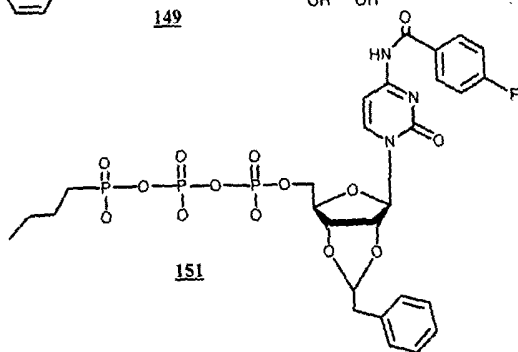
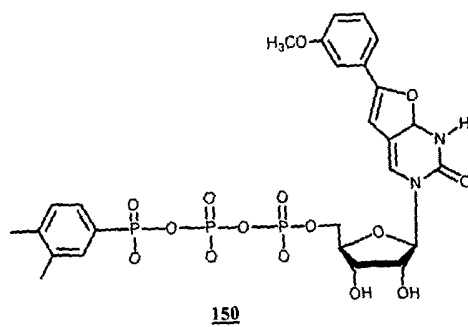
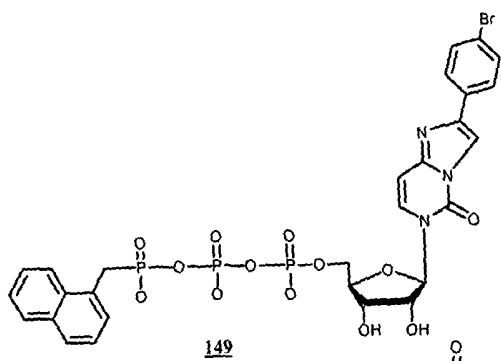


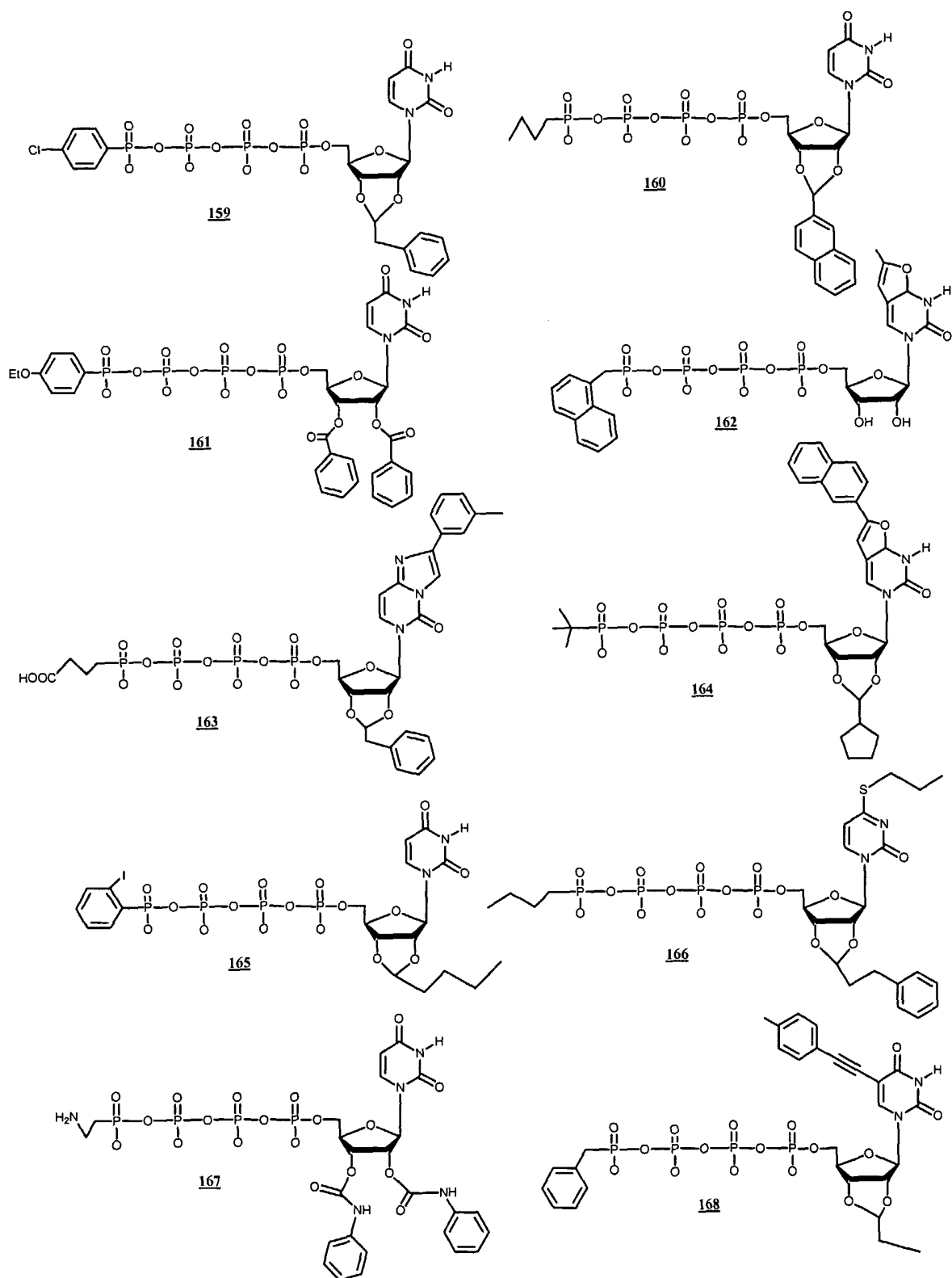


Structures **131-168** exemplify pyrimidine triphosphates and tetraphosphates where A= $CR_1R_2R_3$:

