

## NUCLEOSIDE CYCLICPHOSPHATES

This application is being filed on 8 June 2009, as a PCT International Patent application in the name of Pharmasset, Inc., a U.S. national corporation, applicant  
5 for the designation of all countries except the US, and Jinfa Du and Dhanapalan Nagarathnam, both citizens of the U.S., Ganapati Reddy Pamulapati, a citizen of India, and Bruce S. Ross and Michael Joseph Sofia, both citizens of the U.S., applicants for the designation of the US only.

### 10 Priority Claim

The present application claims priority to U.S. Provisional Patent Application No. 61/060,683, filed June 11, 2008, U.S. Provisional Patent Application No. 61/140,369, filed December 23, 2008, and U.S. Non-Provisional Patent Application No. 12/479,075, filed June 5, 2009. The content of each of the  
15 above-noted applications is hereby incorporated by reference in its entirety.

### Field of Invention

The present invention pertains to nucleoside cyclic phosphates and their use as agents for treating viral diseases. These compounds are inhibitors of RNA-dependent RNA viral replication and are useful as inhibitors of HCV NS5B  
20 polymerase, as inhibitors of HCV replication and for treatment of hepatitis C infection in mammals. The invention provides novel chemical compounds, and the use of these compounds alone or in combination with other antiviral agents for treating HCV infection.

### Background

25 Hepatitis C virus (HCV) infection is a major health problem that leads to chronic liver disease, such as cirrhosis and hepatocellular carcinoma, in a substantial number of infected individuals, estimated to be 2-15% of the world's population. There are an estimated 4.5 million infected people in the United States alone, according to the U.S. Center for Disease Control. According to the World Health  
30 Organization, there are more than 200 million infected individuals worldwide, with

at least 3 to 4 million people being infected each year. Once infected, about 20% of people clear the virus, but the rest can harbor HCV the rest of their lives. Ten to twenty percent of chronically infected individuals eventually develop liver-destroying cirrhosis or cancer. The viral disease is transmitted parenterally by contaminated blood and blood products, contaminated needles, or sexually and vertically from infected mothers or carrier mothers to their offspring. Current treatments for HCV infection, which are restricted to immunotherapy with recombinant interferon- $\alpha$  alone or in combination with the nucleoside analog ribavirin, are of limited clinical benefit as resistance develops rapidly. Moreover, there is no established vaccine for HCV. Consequently, there is an urgent need for improved therapeutic agents that effectively combat chronic HCV infection.

The HCV virion is an enveloped positive-strand RNA virus with a single oligoribonucleotide genomic sequence of about 9600 bases which encodes a polyprotein of about 3,010 amino acids. The protein products of the HCV gene consist of the structural proteins C, E1, and E2, and the non-structural proteins NS2, NS3, NS4A and NS4B, and NS5A and NS5B. The nonstructural (NS) proteins are believed to provide the catalytic machinery for viral replication. The NS3 protease releases NS5B, the RNA-dependent RNA polymerase from the polyprotein chain. HCV NS5B polymerase is required for the synthesis of a double-stranded RNA from a single-stranded viral RNA that serves as a template in the replication cycle of HCV. Therefore, NS5B polymerase is considered to be an essential component in the HCV replication complex (K. Ishi, et al, *Hepatology*, 1999, 29: 1227-1235; V. Lohmann, et al., *Virology*, 1998, 249: 108-118). Inhibition of HCV NS5B polymerase prevents formation of the double-stranded HCV RNA and therefore constitutes an attractive approach to the development of HCV-specific antiviral therapies.

HCV belongs to a much larger family of viruses that share many common features.

#### *Flaviviridae Viruses*

The Flaviviridae family of viruses comprises at least three distinct genera: *pestiviruses*, which cause disease in cattle and pigs; *flaviviruses*, which are the

primary cause of diseases such as dengue fever and yellow fever; and *hepaciviruses*, whose sole member is HCV. The flavivirus genus includes more than 68 members separated into groups on the basis of serological relatedness (Calisher et al., *J. Gen. Virol*, 1993, 70, 37-43). Clinical symptoms vary and include fever, encephalitis and hemorrhagic fever (*Fields Virology*, Editors: Fields, B. N., Knipe, D. M., and Howley, P. M., Lippincott-Raven Publishers, Philadelphia, PA, 1996, Chapter 31, 931-959). Flaviviruses of global concern that are associated with human disease include the Dengue Hemorrhagic Fever viruses (DHF), yellow fever virus, shock syndrome and Japanese encephalitis virus (Halstead, S. B., *Rev. Infect. Dis.*, 1984, 6, 251-264; Halstead, S. B., *Science*, 239:476-481, 1988; Monath, T. P., *New Eng. J. Med*, 1988, 319, 641-643).

The pestivirus genus includes bovine viral diarrhea virus (BVDV), classical swine fever virus (CSFV, also called hog cholera virus) and border disease virus (BDV) of sheep (Moennig, V. et al. *Adv. Vir. Res.* 1992, 41, 53-98). Pestivirus infections of domesticated livestock (cattle, pigs and sheep) cause significant economic losses worldwide. BVDV causes mucosal disease in cattle and is of significant economic importance to the livestock industry (Meyers, G. and Thiel, H.J., *Advances in Virus Research*, 1996, 47, 53-118; Moennig V., et al, *Adv. Vir. Res.* 1992, 41, 53-98). Human pestiviruses have not been as extensively characterized as the animal pestiviruses. However, serological surveys indicate considerable pestivirus exposure in humans.

Pestiviruses and hepaciviruses are closely related virus groups within the Flaviviridae family. Other closely related viruses in this family include the GB virus A, GB virus A-like agents, GB virus-B and GB virus-C (also called hepatitis G virus, HGV). The hepacivirus group (hepatitis C virus; HCV) consists of a number of closely related but genotypically distinguishable viruses that infect humans. There are at least 6 HCV genotypes and more than 50 subtypes. Due to the similarities between pestiviruses and hepaciviruses, combined with the poor ability of hepaciviruses to grow efficiently in cell culture, bovine viral diarrhea virus (BVDV) is often used as a surrogate to study the HCV virus.

The genetic organization of pestiviruses and hepaciviruses is very similar. These positive stranded RNA viruses possess a single large open reading frame

(ORF) encoding all the viral proteins necessary for virus replication. These proteins are expressed as a polyprotein that is co- and post-translationally processed by both cellular and virus-encoded proteinases to yield the mature viral proteins. The viral proteins responsible for the replication of the viral genome RNA are located within approximately the carboxy-terminal. Two-thirds of the ORF are termed nonstructural (NS) proteins. The genetic organization and polyprotein processing of the nonstructural protein portion of the ORF for pestiviruses and hepaciviruses is very similar. For both the pestiviruses and hepaciviruses, the mature nonstructural (NS) proteins, in sequential order from the amino-terminus of the nonstructural protein coding region to the carboxy-terminus of the ORF, consist of p7, NS2, NS3, NS4A, NS4B, NS5A, and NS5B.

The NS proteins of pestiviruses and hepaciviruses share sequence domains that are characteristic of specific protein functions. For example, the NS3 proteins of viruses in both groups possess amino acid sequence motifs characteristic of serine proteinases and of helicases (Gorbalenya et al., *Nature*, 1988, 333, 22; Bazan and Fletterick *Virology*, 1989, 171, 637-639; Gorbalenya et al., *Nucleic Acid Res.*, 1989, 17, 3889-3897). Similarly, the NS5B proteins of pestiviruses and hepaciviruses have the motifs characteristic of RNA-directed RNA polymerases (Koonin, E.V. and Dolja, V.V., *Crit. Rev. Biochem. Molec. Biol.* 1993, 28, 375-430).

The actual roles and functions of the NS proteins of pestiviruses and hepaciviruses in the lifecycle of the viruses are directly analogous. In both cases, the NS3 serine proteinase is responsible for all proteolytic processing of polyprotein precursors downstream of its position in the ORF (Wiskerchen and Collett, *Virology*, 1991, 184, 341-350; Bartenschlager et al., *J. Virol.* 1993, 67, 3835-3844; Eckart et al. *Biochem. Biophys. Res. Comm.* 1993, 192, 399-406; Grakoui et al., *J. Virol.* 1993, 67, 2832-2843; Grakoui et al., *Proc. Natl. Acad. Sci. USA* 1993, 90, 10583-10587; Hijikata et al., *J. Virol.* 1993, 67, 4665-4675; Tome et al., *J. Virol.*, 1993, 67, 4017-4026). The NS4A protein, in both cases, acts as a cofactor with the NS3 serine protease (Bartenschlager et al., *J. Virol.* 1994, 68, 5045-5055; Failla et al., *J. Virol.* 1994, 68, 3753-3760; Xu et al., *J. Virol.*, 1997, 71:53 12-5322). The NS3 protein of both viruses also functions as a helicase (Kim et al., *Biochem. Biophys. Res. Comm.*, 1995, 215, 160-166; Jin and Peterson, *Arch. Biochem.*

*Biophys.*, 1995, 323, 47-53; Warrener and Collett, *J. Virol.* 1995, 69, 1720-1726).  
Finally, the NS5B proteins of pestiviruses and hepaciviruses have the predicted  
RNA-directed RNA polymerases activity (Behrens et al., *EMBO*, 1996, 15, 12-22;  
Lechmann et al., *J. Virol.*, 1997, 71, 8416-8428; Yuan et al., *Biochem. Biophys. Res.*  
5 *Comm.* 1997, 232, 231-235; Hagedorn, PCT WO 97/12033; Zhong et al., *J. Virol.*,  
1998, 72, 9365-9369).

Currently, there are limited treatment options for individuals infected with  
hepatitis C virus. The current approved therapeutic option is the use of  
immunotherapy with recombinant interferon- $\alpha$  alone or in combination with the  
10 nucleoside analog ribavirin. This therapy is limited in its clinical effectiveness and  
only 50% of treated patients respond to therapy. Therefore, there is significant need  
for more effective and novel therapies to address the unmet medical need posed by  
HCV infection.

A number of potential molecular targets for drug development of direct  
15 acting antivirals as anti-HCV therapeutics have now been identified including, but  
not limited to, the NS2-NS3 autoprotease, the NS3 protease, the NS3 helicase and the  
NS5B polymerase. The RNA-dependent RNA polymerase is absolutely essential for  
replication of the single-stranded, positive sense, RNA genome and this enzyme has  
elicited significant interest among medicinal chemists.

20 Inhibitors of HCV NS5B as potential therapies for HCV infection have been  
reviewed: Tan, S.-L., et al., *Nature Rev. Drug Discov.*, 2002, 1, 867-881; Walker,  
M.P. et al., *Exp. Opin. Investigational Drugs*, 2003, 12, 1269-1280; Ni, Z.-J., et al.,  
*Current Opinion in Drug Discovery and Development*, 2004, 7, 446-459; Beaulieu,  
P. L., et al., *Current Opinion in Investigational Drugs*, 2004, 5, 838-850; Wu, J.,  
25 et al., *Current Drug Targets-Infectious Disorders*, 2003, 3, 207-219; Griffith, R.C.,  
et al., *Annual Reports in Medicinal Chemistry*, 2004, 39, 223-237; Carrol, S., et al.,  
*Infectious Disorders-Drug Targets*, 2006, 6, 17-29. The potential for the emergence  
of resistant HCV strains and the need to identify agents with broad genotype  
coverage supports the need for continuing efforts to identify novel and more  
30 effective nucleosides as HCV NS5B inhibitors.

Nucleoside inhibitors of NS5B polymerase can act either as a non-natural

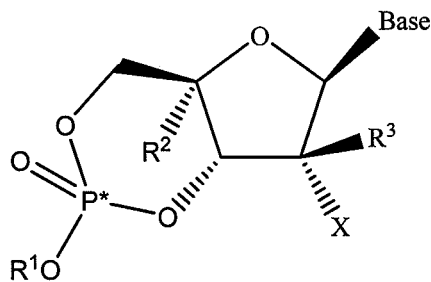
substrate that results in chain termination or as a competitive inhibitor which competes with nucleotide binding to the polymerase. To function as a chain terminator the nucleoside analog must be taken up by the cell and converted *in vivo* to a triphosphate to compete for the polymerase nucleotide binding site. This  
5 conversion to the triphosphate is commonly mediated by cellular kinases which imparts additional structural requirements on a potential nucleoside polymerase inhibitor. Unfortunately, this limits the direct evaluation of nucleosides as inhibitors of HCV replication to cell-based assays capable of *in situ* phosphorylation.

In some cases, the biological activity of a nucleoside is hampered by its poor  
10 substrate characteristics for one or more of the kinases needed to convert it to the active triphosphate form. Formation of the monophosphate by a nucleoside kinase is generally viewed as the rate limiting step of the three phosphorylation events. To circumvent the need for the initial phosphorylation step in the metabolism of a nucleoside to the active triphosphate analog, the preparation of stable phosphate  
15 prodrugs has been reported. Nucleoside cyclic phosphate prodrugs have been shown to be precursors of the active nucleoside triphosphate and to inhibit viral replication when administered to viral infected whole cells (PCT Int. App. WO 2007/027248 A2; Bi-Organic and Medicinal Chemistry Letters, 2007, Vol 17, Page 2452-2455; Journal of American Chemical Society, 1990, Vol 112, Page 7475-7482.)

20 Also limiting the utility of nucleosides as viable therapeutic agents is their sometimes poor physicochemical and pharmacokinetic properties. These poor properties can limit the intestinal absorption of an agent and limit uptake into the target tissue or cell. To improve on their properties prodrugs of nucleosides have been employed.

## 25 SUMMARY OF THE INVENTION

The present invention is directed toward novel cyclic phosphate prodrugs of nucleoside derivatives for the treatment of viral infections in mammals, which is a compound, its stereoisomers, salts (acid or basic addition salts), hydrates, solvates, deuterated analogues, or crystalline forms thereof, represented by the following  
30 structure:



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wherein

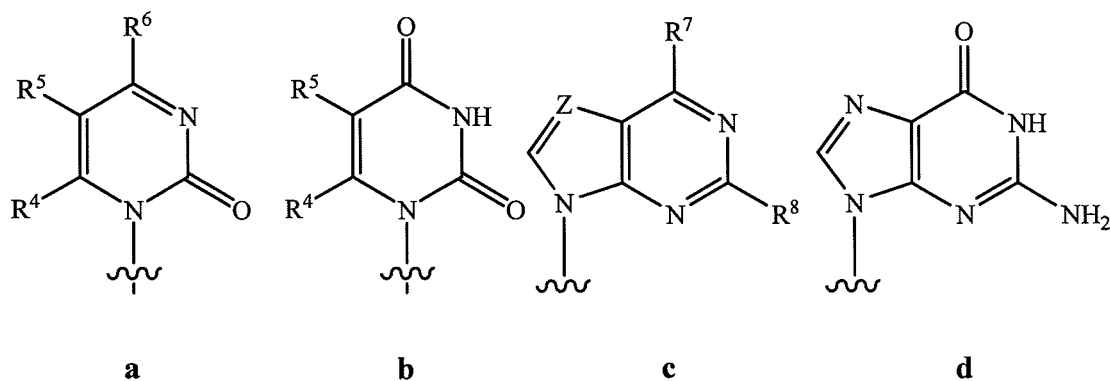
R<sup>1</sup> is hydrogen, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which  
 5 includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are  
 optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>,  
 NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I)  
 lower alkyl, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-  
 C<sub>6</sub>, such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy  
 10 of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>,  
 CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

R<sup>2</sup> is H, an optionally substituted alkyl (including lower alkyl), cyano (CN),  
 CH<sub>3</sub>, vinyl, O-alkyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl alkyl,  
 i.e., -(CH<sub>2</sub>)<sub>o</sub>OH, wherein o is 1 – 10, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p  
 15 is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>),  
 CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, ethynyl alkyne (optionally  
 substituted), or halogen, including F, Cl, Br, or I;

R<sup>3</sup> is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, F, or CN;

X is H, OH, F, OMe, halogen, NH<sub>2</sub>, or N<sub>3</sub>

20 Base is a naturally occurring or modified purine or pyrimidine base  
 represented by the following structures:



wherein

Z is N or CR<sup>9</sup>;

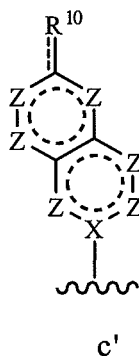
- 5           R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, R<sup>7</sup>, and R<sup>8</sup> are independently H, F, Cl, Br, I, OH, OR', such as alkoxy, aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy, SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';
- 10

- R<sup>9</sup> is an H, halogen (including F, Cl, Br, I), OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, NO<sub>2</sub>, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';
- 15

- wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in
- 20

which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

Alternatively, the Base may be selected from a group of formula c'



5            wherein for structure c',

if Z is a participant in a pi bond (double bond), Z is independently selected from N or C-G; or, if Z is not a participant in a pi bond (double bond), Z is independently selected from O, S, Se, NR<sup>11</sup>, NOR<sup>11</sup>, NNR<sup>11</sup><sub>2</sub>, CO, CS, CNR<sup>11</sup>, SO, S(O)<sub>2</sub>, SeO, Se(O)<sub>2</sub>, or C(G)<sub>2</sub>;

10            each G is independently selected from the group consisting of H, halogen, OR<sup>11</sup>, SR<sup>11</sup>, NR<sup>11</sup><sub>2</sub>, NR<sup>11</sup>OR<sup>11</sup>, N<sub>3</sub>, COOR<sup>11</sup>, CN, CONR<sup>11</sup><sub>2</sub>, C(S)NR<sup>11</sup><sub>2</sub>, C(=NR<sup>11</sup>)NR<sup>11</sup><sub>2</sub>, and R<sup>11</sup>; and where any two adjacent Z are not both selected from O, S, and Se, or not both selected from CO, CS, CNR<sup>11</sup>, SO, S(O)<sub>2</sub>, SeO and Se(O)<sub>2</sub>;

15            wherein, if X is a participant in a pi bond (double bond), X is C; or if X is not a participant in a pi bond (double bond), X is CR<sup>11</sup> or N;

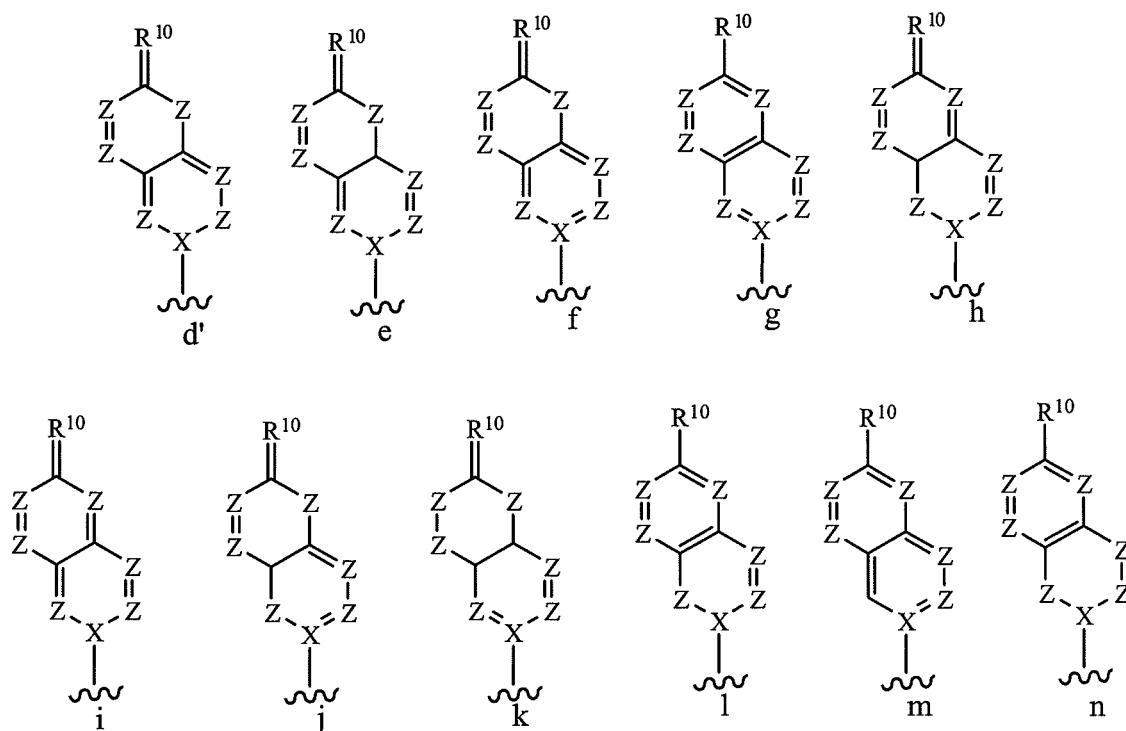
wherein, if R<sup>10</sup> is a participant in a pi bond (double bond), R<sup>10</sup> is O, S, Se, NR<sup>11</sup>, NOR<sup>11</sup> or NNR<sup>11</sup><sub>2</sub>; or if R<sup>10</sup> is not a participant in a pi bond (double bond), R<sup>10</sup> is OR<sup>11</sup>, SR<sup>11</sup>, F, Cl, R<sup>10</sup>, or SeR<sup>10</sup>; and

20            dashed lines (---) indicate a possible pi or double bond;

each R is independently selected from the group consisting of H, CF<sub>3</sub>, optionally substituted alkyl, optionally substituted alkenyl, optionally substituted alkynyl, optionally substituted aryl, optionally substituted acyl, optionally substituted cycloalkyl, optionally substituted cycloalkenyl, optionally substituted heteroaryl, optionally substituted heterocyclyl, and optionally substituted arylalkyl;

25            or

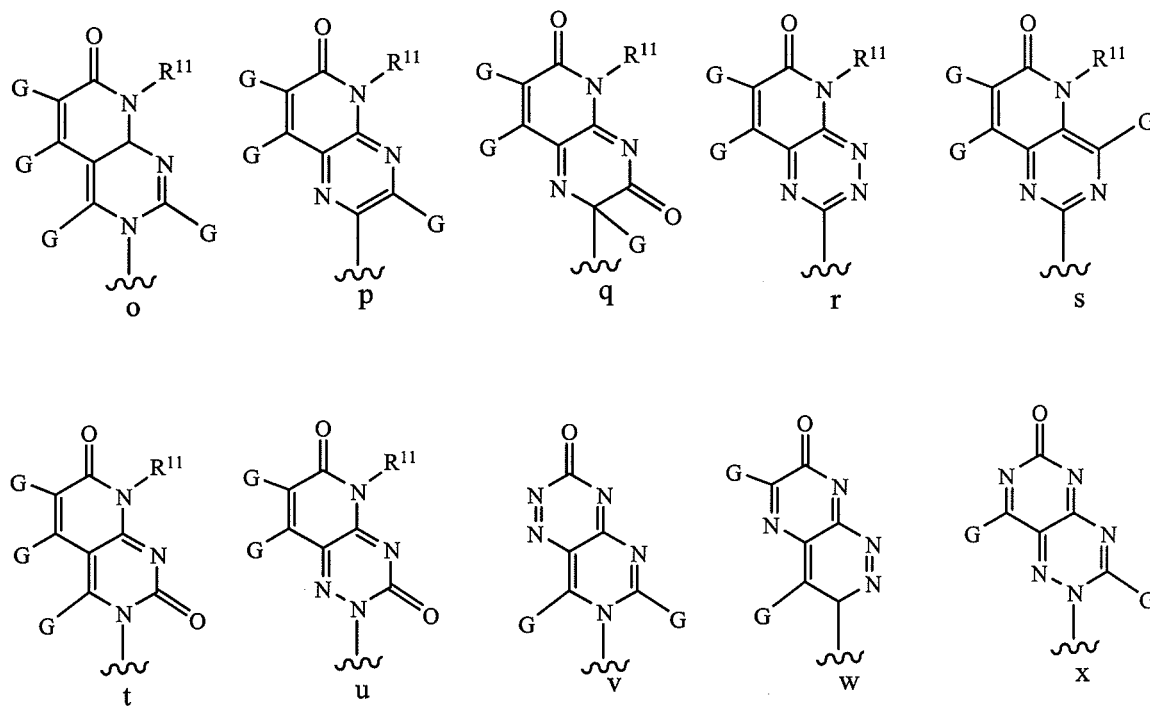
Base may be a structure selected from the group consisting of structures d'-n



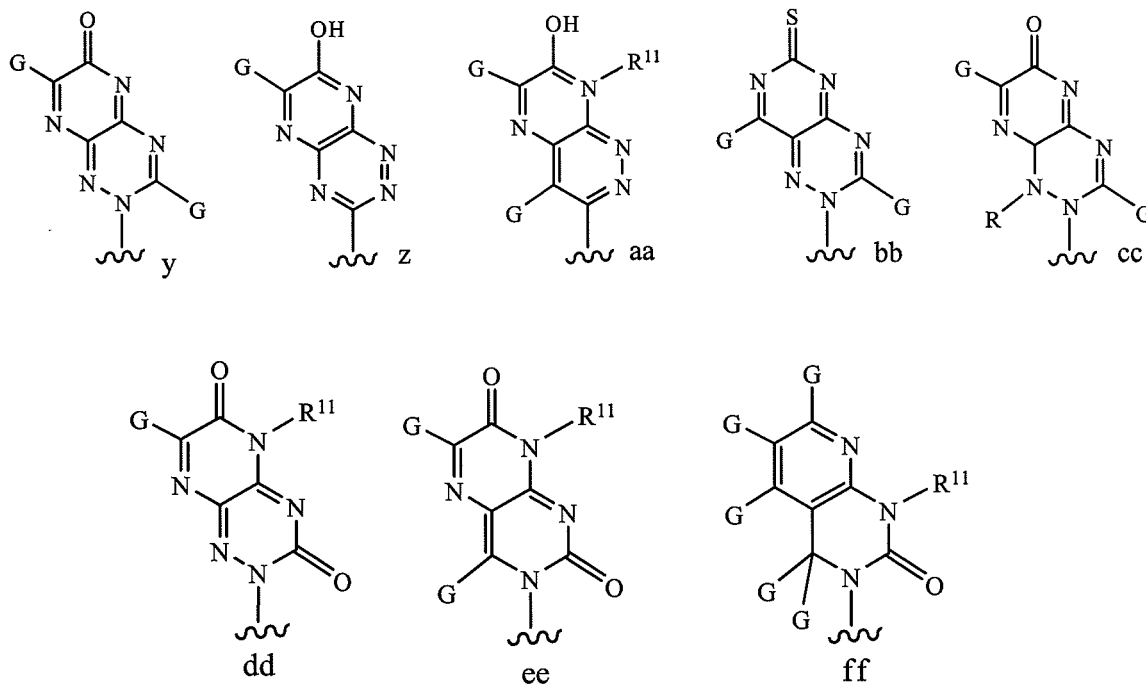
5 wherein Z, X, and  $R^{10}$  are defined as in structure c';

Base may be a structure selected from the group consisting of structures o -

ff



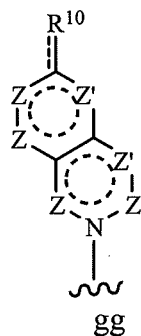
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wherein G and R are defined as in structure c';

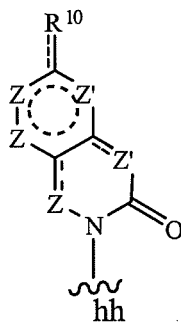
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Base may be a structure gg



wherein each Z' is independently N (if a participant in a pi bond) or NR (if not a participant in a pi bond) and R<sup>10</sup>, R<sup>11</sup>, and Z are defined as in structure c';

Base may be a structure hh

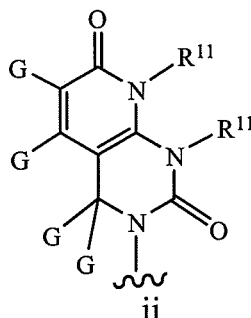


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wherein each Z' is independently N (if a participant in a pi bond) or NR<sup>11</sup> (if not a participant in a pi bond), and each Z is independently CG (if a participant in a

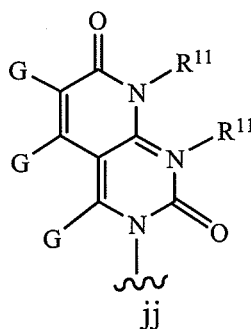
pi bond) or  $>C(G)_2$  (if not a participant in a pi bond), wherein  $R^{10}$  and G are defined as in structure c';

Base may be a structure ii



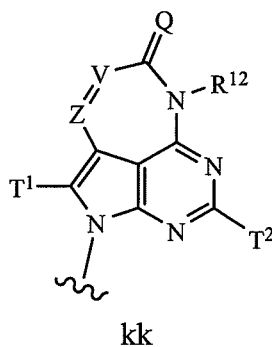
5 wherein  $R^{11}$  and G are defined as in structure c';

Base may be a structure jj



wherein  $R^{11}$  and G are defined as in structure c'; or

Base may be a structure kk



10

wherein for structure kk:

$R^{12}$  is selected from the group consisting of hydrogen and  $C_1$ - $C_3$  alkyl;

Q is absent or is selected from the group consisting of O, S, and NH,

15 provided that when Q is absent, V and NH are both attached to a  $CH_2$  group;

V is selected from the group consisting of N and C-G;

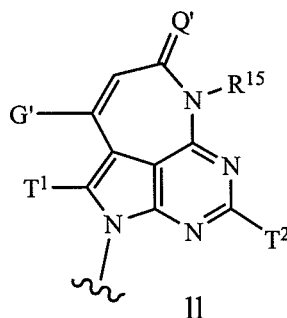
Z is selected from the group consisting of N and C-G';

G and G' are independently selected from the group consisting of hydrogen, amino, aminocarbonyl, methylamino, dimethylamino, acylamino, alkoxyamino, –SO<sub>3</sub>H, –SO<sub>2</sub>NH<sub>2</sub>, aminocarbonylamino, oxycarbonylamino, HR<sup>13</sup>NCHR<sup>14</sup>C(O)NH–, azido, cyano, halo, hydroxyamino, and hydrazino, where R<sup>13</sup> is hydrogen and R<sup>14</sup> is a side-chain of an amino acid or where R<sup>13</sup> and R<sup>14</sup> together with the nitrogen and carbon bound to each group respectively form a pyrrolidinyll group;

with the proviso that V and Z are not identical and that when V is C–H, Z is N;

T<sup>1</sup> and T<sup>2</sup> are independently selected from the group consisting of hydrogen, hydroxyl, C<sub>1</sub>–C<sub>4</sub>-alkoxy, C<sub>1</sub>–C<sub>4</sub>-thioalkoxy, amino, substituted amino, and halo; and each of W, W<sup>1</sup>, and W<sup>2</sup> is independently selected from the group consisting of hydrogen, C<sub>1</sub>–C<sub>4</sub> alkyl, and a prodrug group; or

Base may be a structure II



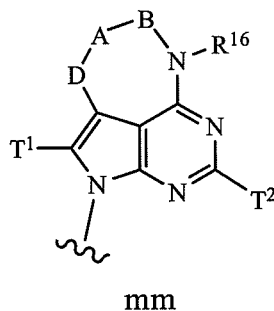
wherein for structure II:

R<sup>15</sup> is hydrogen or C<sub>1</sub>–C<sub>3</sub> alkyl;

Q' is selected from the group consisting of NH, O, and S;

G' is selected from the group consisting of amino, aminocarbonyl, methylamino, dimethylamino, acylamino, –SO<sub>3</sub>H, –SO<sub>2</sub>NH<sub>2</sub>, alkoxyamino, aminocarbonylamino, oxycarbonylamino, HR<sup>13</sup>NCHR<sup>14</sup>C(O)NH–, azido, cyano, halo, hydroxyamino, and hydrazino, where R<sup>13</sup> is hydrogen and R<sup>14</sup> is a side-chain of an amino acid or where R<sup>13</sup> and R<sup>14</sup> together with the nitrogen and carbon bound to each group respectively form a pyrrolidinyll group; or

Base may be a structure mm



where in for structure mm

A and B are independently selected from the group consisting of C=Q, NH,  
 5 and methylene optionally substituted with 1 to 2 halo groups, provided that A and B  
 are not both NH;

D is NH, or -D-A-B- together form a -N=CH-NH-, -(C=Q)-CH<sub>2</sub>-(C=Q)-, -  
 (C=Q)-NH-(C=Q)-, -(CX')=(CX')-(C=Q)-, or -CH=CH-NH- group where X' is  
 halo;

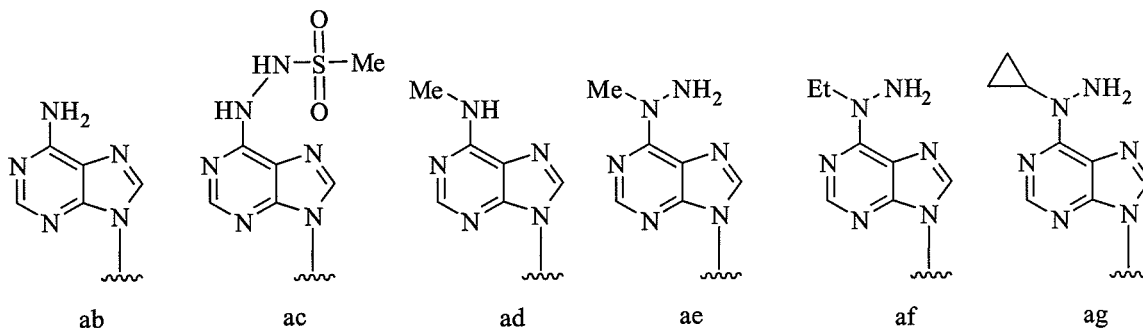
10 each Q is independently selected from the group consisting of O, S, and NH;

R<sup>16</sup> is selected from the group consisting of hydrogen and C<sub>1</sub>-C<sub>3</sub> alkyl;

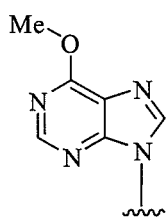
T<sup>1</sup> and T<sup>2</sup> are independently selected from the group consisting of hydrogen,  
 hydroxyl, C<sub>1</sub>-C<sub>4</sub>-alkoxy, C<sub>1</sub>-C<sub>4</sub>-thioalkoxy, amino, substituted amino, and halo; and

Y is selected from the group consisting of a bond, O, and CH<sub>2</sub>; and each of  
 15 W, W<sup>1</sup>.

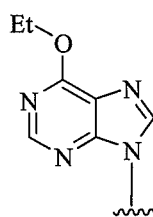
Alternatively, the Base can be selected from among structures ab, ac, ad, ae,  
 af, ag, ah, ai, aj, ak, al, am, an, ao, ap, aq, ar, as, at, av, au, ax, ay, az, ba, bc, bd, be,  
 bf, bg, bh, bi, bj, and bk, depicted below.



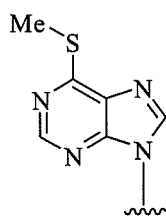
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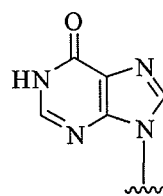
ah



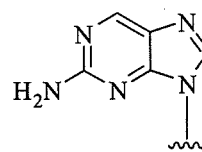
ai



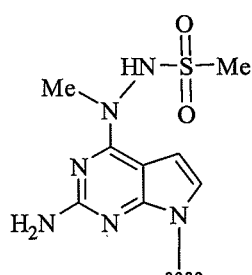
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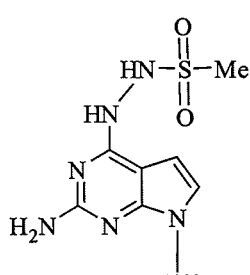
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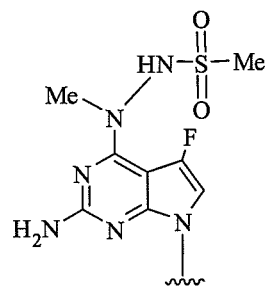
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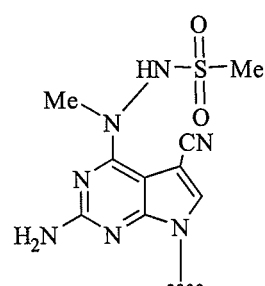
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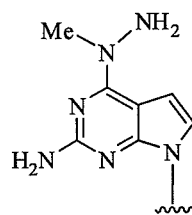
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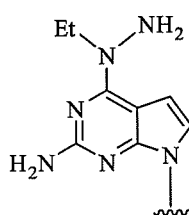
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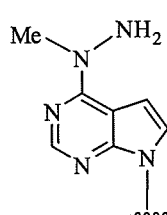
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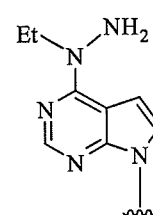
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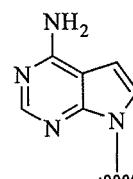
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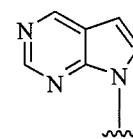
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at

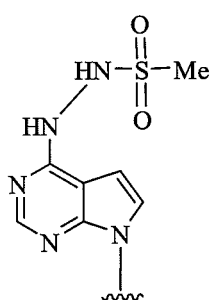


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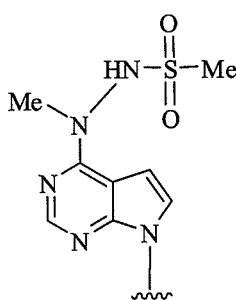


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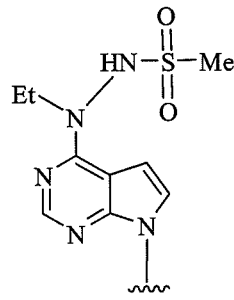
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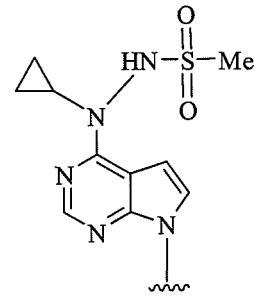
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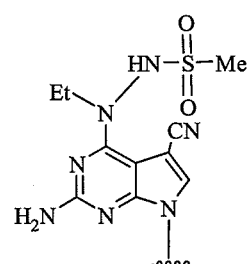
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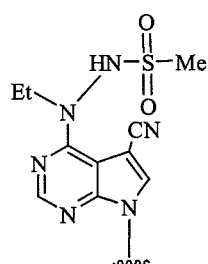
az



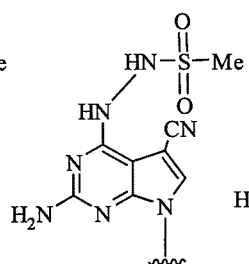
ba



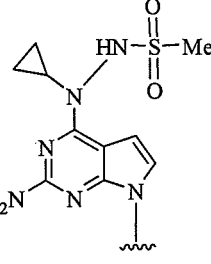
bc



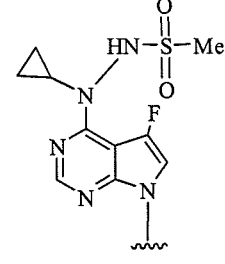
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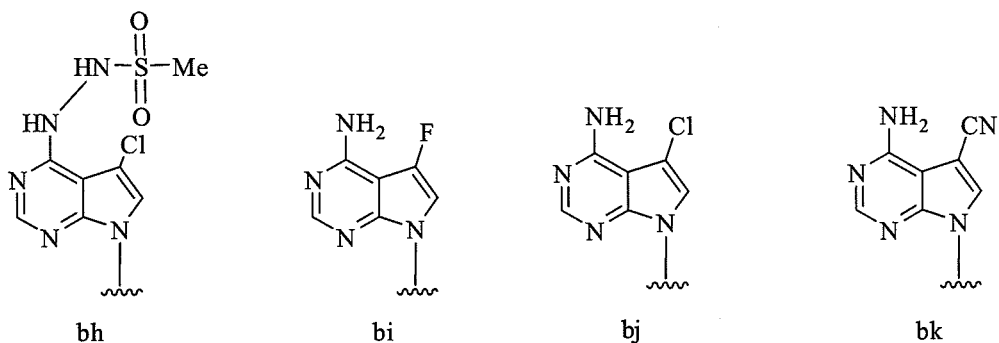
be



bf



bg



## DEFINITIONS

The phrase "a" or "an" entity as used herein refers to one or more of that entity; for example, a compound refers to one or more compounds or at least one compound. As such, the terms "a" (or "an"), "one or more", and "at least one" can be used interchangeably herein.

