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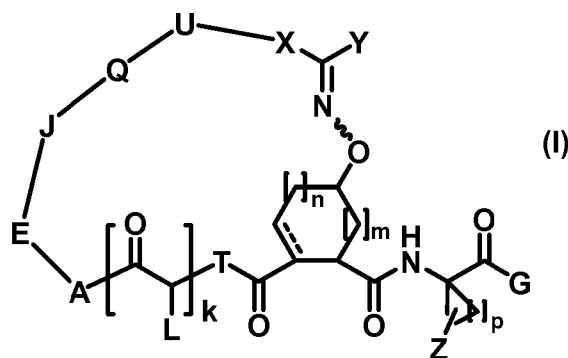
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(54) Title: BRIDGED CARBOCYCLIC OXIME HEPATITIS C VIRUS SERINE PROTEASE INHIBITORS



(57) Abstract: The present invention discloses compounds of formula I, or pharmaceutically acceptable salts, esters, or prodrugs thereof: which inhibit serine protease activity, particularly the activity of hepatitis C virus (HCV) NS3-NS4A protease. Consequently, the compounds of the present invention interfere with the life cycle of the hepatitis C virus and are also useful as antiviral agents. More specifically, the invention relates to oxime compounds containing a carbocyclic P2 unit, and the oxime is tethered to one of the carboxylic acid on P2. The present invention further relates to pharmaceutical compositions comprising the aforementioned compounds for administration to a subject suffering from HCV infection. The invention also relates to methods of treating an HCV infection in a subject by administering a pharmaceutical composition comprising the compounds of the present invention.

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BRIDGED CARBOCYCLIC OXIME HEPATITIS C VIRUS SERINE PROTEASE
INHIBITORS

Inventors: Dong Liu, Yat Sun Or, Zhe Wang

5

RELATED APPLICATIONS

This application claims the benefit of US provisional application number 61/015,336 which was filed on December 20, 2007. The contents of the above application are incorporated herein by reference.

10

TECHNICAL FIELD

The present invention relates to hepatitis C virus (HCV) protease inhibitor compounds having antiviral activity against HCV, which are also useful in the treatment of HCV infections. More specifically, the invention relates to oxime compounds
15 containing a bridged carbocyclic P2 unit, compositions containing such compounds and methods for using the same, as well as processes for making such compounds.

BACKGROUND OF THE INVENTION

HCV is the principal cause of non-A, non-B hepatitis and is an increasingly
20 severe public health problem both in the developed and developing world. It is estimated that the virus infects over 200 million people worldwide, surpassing the number of individuals infected with the human immunodeficiency virus (HIV) by nearly five-fold. HCV infected patients, due to the high percentage of individuals inflicted with chronic infections, are at an elevated risk of developing cirrhosis of the liver, subsequent
25 hepatocellular carcinoma and terminal liver disease. HCV is the most prevalent cause of hepatocellular cancer and cause of patients requiring liver transplantations in the western world.

There are considerable barriers to the development of anti-HCV therapeutics, which include, but are not limited to, the persistence of the virus, the genetic diversity of
30 the virus during replication in the host, the high incident rate of the virus developing drug-resistant mutants, and the lack of reproducible infectious culture systems and small-animal models for HCV replication and pathogenesis. In a majority of cases, given the mild course of the infection and the complex biology of the liver, careful consideration must be given to antiviral drugs, which are likely to have significant side effects.

Only two approved therapies for HCV infection are currently available. The original treatment regimen generally involves a 3-12 month course of intravenous interferon- α (IFN- α), while a new approved second-generation treatment involves co-treatment with IFN- α and general antiviral nucleoside mimics like ribavirin. Both of
5 these treatments suffer from interferon related side effects as well as low efficacy against HCV infections. There exists a need for the development of effective antiviral agents for treatment of HCV infection due to the poor tolerability and disappointing efficacy of existing therapies.

In a patient population where the majority of individuals are chronically infected
10 and asymptomatic, and the prognoses are unknown, an effective drug would desirably possess significantly fewer side effects than the currently available treatments. The hepatitis C non-structural protein-3 (NS3) is a proteolytic enzyme required for processing of the viral polyprotein and consequently viral replication. Despite the huge number of viral variants associated with HCV infection, the active site of the NS3
15 protease remains highly conserved, thus making its inhibition an attractive mode of intervention. Recent success in the treatment of HIV with protease inhibitors supports the concept that the inhibition of NS3 is a key target in the battle against HCV.

HCV is a flaviridae type RNA virus. The HCV genome is enveloped and contains a single strand RNA molecule composed of circa 9600 base pairs. It encodes a
20 polypeptide comprised of approximately 3010 amino acids.

The HCV polyprotein is processed by viral and host peptidase into 10 discreet peptides, which serve a variety of functions. There are three structural proteins: C, E1 and E2. The P7 protein is of unknown function and is comprised of a highly variable sequence. There are six non-structural proteins. NS2 is a zinc-dependent
25 metalloproteinase that functions in conjunction with a portion of the NS3 protein. NS3 incorporates two catalytic functions (separate from its association with NS2): a serine protease at the N-terminal end, which requires NS4A as a cofactor, and an ATP-ase-dependent helicase function at the carboxyl terminus. NS4A is a tightly associated but non-covalent cofactor of the serine protease.

30 The NS3-NS4A protease is responsible for cleaving four sites on the viral polyprotein. The NS3-NS4A cleavage is autocatalytic, occurring in *cis*. The remaining three hydrolyses, NS4A-NS4B, NS4B-NS5A and NS5A-NS5B all occur in *trans*. NS3 is a serine protease, which is structurally classified as a chymotrypsin-like protease. While

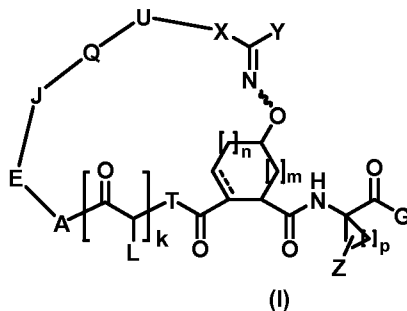
the NS3 serine protease possesses proteolytic activity by itself, the HCV protease enzyme is not an efficient enzyme in terms of catalyzing polyprotein cleavage. It has been shown that a central hydrophobic region of the NS4A protein is required for this enhancement. The complex formation of the NS3 protein with NS4A seems necessary to
 5 the processing events, enhancing the proteolytic efficacy at all of the sites.

A general strategy for the development of antiviral agents is to inactivate virally encoded enzymes, including NS3, that are essential for the replication of the virus. Current efforts directed toward the discovery of NS3 protease inhibitors were reviewed by S. Tan, A. Pause, Y. Shi, N. Sonenberg, Hepatitis C Therapeutics: Current Status and
 10 Emerging Strategies, *Nature Rev. Drug Discov.*, **1**, 867-881 (2002).

SUMMARY OF THE INVENTION

The present invention relates to novel macrocyclic compounds including pharmaceutically acceptable salts, esters, or prodrugs thereof which inhibit serine
 15 protease activity, particularly the activity of hepatitis C virus (HCV) NS3-NS4A protease. Consequently, the compounds of the present invention interfere with the life cycle of the hepatitis C virus and are also useful as antiviral agents. The present invention further relates to pharmaceutical compositions comprising the aforementioned
 20 compounds for administration to a subject suffering from HCV infection. The invention also relates to methods of treating an HCV infection in a subject by administering a pharmaceutical composition comprising the compounds of the present invention.

In one embodiment of the present invention there are disclosed compounds represented by Formula I, or pharmaceutically acceptable salts, esters, or prodrugs thereof:



25

A is absent or NR₁;

R₁ is selected from the group consisting of: H, substituted or unsubstituted C₁-C₈ alkyl, substituted or unsubstituted C₂-C₈ alkenyl or substituted or unsubstituted C₃-C₈ cycloalkyl;

- 5 E is absent or selected from the group consisting of $-(C=O)-$, $-S(O)-$, $-S(O)_2-$, $-(C=N-OR_2)-$, $-(C=N-CN)-$, and $-(C=N-R_2)-$;

R₂ is selected from the group consisting of:

- 10 (i) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
(ii) heterocycloalkyl or substituted heterocycloalkyl; and
(iii) $-C_1-C_8$ alkyl, $-C_2-C_8$ alkenyl, or $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S, or N; substituted $-C_1-C_8$ alkyl, substituted $-C_2-C_8$ alkenyl, or substituted $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N; $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl; $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl;
- 15

J is selected from the group consisting of $-C(R_3R_4)-$, $-O-$, or $-NR_5-$;

R₃, R₄, and R₅ are independently selected from the group consisting of:

- 20 (i) hydrogen;
(ii) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
(iii) heterocycloalkyl or substituted heterocycloalkyl; and
(iv) $-C_1-C_8$ alkyl, $-C_2-C_8$ alkenyl, or $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S, or N; substituted $-C_1-C_8$ alkyl, substituted $-C_2-C_8$ alkenyl, or substituted $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N; $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl; $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl;
- 25

30 Q is selected from the group consisting of:

- (i) $-C_1-C_8$ alkyl, $-C_2-C_8$ alkenyl, or $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S, or N;

- (ii) substituted $-C_1-C_8$ alkyl, substituted $-C_2-C_8$ alkenyl, or substituted $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- (iii) $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl;
- (iv) $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl; and
- 5 (v) aryl; substituted aryl; heteroaryl; substituted heteroaryl;

U is absent or selected from O, S, SO, CO, SO₂, NR₁, NH(CO), NH(CO)NH, NHSO₂, NHSO₂NH, O(CO), O(CO)NH;

10 X and Y are independently selected from the group consisting of:

- (i) absent for X or hydrogen for Y;
- (ii) aryl;
- (iii) substituted aryl;
- (iv) heteroaryl;
- 15 (v) substituted heteroaryl;
- (vi) heterocyclic or substituted heterocyclic;
- (vii) $-C_1-C_8$ alkyl, $-C_2-C_8$ alkenyl, or $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- (viii) substituted $-C_1-C_8$ alkyl, substituted $-C_2-C_8$ alkenyl, or substituted $-C_2-C_8$ alkynyl containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- 20 (ix) $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- (x) $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- 25 (xi) $-W-R_6$, where W is (CO), (CO)O, (CO)NH, (SO), (SO₂), (SO₂)NH; and R₆ are independently selected from the group consisting of:
- (a) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
- (b) heterocyclic; substituted heterocyclic;
- (c) $-C_1-C_8$ alkyl; $-C_2-C_8$ alkenyl, or $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- 30 (d) substituted $-C_1-C_8$ alkyl; substituted $-C_2-C_8$ alkenyl; or substituted $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;

- (e) $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- (f) $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;

5

or X and Y taken together with the carbon atom to which they are attached form a cyclic moiety selected from: substituted or unsubstituted cycloalkyl, cycloalkenyl, or heterocyclic; substituted or unsubstituted cycloalkyl, cycloalkenyl, and heterocyclic fused with one or more aryl, substituted aryl, heteroaryl, substituted heteroaryl, heterocyclic, substituted heterocyclic, cycloalkyl, substituted cycloalkyl, cycloalkenyl or substituted cycloalkenyl;

10

L is selected from the group consisting of:

- (i) hydrogen;
- (ii) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
- (iii) heterocycloalkyl or substituted heterocycloalkyl; and
- (iv) $-C_1-C_8$ alkyl, $-C_2-C_8$ alkenyl, or $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S, or N; substituted $-C_1-C_8$ alkyl, substituted $-C_2-C_8$ alkenyl, or substituted $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N; $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl; $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl;

20

Z is selected from the group consisting of:

- (i) hydrogen;
- (ii) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
- (iii) heterocycloalkyl or substituted heterocycloalkyl; and
- (iv) $-C_1-C_8$ alkyl, $-C_2-C_8$ alkenyl, or $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S, or N; substituted $-C_1-C_8$ alkyl, substituted $-C_2-C_8$ alkenyl, or substituted $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N; $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl; $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl;

30

G is selected from the group consisting of $-\text{NHS}(\text{O})_2-\text{R}_7$; $-\text{NH}(\text{SO}_2)\text{NR}_8\text{R}_9$; OR_8 , and NR_8R_9 ; where:

R_7 is selected from the group consisting of:

- 5 (i) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
 (ii) heterocycloalkyl or substituted heterocycloalkyl; and
 (iii) $-\text{C}_1-\text{C}_8$ alkyl, $-\text{C}_2-\text{C}_8$ alkenyl, or $-\text{C}_2-\text{C}_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N, substituted $-\text{C}_1-\text{C}_8$ alkyl, substituted $-\text{C}_2-\text{C}_8$ alkenyl, or substituted $-\text{C}_2-\text{C}_8$ alkynyl each containing
 10 0, 1, 2, or 3 heteroatoms selected from O, S or N; $-\text{C}_3-\text{C}_{12}$ cycloalkyl, or substituted $-\text{C}_3-\text{C}_{12}$ cycloalkyl; $-\text{C}_3-\text{C}_{12}$ cycloalkenyl, or substituted $-\text{C}_3-\text{C}_{12}$ cycloalkenyl;

R_8 and R_9 are independently selected from the group consisting of:

- 15 (i) hydrogen;
 (ii) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
 (iii) heterocycloalkyl or substituted heterocycloalkyl; and
 (iv) $-\text{C}_1-\text{C}_8$ alkyl, $-\text{C}_2-\text{C}_8$ alkenyl, or $-\text{C}_2-\text{C}_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S, or N; substituted $-\text{C}_1-\text{C}_8$ alkyl, substituted $-\text{C}_2-\text{C}_8$ alkenyl, or substituted $-\text{C}_2-\text{C}_8$ alkynyl each containing
 20 0, 1, 2, or 3 heteroatoms selected from O, S or N; $-\text{C}_3-\text{C}_{12}$ cycloalkyl, or substituted $-\text{C}_3-\text{C}_{12}$ cycloalkyl; $-\text{C}_3-\text{C}_{12}$ cycloalkenyl, or substituted $-\text{C}_3-\text{C}_{12}$ cycloalkenyl;

25 T is absent or is selected from the group consisting of NR_8 , $\text{NR}_1(\text{CO})$ and $\text{NR}_1(\text{CO})\text{O}$;

==== denotes a carbon-carbon single or double bond;

$k = 0$ or 1 ;

30 $m = 0, 1, 2$ or 3 ;

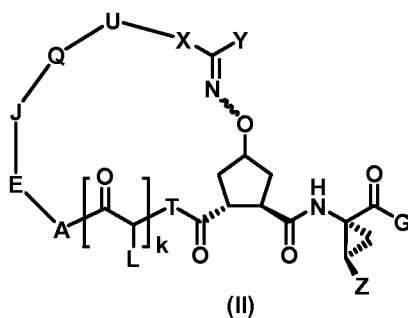
$n = 0, 1, 2$ or 3 ; and

$p = 1, 2$ or 3 .