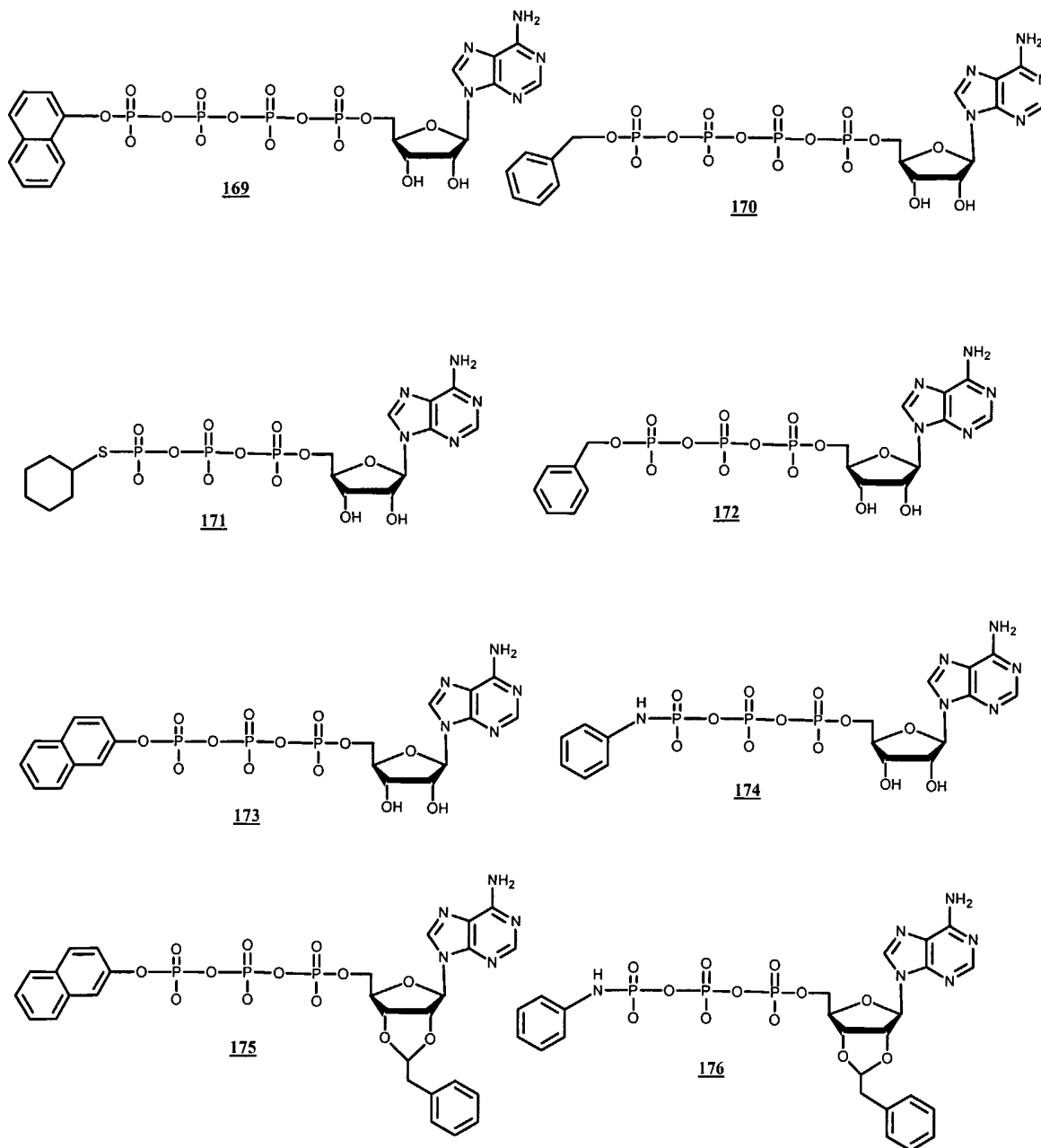


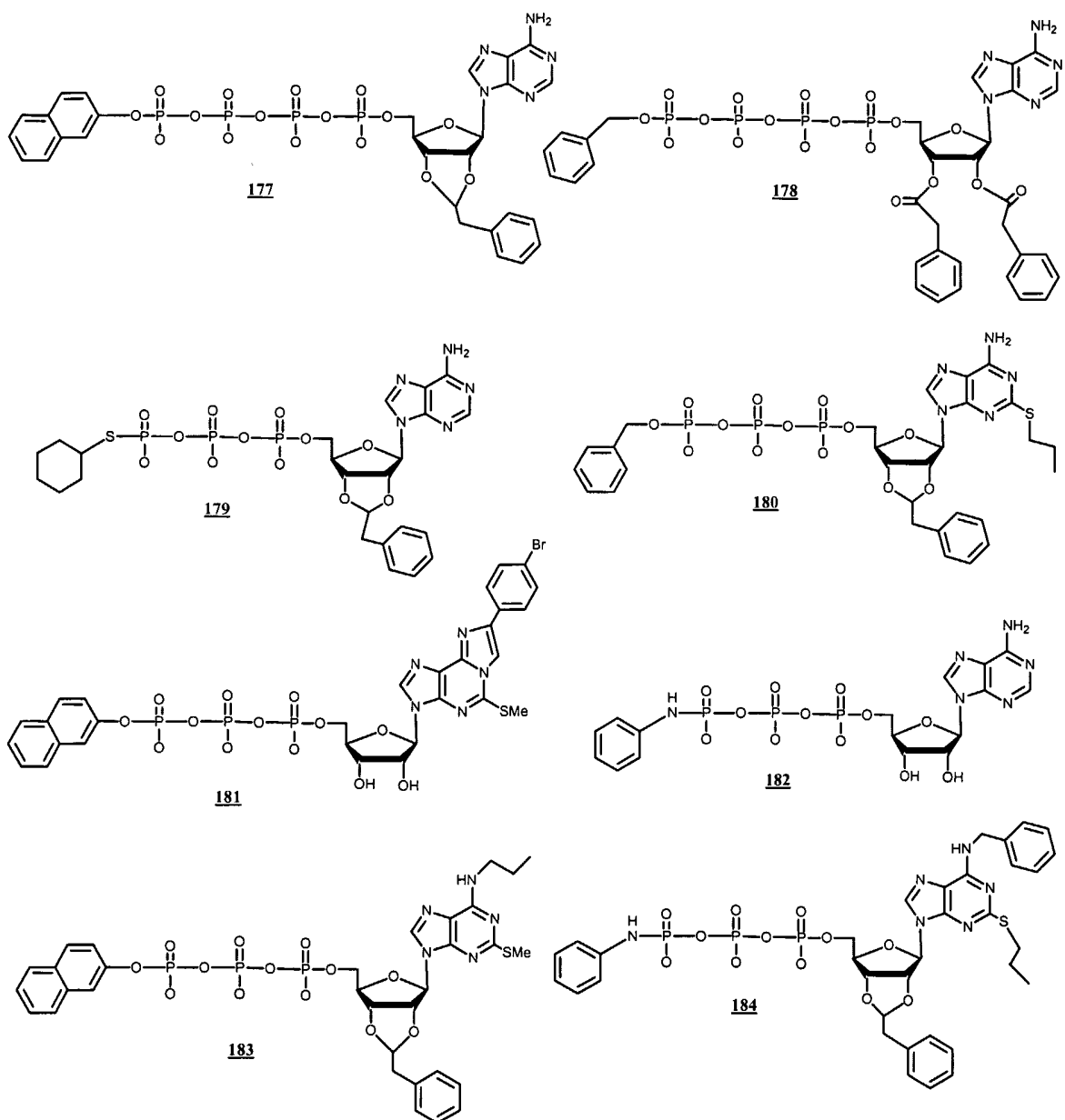


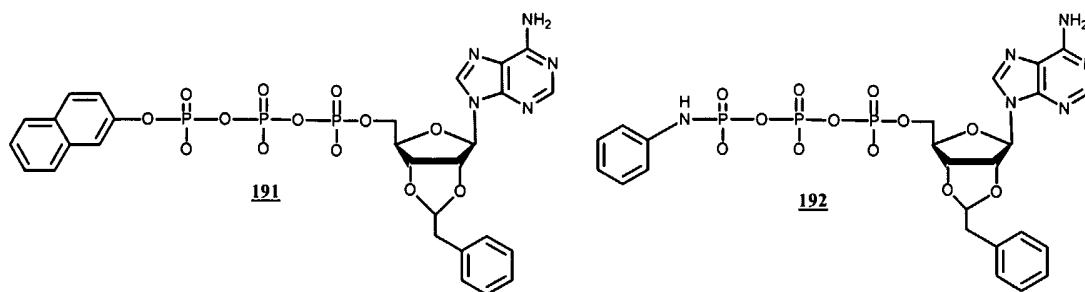
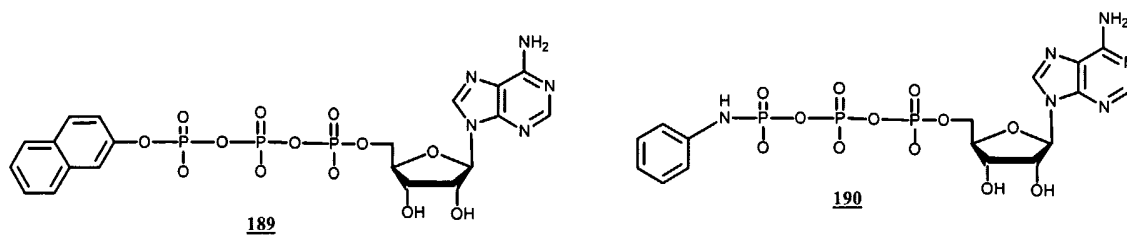
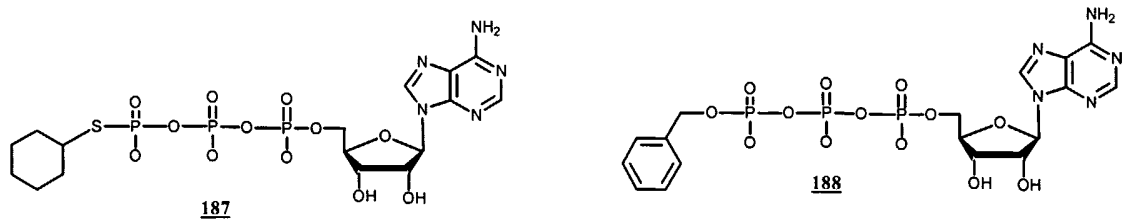
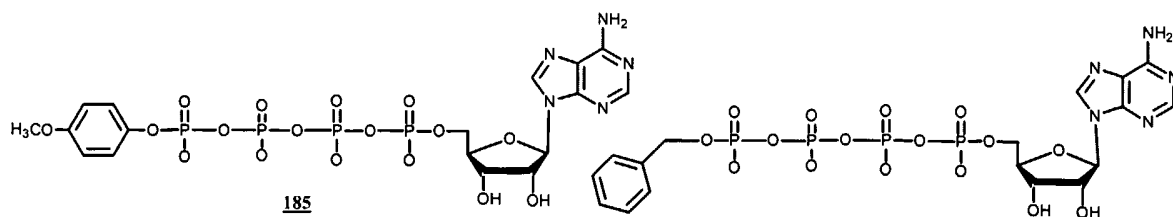