The terms "optional" or "optionally" as used herein means that a subsequently described event or circumstance may but need not occur, and that the description includes instances where the event or circumstance occurs and instances in which it does not. For example, "optional bond" means that the bond may or may not be present, and that the description includes single, double, or triple bonds. Moreover, "optionally substituted" means that the listed substituent is substituted or unsubstituted. In the instance where the substituent is substituted, unless otherwise specified, the substituent bears any one of the substituents defined below. For instance, an optionally substituted alkyl can mean that an alkyl is substituted or unsubstituted. In the case where the alkyl is substituted, i.e., by one or more substituents, the one or more substituents can include alkyl, halogenated alkyl, cycloalkyl, alkenyl, ... aryl, and the like. For example, an alkyl can be substituted by an alkyl (i.e., methyl, ethyl, propyl, etc.), a cycloalkyl (c-propyl, c-butyl, c-pentyl, c-hexyl, etc.), or an aryl (phenyl, substituted phenyl, naphthyl, substituted naphthyl, etc.).

The term "independently" is used herein to indicate that a variable is applied in any one instance without regard to the presence or absence of a variable having that same or a different definition within the same compound. Thus, in a compound in which R appears twice and is defined as "independently carbon or nitrogen", both

R's can be carbon, both R's can be nitrogen, or one R' can be carbon and the other nitrogen.

The term "alkyl" refers to an unbranched or branched chain, saturated, monovalent hydrocarbon residue containing 1 to 30 carbon atoms. The term "C<sub>1-M</sub> alkyl" refers to an alkyl comprising 2 to N carbon atoms, where M is an integer having the following values: 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, or 30. The term "C<sub>1-4</sub> alkyl" refers to an alkyl containing 1 to 4 carbon atoms. The term "lower alkyl" denotes a straight or branched chain hydrocarbon residue comprising 1 to 6 carbon atoms. "C<sub>1-20</sub> alkyl" as used herein refers to an alkyl comprising 1 to 20 carbon atoms. "C<sub>1-10</sub> alkyl" as used herein refers to an alkyl comprising 1 to 10 carbons. Examples of alkyl groups include, but are not limited to, lower alkyl groups include methyl, ethyl, propyl, *i*-propyl, *n*-butyl, *i*-butyl, *t*-butyl or pentyl, isopentyl, neopentyl, hexyl, heptyl, and octyl. The term (ar)alkyl or (heteroaryl)alkyl indicate the alkyl group is optionally substituted by an aryl or a heteroaryl group respectively.

The term "halogenated alkyl" (or "haloalkyl") refers to an unbranched or branched chain alkyl comprising at least one of F, Cl, Br, and I. The term "C<sub>1-3</sub> haloalkyl" refers to a haloalkyl comprising 1 to 3 carbons and at least one of F, Cl, Br, and I. The term "halogenated lower alkyl" refers to a haloalkyl comprising 1 to 6 carbon atoms and at least one of F, Cl, Br, and I. Examples include, but are not limited to, fluoromethyl, chloromethyl, bromomethyl, iodomethyl, difluoromethyl, dichloromethyl, dibromomethyl, diiodomethyl, trifluoromethyl, trichloromethyl, tribromomethyl, triiodomethyl, 1-fluoroethyl, 1-chloroethyl, 1-bromoethyl, 1-iodoethyl, 2-fluoroethyl, 2-chloroethyl, 2-bromoethyl, 2-iodoethyl, 2,2-difluoroethyl, 2,2-dichloroethyl, 2,2-dibromomethyl, 2,2-diiodomethyl, 3-fluoropropyl, 3-chloropropyl, 3-bromopropyl, 2,2,2-trifluoroethyl or 1,1,2,2,2-pentafluoroethyl.

The term "cycloalkyl" refers to a saturated carbocyclic ring comprising 3 to 8 carbon atoms, i.e. cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl or cyclooctyl. The term "C<sub>3-7</sub> cycloalkyl" as used herein refers to a cycloalkyl comprising 3 to 7 carbons in the carbocyclic ring.

The term "alkenyl" refers to an unsubstituted hydrocarbon chain radical having from 2 to 10 carbon atoms having one or two olefinic double bonds, preferably one olefinic double bond. The term " $C_{2-N}$  alkenyl" refers to an alkenyl comprising 2 to N carbon atoms, where N is an integer having the following values:  
5 3, 4, 5, 6, 7, 8, 9, or 10. The term " $C_{2-10}$  alkenyl" refers to an alkenyl comprising 2 to 10 carbon atoms. The term " $C_{2-4}$  alkenyl" refers to an alkenyl comprising 2 to 4 carbon atoms. Examples include, but are not limited to, vinyl, 1-propenyl, 2-propenyl (allyl) or 2-butenyl (crotyl).

The term "halogenated alkenyl" refers to an alkenyl comprising at least one  
10 of F, Cl, Br, and I.

The term "alkynyl" refers to an unbranched or branched hydrocarbon chain radical having from 2 to 10 carbon atoms, preferably 2 to 5 carbon atoms, and having one triple bond. The term " $C_{2-N}$  alkynyl" refers to an alkynyl comprising 2 to N carbon atoms, where N is an integer having the following values: 3, 4, 5, 6, 7, 8,  
15 9, or 10. The term " $C_{2-4}$  alkynyl" refers to an alkynyl comprising 2 to 4 carbon atoms. The term " $C_{2-10}$  alkynyl" refers to an alkynyl comprising 2 to 10 carbons. Examples include, but are limited to, ethynyl, 1-propynyl, 2-propynyl, 1-butylnyl, 2-butylnyl or 3-butylnyl.

The term "halogenated alkynyl" refers to an unbranched or branched  
20 hydrocarbon chain radical having from 2 to 10 carbon atoms, preferably 2 to 5 carbon atoms, and having one triple bond and at least one of F, Cl, Br, and I.

The term "alkoxy" refers to an -O-alkyl group, wherein alkyl is as defined above. Examples include, but are not limited to, methoxy, ethoxy, *n*-propyloxy, *i*-propyloxy, *n*-butyloxy, *i*-butyloxy, *t*-butyloxy. "Lower alkoxy" as used herein  
25 denotes an alkoxy group with a "lower alkyl" group as previously defined. " $C_{1-10}$  alkoxy" refers to an -O-alkyl wherein alkyl is  $C_{1-10}$ .

The term "alkoxyalkyl" refers to an alkyl-O-alkyl group, wherein alkyl is defined above. Examples include, but are not limited to, methoxymethyl, ethoxymethyl, *n*-propyloxymethyl, *i*-propyloxymethyl, *n*-butyloxymethyl, *i*-butyloxymethyl, *t*-butyloxymethyl, and the like, methoxyethyl, ethoxyethyl, *n*-propyloxyethyl, *i*-propyloxyethyl, *n*-butyloxyethyl, *i*-butyloxyethyl, *t*-butyloxyethyl,  
30

and the like, methoxypropyl, ethoxypropyl, *n*-propyloxypropyl, *i*-propyloxypropyl, *n*-butyloxypropyl, *i*-butyloxypropyl, *t*-butyloxypropyl, and the like, etc.

The term "halogenated alkoxy" refers to an -O-alkyl group in which the alkyl group comprises at least one of F, Cl, Br, and I.

- 5           The term "halogenated lower alkoxy" refers to an -O-(lower alkyl) group in which the lower alkyl group comprises at least one of F, Cl, Br, and I.

The terms "alkylamino" or "arylamino" refer to an amino group that has one or two alkyl or aryl substituents, respectively.

- 10           The term "protected," as used herein and unless otherwise defined, refers to a group that is added to an oxygen, nitrogen, or phosphorus atom to prevent its further reaction or for other purposes. A wide variety of oxygen and nitrogen protecting groups are known to those skilled in the art of organic synthesis. Non-limiting examples include: C(O)-alkyl, C(O)Ph, C(O)aryl, CH<sub>3</sub>, CH<sub>2</sub>-alkyl, CH<sub>2</sub>-alkenyl, CH<sub>2</sub>Ph, CH<sub>2</sub>-aryl, CH<sub>2</sub>O-alkyl, CH<sub>2</sub>O-aryl, SO<sub>2</sub>-alkyl, SO<sub>2</sub>-aryl, *tert*-butyldimethylsilyl, *tert*-butyldiphenylsilyl, and 1,3-(1,1,3,3-tetraisopropylidisiloxanylidene).
- 15

- 20           The term "aryl," as used herein, and unless otherwise specified, refers to substituted or unsubstituted phenyl (Ph), biphenyl, or naphthyl, preferably the term aryl refers to substituted or unsubstituted phenyl. The aryl group can be substituted with one or more moieties selected from among hydroxyl, amino, alkylamino, arylamino, alkoxy, aryloxy, nitro, cyano, sulfonic acid, sulfate, phosphonic acid, phosphate, or phosphonate, either unprotected, or protected as necessary, as known to those skilled in the art, for example, as taught in T.W. Greene and P.G.M. Wuts, "Protective Groups in Organic Synthesis," 3rd ed., John Wiley & Sons, 1999.

- 25           The terms "alkaryl" or "alkylaryl" refer to an alkyl group with an aryl substituent. It is understood that the aryl substituent of the "alkaryl" or "alkylaryl" can be substituted with at least one of a halogen (F, Cl, Br, or I), -hydroxyl, a lower alkoxy, such as -OCH<sub>3</sub>, -amino, or an alkylamino, such as -NHR or -NR<sub>2</sub>, where R is a lower alkyl, such as -NHCH<sub>3</sub> or -N(CH<sub>3</sub>)<sub>2</sub>. Moreover, the term "lower alkylaryl" denotes a straight or branched chain hydrocarbon residue comprising 1 to
- 30

6 carbon atoms that is substituted with a substituted or unsubstituted aryl, such as, benzyl. The terms "aralkyl" or "arylalkyl" refer to an aryl group with an alkyl substituent.

The term "halo," as used herein, includes chloro, bromo, iodo and fluoro.

5           The term "acyl" refers to a substituent containing a carbonyl moiety and a non-carbonyl moiety. The carbonyl moiety contains a double-bond between the carbonyl carbon and a heteroatom, where the heteroatom is selected from among O, N and S. When the heteroatom is N, the N is substituted by a lower alkyl. The non-carbonyl moiety is selected from straight, branched, or cyclic alkyl, which includes,  
10 but is not limited to, a straight, branched, or cyclic C<sub>1-20</sub> alkyl, C<sub>1-10</sub> alkyl, or lower alkyl; alkoxyalkyl, including methoxymethyl; aralkyl, including benzyl; aryloxyalkyl, such as phenoxymethyl; or aryl, including phenyl optionally substituted with halogen (F, Cl, Br, I), hydroxyl, C<sub>1</sub> to C<sub>4</sub> alkyl, or C<sub>1</sub> to C<sub>4</sub> alkoxy, sulfonate esters, such as alkyl or aralkyl sulphonyl, including methanesulfonyl, the  
15 mono, di or triphosphate ester, trityl or monomethoxytrityl, substituted benzyl, trialkylsilyl (e.g. dimethyl-t-butylsilyl) or diphenylmethylsilyl. When at least one aryl group is present in the non-carbonyl moiety, it is preferred that the aryl group comprises a phenyl group.

20           The term "lower acyl" refers to an acyl group in which the non-carbonyl moiety is lower alkyl.

          The term "purine" or "pyrimidine" base includes, but is not limited to, adenine, N<sup>6</sup>-alkylpurines, N<sup>6</sup>-acylpurines (wherein acyl is C(O)(alkyl, aryl, alkylaryl, or arylalkyl), N<sup>6</sup>-benzylpurine, N<sup>6</sup>-halopurine, N<sup>6</sup>-vinylpurine, N<sup>6</sup>-acetylenic purine, N<sup>6</sup>-acyl purine, N<sup>6</sup>-hydroxyalkyl purine, N<sup>6</sup>-allylaminopurine, N<sup>6</sup>-  
25 thioallyl purine, N<sup>2</sup>-alkylpurines, N<sup>2</sup>-alkyl-6-thiopurines, thymine, cytosine, 5-fluorocytosine, 5-methylcytosine, 6-azapyrimidine, including 6-azacytosine, 2-and/or 4-mercaptopyrimidine, uracil, 5-halouracil, including 5-fluorouracil, C<sup>5</sup>-alkylpyrimidines, C<sup>5</sup>-benzylpyrimidines, C<sup>5</sup>-halopyrimidines, C<sup>5</sup>-vinylpyrimidine, C<sup>5</sup>-acetylenic pyrimidine, C<sup>5</sup>-acyl pyrimidine, C<sup>5</sup>-hydroxyalkyl purine, C<sup>5</sup>-  
30 amidopyrimidine, C<sup>5</sup>-cyanopyrimidine, C<sup>5</sup>-iodopyrimidine, C<sup>6</sup>-iodo-pyrimidine, C<sup>5</sup>-Br-vinyl pyrimidine, C<sup>6</sup>-Br-vinyl pyrimidine, C<sup>5</sup>-nitropyrimidine, C<sup>5</sup>-amino-

pyrimidine, N<sup>2</sup>-alkylpurines, N<sup>2</sup>-alkyl-6-thiopurines, 5-azacytidinyl, 5-azauracilyl, triazolopyridinyl, imidazolopyridinyl, pyrrolopyrimidinyl, and pyrazolopyrimidinyl. Purine bases include, but are not limited to, guanine, adenine, hypoxanthine, 2,6-diaminopurine, and 6-chloropurine. Functional oxygen and nitrogen groups on the

5 base can be protected as necessary or desired. Suitable protecting groups are well known to those skilled in the art, and include trimethylsilyl, dimethylhexylsilyl, *t*-butyldimethylsilyl, and *t*-butyldiphenylsilyl, trityl, alkyl groups, and acyl groups such as acetyl and propionyl, methanesulfonyl, and *p*-toluenesulfonyl.

The term "heterocycle" or "heterocyclyl" as used herein refers to any 3-, 4-,

10 5-, 6-, 8-, 9-, 10-, or 11-membered saturated or unsaturated ring containing carbon atoms and from one to three heteroatoms independently selected from the group consisting of one, two, or three nitrogens, one oxygen and one nitrogen, and one sulfur and one nitrogen and including any bicyclic group in which any of the defined heterocyclic ring(s) is fused to a benzene ring; wherein the nitrogen and sulfur

15 heteroatoms may be optionally oxidized, wherein the nitrogen heteroatoms may be optionally quaternized, and wherein one or more carbon or nitrogen atoms may be substituted with a lower alkyl. In a disclosed embodiment, heterocycles include, but are not limited to, aziridinyl, azetidiny, pyrrolidinyl, piperidinyl, morpholinyl, piperazinyl, thiomorpholinyl, and the like. In an alternative embodiment,

20 "heterocycle" or "heterocyclyl" include, but are not limited to the following: azepanyl, benzimidazolyl, benzodioxolyl, benzofuranyl, benzofurazanyl, benzopyranyl, benzopyrazolyl, benzotriazolyl, benzothiazolyl, benzothienyl, benzothiofuranyl, benzothiophenyl, benzothiopyranyl, benzoxazepinyl, benzoxazolyl, carbazolyl, carbolinyl, chromanyl, cinnolinyl, diazepanyl,

25 diazapinonyl, dihydrobenzofuranyl, dihydrobenzofuryl, dihydrobenzoimidazolyl, dihydrobenzothienyl, dihydrobenzothiopyranyl, dihydrobenzothiopyranyl sulfone, dihydrobenzothiophenyl, dihydrobenzoxazolyl, dihydrocyclopentapyridinyl, dihydrofuranyl, dihydroimidazolyl, dihydroindolyl, dihydroisooxazolyl, dihydroisoquinolinyl, dihydroisothiazolyl, dihydrooxadiazolyl, dihydrooxazolyl,

30 dihydropyrazinyl, dihydropyrazolyl, dihydropyridinyl, dihydropyrimidinyl, dihydropyrrolyl, dihydroquinolinyl, dihydrotetrazolyl, dihydrothiadiazolyl, dihydrothiazolyl, dihydrothienyl, dihydrotriazolyl, dihydroazetidiny, dioxanyl, dioxidotetrahydrothienyl, dioxidothiomorpholinyl, furyl, furanyl, imidazolyl,

imidazoliny, imidazolidiny, imidazothiazoly, imidazopyridiny, indazoly,  
indolaziny, indoliny, indoly, isobenzofurany, isochromany, isoindoly,  
isoindoliny, isoquinolinone, isoquinoly, isothiazoly, isothiazolidiny, isoxazoliny,  
isoxazoly, methylenedioxybenzoyl, morpholiny, naphthpyridiny, oxadiazoly,  
5 oxazoly, oxazoliny, oxetany, oxoazepiny, oxadiazoly, oxidothiomorpholiny,  
oxodihydrophthalaziny, oxodihydroindoly, oxoimidazolidiny, oxopiperaziny,  
oxopiperdiny, oxopyrrolidiny, oxopyrimidiny, oxopyrroly, oxotriazoly,  
piperidy, piperidiny, piperaziny, pyranly, pyraziny, pyrazoly, pyridaziny,  
pyridinony, pyridopyridiny, pyridaziny, pyridy, pyrimidiny, pyrroly,  
10 pyrrolidiny, quinazoliny, quinoliny, quinoly, quinolinony, quinoxaliny,  
tetrahydrocycloheptapyridiny, tetrahydrofurany, tetrahydrofuryl,  
tetrahydroisoquinoliny, tetrahydropyrany, tetrahydroquinoliny, tetrazoly,  
tetrazolopyridy, thiadiazoly, thiazoly, thiazoliny, thienofuryl, thieny,  
thiomorpholiny, triazoly, azetidiny, 1,4-dioxany, hexahydroazepiny, and the like.

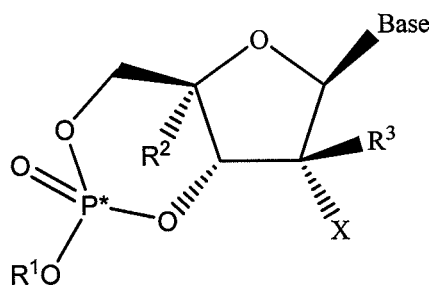
15 The term "tautomerism" and "tautomers" have their accepted plain meanings.

The term "deuterated analogues" refer to compounds in which at least one hydrogen atom of the compound of formula I is replaced with at least one deuterium atom.

The term "P\*" means that the phosphorous atom is chiral and that it has a  
20 corresponding Cahn-Ingold-Prelog designation of "R" or "S" which have their accepted plain meanings.

### DETAILED DESCRIPTION OF THE INVENTION

An aspect of the invention is directed to a compound, its stereoisomers, salts  
25 (acid or basic addition salts), hydrates, solvates, deuterated analogues, or crystalline forms thereof, and the like represented by formula I:

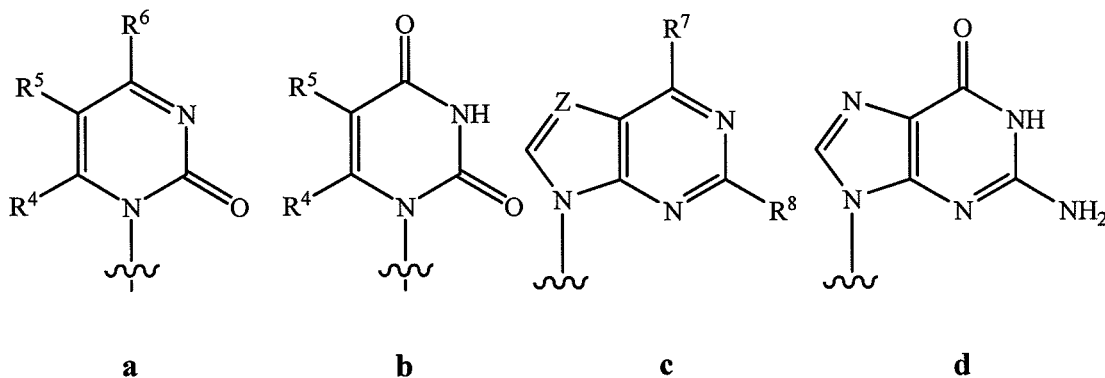


wherein

- (a)  $R^1$  is hydrogen, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>,  
 5 NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';
- 10 (b)  $R^2$  is H, an optionally substituted alkyl (including lower alkyl), cyano (CN), CH<sub>3</sub>, vinyl, O-alkyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl alkyl, i.e., -(CH<sub>2</sub>)<sub>o</sub>OH, wherein o is 1 – 10, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, ethynyl alkylne  
 15 (optionally substituted), or halogen, including F, Cl, Br, or I
- (c)  $R^3$  is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, F, or CN;
- (d) X is H, OH, F, OMe, halogen, NH<sub>2</sub>, or N<sub>3</sub>;

The base is a naturally occurring or modified purine or pyrimidine base represented by the following structures:

20



wherein

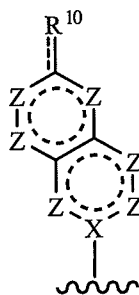
Z is N or CR<sup>9</sup>;

- R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, R<sup>7</sup>, and R<sup>8</sup> are independently H, F, Cl, Br, I, OH, OR', such as alkoxy, aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy, SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

- R<sup>9</sup> is an H, halogen (including F, Cl, Br, I), OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, NO<sub>2</sub>, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

- wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

Alternatively, the Base may be selected from a group of formula c'



c'

wherein for structure c',

if Z is a participant in a pi bond (double bond), Z is independently selected from N or C-G; or, if Z is not a participant in a pi bond (double bond), Z is independently selected from O, S, Se,  $\text{NR}^{11}$ ,  $\text{NOR}^{11}$ ,  $\text{NNR}^{11}_2$ , CO, CS,  $\text{CNR}^{11}$ , SO,  $\text{S(O)}_2$ , SeO,  $\text{Se(O)}_2$ , or  $\text{C(G)}_2$ ;

each G is independently selected from the group consisting of H, halogen,  $\text{OR}^{11}$ ,  $\text{SR}^{11}$ ,  $\text{NR}^{11}_2$ ,  $\text{NR}^{11}\text{OR}^{11}$ ,  $\text{N}_3$ ,  $\text{COOR}^{11}$ , CN,  $\text{CONR}^{11}_2$ ,  $\text{C(S)NR}^{11}_2$ ,  $\text{C(=NR}^{11})\text{NR}^{11}_2$ , and  $\text{R}^{11}$ ; and where any two adjacent Z are not both selected from O, S, and Se, or not both selected from CO, CS,  $\text{CNNR}^{11}$ , SO,  $\text{S(O)}_2$ , SeO and  $\text{Se(O)}_2$ ;

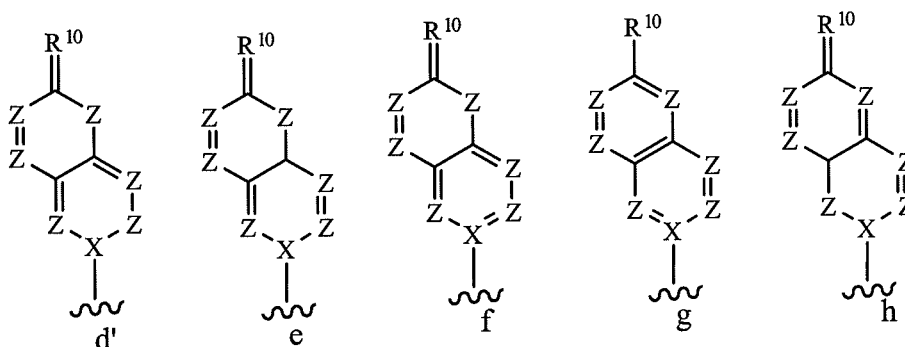
wherein, if X is a participant in a pi bond (double bond), X is C; or if X is not a participant in a pi bond (double bond), X is  $\text{CR}^{11}$  or N;

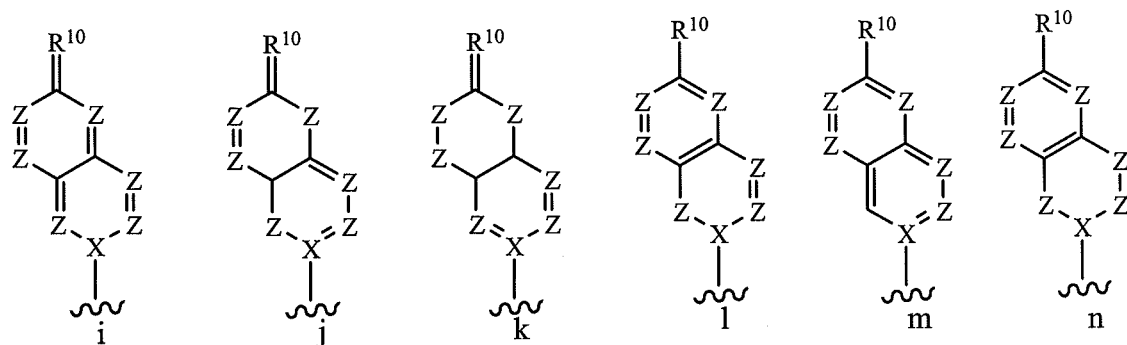
wherein, if  $\text{R}^{10}$  is a participant in a pi bond (double bond),  $\text{R}^{10}$  is O, S, Se,  $\text{NR}^{11}$ ,  $\text{NOR}^{11}$  or  $\text{NNR}^{11}_2$ ; or if  $\text{R}^{10}$  is not a participant in a pi bond (double bond),  $\text{R}^{10}$  is  $\text{OR}^{11}$ ,  $\text{SR}^{11}$ , F, Cl,  $\text{R}^{10}$ , or  $\text{SeR}^{10}$ ; and

dashed lines (---) indicate a possible pi or double bond;

each R is independently selected from the group consisting of H,  $\text{CF}_3$ , optionally substituted alkyl, optionally substituted alkenyl, optionally substituted alkynyl, optionally substituted aryl, optionally substituted acyl, optionally substituted cycloalkyl, optionally substituted cycloalkenyl, optionally substituted heteroaryl, optionally substituted heterocyclyl, and optionally substituted arylalkyl;

Base may be a structure selected from the group consisting of structures d'-n

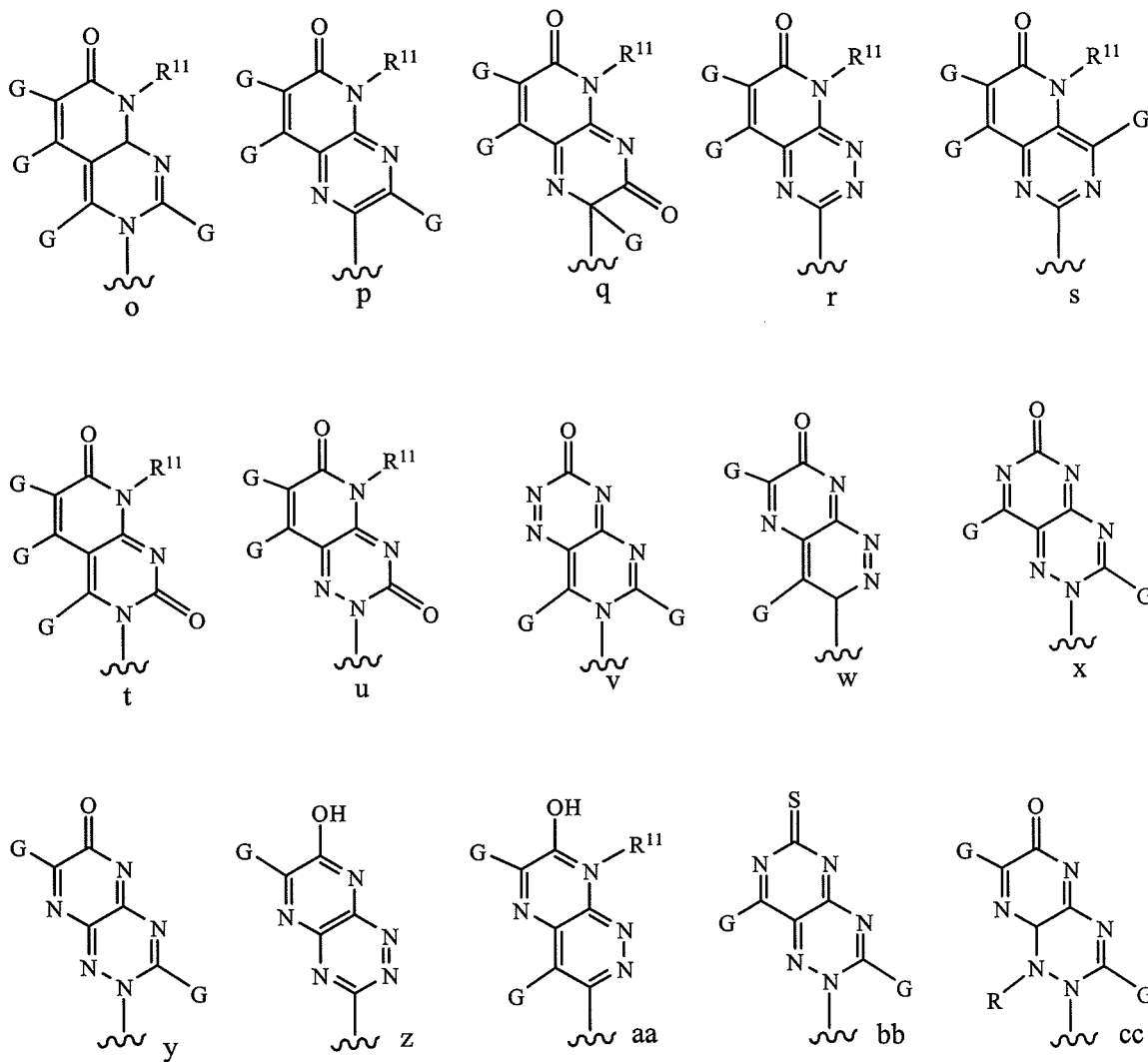




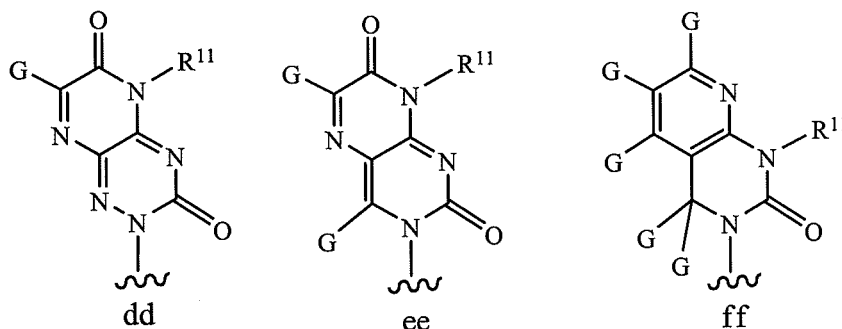
wherein Z, X, and R<sup>10</sup> are defined as in structure c';

Base may be a structure selected from the group consisting of structures o -

5 ff

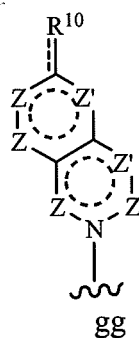


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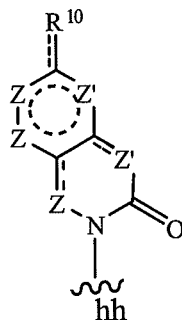
wherein G and R are defined as in structure c';

Base may be a structure gg



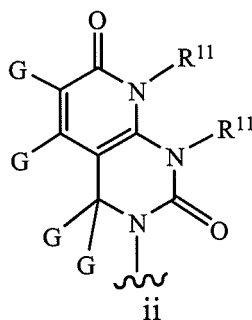
- 5            wherein each Z' is independently N (if a participant in a pi bond) or NR<sup>11</sup> (if not a participant in a pi bond) and R<sup>10</sup>, R<sup>11</sup>, and Z are defined as in structure c';

Base may be a structure hh



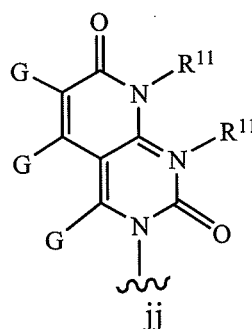
- 10            wherein each Z' is independently N (if a participant in a pi bond) or NR<sup>11</sup> (if not a participant in a pi bond), and each Z is independently CG (if a participant in a pi bond) or >C(G)<sub>2</sub> (if not a participant in a pi bond), wherein R<sup>10</sup> and G are defined as in structure c';

Base may be a structure ii



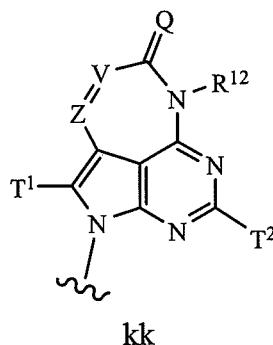
wherein  $R^{11}$  and G are defined as in structure c';

Base may be a structure jj



5 wherein  $R^{11}$  and G are defined as in structure c'; or

Base may be a structure kk



wherein for structure kk:

10  $R^{12}$  is selected from the group consisting of hydrogen and  $C_1$ - $C_3$  alkyl;

Q is absent or is selected from the group consisting of O, S, and NH,

provided that when Q is absent, V and NH are both attached to a  $CH_2$  group;

V is selected from the group consisting of N and C-G;

Z is selected from the group consisting of N and C-G';

15 G and G' are independently selected from the group consisting of hydrogen, amino, aminocarbonyl, methylamino, dimethylamino, acylamino, alkoxyamino,  $-SO_3H$ ,

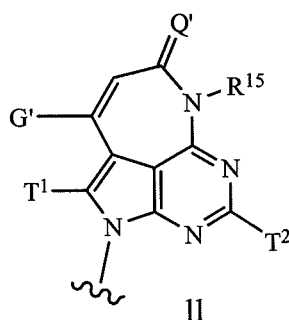
–SO<sub>2</sub>NH<sub>2</sub>, aminocarbonylamino, oxycarbonylamino, HR<sup>13</sup>NCHR<sup>14</sup>C(O)NH–, azido, cyano, halo, hydroxyamino, and hydrazino, where R<sup>13</sup> is hydrogen and R<sup>14</sup> is a side-chain of an amino acid or where R<sup>13</sup> and R<sup>14</sup> together with the nitrogen and carbon bound to each group respectively form a pyrrolidinyll group;

5 with the proviso that V and Z are not identical and that when V is C–H, Z is N;

T<sup>1</sup> and T<sup>2</sup> are independently selected from the group consisting of hydrogen, hydroxyl, C<sub>1</sub>–C<sub>4</sub>-alkoxy, C<sub>1</sub>–C<sub>4</sub>-thioalkoxy, amino, substituted amino, and halo; and

10 each of W, W<sup>1</sup>, and W<sup>2</sup> is independently selected from the group consisting of hydrogen, C<sub>1</sub>–C<sub>4</sub> alkyl, and a prodrug group; or

Base may be a structure II



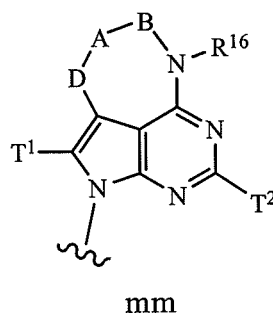
wherein for structure II:

15 R<sup>15</sup> is hydrogen or C<sub>1</sub>–C<sub>3</sub> alkyl;

Q' is selected from the group consisting of NH, O, and S;

G' is selected from the group consisting of amino, aminocarbonyl, methylamino, dimethylamino, acylamino, –SO<sub>3</sub>H, –SO<sub>2</sub>NH<sub>2</sub>, alkoxyamino, aminocarbonylamino, oxycarbonylamino, HR<sup>13</sup>NCHR<sup>14</sup>C(O)NH–, azido, cyano, 20 halo, hydroxyamino, and hydrazino, where R<sup>13</sup> is hydrogen and R<sup>14</sup> is a side-chain of an amino acid or where R<sup>13</sup> and R<sup>14</sup> together with the nitrogen and carbon bound to each group respectively form a pyrrolidinyll group; or

Base may be a structure mm



where in for structure mm

- A and B are independently selected from the group consisting of C=Q, NH,  
 5 and methylene optionally substituted with 1 to 2 halo groups, provided that A and B  
 are not both NH;

D is NH, or -D-A-B- together form a -N=CH-NH-, -(C=Q)-CH<sub>2</sub>-(C=Q)-, -  
 (C=Q)-NH-(C=Q)-, -(CX')=(CX')-(C=Q)-, or -CH=CH-NH- group where X' is  
 halo;

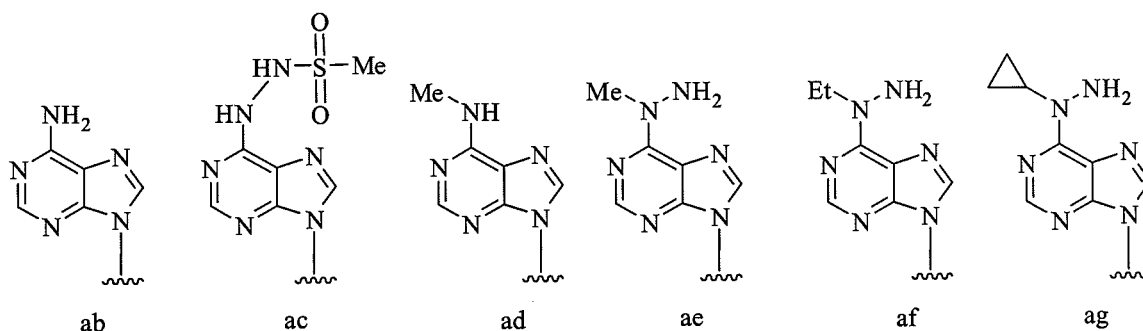
- 10 each Q is independently selected from the group consisting of O, S, and NH;

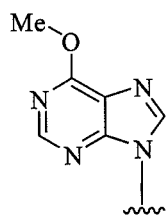
R<sup>16</sup> is selected from the group consisting of hydrogen and C<sub>1</sub>-C<sub>3</sub> alkyl;

T<sup>1</sup> and T<sup>2</sup> are independently selected from the group consisting of hydrogen,  
 hydroxyl, C<sub>1</sub>-C<sub>4</sub>-alkoxy, C<sub>1</sub>-C<sub>4</sub>-thioalkoxy, amino, substituted amino, and halo; and

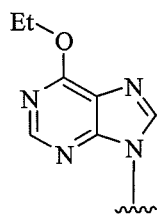
- Y is selected from the group consisting of a bond, O, and CH<sub>2</sub>; and each of  
 15 W, W<sup>1</sup>.