DETAILED DESCRIPTION OF THE INVENTION

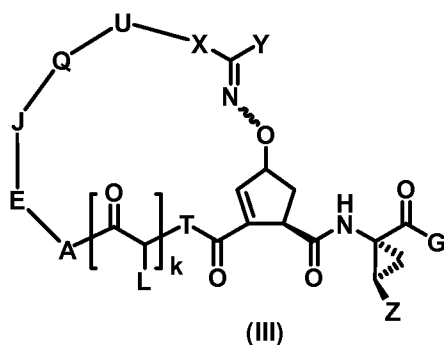
A first embodiment of the invention is a compound represented by Formula I as described above, or a pharmaceutically acceptable salt, ester or prodrug thereof, alone or in combination with a pharmaceutically acceptable carrier or excipient.

5 Another embodiment of the invention is a compound represented by Formula II:



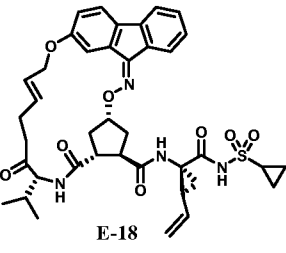
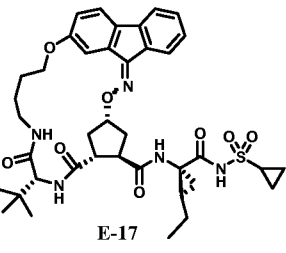
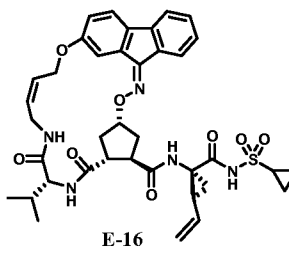
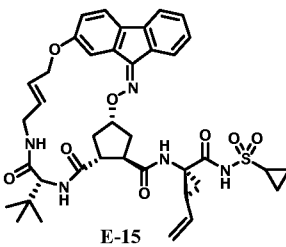
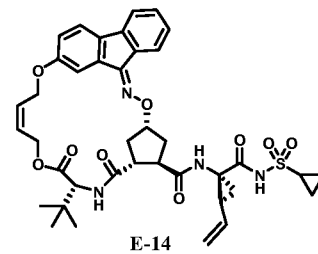
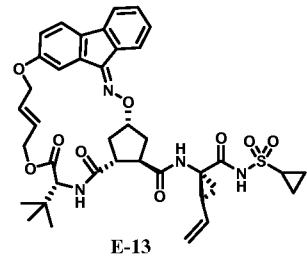
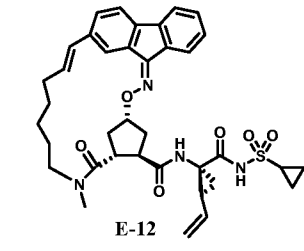
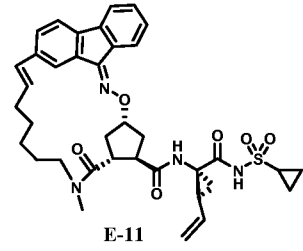
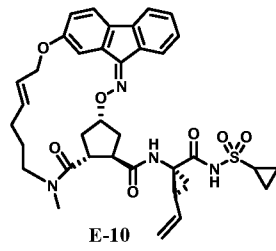
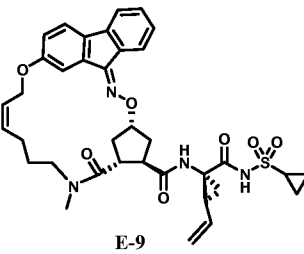
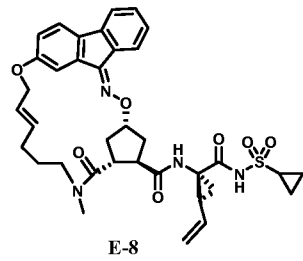
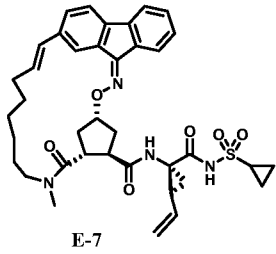
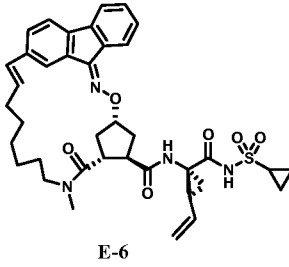
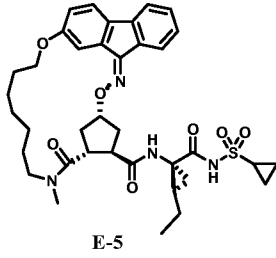
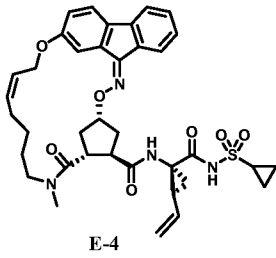
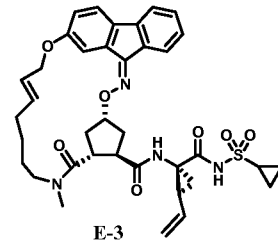
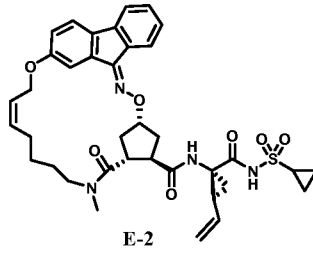
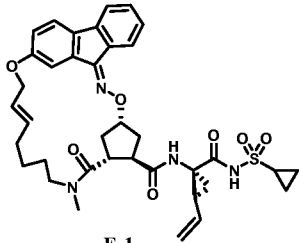
or a pharmaceutically acceptable salt, ester or prodrug thereof, alone or in combination with a pharmaceutically acceptable carrier or excipient, where A, E, J, L, Q, U, X, Y, Z, G, and k are as previously defined in Formula I.

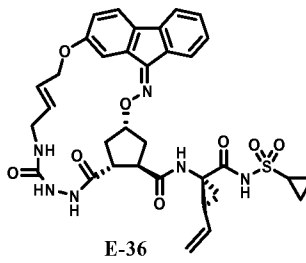
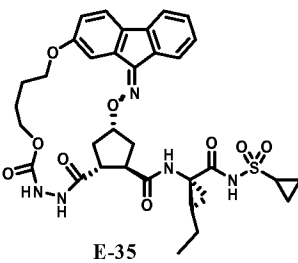
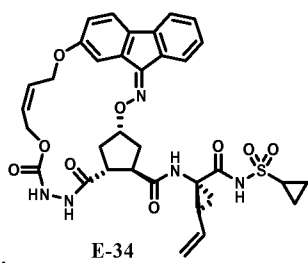
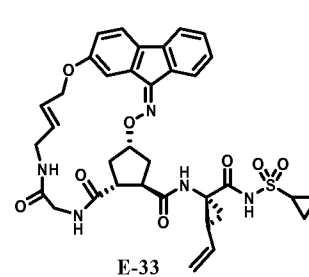
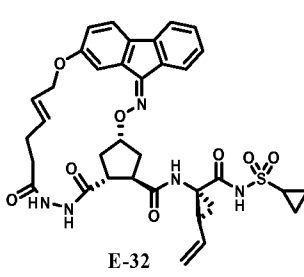
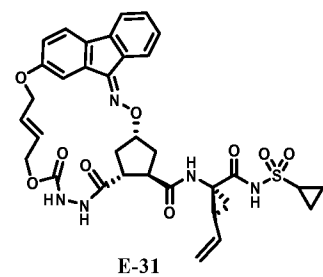
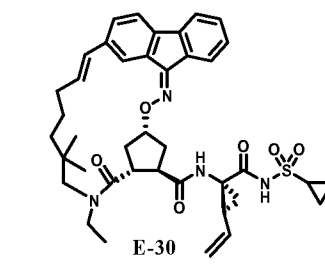
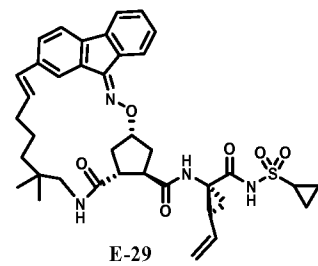
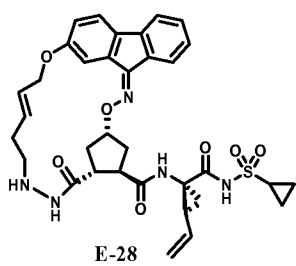
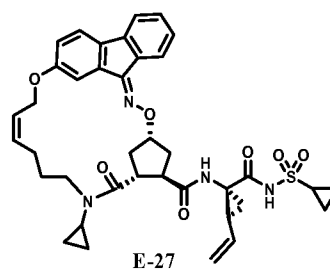
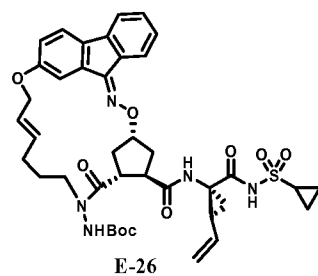
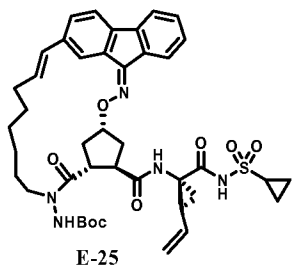
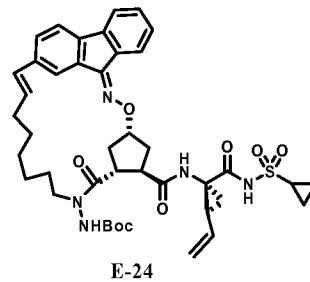
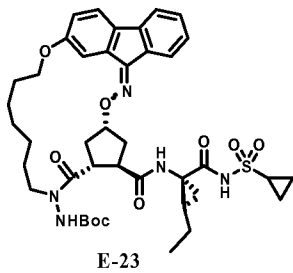
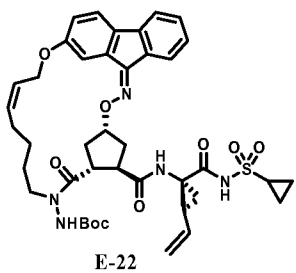
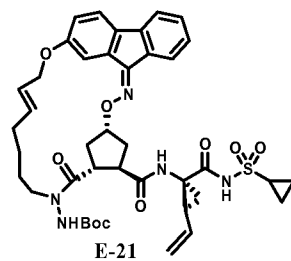
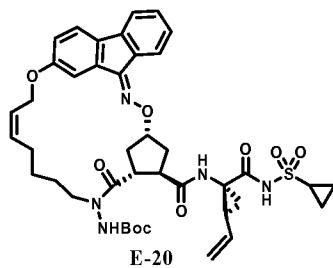
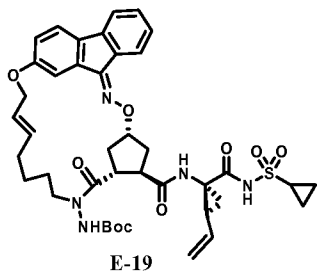
10 Another embodiment of the invention is a compound represented by Formula III:



or a pharmaceutically acceptable salt, ester or prodrug thereof, alone or in combination with a pharmaceutically acceptable carrier or excipient, where A, E, J, L, U, Q, X, Y, Z, G, and k are as previously defined in Formula I.

Representative compounds of the invention include, but are not limited to, the following compounds (E1-E36):





The present invention also features pharmaceutical compositions comprising a compound of the present invention, or a pharmaceutically acceptable salt, ester or prodrug thereof.

Compounds of the present invention can be administered as the sole active
5 pharmaceutical agent, or used in combination with one or more agents to treat or prevent hepatitis C infections or the symptoms associated with HCV infection. Other agents to be administered in combination with a compound or combination of compounds of the invention include therapies for disease caused by HCV infection that suppresses HCV viral replication by direct or indirect mechanisms. These include agents such as host
10 immune modulators (for example, interferon-alpha, pegylated interferon-alpha, interferon-beta, interferon-gamma, CpG oligonucleotides and the like), or antiviral compounds that inhibit host cellular functions such as inosine monophosphate dehydrogenase (for example, ribavirin and the like). Also included are cytokines that modulate immune function. Also included are vaccines comprising HCV antigens or
15 antigen adjuvant combinations directed against HCV. Also included are agents that interact with host cellular components to block viral protein synthesis by inhibiting the internal ribosome entry site (IRES) initiated translation step of HCV viral replication or to block viral particle maturation and release with agents targeted toward the viroporin family of membrane proteins such as, for example, HCV P7 and the like. Other agents to
20 be administered in combination with a compound of the present invention include any agent or combination of agents that inhibit the replication of HCV by targeting proteins of the viral genome involved in the viral replication. These agents include but are not limited to other inhibitors of HCV RNA dependent RNA polymerase such as, for example, nucleoside type polymerase inhibitors described in WO01 90121(A2), or U.S.
25 Pat. No. 6,348,587B1 or WO0160315 or WO0132153 or non-nucleoside inhibitors such as, for example, benzimidazole polymerase inhibitors described in EP 1162196A1 or WO0204425 or inhibitors of HCV protease such as, for example, peptidomimetic type inhibitors such as BILN2061 and the like or inhibitors of HCV helicase.