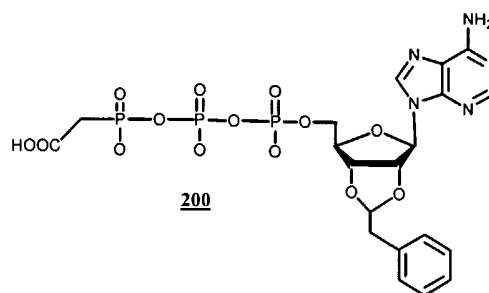
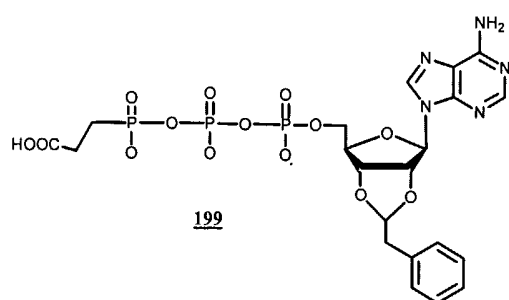
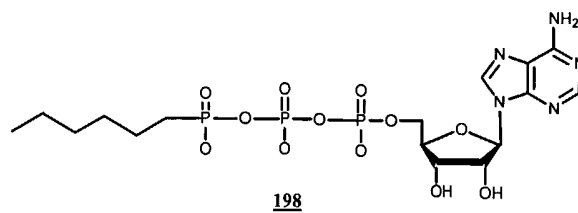
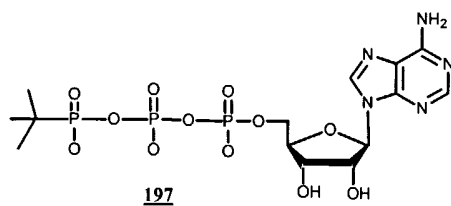
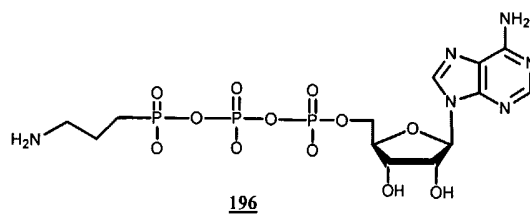
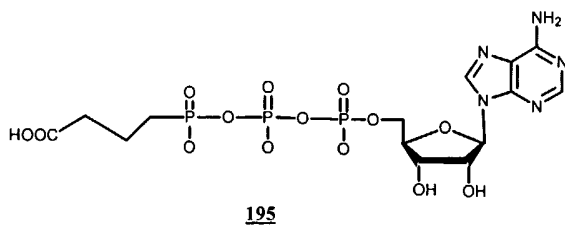
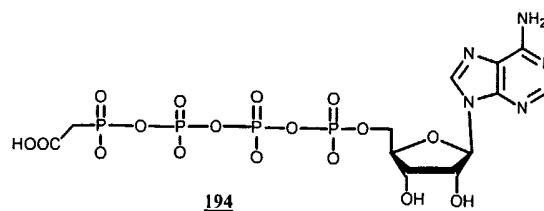
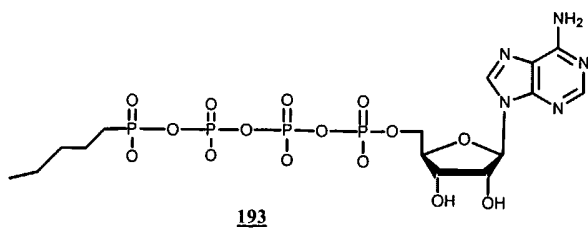
Structures **169-192** exemplify adenosine triphosphates and tetraphosphates where A= OR₁, SR₁, or NR₁R₂:

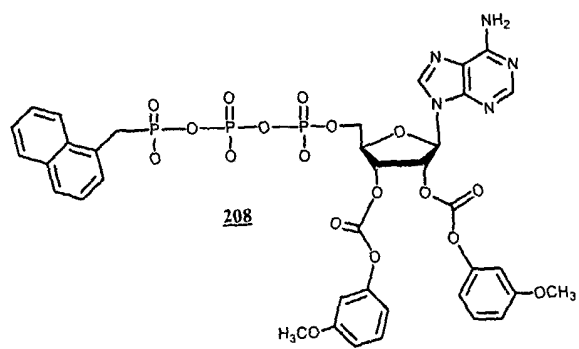
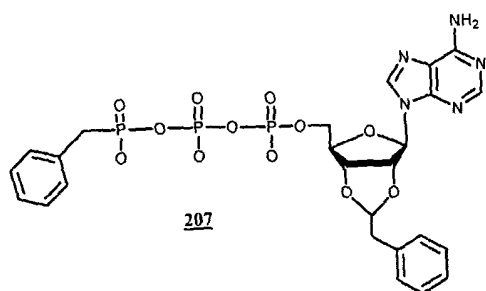
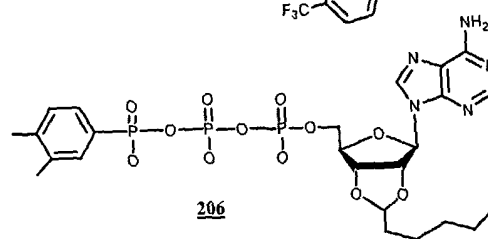
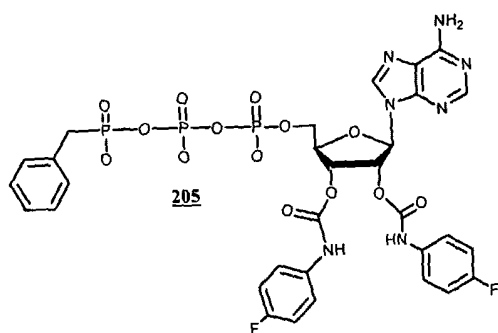
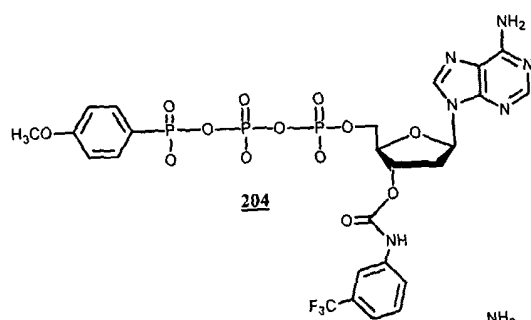
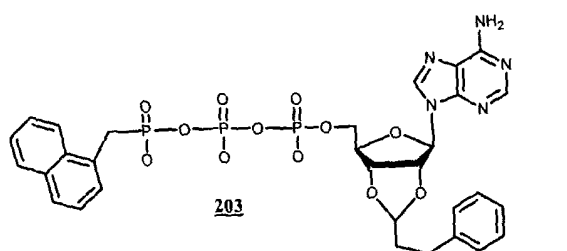
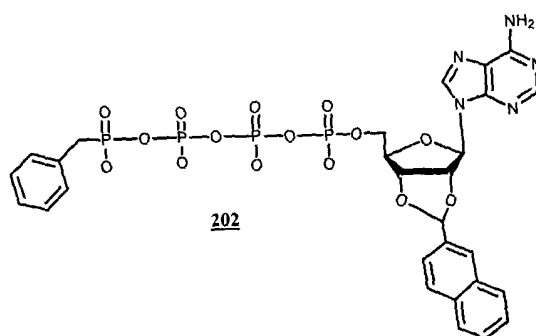
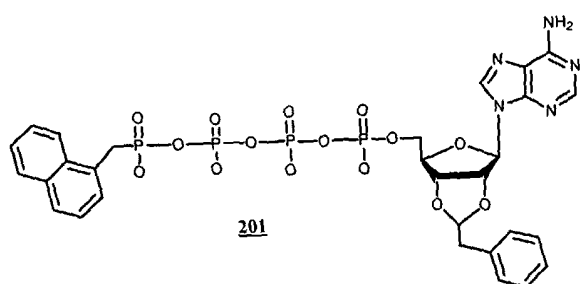