Alternatively, the Base can be selected from among structures ab, ac, ad, ae,  
 af, ag, ah, ai, aj, ak, al, am, an, ao, ap, aq, ar, as, at, av, au, ax, ay, az, ba, bc, bd, be,  
 bf, bg, bh, bi, bj, and bk, depicted below.

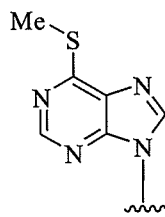




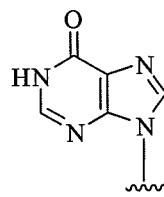
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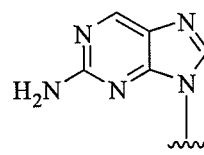
ai



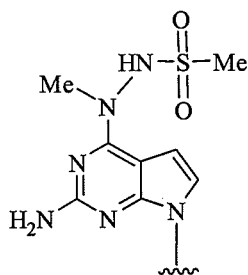
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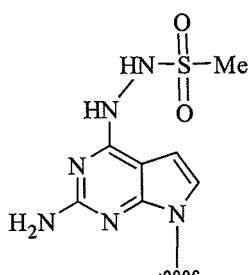
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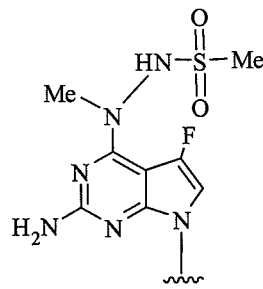
al



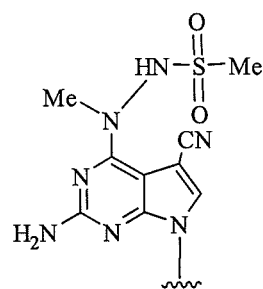
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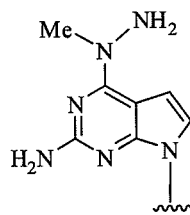
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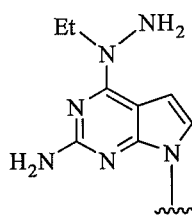
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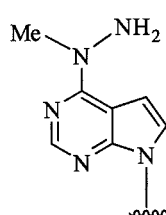
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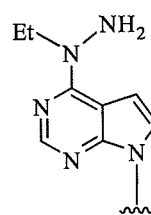
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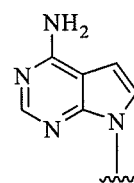
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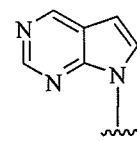
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at

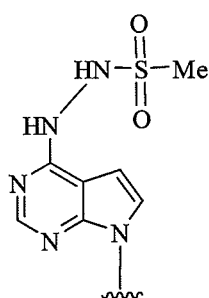


au

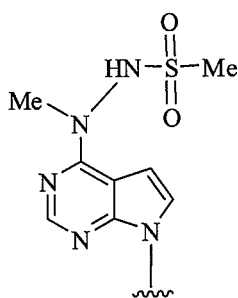


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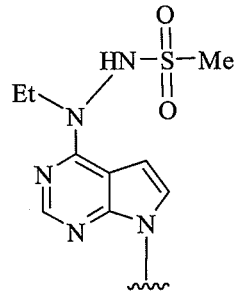
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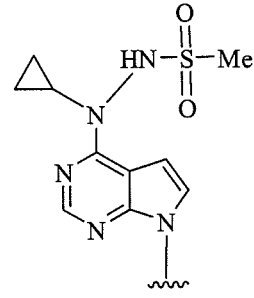
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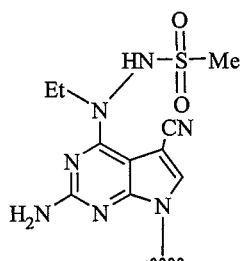
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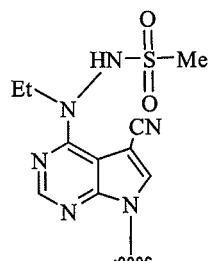
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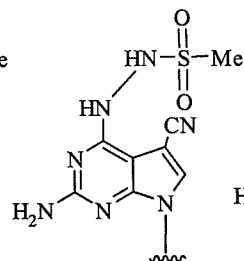
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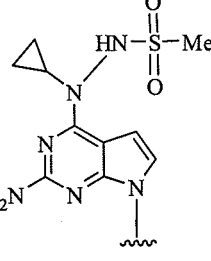
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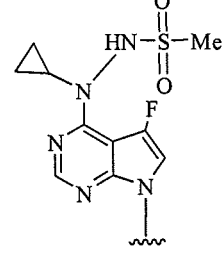
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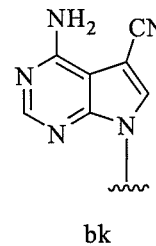
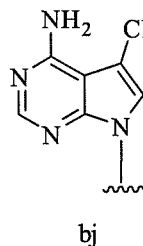
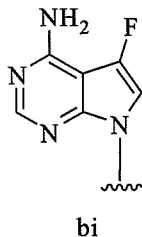
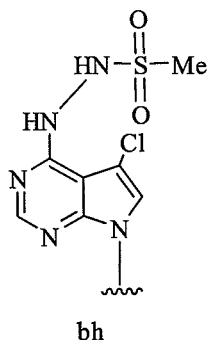
be



bf

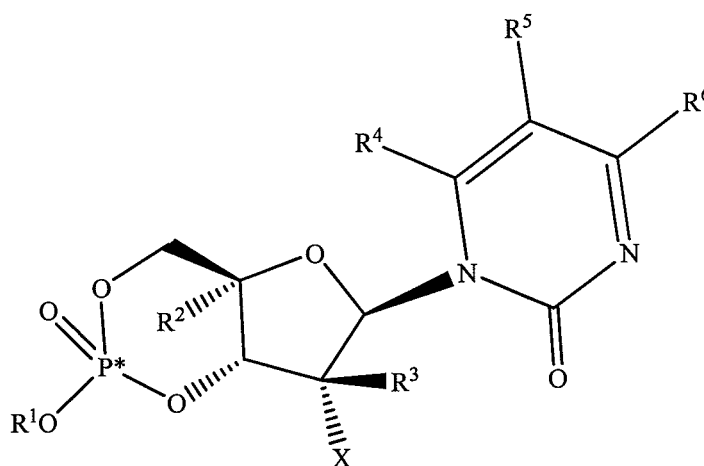


bg



As can be appreciated from the structure represented by formula **I** above, there are myriad ways to express the several embodiments and aspects of each embodiment of the present invention. As seen below, the inventors have disclosed several embodiments, each having several aspects, based on the identity of the modified purine or pyrimidine base. This is not intended to be an explicit or implicit admission that the several embodiments are independent or distinct nor should it be interpreted as such. Rather, it is intended to convey information so that the full breadth of the present invention can be understood. Furthermore, the following embodiments, and aspects thereof, are not meant to be limiting on the full breadth of the invention as recited by the structure of formula **I**.

A first embodiment of the invention is directed to a compound represented by formula **I-1**:



**I-1**

wherein

- (a)  $R^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I),  
 5 halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';
- (b)  $R^2$  is H, lower alkyl, cyano (CN), CH<sub>3</sub>, vinyl, lower alkoxy, including  
 10 OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, ethynyl alkyne (optionally substituted), or halogen, including F, Cl, Br, or I;
- (c)  $R^3$  is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, F, or CN;
- (d) X is H, OH, F, OMe, halogen, NH<sub>2</sub>, or N<sub>3</sub>; and  
 15
- (e)  $R^4$ ,  $R^5$ ,  $R^6$  are independently H, F, Cl, Br, I, OH, OR', such as alkoxy, aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy, SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>;
- 20 wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon  
 25 atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

A first aspect of the first embodiment is directed to a compound represented  
 30 by formula I-1

wherein

- (a)  $R^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>,  
 5 NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';
- 10 (b)  $R^2$  is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;
- (c)  $R^3$  is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, or F;
- 15 (d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>; and
- (e)  $R^4$ ,  $R^5$ ,  $R^6$  are independently H, F, Cl, Br, I, OH, OR', such as alkoxy, aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy, SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>;
- 20 wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon  
 25 atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

A second aspect of the first embodiment is directed to a compound

represented by formula I-1

wherein

- (a)  $R^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b)  $R^2$  is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1-6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

- (c)  $R^3$  is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, or F;

(d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>;

(e)  $R^4$  and  $R^5$  are independently H, F, Cl, OH, OCH<sub>3</sub>, CH<sub>3</sub>, CH<sub>3-q</sub>X<sub>q</sub>, where X is F, Cl, Br, or I and q is 1 to 3, vinyl, CO<sub>2</sub>H, CO<sub>2</sub>CH<sub>3</sub>, CONH<sub>2</sub>, CONHCH<sub>3</sub>, or CON(CH<sub>3</sub>)<sub>2</sub>; and

- (f)  $R^6$  is selected from among OH, OCH<sub>3</sub>, NH<sub>2</sub>, NHCH<sub>3</sub>, N(CH<sub>3</sub>)<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, OC(O)(C<sub>1-20</sub> alkyl), which include but are not limited to OC(O)(CH<sub>2</sub>)<sub>s</sub>CH<sub>3</sub>, NHC(O)(C<sub>1-20</sub> alkyl), which include but are not limited to NHC(O)(CH<sub>2</sub>)<sub>s</sub>CH<sub>3</sub>, N(C(O)(CH<sub>2</sub>)<sub>s</sub>CH<sub>3</sub>)<sub>2</sub>, which include but is not limited to N(C(O)(CH<sub>2</sub>)<sub>s</sub>CH<sub>3</sub>)<sub>2</sub>, where s is an integer selected from 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, and 19;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent

of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon atoms.

A third aspect of the first embodiment is directed to a compound represented by formula **I-1**

wherein

(a)  $\text{R}^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH,  $\text{OR}'$ , SH,  $\text{SR}'$ ,  $\text{NH}_2$ ,  $\text{NHR}'$ ,  $\text{NR}'_2$ ,  $\text{NHR}'_2^+$ ,  $\text{NR}'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of  $\text{C}_2\text{-C}_6$ , lower alkynyl of  $\text{C}_2\text{-C}_6$  such as  $\text{C}\equiv\text{CH}$ , halogenated (F, Cl, Br, I) lower alkynyl of  $\text{C}_2\text{-C}_6$ , lower alkoxy of  $\text{C}_1\text{-C}_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $\text{C}_1\text{-C}_6$ ,  $\text{CO}_2\text{H}$ ,  $\text{CO}_2\text{R}'$ ,  $\text{CONH}_2$ ,  $\text{CONHR}'$ ,  $\text{CONR}'_2$ ,  $\text{CH}=\text{CHCO}_2\text{H}$ , or  $\text{CH}=\text{CHCO}_2\text{R}'$ ;

(b)  $\text{R}^2$  is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including  $\text{OCH}_3$ ,  $\text{OCH}_2\text{CH}_3$ , hydroxyl lower alkyl, i.e.,  $-(\text{CH}_2)_p\text{OH}$ , where p is 1 -6, including hydroxyl methyl ( $\text{CH}_2\text{OH}$ ), fluoromethyl ( $\text{CH}_2\text{F}$ ), azido ( $\text{N}_3$ ),  $\text{CH}_2\text{CN}$ ,  $\text{CH}_2\text{N}_3$ ,  $\text{CH}_2\text{NH}_2$ ,  $\text{CH}_2\text{NHCH}_3$ ,  $\text{CH}_2\text{N}(\text{CH}_3)_2$ , F, Cl, Br, or I;

(c)  $\text{R}^3$  is  $\text{CH}_3$ ,  $\text{CH}_2\text{F}$ ,  $\text{CHF}_2$ ,  $\text{CF}_3$ ;

(d) X is H, OH, F, OMe,  $\text{NH}_2$ , or  $\text{N}_3$ ;

(e)  $\text{R}^4$  and  $\text{R}^5$  are independently H, F, Cl, OH,  $\text{OCH}_3$ ,  $\text{CH}_3$ ,  $\text{CH}_3\text{-qX}_q$ , where X is F, Cl, Br, or I and q is 1 to 3, vinyl,  $\text{CO}_2\text{H}$ ,  $\text{CO}_2\text{CH}_3$ ,  $\text{CONH}_2$ ,  $\text{CONHCH}_3$ , or  $\text{CON}(\text{CH}_3)_2$ ; and

(f)  $\text{R}^6$  is selected from among OH,  $\text{OCH}_3$ ,  $\text{NH}_2$ ,  $\text{NHCH}_3$ ,  $\text{N}(\text{CH}_3)_2$ ,  $\text{NHR}'_2^+$ ,  $\text{NR}'_3^+$ ,  $\text{OC}(\text{O})(\text{C}1\text{-}20 \text{ alkyl})$ , which include but are not limited to  $\text{OC}(\text{O})(\text{CH}_2)_s\text{CH}_3$ ,  $\text{NHC}(\text{O})(\text{C}1\text{-}20 \text{ alkyl})$ , which include but are not limited to  $\text{NHC}(\text{O})(\text{CH}_2)_s\text{CH}_3$ ,  $\text{N}(\text{C}(\text{O})(\text{CH}_2)_s\text{CH}_3)_2$ , which include but is not limited to

$N(C(O)(CH_2)_sCH_3)_2$ , where  $s$  is an integer selected from 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, and 19;

wherein  $R'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $NR'_2$  or  $NHR'_2^+$  each  $R'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $NR'_3^+$  each  $R'$  comprises at least one C atom which are independent of one another or each  $R'$  comprises at least one C atom in which at least two  $R'$  are joined to form a heterocycle comprising at least two carbon atoms.

A fourth aspect of the first embodiment is directed to a compound represented by formula **I-1**

wherein

(a)  $R^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR',  $NH_2$ ,  $NHR'$ ,  $NR'_2$ ,  $NHR'_2^+$ ,  $NR'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of  $C_2$ - $C_6$ , lower alkynyl of  $C_2$ - $C_6$  such as  $C\equiv CH$ , halogenated (F, Cl, Br, I) lower alkynyl of  $C_2$ - $C_6$ , lower alkoxy of  $C_1$ - $C_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $C_1$ - $C_6$ ,  $CO_2H$ ,  $CO_2R'$ ,  $CONH_2$ ,  $CONHR'$ ,  $CONR'_2$ ,  $CH=CHCO_2H$ , or  $CH=CHCO_2R'$ ;

(b)  $R^2$  is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including  $OCH_3$ ,  $OCH_2CH_3$ , hydroxyl lower alkyl, i.e.,  $-(CH_2)_pOH$ , where  $p$  is 1 -6, including hydroxyl methyl ( $CH_2OH$ ), fluoromethyl ( $CH_2F$ ), azido ( $N_3$ ),  $CH_2CN$ ,  $CH_2N_3$ ,  $CH_2NH_2$ ,  $CH_2NHCH_3$ ,  $CH_2N(CH_3)_2$ , F, Cl, Br, or I;

(c)  $R^3$  is  $CH_3$ ,  $CH_2F$ ,  $CHF_2$ ,  $CF_3$ ;

(d) X is F;

(e)  $R^4$  and  $R^5$  are independently H, F, Cl, OH, OCH<sub>3</sub>, CH<sub>3</sub>, CH<sub>3-q</sub>X<sub>q</sub>, where X is F, Cl, Br, or I and q is 1 to 3, vinyl, CO<sub>2</sub>H, CO<sub>2</sub>CH<sub>3</sub>, CONH<sub>2</sub>, CONHCH<sub>3</sub>, or CON(CH<sub>3</sub>)<sub>2</sub>; and

(f)  $R^6$  is selected from among OH, OCH<sub>3</sub>, NH<sub>2</sub>, NHCH<sub>3</sub>, N(CH<sub>3</sub>)<sub>2</sub>, NR'<sub>2</sub>,  
 5 OC(O)(C1-20 alkyl), which include but are not limited to OC(O)(CH<sub>2</sub>)<sub>s</sub>CH<sub>3</sub>,  
 NHC(O)(C1-20 alkyl), which include but are not limited to NHC(O)(CH<sub>2</sub>)<sub>s</sub>CH<sub>3</sub>,  
 N(C(O)(CH<sub>2</sub>)<sub>s</sub>CH<sub>3</sub>)<sub>2</sub>, which include but is not limited to N(C(O)(CH<sub>2</sub>)<sub>s</sub>CH<sub>3</sub>)<sub>2</sub>, where  
 s is an integer selected from 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17,  
 18, and 19;

10 wherein R' is an optionally substituted alkyl, an optionally substituted  
 cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an  
 optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the  
 instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent  
 of one another or are joined to form a heterocycle comprising at least two carbon  
 15 atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom  
 which are independent of one another or each R' comprises at least one C atom in  
 which at least two R' are joined to form a heterocycle comprising at least two carbon  
 atoms.

A fifth aspect of the first embodiment is directed to a compound represented  
 20 by formula I-1

wherein

(a)  $R^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which  
 includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are  
 optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>,  
 25 NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I),  
 halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as  
 C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>,  
 halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR',  
 CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b)  $R^2$  is H,  $-CH_3$ , cyano (CN), vinyl,  $-OCH_3$ ,  $-CH_2OH$ ,  $-CH_2F$ , azido ( $N_3$ ),  $CH_2CN$ ,  $CH_2N_3$ ,  $CH_2NH_2$ ,  $CH_2NHCH_3$ ,  $CH_2N(CH_3)_2$ , F, Cl, Br, or I

(c)  $R^3$  is  $CH_3$ ;

(d) X is F;

5 (e)  $R^4$  and  $R^5$  are independently H, F,  $CH_3$ ,  $CH_3-qF_q$ , and q is 1 to 3, vinyl,  $CO_2CH_3$ ,  $CONH_2$ ,  $CONHCH_3$ , or  $CON(CH_3)_2$ ; and

(f)  $R^6$  is selected from among  $-OH$ ,  $-OCH_3$ ,  $-NH_2$ ,  $-NHCH_3$ ,  $-N(CH_3)_2$ ,  $NR'_2$ ,  $NHR'_2^+$ ,  $NR'_3^+$ ,  $-OC(O)CH_3$ ,  $-NHC(O)CH_3$ ,  $-N(C(O)CH_3)_2$ ;

wherein  $R'$  is an optionally substituted alkyl, an optionally substituted  
 10 cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $NR'_2$  or  $NHR'_2^+$  each  $R'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $NR'_3^+$  each  $R'$  comprises at least one C atom  
 15 which are independent of one another or each  $R'$  comprises at least one C atom in which at least two  $R'$  are joined to form a heterocycle comprising at least two carbon atoms.

A sixth aspect of the first embodiment is directed to a compound represented by formula I-1

20 wherein

(a)  $R^1$  is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR',  $NH_2$ ,  $NHR'$ ,  $NR'_2$ ,  $NHR'_2^+$ ,  $NR'_3^+$ , lower alkyl, lower alkoxy of  $C_1$ - $C_6$ , halogenated (F, Cl, Br, I) lower  
 25 alkoxy of  $C_1$ - $C_6$ ;

(b)  $R^2$  is H,  $-CH_3$ , cyano (CN), vinyl,  $-OCH_3$ ,  $-CH_2OH$ ,  $-CH_2F$ , azido ( $N_3$ ),  $CH_2CN$ ,  $CH_2N_3$ ,  $CH_2NH_2$ ,  $CH_2NHCH_3$ ,  $CH_2N(CH_3)_2$ , F, Cl, Br, or I;

(c)  $R^3$  is  $CH_3$ ;

(d) X is F;

(e)  $R^4$  and  $R^5$  are independently H, F,  $CH_3$ ,  $CH_3-qF_q$ , and q is 1 to 3, vinyl,  $CO_2CH_3$ ,  $CONH_2$ ,  $CONHCH_3$ , or  $CON(CH_3)_2$ ; and

(f)  $R^6$  is selected from among -OH, -OCH<sub>3</sub>, -NH<sub>2</sub>, -NHCH<sub>3</sub>, -N(CH<sub>3</sub>)<sub>2</sub>,  
 5  $NR'_2$ ,  $NHR'_2{}^+$ ,  $NR'_3{}^+$ , -OC(O)CH<sub>3</sub>, -NHC(O)CH<sub>3</sub>, -N(C(O)CH<sub>3</sub>)<sub>2</sub>,

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $NR'_2$  or  $NHR'_2{}^+$  each R' comprise at least one C atom that is independent  
 10 of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $NR'_3{}^+$  each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

15 A seventh aspect of the first embodiment is directed to a compound represented by formula **I-1**

wherein

(a)  $R^1$  is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally  
 20 substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR',  $NR'_2$ ,  $NHR'_2{}^+$ ,  $NR'_3{}^+$ , heterocycle, lower alkyl, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>;

(b)  $R^2$  is H;

(c)  $R^3$  is CH<sub>3</sub>;

25 (d) X is F;

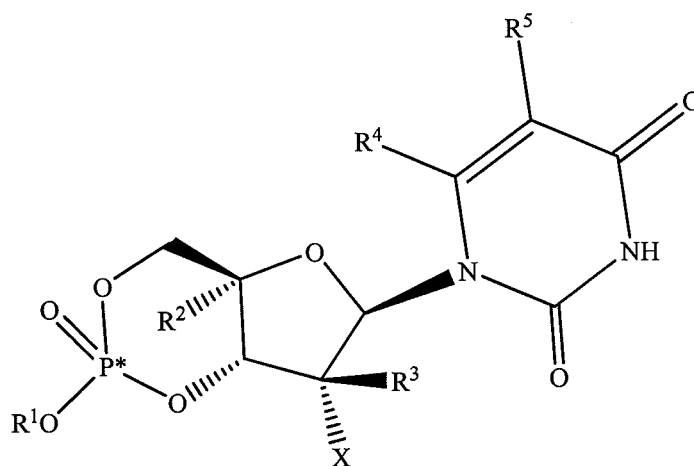
(e)  $R^4$  and  $R^5$  are independently H, F,  $CH_3$ ,  $CH_3-qF_q$ , and q is 1 to 3, vinyl,  $CO_2CH_3$ ,  $CONH_2$ ,  $CONHCH_3$ , or  $CON(CH_3)_2$ ; and

(f)  $R^6$  is selected from among -OH, -OCH<sub>3</sub>, -NH<sub>2</sub>, -NHCH<sub>3</sub>, -N(CH<sub>3</sub>)<sub>2</sub>, NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, -OC(O)CH<sub>3</sub>, -NHC(O)CH<sub>3</sub>, -N(C(O)CH<sub>3</sub>)<sub>2</sub>;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

A second embodiment of the invention is directed to a compound represented by formula **I** in which the base is a structure represented by formula **b** above, wherein R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, X, Y, R<sup>4</sup>, and R<sup>5</sup> are defined in the Summary of the Invention section above.

A first aspect of the second embodiment is directed to a compound represented by formula **I-2**



**I-2**

wherein

(a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are

optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>,  
 5 halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>,  
 10 CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, or F;

(d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>; and

(e) R<sup>4</sup> and R<sup>5</sup> are independently H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>;  
 15

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent  
 20 of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

25 The second aspect of the second embodiment is directed to a compound represented by formula **I-2**

wherein

(a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are

optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>,  
 5 halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>,  
 10 CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, or F;

(d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>; and

(e) R<sup>4</sup> and R<sup>5</sup> are independently H, F, Cl, OH, OCH<sub>3</sub>, CH<sub>3</sub>, CH<sub>3-q</sub>X<sub>q</sub>, where X is F, Cl, Br, or I and q is 1 to 3, vinyl, CO<sub>2</sub>H, CO<sub>2</sub>CH<sub>3</sub>, CONH<sub>2</sub>,  
 15 CONHCH<sub>3</sub>, or CON(CH<sub>3</sub>)<sub>2</sub>;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent  
 20 of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

25 The third aspect of the second embodiment is directed to a compound represented by formula **I-2**

wherein

(a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are

optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>,  
 5 halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>,  
 10 CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>;

(d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>; and

(e) R<sup>4</sup> and R<sup>5</sup> are independently H, F, Cl, OH, OCH<sub>3</sub>, CH<sub>3</sub>, CH<sub>3-q</sub>X<sub>q</sub>, where X is F, Cl, Br, or I and q is 1 to 3, vinyl, CO<sub>2</sub>H, CO<sub>2</sub>CH<sub>3</sub>, CONH<sub>2</sub>,  
 15 CONHCH<sub>3</sub>, or CON(CH<sub>3</sub>)<sub>2</sub>;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent  
 20 of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

25 The fourth aspect of the second embodiment is directed to a compound represented by formula **I-2**

wherein

(a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are

optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>,  
 5 halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>,  
 10 CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>;

(d) X is F; and

(e) R<sup>4</sup> and R<sup>5</sup> are independently H, F, Cl, OH, OCH<sub>3</sub>, CH<sub>3</sub>, CH<sub>3-q</sub>X<sub>q</sub>, where X is F, Cl, Br, or I and q is 1 to 3, vinyl, CO<sub>2</sub>H, CO<sub>2</sub>CH<sub>3</sub>, CONH<sub>2</sub>,  
 15 CONHCH<sub>3</sub>, or CON(CH<sub>3</sub>)<sub>2</sub>;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent  
 20 of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

25 The fifth aspect of the second embodiment is directed to a compound represented by formula **I-2**

wherein

(a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are

optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>,  
 5 halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b) R<sup>2</sup> is H, -CH<sub>3</sub>, cyano (CN), vinyl, -OCH<sub>3</sub>, -CH<sub>2</sub>OH, -CH<sub>2</sub>F, azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is CH<sub>3</sub>;

10 (d) X is F; and

(e) R<sup>4</sup> and R<sup>5</sup> are independently H, F, CH<sub>3</sub>, CH<sub>3-q</sub>F<sub>q</sub>, and q is 1 to 3, vinyl, CO<sub>2</sub>CH<sub>3</sub>, CONH<sub>2</sub>, CONHCH<sub>3</sub>, or CON(CH<sub>3</sub>)<sub>2</sub>;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an  
 15 optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in  
 20 which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

The sixth aspect of the second embodiment is directed to a compound represented by formula I-2

wherein

25 (a) R<sup>1</sup> is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>;

(b)  $R^2$  is H, -CH<sub>3</sub>, cyano (CN), vinyl, -OCH<sub>3</sub>, -CH<sub>2</sub>OH, -CH<sub>2</sub>F, azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c)  $R^3$  is CH<sub>3</sub>;

(d) X is F; and

5 (e)  $R^4$  and  $R^5$  are independently H, F, CH<sub>3</sub>, CH<sub>3-q</sub>F<sub>q</sub>, and q is 1 to 3, vinyl, CO<sub>2</sub>CH<sub>3</sub>, CONH<sub>2</sub>, CONHCH<sub>3</sub>, or CON(CH<sub>3</sub>)<sub>2</sub>;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the  
 10 instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon  
 15 atoms.

The seventh aspect of the second embodiment is directed to a compound represented by formula **I-2**

wherein

(a)  $R^1$  is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is  
 20 not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>;

(b)  $R^2$  is H;

25 (c)  $R^3$  is CH<sub>3</sub>;

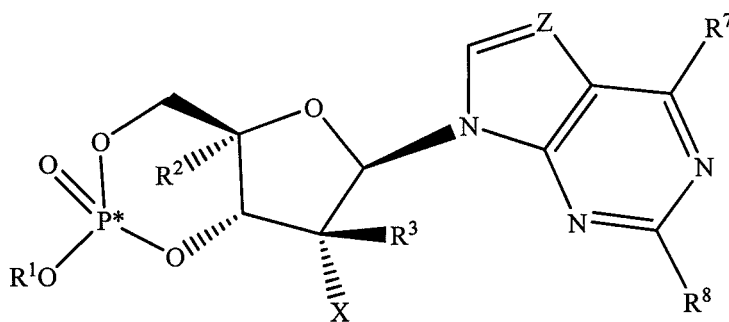
(d) X is F; and

(e)  $R^4$  and  $R^5$  are independently H, F,  $CH_3$ ,  $CH_3-qF_q$ , and  $q$  is 1 to 3, vinyl,  $CO_2CH_3$ ,  $CONH_2$ ,  $CONHCH_3$ , or  $CON(CH_3)_2$ ;

wherein  $R'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $NR'_2$  or  $NHR'_2^+$  each  $R'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $NR'_3^+$  each  $R'$  comprises at least one C atom which are independent of one another or each  $R'$  comprises at least one C atom in which at least two  $R'$  are joined to form a heterocycle comprising at least two carbon atoms.

A third embodiment of the invention is directed to a compound represented by formula **I** in which the base is a structure represented by formula **c** above.

The first aspect of the third embodiment is directed to a compound represented by formula **I-3**



**I-3**

wherein

(a)  $R^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR',  $NH_2$ ,  $NHR'$ ,  $NR'_2$ ,  $NHR'_2^+$ ,  $NR'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of  $C_2-C_6$ , lower alkynyl of  $C_2-C_6$  such as  $C\equiv CH$ , halogenated (F, Cl, Br, I) lower alkynyl of  $C_2-C_6$ , lower alkoxy of  $C_1-C_6$ ,

halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including  
 5 hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, or F;

(d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>;

(e) R<sup>7</sup> and R<sup>8</sup> are independently H, F, Cl, Br, I, OH, OR', such as alkoxy,  
 10 aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy, SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of  
 15 C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(f) Z is N or CR<sup>9</sup>; and

(g) R<sup>9</sup> is an H, halogen (including F, Cl, Br, I), OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NO<sub>2</sub> lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl  
 20 of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

wherein R' is an optionally substituted alkyl, an optionally substituted  
 25 cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom

which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

A second aspect of the third embodiment is directed to a compound  
5 represented by formula I-3

wherein

(a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>,  
10 NHR', NR'<sub>2</sub>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

15 (b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1-6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, or F;

20 (d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>;

(e) R<sup>7</sup> and R<sup>8</sup> are independently H, F, Cl, Br, I, OH, OR', such as alkoxy, aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy, SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-  
25 C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(f) Z is N or CR<sup>9</sup>; and

(g)  $R^9$  is an H, F, OH, OR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

A third aspect of the third embodiment is directed to a compound represented by formula **I-3**

wherein

(1)  $R^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b)  $R^2$  is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c)  $R^3$  is CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>;

(d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>;

(e)  $R^7$  and  $R^8$  are independently H, F, Cl, Br, I, OH, OR', such as alkoxy, aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy, SH, SR',  $NH_2$ ,  $NHR'$ ,  $NR'_2$ ,  $NHR'_2^+$ ,  $NR'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of  $C_2$ - $C_6$ , halogenated (F, Cl, Br, I) lower alkenyl of  $C_2$ - $C_6$ , lower alkynyl of  $C_2$ - $C_6$  such as  $C\equiv CH$ , halogenated (F, Cl, Br, I) lower alkynyl of  $C_2$ - $C_6$ , lower alkoxy of  $C_1$ - $C_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $C_1$ - $C_6$ ,  $CO_2H$ ,  $CO_2R'$ ,  $CONH_2$ ,  $CONHR'$ ,  $CONR'_2$ ,  $CH=CHCO_2H$ , or  $CH=CHCO_2R'$ ;

(f) Z is N or  $CR^9$ ; and

(g)  $R^9$  is an H, F, OH, OR',  $NH_2$ ,  $NHR'$ ,  $NR'_2$ , lower alkyl, halogenated (F, Cl, Br, I) lower alkyl;

wherein  $R'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $NR'_2$  or  $NHR'_2^+$  each  $R'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $NR'_3^+$  each  $R'$  comprises at least one C atom which are independent of one another or each  $R'$  comprises at least one C atom in which at least two  $R'$  are joined to form a heterocycle comprising at least two carbon atoms.

A fourth aspect of the third embodiment is directed to a compound represented by formula I-3

wherein

(a)  $R^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR',  $NH_2$ ,  $NHR'$ ,  $NR'_2$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of  $C_2$ - $C_6$ , lower alkynyl of  $C_2$ - $C_6$  such as  $C\equiv CH$ , halogenated (F, Cl, Br, I) lower alkynyl of  $C_2$ - $C_6$ , lower alkoxy of  $C_1$ - $C_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $C_1$ - $C_6$ ,  $CO_2H$ ,  $CO_2R'$ ,  $CONH_2$ ,  $CONHR'$ ,  $CONR'_2$ ,  $CH=CHCO_2H$ , or  $CH=CHCO_2R'$  wherein  $R'$  is an optionally substituted alkyl, cycloalkyl, alkenyl,

alkynyl, or alkoxyalkyl, which includes, but is not limited to, C<sub>1-10</sub> alkyl, C<sub>3-7</sub> cycloalkyl, C<sub>2-10</sub> alkenyl, C<sub>2-10</sub> alkynyl, or C<sub>1-10</sub> alkoxyalkyl;

(b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including  
 5 hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>;

(d) X is F;

(e) R<sup>7</sup> and R<sup>8</sup> are independently H, F, Cl, Br, I, OH, OR', such as alkoxy,  
 10 aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy, SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>,  
 15 CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(f) Z is N or CR<sup>9</sup>; and

(g) R<sup>9</sup> is an H, F, OH, OR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl;

wherein R' is an optionally substituted alkyl, an optionally substituted  
 20 cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom  
 25 which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms;

A fifth aspect of the third embodiment is directed to a compound represented by formula I-3

wherein

(a)  $R^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>,  
 5 NHR', NR'<sub>2</sub>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R' wherein R' is an optionally substituted alkyl, cycloalkyl, alkenyl,  
 10 alkynyl, or alkoxyalkyl, which includes, but is not limited to, C<sub>1-10</sub> alkyl, C<sub>3-7</sub> cycloalkyl, C<sub>2-10</sub> alkenyl, C<sub>2-10</sub> alkynyl, or C<sub>1-10</sub> alkoxyalkyl;

(b)  $R^2$  is H, -CH<sub>3</sub>, cyano (CN), vinyl, -OCH<sub>3</sub>, -CH<sub>2</sub>OH, -CH<sub>2</sub>F, azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c)  $R^3$  is CH<sub>3</sub>;

15 (d) X is F;

(e)  $R^7$  and  $R^8$  are independently H, F, Cl, Br, I, OH, OR', such as alkoxy, aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy, SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-  
 20 C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(f) Z is N or CR<sup>9</sup>; and

(g)  $R^9$  is an H, F, OH, OR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, lower alkyl, halogenated  
 25 (F, Cl, Br, I) lower alkyl;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent

of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon  
 5 atoms.

A sixth aspect of the third embodiment is directed to a compound represented by formula **I-3**

wherein

- (a)  $\text{R}^1$  is H, heterocycle, lower alkyl, lower alkylaryl, or aryl, which  
 10 includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH,  $\text{OR}'$ , SH,  $\text{SR}'$ ,  $\text{NH}_2$ ,  $\text{NHR}'$ ,  $\text{NR}'_2$ , lower alkoxy of  $\text{C}_1\text{-C}_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $\text{C}_1\text{-C}_6$ , wherein  $\text{R}'$  is an optionally substituted alkyl, cycloalkyl, alkenyl, alkynyl, or alkoxyalkyl, which includes, but is not limited to,  $\text{C}_{1-10}$  alkyl,  $\text{C}_{3-7}$  cycloalkyl,  $\text{C}_{2-10}$   
 15 alkenyl,  $\text{C}_{2-10}$  alkynyl, or  $\text{C}_{1-10}$  alkoxyalkyl;
- (b)  $\text{R}^2$  is H,  $-\text{CH}_3$ , cyano (CN), vinyl,  $-\text{OCH}_3$ ,  $-\text{CH}_2\text{OH}$ ,  $-\text{CH}_2\text{F}$ , azido ( $\text{N}_3$ ),  $\text{CH}_2\text{CN}$ ,  $\text{CH}_2\text{N}_3$ ,  $\text{CH}_2\text{NH}_2$ ,  $\text{CH}_2\text{NHCH}_3$ ,  $\text{CH}_2\text{N}(\text{CH}_3)_2$ , F, Cl, Br, or I;
- (c)  $\text{R}^3$  is  $\text{CH}_3$ ;
- (d) X is F;
- (e)  $\text{R}^7$  and  $\text{R}^8$  are independently H, F, Cl, Br, I, OH,  $\text{OR}'$ , such as alkoxy, aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy, SH,  $\text{SR}'$ ,  $\text{NH}_2$ ,  $\text{NHR}'$ ,  $\text{NR}'_2$ ,  $\text{NHR}'_2^+$ ,  $\text{NR}'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of  $\text{C}_2\text{-C}_6$ , halogenated (F, Cl, Br, I) lower alkenyl of  $\text{C}_2\text{-C}_6$ , lower alkynyl of  $\text{C}_2\text{-C}_6$  such as  $\text{C}\equiv\text{CH}$ , halogenated (F, Cl, Br, I) lower alkynyl  
 20 of  $\text{C}_2\text{-C}_6$ , lower alkoxy of  $\text{C}_1\text{-C}_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $\text{C}_1\text{-C}_6$ ,  $\text{CO}_2\text{H}$ ,  $\text{CO}_2\text{R}'$ ,  $\text{CONH}_2$ ,  $\text{CONHR}'$ ,  $\text{CONR}'_2$ ,  $\text{CH}=\text{CHCO}_2\text{H}$ , or  $\text{CH}=\text{CHCO}_2\text{R}'$ ;  
 25
- (f) Z is N or  $\text{CR}^9$ ; and

(g)  $R^9$  is an H, F, OH, OR',  $NH_2$ ,  $NHR'$ ,  $NR'_2$ , lower alkyl, halogenated (F, Cl, Br, I) lower alkyl;

wherein  $R'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $NR'_2$  or  $NHR'_2^+$  each  $R'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $NR'_3^+$  each  $R'$  comprises at least one C atom which are independent of one another or each  $R'$  comprises at least one C atom in which at least two  $R'$  are joined to form a heterocycle comprising at least two carbon atoms.