Other agents to be administered in combination with a compound of the present
30 invention include any agent or combination of agents that inhibit the replication of other viruses for co-infected individuals. These agents include but are not limited to therapies for disease caused by hepatitis B (HBV) infection.

Accordingly, one aspect of the invention is directed to a method for treating or preventing an infection caused by an RNA-containing virus comprising co-administering

to a patient in need of such treatment one or more agents selected from the group consisting of a host immune modulator and a second antiviral agent, or a combination thereof, with a therapeutically effective amount of a compound or combination of compounds of the invention, or a pharmaceutically acceptable salt, stereoisomer, 5 tautomer, prodrug, salt of a prodrug, or combination thereof. Examples of the host immune modulator are, but not limited to, interferon-alpha, pegylated-interferon-alpha, interferon-beta, interferon-gamma, a cytokine, a vaccine, and a vaccine comprising an antigen and an adjuvant, and said second antiviral agent inhibits replication of HCV either by inhibiting host cellular functions associated with viral replication or by 10 targeting proteins of the viral genome.

Further aspect of the invention is directed to a method of treating or preventing infection caused by an RNA-containing virus comprising co-administering to a patient in need of such treatment an agent or combination of agents that treat or alleviate symptoms of HCV infection including cirrhosis and inflammation of the liver, with a 15 therapeutically effective amount of a compound or combination of compounds of the invention, or a pharmaceutically acceptable salt, stereoisomer, tautomer, prodrug, salt of a prodrug, or combination thereof. Yet another aspect of the invention provides a method of treating or preventing infection caused by an RNA-containing virus comprising co-administering to a patient in need of such treatment one or more agents that treat patients 20 for disease caused by hepatitis B (HBV) infection, with a therapeutically effective amount of a compound or a combination of compounds of the invention, or a pharmaceutically acceptable salt, stereoisomer, tautomer, prodrug, salt of a prodrug, or combination thereof. An agent that treats patients for disease caused by hepatitis B (HBV) infection may be for example, but not limited thereto, L- deoxythymidine, 25 adefovir, lamivudine or tenfovir, or any combination thereof. Example of the RNA-containing virus includes, but not limited to, hepatitis C virus (HCV).

Another aspect of the invention provides a method of treating or preventing infection caused by an RNA-containing virus comprising co-administering to a patient in need of such treatment one or more agents that treat patients for disease caused by human 30 immunodeficiency virus (HIV) infection, with a therapeutically effective amount of a compound or a combination of compounds of the invention, or a pharmaceutically acceptable salt, stereoisomer, tautomer, prodrug, salt of a prodrug, or combination thereof. The agent that treats patients for disease caused by human immunodeficiency

virus (HIV) infection. Example of the RNA-containing virus includes, but not limited to, hepatitis C virus (HCV). In addition, the present invention provides the use of a compound or a combination of compounds of the invention, or a therapeutically acceptable salt form, stereoisomer, or tautomer, prodrug, salt of a prodrug, or
5 combination thereof, and one or more agents selected from the group consisting of a host immune modulator and a second antiviral agent, or a combination thereof, to prepare a medicament for the treatment of an infection caused by an RNA-containing virus in a patient, particularly hepatitis C virus. Examples of the host immune modulator are, but not limited to, interferon-alpha, pegylated- interferon-alpha, interferon-beta, interferon-
10 gamma, a cytokine, a vaccine, and a vaccine comprising an antigen and an adjuvant, and said second antiviral agent inhibits replication of HCV either by inhibiting host cellular functions associated with viral replication or by targeting proteins of the viral genome.

When used in the above or other treatments, combination of compound or compounds of the invention, together with one or more agents as defined herein above,
15 can be employed in pure form or, where such forms exist, in pharmaceutically acceptable salt form, prodrug, salt of a prodrug, or combination thereof. Alternatively, such combination of therapeutic agents can be administered as a pharmaceutical composition containing a therapeutically effective amount of the compound or combination of
20 compounds of interest, or their pharmaceutically acceptable salt form, prodrugs, or salts of the prodrug, in combination with one or more agents as defined hereinabove, and a pharmaceutically acceptable carrier. Such pharmaceutical compositions can be used for inhibiting the replication of an RNA-containing virus, particularly Hepatitis C virus (HCV), by contacting said virus with said pharmaceutical composition. In addition, such
25 compositions are useful for the treatment or prevention of an infection caused by an RNA-containing virus, particularly Hepatitis C virus (HCV).

Hence, further aspect of the invention is directed to a method of treating or preventing infection caused by an RNA-containing virus, particularly a hepatitis C virus (HCV), comprising administering to a patient in need of such treatment a pharmaceutical composition comprising a compound or combination of compounds of the invention or a
30 pharmaceutically acceptable salt, stereoisomer, or tautomer, prodrug, salt of a prodrug, or combination thereof, one or more agents as defined hereinabove, and a pharmaceutically acceptable carrier.

When administered as a combination, the therapeutic agents can be formulated as separate compositions which are given at the same time or within a predetermined period of time, or the therapeutic agents can be given as a single unit dosage form.

Antiviral agents contemplated for use in such combination therapy include agents
5 (compounds or biologicals) that are effective to inhibit the formation and/or replication of a virus in a mammal, including but not limited to agents that interfere with either host or viral mechanisms necessary for the formation and/or replication of a virus in a mammal. Such agents can be selected from another anti-HCV agent; an HIV inhibitor; an HAV inhibitor; and an HBV inhibitor.

10 Other anti-HCV agents include those agents that are effective for diminishing or preventing the progression of hepatitis C related symptoms or disease. Such agents include but are not limited to immunomodulatory agents, inhibitors of HCV NS3 protease, other inhibitors of HCV polymerase, inhibitors of another target in the HCV life cycle and other anti-HCV agents, including but not limited to ribavirin, amantadine,
15 levovirin and viremagine.

Immunomodulatory agents include those agents (compounds or biologicals) that are effective to enhance or potentiate the immune system response in a mammal. Immunomodulatory agents include, but are not limited to, inosine monophosphate dehydrogenase inhibitors such as VX-497 (merimepodib, Vertex Pharmaceuticals), class
20 I interferons, class II interferons, consensus interferons, asialo-interferons pegylated interferons and conjugated interferons, including but not limited to interferons conjugated with other proteins including but not limited to human albumin. Class I interferons are a group of interferons that all bind to receptor type I, including both naturally and synthetically produced class I interferons, while class II interferons all bind
25 to receptor type II. Examples of class I interferons include, but are not limited to, [alpha]-, [beta]-, [delta]-, [omega]-, and [tau]-interferons, while examples of class II interferons include, but are not limited to, [gamma]-interferons.

Inhibitors of HCV NS3 protease include agents (compounds or biologicals) that are effective to inhibit the function of HCV NS3 protease in a mammal. Inhibitors of
30 HCV NS3 protease include, but are not limited to, those compounds described in WO 99/07733, WO 99/07734, WO 00/09558, WO 00/09543, WO 00/59929, WO 03/064416, WO 03/064455, WO 03/064456, WO 2004/030670, WO 2004/037855, WO 2004/039833, WO 2004/101602, WO 2004/101605, WO 2004/103996, WO

2005/028501, WO 2005/070955, WO 2006/000085, WO 2006/007700 and WO
2006/007708 (all by Boehringer Ingelheim), WO 02/060926, WO 03/053349,
WO03/099274, WO 03/099316, WO 2004/032827, WO 2004/043339, WO
2004/094452, WO 2005/046712, WO 2005/051410, WO 2005/054430 (all by BMS),
5 WO 2004/072243, WO 2004/093798, WO 2004/113365, WO 2005/010029 (all by
Enanta), WO 2005/037214 (Intermune) and WO 2005/051980 (Schering), and the
candidates identified as VX-950, ITMN-191 and SCH 503034.

Inhibitors of HCV polymerase include agents (compounds or biologicals) that are
effective to inhibit the function of an HCV polymerase. Such inhibitors include, but are
10 not limited to, non-nucleoside and nucleoside inhibitors of HCV NS5B polymerase.
Examples of inhibitors of HCV polymerase include but are not limited to those
compounds described in: WO 02/04425, WO 03/007945, WO 03/010140, WO
03/010141, WO 2004/064925, WO 2004/065367, WO 2005/080388 and WO
2006/007693 (all by Boehringer Ingelheim), WO 2005/049622 (Japan Tobacco), WO
15 2005/014543 (Japan Tobacco), WO 2005/012288 (Genelabs), WO 2004/087714
(IRBM), WO 03/101993 (Neogenesis), WO 03/026587 (BMS), WO 03/000254 (Japan
Tobacco), and WO 01/47883 (Japan Tobacco), and the clinical candidates XTL-2125,
HCV 796, R-1626 and NM 283.

Inhibitors of another target in the HCV life cycle include agents (compounds or
20 biologicals) that are effective to inhibit the formation and/or replication of HCV other
than by inhibiting the function of the HCV NS3 protease. Such agents may interfere with
either host or HCV viral mechanisms necessary for the formation and/or replication of
HCV. Inhibitors of another target in the HCV life cycle include, but are not limited to,
entry inhibitors, agents that inhibit a target selected from a helicase, a NS2/3 protease
25 and an internal ribosome entry site (IRES) and agents that interfere with the function of
other viral targets including but not limited to an NS5A protein and an NS4B protein.

It can occur that a patient may be co-infected with hepatitis C virus and one or
more other viruses, including but not limited to human immunodeficiency virus (HIV),
hepatitis A virus (HAV) and hepatitis B virus (HBV). Thus also contemplated is
30 combination therapy to treat such co-infections by co-administering a compound
according to the present invention with at least one of an HIV inhibitor, an HAV
inhibitor and an HBV inhibitor.

According to yet another embodiment, the pharmaceutical compositions of the
present invention may further comprise inhibitor(s) of other targets in the HCV life

cycle, including, but not limited to, helicase, polymerase, metalloprotease, and internal ribosome entry site (IRES).

According to another embodiment, the pharmaceutical compositions of the present invention may further comprise another anti-viral, anti-bacterial, anti-fungal or
5 anti-cancer agent, or an immune modulator, or another therapeutic agent.

According to still another embodiment, the present invention includes methods of treating viral infection such as, but not limited to, hepatitis C infections in a subject in need of such treatment by administering to said subject an effective amount of a
10 compound of the present invention or a pharmaceutically acceptable salt, ester, or prodrug thereof.

According to a further embodiment, the present invention includes methods of treating hepatitis C infections in a subject in need of such treatment by administering to said subject an anti-HCV virally effective amount or an inhibitory amount of a
15 pharmaceutical composition of the present invention.

An additional embodiment of the present invention includes methods of treating biological samples by contacting the biological samples with the compounds of the present invention.

Yet a further aspect of the present invention is a process of making any of the compounds delineated herein employing any of the synthetic means delineated herein.
20

DEFINITIONS

Listed below are definitions of various terms used to describe this invention. These definitions apply to the terms as they are used throughout this specification and claims, unless otherwise limited in specific instances, either individually or as part of a
25 larger group.

The term "viral infection" refers to the introduction of a virus into cells or tissues, e.g., hepatitis C virus (HCV). In general, the introduction of a virus is also associated with replication. Viral infection may be determined by measuring virus antibody titer in samples of a biological fluid, such as blood, using, e.g., enzyme immunoassay. Other
30 suitable diagnostic methods include molecular based techniques, such as RT-PCR, direct hybrid capture assay, nucleic acid sequence based amplification, and the like. A virus may infect an organ, e.g., liver, and cause disease, e.g., hepatitis, cirrhosis, chronic liver disease and hepatocellular carcinoma.

The term "anti-cancer agent" refers to a compound or drug capable of preventing or inhibiting the advancement of cancer. Examples of such agents include cis-platin, actinomycin D, doxorubicin, vincristine, vinblastine, etoposide, amsacrine, mitoxantrone, tenipaside, taxol, colchicine, cyclosporin A, phenothiazines or
5 thioxantheres.

The term "anti-fungal agent" shall used to describe a compound which may be used to treat a fungus infection other than 3-AP, 3-AMP or prodrugs of 3-AP and 3-AMP according to the present invention. Anti-fungal agents according to the present invention include, for example, terbinafine, fluconazole, itraconazole, posaconazole, clotrimazole,
10 griseofulvin, nystatin, tolnaftate, caspofungin, amphotericin B, liposomal amphotericin B, and amphotericin B lipid complex.

The term "antibacterial agent" refers to both naturally occurring antibiotics produced by microorganisms to suppress the growth of other microorganisms, and agents synthesized or modified in the laboratory which have either bactericidal or bacteriostatic
15 activity, e.g., β -lactam antibacterial agents, glycopeptides, macrolides, quinolones, tetracyclines, and aminoglycosides. In general, if an antibacterial agent is bacteriostatic, it means that the agent essentially stops bacterial cell growth (but does not kill the bacteria); if the agent is bacteriocidal, it means that the agent kills the bacterial cells (and may stop growth before killing the bacteria).

The term "immune modulator" refers to any substance meant to alter the working of the humoral or cellular immune system of a subject. Such immune modulators include inhibitors of mast cell-mediated inflammation, interferons, interleukins, prostaglandins,
20 steroids, cortico-steroids, colony-stimulating factors, chemotactic factors, etc.

The term "C₁-C₆ alkyl," or "C₁-C₈ alkyl," as used herein, refer to saturated,
25 straight- or branched-chain hydrocarbon radicals containing between one and six, or one and eight carbon atoms, respectively. Examples of C₁-C₆ alkyl radicals include, but are not limited to, methyl, ethyl, propyl, isopropyl, *n*-butyl, *tert*-butyl, neopentyl, *n*-hexyl radicals; and examples of C₁-C₈ alkyl radicals include, but are not limited to, methyl, ethyl, propyl, isopropyl, *n*-butyl, *tert*-butyl, neopentyl, *n*-hexyl, heptyl, and octyl
30 radicals.