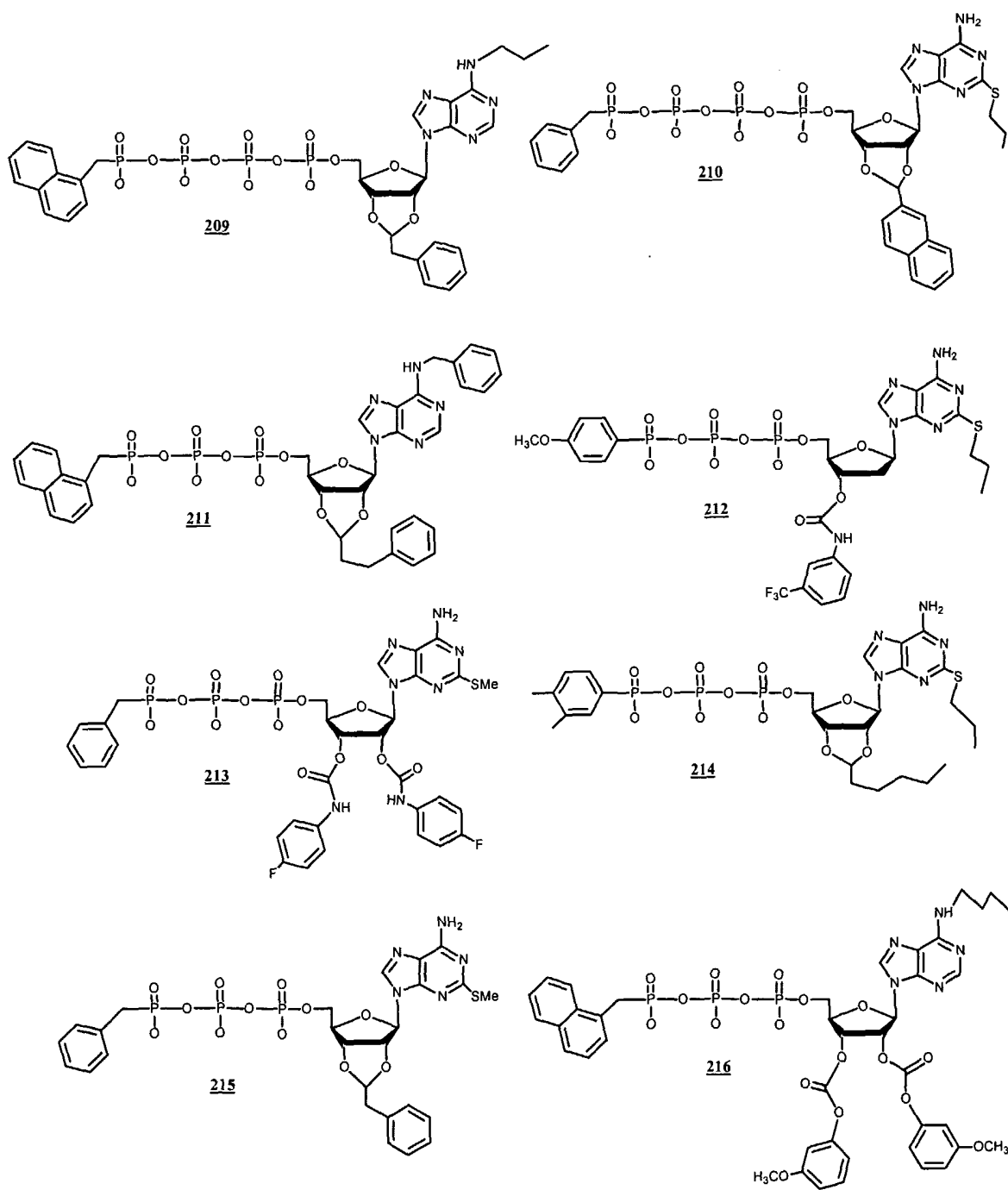




Structures **193-216** exemplify adenosine triphosphates and tetraphosphates where A=CR₁R₂R₃:







5

More preferred compounds from the structures above (with the above compound number in parentheses) include:

2'3'-O-methylenebenzyl β -(cyclohexyl) UDP (5), 2'-phenylcarbamoyl β -benzyl UDP (14), 2'-(phenoxy)formyl β -propyl UDP (15), 6-phenyl-furanopyrimidine riboside β -(3-carboxyphenyl)methyl diphosphate (20), 4-thiobenzyl pyrimidine riboside β -benzyl diphosphate (21), 2',3'-dibenzoyl β -propyl UDP (29), 5-(3-methoxyphenyl)ethenocytosine

5 2'-deoxy-3'-phenylcarbamoyl riboside β -propyl diphosphate (33), N⁴-propyl-2',3'-dibenzoyl β -benzyl CDP (36), 2'3'-O-methylenebenzyl β -(2-methylpropylphosphono) UDP (37), 2'-phenylcarbamoyl β -(2-carboxyethylphosphono) UDP (48), N⁴-(4-fluorophenylcarbamoyl) β -(o-methylbenzylphosphono) CDP (54), 2',3'-di(phenoxy)formyl β -(pentylphosphono) UDP (61), N⁴-propyl-2',3'-dibenzoyl β -(2-carboxyethylphosphono)

10 CDP (72), 2'-deoxy γ -benzyl UTP (77), γ -(thiocyclohexyl) UTP (79), 6-(3-methylphenyl)-furanopyrimidine riboside δ -(2-naphthalenemethyl) tetraphosphate (86), 2'3'-O-methylenebenzyl γ -propyl UTP (93), 5-(3-methylphenyl)ethenocytosine 2'3'-O-methylenebenzyl riboside δ -propyl tetraphosphate (105), 5-(3-methoxyphenyl)ethenocytidine riboside γ -(2-naphthalenemethyl) triphosphate (111), N⁴-(benzyloxyformyl)-2'-deoxy γ -benzyl CTP (115), N⁴,3'-dibenzoyl-2'-deoxy γ -(2-naphthalmethyl) CTP (123), 5-(3-trifluoromethylphenyl)ethenocytidine γ -(1-naphthalenemethylphosphono) triphosphate (135), 4-thiopropyl pyrimidine riboside γ -(4-aminocarboxybutylphosphono) triphosphate (138), 2'3'-O-methylenephenethyl γ -(3,4-dimethylphenylphosphono) UTP (147), 5-iodo-2'3'-O-methylenebutyl γ -(1-naphthalenemethylphosphono) UTP (157), 2',3'-dibenzoyl δ -(4-ethoxyphenylphosphono) uridine tetraphosphate (161), 2'3'-O-methylenebenzyl γ -(2-naphthalene) ATP (175), 2-thiopropyl-2'3'-O-methylenebenzyl γ -benzyl ATP (180), 2-thiomethyl-N⁶-propyl-2'3'-O-methylenebenzyl γ -(2-naphthalene) ATP (183), 2'3'-O-methylenebenzyl γ -anilino ATP (192), 2'3'-O-methylenebenzyl γ -(carboxymethylphosphono) ATP (200), 2'3'-O-

25 methylenebenzyl δ -(1-naphthalene) adenosine tetraphosphate (201), 2-thiopropyl-2'-deoxy-3'-(3-trifluoromethylphenyl)carbamoyl γ -(4-methoxyphenylphosphono) ATP (212); with the following compounds being most preferred; 2'3'-O-methylenebenzyl β -(cyclohexyl) UDP (5), 5-(3-methoxyphenyl)ethenocytosine 2'-deoxy-3'-phenylcarbamoyl riboside β -propyl diphosphate (33), 2'3'-O-methylenebenzyl β -(2-methylpropylphosphono) UDP (37),

30 2',3'-di(phenoxy)formyl β -(pentylphosphono) UDP (61), 2'3'-O-methylenebenzyl γ -(propyl) UTP (93), 5-(3-methylphenyl)ethenocytosine 2'3'-O-methylenebenzyl riboside δ -

propyl tetraphosphate (105), 5-(3-trifluoromethylphenyl)ethenocytidine γ -(1-naphthalenemethylphosphono) triphosphate (135), 2',3'-dibenzoyl δ -(4-ethoxyphenylphosphono) uridine tetraphosphate (161), 2-thiopropyl-2'3'-O-methylenebenzyl γ -benzyl ATP (180), and), 2'3'-O-methylenebenzyl δ -(1-naphthalene) adenosine tetraphosphate (201).

The invention is illustrated further by the following examples that are not to be construed as limiting the invention in scope to the specific procedures described in them.

10

EXAMPLES

Example 1. γ -(n-propyl)-uridine 5'-triphosphate.