A seventh aspect of the third embodiment is directed to a compound represented by formula **I-3**

wherein

(a)  $R^1$  is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR',  $NH_2$ ,  $NHR'$ ,  $NR'_2$ , lower alkoxy of  $C_1$ - $C_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $C_1$ - $C_6$ , wherein  $R'$  is an optionally substituted alkyl, cycloalkyl, alkenyl, alkynyl, or alkoxyalkyl, which includes, but is not limited to,  $C_{1-10}$  alkyl,  $C_{3-7}$  cycloalkyl,  $C_{2-10}$  alkenyl,  $C_{2-10}$  alkynyl, or  $C_{1-10}$  alkoxyalkyl;

(b)  $R^2$  is H;

(c)  $R^3$  is  $CH_3$ ;

(d) X is F;

(e)  $R^7$  and  $R^8$  are independently H, F, Cl, Br, I, OH, OR', such as alkoxy, aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy, SH, SR',  $NH_2$ ,  $NHR'$ ,  $NR'_2$ ,  $NHR'_2^+$ ,  $NR'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of  $C_2$ - $C_6$ , halogenated (F, Cl, Br, I) lower alkenyl of  $C_2$ - $C_6$ , lower alkynyl of  $C_2$ - $C_6$  such as  $C\equiv CH$ , halogenated (F, Cl, Br, I) lower alkynyl

of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(f) Z is N or CR<sup>9</sup>; and

(g) R<sup>9</sup> is an H, F, OH, OR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, lower alkyl, halogenated  
5 (F, Cl, Br, I) lower alkyl;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent  
10 of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

15 An eighth aspect of the third embodiment is directed to a compound represented by formula I-3

wherein

(a) R<sup>1</sup> is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally  
20 substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, wherein R' is an optionally substituted alkyl, cycloalkyl, alkenyl, alkynyl, or alkoxyalkyl, which includes, but is not limited to, C<sub>1-10</sub> alkyl, C<sub>3-7</sub> cycloalkyl, C<sub>2-10</sub> alkenyl, C<sub>2-10</sub> alkynyl, or C<sub>1-10</sub> alkoxyalkyl;

25 (b) R<sup>2</sup> is H;

(c) R<sup>3</sup> is CH<sub>3</sub>;

(d) X is F;

(e)  $R^7$  is  $OR'$ , such as alkoxy, aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy and  $R^8$  is  $NH_2$ ;

(f)  $Z$  is  $N$ ; and

wherein  $R'$  is an optionally substituted alkyl, an optionally substituted  
5 cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $NR'_2$  or  $NHR'_2^+$  each  $R'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $NR'_3^+$  each  $R'$  comprises at least one C atom  
10 which are independent of one another or each  $R'$  comprises at least one C atom in which at least two  $R'$  are joined to form a heterocycle comprising at least two carbon atoms.

A ninth aspect of the third embodiment is directed to a compound represented by formula **I-3**

15 wherein

(a)  $R^1$  is H or lower alkyl;

(b)  $R^2$  is H;

(c)  $R^3$  is  $CH_3$ ;

(d)  $X$  is F;

20 (e)  $R^7$  is  $OR'$ , such as alkoxy, aryloxy, benzyloxy, substituted aryloxy, and substituted benzyloxy and  $R^8$  is  $NH_2$ ;

(f)  $Z$  is  $N$ ; and

wherein  $R'$  is an optionally substituted alkyl, an optionally substituted  
cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an  
25 optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $NR'_2$  or  $NHR'_2^+$  each  $R'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon

atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon atoms.

- 5           A tenth aspect of the third embodiment is directed to a compound represented by formula **I-3**

wherein

- (a)    $\text{R}^1$  is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR',  $\text{NH}_2$ ,  $\text{NHR}'$ ,  $\text{NR}'_2$ , lower alkoxy of  $\text{C}_1\text{-C}_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $\text{C}_1\text{-C}_6$ , wherein  $\text{R}'$  is an optionally substituted alkyl, cycloalkyl, alkenyl, alkynyl, or alkoxyalkyl, which includes, but is not limited to,  $\text{C}_{1-10}$  alkyl,  $\text{C}_{3-7}$  cycloalkyl,  $\text{C}_{2-10}$  alkenyl,  $\text{C}_{2-10}$  alkynyl, or  $\text{C}_{1-10}$  alkoxyalkyl;
- 10           (b)    $\text{R}^2$  is H;
- (c)    $\text{R}^3$  is  $\text{CH}_3$ ;
- (d)   X is F;
- (e)    $\text{R}^7$  is  $\text{NHR}'$ ,  $\text{NR}'_2$ ,  $\text{NHR}'_2^+$ , or  $\text{NR}'_3^+$  and  $\text{R}^8$  is  $\text{NH}_2$ ;
- 15           (f)   Z is N; and

- 20           wherein  $\text{R}'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $\text{NR}'_2$  or  $\text{NHR}'_2^+$  each  $\text{R}'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon atoms.
- 25

An eleventh aspect of the third embodiment is directed to a compound represented by formula **I-3** wherein (a)  $R^1$  is  $CH_3$  or  $iPr$ ; (b)  $R^2$  is H; (c)  $R^3$  is  $CH_3$ ; (d) X is F; (e)  $R^7$  and  $R^8$  are independently H, F, OH,  $OCH_3$ , SH,  $SCH_3$ ,  $NH_2$ ,  $NHCH_3$ ,  $N(CH_3)_2$ ,  $NR'_2$ ,  $CH_3$ ,  $CH_{3-q}X_q$ , where X is F, Cl, Br, or I and q is 1 to 3, vinyl,  $CO_2H$ ,  $CO_2CH_3$ ,  $CONH_2$ ,  $CONHCH_3$ ,  $CON(CH_3)_2$ , or  $OR'$ , such as OMe, OEt, OBn, and (f) Z is N; wherein  $R'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $NR'_2$ , each  $R'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $NR'_3$  each  $R'$  comprises at least one C atom which are independent of one another or each  $R'$  comprises at least one C atom in which at least two  $R'$  are joined to form a heterocycle comprising at least two carbon atoms.

A twelfth aspect of the third embodiment is directed to a compound represented by formula **I-3** wherein (a)  $R^1$  is  $CH_3$  or  $iPr$ ; (b)  $R^2$  is H; (c)  $R^3$  is  $CH_3$ ; (d) X is F; (e)  $R^7$  is  $-N(-CH_2CH_2CH_2-)$  (azetidin-1-yl); and  $R^8$  is  $NH_2$ ; and (f) Z is N.

A thirteenth aspect of the third embodiment is directed to a compound represented by formula **I** wherein (a)  $R^1$  is  $CH_3$  or  $iPr$ ; (b)  $R^2$  is H; (c)  $R^3$  is  $CH_3$ ; (d) X is F; (e)  $R^7$  is OEt and  $R^8$  is  $NH_2$ ; and (f) Z is N.

A fourteenth aspect of the third embodiment is directed to a compound represented by formula **I-3** wherein (a)  $R^1$  is  $CH_3$  or  $iPr$ ; (b)  $R^2$  is H; (c)  $R^3$  is  $CH_3$ ; (d) X is F; (e)  $R^7$  is OEt and  $R^8$  is  $NH_2$ ; and (f) Z is N.

A fifteenth aspect of the third embodiment is directed to a compound represented by formula **I-3** wherein (a)  $R^1$  is  $CH_3$ ; (b)  $R^2$  is H; (c)  $R^3$  is  $CH_3$ ; (d) X is F; (e)  $R^7$  is  $-N(-CH_2CH_2CH_2-)$  (azetidin-1-yl); and  $R^8$  is  $NH_2$ ; and (f) Z is N.

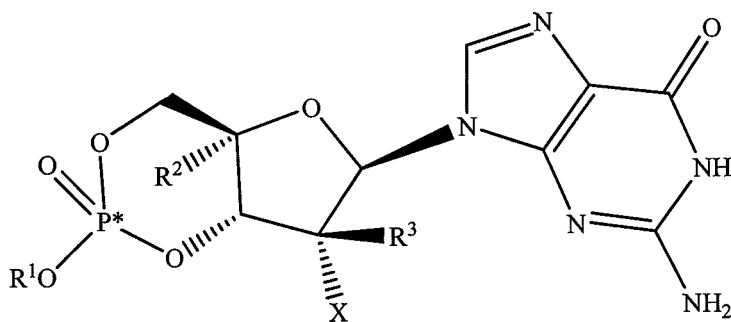
A sixteenth aspect of the third embodiment is directed to a compound represented by formula **I-3** wherein (a)  $R^1$  is  $CH_3$ ; (b)  $R^2$  is H; (c)  $R^3$  is  $CH_3$ ; (d) X is F; (e)  $R^7$  is OEt and  $R^8$  is  $NH_2$ ; and (f) Z is N.

A seventeenth aspect of the third embodiment is directed to a compound represented by formula **I-3** wherein (a)  $R^1$  is  $i$ Pr; (b)  $R^2$  is H; (c)  $R^3$  is  $CH_3$ ; (d) X is F; (e)  $R^7$  is OEt and  $R^8$  is  $NH_2$ ; and (f) Z is N.

5 An  $N^{th}$  aspect of the third embodiment is directed to a compound as exemplified below.

A fourth embodiment of the invention is directed to a compound represented by formula **I** in which the base is a structure represented by formula **d** above, wherein  $R^1$ ,  $R^2$ ,  $R^3$ , X, and Y are defined in the Summary of the Invention section above.

10 The first aspect of the fourth embodiment is directed to a compound represented by formula **I-4**



**I-4**

wherein

15 (a)  $R^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR',  $NH_2$ ,  $NHR'$ ,  $NR'_2$ ,  $NHR'_2^+$ ,  $NR'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of  $C_2$ - $C_6$ , lower alkynyl of  $C_2$ - $C_6$  such as  
20  $C\equiv CH$ , halogenated (F, Cl, Br, I) lower alkynyl of  $C_2$ - $C_6$ , lower alkoxy of  $C_1$ - $C_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $C_1$ - $C_6$ ,  $CO_2H$ ,  $CO_2R'$ ,  $CONH_2$ ,  $CONHR'$ ,  $CONR'_2$ ,  $CH=CHCO_2H$ , or  $CH=CHCO_2R'$ ;

(b)  $R^2$  is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including  $OCH_3$ ,  $OCH_2CH_3$ , hydroxyl lower alkyl, i.e.,  $-(CH_2)_pOH$ , where p is 1 -6, including

hydroxyl methyl ( $\text{CH}_2\text{OH}$ ), fluoromethyl ( $\text{CH}_2\text{F}$ ), azido ( $\text{N}_3$ ),  $\text{CH}_2\text{CN}$ ,  $\text{CH}_2\text{N}_3$ ,  $\text{CH}_2\text{NH}_2$ ,  $\text{CH}_2\text{NHCH}_3$ ,  $\text{CH}_2\text{N}(\text{CH}_3)_2$ , F, Cl, Br, or I;

(c)  $\text{R}^3$  is H,  $\text{CH}_3$ ,  $\text{CH}_2\text{F}$ ,  $\text{CHF}_2$ ,  $\text{CF}_3$ , or F; and

(d) X is H, OH, F, OMe,  $\text{NH}_2$ , or  $\text{N}_3$ ;

5 wherein  $\text{R}'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $\text{NR}'_2$  or  $\text{NHR}'_2^+$  each  $\text{R}'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon  
10 atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon atoms.

The second aspect of the fourth embodiment is directed to a compound  
15 represented by formula **I-4**

wherein

(a)  $\text{R}^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR',  $\text{NH}_2$ ,  
20  $\text{NHR}'$ ,  $\text{NR}'_2$ ,  $\text{NHR}'_2^+$ ,  $\text{NR}'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of  $\text{C}_2\text{-C}_6$ , lower alkynyl of  $\text{C}_2\text{-C}_6$  such as  $\text{C}\equiv\text{CH}$ , halogenated (F, Cl, Br, I) lower alkynyl of  $\text{C}_2\text{-C}_6$ , lower alkoxy of  $\text{C}_1\text{-C}_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $\text{C}_1\text{-C}_6$ ,  $\text{CO}_2\text{H}$ ,  $\text{CO}_2\text{R}'$ ,  $\text{CONH}_2$ ,  $\text{CONHR}'$ ,  $\text{CONR}'_2$ ,  $\text{CH}=\text{CHCO}_2\text{H}$ , or  $\text{CH}=\text{CHCO}_2\text{R}'$ ;

25 (b)  $\text{R}^2$  is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including  $\text{OCH}_3$ ,  $\text{OCH}_2\text{CH}_3$ , hydroxyl lower alkyl, i.e.,  $-(\text{CH}_2)_p\text{OH}$ , where p is 1 -6, including hydroxyl methyl ( $\text{CH}_2\text{OH}$ ), fluoromethyl ( $\text{CH}_2\text{F}$ ), azido ( $\text{N}_3$ ),  $\text{CH}_2\text{CN}$ ,  $\text{CH}_2\text{N}_3$ ,  $\text{CH}_2\text{NH}_2$ ,  $\text{CH}_2\text{NHCH}_3$ ,  $\text{CH}_2\text{N}(\text{CH}_3)_2$ , F, Cl, Br, or I;

(c)  $\text{R}^3$  is H,  $\text{CH}_3$ ,  $\text{CH}_2\text{F}$ ,  $\text{CHF}_2$ ,  $\text{CF}_3$ , or F; and

(d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the  
 5 instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon  
 10 atoms.

The third aspect of the fourth embodiment is directed to a compound represented by formula **I-4**

wherein

(a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which  
 15 includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>,  
 20 halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>,  
 25 CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>; and

(d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an

optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $\text{NR}'_2$  or  $\text{NHR}'_2^+$  each  $\text{R}'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon atoms.

The fourth aspect of the fourth embodiment is directed to a compound represented by formula **I-4**

wherein

(a)  $\text{R}^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH,  $\text{OR}'$ , SH,  $\text{SR}'$ ,  $\text{NH}_2$ ,  $\text{NHR}'$ ,  $\text{NR}'_2$ ,  $\text{NHR}'_2^+$ ,  $\text{NR}'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of  $\text{C}_2\text{-C}_6$ , lower alkynyl of  $\text{C}_2\text{-C}_6$  such as  $\text{C}\equiv\text{CH}$ , halogenated (F, Cl, Br, I) lower alkynyl of  $\text{C}_2\text{-C}_6$ , lower alkoxy of  $\text{C}_1\text{-C}_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $\text{C}_1\text{-C}_6$ ,  $\text{CO}_2\text{H}$ ,  $\text{CO}_2\text{R}'$ ,  $\text{CONH}_2$ ,  $\text{CONHR}'$ ,  $\text{CONR}'_2$ ,  $\text{CH=CHCO}_2\text{H}$ , or  $\text{CH=CHCO}_2\text{R}'$ ;

(b)  $\text{R}^2$  is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including  $\text{OCH}_3$ ,  $\text{OCH}_2\text{CH}_3$ , hydroxyl lower alkyl, i.e.,  $-(\text{CH}_2)_p\text{OH}$ , where p is 1 -6, including hydroxyl methyl ( $\text{CH}_2\text{OH}$ ), fluoromethyl ( $\text{CH}_2\text{F}$ ), azido ( $\text{N}_3$ ),  $\text{CH}_2\text{CN}$ ,  $\text{CH}_2\text{N}_3$ ,  $\text{CH}_2\text{NH}_2$ ,  $\text{CH}_2\text{NHCH}_3$ ,  $\text{CH}_2\text{N}(\text{CH}_3)_2$ , F, Cl, Br, or I;

(c)  $\text{R}^3$  is  $\text{CH}_3$ ,  $\text{CH}_2\text{F}$ ,  $\text{CHF}_2$ ,  $\text{CF}_3$ ; and

(d) X is F;

wherein  $\text{R}'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $\text{NR}'_2$  or  $\text{NHR}'_2^+$  each  $\text{R}'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon

atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon atoms.

- 5           The fifth aspect of the fourth embodiment is directed to a compound represented by formula **I-4**

wherein

- (a)  $\text{R}^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are  
 10 optionally substituted with at least one of H, F, Cl, Br, I, OH,  $\text{OR}'$ , SH,  $\text{SR}'$ ,  $\text{NH}_2$ ,  $\text{NHR}'$ ,  $\text{NR}'_2$ ,  $\text{NHR}'_2^+$ ,  $\text{NR}'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of  $\text{C}_2\text{-C}_6$ , lower alkynyl of  $\text{C}_2\text{-C}_6$  such as  $\text{C}\equiv\text{CH}$ , halogenated (F, Cl, Br, I) lower alkynyl of  $\text{C}_2\text{-C}_6$ , lower alkoxy of  $\text{C}_1\text{-C}_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $\text{C}_1\text{-C}_6$ ,  $\text{CO}_2\text{H}$ ,  $\text{CO}_2\text{R}'$ ,  $\text{CONH}_2$ ,  $\text{CONHR}'$ ,  
 15  $\text{CONR}'_2$ ,  $\text{CH}=\text{CHCO}_2\text{H}$ , or  $\text{CH}=\text{CHCO}_2\text{R}'$ ;

(b)  $\text{R}^2$  is H,  $-\text{CH}_3$ , cyano (CN), vinyl,  $-\text{OCH}_3$ ,  $-\text{CH}_2\text{OH}$ ,  $-\text{CH}_2\text{F}$ , azido ( $\text{N}_3$ ),  $\text{CH}_2\text{CN}$ ,  $\text{CH}_2\text{N}_3$ ,  $\text{CH}_2\text{NH}_2$ ,  $\text{CH}_2\text{NHCH}_3$ ,  $\text{CH}_2\text{N}(\text{CH}_3)_2$ , F, Cl, Br, or I;

(c)  $\text{R}^3$  is  $\text{CH}_3$ ; and

(d) X is F;

- 20           wherein  $\text{R}'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $\text{NR}'_2$  or  $\text{NHR}'_2^+$  each  $\text{R}'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon  
 25 atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon atoms.

The sixth aspect of the fourth embodiment is directed to a compound represented by formula I-4

wherein

(a)  $R^1$  is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR',  $NH_2$ ,  $NHR'$ ,  $NR'_2$ ,  $NHR'_2^+$ ,  $NR'_3^+$ , heterocycle, lower alkoxy of  $C_1$ - $C_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $C_1$ - $C_6$ , wherein  $R'$  is an optionally substituted alkyl, cycloalkyl, alkenyl, alkynyl, or alkoxyalkyl, which includes, but is not limited to,  $C_{1-10}$  alkyl,  $C_{3-7}$  cycloalkyl,  $C_{2-10}$  alkenyl,  $C_{2-10}$  alkynyl, or  $C_{1-10}$  alkoxyalkyl;

(b)  $R^2$  is H,  $-CH_3$ , cyano (CN), vinyl,  $-OCH_3$ ,  $-CH_2OH$ ,  $-CH_2F$ , azido ( $N_3$ ),  $CH_2CN$ ,  $CH_2N_3$ ,  $CH_2NH_2$ ,  $CH_2NHCH_3$ ,  $CH_2N(CH_3)_2$ , F, Cl, Br, or I;

(c)  $R^3$  is  $CH_3$ ; and

(d) X is F;

wherein  $R'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $NR'_2$  or  $NHR'_2^+$  each  $R'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $NR'_3^+$  each  $R'$  comprises at least one C atom which are independent of one another or each  $R'$  comprises at least one C atom in which at least two  $R'$  are joined to form a heterocycle comprising at least two carbon atoms.

The seventh aspect of the fourth embodiment is directed to a compound represented by formula I-4

wherein

(a)  $R^1$  is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally

- substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, wherein R' is an optionally substituted alkyl, cycloalkyl, alkenyl, alkynyl, or alkoxyalkyl, which includes, but is not limited to, C<sub>1-10</sub> alkyl, C<sub>3-7</sub>
- 5 cycloalkyl, C<sub>2-10</sub> alkenyl, C<sub>2-10</sub> alkynyl, or C<sub>1-10</sub> alkoxyalkyl;

(b) R<sup>2</sup> is H;

(c) R<sup>3</sup> is CH<sub>3</sub>; and

(d) X is F;

- wherein R' is an optionally substituted alkyl, an optionally substituted
- 10 cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom
- 15 which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

- A fifth embodiment of the invention is directed to a compound represented by formula I in which the Base is a structure selected from among the structures c',
- 20 d', e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, aa, bb, cc, dd, ee, ff, gg, hh, ii, jj, kk, ll, and mm above, wherein R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, X, and Y are defined in the Summary of the Invention section above.

- The first aspect of the fifth embodiment is directed to a compound represented by formula I in which the Base is a structure selected from among the
- 25 structures c', d', e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, aa, bb, cc, dd, ee, ff, gg, hh, ii, jj, kk, ll, and mm above,

wherein

- (a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are

optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>,  
 5 halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>,  
 10 CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, or F; and

(d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an  
 15 optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in  
 20 which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

The second aspect of the fifth embodiment is directed to a compound represented by formula I in which the Base is a structure selected from among the structures c', d', e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, aa, bb, cc, dd,  
 25 ee, ff, gg, hh, ii, jj, kk, ll, and mm above,

wherein

(a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>,

NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I),  
 halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as  
 C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>,  
 halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR',  
 5 CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including  
 OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including  
 hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>,  
 CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I

10 (c) R<sup>3</sup> is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, or F; and

(d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>;

wherein R' is an optionally substituted alkyl, an optionally substituted  
 cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an  
 optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the  
 15 instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent  
 of one another or are joined to form a heterocycle comprising at least two carbon  
 atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom  
 which are independent of one another or each R' comprises at least one C atom in  
 which at least two R' are joined to form a heterocycle comprising at least two carbon  
 20 atoms.

The third aspect of fifth embodiment is directed to a compound represented  
 by formula I in which the Base is a structure selected from among the structures c',  
 d', e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, aa, bb, cc, dd, ee, ff, gg, hh,  
 ii, jj, kk, ll, and mm above,

25 wherein

(a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which  
 includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are  
 optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>,  
 NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I),

halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

- 5 (b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I

(c) R<sup>3</sup> is CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>; and

- 10 (d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

- 20 The fourth aspect of fifth embodiment is directed to a compound represented by formula I in which the Base is a structure selected from among the structures c', d', e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, aa, bb, cc, dd, ee, ff, gg, hh, ii, jj, kk, ll, and mm above,

wherein

- 25 (a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as

C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R;

- (b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including  
 5 OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1 -6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>; and

(d) X is F;

- 10 wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon  
 15 atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

- The fifth aspect of the fifth embodiment is directed to a compound  
 20 represented by formula I in which the Base is a structure selected from among the structures c', d', e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, aa, bb, cc, dd, ee, ff, gg, hh, ii, jj, kk, ll, and mm above,

wherein

- (a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which  
 25 includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>,

halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b) R<sup>2</sup> is H, -CH<sub>3</sub>, cyano (CN), vinyl, -OCH<sub>3</sub>, -CH<sub>2</sub>OH, -CH<sub>2</sub>F, azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

5 (c) R<sup>3</sup> is CH<sub>3</sub>; and

(d) X is F;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the  
 10 instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon  
 15 atoms.

The sixth aspect of the fifth embodiment is directed to a compound represented by formula I in which the Base is a structure selected from among the structures c', d', e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, aa, bb, cc, dd, ee, ff, gg, hh, ii, jj, kk, ll, and mm above,

20 wherein

(a) R<sup>1</sup> is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower  
 25 alkoxy of C<sub>1</sub>-C<sub>6</sub>;

(b) R<sup>2</sup> is H, -CH<sub>3</sub>, cyano (CN), vinyl, -OCH<sub>3</sub>, -CH<sub>2</sub>OH, -CH<sub>2</sub>F, azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is CH<sub>3</sub>; and

(d) X is F;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

The seventh aspect of the fifth embodiment is directed to a compound represented by formula I in which the Base is a structure selected from among the structures c', d', e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, aa, bb, cc, dd, ee, ff, gg, hh, ii, jj, kk, ll, and mm above,

wherein

(a) R<sup>1</sup> is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>;

(b) R<sup>2</sup> is H;

(c) R<sup>3</sup> is CH<sub>3</sub>; and

(d) X is F;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom

which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

A sixth embodiment of the invention is directed to a compound represented  
 5 by formula I in which the Base is a structure selected from among the structures ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am, an, ao, ap, aq, ar, as, at, av, au, ax, ay, az, ba, bc, bd, be, bf, bg, bh, bi, bj, and bk, depicted above, wherein R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, X, and Y are defined in the Summary of the Invention section above.

The first aspect of the sixth embodiment is directed to a compound  
 10 represented by formula I in which the Base is a structure selected from among the structures ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am, an, ao, ap, aq, ar, as, at, av, au, ax, ay, az, ba, bc, bd, be, bf, bg, bh, bi, bj, and bk, depicted above,

wherein

(a) R<sup>1</sup> is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which  
 15 includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>,  
 20 halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

(b) R<sup>2</sup> is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including  
 OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1-6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>,  
 25 CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I;

(c) R<sup>3</sup> is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, or F; and

(d) X is H, OH, F, OMe, NH<sub>2</sub>, or N<sub>3</sub>;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an

optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $\text{NR}'_2$  or  $\text{NHR}'_2^+$  each  $\text{R}'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon atoms.

The second aspect of the sixth embodiment is directed to a compound represented by formula I in which the Base is a structure selected from among the structures ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am, an, ao, ap, aq, ar, as, at, av, au, ax, ay, az, ba, bc, bd, be, bf, bg, bh, bi, bj, and bk, depicted above,

wherein

(a)  $\text{R}^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH,  $\text{OR}'$ , SH,  $\text{SR}'$ ,  $\text{NH}_2$ ,  $\text{NHR}'$ ,  $\text{NR}'_2$ ,  $\text{NHR}'_2^+$ ,  $\text{NR}'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of  $\text{C}_2\text{-C}_6$ , lower alkynyl of  $\text{C}_2\text{-C}_6$  such as  $\text{C}\equiv\text{CH}$ , halogenated (F, Cl, Br, I) lower alkynyl of  $\text{C}_2\text{-C}_6$ , lower alkoxy of  $\text{C}_1\text{-C}_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $\text{C}_1\text{-C}_6$ ,  $\text{CO}_2\text{H}$ ,  $\text{CO}_2\text{R}'$ ,  $\text{CONH}_2$ ,  $\text{CONHR}'$ ,  $\text{CONR}'_2$ ,  $\text{CH}=\text{CHCO}_2\text{H}$ , or  $\text{CH}=\text{CHCO}_2\text{R}'$ ;

(b)  $\text{R}^2$  is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including  $\text{OCH}_3$ ,  $\text{OCH}_2\text{CH}_3$ , hydroxyl lower alkyl, i.e.,  $-(\text{CH}_2)_p\text{OH}$ , where p is 1 -6, including hydroxyl methyl ( $\text{CH}_2\text{OH}$ ), fluoromethyl ( $\text{CH}_2\text{F}$ ), azido ( $\text{N}_3$ ),  $\text{CH}_2\text{CN}$ ,  $\text{CH}_2\text{N}_3$ ,  $\text{CH}_2\text{NH}_2$ ,  $\text{CH}_2\text{NHCH}_3$ ,  $\text{CH}_2\text{N}(\text{CH}_3)_2$ , F, Cl, Br, or I;

(c)  $\text{R}^3$  is H,  $\text{CH}_3$ ,  $\text{CH}_2\text{F}$ ,  $\text{CHF}_2$ ,  $\text{CF}_3$ , or F; and

(d) X is H, OH, F, OMe,  $\text{NH}_2$ , or  $\text{N}_3$ ;

wherein  $\text{R}'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the

instance of  $\text{NR}'_2$  or  $\text{NHR}'_2^+$  each  $\text{R}'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in  
 5 which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon atoms.

The third aspect of sixth embodiment is directed to a compound represented by formula I in which the Base is a structure selected from among the structures ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am, an, ao, ap, aq, ar, as, at, av, au, ax, ay, az, ba,  
 10 bc, bd, be, bf, bg, bh, bi, bj, and bk, depicted above,

wherein

- (a)  $\text{R}^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH,  $\text{OR}'$ , SH,  $\text{SR}'$ ,  $\text{NH}_2$ ,  
 15  $\text{NHR}'$ ,  $\text{NR}'_2$ ,  $\text{NHR}'_2^+$ ,  $\text{NR}'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of  $\text{C}_2\text{-C}_6$ , lower alkynyl of  $\text{C}_2\text{-C}_6$  such as  $\text{C}\equiv\text{CH}$ , halogenated (F, Cl, Br, I) lower alkynyl of  $\text{C}_2\text{-C}_6$ , lower alkoxy of  $\text{C}_1\text{-C}_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $\text{C}_1\text{-C}_6$ ,  $\text{CO}_2\text{H}$ ,  $\text{CO}_2\text{R}'$ ,  $\text{CONH}_2$ ,  $\text{CONHR}'$ ,  $\text{CONR}'_2$ ,  $\text{CH}=\text{CHCO}_2\text{H}$ , or  $\text{CH}=\text{CHCO}_2\text{R}'$ ;
- 20 (b)  $\text{R}^2$  is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including  $\text{OCH}_3$ ,  $\text{OCH}_2\text{CH}_3$ , hydroxyl lower alkyl, i.e.,  $-(\text{CH}_2)_p\text{OH}$ , where p is 1-6, including hydroxyl methyl ( $\text{CH}_2\text{OH}$ ), fluoromethyl ( $\text{CH}_2\text{F}$ ), azido ( $\text{N}_3$ ),  $\text{CH}_2\text{CN}$ ,  $\text{CH}_2\text{N}_3$ ,  $\text{CH}_2\text{NH}_2$ ,  $\text{CH}_2\text{NHCH}_3$ ,  $\text{CH}_2\text{N}(\text{CH}_3)_2$ , F, Cl, Br, or I;
- (c)  $\text{R}^3$  is  $\text{CH}_3$ ,  $\text{CH}_2\text{F}$ ,  $\text{CHF}_2$ ,  $\text{CF}_3$ ; and
- 25 (d) X is H, OH, F, OMe,  $\text{NH}_2$ , or  $\text{N}_3$ ;

wherein  $\text{R}'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $\text{NR}'_2$  or  $\text{NHR}'_2^+$  each  $\text{R}'$  comprise at least one C atom that is independent

of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon atoms.

The fourth aspect of sixth embodiment is directed to a compound represented by formula I in which the Base is a structure selected from among the structures ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am, an, ao, ap, aq, ar, as, at, av, au, ax, ay, az, ba, bc, bd, be, bf, bg, bh, bi, bj, and bk, depicted above,

wherein

(a)  $\text{R}^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH,  $\text{OR}'$ , SH,  $\text{SR}'$ ,  $\text{NH}_2$ ,  $\text{NHR}'$ ,  $\text{NR}'_2$ ,  $\text{NHR}'_2^+$ ,  $\text{NR}'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of  $\text{C}_2\text{-C}_6$ , lower alkynyl of  $\text{C}_2\text{-C}_6$  such as  $\text{C}\equiv\text{CH}$ , halogenated (F, Cl, Br, I) lower alkynyl of  $\text{C}_2\text{-C}_6$ , lower alkoxy of  $\text{C}_1\text{-C}_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $\text{C}_1\text{-C}_6$ ,  $\text{CO}_2\text{H}$ ,  $\text{CO}_2\text{R}'$ ,  $\text{CONH}_2$ ,  $\text{CONHR}'$ ,  $\text{CONR}'_2$ ,  $\text{CH}=\text{CHCO}_2\text{H}$ , or  $\text{CH}=\text{CHCO}_2\text{R}'$ ;

(b)  $\text{R}^2$  is H, a lower alkyl, cyano (CN), vinyl, O-(lower alkyl), including  $\text{OCH}_3$ ,  $\text{OCH}_2\text{CH}_3$ , hydroxyl lower alkyl, i.e.,  $-(\text{CH}_2)_p\text{OH}$ , where p is 1 -6, including hydroxyl methyl ( $\text{CH}_2\text{OH}$ ), fluoromethyl ( $\text{CH}_2\text{F}$ ), azido ( $\text{N}_3$ ),  $\text{CH}_2\text{CN}$ ,  $\text{CH}_2\text{N}_3$ ,  $\text{CH}_2\text{NH}_2$ ,  $\text{CH}_2\text{NHCH}_3$ ,  $\text{CH}_2\text{N}(\text{CH}_3)_2$ , F, Cl, Br, or I;

(c)  $\text{R}^3$  is  $\text{CH}_3$ ,  $\text{CH}_2\text{F}$ ,  $\text{CHF}_2$ ,  $\text{CF}_3$ ; and

(d) X is F;

wherein  $\text{R}'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of  $\text{NR}'_2$  or  $\text{NHR}'_2^+$  each  $\text{R}'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon

atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon atoms.

- 5           The fifth aspect of the sixth embodiment is directed to a compound represented by formula I in which the Base is a structure selected from among the structures ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am, an, ao, ap, aq, ar, as, at, av, au, ax, ay, az, ba, bc, bd, be, bf, bg, bh, bi, bj, and bk, depicted above,

wherein

- 10           (a)  $\text{R}^1$  is H, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH,  $\text{OR}'$ , SH,  $\text{SR}'$ ,  $\text{NH}_2$ ,  $\text{NHR}'$ ,  $\text{NR}'_2$ ,  $\text{NHR}'_2^+$ ,  $\text{NR}'_3^+$ , heterocycle, lower alkyl, halogenated (F, Cl, Br, I), halogenated (F, Cl, Br, I) lower alkenyl of  $\text{C}_2\text{-C}_6$ , lower alkynyl of  $\text{C}_2\text{-C}_6$  such as
- 15  $\text{C}\equiv\text{CH}$ , halogenated (F, Cl, Br, I) lower alkynyl of  $\text{C}_2\text{-C}_6$ , lower alkoxy of  $\text{C}_1\text{-C}_6$ , halogenated (F, Cl, Br, I) lower alkoxy of  $\text{C}_1\text{-C}_6$ ,  $\text{CO}_2\text{H}$ ,  $\text{CO}_2\text{R}'$ ,  $\text{CONH}_2$ ,  $\text{CONHR}'$ ,  $\text{CONR}'_2$ ,  $\text{CH=CHCO}_2\text{H}$ , or  $\text{CH=CHCO}_2\text{R}'$ ;
- (b)  $\text{R}^2$  is H,  $-\text{CH}_3$ , cyano (CN), vinyl,  $-\text{OCH}_3$ ,  $-\text{CH}_2\text{OH}$ ,  $-\text{CH}_2\text{F}$ , azido ( $\text{N}_3$ ),  $\text{CH}_2\text{CN}$ ,  $\text{CH}_2\text{N}_3$ ,  $\text{CH}_2\text{NH}_2$ ,  $\text{CH}_2\text{NHCH}_3$ ,  $\text{CH}_2\text{N}(\text{CH}_3)_2$ , F, Cl, Br, or I;
- 20           (c)  $\text{R}^3$  is  $\text{CH}_3$ ; and
- (d) X is F;

wherein  $\text{R}'$  is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the

25 instance of  $\text{NR}'_2$  or  $\text{NHR}'_2^+$  each  $\text{R}'$  comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in

which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

The sixth aspect of the sixth embodiment is directed to a compound represented by formula I in which the Base is a structure selected from among the  
5 structures ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am, an, ao, ap, aq, ar, as, at, av, au, ax, ay, az, ba, bc, bd, be, bf, bg, bh, bi, bj, and bk, depicted above,

wherein

(a) R<sup>1</sup> is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally  
10 substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>;

(b) R<sup>2</sup> is H, -CH<sub>3</sub>, cyano (CN), vinyl, -OCH<sub>3</sub>, -CH<sub>2</sub>OH, -CH<sub>2</sub>F, azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, F, Cl, Br, or I

15 (c) R<sup>3</sup> is CH<sub>3</sub>; and

(d) X is F;

wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the  
20 instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon  
25 atoms.

The seventh aspect of the sixth embodiment is directed to a compound represented by formula I in which the Base is a structure selected from among the structures ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am, an, ao, ap, aq, ar, as, at, av, au, ax, ay, az, ba, bc, bd, be, bf, bg, bh, bi, bj, and bk, depicted above,

wherein

- (a)  $R^1$  is H, lower alkyl, lower alkylaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>,  
 5 NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>;

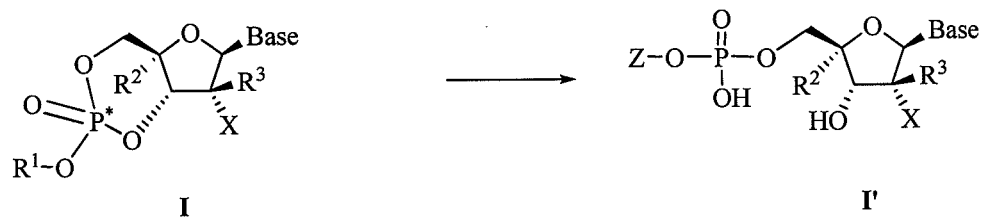
(b)  $R^2$  is H;

(c)  $R^3$  is CH<sub>3</sub>; and

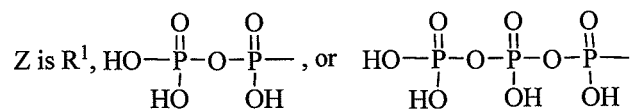
(d) X is F;

- 10 wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent of one another or are joined to form a heterocycle comprising at least two carbon  
 15 atoms, and where for the instance of NR'<sub>3</sub><sup>+</sup> each R' comprises at least one C atom which are independent of one another or each R' comprises at least one C atom in which at least two R' are joined to form a heterocycle comprising at least two carbon atoms.