The term "C₂-C₆ alkenyl," or "C₂-C₈ alkenyl," as used herein, denote a monovalent group derived from a hydrocarbon moiety by the removal of a single hydrogen atom wherein the hydrocarbon moiety has at least one carbon-carbon double

bond and contains from two to six, or two to eight carbon atoms, respectively. Alkenyl groups include, but are not limited to, for example, ethenyl, propenyl, butenyl, 1-methyl-2-buten-1-yl, heptenyl, octenyl and the like.

The term "C₂-C₆ alkynyl," or "C₂-C₈ alkynyl," as used herein, denote a
5 monovalent group derived from a hydrocarbon moiety by the removal of a single hydrogen atom wherein the hydrocarbon moiety has at least one carbon-carbon triple bond and contains from two to six, or two to eight carbon atoms, respectively. Representative alkynyl groups include, but are not limited to, for example, ethynyl, 1-propynyl, 1-butyne, heptynyl, octynyl and the like.

10 The term "C₃-C₈-cycloalkyl", or "C₃-C₁₂-cycloalkyl," as used herein, denotes a monovalent group derived from a monocyclic or polycyclic saturated carbocyclic ring compound by the removal of a single hydrogen atom where the saturated carbocyclic ring compound has from 3 to 8, or from 3 to 12, ring atoms, respectively. Examples of C₃-C₈-cycloalkyl include, but not limited to, cyclopropyl, cyclobutyl, cyclopentyl,
15 cyclohexyl, cyclopentyl and cyclooctyl; and examples of C₃-C₁₂-cycloalkyl include, but not limited to, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, bicyclo [2.2.1] heptyl, and bicyclo [2.2.2] octyl.

The term "C₃-C₈-cycloalkenyl", or "C₃-C₁₂-cycloalkenyl" as used herein, denote a
20 monovalent group derived from a monocyclic or polycyclic carbocyclic ring compound having at least one carbon-carbon double bond by the removal of a single hydrogen atom where the carbocyclic ring compound has from 3 to 8, or from 3 to 12, ring atoms, respectively. Examples of C₃-C₈-cycloalkenyl include, but not limited to, cyclopropenyl, cyclobutenyl, cyclopentenyl, cyclohexenyl, cycloheptenyl, cyclooctenyl, and the like; and examples of C₃-C₁₂-cycloalkenyl include, but not limited to, cyclopropenyl,
25 cyclobutenyl, cyclopentenyl, cyclohexenyl, cycloheptenyl, cyclooctenyl, and the like.

The term "aryl," as used herein, refers to a mono- or bicyclic carbocyclic ring system having one or two aromatic rings including, but not limited to, phenyl, naphthyl, tetrahydronaphthyl, indanyl, indenyl and the like.

The term "arylalkyl," as used herein, refers to a C₁-C₃ alkyl or C₁-C₆ alkyl
30 residue attached to an aryl ring. Examples include, but are not limited to, benzyl, phenethyl and the like.

The term "heteroaryl," as used herein, refers to a mono-, bi-, or tri-cyclic aromatic radical or ring having from five to ten ring atoms of which at least one ring

atom is selected from S, O and N; wherein any N or S contained within the ring may be optionally oxidized. Heteroaryl includes, but is not limited to, pyridinyl, pyrazinyl, pyrimidinyl, pyrrolyl, pyrazolyl, imidazolyl, thiazolyl, oxazolyl, isooxazolyl, thiadiazolyl, oxadiazolyl, thiophenyl, furanyl, quinolinyl, isoquinolinyl, benzimidazolyl, benzooxazolyl, quinoxalinyl, and the like.

The term "heteroarylalkyl," as used herein, refers to a C₁-C₃ alkyl or C₁-C₆ alkyl residue attached to a heteroaryl ring. Examples include, but are not limited to, pyridinylmethyl, pyrimidinylethyl and the like.

The term "substituted" as used herein, refers to independent replacement of one, two, or three or more of the hydrogen atoms thereon with substituents including, but not limited to, -F, -Cl, -Br, -I, -OH, protected hydroxy, -NO₂, -CN, -NH₂, N₃, protected amino, alkoxy, alkylthio, oxo, -halo- C₁-C₁₂-alkyl, -halo- C₂-C₁₂-alkenyl, -halo- C₂-C₁₂-alkynyl, -halo-C₃-C₁₂-cycloalkyl, -NH -C₁-C₁₂-alkyl, -NH -C₂-C₁₂-alkenyl, -NH -C₂-C₁₂-alkynyl, -NH -C₃-C₁₂-cycloalkyl, -NH -aryl, -NH -heteroaryl, -NH -heterocycloalkyl, -dialkylamino, -diarylamino, -diheteroarylamino, -O-C₁-C₁₂-alkyl, -O-C₂-C₁₂-alkenyl, -O-C₂-C₁₂-alkynyl, -O-C₃-C₁₂-cycloalkyl, -O-aryl, -O-heteroaryl, -O-heterocycloalkyl, -C(O)- C₁-C₁₂-alkyl, -C(O)- C₂-C₁₂-alkenyl, -C(O)- C₂-C₁₂-alkynyl, -C(O)-C₃-C₁₂-cycloalkyl, -C(O)-aryl, -C(O)-heteroaryl, -C(O)-heterocycloalkyl, -CONH₂, -CONH- C₁-C₁₂-alkyl, -CONH- C₂-C₁₂-alkenyl, -CONH- C₂-C₁₂-alkynyl, -CONH-C₃-C₁₂-cycloalkyl, -CONH-aryl, -CONH-heteroaryl, -CONH-heterocycloalkyl, -OCO₂- C₁-C₁₂-alkyl, -OCO₂- C₂-C₁₂-alkenyl, -OCO₂- C₂-C₁₂-alkynyl, -OCO₂-C₃-C₁₂-cycloalkyl, -OCO₂-aryl, -OCO₂-heteroaryl, -OCO₂-heterocycloalkyl, -OCONH₂, -OCONH- C₁-C₁₂-alkyl, -OCONH- C₂-C₁₂-alkenyl, -OCONH- C₂-C₁₂-alkynyl, -OCONH- C₃-C₁₂-cycloalkyl, -OCONH- aryl, -OCONH- heteroaryl, -OCONH- heterocycloalkyl, -NHC(O)- C₁-C₁₂-alkyl, -NHC(O)-C₂-C₁₂-alkenyl, -NHC(O)-C₂-C₁₂-alkynyl, -NHC(O)-C₃-C₁₂-cycloalkyl, -NHC(O)-aryl, -NHC(O)-heteroaryl, -NHC(O)-heterocycloalkyl, -NHCO₂- C₁-C₁₂-alkyl, -NHCO₂- C₂-C₁₂-alkenyl, -NHCO₂- C₂-C₁₂-alkynyl, -NHCO₂- C₃-C₁₂-cycloalkyl, -NHCO₂- aryl, -NHCO₂- heteroaryl, -NHCO₂- heterocycloalkyl, -NHC(O)NH₂, -NHC(O)NH- C₁-C₁₂-alkyl, -NHC(O)NH-C₂-C₁₂-alkenyl, -NHC(O)NH-C₂-C₁₂-alkynyl, -NHC(O)NH-C₃-C₁₂-cycloalkyl, -NHC(O)NH-aryl, -NHC(O)NH-heteroaryl, -NHC(O)NH-heterocycloalkyl, NHC(S)NH₂, -NHC(S)NH- C₁-C₁₂-alkyl, -NHC(S)NH- C₂-C₁₂-alkenyl, -NHC(S)NH-C₂-C₁₂-alkynyl, -NHC(S)NH-C₃-C₁₂-cycloalkyl, -NHC(S)NH-aryl, -NHC(S)NH-heteroaryl, -NHC(S)NH-heterocycloalkyl, -

NHC(NH)NH₂, -NHC(NH)NH- C₁-C₁₂-alkyl, -NHC(NH)NH-C₂-C₁₂-alkenyl, -
 NHC(NH)NH-C₂-C₁₂-alkynyl, -NHC(NH)NH-C₃-C₁₂-cycloalkyl, -NHC(NH)NH-aryl, -
 NHC(NH)NH-heteroaryl, -NHC(NH)NH-heterocycloalkyl, -NHC(NH)-C₁-C₁₂-alkyl, -
 NHC(NH)-C₂-C₁₂-alkenyl, -NHC(NH)-C₂-C₁₂-alkynyl, -NHC(NH)-C₃-C₁₂-cycloalkyl, -
 5 NHC(NH)-aryl, -NHC(NH)-heteroaryl, -NHC(NH)-heterocycloalkyl, -C(NH)NH-C₁-
 C₁₂-alkyl, -C(NH)NH-C₂-C₁₂-alkenyl, -C(NH)NH-C₂-C₁₂-alkynyl, -C(NH)NH-C₃-C₁₂-
 cycloalkyl, -C(NH)NH-aryl, -C(NH)NH-heteroaryl, -C(NH)NH-heterocycloalkyl, -S(O)-
 C₁-C₁₂-alkyl, - S(O)-C₂-C₁₂-alkenyl, - S(O)-C₂-C₁₂-alkynyl, - S(O)-C₃-C₁₂-cycloalkyl, -
 S(O)-aryl, - S(O)-heteroaryl, - S(O)-heterocycloalkyl -SO₂NH₂, -SO₂NH- C₁-C₁₂-alkyl, -
 10 SO₂NH- C₂-C₁₂-alkenyl, -SO₂NH- C₂-C₁₂-alkynyl, -SO₂NH- C₃-C₁₂-cycloalkyl, -
 SO₂NH- aryl, -SO₂NH- heteroaryl, -SO₂NH- heterocycloalkyl, -NHSO₂-C₁-C₁₂-alkyl, -
 NHSO₂-C₂-C₁₂-alkenyl, - NHSO₂-C₂-C₁₂-alkynyl, -NHSO₂-C₃-C₁₂-cycloalkyl, -NHSO₂-
 aryl, -NHSO₂-heteroaryl, -NHSO₂-heterocycloalkyl, -CH₂NH₂, -CH₂SO₂CH₃, -aryl, -
 arylalkyl, -heteroaryl, -heteroarylalkyl, -heterocycloalkyl, -C₃-C₁₂-cycloalkyl,
 15 polyalkoxyalkyl, polyalkoxy, -methoxymethoxy, -methoxyethoxy, -SH, -S-C₁-C₁₂-alkyl,
 -S-C₂-C₁₂-alkenyl, -S-C₂-C₁₂-alkynyl, -S-C₃-C₁₂-cycloalkyl, -S-aryl, -S-heteroaryl, -S-
 heterocycloalkyl, methylthiomethyl, or -L'-R', wherein L' is C₁-C₆alkylene, C₂-
 C₆alkenylene or C₂-C₆alkynylene, and R' is aryl, heteroaryl, heterocyclic, C₃-
 C₁₂cycloalkyl or C₃-C₁₂cycloalkenyl. It is understood that the aryls, heteroaryls, alkyls,
 20 and the like can be further substituted. In some cases, each substituent in a substituted
 moiety is additionally optionally substituted with one or more groups, each group being
 independently selected from -F, -Cl, -Br, -I, -OH, -NO₂, -CN, or -NH₂.

In accordance with the invention, any of the aryls, substituted aryls, heteroaryls
 and substituted heteroaryls described herein, can be any aromatic group. Aromatic
 25 groups can be substituted or unsubstituted.

It is understood that any alkyl, alkenyl, alkynyl, cycloalkyl and cycloalkenyl
 moiety described herein can also be an aliphatic group, an alicyclic group or a
 heterocyclic group. An "aliphatic group" is non-aromatic moiety that may contain any
 combination of carbon atoms, hydrogen atoms, halogen atoms, oxygen, nitrogen or other
 30 atoms, and optionally contain one or more units of unsaturation, e.g., double and/or triple
 bonds. An aliphatic group may be straight chained, branched or cyclic and preferably
 contains between about 1 and about 24 carbon atoms, more typically between about 1
 and about 12 carbon atoms. In addition to aliphatic hydrocarbon groups, aliphatic groups
 include, for example, polyalkoxyalkyls, such as polyalkylene glycols, polyamines, and

polyimines, for example. Such aliphatic groups may be further substituted. It is understood that aliphatic groups may be used in place of the alkyl, alkenyl, alkynyl, alkylene, alkenylene, and alkynylene groups described herein.

5 The term "alicyclic," as used herein, denotes a monovalent group derived from a monocyclic or polycyclic saturated carbocyclic ring compound by the removal of a single hydrogen atom. Examples include, but not limited to, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, bicyclo [2.2.1] heptyl, and bicyclo [2.2.2] octyl. Such alicyclic groups may be further substituted.

10 The term "heterocycloalkyl" and "heterocyclic" can be used interchangeably and refer to a non-aromatic 3-, 4-, 5-, 6- or 7-membered ring or a bi- or tri-cyclic group fused system, where (i) each ring contains between one and three heteroatoms independently selected from oxygen, sulfur and nitrogen, (ii) each 5-membered ring has 0 to 1 double bonds and each 6-membered ring has 0 to 2 double bonds, (iii) the nitrogen and sulfur heteroatoms may optionally be oxidized, (iv) the nitrogen heteroatom may optionally be
15 quaternized, (v) any of the above rings may be fused to a benzene ring, and (vi) the remaining ring atoms are carbon atoms which may be optionally oxo-substituted. Representative heterocycloalkyl groups include, but are not limited to, [1,3]dioxolane, pyrrolidinyl, pyrazolinyl, pyrazolidinyl, imidazolinyl, imidazolidinyl, piperidinyl, piperazinyl, oxazolidinyl, isoxazolidinyl, morpholinyl, thiazolidinyl, isothiazolidinyl, quinoxalanyl, pyridazinonyl, and tetrahydrofuryl. Such heterocyclic groups may be
20 further substituted to give substituted heterocyclic.