Uridine 5'-triphosphate, ditributylammonium salt (106 mg, 0.124 mmol) dissolved in dry N,N dimethylformamide (400 μ L) was treated with N,N'-dicyclohexylcarbodiimide (33.4 mg, 0.162 mmol) for one hour at room temperature. After verifying that there was complete conversion to the cyclical trimetaphosphate by ^{31}P NMR, tributylamine (88 μ L, 0.373 mmol) and excess n-propanol (1 mL) were added and the reaction mixture heated to 65°C for 2.5 days. HPLC (AX300, gradient from 75% water/25% acetonitrile to 75% 0.5 M KH₂PO₄ over 20 min, 1 mL/min, monitor at 260nm) showed > 90% conversion to product, so the solvents were removed on a rotary evaporator. The product was purified by semi-preparative HPLC (AX300, gradient from 75% water/25% acetonitrile to 75% 1 M ammonium acetate/25% acetonitrile over 20 min, 2 mL/min, monitor at 260 nm) yielding 19.5 mg (28 %) of the title product.

^1H NMR (D₂O, 300 MHz): δ 7.78 (d, 1H), 5.79 (m, 2H), 4.19 (M, 2H), 4.04 (m, 3H), 3.73 (q, 2H), 1.46 (m, 2H), 0.72 (t, 3H). ^{31}P NMR (D₂O, 121.47 MHz): δ -9.60 (d, 1P), -10.34 (d, 1P), -21.98 (t, 1P).

Example 2. γ -(2-propyl)-uridine 5'-triphosphate.

The title product was obtained from the reaction between uridine 5'-triphosphate and 2-propyl alcohol, according to the method of example 1. Yield= 14%.

- 5 ^1H NMR (D_2O , 300 MHz): δ 7.80 (d, 1H), 5.81 (m, 2H), 4.23 (M, 1H), 4.11 (m, 2H), 4.07 (m, 3H), 1.10 (d, 6H). ^{31}P NMR (D_2O , 121.47 MHz): δ -9.60 (d, 1P), -10.34 (d, 1P), -21.98 (t, 1P).

10 **Example 3. γ -(n-butyl)-uridine 5'-triphosphate.**

The title product was obtained from the reaction between uridine 5'-triphosphate and n-butyl alcohol, according to the method of example 1. Yield= 39%.

- 15 ^1H NMR (D_2O , 300 MHz): δ 7.82 (d, 1H), 5.83 (m, 2H), 4.22 (M, 1H), 4.11 (m, 3H), 3.80 (q, 2H), 1.46 (t, 2H), 1.21 (q, 2H), 0.72 (t, 3H). ^{31}P NMR (D_2O , 121.47 MHz): δ -9.44 (d, 1P), -10.18 (d, 1P), -21.82 (t, 1P).

20 **Example 4. γ -(n-hexyl)-uridine 5'-triphosphate.**

The title product was obtained from the reaction between uridine 5'-triphosphate and n-hexyl alcohol, according to the method of example 1. Yield= 12%.

- 25 ^1H NMR (D_2O , 300 MHz): δ 7.80 (d, 1H), 5.81 (d, 2H), 4.20 (M, 2H), 4.11 (m, 3H), 3.78 (q, 2H), 1.41 (t, 2H), 1.09 (q, 6H), 0.68 (t, 3H). ^{31}P NMR (D_2O , 121.47 MHz): δ -9.58 (d, 1P), -10.22 (d, 1P), -21.68 (t, 1P).

Example 5. γ -(farnesyl)-uridine 5'-triphosphate.

The title product was obtained from the reaction between uridine 5'-triphosphate and farnesol (as a mixture of isomers), according to the method of example 1. Yield= 8%, as an unstable solid.

^1H NMR (D_2O , 300 MHz): δ 7.78 (d, 1H), 5.87 (d, 2H), 5.22 (m, 1H), 4.98 (m, 2H), 4.23 (m, 2H), 4.18 (m, 3H), 4.01 (m, 2H), 1.81 (t, 8H), 1.24 (d, 12H). ^{31}P NMR (D_2O , 121.47 MHz): δ -9.69 (d, 1P), -10.18 (d, 1P), -21.88 (t, 1P).

Example 6. γ -(cholesteryl)-uridine 5'-triphosphate.

The title product is obtained from the reaction between uridine 5'-triphosphate and cholesterol, according to the general method of example 1. If necessary, this process can be enhanced by the addition of catalysts such as pyridine, 4-dimethylaminopyridine, diazabicycloundecene (DBU) and the like.

As demonstrated in the preceding examples 1-6, different nucleophiles can be used to open the cyclical trimetaphosphate, giving derivatives with unique substituents on the γ phosphate. Thus, for example, the activated triphosphate can be reacted with 2-naphthylmethyl alcohol to give structure 91, or with cyclohexylmethyl alcohol to give 78. Alternately, nitrogen nucleophiles (giving products such as structures 81 and 82), or sulfur nucleophiles (giving products such as 79 and 89) can be used. Yet another choice would be the use of phosphate nucleophiles, giving δ -substituted tetraphosphate derivatives falling within the scope of the invention. Thus, for example, treatment of the cyclical trimetaphosphate with 2-naphthylmethyl phosphate would yield structure 76, while benzyl phosphate would yield 85. Yet another choice would be the use of phosphonic acid derivatives as nucleophiles, again giving δ -substituted tetraphosphate derivatives falling within the scope of the invention (for example, structures 131, 132, and 133).

Finally, the above Examples are illustrative and more elaborate molecules can be used to generate other compounds within the scope of the present invention, bearing novel substituents on the sugar and /or the base, by use of the appropriate reagents.

Example 7. 2',3'-((benzyl)methylenedioxy)- γ -(n-propyl)-uridine 5'-triphosphate.

Uridine 5'-triphosphate, trisodium salt (1.0g, 1.82 mmol) was dissolved in 98% formic acid (5 mL) and phenylacetaldehyde, dimethyl acetal (602 μ L, 3.64mmol) added. The reaction
5 was stirred overnight at ambient temperature, at which point TLC (silica gel, 50% isopropanol / 50% ammonium hydroxide) and HPLC (C18) showed good conversion to a less polar product. The formic acid was removed on a rotary evaporator, and the residue partitioned between 1 M sodium bicarbonate (15 mL) and ethyl acetate (25 mL). The layers were separated and the aqueous was washed with a further portion of ethyl acetate (25 mL).

10 The aqueous layer was stripped and the residue lyophilized overnight. The crude product was dissolved in water (5 mL) and the components separated by preparative HPLC (Waters Novapak C18, 6 μ m, 25 X 100 mm, gradient from 0.1 M ammonium acetate to methanol over 30 minutes, 30 mL/min, monitor at 260 nm). The yield of the acetal was 352 mg (30 %).

15 ^1H NMR (D_2O , 300 MHz): δ 7.62 (d, 1H), 7.22 (m, 5H), 5.73 (d, 1H), 5.40 (d, 1H), 5.32 (t, 1H), 4.69 (m, 2H), 4.33 (m, 1H), 4.00 (m, 2H), 3.01 (d, 2H). ^{31}P NMR (D_2O , 121.47 MHz): δ -7.47 (d, 1P), -10.54 (d, 1P), -21.46 (t, 1P).

The title compound is obtained by further manipulation according to the method of example 1.

Example 8. 2',3'-((benzyl)methylenedioxy)-uridine 5'-monophosphate.

Uridine 5'-monophosphate, disodium salt (1.0g, 2.72 mmol) was dissolved in 98% formic acid (7.5 mL) and phenylacetaldehyde, dimethyl acetal (900 μ L, 5.44mmol) added. The
25 reaction was stirred for 2 days at 30°C, after which the formic acid was removed and the residue partitioned between 1 M sodium bicarbonate (20mL) and ethyl acetate (20mL). The layers were separated and the aqueous was extracted once more with ethyl acetate (20 mL). The aqueous layer was concentrated to 8 mL and the product separated using preparative HPLC, as described in example 7. Yield=241 mg (19%).

30 The product so obtained is converted to the monotributylammonium salt by direct treatment with an excess of tributylamine in aqueous methanol, after which it is dried by repeated evaporation with dry N,N dimethylformamide. This is treated with 1, 1'-

carbonyldiimidazole to activate the monophosphate as the corresponding imidazolide, which is coupled with a variety of phosphate-containing nucleophiles, such as cyclohexylphosphate (giving structure 5), n-propylphosphate (giving 9), benzyl phosphate (giving 10), isobutylphosphonic acid (giving 37), 1-naphthylmethylphosphonic acid (giving 41), and n-hexylphosphonic acid (giving 45).