- A seventh embodiment of the present invention is directed to a compound  
 20 represented by formula I' its stereoisomers, salts, pharmaceutically acceptable salts, hydrates, solvates, crystalline, or metabolite forms thereof obtained by hydrolysis of the compound represented by formula I, followed by subsequent phosphorylation of the resultant hydrolysis product of the compound of formula I':



- 25 wherein



where  $R^7$  is as defined herein above.

### DOSAGE, ADMINISTRATION, AND USE

An eighth embodiment of the present invention is directed to a composition for the treatment of any of the viral agents disclosed herein said composition comprising a pharmaceutically acceptable medium selected from among an excipient, carrier, diluent, or equivalent medium and a compound, that is intended to include its salts (acid or basic addition salts), hydrates, solvates, and crystalline forms can be obtained, represented by formula I.

It is contemplated that the formulation of the eighth embodiment can contain any of the compounds contemplated in any of the aspects of the first, second, third, fourth, fifth, sixth, and seventh embodiments either alone or in combination with another compound of the present invention.

The compounds of the present invention may be formulated in a wide variety of oral administration dosage forms and carriers. Oral administration can be in the form of tablets, coated tablets, hard and soft gelatin capsules, solutions, emulsions, syrups, or suspensions. Compounds of the present invention are efficacious when administered by suppository administration, among other routes of administration. The most convenient manner of administration is generally oral using a convenient daily dosing regimen which can be adjusted according to the severity of the disease and the patient's response to the antiviral medication.

A compound or compounds of the present invention, as well as their pharmaceutically acceptable salts, together with one or more conventional excipients, carriers, or diluents, may be placed into the form of pharmaceutical compositions and unit dosages. The pharmaceutical compositions and unit dosage forms may be comprised of conventional ingredients in conventional proportions, with or without additional active compounds and the unit dosage forms may contain any suitable effective amount of the active ingredient commensurate with the intended daily dosage range to be employed. The pharmaceutical compositions may

be employed as solids, such as tablets or filled capsules, semisolids, powders, sustained release formulations, or liquids such as suspensions, emulsions, or filled capsules for oral use; or in the form of suppositories for rectal or vaginal administration. A typical preparation will contain from about 5% to about 95%  
5 active compound or compounds (w/w). The term "preparation" or "dosage form" is intended to include both solid and liquid formulations of the active compound and one skilled in the art will appreciate that an active ingredient can exist in different preparations depending on the desired dose and pharmacokinetic parameters.

The term "excipient" as used herein refers to a compound that is used to  
10 prepare a pharmaceutical composition, and is generally safe, non-toxic and neither biologically nor otherwise undesirable, and includes excipients that are acceptable for veterinary use as well as human pharmaceutical use. The compounds of this invention can be administered alone but will generally be administered in admixture with one or more suitable pharmaceutical excipients, diluents or carriers selected  
15 with regard to the intended route of administration and standard pharmaceutical practice.

A "pharmaceutically acceptable salt" form of an active ingredient may also initially confer a desirable pharmacokinetic property on the active ingredient which were absent in the non-salt form, and may even positively affect the  
20 pharmacodynamics of the active ingredient with respect to its therapeutic activity in the body. The phrase "pharmaceutically acceptable salt" of a compound as used herein means a salt that is pharmaceutically acceptable and that possesses the desired pharmacological activity of the parent compound. Such salts include: (1) acid addition salts, formed with inorganic acids such as hydrochloric acid,  
25 hydrobromic acid, sulfuric acid, nitric acid, phosphoric acid, and the like; or formed with organic acids such as glycolic acid, pyruvic acid, lactic acid, malonic acid, malic acid, maleic acid, fumaric acid, tartaric acid, citric acid, 3-(4-hydroxybenzoyl)benzoic acid, cinnamic acid, mandelic acid, methanesulfonic acid, ethanesulfonic acid, 1,2-ethane-disulfonic acid, 2-hydroxyethanesulfonic acid,  
30 benzenesulfonic acid, 4-chlorobenzenesulfonic acid, 2-naphthalenesulfonic acid, 4-toluenesulfonic acid, camphorsulfonic acid, lauryl sulfuric acid, gluconic acid, glutamic acid, salicylic acid, muconic acid, and the like or (2) basic addition salts

formed with the conjugate bases of any of the inorganic acids listed above, wherein the conjugate bases comprise a cationic component selected from among  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{NH}_g\text{R}^{g+}$ , in which  $\text{R}^g$  is a  $\text{C}_{1-3}$  alkyl and  $g$  is a number selected from among 0, 1, 2, 3, or 4. It should be understood that all references to

- 5 pharmaceutically acceptable salts include solvent addition forms (solvates) or crystal forms (polymorphs) as defined herein, of the same acid addition salt.

Solid form preparations include, for example, powders, tablets, pills, capsules, suppositories, and dispersible granules. A solid carrier may be one or more substances which may also act as diluents, flavoring agents, solubilizers, lubricants, suspending agents, binders, preservatives, tablet disintegrating agents, or an encapsulating material. In powders, the carrier generally is a finely divided solid which is a mixture with the finely divided active component. In tablets, the active component generally is mixed with the carrier having the necessary binding capacity in suitable proportions and compacted in the shape and size desired. Suitable carriers include but are not limited to magnesium carbonate, magnesium stearate, talc, sugar, lactose, pectin, dextrin, starch, gelatin, tragacanth, methylcellulose, sodium carboxymethylcellulose, a low melting wax, cocoa butter, and the like. Solid form preparations may contain, in addition to the active component, colorants, flavors, stabilizers, buffers, artificial and natural sweeteners, dispersants, thickeners, solubilizing agents, and the like. Examples of solid formulations are exemplified in EP 0524579; US 6,635,278; US 2007/0099902; US 7,060,294; US 2006/0188570; US 2007/0077295; US 2004/0224917; US 7,462,608; US 2006/0057196; US 6,267,985; US 6,294,192; US 6,569,463; US 6,923,988; US 2006/0034937; US 6,383,471; US 6,395,300; US 6,645,528; US 6,932,983; US 2002/0142050; US 2005/0048116; US 2005/0058710; US 2007/0026073; US 2007/0059360; and US 2008/0014228, each of which is incorporated by reference.

Liquid formulations also are suitable for oral administration include liquid formulation including emulsions, syrups, elixirs and aqueous suspensions. These include solid form preparations which are intended to be converted to liquid form preparations shortly before use. Examples of liquid formulation are exemplified in U.S. Patent Nos. 3,994,974; 5,695,784; and 6,977,257. Emulsions may be prepared in solutions, for example, in aqueous propylene glycol solutions or may contain

emulsifying agents such as lecithin, sorbitan monooleate, or acacia. Aqueous suspensions can be prepared by dispersing the finely divided active component in water with viscous material, such as natural or synthetic gums, resins, methylcellulose, sodium carboxymethylcellulose, and other well known suspending agents.

The compounds of the present invention may be formulated for administration as suppositories. A low melting wax, such as a mixture of fatty acid glycerides or cocoa butter is first melted and the active component is dispersed homogeneously, for example, by stirring. The molten homogeneous mixture is then poured into convenient sized molds, allowed to cool, and to solidify.

The compounds of the present invention may be formulated for vaginal administration. Pessaries, tampons, creams, gels, pastes, foams or sprays containing in addition to the active ingredient such carriers as are known in the art to be appropriate.

Suitable formulations along with pharmaceutical carriers, diluents and excipients are described in *Remington: The Science and Practice of Pharmacy 1995*, edited by E. W. Martin, Mack Publishing Company, 19th edition, Easton, Pennsylvania, which is hereby incorporated by reference. A skilled formulation scientist may modify the formulations within the teachings of the specification to provide numerous formulations for a particular route of administration without rendering the compositions of the present invention unstable or compromising their therapeutic activity.

The modification of the present compounds to render them more soluble in water or other vehicle, for example, may be easily accomplished by minor modifications (e.g., salt formulation), which are well within the ordinary skill in the art. It is also well within the ordinary skill of the art to modify the route of administration and dosage regimen of a particular compound in order to manage the pharmacokinetics of the present compounds for maximum beneficial effect in patients.

Additionally, the compound of formula I may be independently formulated in conjunction with liposomes or micelles. As to liposomes, it is contemplated that

the purified compounds can be formulated in a manner as disclosed in U.S. Patent Nos. 5,013,556; U.S. 5,213,804; 5,225,212; 5,891,468; 6,224,903; 6,180,134; 5,192,549; 5,316,771; 4,797,285; 5,376,380; 6,060,080; 6,132,763; 6,653,455; 6,680,068; 7,060,689; 7,070,801; 5,077,057; 5,277,914; 5,549,910; 5,567,434; 5,077,056; 5,154,930; 5,736,155; 5,827,533; 5,882,679; 6,143,321; 6,200,598; 6,296,870; 6,726,925; and 6,214,375, each of which is incorporated by reference. As to micelles, it is contemplated that the purified compounds can be formulated in a manner as disclosed in U.S. Patent Nos. 5,145,684 and 5,091,188, both of which are incorporated by reference.

10 A ninth embodiment of the present invention is directed to a use of the compound represented by formula I in the manufacture of a medicament for the treatment of any condition the result of an infection by any one of the following viral agents: hepatitis C virus, West Nile virus, yellow fever virus, dengue virus, rhinovirus, polio virus, hepatitis A virus, bovine viral diarrhea virus and Japanese encephalitis virus.

The term "medicament" means a substance used in a method of treatment and/or prophylaxis of a subject in need thereof, wherein the substance includes, but is not limited to, a composition, a formulation, a dosage form, and the like, comprising the compound of formula I. It is contemplated that the compound of the use of the compound represented by formula I in the manufacture of a medicament for the treatment of any of the antiviral conditions disclosed herein of the ninth embodiment can be any of the compounds contemplated in any of the aspects of the first, second, third, fourth, fifth, sixth, and seventh embodiments or those specifically exemplified, either alone or in combination with another compound of the present invention. A medicament includes, but is not limited to, any one of the compositions contemplated by the eighth embodiment of the present invention.

A tenth embodiment of the present invention is directed to a method of treatment and/or prophylaxis in a subject in need thereof said method comprises administering a therapeutically effective amount of the compound represented by formula I to the subject.

A first aspect of the tenth embodiment is directed to a method of treatment and/or prophylaxis in a subject in need thereof said method comprises administering a therapeutically effective of at least two compounds falling within the scope of the compound represented by formula I to the subject.

- 5           A second aspect of the tenth embodiment is directed to a method of treatment and/or prophylaxis in a subject in need thereof said method comprises alternatively or concurrently administering a therapeutically effective of at least two compounds falling within the scope of the compound represented by formula I to the subject.

- 10           It is intended that a subject in need thereof is one that has any condition the result of an infection by any of the viral agents disclosed herein, which includes, but is not limited to, hepatitis C virus, West Nile virus, yellow fever virus, degue virus, rhinovirus, polio virus, hepatitis A virus, bovine viral diarrhea virus or Japanese encephalitis virus, flaviviridae viruses or pestiviruses or hepaciviruses or a viral agent causing symptoms equivalent or comparable to any of the above-listed viruses.

- 15           The term "subject" means a mammal, which includes, but is not limited to, cattle, pigs, sheep, chicken, turkey, buffalo, llama, ostrich, dogs, cats, and humans, preferably the subject is a human. It is contemplated that in the method of treating a subject thereof of the tenth embodiment can be any of the compounds contemplated in any of the aspects of the first, second, third, fourth, fifth, sixth, and seventh  
20           embodiments or those specifically recited in the tables above, either alone or in combination with another compound of the present invention.

- The term "therapeutically effective amount" as used herein means an amount required to reduce symptoms of the disease in an individual. The dose will be adjusted to the individual requirements in each particular case. That dosage can  
25           vary within wide limits depending upon numerous factors such as the severity of the disease to be treated, the age and general health condition of the patient, other medicaments with which the patient is being treated, the route and form of administration and the preferences and experience of the medical practitioner involved. For oral administration, a daily dosage of between about 0.001 and about  
30           10 g, including all values in between, such as 0.001, 0.0025, 0.005, 0.0075, 0.01, 0.025, 0.050, 0.075, 0.1, 0.125, 0.150, 0.175, 0.2, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3,

3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, and 9.5, per day should be appropriate in monotherapy and/or in combination therapy. A particular daily dosage is between about 0.01 and about 1 g per day, including all incremental values of 0.01 g (i.e., 10 mg) in between, a preferred daily dosage about 0.01 and about 0.8 g per day, more preferably about 0.01 and about 0.6 g per day, and most preferably about 0.01 and about 0.25 g per day, each of which including all incremental values of 0.01 g in between. Generally, treatment is initiated with a large initial "loading dose" to rapidly reduce or eliminate the virus following by a decreasing the dose to a level sufficient to prevent resurgence of the infection. One of ordinary skill in treating diseases described herein will be able, without undue experimentation and in reliance on personal knowledge, experience and the disclosures of this application, to ascertain a therapeutically effective amount of the compounds of the present invention for a given disease and patient.

Therapeutic efficacy can be ascertained from tests of liver function including, but not limited to protein levels such as serum proteins (e.g., albumin, clotting factors, alkaline phosphatase, aminotransferases (e.g., alanine transaminase, aspartate transaminase), 5'-nucleosidase,  $\gamma$ -glutamyltranspeptidase, etc.), synthesis of bilirubin, synthesis of cholesterol, and synthesis of bile acids; a liver metabolic function, including, but not limited to, carbohydrate metabolism, amino acid and ammonia metabolism. Alternatively the therapeutic effectiveness may be monitored by measuring HCV-RNA. The results of these tests will allow the dose to be optimized.

A third aspect of the tenth embodiment, to a method of treatment and/or prophylaxis in a subject in need thereof said method comprises administering to the subject a therapeutically effective of a compound represented by formula I and a therapeutically effective amount of another antiviral agent; wherein the administration is concurrent or alternative. It is understood that the time between alternative administration can range between 1-24 hours, which includes any sub-range in between including, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, and 23 hours. Examples of "another antiviral agent" include, but are not limited to: HCV NS3 protease inhibitors (see WO 2008010921, WO 2008010921, EP 1881001, WO 2007015824, WO 2007014925, WO 2007014926,

WO 2007014921, WO 2007014920, WO 2007014922, US 2005267018, WO  
2005095403, WO 2005037214, WO 2004094452, US 2003187018, WO  
200364456, WO 2005028502, and WO 2003006490); HCV NS5B Inhibitors (see  
US 2007275947, US20072759300, WO2007095269, WO 2007092000, WO  
5 2007076034, WO 200702602, US 2005-98125, WO 2006093801, US 2006166964,  
WO 2006065590, WO 2006065335, US 2006040927, US 2006040890, WO  
2006020082, WO 2006012078, WO 2005123087, US 2005154056, US  
2004229840, WO 2004065367, WO 2004003138, WO 2004002977, WO  
2004002944, WO 2004002940, WO 2004000858, WO 2003105770, WO  
10 2003010141, WO 2002057425, WO 2002057287, WO 2005021568, WO  
2004041201, US 20060293306, US 20060194749, US 20060241064, US 6784166,  
WO 2007088148, WO 2007039142, WO 2005103045, WO 2007039145, WO  
2004096210, and WO 2003037895); HCV NS4 Inhibitors (see WO 2007070556 and  
WO 2005067900); HCV NS5a Inhibitors (see US 2006276511, WO 2006120252,  
15 WO 2006120251, WO 2006100310, WO 2006035061); Toll-like receptor agonists  
(see WO 2007093901); and other inhibitors (see WO 2004035571, WO  
2004014852, WO 2004014313, WO 2004009020, WO 2003101993, WO  
2000006529).

A fourth aspect of the tenth embodiment, to a method of treatment and/or  
20 prophylaxis in a subject in need thereof said method comprises alternatively or  
concurrently administering a therapeutically effective of a compound represented by  
formula I and another antiviral agent to the subject. It is understood that the time  
between alternative administration can range between 1-24 hours, which includes  
any sub-range in between including, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16,  
25 17, 18, 19, 20, 21, 22, and 23 hours.

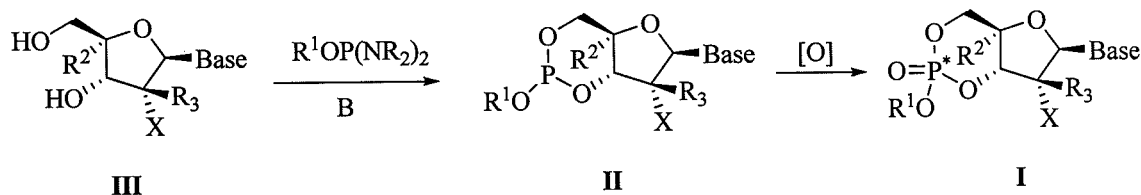
It is contemplated that the another antiviral agent such as interferon- $\alpha$  ,  
interferon- $\beta$ , pegylated interferon- $\alpha$ , ribavirin, levovirin, viremagine, another  
nucleoside HCV polymerase inhibitor, a HCV non-nucleoside polymerase inhibitor,  
a HCV protease inhibitor, a HCV helicase inhibitor or a HCV fusion inhibitor.  
30 When the active compound or its derivative or salt are administered in combination  
with another antiviral agent the activity may be increased over the parent compound.  
When the treatment is combination therapy, such administration may be concurrent

or sequential with respect to that of the nucleoside derivatives. "Concurrent administration" as used herein thus includes administration of the agents at the same time or at different times. Administration of two or more agents at the same time can be achieved by a single formulation containing two or more active ingredients or  
 5 by substantially simultaneous administration of two or more dosage forms with a single active agent.

It will be understood that references herein to treatment extend to prophylaxis as well as to the treatment of existing conditions. Furthermore, the term "treatment" of a HCV infection, as used herein, also includes treatment or  
 10 prophylaxis of a disease or a condition associated with or mediated by HCV infection, or the clinical symptoms thereof.

An eleventh embodiment of the present invention is directed to a process for preparing the compound of formula **I**, which comprises reacting **III** with  $R^1OP(NR_2)_2$ , and then oxidizing **II** to form **I** according to the following scheme

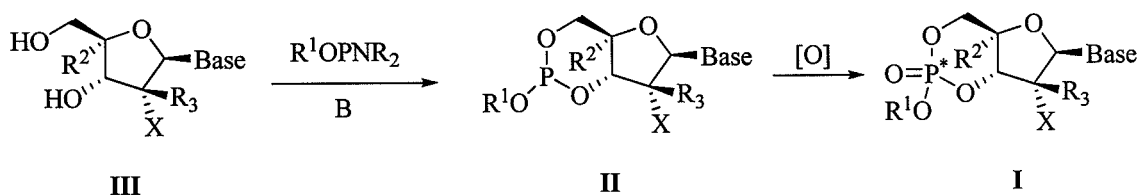
15



wherein  $R^1$ ,  $R^2$ ,  $R^3$ ,  $X$ , and Base are defined above;

wherein  $R^1OP(NR_2)_2$  is a dialkylamino- $R^1$ phosphite, **B** is a Brønsted base,  
 20 and  $[O]$  is an oxidant, such as, for example, m-chloroperbenzoic acid (MCPBA), hydrogen peroxide,  $NO_2/N_2O_4$ , etc.

A twelfth embodiment of the present invention is directed to a product, **I**, prepared by a process which comprises reacting **III** with  $R^1OP(NR_2)_2$ , and then oxidizing **II** according to the following scheme



wherein  $R^1$ ,  $R^2$ ,  $R^3$ ,  $X$ , and Base are defined above;

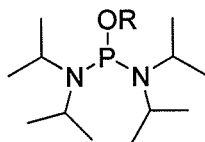
- 5            wherein  $R^1OP(NR_2)_2$  is a dialkylamino-alkylphosphite, B is a Brönsted base, and [O] is an oxidant, such as, for example, m-chloroperbenzoic acid (MCPBA), hydrogen peroxide,  $NO_2/N_2O_4$ , etc.

### **Compounds and Preparation**

- The nucleoside analog is made by conventional procedures disclosed in any one of U.S. Published Application Nos. 2005/0009737, 2006/0199783, 2006/0122146, and 2007/0197463, each of which is incorporated by reference in its entirety. Bases represented by the structures c', d', e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, aa, bb, cc, dd, ee, ff, gg, hh, ii, jj, kk, ll, and mm are prepared and coupled to a given sugar using methods known in the art, such as, for example, as disclosed in WO 2006/094347, WO 2005/021568, US 2006/0252715, and US 2006/0194749, each of which is incorporated by reference in its entirety. Bases represented by the structures formula I in which the Base is a structure selected from among the structures ab, ac, ad, ae, af, ag, ah, ai, aj, ak, al, am, an, ao, ap, aq, ar, as, at, av, au, ax, ay, az, ba, bc, bd, be, bf, bg, bh, bi, bj, and bk, depicted above, are prepared and coupled to a given sugar using methods known in the art, such as, for example, as disclosed in WO 2007/027248 which is incorporated by reference in its entirety.

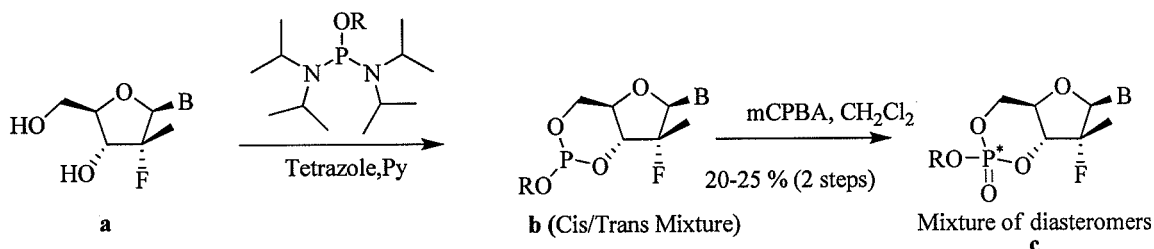
- Disclosed  $^1H$ -NMR values were recorded on a Varian AS-400 instrument. Mass spectral data were obtained using either a Micromass-Quattro micro API or a Waters Acquity.

### **General Experimental Procedure for the Preparation of bis(*N,N'*-diisopropylamino) alkylphosphite:**



The alcohol (1.0 equiv) was added drop-wise to phosphorous trichloride (1.0 equiv) very slowly, while stirring. The inner temperature of the reaction flask was kept between 20 and 30°C, and the produced hydrochloric acid was absorbed in a gas trap containing aqueous sodium bicarbonate. The residue was distilled under reduced pressure to give pure alkoxydichlorophosphine. This compound was added to a stirred solution of *N,N*-diisopropylamine (6.0 equiv) in dry ether (5mL/mmol) drop-wise, very slowly at 0°C. After completion of the addition the mixture was allowed to warm to room temperature at which temperature it was stirred over night. The ammonium salt was removed by filtration, and the filtrate was concentrated. The residue was distilled under reduced pressure to give bis(*N,N*-diisopropylamino)alkylphosphite as a colorless liquid (10-40 %). (See, e.g., N. L. H. L. Breeders *et. al. J. Am. Chem. Soc.* **1990**, *112*, 1415-1482)

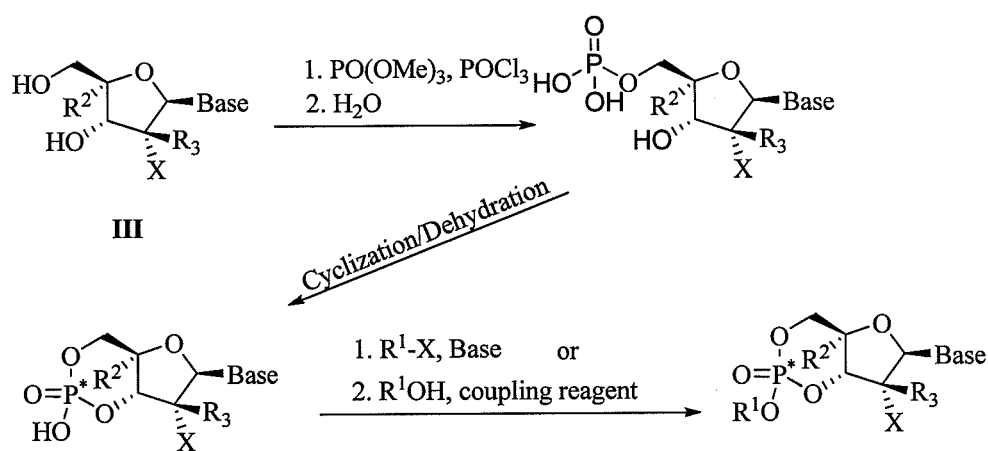
#### General Method for the Preparation of 3',5'-Cyclic Phosphates



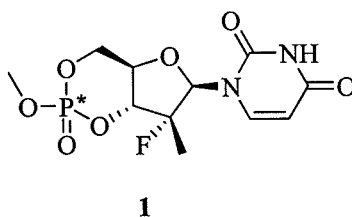
**General Experimental Procedure:** To a stirred solution of 3',5'-dihydroxy nucleoside **a** (1.0 equiv) in dry pyridine (5 mL/mmol) is added a 0.45M solution of tetrazole in acetonitrile (2.5 equiv) followed by bis(*N,N*-diisopropylamino)alkylphosphite (1.0 equiv) at room temperature. After stirring the mixture at room temperature for 2h, TLC indicates the disappearance of starting material **A** and formation of two non-polar products. The reaction mixture is concentrated under reduced pressure at room temperature and the residue is triturated with EtOAc (10 mL/mmol). The precipitated tetrazole salts are removed by filtration and the filtrate is concentrated under reduced pressure. The residue is chromatographed to give cis and trans cyclicphosphites **b** in about 1:1 ratio.

To a stirred solution of the phosphate **b** (1 equiv) in dichloromethane (10 mL/mmol) is added a 77% m-CPBA (1.2 equiv) at room temperature. After 5 min, the TLC indicates the completion of the reaction. Solvent is evaporated and the residue is chromatographed using a short silica gel column to give pure product as a white solid (20-25 % overall yield, 2 steps). <sup>1</sup>H NMR indicates that the product **c** is a mixture of two diastereomers.

These cyclic phosphates can also be prepared via an alternate route described below. Nucleoside **III** can be reacted with POCl<sub>3</sub> to produce the nucleoside mono phosphate, which upon cyclization and dehydration would give cyclic phosphate. Thus, upon alkylation with appropriate alkyl halide in the presence of bases such as TEA, DIEA in solvents such as DMF, acetonitrile etc or coupling with alcohols in the presence of reagents like DCC or EDC or MSNT would give desired products, using the procedures disclosed in, for example, Beres et al. *J. Med. Chem.* **1986**, 29, 1243-1249 and WO 2007/027248 both of which are incorporated by reference, and as depicted in the following scheme.



**Preparation of 1-((2S,4aR,6R,7R,7aR)-7-Fluoro-2-methoxy-7-methyl-2-oxotetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-1H-pyrimidine-2,4-dione (1)**



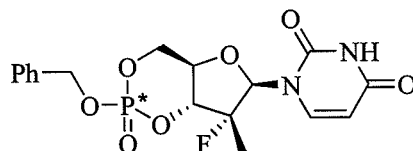
To a stirred solution of 1-((2R,3R,4R,5R)-3-fluoro-4-hydroxy-5-(hydroxymethyl)-3-methyltetrahydrofuran-2-yl)pyrimidine-2,4(1H,3H)-dione (730 mg, 2.8 mmol) in dry pyridine (15 mL) was added a 0.45M solution of tetrazole in acetonitrile (15 mL) followed by bis(N,N-diisopropylamino)methylphosphite (0.971 mL, 3.3 mmol) at room temperature. After 2h, TLC indicated disappearance of the starting material and two non-polar products. The reaction mixture was concentrated under reduced pressure at room temperature and the residue was triturated with EtOAc (30 mL). Tetrazole salts precipitated were filtered off and the filtrate was concentrated under reduced pressure. The residue was chromatographed using 0-40 % EtOAc/hexanes gradient to give pure product 2 (92 mg) and mixture of product 1&2 (102 mg). <sup>1</sup>H NMR confirmed that the product 2 is a single isomer of the required compound. Stereochemistry is not determined.

To a stirred solution of phosphite (30 g, 0.09 mmol) in dichloromethane (1 mL) was added a 77% m-CPBA (26 mg, 0.113 mmol) at room temperature. After 5 min, the TLC indicated the completion of the reaction. The solvent was evaporated and the residue was chromatographed using a short silica gel (2 g) column with 70 - 100 % EtOAc/hexanes gradient to give pure product as a white solid (21 mg). <sup>1</sup>H NMR indicated that the product (1) is a mixture of isomers designated as **1a** and **1b**.

Data for **1a**: <sup>31</sup>P NMR (162 MHz, CD<sub>3</sub>OD): δ -1.54 (minor diastereomer), -2.30 (major diastereomer).; <sup>1</sup>H NMR (400 MHz, CD<sub>3</sub>OD): δ 7.60-7.58 (m, 1H), 6.36 (d, J=20.8Hz, 1H), 5.76 (d, J=8.0Hz, 1H), 4.787-4.484 (m, 4H), 3.85 (d, J=12Hz, 3H), 1.44 (d, J=22.0Hz, 3H); MS (ESI) *m/z* 337 (M+H)<sup>+</sup>.

Data for **1b**: <sup>31</sup>P NMR (162 MHz, CDCl<sub>3</sub>+DMSO): δ -3.82 (minor), -4.54 (major); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>+DMSO): δ 11.41 and 11.25 (two s, 1H), 7.32 (bs, 1H), 6.38 (d, J=21.2Hz, 1H), 5.75-5.70 (m, 1H), 5.45-5.20 (, 1H), 4.64-4.01 (m, 4H), 1.59 and 1.45 (two d, J= 22.4Hz, 3H); MS (ESI) *m/z* 337 (M+H)<sup>+</sup>.

**Preparation of 1-((2S,4aR,6R,7R,7aR)-2-Benzyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-1H-pyrimidine-2,4-dione (2)**



2

To a stirred solution of 1-((2R,3R,4R,5R)-3-fluoro-4-hydroxy-5-(hydroxymethyl)-3-methyltetrahydrofuran-2-yl)pyrimidine-2,4(1H,3H)-dione (1.04 g, 4 mmol, 1.0 equiv) in dry pyridine (22 mL) was added a 0.45M solution of tetrazole in acetonitrile (22.2 mL, 10 mmol, 2.5 equiv) followed by bis(N,N-diisopropylamino)benzylphosphite (1.35 mL, 4.6 mmol, 1.0 equiv) at room temperature. After stirring the mixture at room temperature for 2h, TLC indicated disappearance of starting material and a non polar product. The reaction mixture was concentrated under reduced pressure at room temperature and the residue was chromatographed (Analogix, SF25-40g, 35-100 % EOAc/Hexanes gradient, 1h) gave pure product as a white powder (640 mg, 40.4 % yield).

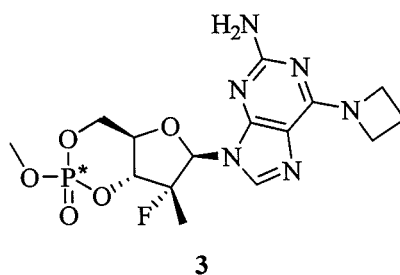
To a stirred solution of phosphite (640 mg, 1.6 mmol) in dichloromethane (5mL) was added a 77% m-CPBA (430 mg, 1.92 mmol, 1.2 equiv) at room temperature. After 5 min, TLC indicated the completion of the reaction and two well separated polar products. The solvent was evaporated and the residue was chromatographed (Analogix, 30-85 % EtOAc/hexanes gradient, 60 min) to give pure product 1 (340 mg, 51.1 % yield) and product 2 (194 mg, 29.1 % yield) as a white solids. <sup>1</sup>H-NMR indicated that the product 2 is a single diastereomer of the required compound (2a) which assigned as trans isomer based on the literature. The cis product (2a) is a mixture of diastereomers.

Data for 2a: <sup>31</sup>P NMR (162 MHz, CDCl<sub>3</sub>) δ -2.79; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 9.34 (bs, 1H), 7.39 (s, 5H), 7.33 (d, J=7.2Hz, 1H), 6.38 (d, J=19.2Hz, 1H), 5.79 (d, J=8.4Hz, 1H), 5.24-5.15 (m, 2H), 4.60 (bs, 2H), 4.38-4.35 (m, 2H), 1.46 (d, J=22Hz, 3H); MS (ESI) m/z 413 (M+H)<sup>+</sup>.

Data for 2b: <sup>31</sup>P NMR (162 MHz, CDCl<sub>3</sub>): δ 4.76 (minor), -5.64 (major); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 9.64 (bs, 1H), 7.45-7.39 (m, 5H), 7.17 and 6.90 (two bs, 1H), 6.29 (d, J=18.8 Hz, 1H), 5.78 (d, J=7.6Hz, 1H), 5.20-5.14 (m, 3H),

4.54-4.48 (m, 1H) 4.27 (bs, 2H), 3.53 (bd,  $J=12.0\text{Hz}$ , 1H), 1.37 and 1.16 (two d,  $J=20.8\text{Hz}$ , 3H); **MS (ESI)**  $m/z$  413 ( $M+H$ )<sup>+</sup>.

**Preparation of 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine (3)**

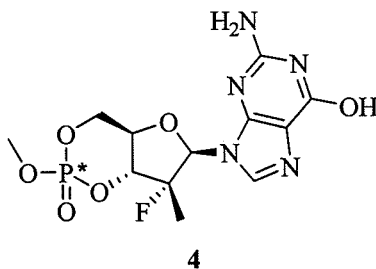


To a stirred solution of (2R,3R,4R,5R)-5-(2-amino-6-(azetidin-1-yl)-9H-purin-9-yl)-4-fluoro-2-(hydroxymethyl)-4-methyltetrahydrofuran-3-ol (100 mg, 0.3 mmol) in dry pyridine (1.5 mL) was added a 0.45M solution of tetrazole in acetonitrile (1.64 mL, 0.74 mmol) followed by bis(*N,N*-diisopropylamino)methylphosphoramidite (101 μL, 0.35 mmol) at room temperature. After stirring the mixture at room temperature for 2h, TLC indicated disappearance of starting material. The reaction mixture was concentrated under reduced pressure at room temperature and the residue was triturated with EtOAc (30 mL). Tetrazole salts precipitated were filtered off and the filtrate was concentrated under reduced pressure. The crude compound (120 mg) was used in the next step without further purification.

To a stirred solution of cyclic-phosphite (119 mg, crude from the previous experiment, 0.3 mmol) in dichloromethane (3 mL) was added a 77 % *m*-CPBA (78 mg, 0.35 mmol) at room temperature. After 5min, the solvent was evaporated and the residue was chromatographed (Analogix, SF10-8 g column) using 0-2.5 % MeOH/CH<sub>2</sub>Cl<sub>2</sub> gradient to give pure product as a white solid (23 mg, 18.6% two steps).

Data for **3**: <sup>31</sup>P NMR (162 MHz, CDCl<sub>3</sub>): δ -1.26, -3.58; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.45 and 7.44 (two s, 1H), 5.45 (d,  $J=20\text{Hz}$ , 1H), 4.89-4.41 (m, 10H), 3.93 (app. t,  $J=13.0\text{Hz}$ , 3H), 2.49 (bs, 2H), 1.39 (overlapping d,  $J=22.4\text{Hz}$ , 3H); **MS (ESI)**  $m/z$  415 ( $M+H$ )<sup>+</sup>.

**Preparation of 2-Amino-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2 $\lambda^5$ -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol (4)**



5

To a stirred solution of 2-amino-9-((2R,3R,4R,5R)-3-fluoro-4-hydroxy-5-(hydroxymethyl)-3-methyltetrahydrofuran-2-yl)-9H-purin-6-ol (116 mg, 0.33 mmol, 1.0 equiv) in dry pyridine (1.65 mL) was added a 0.45M solution of tetrazole in acetonitrile (1.8 mL, 0.85 mmol, 2.5 equiv) followed by bis(*N,N*-diisopropylamino)methylphosphite (114  $\mu$ L, 0.396 mmol, 1.2 equiv) at room temperature. After stirring the mixture at room temperature for 2h, TLC indicated the disappearance of starting material and a non-polar product. The reaction mixture was concentrated under reduced pressure at room temperature and the residue was triturated with EtOAc (5 mL). Tetrazole salts precipitated were filtered off and the filtrate was concentrated under reduced pressure.

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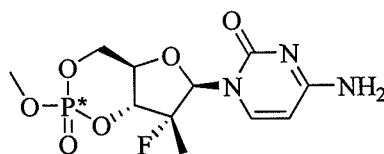
The above residue was redissolved in dichloromethane in dichloromethane (3 mL) and was added a 77% m-CPBA (21 mg, 0.395 mmol, 1.2 equiv) at room temperature. After 5 min, TLC indicated the completion of the reaction. The solvent was evaporated and the residue was chromatographed using a short silica gel column to give pure product as a white solid (3.4 mg, 9% overall yield, 2 steps).

20

Data for 4:  $^{31}\text{P}$  NMR (162 MHz,  $\text{CD}_3\text{OD}$ ):  $\delta$  -3.33;  $^1\text{H}$  NMR (400 MHz,  $\text{CD}_3\text{OD}$ ):  $\delta$  9.03 (s, 2H), 7.81 (s, 1H), 6.17 (d,  $J=20.4\text{Hz}$ , 1H), 4.66 (dd,  $J=9.3, 5.1\text{Hz}$ , 1H), 4.62-4.54 (m, 2H), 4.29-4.23 (m, 1H), 3.82 (d,  $J=11.2\text{Hz}$ , 3H), 3.37 (quintet,  $J=6.4\text{Hz}$ , 2H), 1.22 (d,  $J=6.4\text{Hz}$ , 3H); MS (ESI)  $m/z$  376 ( $\text{M}+\text{H}$ ) $^+$ .