It will be apparent that in various embodiments of the invention, the substituted or unsubstituted alkyl, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, cycloalkynyl, arylalkyl, heteroarylalkyl, and heterocycloalkyl are intended to be monovalent or
25 divalent. Thus, alkylene, alkenylene, and alkynylene, cycloalkylene, cycloalkenylene, cycloalkynylene, arylalkylene, hetoerarylalkylene and heterocycloalkylene groups are to be included in the above definitions, and are applicable to provide the formulas herein with proper valency.

The term "hydroxy activating group", as used herein, refers to a labile chemical
30 moiety which is known in the art to activate a hydroxy group so that it will depart during synthetic procedures such as in a substitution or elimination reactions. Examples of hydroxy activating group include, but not limited to, mesylate, tosylate, triflate, *p*-nitrobenzoate, phosphonate and the like.

The term "activated hydroxy", as used herein, refers to a hydroxy group activated with a hydroxy activating group, as defined above, including mesylate, tosylate, triflate, p-nitrobenzoate, phosphonate groups, for example.

5 The term "protected hydroxy," as used herein, refers to a hydroxy group protected with a hydroxy protecting group, as defined above, including benzoyl, acetyl, trimethylsilyl, triethylsilyl, methoxymethyl groups.

The terms "halo" and "halogen," as used herein, refer to an atom selected from fluorine, chlorine, bromine and iodine.

10 The compounds described herein contain one or more asymmetric centers and thus give rise to enantiomers, diastereomers, and other stereoisomeric forms that may be defined, in terms of absolute stereochemistry, as (R)- or (S)-, or as (D)- or (L)- for amino acids. The present invention is meant to include all such possible isomers, as well as their racemic and optically pure forms. Optical isomers may be prepared from their respective optically active precursors by the procedures described above, or by resolving
15 the racemic mixtures. The resolution can be carried out in the presence of a resolving agent, by chromatography or by repeated crystallization or by some combination of these techniques, which are known to those skilled in the art. Further details regarding resolutions can be found in Jacques, et al., Enantiomers, Racemates, and Resolutions (John Wiley & Sons, 1981). When the compounds described herein contain olefinic
20 double bonds or other centers of geometric asymmetry, and unless specified otherwise, it is intended that the compounds include both E and Z geometric isomers. Likewise, all tautomeric forms are also intended to be included. The configuration of any carbon-carbon double bond appearing herein is selected for convenience only and is not intended to designate a particular configuration unless the text so states; thus a carbon-
25 carbon double bond depicted arbitrarily herein as *trans* may be *cis*, *trans*, or a mixture of the two in any proportion.

The term "subject" as used herein refers to a mammal. A subject therefore refers to, for example, dogs, cats, horses, cows, pigs, guinea pigs, and the like. Preferably the subject is a human. When the subject is a human, the subject may be referred to herein
30 as a patient.

As used herein, the term "pharmaceutically acceptable salt" refers to those salts of the compounds formed by the process of the present invention which are, within the scope of sound medical judgment, suitable for use in contact with the tissues of humans and lower animals without undue toxicity, irritation, allergic response and the like, and

are commensurate with a reasonable benefit/risk ratio. Pharmaceutically acceptable salts are well known in the art.

The term "hydroxy protecting group," as used herein, refers to a labile chemical moiety which is known in the art to protect a hydroxy group against undesired reactions during synthetic procedures. After said synthetic procedure(s) the hydroxy protecting group as described herein may be selectively removed. Hydroxy protecting groups as known in the art are described generally in T.H. Greene and P.G., S. M. Wuts, Protective Groups in Organic Synthesis, 3rd edition, John Wiley & Sons, New York (1999).

Examples of hydroxy protecting groups include benzyloxycarbonyl, 4-

nitrobenzyloxycarbonyl, 4-bromobenzyloxycarbonyl, 4-methoxybenzyloxycarbonyl, methoxycarbonyl, tert-butoxycarbonyl, isopropoxycarbonyl, diphenylmethoxycarbonyl, 2,2,2-trichloroethoxycarbonyl, 2-(trimethylsilyl)ethoxycarbonyl, 2-furfuryloxycarbonyl, allyloxycarbonyl, acetyl, formyl, chloroacetyl, trifluoroacetyl, methoxyacetyl,

phenoxyacetyl, benzoyl, methyl, t-butyl, 2,2,2-trichloroethyl, 2-trimethylsilyl ethyl, 1,1-dimethyl-2-propenyl, 3-methyl-3-butenyl, allyl, benzyl, para-

methoxybenzyl, diphenylmethyl, triphenylmethyl (trityl), tetrahydrofuryl, methoxymethyl, methylthiomethyl, benzyloxymethyl, 2,2,2-trichloroethoxymethyl, 2-(trimethylsilyl)ethoxymethyl, methanesulfonyl, para-toluenesulfonyl, trimethylsilyl, triethylsilyl, triisopropylsilyl, and the like. Preferred hydroxy protecting groups for the

present invention are acetyl (Ac or $-C(O)CH_3$), benzoyl (Bz or $-C(O)C_6H_5$), and trimethylsilyl (TMS or $-Si(CH_3)_3$). Berge, *et al.* describes pharmaceutically acceptable salts in detail in *J. Pharmaceutical Sciences*, 66: 1-19 (1977). The salts can be prepared *in situ* during the final isolation and purification of the compounds of the invention, or

separately by reacting the free base function with a suitable organic acid. Examples of pharmaceutically acceptable salts include, but are not limited to, nontoxic acid addition salts e.g., salts of an amino group formed with inorganic acids such as hydrochloric acid, hydrobromic acid, phosphoric acid, sulfuric acid and perchloric acid or with organic acids such as acetic acid, maleic acid, tartaric acid, citric acid, succinic acid or malonic acid or by using other methods used in the art such as ion exchange. Other

pharmaceutically acceptable salts include, but are not limited to, adipate, alginate, ascorbate, aspartate, benzenesulfonate, benzoate, bisulfate, borate, butyrate, camphorate, camphorsulfonate, citrate, cyclopentanepropionate, digluconate, dodecylsulfate, ethanesulfonate, formate, fumarate, glucoheptonate, glycerophosphate, gluconate, hemisulfate, heptanoate, hexanoate, hydroiodide, 2-hydroxy-ethanesulfonate,

lactobionate, lactate, laurate, lauryl sulfate, malate, maleate, malonate, methanesulfonate, 2-naphthalenesulfonate, nicotinate, nitrate, oleate, oxalate, palmitate, pamoate, pectinate, persulfate, 3-phenylpropionate, phosphate, picrate, pivalate, propionate, stearate, succinate, sulfate, tartrate, thiocyanate, *p*-toluenesulfonate, undecanoate, valerate salts, and the like. Representative alkali or alkaline earth metal salts include sodium, lithium, potassium, calcium, magnesium, and the like. Further pharmaceutically acceptable salts include, when appropriate, nontoxic ammonium, quaternary ammonium, and amine cations formed using counterions such as halide, hydroxide, carboxylate, sulfate, phosphate, nitrate, alkyl having from 1 to 6 carbon atoms, sulfonate and aryl sulfonate.

The term "amino protecting group," as used herein, refers to a labile chemical moiety which is known in the art to protect an amino group against undesired reactions during synthetic procedures. After said synthetic procedure(s) the amino protecting group as described herein may be selectively removed. Amino protecting groups as known in the art are described generally in T.H. Greene and P.G. M. Wuts, Protective Groups in Organic Synthesis, 3rd edition, John Wiley & Sons, New York (1999). Examples of amino protecting groups include, but are not limited to, *t*-butoxycarbonyl, 9-fluorenylmethoxycarbonyl, benzyloxycarbonyl, and the like.

As used herein, the term "pharmaceutically acceptable ester" refers to esters of the compounds formed by the process of the present invention which hydrolyze *in vivo* and include those that break down readily in the human body to leave the parent compound or a salt thereof. Suitable ester groups include, for example, those derived from pharmaceutically acceptable aliphatic carboxylic acids, particularly alkanolic, alkenolic, cycloalkanoic and alkanedioic acids, in which each alkyl or alkenyl moiety advantageously has not more than 6 carbon atoms. Examples of particular esters include, but are not limited to, formates, acetates, propionates, butyrates, acrylates and ethylsuccinates.

The term "pharmaceutically acceptable prodrugs" as used herein refers to those prodrugs of the compounds formed by the process of the present invention which are, within the scope of sound medical judgment, suitable for use in contact with the tissues of humans and lower animals with undue toxicity, irritation, allergic response, and the like, commensurate with a reasonable benefit/risk ratio, and effective for their intended use, as well as the zwitterionic forms, where possible, of the compounds of the present invention. "Prodrug", as used herein means a compound, which is convertible *in vivo* by metabolic means (e.g. by hydrolysis) to afford any compound delineated by the formulae

of the instant invention. Various forms of prodrugs are known in the art, for example, as discussed in Bundgaard, (ed.), *Design of Prodrugs*, Elsevier (1985); Widder, et al. (ed.), *Methods in Enzymology*, vol. 4, Academic Press (1985); Krogsgaard-Larsen, et al., (ed). "Design and Application of Prodrugs, *Textbook of Drug Design and Development*,
5 Chapter 5, 113-191 (1991); Bundgaard, et al., *Journal of Drug Deliver Reviews*, 8:1-38(1992); Bundgaard, *J. of Pharmaceutical Sciences*, 77:285 et seq. (1988); Higuchi and Stella (eds.) *Prodrugs as Novel Drug Delivery Systems*, American Chemical Society (1975); and Bernard Testa & Joachim Mayer, "Hydrolysis In Drug And Prodrug Metabolism: Chemistry, Biochemistry And Enzymology," John Wiley and Sons, Ltd.
10 (2002).

The term "acyl" includes residues derived from acids, including but not limited to carboxylic acids, carbamic acids, carbonic acids, sulfonic acids, and phosphorous acids. Examples include aliphatic carbonyls, aromatic carbonyls, aliphatic sulfonyls, aromatic sulfinyls, aliphatic sulfinyls, aromatic phosphates and aliphatic phosphates. Examples of
15 aliphatic carbonyls include, but are not limited to, acetyl, propionyl, 2-fluoroacetyl, butyryl, 2-hydroxy acetyl, and the like.

The term "aprotic solvent," as used herein, refers to a solvent that is relatively inert to proton activity, i.e., not acting as a proton-donor. Examples include, but are not limited to, hydrocarbons, such as hexane and toluene, for example, halogenated
20 hydrocarbons, such as, for example, methylene chloride, ethylene chloride, chloroform, and the like, heterocyclic compounds, such as, for example, tetrahydrofuran and N-methylpyrrolidinone, and ethers such as diethyl ether, bis-methoxymethyl ether. Such solvents are well known to those skilled in the art, and individual solvents or mixtures thereof may be preferred for specific compounds and reaction conditions, depending
25 upon such factors as the solubility of reagents, reactivity of reagents and preferred temperature ranges, for example. Further discussions of aprotic solvents may be found in organic chemistry textbooks or in specialized monographs, for example: Organic Solvents Physical Properties and Methods of Purification, 4th ed., edited by John A. Riddick *et al.*, Vol. II, in the Techniques of Chemistry Series, John Wiley & Sons, NY,
30 1986.

The terms "protogenic organic solvent" or "protic solvent" as used herein, refer to a solvent that tends to provide protons, such as an alcohol, for example, methanol, ethanol, propanol, isopropanol, butanol, t-butanol, and the like. Such solvents are well known to those skilled in the art, and individual solvents or mixtures thereof may be

preferred for specific compounds and reaction conditions, depending upon such factors as the solubility of reagents, reactivity of reagents and preferred temperature ranges, for example. Further discussions of protogenic solvents may be found in organic chemistry textbooks or in specialized monographs, for example: Organic Solvents Physical

5 Properties and Methods of Purification, 4th ed., edited by John A. Riddick *et al.*, Vol. II, in the Techniques of Chemistry Series, John Wiley & Sons, NY, 1986.

Combinations of substituents and variables envisioned by this invention are only those that result in the formation of stable compounds. The term “stable”, as used herein, refers to compounds which possess stability sufficient to allow manufacture and which
10 maintains the integrity of the compound for a sufficient period of time to be useful for the purposes detailed herein (e.g., therapeutic or prophylactic administration to a subject).

The synthesized compounds can be separated from a reaction mixture and further purified by a method such as column chromatography, high pressure liquid
15 chromatography, or recrystallization. Additionally, the various synthetic steps may be performed in an alternate sequence or order to give the desired compounds. In addition, the solvents, temperatures, reaction durations, etc. delineated herein are for purposes of illustration only and variation of the reaction conditions can produce the desired bridged macrocyclic products of the present invention. Synthetic chemistry transformations and
20 protecting group methodologies (protection and deprotection) useful in synthesizing the compounds described herein include, for example, those described in R. Larock, Comprehensive Organic Transformations, VCH Publishers (1989); T.W. Greene and P.G.M. Wuts, Protective Groups in Organic Synthesis, 2d. Ed., John Wiley and Sons (1991); L. Fieser and M. Fieser, Fieser and Fieser's Reagents for Organic Synthesis, John
25 Wiley and Sons (1994); and L. Paquette, ed., Encyclopedia of Reagents for Organic Synthesis, John Wiley and Sons (1995).

The compounds of this invention may be modified by appending various functionalities via synthetic means delineated herein to enhance selective biological properties. Such modifications include those which increase biological penetration into a
30 given biological system (e.g., blood, lymphatic system, central nervous system), increase oral availability, increase solubility to allow administration by injection, alter metabolism and alter rate of excretion.