By this general method, a variety of diphosphates bearing substituents on the β phosphate falling within the scope of this invention can be produced. These diphosphates can be further modified with other groups on the sugar and/or the base, as previously described for tri- and tetraphosphates.

Example 9. Uridine 5'-monophosphate (2-fluoro-4-nitrobenzyl)ester

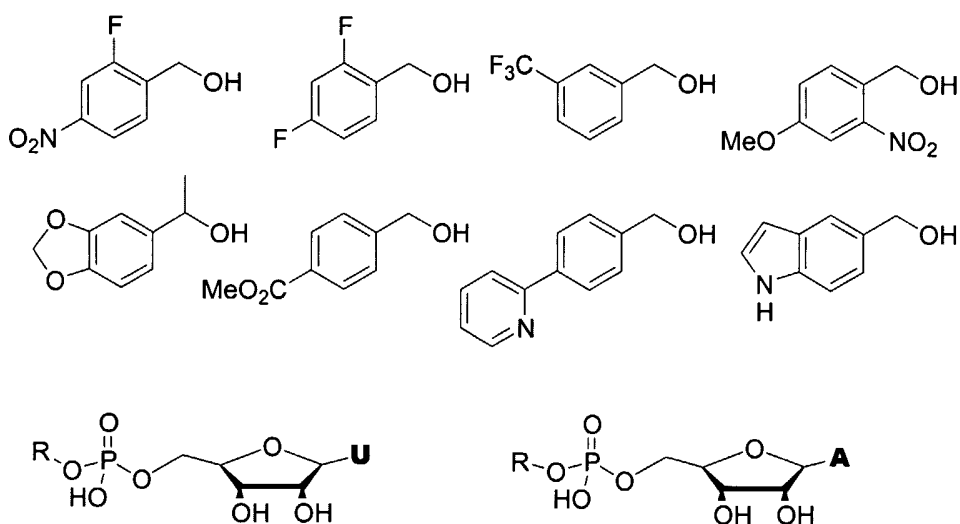
A solution of 2', 3'- O-isopropylidene-uridine 5'-monophosphoric acid (0.2 mmol) and 2-fluoro-4-nitrobenzyl alcohol (0.4 mmol) in pyridine (5 mL) is treated with triphenylphosphine (6mmol) and diethylazodicarboxylate (4 mmol) 7 hours at 28 °C. The solvents are removed in vacuo and the residue chromatographed on silica gel with methanol-chloroform as eluent, to isolate 2', 3'- O-isopropylidene-uridine 5'-monophosphate (2-fluoro-4-nitrobenzyl)ester. This compound is treated with methanolic HCl 20 minutes at 28 °C, and the solvent removed in vacuo to afford the title compound.

Example 10. Parallel synthesis of nucleotide aryl phosphodiester

An 8x8 array of 2', 3'- O-isopropylidene-uridine and 2', 3'- O-isopropylidene--6-N-benzoyl-adenosine (0.1 mmol) in a reaction block are dissolved in dichloromethane (3 mL/well) and treated with 2-cyanoethyl-N,N'-diisopropyl chlorophosphoramidite (0.2 mmol) and triethylamine (0.4 mmol) per well 20 minutes at 25 °C on a shaker. The solvent is evaporated under a stream of nitrogen and the block dried in a vacuum oven overnight. To each of the uridine-containing wells is added 0.2 mmol of a different alcohol selected from the group of Table A, as a solution in dichloromethane. The process is repeated for the adenosine-containing wells. Tetrazole (0.3 mmol) is added and the array is shaken 10 minutes at 25 °C. The reaction block is next immersed in a CO₂-acetonitrile bath and mCPBA (0.5 mmol in 1 mL THF/well) added. The block is shaken and allowed to come to

room temperature. An additional 2 mL of dichloromethane per well is added and each well extracted with 5% sodium thiosulfite (2 x 1 mL) followed by 10% sodium bicarbonate (1 x 1 mL) and brine (1 x 1 mL). The organic phase is made 50% in trifluoroacetic acid and shaken 60 minutes at 25 °C. The organic phase is again dried under nitrogen and treated with aqueous ammonia in THF overnight. It is then evaporated under a stream of nitrogen, and the residue extracted with ether (3 x 1 mL). Each product is solubilized in alcohol and applied to the top of individual C18 extraction columns. Nitrogen is passed through the column to evaporate the alcohol and the column is eluted stepwise with water, 10% methanol-water, 25% methanol-water, and 50% methanol-water to afford the desired products.

Table A. Coupling Partners for 2', 3'-O-isopropylidene-uridine 5'-phosphoramidate and 2', 3'-O-isopropylidene-6-N-benzoyl-adenosine 5'-phosphoramidate.



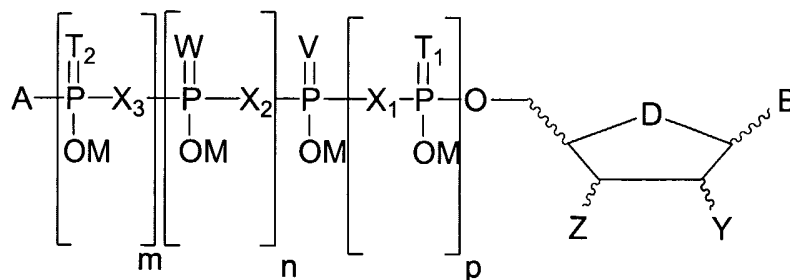
The invention, and the manner and process of making and using it, are now described in such full, clear, concise and exact terms as to enable any person skilled in the art to which it pertains, to make and use the same. It is to be understood that the foregoing describes preferred embodiments of the present invention and that modifications may be made therein without departing from the scope of the present invention as set forth in the claims. To particularly point out and distinctly claim the subject matter regarded as invention, the following claims conclude this specification.

WHAT IS CLAIMED:

1. A compound of Formula I, or a pharmaceutically acceptable salt thereof:

Formula I

5



10 wherein

A is a covalently bound substituent having a maximum molecular weight of 1000 and is selected from the group consisting of an amino acid, a peptide, a polypeptide, an oligonucleotide, a natural or non-natural steroid, OR₁, SR₁, NR₁R₂, and CR₁R₂R₃, wherein R₁, R₂, and R₃ are independently hydrogen, alkyl, cycloalkyl, aryl, arylalkyl, phosphonate, or acylthioalkyl with or without substituents or heteroatoms; or taken together to form a cycloalkyl or aryl ring, with or without substituents or heteroatoms, with the exception of OR₁ and SR₁ not being OH or SH;

X₁, X₂, and X₃ are independently oxygen, methylene, monochloromethylene, dichloromethylene, monofluoromethylene, difluoromethylene, or imido;

20 $T_1, T_2, W,$ and V are independently oxygen or sulfur;

$$m = 0, 1 \text{ or } 2;$$
$$n = 0 \text{ or } 1;$$
 $p = 0, 1, \text{ or } 2$;

where the sum of $m+n+p$ is from 0 to 5;

25 M = H or a pharmaceutically-acceptable inorganic or organic counter ion;

$$D = O \text{ or } CH_2;$$

B is a purine or a pyrimidine residue according to general Formulae IV and V which is linked to the 1' position of the furanose or carbocycle via the 9- or 1- position of the base, respectively;

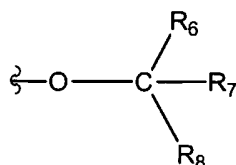
Y = H, OH, or OR₄;

5 Z = H, OH, or OR₅; with the proviso that Y and Z are not both H;

R₄ and R₅ are residues which are linked directly to the 2' and /or 3' oxygens of the furanose or carbocycle via a carbon atom according to Formula II, or linked directly to the two 2' and 3' oxygens of the furanose or carbocycle via a common carbon atom according to Formula III;

10

Formula II



15

wherein:

O is the corresponding 2' and/or 3' oxygen of the furanose or carbocycle;

C is the carbon atom;

20 R₆, R₇, and R₈ are H, an alkyl, cycloalkyl, aralkyl, aryl, substituted aralkyl, or substituted aryl, such that the moiety defined according to Formula II is an ether; or

R₆ and R₇ are H, an alkyl, cycloalkyl, aralkyl, aryl, substituted aralkyl, or substituted aryl, and R₈ is alkoxy, cycloalkoxy, aralkyloxy, aryloxy, substituted aralkyloxy, or substituted aryloxy such that the moiety defined according to formula II is an acyclic acetal or ketal; or R₆ and R₇ are taken together as oxygen or sulfur doubly bonded to C, and R₈ is alkyl,