25

**Preparation of 4-Amino-1-((2R,4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2 $\lambda^5$ -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-1H-pyrimidin-2-one (5)**



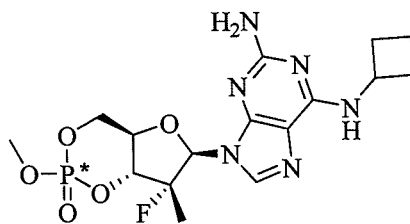
5

To a stirred solution of 4-amino-1-((2R,3R,4R,5R)-3-fluoro-4-hydroxy-5-(hydroxymethyl)-3-methyltetrahydrofuran-2-yl)pyrimidin-2(1H)-one (1.0 g, 3.86 mmol, 1.0 equiv) in dry pyridine (21 mL) was added a 0.45 M solution of tetrazole in acetonitrile (21 mL, 9.5 mmol, 2.5 equiv) followed by bis(*N,N*-diisopropylamino)methylphosphite (1.3 mL, 4.6 mmol, 1.2 equiv) at room temperature. After stirring the mixture at room temperature for 2h, TLC indicated no starting material and a non polar product. The reaction mixture was concentrated under reduced pressure at room temperature and the residue was triturated with EtOAc (25 mL). Tetrazole salts precipitated were filtered off and the filtrate was concentrated under reduced pressure. Column chromatography of the crude compound (SF25-40g, Analogix 0-20% MeOH/CH<sub>2</sub>Cl<sub>2</sub> gradient, 1h) gave pure product as a white powder (334 mg, 27 % yield).

To a stirred solution of phosphite (334 mg, 1.05 mmol) in dichloromethane (3 mL) was added a 77% *m*-CPBA (309 mg, 1.26 mmol, 1.2 equiv) at room temperature. After 5 min, TLC indicated the completion of the reaction. The solvent was evaporated and the residue was chromatographed using a short silica gel column to give pure product as a white solid (80 mg, 23% yield). <sup>1</sup>H NMR indicated that the product is a mixture of *cis* and *trans* isomers and their diastereomers.

Data for **5**: <sup>31</sup>P NMR (162 MHz, CD<sub>3</sub>OD): δ -0.70, -2.22, -2.77 (minor), -3.46 (major); <sup>1</sup>H NMR (400 MHz, CD<sub>3</sub>OD): δ 7.62 (d, J=7.6 Hz, 1H), 6.41 (d, J=21.2Hz, 1H), 5.97 (d, J=7.2Hz, 1H), 4.77-4.57 (m, 2H), 4.48-4.18 (m, 4H), 3.88 (d, J=11.2Hz) and 3.87 (d, J=12.0Hz, total 3H), 1.55 and 1.39 (two d, J=22.4Hz, 3H); MS (ESI) *m/z* 336 (M+H)<sup>+</sup>.

**N<sup>6</sup>-Cyclobutyl-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purine-2,6-diamine (6)**



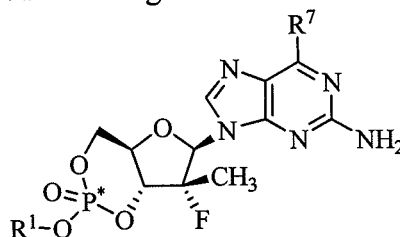
6

Compound **6** was prepared using a similar procedure described for the preparation of compound **4**. Except that the N<sup>6</sup>-cyclobutyl-amino-purine derivative was employed rather than the 6-hydroxy-purine derivative.

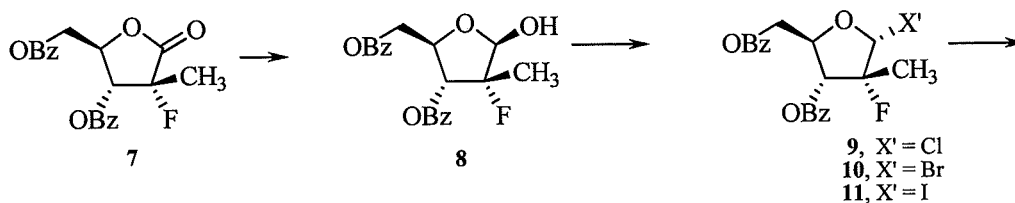
5 Data for **6**: <sup>31</sup>P NMR (162 MHz, CDCl<sub>3</sub>): δ -1.26, -3.64; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.49 and 7.48 (two s, 1H), 6.02 (bs, 2H), 5.97 (d, J=19.2Hz, 1H), 4.88 (bs, 1H), 4.73 (bs, 1H), 4.65-4.58 (m, 2H), 4.53-4.37 (m, 2H) 3.95 and 3.91 (two d, J=11.6Hz, 3H-, 2.42 (bs, 2H), 2.00-1.95 (m, 2H), 1.79-1.73 (m, 2H), 1.38 (overlapping d, J=22.4Hz, 3H); MS (ESI) *m/z* 429 (M+H)<sup>+</sup>.

10

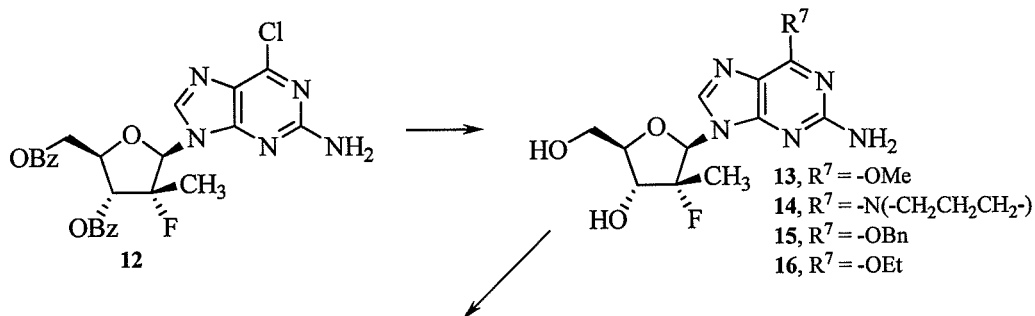
Methods for preparing a compound having the structure:

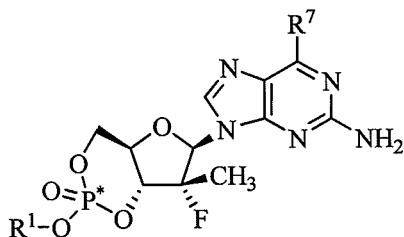


are included below. Inspection of the scheme below shows that compounds **17** and **3** are the same.



15





17, R<sup>7</sup> = -N(-CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>-), R<sup>1</sup> = Me

18, R<sup>7</sup> = -OEt, R<sup>1</sup> = Me

19, R<sup>7</sup> = -OEt, R<sup>1</sup> = <sup>i</sup>Pr

Compound (7) can be obtained by a process disclosed at page 5 in U.S. Published Application No. 2008/0139802 (which corresponds to WO 2008/045419),  
 5 at pages 11-13 in WO 2006/012440, and at pages 20-22 and 30-31 in WO 2006/031725, each of which is hereby incorporated by reference.

The use of the convergent glycosylation route to prepare 2'-deoxy-2'-fluoro-2'-C-methyl purine nucleosides and their corresponding nucleotide phosphoramidates came about with the development of the synthesis of 3,5-di-O-benzoyl-2-deoxy-2-fluoro-2-C-methylribonolactone (Chun, K.; Wang, P. Intl. Pat.  
 10 Appl. WO 2006/031725).

After several attempts using Vorbrueggen-type Lewis acid mediated coupling and the ribonolactol 1-O-acetate of 3,5-di-O-benzoyl-2-deoxy-2-fluoro-2-C-methylribonolactone, we observed very low coupling yields and the undesired  $\alpha$ -  
 15 anomer was the major product. Mitsunobu coupling with the ribonolactol (8) did give the desired product but with no stereoselectivity and very difficult chromatographic separation resulting in isolated yields of 6-10% for this step alone and the method was not scaleable.

The preferred approach became the S<sub>N</sub>2 type reaction using a halo-sugar and  
 20 a salt of the purine base. Again, the challenge of this approach was how to obtain an  $\alpha$  halo-sugar stereospecifically in high yield to take advantage the inversion of configuration expected with S<sub>N</sub>2 type reactions. A typical method treats an anomeric mixture of the 1-O-acetate of a sugar with HCl or HBr in acetic acid. However, this method resulted in production of unfavorable anomeric mixtures. Reducing the  
 25 lactone (e.g., with LiAlH(t-BuO)<sub>3</sub> or Red-Al) initially generates at 2:1 ratio of  $\beta/\alpha$  anomers but after initial purification through a silica gel filtration column, the resulting oil slowly anomerizes to form pure crystalline  $\beta$ -anomer of the lactol (8).

This can be accelerated from several days at ambient temperature to 5-17 h at 50°C with seeding  $\beta$ -crystals. We observed that once the lactol is in solution, it slowly anomerizes back towards the 2:1 equilibrium in solvents such as dichloromethane or chloroform at ambient temperature. This process can be slowed considerable by  
5 chilling the solution (e.g., -20°C).

Chlorination through an  $S_N2$  mechanism with N-chlorosuccinimide (NCS) produced an  $\alpha$ -chlorosugar (**9**) in a stereospecific manner in almost quantitative yield.

To obtain an  $\alpha$ -bromosugar (**10**), many bromination conditions were tried  
10 including N-bromosuccinimide (NBS) and HBr in acetic acid. Among them, we followed a general bromination reaction using a combination of triphenylphosphine ( $PPh_3$ ) and carbon tetrabromide ( $CBr_4$ ) (e.g., Hooz et al, *Can. J. Chem.*, **1968**, 46, 86-87). Under the conditions of using methylene chloride as the solvent and maintaining a low temperature (-10 to -20°C) we obtained the best result where the  
15 desired  $\alpha/\beta$  isomer ratio was greater than 10:1, in a yield of greater than 80%. Applicants believe that there are no literature precedents describing this level of stereoselectivity for this reaction type. Another practical observation was that by conducting the bromination under sub-ambient temperature conditions, such as, most preferably about -20°C) and exposing the cold reaction solution to silica gel as  
20 soon as possible after the completion of the reaction minimizes anomerization of the bromosugar. The bromosugar can be purified through a silica gel filtration column. Once treated with silica gel, the bromosugar it is practically stable even at elevated temperatures.

The iodosugar (**11**) was prepared in a similar manner, which can be coupled  
25 with the purine to produce the key intermediate (**12**).

Following the general purine coupling method of Bauta et al (Intl. Pat. Appl. WO 2003/011877), we coupled the  $\alpha$ -bromosugar (**10**) with the potassium salt of 6-chloro-2-amino-purine in t-butanol in acetonitrile. The reaction took over a week at ambient temperatures. The reaction was optimized to go to completion in 24 h at  
30 50°C. After partial purification through a silica gel filtration column, the anomeric mixture was isolated in 63% yield in a ratio of 14:1  $\beta/\alpha$ . The  $\beta$ -anomer (**12**) could

be selectively crystallized out from a methanolic solution to give the pure desired  $\beta$ -anomer (6) in 55% yield from the bromosugar (10).

With the key intermediate 12 in hand, conversion to unprotected 2-amino-6-substituted purines (e.g., 13-16) was accomplished. Cyclic phosphate derivatives (e.g., 17-19) were prepared as described in *Can J. Chem.*, **1993**, *71*, 855 or as disclosed in U.S. Provisional Patent Application No. 61/060,683, filed June 11, 2008, pp. 79-89.

**Synthesis of ((2R,3R,4R,5R)-3-(benzoyloxy)-4-fluoro-5-hydroxy-4-methyltetrahydrofuran-2-yl)methyl benzoate (8)**

To a 5 L of dry three-neck round-bottomed flask fit with a mechanical stirrer, addition funnel and thermometer was charged the lactone ((2R,3R,4R)-3-(benzoyloxy)-4-fluoro-4-methyl-5-oxotetrahydrofuran-2-yl)methyl benzoate (7, 379 g, 1.018 mol). The solid was dissolved in anhydrous THF (1.75 L) and cooled to -30°C under a nitrogen atmosphere. A solution of lithium tri-tert-butoxyaluminumhydride (1.0 M in THF, 1.527 L) was added to the lactone solution while stirring over 1 h and maintaining the -30°C temperature. After finishing the addition, the temperature was slowly increased and the reaction was followed by TLC (lactol  $R_f$  0.4, 30% EtOAc in hexanes). The reaction was complete after 1h 15 min (temperature reached -10°C). The reaction was quenched by addition of Ethyl acetate (900 mL) via addition funnel. Sat.  $\text{NH}_4\text{Cl}$  (40 mL) was added at 0°C. The cloudy mixture was decanted into a 10 L round-bottomed flask. The solid residue left behind was filtered and washed with ethyl acetate (2x200 mL). The filtrate was combined with the decanted solution and the combined solution was concentrated under reduced pressure. The oily residue was dissolved in ethyl acetate (2 L) and washed with 3  $N\text{HCl}$  (600 mL). The aqueous layer was back-extracted with ethyl acetate (3x400 mL). The combined organic layer was washed with water (3x800 mL), sat.  $\text{NaHCO}_3$  (400 mL) and brine (400 mL). The organic solution was dried over  $\text{MgSO}_4$ , filtered and concentrated under reduced pressure to afford a light brown oily residue. The residue was purified by plug column (2.2 kg of 40-63 micron silica gel, packed in a 6 L sintered glass funnel, 22 cm length of silica gel, diameter 15 cm) using suction and a step-gradient of 5%, 10%, 20%, and 30% ethyl

acetate in hexanes –ca 5 L of each). The product containing fractions were combined and concentrated under reduced pressure to a colorless, very thick liquid (310.4 g).

The liquid slowly solidified after adding crystalline beta product as seeds (ca 100 mg spread out) under vacuum (0.2 mmHg) at 50°C. The process of solidification was complete in 20 hours at 50°C with or without vacuum. The white solid thus collected (293.8 g, 77%) has a mp of 79-80°C and ratio of  $\beta/\alpha$  is 20:1 based on NMR.

<sup>1</sup>H-NMR (DMSO-*d*<sub>6</sub>)  $\beta$ -isomer,  $\delta$  = 5.20 (dd, 1 H, OH);  $\alpha$ -isomer,  $\delta$  = 5.40 (dd, 1 H, OH). ( $\beta$ -lactol) (DMSO-*d*<sub>6</sub>):  $\delta$  7.99 (m, 2 H, arom.), 7.93 (m, 2 H, arom.), 7.70 (m, 1 H, arom.), 7.61 (m, 1 H, arom.), 7.55 (m, 2 H, arom.), 7.42 (m, 2 H, arom.), 7.32 (dd, 1 H, C1-H), 5.54 (dd, 1 H, C3-H), 5.20 (dd, 1 H, OH), 4.55-4.50 (m, 1 H, C5-Ha), 4.46-4.40 (m, 2 H, C5-Hb and C4-H), 1.42 (d, 3 H, CH<sub>3</sub>).

**Synthesis of ((2R,3R,4R,5R)-3-(benzoyloxy)-5-chloro-4-fluoro-4-methyltetrahydrofuran-2-yl)methyl benzoate (9)**

To a solution of mixture of compound **8** (1.0 g, 2.67 mmol) and PPh<sub>3</sub> (1.4 g, 5.34 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (15 mL) was added NCS (1.07 g, 8.01 mmol) portionwise at 0°C. Then the resulting mixture was stirred at rt for 1h and poured into a silica gel column and eluted with EtOAc-hexanes (1:4) using pressure. The collected right fractions were combined, concentrated, and co-evaporated with CH<sub>2</sub>Cl<sub>2</sub> several times and used next step (1.0 g, 95%).

<sup>1</sup>H-NMR (CDCl<sub>3</sub>)  $\delta$  = 8.13-8.02 (m, 4H, aromatic), 7.78-7.50 (m, aromatic, 2H), 7.53-7.43 (m, 4H, aromatic), 6.01 (s, 1H, H-1), 5.28 (dd, 1H, *J* = 3.2, 5.6 Hz, H-3), 4.88 (m, 1H, H-H-4), 4.77 (dd, 1H, *J* = 3.2, 12.4 Hz, H-5), 4.61 (dd, 1H, *J* = 4.0, 12.4 Hz, H-5'), 1.73 (d, 3H, *J* = 21.6 Hz, CH<sub>3</sub>).

**Synthesis of ((2R,3R,4R,5R)-3-(benzoyloxy)-5-bromo-4-fluoro-4-methyltetrahydrofuran-2-yl)methyl benzoate (10)**

Anhydrous dichloromethane (5.6 L) was charged into a reactor and cooled to -22°C or below. Triphenylphosphine (205.4 g, 0.783 mol) was added to the cold solvent and the suspension was stirred to form a solution. The lactol (**8**, 209.4 g,

0.559 mol) in solid form was added to the cold solution and stirred for 15 mins. Carbon tetrabromide (278.2 g, 0.839 mol) was added portion-wise while maintaining the temperature of the solution between -22°C to -20 °C under a flow of nitrogen gas (approx. 30 min). After finishing the addition of CBr<sub>4</sub>, the temperature was slowly  
5 raised to -17°C over 20 mins. The reaction was judged to be >95% complete by TLC (R<sub>f</sub>s 0.61 ( $\alpha$ ), 0.72 ( $\beta$ ), 0.36 lactol; 20% EtOAc in hexanes). The reaction solution was immediately transferred to a vessel containing 230 g of flash chromatography grade silica gel (40-63 microns). The stirred mixture was immediately passed through a pad of silica gel (680 g) in a 2.5 L sintered glass  
10 Buchner funnel. The filtrate was concentrated under reduced pressure to about 800 mL and the ratio of  $\alpha/\beta$  isomers of the crude product was 10:1 as determined by <sup>1</sup>H-NMR. (CDCl<sub>3</sub>)  $\delta$  = 6.35, (s,  $\alpha$  C1-H), 6.43, (d,  $\beta$  C1-H). The residue was purified by plug column chromatography using 2.1 kg of silica gel in a 6 L sintered glass Buchner funnel and eluted (via suction) with a stepwise gradient elution of 1%, 5%,  
15 8% 12% EtOAc in hexane (ca 4 L each) to remove non-polar impurities followed by 12%, 25% EtOAc in hexane (6 L total) to elute the product. The product containing fractions were combined into two fractions, concentrated under reduced pressure, dried under vacuum (0.1 mmHg, ambient temp., 20 h) to colorless oils. Main fraction (197 g, 89%  $\alpha/\beta$  = 20:1). The alpha isomer crystallized from a small  
20 portion of the oil upon standing at 0°C for several weeks to give large, thin plates, mp 59-61°C. The pure beta isomer crystallized from a mixture of alpha and beta product oil from an earlier less selective run to give needles, mp 77-79°C.

<sup>1</sup>H-NMR ( $\beta$ -bromide) (CDCl<sub>3</sub>):  $\delta$  = 8.08 (m, 2 H, arom.), 8.04 (m, 2 H, arom.), 7.62 (m, 1 H, arom.), 7.54-7.45 (m, 3 H, arom.), 7.35 (m, 2 H, arom.), 6.43  
25 (d, 1 H, C1-H), 6.04 (dd, 1 H, C3-H), 4.78-4.73 (m, 2 H, C4-H and C5-Ha), 4.63-4.58 (m, 1 H, C5-Hb), 1.76 (d, 3 H, CH<sub>3</sub>).  $\alpha$ -bromide,  $\alpha/\beta$  = 20:1) (CDCl<sub>3</sub>):  $\delta$  8.13 (m, 2 H, arom.), 8.02 (m, 2 H, arom.), 7.63-7.56 (m, 2 H, arom.), 7.50-7.42 (m, 4 H, arom.), 6.34 (s, 1 H, C1-H), 5.29 (dd, 1 H, C3-H), 4.88 (m, 1 H, C4-H), 4.78 (dd, 1 H, C5-Ha), 4.63 (dd, 1 H, C5-Hb), 1.72 (d, 3 H, CH<sub>3</sub>).

**Synthesis of ((2R,3R,4R,5R)-3-(benzoyloxy)-4-fluoro-5-iodo-4-methyltetrahydrofuran-2-yl)methyl benzoate (11)**

To a solution of compound **8** (1 g, 2.67 mmol), triphenylphosphine (700 mg, 2.67 mmol), and imidazole (180 mg, 2.67 mmol) in anhydrous CH<sub>2</sub>Cl<sub>2</sub> (10 mL) iodine (680 mg, 2.68 mmol) was added. The resulting mixture was stirred for 30 min and poured into a silica gel column and eluted with EtOAc-hexanes (1:4) to give a syrupy product (1.3 g, quantitative) and used in next reaction without further characterization.

**Synthesis of (2R,3R,4R,5R)-5-(2-amino-6-chloro-9H-purin-9-yl)-2-(benzoyloxymethyl)-4-fluoro-4-methyltetrahydrofuran-3-yl benzoate (12)**

To a 12 L of three-neck round-bottomed flask was charged 6-chloro-2-aminopurine (225.4 g, 1.329 mol). Anhydrous tert-BuOH (4.5 L) was added and the solution was stirred with a mechanical stirrer at ambient temperature. Potassium tert-butoxide (solid, 151.6 g, 1.35 mol) was added portion-wise under a flow of nitrogen gas while stirring. The mixture was stirred at RT for an additional 30 min. To a 5 L round-bottomed flask was loaded the  $\alpha$ -bromide (**10**, 197 g, 0.451 mol) and 3 L of anhydrous acetonitrile at ambient temperature. The bromide solution was added to the purine base suspension over 1 min at ambient temperature. The 5L flask was rinsed with acetonitrile (2x1L) to transfer bromide completely to the reaction mixture. The mixture was heated gradually to 50°C over 2 h with a heating mantle and controller, and stirred for 20 h. The reaction was almost complete as shown by TLC beta (R<sub>f</sub> 0.28, 30% EtOAc in hexanes). The reaction was quenched by the addition of sat. NH<sub>4</sub>Cl (200 mL) to form a suspension. The suspended solid<sup>1</sup> was removed by filtration through a 3 cm pad of Celite in a 2.5 L porcelain Buchner funnel. The solid was washed with toluene (3x100 mL). The combined filtrate was neutralized by adding 6 N HCl solution until pH 7 (approx 220 mL). The mixture was concentrated under reduced pressure. When the volume of mixture was reduced to about one-third volume, additional precipitated solid was removed by filtration in a similar manner. The filtrate was further concentrated to a volume of about 800 mL. The residue was loaded onto a plug column (1.6 kg flash grade silica gel in a 6 L sintered glass Buchner funnel) and eluted (via suction) with a gradient of 10%

ethyl acetate in hexanes (6 L) to remove non-polar impurities, 30% ethyl acetate in hexanes to afford a small amount of lactol (6 L), and then 40%~45% ethyl acetate in hexanes (4 L) to elute the main amount of product. The product containing fractions were combined, concentrated under reduced pressure and dried under vacuum (0.2 mmHg, 24 h, ambient temp.) to a white foam solid (150.7 g,  $\beta/\alpha = 14:1$  by NMR).

$^1\text{H-NMR}$ . ( $\text{CDCl}_3$ ) beta:  $\delta = 1.33$  (d, 22.4 Hz, 2'-C-CH<sub>3</sub>), alpha: 1.55 (d, 22 Hz, 2'-C-CH<sub>3</sub>).

The product mixture foam was dissolved in methanol (700 mL) at ambient temperature. Upon standing, a solid slowly formed over 2 h. The suspension was cooled in a freezer to -5°C for 17 h. The resulting white solid was collected by filtration and washed with cold MeOH (-5°C, 3x60 mL) and ethyl ether (3x100 mL). The solid was dried under vacuum (0.2 mmHg, 24 h, ambient temp.) to afford 110.5 g of  $\beta$ -product with excellent de ( $\beta/\alpha$  99.8:1 by HPLC). The filtrate was partially concentrated (ca. 400 mL) and then diluted with more MeOH (400 mL) while heating to 60°C. The solution was cooled down to ambient temperature, seeded and the cooled to -5°C. The second crop was collected, washed and dried in a similar manner to give more product as a white solid (12.26 g) with similar diastereomeric purity. The mother liquor was concentrated to dryness under reduced pressure (ca. 25 g). The residue was a mixture of  $\beta$  and  $\alpha$ -isomers. It was subjected to automated silica gel column chromatography (Analogix, 240 g cartridge, 40% to 50% ethyl acetate in hexanes) to afford 14.52 g of product foam which was recrystallized from MeOH, washed and dried in a similar manner to afford an additional 8.46 g of product in high purity.

The three solids were judged to be of similar purity and they were combined to give 131.2 g of white crystalline product **12**, (55% from bromosugar, 49% from lactol). Mp 160.5-162.0°C. HPLC purity 99.5% including 0.20 % alpha.

$^1\text{H-NMR}$  (pure  $\beta$ -anomer,  $\text{CDCl}_3$ ):  $\delta = 8.03$  (m, 2 H, arom.), 7.93 (m, 2 H, arom.), 7.88 (s, 1 H, C8-H), 7.60 (m, 1 H, arom.), 7.50 (m, 1 H, arom.), 7.44 (m, 2 H, arom.), 7.33 (m, 2 H, arom.), 6.44 (dd, 1 H, C1'-H), 6.12 (d, 1 H, C3'-H), 5.35 (s, 2 H, NH<sub>2</sub>), 5.00 (dd, 1 H, C5'-Ha), 4.76 (m, 1 H, C4'-H), 4.59 (dd, 1 H, C5'-Hb), 1.33 (d, 3 H, CH<sub>3</sub>).

<sup>1</sup>H-NMR ( $\alpha$ -isomer, CDCl<sub>3</sub>):  $\delta$  = 8.11-8.09 (m, 3 H, arom. and C8-H), 8.01 (m, 2 H, arom.), 7.63 (m, 1 H, arom.), 7.55 (m, 1 H, arom.), 7.48 (m, 2 H, arom.), 7.39 (m, 2 H, arom.), 6.35 (d, 1 H, C1'-H), 5.76 (dd, 1 H, C3'-H), 5.18 (s, 2 H, NH<sub>2</sub>), 4.93-4.89 (m, 1 H, C4'-H), 4.75-4.71 (m, 1 H, C5'-Ha), 4.58-4.54 (m, 1 H, C5'-Hb),  
5 1.55 (d, 3 H, CH<sub>3</sub>).

**Synthesis of (2R,3R,4R,5R)-5-(2-amino-6-chloro-9H-purin-9-yl)-2-(benzoyloxymethyl)-4-fluoro-4-methyltetrahydrofuran-3-yl benzoate (12) from compound 9**

To a solution of compound 9 (450 mg, 2.68 mmol) in chlorobenzene (1.5  
10 mL) were added potassium salt of the base (1.37 g, 8.05 mmol) in t-butanol (5 mL) and subsequently anhydrous acetonitrile (5 mL) at rt. The resulting mixture was stirred at 80-140°C in a sealed tube for 7 days and concentrated *in vacuo* after neutralization with HCl. The residue was purified by silica gel column chromatography (hexanes:EtOAc = 2:1) to give compound 12 (90 mg, 15%) as a  
15 white foam.

**Synthesis of (2R,3R,4R,5R)-5-(2-amino-6-chloro-9H-purin-9-yl)-2-(benzoyloxymethyl)-4-fluoro-4-methyltetrahydrofuran-3-yl benzoate (12) from compound 11**

20 To a solution of compound 11 (1.3 g, 2.68 mmol) in t-butanol (10 mL) was added sodium salt of the base (1.37 g, 8.05 mmol) in DMF (10 mL) at ambient temperature. The resulting mixture was stirred for 15h and concentrated in vacuo. The residue was purified by silica gel column chromatography (hexanes:EtOAc = 2:1) to give compound 12 (220 mg, 16%) as a white foam.

25

**Synthesis of (2R,3R,4R,5R)-5-(2-amino-6-methoxy-9H-purin-9-yl)-4-fluoro-2-(hydroxymethyl)-4-methyltetrahydrofuran-3-ol (13)**

To a 250 mL dry round-bottomed flask was charged (2R,3R,4R,5R)-5-(2-amino-6-chloro-9H-purin-9-yl)-2-(benzoyloxymethyl)-4-fluoro-4-methyltetrahydrofuran-3-yl benzoate (12, 7.50 g, 14.26 mmol). Anhydrous  
30 methanol (30 mL) was added and a white suspension was formed. At 50°C, a

solution of sodium methoxide in methanol (25%, 19.7 mL, 64.17 mmol) was added via a dry syringe under a nitrogen atmosphere. A white cloudy reaction mixture was formed. After 3.5 h at 50°C, the reaction was complete with no starting material left as shown by TLC test. The mixture was cooled down to room temperature and  
5 neutralized by addition of glacial acetic acid (3 mL). A white solid was filtered out and washed with methanol (3x5 mL). The filtrate was mixed with 20 g of silica gel and concentrated to dryness. The mixture was loaded in line with a silica gel cartridge and separated via column chromatography using a gradient of methanol in dichloromethane 0 to 15% MeOH. The product eluted out at 12% methanol in  
10 dichloromethane. The product containing fractions were combined, concentrated under reduced pressure and dried under vacuum (0.2 mmHg, 50°C, 24 h) to a white powder solid (4.45 g, 98% yield), mp 199-202°C.

<sup>1</sup>H-NMR (DMSO-*d*<sub>6</sub>): δ = 8.18 (1 H, s, C8-H), 6.61 (2 H, s, NH<sub>2</sub>), 6.05 (1 H, d, C1'-H), 5.68 (1 H, d, 3'-OH), 5.26 (1 H, m, 5'-OH), 4.23-4.13 (1 H, m, C3'-H),  
15 3.96 (3 H, s, OCH<sub>3</sub>), 3.92-3.83 (2 H, m, C4'-H and C5'-H<sub>a</sub>), 3.70-3.67 (1 H, m, C5'-H<sub>b</sub>), 1.06 (3 H, d, C2'-CH<sub>3</sub>).

**Synthesis of (2R,3R,4R,5R)-5-(2-amino-6-(azetidin-1-yl)-9H-purin-9-yl)-4-fluoro-2-(hydroxymethyl)-4-methyltetrahydrofuran-3-ol (14)**

20 To a 350 mL of dry seal pressure flask (Chemglass) were added (2R,3R,4R,5R)-5-(2-amino-6-chloro-9H-purin-9-yl)-2-(benzoyloxymethyl)-4-fluoro-4-methyltetrahydrofuran-3-yl benzoate (**12**, 3.6 g, 6.85 mmol) and 150 mL of absolute ethanol. Azetidine hydrochloride (2.56 g, 27.4 mmol) was added and then followed by triethylamine (4.16 g, 41.1 mmol). The suspension was stirred and  
25 heated to 70°C while sealed for 5 hours. All the starting material was consumed but the benzoyl groups remained as shown by TLC. Sodium methoxide (7.8 mL, 34.3 mmol, 25% solution in methanol) was added to the mixture and heated at 50°C. The reaction was complete after 3.5 h. The reaction mixture was allowed to cool to room temperature and neutralized by addition of glacial acetic acid (0.41 g, 6.85 mmol).  
30 The mixture was concentrated under reduced pressure and then the residue was triturated with ethyl acetate. The resulting solid was removed by filtration and the solid was washed with EtOAc (2x 15 mL). The filtrate was concentrated under

reduced pressure and the residue was purified via column chromatography (Analogix, 120 g cartridge, gradient of 0 to 15% MeOH in DCM). The pure product containing fractions were combined, concentrated under reduced pressure and dried (50°C, 0.2 mmHg, 17 h) to a light pink colored foam solid (2.15 g, 6.35 mmol, 93%).

<sup>1</sup>H-NMR (DMSO-*d*<sub>6</sub>)  $\delta$  = 8.00 (s, 1 H, C8-H), 6.03 (s, 2 H, NH<sub>2</sub>), 6.00 (d, 1 H, C1'-H), 5.64 (d, 1 H, 3'-OH), 5.24 (t, 1 H, 5'-OH), 4.24-4.10 (m, 5 H, N-CH<sub>2</sub> of azetidine, C3'-H), 3.90-3.81 (m, 2 H, C4'-H and C5'-H<sub>a</sub>), 3.69-3.64 (m, 1 H, C5'-H<sub>b</sub>), 2.37 (penta, 2 H, center CH<sub>2</sub> of azetidine), 1.05 (d, 3 H, C2'-CH<sub>3</sub>).

10 **Synthesis of (2R,3R,4R,5R)-5-(2-amino-6-(benzyloxy)-9H-purin-9-yl)-4-fluoro-2-(hydroxymethyl)-4-methyltetrahydrofuran-3-ol (15)**

To a 500 mL of dry round-bottomed flask were added (2R,3R,4R,5R)-5-(2-amino-6-chloro-9H-purin-9-yl)-2-(benzyloxymethyl)-4-fluoro-4-methyltetrahydrofuran-3-yl benzoate (**12**, 8.0 g, 15.2 mmol) and anhydrous benzyl alcohol (128 mL). To another 250 mL of dry round-bottomed flask were charged NaH (60% in mineral oil, 2.44 g, 60.8 mmol) and anhydrous DMF (40 mL). The suspension was stirred at 0°C in an ice-water bath. Benzyl alcohol (27 mL) was added drop-wise via a syringe. A solution was slowly formed and it was transferred to the nucleoside suspension quickly under a nitrogen atmosphere at room temperature. The mixture was heated to 50°C and stirred. The reaction was complete after 3 h and cooled to ambient temperature. It was neutralized by the addition of 4 N HCl to *ca.* pH=7 (12 mL). The solution was concentrated under reduced pressure (4 mbar, 90°C bath). The cloudy residue was diluted with dichloromethane (100 mL) and washed with water (3x 30 mL), brine (30 mL) and dried over Na<sub>2</sub>SO<sub>4</sub>. The suspension was filtered and the filtrate was concentrated under reduced pressure to an oily residue. This was purified by column chromatography (Analogix, 0 to 8% gradient of MeOH in DCM). The product eluted at 4% MeOH in DCM. The product containing fractions were combined, concentrated under reduced pressure and dried (50°C, 0.2 mmHg, 17 h) to a white foam solid (4.57 g, 11.7 mmol, 77.2%).

<sup>1</sup>H-NMR (DMSO-*d*<sub>6</sub>)  $\delta$  = 8.18 (s, 1 H, 8-H), 7.53-7.51 (m, 2 H, arom-H), 7.43-7.34 (m, 3 H, arom-H), 6.66 (s, 2 H, NH<sub>2</sub>), 6.05 (d, 1 H, C1'-H), 5.67 (d, 1 H,

3'-OH), 5.48 (dd, 2 H, CH<sub>2</sub> of Benzyl), 5.25 (t, 1 H, 5'-OH), 4.18 (dt, 1 H, C3'-H), 3.92-3.82 (m, 2 H, C4'-H and C5'-H<sub>a</sub>), 3.71-3.66 (m, 1 H, C5'-H<sub>b</sub>), 1.07 (d, 3 H, C2'-CH<sub>3</sub>).

**5 Synthesis of (2R,3R,4R,5R)-5-(2-amino-6-ethoxy-9H-purin-9-yl)-4-fluoro-2-(hydroxymethyl)-4-methyltetrahydrofuran-3-ol (16)**

To a 500 mL of dry round-bottomed flask was loaded (12, 11 g, 20.92 mmol). Anhydrous absolute ethanol (210 mL) was added and followed by  
10 anhydrous K<sub>2</sub>CO<sub>3</sub> (28.91 g, 209.2 mmol). The suspension was stirred and heated at 75°C under nitrogen for 5.5 h. All the starting material was consumed at that time by TLC test. The mixture was cooled to room temperature and solid was filtered out. The filtrate was neutralized by addition of glacial acetic acid (2.52 g) to pH~7 and concentrated under reduced pressure. The residue was dissolved in methanol  
15 and mixed with silica gel (15 g). The dried mixture of crude product and silica gel was transferred to an empty cartridge and separated through column chromatography (Analogix 220 g, gradient of 0 to 15% MeOH in DCM) to afford product (5% MeOH in DCM) as a white foam solid (3.73 g, 54.5%). A second white solid was isolated from column (10% MeOH in DCM, 1.44 g) and it is a  
20 mixture of two dimers of nucleoside. A more polar, third white solid was collected from column (15% MeOH in DCM, 0.47 g) and it is a mixture of trimers of nucleoside. HPLC purity of product 99.94%.

<sup>1</sup>H-NMR (DMSO-*d*<sub>6</sub>): δ 8.16 (s, 1 H, 8-H), 6.55 (s, 2 H, NH<sub>2</sub>), 6.04 (d, 1 H, C1'-H), 5.66 (d, 1 H, 3'-OH), 5.24 (m, 1 H, 5'-OH), 4.44 (q, 2 H, 6-OCH<sub>2</sub>), 4.23-4.08  
25 (m, 1 H, C3'-H), 3.91-3.82 (m, 2 H, C4'-H and C5'-H<sub>a</sub>), 3.71-3.66 (m, 1 H, C5'-H<sub>b</sub>), 1.36 (t, 3 H, CH<sub>3</sub> of ethyl), 1.06 (d, 3 H, C2'-CH<sub>3</sub>).

**Synthesis of 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-tetrahydro-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine  
30 phosphite precursor to 17**

(2R,3R,4R,5R)-5-(2-Amino-6-azetidin-1-yl-purin-9-yl)-4-fluoro-2-hydroxymethyl-4-methyl-tetrahydro-furan-3-ol (14, 340 mg, 1.0 mmol) was

dissolved in anhydrous pyridine (6 ml) at ambient temperature. A solution of 0.45 M 1H-tetrazole in acetonitrile (5.5 mL, 2.5 mmol) was added followed by bis (N,N-diisopropylamino)methylphosphoramidite (317  $\mu$ L, 1.1 mmol). The mixture was stirred at ambient temperature for 17 h. The solvent was concentrated under reduced pressure and the residue was triturated with ethyl acetate (20 mL). The resulting precipitant of salts was removed by filtration and the filtrate was concentrated under reduced pressure. The residue was purified by silica gel column chromatography using a gradient of ethyl acetate in hexanes (40-80%). The product containing fractions were combined and concentrated to a white solid, 47 mg (12% yield).

10

**Synthesis of 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydrofuro[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine (17, cf. 3)**

15 To a stirred solution of the cyclic phosphite (47 mg, 0.12 mmol) in dichloromethane (2 mL) was added 77% mCPBA (32mg, 0.14 mmol) at ambient temperature. After 5 min, the solution was concentrated under reduced pressure the residue was purified by silica gel column chromatography (4 g) using a gradient of ethyl acetate in hexanes (80-100%). The pure product fractions were combined and concentrated under reduced pressure to a white solid, 21 mg (43%).