PHARMACEUTICAL COMPOSITIONS

The pharmaceutical compositions of the present invention comprise a therapeutically effective amount of a compound of the present invention formulated together with one or more pharmaceutically acceptable carriers. As used herein, the term "pharmaceutically acceptable carrier" means a non-toxic, inert solid, semi-solid or liquid filler, diluent, encapsulating material or formulation auxiliary of any type. Some examples of materials which can serve as pharmaceutically acceptable carriers are sugars such as lactose, glucose and sucrose; starches such as corn starch and potato starch; cellulose and its derivatives such as sodium carboxymethyl cellulose, ethyl cellulose and cellulose acetate; powdered tragacanth; malt; gelatin; talc; excipients such as cocoa butter and suppository waxes; oils such as peanut oil, cottonseed oil; safflower oil; sesame oil; olive oil; corn oil and soybean oil; glycols; such a propylene glycol; esters such as ethyl oleate and ethyl laurate; agar; buffering agents such as magnesium hydroxide and aluminum hydroxide; alginic acid; pyrogen-free water; isotonic saline; Ringer's solution; ethyl alcohol, and phosphate buffer solutions, as well as other non-toxic compatible lubricants such as sodium lauryl sulfate and magnesium stearate, as well as coloring agents, releasing agents, coating agents, sweetening, flavoring and perfuming agents, preservatives and antioxidants can also be present in the composition, according to the judgment of the formulator. The pharmaceutical compositions of this invention can be administered to humans and other animals orally, rectally, parenterally, intracisternally, intravaginally, intraperitoneally, topically (as by powders, ointments, or drops), buccally, or as an oral or nasal spray.

The pharmaceutical compositions of this invention may be administered orally, parenterally, by inhalation spray, topically, rectally, nasally, buccally, vaginally or via an implanted reservoir, preferably by oral administration or administration by injection. The pharmaceutical compositions of this invention may contain any conventional non-toxic pharmaceutically-acceptable carriers, adjuvants or vehicles. In some cases, the pH of the formulation may be adjusted with pharmaceutically acceptable acids, bases or buffers to enhance the stability of the formulated compound or its delivery form. The term parenteral as used herein includes subcutaneous, intracutaneous, intravenous, intramuscular, intraarticular, intraarterial, intrasynovial, intracisternal, intrathecal, intralesional and intracranial injection or infusion techniques.

Liquid dosage forms for oral administration include pharmaceutically acceptable emulsions, microemulsions, solutions, suspensions, syrups and elixirs. In addition to the active compounds, the liquid dosage forms may contain inert diluents commonly used in the art such as, for example, water or other solvents, solubilizing agents and emulsifiers
5 such as ethyl alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, 1,3-butylene glycol, dimethylformamide, oils (in particular, cottonseed, groundnut, corn, germ, olive, castor, and sesame oils), glycerol, tetrahydrofurfuryl alcohol, polyethylene glycols and fatty acid esters of sorbitan, and mixtures thereof. Besides inert diluents, the oral compositions can also include
10 adjuvants such as wetting agents, emulsifying and suspending agents, sweetening, flavoring, and perfuming agents.

Injectable preparations, for example, sterile injectable aqueous or oleaginous suspensions may be formulated according to the known art using suitable dispersing or wetting agents and suspending agents. The sterile injectable preparation may also be a
15 sterile injectable solution, suspension or emulsion in a nontoxic parenterally acceptable diluent or solvent, for example, as a solution in 1,3-butanediol. Among the acceptable vehicles and solvents that may be employed are water, Ringer's solution, U.S.P. and isotonic sodium chloride solution. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose any bland fixed oil can
20 be employed including synthetic mono- or diglycerides. In addition, fatty acids such as oleic acid are used in the preparation of injectables.

The injectable formulations can be sterilized, for example, by filtration through a bacterial-retaining filter, or by incorporating sterilizing agents in the form of sterile solid compositions which can be dissolved or dispersed in sterile water or other sterile
25 injectable medium prior to use.

In order to prolong the effect of a drug, it is often desirable to slow the absorption of the drug from subcutaneous or intramuscular injection. This may be accomplished by the use of a liquid suspension of crystalline or amorphous material with poor water solubility. The rate of absorption of the drug then depends upon its rate of dissolution,
30 which, in turn, may depend upon crystal size and crystalline form. Alternatively, delayed absorption of a parenterally administered drug form is accomplished by dissolving or suspending the drug in an oil vehicle. Injectable depot forms are made by forming microcapsule matrices of the drug in biodegradable polymers such as polylactide-polyglycolide. Depending upon the ratio of drug to polymer and the nature

of the particular polymer employed, the rate of drug release can be controlled. Examples of other biodegradable polymers include poly(orthoesters) and poly(anhydrides). Depot injectable formulations are also prepared by entrapping the drug in liposomes or microemulsions which are compatible with body tissues.

5 Compositions for rectal or vaginal administration are preferably suppositories which can be prepared by mixing the compounds of this invention with suitable non-irritating excipients or carriers such as cocoa butter, polyethylene glycol or a suppository wax which are solid at ambient temperature but liquid at body temperature and therefore melt in the rectum or vaginal cavity and release the active compound.

10 Solid dosage forms for oral administration include capsules, tablets, pills, powders, and granules. In such solid dosage forms, the active compound is mixed with at least one inert, pharmaceutically acceptable excipient or carrier such as sodium citrate or dicalcium phosphate and/or: a) fillers or extenders such as starches, lactose, sucrose, glucose, mannitol, and silicic acid, b) binders such as, for example,
15 carboxymethylcellulose, alginates, gelatin, polyvinylpyrrolidone, sucrose, and acacia, c) humectants such as glycerol, d) disintegrating agents such as agar-agar, calcium carbonate, potato or tapioca starch, alginic acid, certain silicates, and sodium carbonate, e) solution retarding agents such as paraffin, f) absorption accelerators such as quaternary ammonium compounds, g) wetting agents such as, for example, cetyl alcohol
20 and glycerol monostearate, h) absorbents such as kaolin and bentonite clay, and i) lubricants such as talc, calcium stearate, magnesium stearate, solid polyethylene glycols, sodium lauryl sulfate, and mixtures thereof. In the case of capsules, tablets and pills, the dosage form may also comprise buffering agents.

 Solid compositions of a similar type may also be employed as fillers in soft and
25 hard-filled gelatin capsules using such excipients as lactose or milk sugar as well as high molecular weight polyethylene glycols and the like.

 The active compounds can also be in micro-encapsulated form with one or more excipients as noted above. The solid dosage forms of tablets, dragees, capsules, pills, and granules can be prepared with coatings and shells such as enteric coatings, release
30 controlling coatings and other coatings well known in the pharmaceutical formulating art. In such solid dosage forms the active compound may be admixed with at least one inert diluent such as sucrose, lactose or starch. Such dosage forms may also comprise, as is normal practice, additional substances other than inert diluents, e.g., tableting lubricants and other tableting aids such a magnesium stearate and microcrystalline

cellulose. In the case of capsules, tablets and pills, the dosage forms may also comprise buffering agents. They may optionally contain opacifying agents and can also be of a composition that they release the active ingredient(s) only, or preferentially, in a certain part of the intestinal tract, optionally, in a delayed manner. Examples of embedding
5 compositions which can be used include polymeric substances and waxes.

Dosage forms for topical or transdermal administration of a compound of this invention include ointments, pastes, creams, lotions, gels, powders, solutions, sprays, inhalants or patches. The active component is admixed under sterile conditions with a pharmaceutically acceptable carrier and any needed preservatives or buffers as may be
10 required. Ophthalmic formulation, ear drops, eye ointments, powders and solutions are also contemplated as being within the scope of this invention.

The ointments, pastes, creams and gels may contain, in addition to an active compound of this invention, excipients such as animal and vegetable fats, oils, waxes, paraffins, starch, tragacanth, cellulose derivatives, polyethylene glycols, silicones,
15 bentonites, silicic acid, talc and zinc oxide, or mixtures thereof.

Powders and sprays can contain, in addition to the compounds of this invention, excipients such as lactose, talc, silicic acid, aluminum hydroxide, calcium silicates and polyamide powder, or mixtures of these substances. Sprays can additionally contain
20 customary propellants such as chlorofluorohydrocarbons.

Transdermal patches have the added advantage of providing controlled delivery of a compound to the body. Such dosage forms can be made by dissolving or dispensing the compound in the proper medium. Absorption enhancers can also be used to increase the flux of the compound across the skin. The rate can be controlled by either providing
25 a rate controlling membrane or by dispersing the compound in a polymer matrix or gel.

ANTIVIRAL ACTIVITY

An inhibitory amount or dose of the compounds of the present invention may range from about 0.01 mg/Kg to about 500 mg/Kg, alternatively from about 1 to about 50 mg/Kg. Inhibitory amounts or doses will also vary depending on route of
30 administration, as well as the possibility of co-usage with other agents.

According to the methods of treatment of the present invention, viral infections are treated or prevented in a subject such as a human or lower mammal by administering to the subject an anti-hepatitis C virally effective amount or an inhibitory amount of a compound of the present invention, in such amounts and for such time as is necessary to

achieve the desired result. An additional method of the present invention is the treatment of biological samples with an inhibitory amount of a compound of composition of the present invention in such amounts and for such time as is necessary to achieve the desired result.

5 The term "anti-hepatitis C virally effective amount" of a compound of the invention, as used herein, mean a sufficient amount of the compound so as to decrease the viral load in a biological sample or in a subject (e.g., resulting in at least 10%, preferably at least 50%, more preferably at least 80%, and most preferably at least 90% or 95%, reduction in viral load). As well understood in the medical arts, an anti-hepatitis
10 C virally effective amount of a compound of this invention will be at a reasonable benefit/risk ratio applicable to any medical treatment.

 The term "inhibitory amount" of a compound of the present invention means a sufficient amount to decrease the hepatitis C viral load in a biological sample or a subject (e.g., resulting in at least 10%, preferably at least 50%, more preferably at least 80%, and
15 most preferably at least 90% or 95%, reduction in viral load). It is understood that when said inhibitory amount of a compound of the present invention is administered to a subject it will be at a reasonable benefit/risk ratio applicable to any medical treatment as determined by a physician. The term "biological sample(s)," as used herein, means a
20 substance of biological origin intended for administration to a subject. Examples of biological samples include, but are not limited to, blood and components thereof such as plasma, platelets, subpopulations of blood cells and the like; organs such as kidney, liver, heart, lung, and the like; sperm and ova; bone marrow and components thereof; or stem cells. Thus, another embodiment of the present invention is a method of treating a
25 biological sample by contacting said biological sample with an inhibitory amount of a compound or pharmaceutical composition of the present invention.

 Upon improvement of a subject's condition, a maintenance dose of a compound, composition or combination of this invention may be administered, if necessary. Subsequently, the dosage or frequency of administration, or both, may be reduced, as a function of the symptoms, to a level at which the improved condition is retained when
30 the symptoms have been alleviated to the desired level, treatment should cease. The subject may, however, require intermittent treatment on a long-term basis upon any recurrence of disease symptoms.

 It will be understood, however, that the total daily usage of the compounds and compositions of the present invention will be decided by the attending physician within

the scope of sound medical judgment. The specific inhibitory dose for any particular patient will depend upon a variety of factors including the disorder being treated and the severity of the disorder; the activity of the specific compound employed; the specific composition employed; the age, body weight, general health, sex and diet of the patient; 5 the time of administration, route of administration, and rate of excretion of the specific compound employed; the duration of the treatment; drugs used in combination or coincidental with the specific compound employed; and like factors well known in the medical arts.

The total daily inhibitory dose of the compounds of this invention administered to 10 a subject in single or in divided doses can be in amounts, for example, from 0.01 to 50 mg/kg body weight or more usually from 0.1 to 25 mg/kg body weight. Single dose compositions may contain such amounts or submultiples thereof to make up the daily dose. In general, treatment regimens according to the present invention comprise administration to a patient in need of such treatment from about 10 mg to about 1000 mg 15 of the compound(s) of this invention per day in single or multiple doses.

Unless otherwise defined, all technical and scientific terms used herein are accorded the meaning commonly known to one with ordinary skill in the art. All publications, patents, published patent applications, and other references mentioned herein are hereby incorporated by reference in their entirety.

20

ABBREVIATIONS

Abbreviations used in the descriptions of the schemes and the examples that follow are:

ACN for acetonitrile;
25 aq. for aqueous;
CDI for 1,1'-carbonyldiimidazole;
COD for cyclooctadiene;
DAST for diethylaminosulfur trifluoride;
DABCYL for 6-(N-4'-carboxy-4-(dimethylamino)azobenzene)- aminoethyl-
30 1-O-(2-cyanoethyl)-(N,N-diisopropyl)-phosphoramidite;
DBU for 1,8-diazabicyclo[5.4.0]undec-7-ene;
DCM for dichloromethane;
DIAD for diisopropyl azodicarboxylate;
DIEA for diisopropyl ethylamine;

- DMAP for N,N-dimethylaminopyridine;
DME for ethylene glycol dimethyl ether;
DMF for N,N-dimethyl formamide;
DMSO for dimethylsulfoxide;
5 ESI for electrospray ionization;
Et for ethyl;
EtOAc for ethyl acetate;
g for gram(s);
h for hour(s);
10 HATU for O-(7-Azabenzotriazole-1-yl)-N,N,N',N'-tetramethyluronium
hexafluoro-phosphate;
Hoveyda's Cat. for Dichloro(*o*-isopropoxyphenylmethylene)
(tricyclohexylphosphine)ruthenium(II);
HPLC for high-performance liquid chromatography;
15 Me for methyl;
MeOH for methanol;
mg for milligram(s);
min for minute(s);
MS for mass spectrometry;
20 NMR for nuclear magnetic resonance;
Ph for phenyl;
rt for room temperature;
RT-PCR for reverse transcription-polymerase chain reaction;
TEA for triethyl amine;
25 TFA for trifluoroacetic acid;
THF for tetrahydrofuran;
TLC for thin layer chromatography;
PPh₃ for triphenylphosphine;
*t*BOC or Boc for *tert*-butyloxy carbonyl.