25 cycloalkyl, aralkyl, aryl, substituted aralkyl, or substituted aryl, such that the moiety defined according to Formula II is an ester or thioester; or

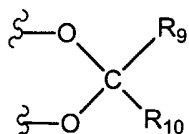
R₆ and R₇ are taken together as oxygen or sulfur doubly bonded to C, and R₈ is amino or mono- or disubstituted amino, where the substituents are alkyl, cycloalkyl, aralkyl, aryl,

substituted aralkyl, or substituted aryl, such that the moiety according to Formula II is a carbamate or thiocarbamate; or

R_6 and R_7 are taken together as oxygen or sulfur doubly bonded to C, and R_8 is alkoxy, cycloalkoxy, aralkyloxy, aryloxy, substituted aralkyloxy, or substituted aryloxy, such that the moiety according to Formula II is a carbonate or thiocarbonate; or

R_8 is not present and R_6 and R_7 are taken together as oxygen or sulfur doubly bonded to C and both the 2' and 3' oxygens of the furanose are directly bound to C to form a cyclical carbonate or thiocarbonate;

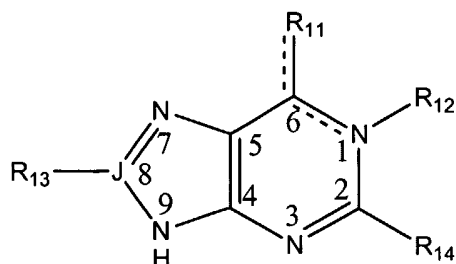
Formula III



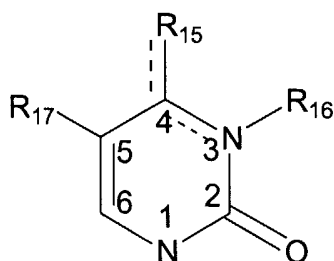
wherein:

O is the 2' and 3' oxygens of the furanose or carbocycle; and the 2' and 3' oxygens of the furanose or carbocycle are linked by a common carbon atom (C) to form a cyclical acetal, cyclical ketal, or cyclical orthoester;

for cyclical acetals and ketals, R_9 and R_{10} are independently hydrogen, alkyl, cycloalkyl, aralkyl, aryl, substituted aralkyl, substituted aryl, or can be joined together to form a homocyclic or heterocyclic ring composed of 3 to 8 atoms, preferably 3 to 6 atoms; for cyclical orthoesters, R_9 is hydrogen, alkyl, cycloalkyl, aralkyl, aryl, substituted aralkyl, or substituted aryl, R_{10} is alkyloxy, cycloalkyloxy, aralkyloxy, aryloxy, substituted aralkyloxy, or substituted aryloxy;

Formula IV

5

Formula V

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wherein:

R₁₁ and R₁₅ are hydroxy, oxo, amino, mercapto, alkylthio, alkyloxy, aryloxy, alkylamino, cycloalkylamino, aralkylamino, arylamino, diaralkylamino, diarylamino, or dialkylamino, where the alkyl groups are optionally linked to form a heterocycle; or

- 15 R₁₁ and R₁₅ are acylamino, provided that they incorporate an amino residue from the C-6 position of the purine or the C-4 position of the pyrimidine; or
- when R₁₁ in a purine or R₁₅ in a pyrimidine has as its first atom nitrogen, R₁₁ and R₁₂ or R₁₅ and R₁₆ are taken together to form a 5-membered fused imidazole ring, optionally substituted on the etheno ring with alkyl, cycloalkyl, aralkyl, or aryl moieties, as described
- 20 for R₆-R₁₀ above;

when R₁₅ in a pyrimidine has as its first atom oxygen, R₁₅ and R₁₇ are taken together to form a 5-membered dihydrofuran ring, optionally substituted on the dihydrofuran ring with alkyl, cycloalkyl, aralkyl, or aryl moieties, as described for R₆-R₁₀ above;

J is carbon or nitrogen, with the provision that when nitrogen, R₁₃ is not present;

5 R₁₂ is hydrogen, O or is absent;

R₁₆ is hydrogen, or acyl;

R₁₃ is hydrogen, alkyl, bromo, azido, alkylamino, arylamino or aralkylamino, alkoxy, aryloxy or aralkyloxy, alkylthio, arylthio or aralkylthio, or ω -E(C₁₋₆ alkyl)G-, wherein E and G are independently amino, mercapto, hydroxy or carboxyl;

10 R₁₄ is hydrogen, chlorine, amino, monosubstituted amino, disubstituted amino, alkylthio, arylthio, or aralkylthio, where the substituent on sulfur contains up to a maximum of 20 carbon atoms, with or without unsaturation;

R₁₇ is hydrogen, methyl, alkyl, halo, alkyl, alkenyl, substituted alkenyl, alkynyl, or substituted alkynyl.

15

2. The composition according to Claim 1, wherein:

A is selected from the group consisting of OR₁, SR₁, NR₁R₂, and CR₁R₂R₃, wherein R₁, R₂, and R₃ are independently hydrogen, alkyl, cycloalkyl, aryl, arylalkyl, phosphonate, or acylthioalkyl with or without substituents or heteroatoms; or taken together to form a
20 cycloalkyl or aryl ring, with or without substituents or heteroatoms, with the proviso of OR₁ and SR₁ not being OH or SH;

X₁, X₂, and X₃ are each oxygen;

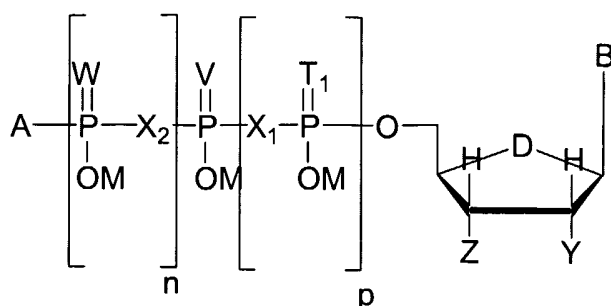
T₁, T₂, W, and V are each oxygen;

D =O.

25

3 The composition according to Claim 1, wherein Formula I is a compound of Formula Ia:

Formula Ia



5

wherein the variable groups are defined in Claim 1.

4. The composition according to Claim 3, wherein: A is selected from the group consisting of OR_1 , SR_1 , NR_1R_2 , and $CR_1R_2R_3$, wherein R_1 , R_2 , and R_3 are independently
 10 hydrogen, alkyl, cycloalkyl, aryl, arylalkyl, phosphonate, or acylthioalkyl with the proviso of OR_1 and SR_1 not being OH or SH; optionally NR_1R_2 or $CR_1R_2R_3$ is taken together to form a ring with or without substituents or heteroatoms;
 X_1 , X_2 , and X_3 are oxygen, dichloromethylene, or difluoromethylene;;
 T_1 , T_2 , W, and V are oxygen;
 15 the sum of $m+n+p$ is from 0 to 4;
 M is sodium salt;
 D is oxygen;
 Y and Z are both OH.

- 20 5. A compound selected from the group consisting of: 2'3'-O-methylenebenzyl β -(cyclohexyl) UDP (5), 2'-phenylcarbamoyl β -benzyl UDP (14), 2'-(phenoxy)formyl β -propyl UDP (15), 6-phenyl-furanopyrimidine riboside β -(3-carboxyphenyl)methyl diphosphate (20), 4-thiobenzyl pyrimidine riboside β -benzyl diphosphate (21), 2',3'-dibenzoyl β -propyl UDP (29), 5-(3-methoxyphenyl)ethenocytosine 2'-deoxy-3'-
 25 phenylcarbamoyl riboside β -propyl diphosphate (33), N^4 -propyl-2',3'-dibenzoyl β -benzyl CDP (36), 2'3'-O-methylenebenzyl β -(2-methylpropylphosphono) UDP (37), 2'-phenylcarbamoyl β -(2-carboxyethylphosphono) UDP (48), N^4 -(4-fluorophenylcarbamoyl) β -(o-methylbenzylphosphono) CDP (54), 2',3'-di(phenoxy)formyl β -(pentylphosphono)