20

$^1\text{H-NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  = 7.45 and 7.44 (two s, 1H), 5.45 (d,  $J=20\text{Hz}$ , 1H), 4.89-4.41 (m, 10H), 3.93 (app. t,  $J=13.0\text{Hz}$ , 3H), 2.49 (bs, 2H), 1.39 (overlapping d,  $J=22.4\text{Hz}$ , 3H); MS (ESI)  $m/z$  415 ( $\text{M}+\text{H}$ ) $^+$ .

$^{31}\text{P-NMR}$  (162 MHz,  $\text{CDCl}_3$ ):  $\delta$  = -1.26, -3.58;

25

**Synthesis of 6-Ethoxy-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2,5-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine (18)**

30 (2R,3R,4R,5R)-5-(2-Amino-6-ethoxy-purin-9-yl)-4-fluoro-2-hydroxymethyl-4-methyl-tetrahydro-furan-3-ol (16, 150 mg, 0.46 mmol) was dissolved in anhydrous pyridine (2 ml) at 0°C. A solution of 0.45 M 1H-tetrazole in acetonitrile (2.55 mL) was added followed by bis (N,N-diisopropylamino)methylphosphoramidite (0.16 mL, 0.55 mmol). The mixture was

allowed to slowly warm to ambient temperature over 5 h. TLC indicated a complete reaction. The reaction was quenched upon the addition of water (0.1 mL). The reaction solution was concentrated under reduced pressure and then the residue was triturated with ethyl acetate (5 mL). The resulting white precipitate was removed by  
 5 filtration and the filtrate was concentrated under reduced pressure. The resulting intermediate cyclic phosphite residue was dissolved in acetonitrile (2 mL) and then treated with t-butyl hydroperoxide (70% in water, 0.25 mL) for 17 at ambient temperature. TLC indicated a complete reaction. The reaction solution was concentrated under reduced pressure and the residue was purified by column  
 10 chromatography (Analogix using a gradient of 0 to 10% IPA in DCM). The product containing fractions were combined and concentrated under reduced pressure to a white solid, 80 mg (34% yield) as a mixture of two diastereomers ~2:1.

$^1\text{H-NMR}$  (400 MHz,  $\text{DMSO-}d_6$ ):  $\delta$  = 8.16 (s, 1.5H), 6.65 (s, 2H), 6.55 (bs, 1H), 6.28 (d,  $J$  = 20.8 Hz, 1.5H), 4.78-4.60 (m, 4.5H), 4.45 (q,  $J$  = 6.8 Hz, 1H), 4.44  
 15 (q,  $J$  = 6.8 Hz, 2H), 4.28-4.22 (m, 1.5H), 3.83 (d,  $J$  = 11.6 Hz, 1.5H), 3.76 (d,  $J$  = 11.6 Hz, 3H), 1.36 (t,  $J$  = 7.2 Hz, 1.5H), 1.36 (t,  $J$  = 7.2 Hz, 3H), 2.46 (d,  $J$  = 22.4 Hz, 1.5H), 2.44 (d,  $J$  = 22.8 Hz, 3H).

$^{31}\text{P-NMR}$  (162 MHz,  $\text{DMSO-}d_6$ ):  $\delta$  -3.25, -4.16.

LRMS (ESI):  $[\text{M} + \text{H}]^+$  calculated for  $\text{C}_{14}\text{H}_{20}\text{FN}_5\text{O}_6\text{P}$  404.3, found 404.3.

20 **Synthesis of 6-Ethoxy-9-((4aR,6R,7R,7aR)-7-fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2,5-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-yl amine (19)**

(2R,3R,4R,5R)-5-(2-Amino-6-ethoxy-purin-9-yl)-4-fluoro-2-hydroxymethyl-4-methyl-tetrahydro-furan-3-ol (16, 150 mg, 0.46 mmol) was  
 25 dissolved in anhydrous pyridine (2 ml) at 0°C. A solution of 0.45 M 1H-tetrazole in acetonitrile (2.55 mL) was added followed by bis (N,N-diisopropylamino)isopropylphosphoramidite (0.16 mL, 0.55 mmol, 1.2 eq). The mixture was allowed to slowly warm to ambient temperature over 3 h. TLC  
 30 indicated a complete reaction. The reaction was quenched upon the addition of water (0.1 mL). The reaction solution was concentrated under reduced pressure and

then the residue was triturated with ethyl acetate (5 mL). The resulting white precipitate was removed by filtration and the filtrate was concentrated under reduced pressure. The resulting intermediate cyclic phosphite residue was dissolved in acetonitrile (2 mL) and then treated with t-butyl hydroperoxide (70% in water, 0.19 mL) for 5 h at ambient temperature. TLC indicated a complete reaction. The reaction solution was concentrated under reduced pressure and the residue was purified by column chromatography (Analogix using a gradient of 0 to 5% IPA in DCM). The two diastereomers (**19a** and **19b**) were separable. Fractions containing each diastereomer were separately combined and concentrated under reduced pressure to white solids to give 20 mg of each diastereomer (combined yield 20%).

**19a**

**<sup>31</sup>P-NMR (162 MHz, DMSO):**  $\delta$  -6.49;

**<sup>1</sup>H-NMR (400 MHz, DMSO):**  $\delta$  = 8.17 (s, 1H), 6.47 (bs, 2H), 6.27 (d, J = 21.2 Hz, 1H), 4.73-4.62 (m, 4H), 4.45 (q, J = 7.0 Hz, 2H), 4.27-4.21 (m, 1H), 1.39-1.34 (m, 9H), 1.20 (d, J = 22.8 Hz, 3H).

**MS (ESI):**  $m/z$  432.4 [M + H]<sup>+</sup>.

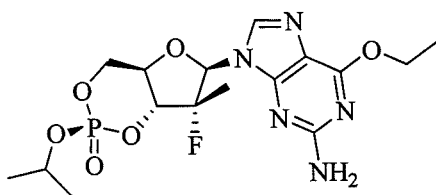
**19b**

**<sup>31</sup>P-NMR (162 MHz, DMSO):**  $\delta$  = -4.68;

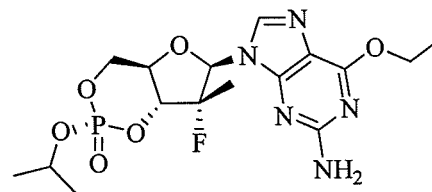
**<sup>1</sup>H-NMR (400 MHz, DMSO):**  $\delta$  8.15 (s, 1H), 6.63 (s, 2H), 6.27 (d, J = 21.2 Hz, 1H), 4.74-4.58 (m, 4H), 4.45 (q, J = 6.4 Hz, 2H), 4.42-4.37 (m, 1H), 1.36 (t, J = 7.2 Hz, 3H), 1.32 (d, J = 3.6 Hz, 3H), 1.30 (d, J = 3.6 Hz, 3H), 1.22 (d, J = 22.8 Hz, 3H).

**MS (ESI):**  $m/z$  432.4 [M + H]<sup>+</sup>.

The structures for **19a** and **19b** are represented below.



19a



19b

The following compounds were prepared based on the procedures described herein. Example 41 was prepared by catalytic hydrogenation of Example 44 and in a similar way Example 45 was prepared from Example 48. Diastereomers of some of the compounds have been resolved, but where the absolute stereochemistry is not known, the same structures are provided.

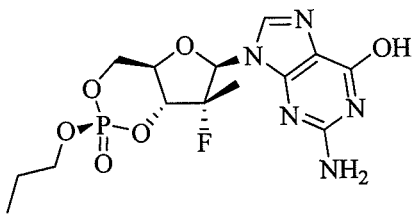
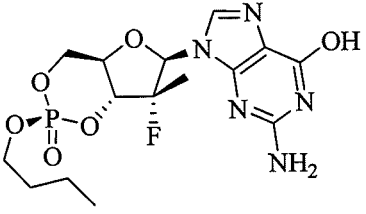
| Ex No | Structure | Chemical Name                                                                                                                                                            | Analytical Data                                                                                          |
|-------|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| 20    |           | 9-((4aR,6R,7R,7aR)-7-Fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-N <sup>6</sup> -propyl-9H-purine-2,6-diamine    | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -1.22, -3.64; MS (ESI) m/z 417 (M+H) <sup>+</sup> . |
| 21    |           | 9-((4aR,6R,7R,7aR)-2-Ethoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-N <sup>6</sup> -propyl-9H-purine-2,6-diamine     | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -4.78; MS (ESI) m/z 431.3 (M+H) <sup>+</sup> .      |
| 22    |           | 9-((4aR,6R,7R,7aR)-7-Fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-N <sup>6</sup> -propyl-9H-purine-2,6-diamine    | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -4.75; MS (ESI) m/z 445.3 (M+H) <sup>+</sup> .      |
| 23    |           | 9-((4aR,6R,7R,7aR)-7-Fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-N <sup>6</sup> -propyl-9H-purine-2,6-diamine | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -5.77; MS (ESI) m/z 445.3 (M+H) <sup>+</sup> .      |
| 24    |           | 9-((4aR,6R,7R,7aR)-2-Butoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-N <sup>6</sup> -propyl-9H-purine-2,6-diamine     | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -4.74; MS (ESI) m/z 459.4 (M+H) <sup>+</sup> .      |

| Ex No | Structure | Chemical Name                                                                                                                                                              | Analytical Data                                                                                                                                                                                                                                                                                          |
|-------|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 25    |           | 9-((4aR,6R,7R,7aR)-7-Fluoro-7-methyl-2-oxo-2-phenoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-N <sup>6</sup> -propyl-9H-purine-2,6-diamine      | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -10.84; MS (ESI) m/z 479.3 (M+H) <sup>+</sup> .                                                                                                                                                                                                     |
| 26    |           | N <sup>6</sup> -Cyclopentyl-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purine-2,6-diamine | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -1.20, -3.64; MS (ESI) m/z 443(M+H) <sup>+</sup> .                                                                                                                                                                                                  |
| 27    |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-ethoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine                 | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -4.78; MS (ESI) m/z 429.3 (M+H) <sup>+</sup> .                                                                                                                                                                                                      |
| 28a   |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine                | <sup>1</sup> H NMR (400MHz, DMSO): δ 7.95 (s, 1H), 6.22 (d, J = 20.8Hz, 1H), 6.07 (s, 2H), 4.65-4.75 (m, 1H), 4.50-4.65 (m, 1H), 4.15-4.45 (m, 5H), 3.95-4.10 (m, 3H), 2.30-2.40 (m, 2H), 1.60-1.70 (m, 2H), 1.20 (d, J = 22.8Hz, 3H), 0.90 (t, J = 7.2Hz, 3H). MS(ESI), m/z 443.14 (M+1) <sup>+</sup> . |
| 28b   |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine                | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -4.75; MS (ESI) m/z 443.3 (M+H) <sup>+</sup> .                                                                                                                                                                                                      |
| 29    |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-7-fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine             | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -5.77; MS (ESI) m/z 443.3 (M+H) <sup>+</sup> .                                                                                                                                                                                                      |

| Ex No | Structure | Chemical Name                                                                                                                                                      | Analytical Data                                                                                                                                                                                                                                                                                   |
|-------|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 30    |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-butoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine         | <sup>1</sup> H NMR (400MHz, DMSO): δ 7.91 (s, 1H), 6.21 (d, J = 20.8Hz, 1H), 5.85 (s, 2H), 4.50-4.75 (m, 3H), 3.90-4.40 (m, 7H), 2.30-2.40 (m, 2H), 1.60-1.70 (m, 2H), 1.30-1.40 (m, 2H), 1.15 (d, J = 22.8Hz, 3H), 0.85 (t, J = 7.2Hz, 3H). MS(ESI), m/z 457.17(M+1) <sup>+</sup> .              |
| 31    |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclobutoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine    | <sup>1</sup> H NMR (400MHz, DMSO): δ 7.95 (s, 1H), 6.25 (d, J = 22.2Hz, 1H), 5.99 (s, 2H), 4.74-4.83 (m, 1H), 4.60-4.69 (m, 2H), 4.19-4.31 (m, 6H), 2.30-2.39 (m, 2H), 2.22-2.27 (m, 4H), 1.67-1.75 (m, 1H), 1.46-1.58 (m, 1H), 1.19 (d, J = 22.4Hz, 3H). MS(ESI), m/z 455.2 (M+1) <sup>+</sup> . |
| 32a   |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclopentyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine | <sup>1</sup> H NMR (400MHz, DMSO): δ 7.96 (s, 1H), 6.21 (d, J = 21.2Hz, 1H), 6.07 (s, 2H), 4.85-4.95 (m, 1H), 4.55-4.70 (m, 2H), 4.00-4.45 (m, 6H), 2.30-2.40 (m, 2H), 1.75-1.85 (m, 3H), 1.50-1.70 (m, 5H), 1.20 (d, J = 22.4Hz, 6H). MS(ESI), m/z 469.11 (M+1) <sup>+</sup> .                   |

| Ex No | Structure | Chemical Name                                                                                                                                                      | Analytical Data                                                                                                                                                                                                                                                                                                |
|-------|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 32b   |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclopentyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine | <sup>1</sup> H NMR (400MHz, DMSO): δ 7.94 (s, 1H), 6.24 (d, J = 20.8Hz, 1H), 5.85 (s, 2H), 4.85-4.95 (m, 1H), 4.60-4.75 (m, 2H), 4.00-4.60 (m, 6H), 2.30-2.40 (m, 2H), 1.80-1.90 (m, 3H), 1.70-1.80 (m, 3H), 1.50-1.60 (m, 2H), 1.14 (d, J = 22.4Hz, 6H). MS(ESI), m/z 469.10 (M+1) <sup>+</sup> .             |
| 33a   |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclohexyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine  | <sup>1</sup> H NMR (400MHz, DMSO): δ 7.94 (s, 1H), 6.23 (d, J = 21.2Hz, 1H), 5.80 (s, 2H), 4.55-4.75 (m, 2H), 4.35-4.45 (m, 2H), 4.00-4.35 (m, 5H), 2.30-2.40 (m, 2H), 1.85-2.00 (m, 2H), 1.65-1.80 (m, 2H), 1.50-1.65 (m, 2H), 1.40-1.50 (m, 1H), 1.10-1.40 (m, 6H). MS(ESI), m/z 483.13 (M+1) <sup>+</sup> . |
| 33b   |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclohexyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine  | <sup>1</sup> H NMR (400MHz, DMSO): δ 7.97 (s, 1H), 6.20 (d, J = 21.6Hz, 1H), 6.05 (s, 2H), 4.65-4.75 (m, 1H), 4.50-4.65 (m, 1H), 4.30-4.45 (m, 3H), 4.10-4.30 (m, 4H), 2.30-2.40 (m, 2H), 1.80-1.90 (m, 2H), 1.60-1.70 (m, 2H), 1.40-1.60 (m, 3H), 1.15-1.40 (m, 6H). MS(ESI), m/z                             |

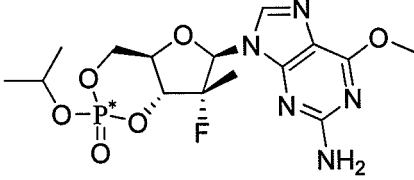
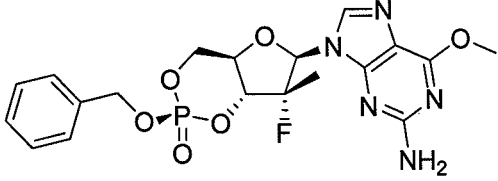
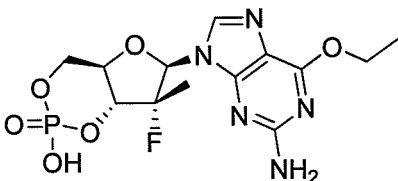
| Ex No | Structure | Chemical Name                                                                                                                                                          | Analytical Data                                                                                                                                                                                                                                                                                    |
|-------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |           |                                                                                                                                                                        | 483.13 (M+1) <sup>+</sup> .                                                                                                                                                                                                                                                                        |
| 34a   |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclopropylmethoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine | <sup>1</sup> H NMR (400MHz, DMSO): δ 8.03 (s, 1H), 6.29 (d, J = 21.6Hz, 1H), 6.16 (s, 2H), 5.10-5.25 (m, 1H), 4.60-4.85 (m, 2H), 4.15-4.50 (m, 5H), 2.30-2.45 (m, 4H), 2.10-2.25 (m, 2H), 1.70-1.80 (m, 1H), 1.50-1.60 (m, 1H), 1.28 (d, J = 22.8Hz, 3H). MS(ESI), m/z 455.13 (M+1) <sup>+</sup> . |
| 34b   |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclopropylmethoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine | <sup>1</sup> H NMR (400MHz, DMSO): δ = 7.95 (s, 1H), 6.23 (d, J = 20.8Hz, 1H), 5.85 (s, 2H), 4.60-4.80 (m, 3H), 4.10-4.40 (m, 6H), 2.30-2.40 (m, 2H), 2.20-2.30 (m, 4H), 1.60-1.75 (m, 1H), 1.45-1.55 (m, 1H), 1.18 (d, J = 22.8Hz, 3H). MS(ESI), m/z 455.13 (M+1) <sup>+</sup> .                  |
| 35    |           | 6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-phenoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine            | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -10.84; MS (ESI) m/z 477.3 (M+H) <sup>+</sup> .                                                                                                                                                                                               |
| 36a   |           | 2-Amino-9-((2S,4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol                      | <sup>1</sup> H NMR (400 MHz, DMSO-d <sub>6</sub> ) δ 10.80 (s, 1H), 7.99 (s, 1H), 7.34 (s, 1H), 6.65 (s, 2H), 6.18 (d, J = 20.8 Hz, 1H), 4.78-4.57 (m, 2H), 4.41 (m,                                                                                                                               |

| Ex No | Structure                                                                           | Chemical Name                                                                                                                                     | Analytical Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
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|       |                                                                                     |                                                                                                                                                   | <sup>1</sup> H), 4.03 (q, J = 8.0 Hz, 2H), 1.65 (sextet, J = 7.2 Hz, 2H), 1.24 (d, J = 22.8 Hz, 3H), 0.92 (t, J = 7.2 Hz, 3H); <sup>31</sup> P NMR (162 MHz, DMSO-d <sub>6</sub> ) δ -4.05; <b>LRMS (ESI)</b> calculated for C <sub>14</sub> H <sub>20</sub> FN <sub>5</sub> O <sub>6</sub> P [(M + H) <sup>+</sup> ] 404.3, found 404.3.                                                                                                                                                           |
| 36b   |  | 2-Amino-9-((2R,4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol | <sup>1</sup> H NMR (400 MHz, DMSO-d <sub>6</sub> ) δ 10.77 (s, 1H), 8.02 (s, 1H), 7.34 (s, 1H), 6.53 (bs, 2H), 6.19 (d, J = 20.8 Hz, 1H), 4.74-4.61 (m, 2H), 4.24 (m, 1H), 4.08 (q, J = 8.4 Hz, 2H), 1.72 (sextet, J = 7.2 Hz, 2H), 1.22 (d, J = 22.8 Hz, 3H), 0.95 (t, J = 7.2 Hz, 3H); <sup>31</sup> P NMR (162 MHz, DMSO-d <sub>6</sub> ) δ -5.36; <b>LRMS (ESI)</b> calculated for C <sub>14</sub> H <sub>20</sub> FN <sub>5</sub> O <sub>6</sub> P [(M + H) <sup>+</sup> ] 404.3, found 404.3. |
| 37    |  | 2-Amino-9-((2R,4aR,6R,7R,7aR)-2-butoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol  | <sup>1</sup> H NMR (400MHz, DMSO): δ 10.76 (s, 1H), 7.98 (s, 1H), 6.51 (s, 2H), 6.17 (d, J=21.6Hz, 1H), 4.55-4.71 (m, 3H), 4.05-4.25 (m, 3H), 1.60-1.70 (m, 2H), 1.30-1.40 (m, 2H), 1.19 (d, J=22.8Hz, 3H), 0.88 (t, J=7.2Hz, 3H).                                                                                                                                                                                                                                                                  |

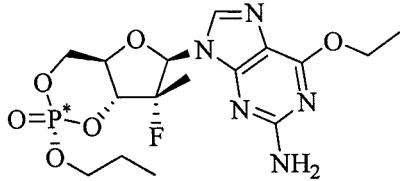
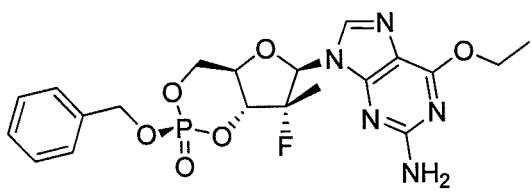
| Ex No | Structure | Chemical Name                                                                                                                                                                     | Analytical Data                                                                                                                                                                                                                                                                                                                                                        |
|-------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |           |                                                                                                                                                                                   | <b>MS(ESI) m/z</b><br>418.09 (M+1) <sup>+</sup> .                                                                                                                                                                                                                                                                                                                      |
| 38a   |           | 2-Amino-9-<br>((4aR,6R,7R,7aR)-2-<br>cyclopropylmethoxy-7-<br>fluoro-7-methyl-2-oxo-<br>tetrahydro-2λ <sup>5</sup> -furo[3,2-<br>d][1,3,2]dioxaphosphinin-<br>6-yl)-9H-purin-6-ol | <b><sup>1</sup>H NMR</b><br>(400MHz,<br>DMSO): δ<br>10.76 (s, 1H),<br>7.99 (s, 1H),<br>6.48 (s, 2H),<br>6.16 (d, J =<br>21.2Hz, 1H),<br>4.55-4.80 (m,<br>3H), 3.95-4.20<br>(m, 2H), 2.15-<br>2.35 (m, 4H),<br>1.60-1.70 (m,<br>1H), 1.40-1.50<br>(m, 1H), 1.18 (d,<br>J = 22.8Hz, 3H).<br><b>MS(ESI), m/z</b><br>416.05 (M+1) <sup>+</sup> .                           |
| 38b   |           | 2-Amino-9-<br>((4aR,6R,7R,7aR)-2-<br>cyclopropylmethoxy-7-<br>fluoro-7-methyl-2-oxo-<br>tetrahydro-2λ <sup>5</sup> -furo[3,2-<br>d][1,3,2]dioxaphosphinin-<br>6-yl)-9H-purin-6-ol | <b><sup>1</sup>H NMR</b><br>(400MHz,<br>DMSO): δ<br>10.76 (s, 1H),<br>7.91 (s, 1H),<br>6.65 (s, 2H),<br>6.12 (d, J =<br>21.6Hz, 1H),<br>4.50-4.75 (m,<br>3H), 3.90-4.40<br>(m, 2H), 2.15-<br>2.30 (m, 2H),<br>2.00-2.15 (m,<br>2H), 1.60-1.70<br>(m, 1H), 1.35-<br>1.45 (m, 1H),<br>1.18 (d, J =<br>22.8Hz, 3H).<br><b>MS(ESI), m/z</b><br>416.07 (M+1) <sup>+</sup> . |
| 39    |           | 2-Amino-9-<br>((4aR,6R,7R,7aR)-2-<br>cyclopentyloxy-7-fluoro-<br>7-methyl-2-oxo-<br>tetrahydro-2λ <sup>5</sup> -furo[3,2-<br>d][1,3,<br>2]dioxaphosphinin-6-yl)-<br>9H-purin-6-ol | <b><sup>1</sup>H NMR</b><br>(400MHz,<br>DMSO): δ<br>10.79 (s, 1H),<br>8.01 (s, 1H),<br>6.50 (s, 2H),<br>6.19 (d, J =<br>20.8Hz, 1H),<br>4.88-4.90 (m,<br>1H), 4.50-4.70<br>(m, 3H), 4.20-<br>4.30 (m, 1H),<br>1.80-2.00 (m,                                                                                                                                            |

| Ex No | Structure | Chemical Name                                                                                                                                           | Analytical Data                                                                                                                                                                                                                                                                                           |
|-------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |           |                                                                                                                                                         | 4H), 1.65-1.80 (m, 2H), 1.50-1.60 (m, 2H), 1.19 (d, J = 22.4Hz, 6H).<br><b>MS(ESI)</b> , m/z 430.03 (M+1) <sup>+</sup> .                                                                                                                                                                                  |
| 40a   |           | 2-Amino-9-((2S,4aR,6R,7R,7aR)-2-cyclohexyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol | <b><sup>1</sup>H NMR (400MHz, DMSO)</b> : δ 10.75 (s, 1H), 7.99 (s, 1H), 6.46 (s, 2H), 6.17 (d, J = 21.2Hz, 1H), 4.50-4.90 (m, 3H), 4.30-4.40 (m, 1H), 4.15-4.25 (m, 1H), 1.80-2.00 (m, 2H), 1.60-1.75 (m, 2H), 1.40-1.60 (m, 3H), 1.10-1.35 (m, 6H).<br><b>MS(ESI)</b> , m/e 444.08 (M+1) <sup>+</sup> . |
| 40b   |           | 2-Amino-9-((2R,4aR,6R,7R,7aR)-2-cyclohexyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol | <b><sup>1</sup>H NMR (400MHz, DMSO)</b> : δ 10.73 (s, 1H), 7.94 (s, 1H), 6.60 (s, 2H), 6.15 (d, J = 21.2Hz, 1H), 4.50-5.30 (m, 3H), 4.20-4.45 (m, 2H), 1.80-1.95 (m, 2H), 1.60-1.70 (m, 2H), 1.38-1.55 (m, 3H), 1.10-1.35 (m, 6H).<br><b>MS(ESI)</b> , m/z 444.11 (M+1) <sup>+</sup> .                    |
| 41    |           | (4aR,6R,7R,7aR)-6-(2-Amino-6-methoxy-purin-9-yl)-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-2-ol             | <b><sup>31</sup>P NMR (162 MHz, DMSO)</b> : δ -5.00;<br><b><sup>1</sup>H NMR (400 MHz, DMSO)</b> : δ: 8.14 (s, 1 H), 6.55 (bs, 2H), 6.24 (d, J=21.2 Hz, 1H), 4.57-4.46 (m, 3 H), 4.19- 4.16 (m, 1 H), 3.95 (s, 3H), 1.19 (d, J=22.8 Hz, 3H);<br><b>MS (ESI)</b> : m/z                                     |

| Ex No | Structure | Chemical Name                                                                                                                                            | Analytical Data                                                                                                                                                                                                                                                                                                                        |
|-------|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |           |                                                                                                                                                          | 374.4 [M+1] <sup>+</sup>                                                                                                                                                                                                                                                                                                               |
| 42a   |           | 9-((4aR,6R,7R,7aR)-2-Butoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-methoxy-9H-purin-2-ylamine     | <sup>1</sup> H NMR (CDCl <sub>3</sub> , 400 MHz) δ: 7.59 (s, 1 H), 6.03 (d, J = 19.6 Hz, 1 H), 4.87 (s, 2 H), 4.59- 4.69 (m, 1 H), 4.38- 4.51 (m, 2 H), 4.22- 4.28 (m, 2 H), 4.08 (s, 3 H), 1.75- 1.82 (m, 2 H), 1.44- 1.52 (m, 2 H), 1.34 (d, J = 22 Hz, 3 H), 0.98 (t, J = 7.6 Hz, 3 H).                                             |
| 42b   |           | 9-((4aR,6R,7R,7aR)-2-Butoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-methoxy-9H-purin-2-ylamine     | <sup>1</sup> H NMR (CDCl <sub>3</sub> , 400 MHz) δ: 7.58 (s, 1 H), 5.97 (d, J = 20 Hz, 1 H), 5.13 (s, 2 H), 4.60- 4.66 (m, 2 H), 4.37- 4.43 (m, 1 H), 4.18- 4.24 (m, 2 H), 4.06 (s, 3 H), 1.68- 1.76(m, 2 H), 1.40- 1.47 (m, 2 H), 1.32 (d, J = 29.2 Hz, 3 H), 0.95 (t, J = 14.8 Hz, 3 H).<br>MS (ESI): m/z 432.1 [M+1] <sup>+</sup> . |
| 43a   |           | 9-((4aR,6R,7R,7aR)-7-Fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-methoxy-9H-purin-2-ylamine | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -5.99;<br><sup>1</sup> H NMR (CDCl <sub>3</sub> , 400 MHz) δ: 7.59 (s, 1 H), 6.02 (d, J = 18.8 Hz, 1 H), 4.86- 4.91 (m, 2 H), 4.58- 4.67 (m, 1 H), 4.50 (t, J = 9.8 Hz, 1 H), 4.38- 4.43(m, 1 H), 4.08 (s, 3 H), 1.40- 1.48 (m, 6 H), 1.39 (d, J =                                |

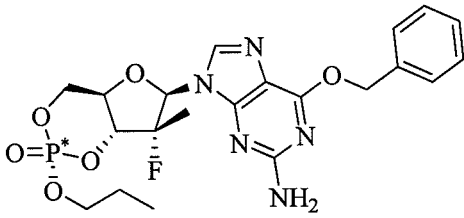
| Ex No | Structure                                                                           | Chemical Name                                                                                                                                               | Analytical Data                                                                                                                                                                                                                                                                                                                                                         |
|-------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |                                                                                     |                                                                                                                                                             | 16.4Hz, 3 H).<br><b>MS (ESI):</b> m/z 418.4 [M+1] <sup>+</sup> .                                                                                                                                                                                                                                                                                                        |
| 43b   |    | 9-((2R,4aR,6R,7R,7aR)-7-Fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-methoxy-9H-purin-2-ylamine | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -2.47;<br><sup>1</sup> H NMR (CDCl <sub>3</sub> , 400 MHz) δ: 7.57 (s, 1 H), 5.98 (d, J = 20 Hz, 1 H), 5.06 (s, 1 H), 4.79- 4.85 (m, 1 H), 4.58- 4.64 (m, 2 H), 4.41- 4.45(m, 1 H), 4.08 (s, 3 H), 1,34- 1.47 (m, 9 H);<br><b>MS (ESI):</b> m/z 418.4 [M+1] <sup>+</sup>                                           |
| 44    |  | 9-((2R,4aR,6R,7R,7aR)-2-Benzyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-methoxy-9H-purin-2-ylamine  | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -4.88;<br><sup>1</sup> H NMR (400 MHz, CDCl <sub>3</sub> ) δ: 7.51-7.49 (m, 3H), 7.44-7.37 (m, 3H), 5.93 (d, J=19.6Hz, 1H), 5.26-5.19 (m, 2H), 4.63(dd, J=8.8, 4.0Hz, 1H), 4.57 (dd, J=8.8, 4.4Hz, 1H), 4.45-4.33 (m, 4H), 4.04 (s, 3H), 1.18(d, J=22.4Hz, 3H);<br><b>MS (ESI):</b> m/z 466.4 [M+1] <sup>+</sup> . |
| 45    |  | (4aR,6R,7R,7aR)-6-(2-Amino-6-ethoxy-purin-9-yl)-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-2-ol                  | <sup>31</sup> P NMR (162 MHz, DMSO): δ -4.97;<br><sup>1</sup> H NMR (400 MHz, DMSO) δ: 8.13 (s, 1 H), 6.51 (bs, 2H), 6.23 (d, J=21.2 Hz, 1H), 4.56- 4.46 (m, 3 H), 4.43 (q, J=7.2Hz, 2H), 4.18- 4.12 (m, 1 H), 1.34 (t, J=7.2Hz, 3H), 1.19 (d, J=22.8 Hz, 3H);                                                                                                          |

| Ex No | Structure | Chemical Name                                                                                                                                        | Analytical Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |           |                                                                                                                                                      | <b>MS (ESI):</b> m/z 390.3 [M+1] <sup>+</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 46    |           | 6-Ethoxy-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine | Mixture of cis/trans isomers (ca. 1.5/1):<br><b><sup>1</sup>H NMR</b> (400 MHz, DMSO-d <sub>6</sub> ) δ 8.16 (s, 2.5H), 6.65 (s, 3H), 6.55 (s, 2H), 6.28 (d, J = 20.8 Hz, 2.5H), 4.78-4.60 (m, 7.5H), 4.45 (q, J = 6.8 Hz, 1H), 4.44 (q, J = 6.8 Hz, 1.5H), 4.25 (m, 2.5H), 3.83 (d, J = 11.6 Hz, 3H), 3.76 (d, J = 11.6 Hz, 4.5H), 1.36 (t, J = 7.2 Hz, 3H), 1.36 (t, J = 7.2 Hz, 4.5H), 1.23 (d, J = 22.4 Hz, 3H), 1.22 (d, J = 22.8 Hz, 4.5H);<br><b><sup>31</sup>P NMR</b> (162 MHz, DMSO-d <sub>6</sub> ) δ -3.25, -4.16;<br><b>LRMS (ESI)</b> calculated for C <sub>14</sub> H <sub>20</sub> FN <sub>5</sub> O <sub>6</sub> P [(M + H) <sup>+</sup> ] 404.3, found 404.3. |
| 47a   |           | 6-Ethoxy-9-((4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine | <b><sup>1</sup>H NMR</b> (400 MHz, DMSO-d <sub>6</sub> ) δ 8.16 (s, 1H), 6.50 (bs, 2H), 6.29 (d, J = 20.8 Hz, 1H), 4.74-4.63 (m, 2H), 4.45 (q, J = 7.2 Hz, 2H), 4.25-4.22 (m, 1H), 4.09 (q, J = 7.6 Hz, 2H), 1.73 (quintet, J = 6.8 Hz, 2H),                                                                                                                                                                                                                                                                                                                                                                                                                                    |

| Ex No | Structure                                                                           | Chemical Name                                                                                                                                           | Analytical Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |                                                                                     |                                                                                                                                                         | 1.37 (t, J = 7.2 Hz, 3H), 1.21 (d, J = 22.8 Hz, 3H), 0.94 (t, J = 7.2 Hz, 3H);<br><sup>31</sup> P NMR (162 MHz, DMSO-d <sub>6</sub> ) δ -5.29;<br><b>LRMS (ESI)</b> calculated for C <sub>16</sub> H <sub>24</sub> FN <sub>5</sub> O <sub>6</sub> P [(M + H) <sup>+</sup> ] 432.4, found 432.3.                                                                                                                                                                                                                                  |
| 47b   |  | 6-Ethoxy-9-((2S,4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine | <sup>1</sup> H NMR (400 MHz, DMSO-d <sub>6</sub> ) δ 8.15 (s, 1H), 6.64 (bs, 2H), 6.27 (d, J = 21.2 Hz, 1H), 4.76-4.63 (m, 2H), 4.44 (q, J = 7.2 Hz, 2H), 4.41 (m, 1H), 4.04 (q, J = 8.0 Hz, 2H), 1.66 (sextet, J = 7.2 Hz, 2H), 1.36 (t, J = 7.2 Hz, 3H), 1.23 (d, J = 23.2 Hz, 3H), 0.92 (t, J = 7.6 Hz, 3H);<br><sup>31</sup> P NMR (162 MHz, DMSO-d <sub>6</sub> ) δ -3.95;<br><b>LRMS (ESI)</b> calculated for C <sub>16</sub> H <sub>24</sub> FN <sub>5</sub> O <sub>6</sub> P [(M + H) <sup>+</sup> ] 432.4, found 432.3. |
| 48    |  | 9-((4aR,6R,7R,7aR)-2-Benzyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-ethoxy-9H-purin-2-ylamine  | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -4.87;<br><sup>1</sup> H NMR (400 MHz, CDCl <sub>3</sub> ) δ: 7.51-7.49 (m, 3H), 7.44-7.39 (m, 3H), 5.93 (d, J=19.6Hz, 1H), 5.27-5.19 (m, 2H), 4.63(dd, J=8.8, 4.4Hz, 1H), 4.58 (dd, J=8.8, 4.4Hz, 1H), 4.51 (q, J=7.0Hz, 2H), 4.46-4.33 (m,                                                                                                                                                                                                                                |

| Ex No | Structure | Chemical Name                                                                                                                                           | Analytical Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |           |                                                                                                                                                         | 4H), 1.45 (t, J=7.2Hz, 3H), 1.20(d, J=22.4Hz, 3H);<br><b>MS (ESI):</b> m/z 480.3 [M+1] <sup>+</sup> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 49    |           | 6-Ethoxy-9-((4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-phenoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine    | Mixture of cis/trans isomers (ca. 1/0.5):<br><b><sup>1</sup>H NMR</b> (400 MHz, DMSO-d <sub>6</sub> ) δ 8.22 (s, 1H), 8.12 (s, 0.5H), 7.49-7.27 (m, 7.5H), 6.70 (bs, 0.5H), 6.56 (bs, 1H), 6.33 (d, J = 20.8 Hz, 1H), 6.30 (d, J = 20.8 Hz, 0.5H), 4.95-4.78 (m, 3H), 4.60-4.32 (m, 6H), 1.36 (t, J = 7.2 Hz, 3H), 1.36 (t, J = 7.2 Hz, 1.5H), 1.21 (d, J = 22.4 Hz, 4.5H);<br><b><sup>31</sup>P NMR</b> (162 MHz, DMSO-d <sub>6</sub> ) δ -10.16, -11.11;<br><b>LRMS (ESI)</b> calculated for C <sub>19</sub> H <sub>22</sub> FN <sub>5</sub> O <sub>6</sub> P [(M + H) <sup>+</sup> ] 466.4, found 466.3. |
| 50    |           | 9-((4aR,6R,7R,7aR)-7-Fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine   | <b><sup>31</sup>P NMR</b> (162 MHz, CDCl <sub>3</sub> ): δ -1.35, -3.90;<br><b>MS (ESI)</b> m/z 418.3 (M+H) <sup>+</sup> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 51    |           | 9-((2S,4aR,6R,7R,7aR)-2-Ethoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine | <b><sup>31</sup>P NMR</b> (162 MHz, CDCl <sub>3</sub> ): δ -2.01, -4.98;<br><b>MS (ESI)</b> m/z 432.1 (M+H) <sup>+</sup> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

| Ex No | Structure | Chemical Name                                                                                                                                               | Analytical Data                                                                                                                                                                                             |
|-------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 52a   |           | 9-((2R,4aR,6R,7R,7aR)-7-Fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine    | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -4.945; MS (ESI) m/z 446.1 (M+H) <sup>+</sup> .                                                                                                        |
| 52b   |           | 9-((2S,4aR,6R,7R,7aR)-7-Fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine    | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -1.90; MS (ESI) m/z 446.1 (M+H) <sup>+</sup> .                                                                                                         |
| 53a   |           | 9-((2R,4aR,6R,7R,7aR)-7-Fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -5.97; MS (ESI) m/z 446.1 (M+H) <sup>+</sup> .                                                                                                         |
| 53b   |           | 9-((2S,4aR,6R,7R,7aR)-7-Fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -2.51; MS (ESI) m/z 446.1 (M+H) <sup>+</sup> .                                                                                                         |
| 54    |           | 9-((2S,4aR,6R,7R,7aR)-2-Butoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine     | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -4.92; MS (ESI) m/z 460.1 (M+H) <sup>+</sup> .                                                                                                         |
| 55    |           | 9-((4aR,6R,7R,7aR)-7-Fluoro-7-methyl-2-oxo-2-phenoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine       | <sup>31</sup> P NMR (162 MHz, CDCl <sub>3</sub> ): δ -11.05; MS (ESI) m/z 480.3 (M+H) <sup>+</sup> .                                                                                                        |
| 56    |           | 6-Benzyloxy-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine     | Mixture of cis/trans isomers (ca. 1.5/1): <sup>1</sup> H NMR (400 MHz, DMSO-d <sub>6</sub> ) δ 8.16 (s, 2.5H), 7.53-7.34 (m, 12.5H), 6.74 (s, 3H), 6.64 (s, 2H), 6.18 (d, J = 21.2 Hz, 2.5H), 5.48 (s, 3H), |

| Ex No | Structure                                                                           | Chemical Name                                                                                                                                              | Analytical Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|-------|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|       |                                                                                     |                                                                                                                                                            | 5.48 (s, 2H), 4.78-4.60 (m, 6H), 4.44 (m, 2.5H), 4.26 (m, 1.5H), 3.83 (d, J = 10.8 Hz, 3H), 3.76 (d, J = 11.6 Hz, 4.5H), 1.24 (d, J = 22.4 Hz, 3H), 1.23 (d, J = 22.8 Hz, 4.5H); <sup>31</sup> P NMR (162 MHz, DMSO-d6) δ -3.25, -4.17; <b>LRMS (ESI)</b> calculated for C <sub>19</sub> H <sub>22</sub> FN <sub>5</sub> O <sub>6</sub> P [(M + H) <sup>+</sup> ] 466.4, found 466.3.                                                                                                                                      |
| 57    |  | 6-Benzyloxy-9-((2S,4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ <sup>5</sup> -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine | <sup>1</sup> H NMR (400 MHz, DMSO-d6) δ 8.17 (s, 1H), 7.52-7.34 (m, 5H), 6.73 (bs, 2H), 6.28 (d, J = 21.2 Hz, 1H), 5.50 (d, J = 12.0 Hz, 1H), 5.46 (d, J = 12.0 Hz, 1H), 4.76-4.62 (m, 2H), 4.45-4.38 (m, 1H), 4.04 (q, J = 8.0 Hz, 2H), 1.66 (sextet, J = 7.2 Hz, 2H), 1.23 (d, J = 23.2 Hz, 3H), 0.92 (t, J = 7.6 Hz, 3H); <sup>31</sup> P NMR (162 MHz, DMSO-d6) δ -3.96; <b>LRMS (ESI)</b> calculated for C <sub>21</sub> H <sub>26</sub> FN <sub>5</sub> O <sub>6</sub> P [(M + H) <sup>+</sup> ] 494.4, found 494.3. |

**HCV replicon assay.** HCV replicon RNA-containing Huh7 cells (clone A cells; Apath, LLC, St. Louis, Mo.) were kept at exponential growth in Dulbecco's modified Eagle's medium (high glucose) containing 10% fetal bovine serum, 4 mM

5 L-glutamine and 1 mM sodium pyruvate, 1× nonessential amino acids, and G418

(1,000  $\mu\text{g/ml}$ ). Antiviral assays were performed in the same medium without G418. Cells were seeded in a 96-well plate at 1,500 cells per well, and test compounds were added immediately after seeding. Incubation time 4 days. At the end of the incubation step, total cellular RNA was isolated (RNeasy 96 kit; Qiagen). Replicon RNA and an internal control (TaqMan rRNA control reagents; Applied Biosystems) were amplified in a single-step multiplex RT-PCR protocol as recommended by the manufacturer. The HCV primers and probe were designed with Primer Express software (Applied Biosystems) and covered highly conserved 5'-untranslated region (UTR) sequences (sense, 5'-AGCCATGGCGTTAGTA(T)GAGTGT-3', and antisense, 5'-TTCCGCAGACCACTATGG-3'; probe, 5'-FAM-CCTCCAGGACCCCCCTCCC-TAMRA-3').