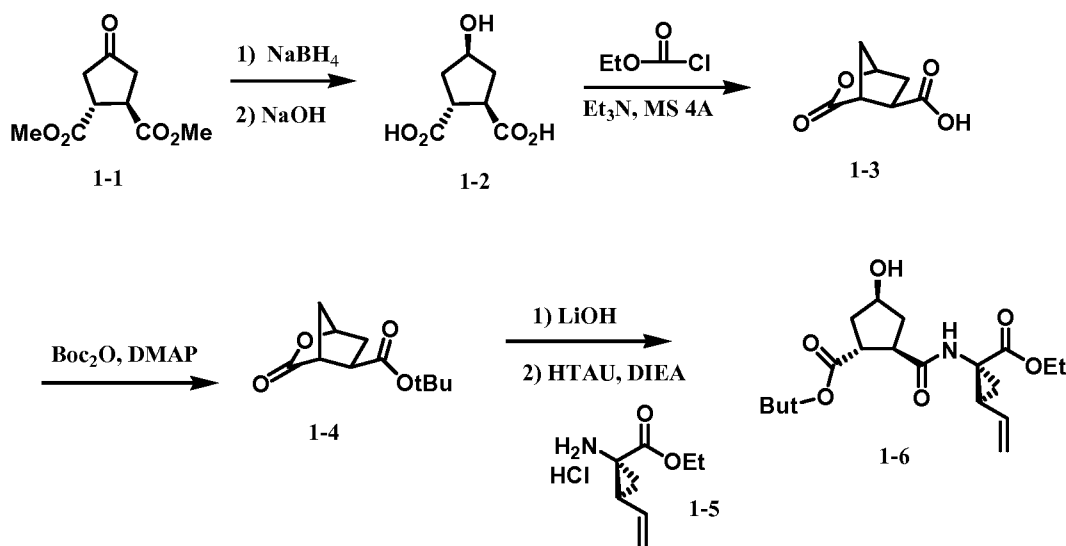
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SYNTHETIC METHODS

The compounds and processes of the present invention will be better understood in connection with the following synthetic schemes that illustrate the methods by which the compounds of the invention may be prepared, which are intended as an illustration

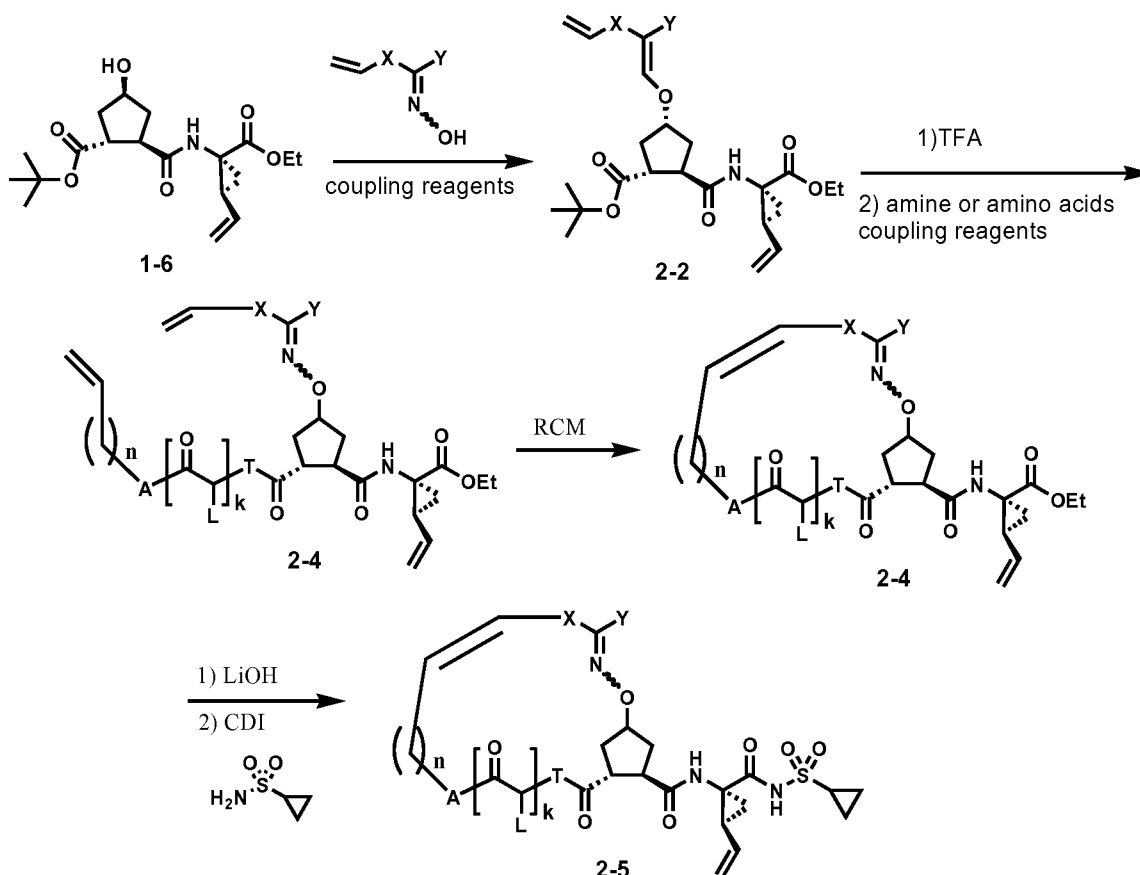
only and not limiting of the scope of the invention. Various changes and modifications to the disclosed embodiments will be apparent to those skilled in the art and such changes and modifications including, without limitation, those relating to the chemical structures, substituents, derivatives, formulations and/or methods of the invention may be made without departing from the spirit of the invention and the scope of the appended claims.

Scheme 1



10

Scheme 1 describes the synthesis of common intermediate **1-6**. The sequence started from commercially available **1-1**, following literature procedure (P.A. Bartlett and F.R. Green JACS 1978, 4858) to get **1-3**. The free acid was protected, and then treated with LiOH to open the lactone. The resulting acid was coupled with **1-5** to give **1-6**.

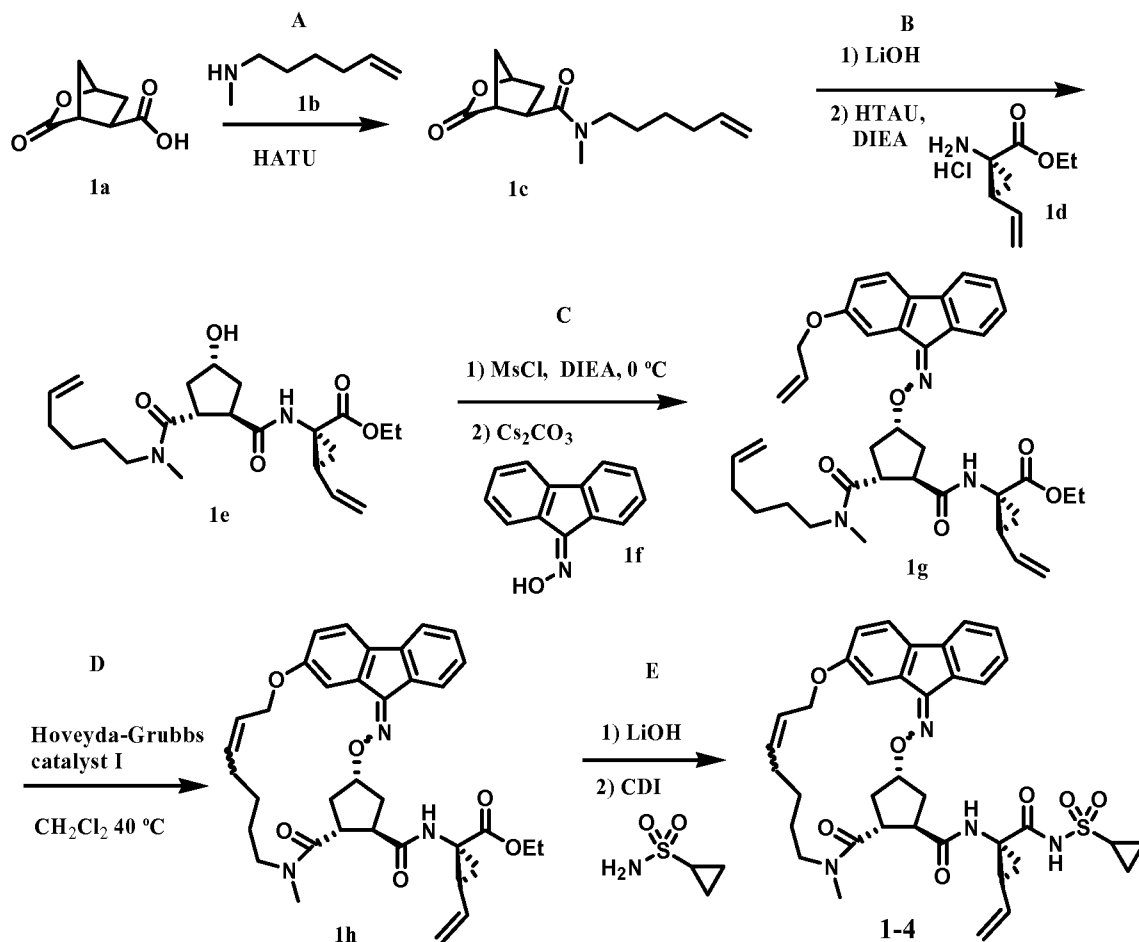
Scheme 2

Scheme 2 illustrates a very general synthesis of the tethered compounds. The oxime
 5 intermediate **2-2** can be made through SN2 replacement of activated hydroxyl group by
 converting hydroxy intermediate **1-6** to a suitable leaving group such as, but not limited to
 OMs, OTs, OTf, bromide, or iodide. Alternatively, intermediate **2-2** can be made
 using Mitsunobu conditions. TFA deprotection followed by coupling of amine or amino
 acid with terminal alkene give compound **2-3**. Ring closing metathesis formed
 10 macrocyclic **2-4**, which was converted to corresponding sulfonamide **2-5**.

EXAMPLES

The compounds and processes of the present invention will be better understood
 in connection with the following examples, which are intended as an illustration only and
 15 not limiting of the scope of the invention. Various changes and modifications to the
 disclosed embodiments will be apparent to those skilled in the art and such changes and
 modifications including, without limitation, those relating to the chemical structures,
 substituents, derivatives, formulations and/or methods of the invention may be made
 without departing from the spirit of the invention and the scope of the appended claims.

Example 1-4.



Step 1A

- 5 To HATU (340mg, 0.9 mmol) and **1b** (110mg, 1mmol) in DMF (3mL) in ice bath were added **1a** (129mg, 0.83mmol) in DMF (3mL) followed by DIEA (0.36 mL). After stirred for 40 min at 0 °C, the mixture was allowed to warm to rt overnight. The mixture was diluted with EtOAc, which was washed with NaHCO₃ (sat), brine, dried over Na₂SO₄, filtered and concentrated. The residue was purified by silica gel chromatography to give
- 10 desired product **1c** (100 mg).

Step 1B

Compound **1c** (85mg, 0.339 mmol) in water (4 mL) was treated with LiOH (1M, 0.68 mL) at 0 °C. The reaction mixture was stirred for 2h at 0 °C. HCl (1M) was added slowly to adjust the pH to around 4. The solvents were removed. The residue was dissolved in DMF (2.5 mL). To this solution were added DIEA (0.175 mL, 1 mmol), **1d** (122mg, 0.374mmol), HATU (150mg, 0.39mmol). The reaction mixture was stirred for 3 h at room temperature. The mixture was diluted with EtOAc, which was washed with water, brine, dried over Na₂SO₄, filtered and concentrated. The residue was purified by silica gel chromatography to give desired product **1e** (150 mg).

10

Step 1C

Compound **1e** (148mg, 0.365mmol) in CH₂Cl₂ (3 mL) was treated with MsCl (42 μL, 0.55 mmol) and DIEA (192 μL, 1.1mmol) at 0 °C. The reaction mixture was stirred for 1 h at 0 °C. The mixture was diluted with EtOAc, washed with brine (twice), dried over MgSO₄, filtered and concentrated. The residue was dissolved in DMF. The residue was dissolved in DMF (3 mL), and then charged with Cs₂CO₃ (0.238g, 0.73mmol) and **1f** (120mg, 0.475 mmol). The reaction mixture was stirred overnight at 50 °C, diluted with EtOAc, washed with brine, dried over Na₂SO₄, filtered and concentrated. The residue was purified by silica gel chromatography to give desired product **1g** (130 mg).

20

Step 1D

Compound **1g** (42mg) in CH₂Cl₂ (40 mL) was bubbled with N₂ for 10 min, and then charged with Hoveyda-Grubbs catalyst I (5mg). The reaction mixture was stirred at 40 °C for 24 h. The solvents were removed. The residue was purified by silica gel chromatography to give desired product **1h**.

25

Step 1E

Compound **1h** (13 mg) in THF/MeOH (3 mL/0.5 mL) was treated with LiOH (1M, 1.5mL). The reaction mixture was stirred for 20h at RT. HCl (1M) was added slowly to adjust the pH to 4-5. The reaction mixture was extracted with EtOAc. The organic extracts were washed with brine, dried over Na₂SO₄, filtered and concentrated. To the residue in CH₂Cl₂ were added CDI (2eq). The reaction mixture was stirred at 40 °C for 1h and then added cyclopropylsulfonamide and DBU. The reaction mixture was stirred overnight at 40 °C. The reaction mixture was extracted with EtOAc. The organic

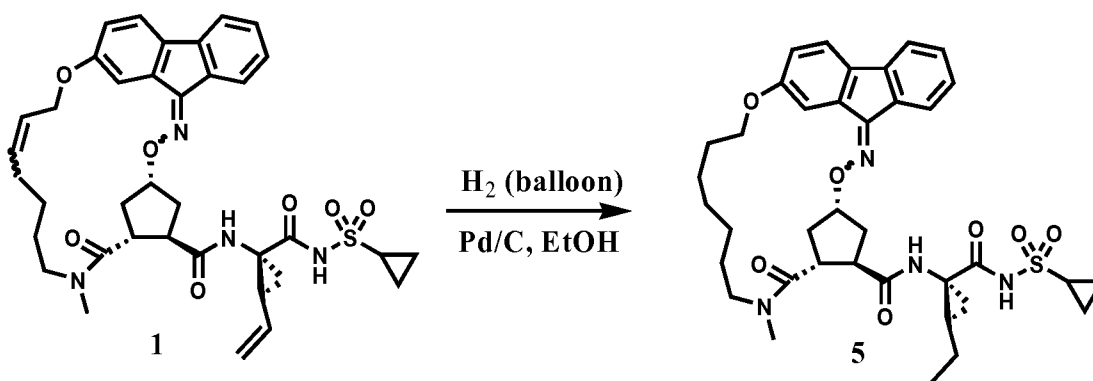
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extracts were washed with 1M NaHCO₃, brine, dried over Na₂SO₄, filtered and concentrated. The residue was purified by reverse phase prep HPLC to give example 1 to 4.