UDP (61), N⁴-propyl-2',3'-dibenzoyl β-(2-carboxyethylphosphono) CDP (72), 2'-deoxy γ-benzyl UTP (77), γ-(thiocyclohexyl) UTP (79), 6-(3-methylphenyl)-furanopyrimidine riboside δ-(2-naphthalenemethyl) tetraphosphate (86), 2'3'-O-methylenebenzyl γ-propyl UTP (93), 5-(3-methylphenyl)ethenocytosine 2'3'-O-methylenebenzyl riboside δ-propyl tetraphosphate (105), 5-(3-methoxyphenyl)ethenocytidine riboside γ-(2-naphthalenemethyl) triphosphate (111), N⁴-(benzyloxyformyl)-2'-deoxy γ-benzyl CTP (115), N⁴,3'-dibenzoyl-2'-deoxy γ-(2-naphthylmethyl) CTP (123), 5-(3-trifluoromethylphenyl)ethenocytidine γ-(1-naphthalenemethylphosphono) triphosphate (135), 4-thiopropyl pyrimidine riboside γ-(4-aminocarboxybutylphosphono) triphosphate (138), 2'3'-O-methylenephennethyl γ-(3,4-dimethylphenylphosphono) UTP (147), 5-iodo-2'3'-O-methylenebutyl γ-(1-naphthalenemethylphosphono) UTP (157), 2',3'-dibenzoyl δ-(4-ethoxyphenylphosphono) uridine tetraphosphate (161), 2'3'-O-methylenebenzyl γ-(2-naphthalene) ATP (175), 2-thiopropyl-2'3'-O-methylenebenzyl γ-benzyl ATP (180), 2-thiomethyl-N⁶-propyl-2'3'-O-methylenebenzyl γ-(2-naphthalene) ATP (183), 2'3'-O-methylenebenzyl γ-anilino ATP (192), 2'3'-O-methylenebenzyl γ-(carboxymethylphosphono) ATP (200), 2'3'-O-methylenebenzyl δ-(1-naphthalene) adenosine tetraphosphate (201), and 2-thiopropyl-2'-deoxy-3'-(3-trifluoromethylphenyl)carbamoyl γ-(4-methoxyphenylphosphono) ATP (212).

6. The compound a according to Claim 6, wherein the compound is selected from the group consisting of: 2'3'-O-methylenebenzyl β-(cyclohexyl) UDP (5), 5-(3-methoxyphenyl)ethenocytosine 2'-deoxy-3'-phenylcarbamoyl riboside β-propyl diphosphate (33), 2'3'-O-methylenebenzyl β-(2-methylpropylphosphono) UDP (37), 2',3'-di(phenoxy)formyl β-(pentylphosphono) UDP (61), 2'3'-O-methylenebenzyl γ-(propyl) UTP (93), 5-(3-methylphenyl)ethenocytosine 2'3'-O-methylenebenzyl riboside δ-propyl tetraphosphate (105), 5-(3-trifluoromethylphenyl)ethenocytidine γ-(1-naphthalenemethylphosphono) triphosphate (135), 2',3'-dibenzoyl δ-(4-ethoxyphenylphosphono) uridine tetraphosphate (161), 2-thiopropyl-2'3'-O-methylenebenzyl γ-benzyl ATP (180), and), 2'3'-O-methylenebenzyl δ-(1-naphthalene) adenosine tetraphosphate (201).

7. A pharmaceutical composition comprising the compound of Claims 1, 5 or 6, in a pharmaceutically acceptable carrier.

8. The pharmaceutical composition according to Claim 7, wherein the compound is in a formulation selected from the group consisting of: aqueous solution, liquid/liquid suspension, gel, gel-like, and solid formulations.

9. A method of preventing, diagnosing, or treating epithelial or retinal tissue disease or condition of a subject in need of such prevention or treatment; comprising administering to said subject the compound of Claim 1 in an amount effective to prevent or treat said epithelial or retinal tissue disease or condition, wherein said epithelial or retinal tissue disease or condition is selected from the group consisting of eye diseases, respiratory diseases, gastrointestinal tract diseases, inflammatory diseases, and allergic diseases.

10. The method according to Claim 9, wherein the process of preventing or treating epithelial or retinal tissue disease or condition associated therewith comprises:

(a) identifying a mammal at risk for epithelial or retinal tissue diseases or condition; and

(b) applying a composition comprising a compound of Formula I in an amount effective to prevent or treat said epithelial or retinal tissue disease or condition associated therewith.

11. The method according to Claim 9, wherein the process of preventing or treating epithelial or retinal tissue disease or condition associated therewith comprises:

(a) applying to a mammal at risk for or presenting epithelial or retinal tissue diseases or condition a composition comprising a compound of Formula I in an amount effective to prevent the incidence of epithelial or retinal tissue diseases or condition, and

(b) determining whether such disease or condition developed or was reduced.

12. The method according to Claim 9, wherein said epithelial or retinal tissue disease or condition is selected from the group consisting of vaginal and cervical dryness, chronic bronchitis, chronic obstructive pulmonary disorder, pneumonia, cystic fibrosis, ciliary

dyskinesia, sinusitis, lung cancer, otitis media, retinal detachment, retinal edema, dry eye, dry mouth, gastroesophageal reflux disease(GERD), diarrhea, irritable bowel disease, constipation, glaucoma associated with elevated intraocular pressure, retinal degenerative diseases, corneal edema, allergic conjunctivitis, ocular surface inflammation, and allergic rhinitis.

13. The method according to Claim 9, wherein said epithelial or retinal tissue disease or condition is a retinal degenerative disease selected from the group consisting of inherited retinal degenerative diseases, acquired retinal degenerative diseases, and inflammation-induced retinal degenerative diseases.

14. The method according to Claim 13, wherein 1) said inherited retinal degenerative disease is selected from the group consisting of macular degeneration, Stargardt's disease, Best's disease, glaucoma, retinitis pigmentosa, and optic nerve degeneration; 2) said acquired retinal degenerative disease is selected from the group consisting of cystoid macular edema, retinal detachment, photic damage, ischemic retinopathies, retinopathies, and peripheral vitreoretinopathy; and 3) said inflammation-induced retinal degenerative disease is selected from the group consisting of viral-, bacterial- or toxin-induced retinal degeneration, optic neuritis, and uveitis.

15. The method according to Claim 9, wherein said epithelial or retinal tissue disease or condition is a respiratory disease and said compound is administered to the lungs of said subject in an amount sufficient to achieve at least one result selected from the group of results consisting of hydrating lung mucus secretions, enhancing ciliary beat frequency, facilitating expectoration, enhancing lung secretion removal, enhancing sputum induction, facilitating lung sample expectoration, and enhancing cough clearance.

16. The method according to Claim 9, wherein said epithelial or retinal tissue disease or condition is an eye disease selected from the group consisting of; a) dry eye disease and said compound is administered to at least one eye of said subject in an amount sufficient to increase hydration and lubrication of ocular surfaces and b) edematous retinal disorders, including retinal detachment and retinal edema, and said compound is administered to at

least one eye of said subject in an amount sufficient to stimulate the removal of pathological fluid accumulation in intra-retinal and subretinal spaces associated with edematous retinal disorders.

5 17 The method according to Claim 16, wherein the compound used for dry eye disease is administered to the eye in a topical administration carrier vehicle selected from a group consisting of: drops of liquid, liquid wash, gels, ointments, sprays and liposomes; and the compound used for edematous retinal disorders is administered to the eye in the form of an liquid in an injection into the vitreous, bolus or sustained infusion into the vitreous, by
10 sustained release into the vitreal cavity, by retrobulbar conjunctival injection, release, or infusion, by transcleral injection, by sustained transcleral release or infusion, by ocular surface instillation, or by acute and chronic injection or infusions.

18. The method according to Claim 9, wherein said administering is by systemic
15 administration involving the administration to said subject said compound of Formula I by a method selected from the group of methods consisting of: a) administering a liquid/liquid suspension of said compound via nose drops or nasal spray; b) administering a nebulized liquid of said compound to oral or nasopharyngeal airways of said subject; c) administering an oral form of said compound including chewable gum; d) administering an injectable form
20 of said compound; e) administering a suppository form of said compound; f) administering an intra-operative instillation of a gel, cream, powder, foam, crystals, liposomes, spray or liquid suspension form of said compound; and g) administering said compound in a form of a transdermal patch or a transdermal pad: such that a therapeutically effective amount of said compound contacts the intended tissues of said subject via systemic absorption and
25 circulation.

19. A method of preventing or treating diseases associated with platelet aggregation and thrombosis in humans and other mammals, comprising administering to a subject a pharmaceutical composition containing the compound of 2 of Claim 1 in an amount
30 effective to inhibit ADP-induced platelet aggregation.