To express the antiviral effectiveness of a compound, the threshold RT-PCR cycle of the test compound was subtracted from the average threshold RT-PCR cycle of the no-drug control ( $\Delta\text{Ct}_{\text{HCV}}$ ). A  $\Delta\text{Ct}$  of 3.3 equals a 1-log 10 reduction (equal to the 90% effective concentration [ $\text{EC}_{90}$ ]) in replicon RNA levels. The cytotoxicity of the test compound could also be expressed by calculating the  $\Delta\text{Ct}_{\text{rRNA}}$  values. The  $\Delta\Delta\text{Ct}$  specificity parameter could then be introduced ( $\Delta\text{Ct}_{\text{HCV}} - \Delta\text{Ct}_{\text{rRNA}}$ ), in which the levels of HCV RNA are normalized for the rRNA levels and calibrated against the no-drug control.

| No         | CloneA $\text{EC}_{90}$ |
|------------|-------------------------|
| <b>1a</b>  | 5.35                    |
| <b>1b</b>  | 17.39                   |
| <b>2a</b>  | 25.25                   |
| <b>2b</b>  | 17.74                   |
| <b>3</b>   | 0.75                    |
| <b>4</b>   | 11.68                   |
| <b>5</b>   | 8.06                    |
| <b>6</b>   | 1.55                    |
| <b>17</b>  | 0.71                    |
| <b>18</b>  | 0.48                    |
| <b>19</b>  | 0.60                    |
| <b>32a</b> | 8.54                    |
| <b>32b</b> | 4.7                     |
| <b>38b</b> | 26.6                    |
| <b>41</b>  | 0.098                   |
| <b>43a</b> | 0.29                    |
| <b>43b</b> | 0.06                    |
| <b>44</b>  | 0.053                   |
| <b>45</b>  | 0.70                    |

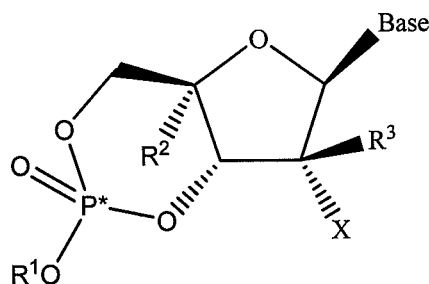
| No | CloneA EC <sub>90</sub> |
|----|-------------------------|
| 48 | 0.32                    |

The contents of U.S. Patent Application No. 12/053,015, filed March 21, 2008 (see also WO 2008/121634), U.S. Provisional Patent Application No. 61/060,683, filed June 11, 2008, U.S. Provisional Patent Application No. 61/140,317, filed December 23, 2008, and U.S. Non-Provisional Patent Application No. 12/479,075, filed June 5, 2009 are hereby incorporated by reference in their entirety. Moreover, the patent and non-patent references disclosed herein are incorporated by reference. In the event that the incorporated subject matter contains a term that conflicts with a term disclosed in the present application text, the meaning of the term contained in the present application controls provided that the overall meaning of the incorporated subject matter is not lost.

We claim:

1. A compound, its stereoisomers, salts (acid or basic addition salts), hydrates, solvates, deuterated analogues, or crystalline forms thereof represented by formula I:

5



I

wherein

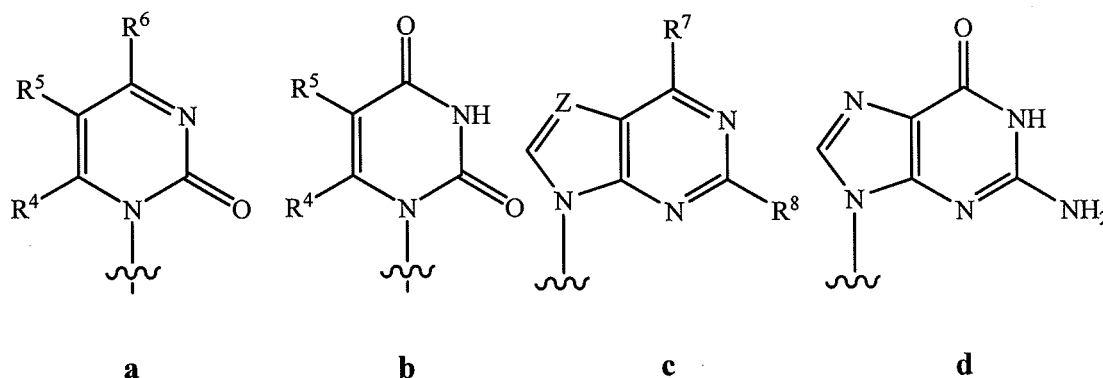
$R^1$  is hydrogen, n-alkyl, branched alkyl, cycloalkyl, alkaryl, or aryl, which includes, but is not limited to, phenyl or naphthyl, where phenyl or naphthyl are optionally substituted with at least one of H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

$R^2$  is H, an optionally substituted alkyl (including lower alkyl), cyano (CN), CH<sub>3</sub>, vinyl, O-alkyl, O-(lower alkyl), including OCH<sub>3</sub>, OCH<sub>2</sub>CH<sub>3</sub>, hydroxyl alkyl, i.e., -(CH<sub>2</sub>)<sub>o</sub>OH, wherein o is 1 – 10, hydroxyl lower alkyl, i.e., -(CH<sub>2</sub>)<sub>p</sub>OH, where p is 1-6, including hydroxyl methyl (CH<sub>2</sub>OH), fluoromethyl (CH<sub>2</sub>F), azido (N<sub>3</sub>), CH<sub>2</sub>CN, CH<sub>2</sub>N<sub>3</sub>, CH<sub>2</sub>NH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>3</sub>, CH<sub>2</sub>N(CH<sub>3</sub>)<sub>2</sub>, ethynyl alkyne (optionally substituted), or halogen, including F, Cl, Br, or I;

$R^3$  is H, CH<sub>3</sub>, CH<sub>2</sub>F, CHF<sub>2</sub>, CF<sub>3</sub>, F, or CN;

X is H, OH, F, OMe, halogen, NH<sub>2</sub>, or N<sub>3</sub>;

Base is a naturally occurring or modified purine or pyrimidine base represented by the following structures:



5

wherein

Z is N or CR<sup>9</sup>;

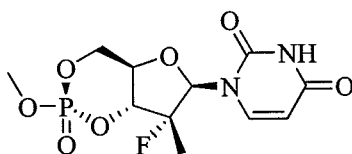
R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, R<sup>7</sup>, and R<sup>8</sup> are independently H, F, Cl, Br, I, OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NHR'<sub>2</sub><sup>+</sup>, NR'<sub>3</sub><sup>+</sup>, heterocycle, lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub> such as C≡CH, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

R<sup>9</sup> is an H, halogen (including F, Cl, Br, I), OH, OR', SH, SR', NH<sub>2</sub>, NHR', NR'<sub>2</sub>, NO<sub>2</sub> lower alkyl, halogenated (F, Cl, Br, I) lower alkyl, lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkenyl of C<sub>2</sub>-C<sub>6</sub>, lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkynyl of C<sub>2</sub>-C<sub>6</sub>, lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, halogenated (F, Cl, Br, I) lower alkoxy of C<sub>1</sub>-C<sub>6</sub>, CO<sub>2</sub>H, CO<sub>2</sub>R', CONH<sub>2</sub>, CONHR', CONR'<sub>2</sub>, CH=CHCO<sub>2</sub>H, or CH=CHCO<sub>2</sub>R';

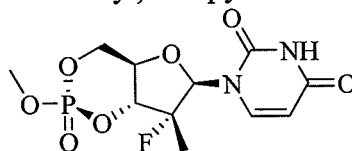
wherein R' is an optionally substituted alkyl, an optionally substituted cycloalkyl, an optionally substituted alkynyl, an optionally substituted alkenyl, or an optionally substituted acyl, an optionally substituted alkoxyalkyl, where for the instance of NR'<sub>2</sub> or NHR'<sub>2</sub><sup>+</sup> each R' comprise at least one C atom that is independent

of one another or are joined to form a heterocycle comprising at least two carbon atoms, and where for the instance of  $\text{NR}'_3^+$  each  $\text{R}'$  comprises at least one C atom which are independent of one another or each  $\text{R}'$  comprises at least one C atom in which at least two  $\text{R}'$  are joined to form a heterocycle comprising at least two carbon atoms.

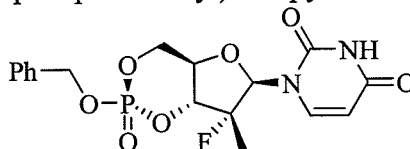
2. A compound its stereoisomer, salt, hydrate, solvate, or crystalline form thereof selected from among



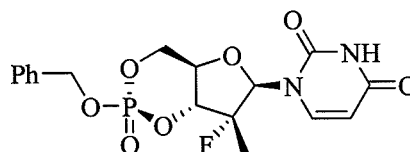
10 1-((2S,4aR,6R,7R,7aR)-7-Fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-1H-pyrimidine-2,4-dione;



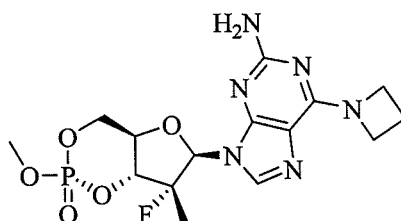
15 1-((2R,4aR,6R,7R,7aR)-7-Fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-1H-pyrimidine-2,4-dione;



20 1-((2S,4aR,6R,7R,7aR)-2-Benzyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-1H-pyrimidine-2,4-dione;

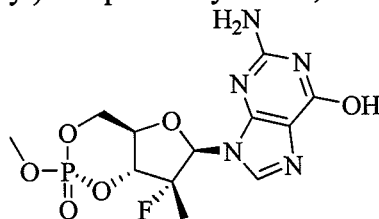


25 1-((2R,4aR,6R,7R,7aR)-2-Benzyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-1H-pyrimidine-2,4-dione;

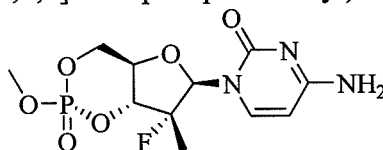


6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-

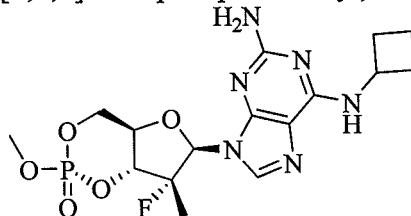
7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2 $\lambda^5$ -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;



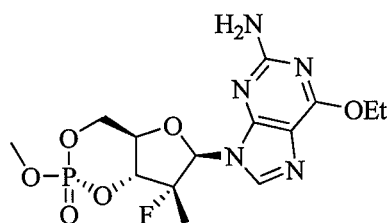
- 5 2-Amino-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2 $\lambda^5$ -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol;



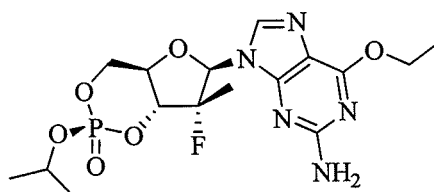
- 10 4-Amino-1-((2R,4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2 $\lambda^5$ -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-1H-pyrimidin-2-one;



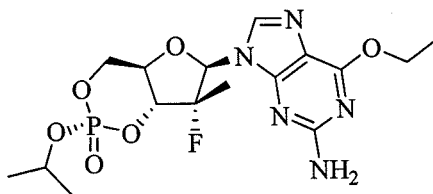
- 15 N<sup>6</sup>-Cyclobutyl-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2 $\lambda^5$ -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purine-2,6-diamine;



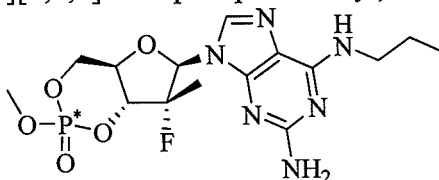
6-Ethoxy-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2,5-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;



- 20 6-Ethoxy-9-((2S,4aR,6R,7R,7aR)-7-fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2 $\lambda^5$ -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;

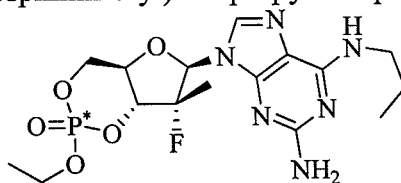


6-Ethoxy-9-((2R,4aR,6R,7R,7aR)-7-fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;



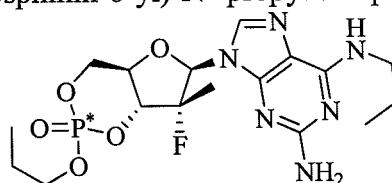
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9-((4aR,6R,7R,7aR)-7-Fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-N<sup>6</sup>-propyl-9H-purine-2,6-diamine;



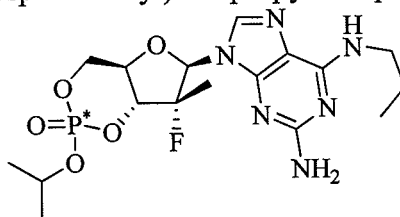
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9-((4aR,6R,7R,7aR)-2-Ethoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-N<sup>6</sup>-propyl-9H-purine-2,6-diamine;



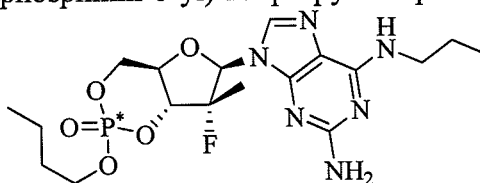
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9-((4aR,6R,7R,7aR)-7-Fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-N<sup>6</sup>-propyl-9H-purine-2,6-diamine;

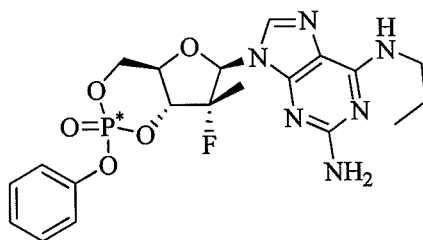


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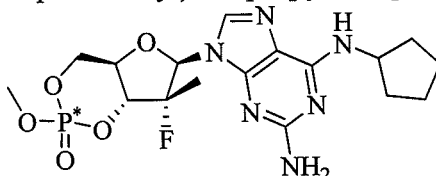
9-((4aR,6R,7R,7aR)-7-Fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-N<sup>6</sup>-propyl-9H-purine-2,6-diamine;



9-((4aR,6R,7R,7aR)-2-Butoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-N<sup>6</sup>-propyl-9H-purine-2,6-diamine;

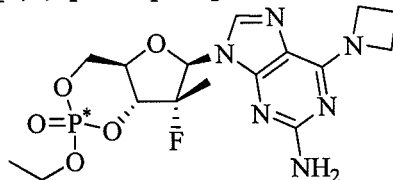


9-((4aR,6R,7R,7aR)-7-Fluoro-7-methyl-2-oxo-2-phenoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-N<sup>6</sup>-propyl-9H-purine-2,6-diamine;



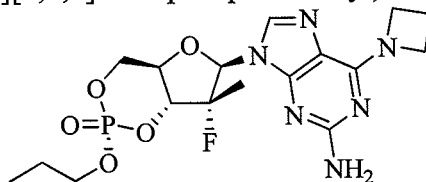
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N<sup>6</sup>-Cyclopentyl-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purine-2,6-diamine;



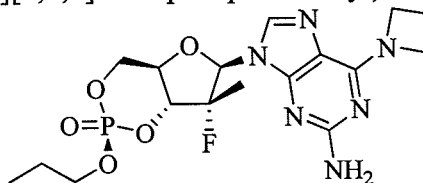
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6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-ethoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;



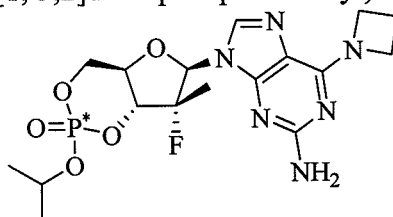
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6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;

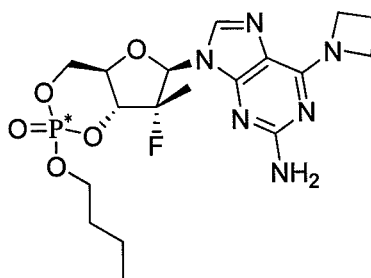


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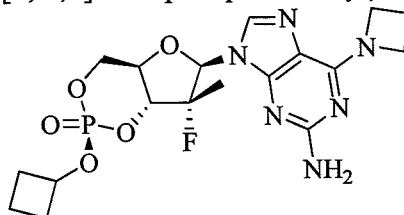
6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-isopropoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;



6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-7-fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;

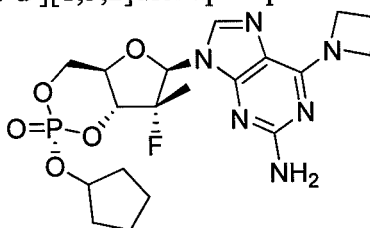


6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-butoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;



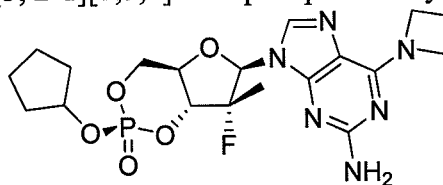
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6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclobutoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;



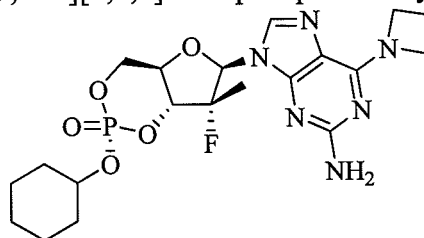
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6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclopentyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;



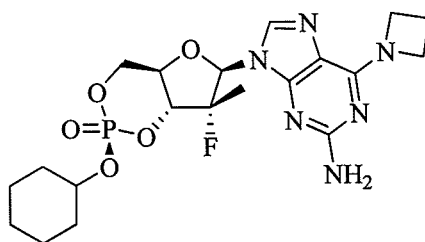
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6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclopentyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;

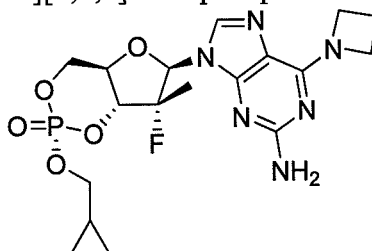


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6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclohexyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;

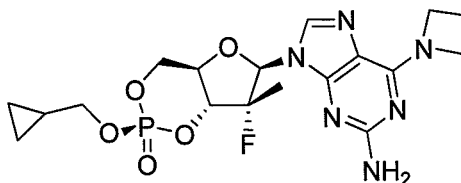


6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclohexyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;



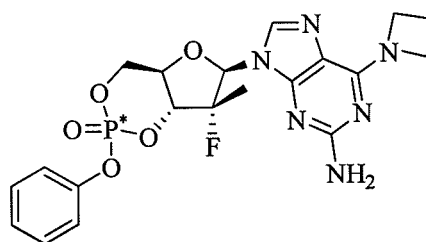
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6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-2-cyclopropylmethoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;



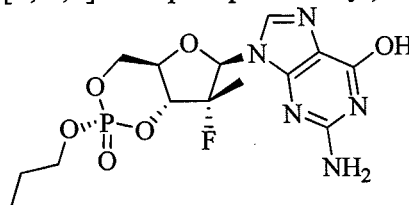
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6-Azetidin-1-yl-9-((4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-phenoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;



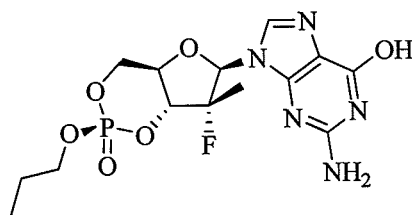
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2-Amino-9-((2S,4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol;

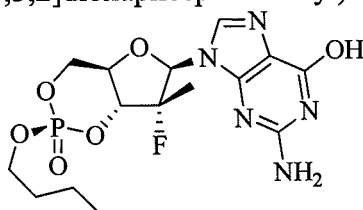


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2-Amino-9-((2S,4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol;

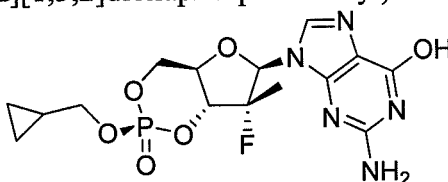


2-Amino-9-((2R,4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2 $\lambda^5$ -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol;



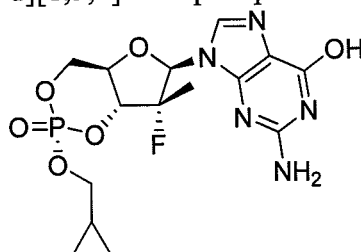
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2-Amino-9-((2R,4aR,6R,7R,7aR)-2-butoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2 $\lambda^5$ -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol;



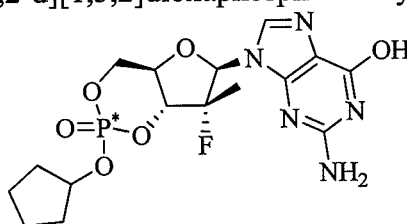
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2-Amino-9-((4aR,6R,7R,7aR)-2-cyclopropylmethoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2 $\lambda^5$ -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol;



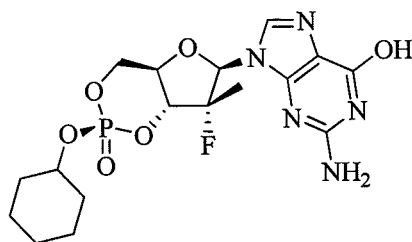
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2-Amino-9-((4aR,6R,7R,7aR)-2-cyclopropylmethoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2 $\lambda^5$ -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol;

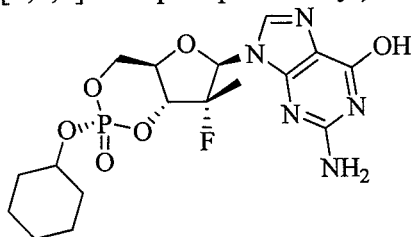


20

2-Amino-9-((4aR,6R,7R,7aR)-2-cyclopentyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2 $\lambda^5$ -furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol;

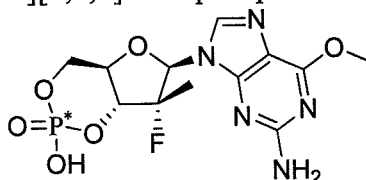


2-Amino-9-((2S,4aR,6R,7R,7aR)-2-cyclohexyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol;



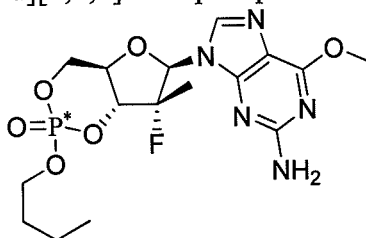
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2-Amino-9-((2R,4aR,6R,7R,7aR)-2-cyclohexyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-6-ol;



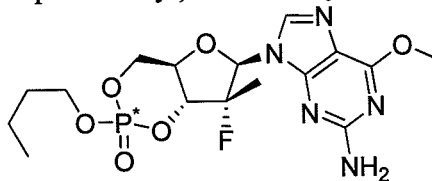
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(4aR,6R,7R,7aR)-6-(2-Amino-6-methoxy-purin-9-yl)-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-2-ol;

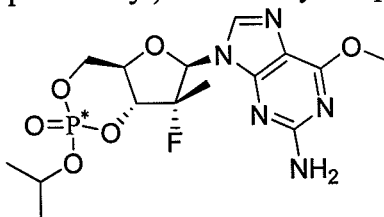


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9-((4aR,6R,7R,7aR)-2-Butoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-methoxy-9H-purin-2-ylamine;

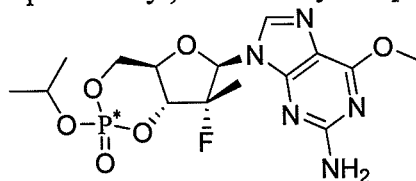


9-((4aR,6R,7R,7aR)-2-Butoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-methoxy-9H-purin-2-ylamine;

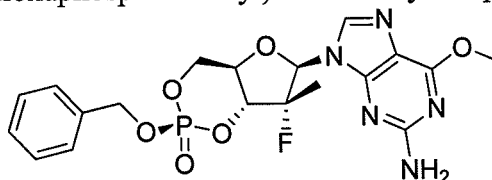


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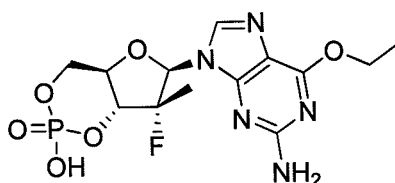
9-((4aR,6R,7R,7aR)-7-Fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-methoxy-9H-purin-2-ylamine;



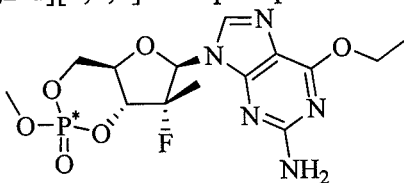
5 9-((2R,4aR,6R,7R,7aR)-7-Fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-methoxy-9H-purin-2-ylamine;



10 9-((2R,4aR,6R,7R,7aR)-2-Benzoyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-methoxy-9H-purin-2-ylamine;

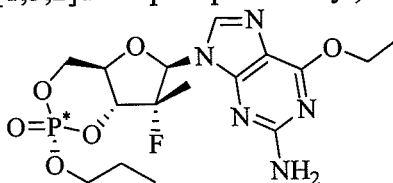


(4aR,6R,7R,7aR)-6-(2-Amino-6-ethoxy-purin-9-yl)-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-2-ol;



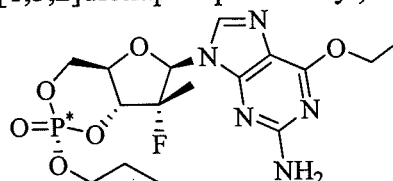
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6-Ethoxy-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;

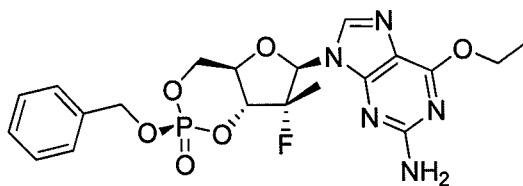


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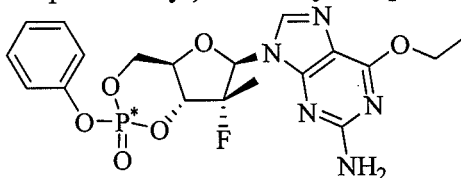
6-Ethoxy-9-((4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;



25 6-Ethoxy-9-((2S,4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;

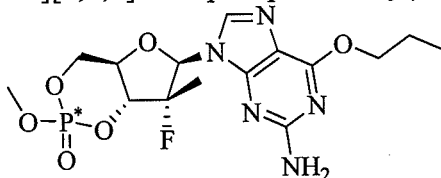


9-((4aR,6R,7R,7aR)-2-Benzyloxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-ethoxy-9H-purin-2-ylamine;

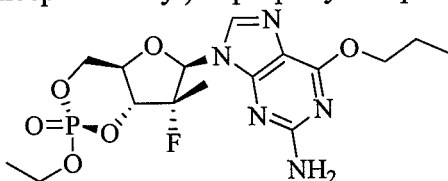


5

6-Ethoxy-9-((4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-phenoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine;

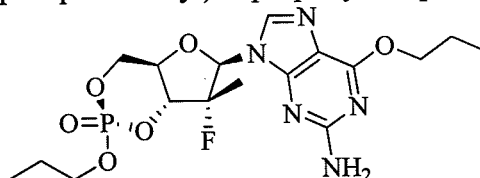


10 9-((4aR,6R,7R,7aR)-7-Fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine;



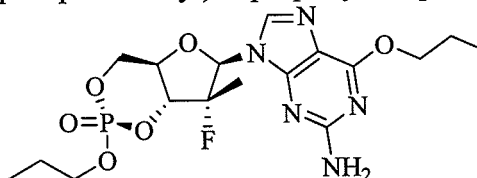
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9-((2S,4aR,6R,7R,7aR)-2-Ethoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine;

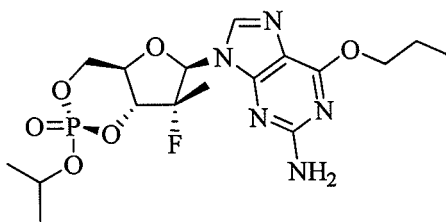


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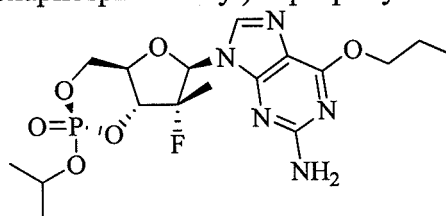
9-((2R,4aR,6R,7R,7aR)-7-Fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine;



9-((2S,4aR,6R,7R,7aR)-7-Fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine;

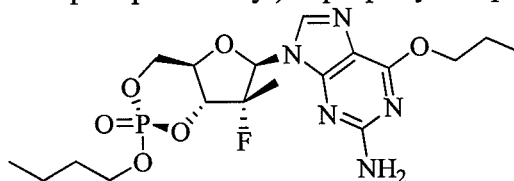


9-((2R,4aR,6R,7R,7aR)-7-Fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine;



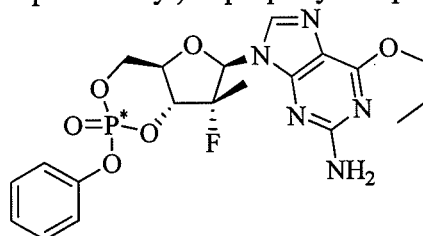
5

9-((2S,4aR,6R,7R,7aR)-7-Fluoro-2-isopropoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine;



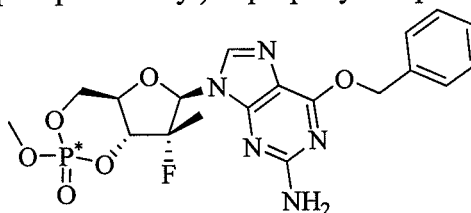
10

9-((2S,4aR,6R,7R,7aR)-2-Butoxy-7-fluoro-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine;

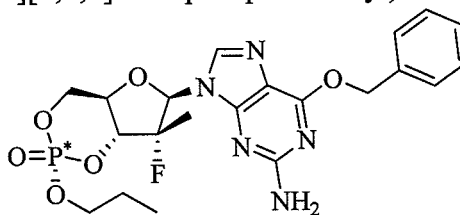


15

9-((4aR,6R,7R,7aR)-7-Fluoro-7-methyl-2-oxo-2-phenoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-6-propoxy-9H-purin-2-ylamine;



6-Benzyloxy-9-((4aR,6R,7R,7aR)-7-fluoro-2-methoxy-7-methyl-2-oxo-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine; and



20

6-Benzyloxy-9-((2S,4aR,6R,7R,7aR)-7-fluoro-7-methyl-2-oxo-2-propoxy-tetrahydro-2λ<sup>5</sup>-furo[3,2-d][1,3,2]dioxaphosphinin-6-yl)-9H-purin-2-ylamine.

3. A composition for the treatment and/or prophylaxis of any of the viral  
5 agents disclosed herein said composition comprising a pharmaceutically acceptable medium selected from among an excipient, carrier, diluent, and equivalent medium and the compound of claim 1.

4. A composition for the treatment and/or prophylaxis of any of the viral  
10 agents disclosed herein said composition comprising a pharmaceutically acceptable medium selected from among an excipient, carrier, diluent, and equivalent medium and the compound of claim 2.

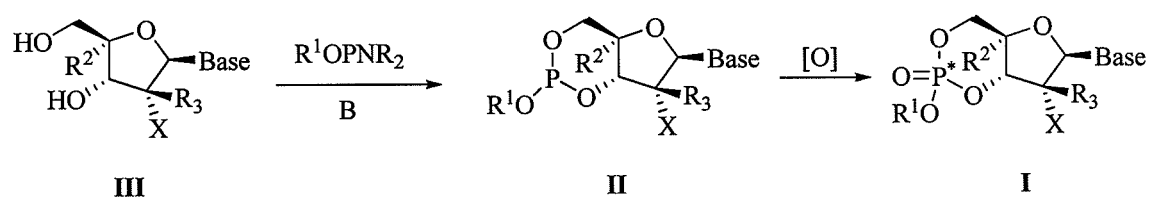
5. A use of the compound of claim 1 in the manufacture of a medicament for the treatment of any condition the result of an infection by hepatitis C virus, West Nile virus, yellow fever virus, dengue virus, rhinovirus, polio virus,  
15 hepatitis A virus, bovine viral diarrhea virus or Japanese encephalitis virus.

6. A use of the compound of claim 2 in the manufacture of a medicament for the treatment of any condition the result of an infection by hepatitis C virus, West Nile virus, yellow fever virus, dengue virus, rhinovirus, polio virus, hepatitis A virus, bovine viral diarrhea virus or Japanese encephalitis virus.

20 7. A method of treatment in a subject in need thereof, which comprises: administering a therapeutically effective amount of the compound of claim 1 to the subject.

8. A method of treatment in a subject in need thereof, which comprises: administering a therapeutically effective amount of the compound of claim 2  
25 to the subject.

9. A process for preparing the compound of claim 1  
said process comprising reacting **III** with R<sup>1</sup>OP(NR<sub>2</sub>)<sub>2</sub>, and then oxidizing **II**  
to form **I** according to the following scheme



wherein R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, X, and Base are defined above;

- 5            wherein R<sup>1</sup>OP(NR<sub>2</sub>)<sub>2</sub> is a dialkylamino-R<sup>1</sup>phosphite, B is a Brønsted base, and [O] is an oxidant.

10.        A composition obtained by the process of claim 9.