MS (ESI): $m/z = 687.19$ [M+H]. (same MS for all 4 isomers)

5

Example 5.

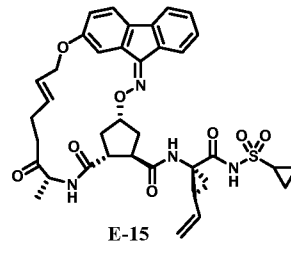
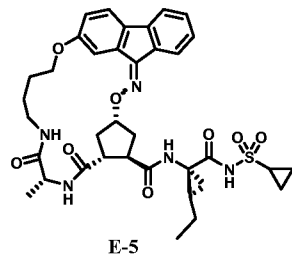
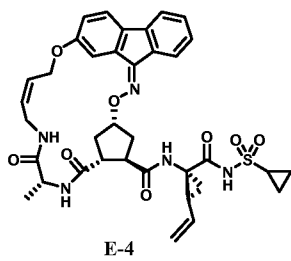
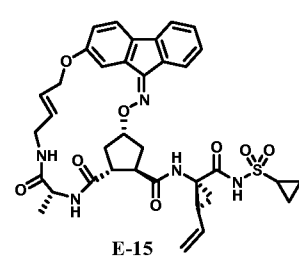
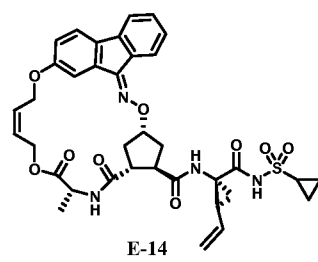
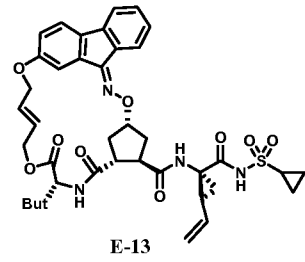
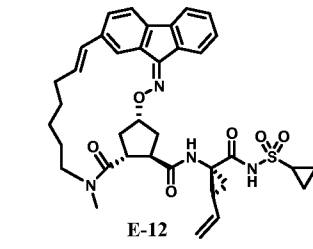
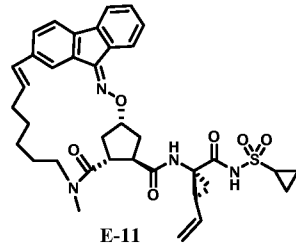
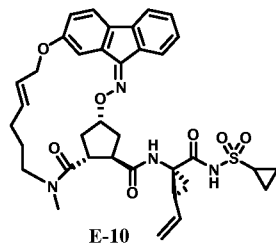
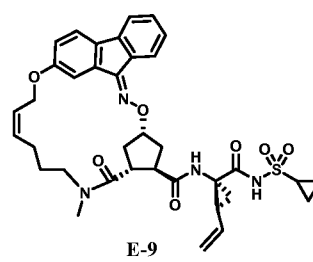
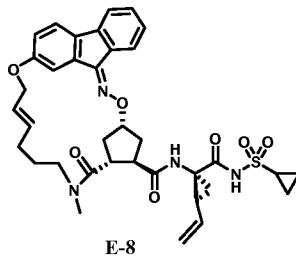
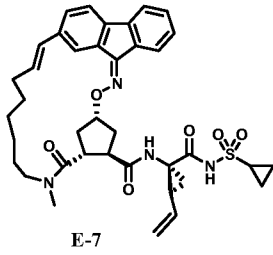
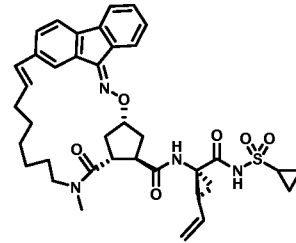


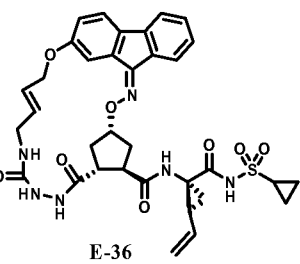
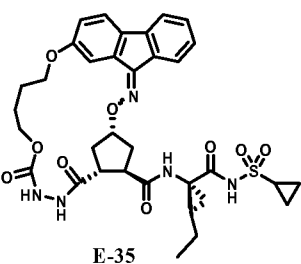
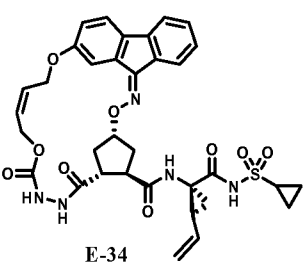
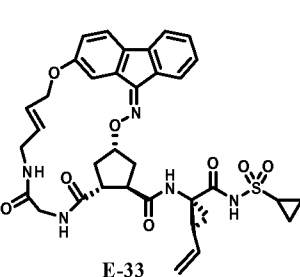
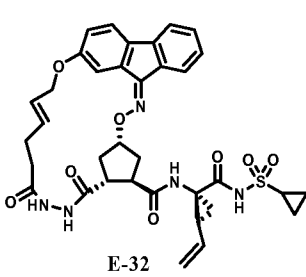
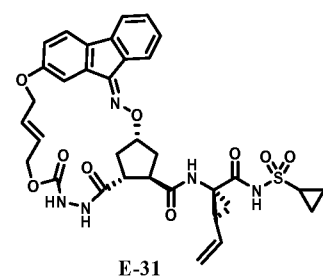
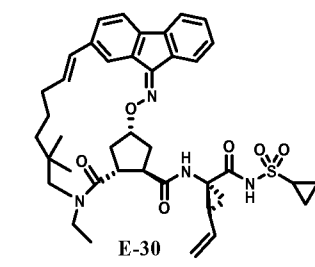
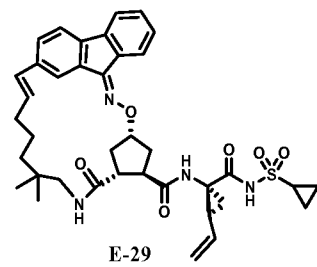
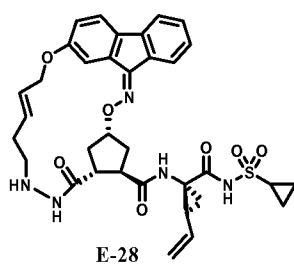
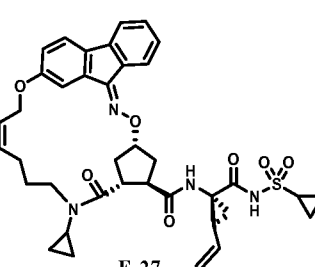
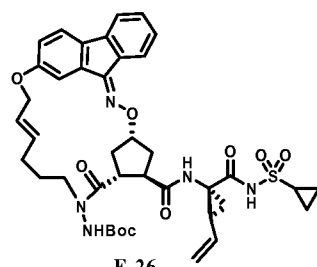
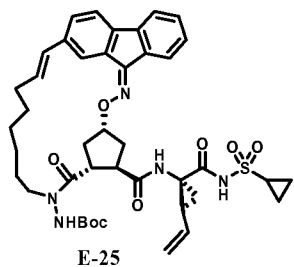
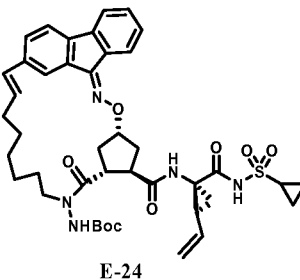
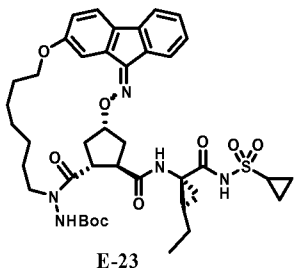
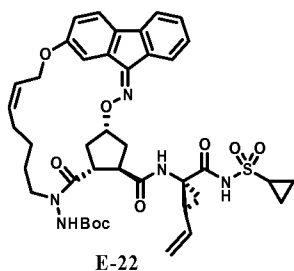
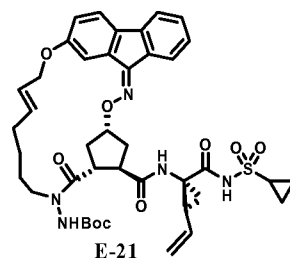
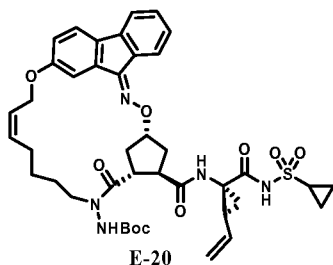
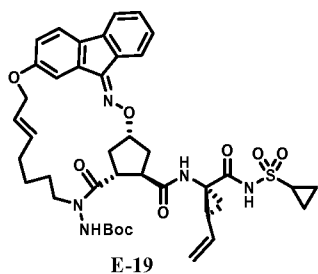
To compound 1 (6mg) in EtOH (1.5mL) was charged Pd/C (3mg) . The mixture was stirred under H₂ balloon for 12h. Mixture filtered through celite, purified by reverse phase prep HPLC to give example 5.

10

MS (ESI): $m/z = 691.30$ [M+H].

Example 6 to Example 36 are made following the similar procedures as Example 1-5 or following the general procedures described in the Synthetic Methods section.





The compounds of the present invention exhibit potent inhibitory properties against the HCV NS3 protease. The following examples describe assays in which the compounds of the present invention can be tested for anti-HCV effects.

5 Example 37. NS3/NS4a Protease Enzyme Assay

HCV protease activity and inhibition is assayed using an internally quenched fluorogenic substrate. A DABCYL and an EDANS group are attached to opposite ends of a short peptide. Quenching of the EDANS fluorescence by the DABCYL group is relieved upon proteolytic cleavage. Fluorescence is measured with a Molecular Devices
10 Fluoromax (or equivalent) using an excitation wavelength of 355 nm and an emission wavelength of 485 nm.

The assay is run in Corning white half-area 96-well plates (VWR 29444-312 [Corning 3693]) with full-length NS3 HCV protease 1b tethered with NS4A cofactor (final enzyme concentration 1 to 15 nM). The assay buffer is complemented with 10 μ M
15 NS4A cofactor Pep 4A (Anaspec 25336 or in-house, MW 1424.8). RET S1 (Ac-Asp-Glu-Asp(EDANS)-Glu-Glu-Abu-[COO]Ala-Ser-Lys-(DABCYL)-NH₂, AnaSpec 22991, MW 1548.6) is used as the fluorogenic peptide substrate. The assay buffer contains 50 mM Hepes at pH 7.5, 30 mM NaCl and 10 mM BME. The enzyme reaction is followed over a 30 minutes time course at room temperature in the absence and presence of
20 inhibitors.

The peptide inhibitors HCV Inh 1 (Anaspec 25345, MW 796.8) Ac-Asp-Glu-Met-Glu-Glu-Cys-OH, [-20⁰C] and HCV Inh 2 (Anaspec 25346, MW 913.1) Ac-Asp-Glu-Dif-Cha-Cys-OH, are used as reference compounds.

IC50 values are calculated using XLFit in ActivityBase (IDBS) using equation
25 205: $y=A+((B-A)/(1+((C/x)^D)))$.

Example 38. Cell-Based Replicon Assay

Quantification of HCV replicon RNA in cell lines (HCV Cell Based Assay)

Cell lines, including Huh-11-7 or Huh 9-13, harboring HCV replicons (Lohmann, et al
30 Science 285:110-113, 1999) are seeded at 5×10^3 cells/well in 96 well plates and fed media containing DMEM (high glucose), 10% fetal calf serum, penicillin-streptomycin and non-essential amino acids. Cells are incubated in a 5% CO₂ incubator at 37 °C. At the end of the incubation period, total RNA is extracted and purified from cells using Qiagen Rneasy 96 Kit (Catalog No. 74182). To amplify the HCV RNA so that sufficient

material can be detected by an HCV specific probe (below), primers specific for HCV (below) mediate both the reverse transcription of the HCV RNA and the amplification of the cDNA by polymerase chain reaction (PCR) using the TaqMan One-Step RT-PCR Master Mix Kit (Applied Biosystems catalog no. 4309169). The nucleotide sequences of the RT-PCR primers, which are located in the NS5B region of the HCV genome, are the following:

HCV Forward primer "RBNS5bfor"

5'GCTGCGGCCTGTCGAGCT:

HCV Reverse primer "RBNS5Brev":

10 5'CAAGGTCGTCTCCGCATAC.

Detection of the RT-PCR product is accomplished using the Applied Biosystems (ABI) Prism 7700 Sequence Detection System (SDS) that detects the fluorescence that is emitted when the probe, which is labeled with a fluorescence reporter dye and a quencher dye, is processed during the PCR reaction. The increase in the amount of fluorescence is measured during each cycle of PCR and reflects the increasing amount of RT-PCR product. Specifically, quantification is based on the threshold cycle, where the amplification plot crosses a defined fluorescence threshold. Comparison of the threshold cycles of the sample with a known standard provides a highly sensitive measure of relative template concentration in different samples (ABI User Bulletin #2 December 11, 1997). The data is analyzed using the ABI SDS program version 1.7. The relative template concentration can be converted to RNA copy numbers by employing a standard curve of HCV RNA standards with known copy number (ABI User Bulletin #2 December 11, 1997).

The RT-PCR product was detected using the following labeled probe:

5' FAM-CGAAGCTCCAGGACTGCACGATGCT-TAMRA

FAM= Fluorescence reporter dye.

5 TAMRA:=Quencher dye.

The RT reaction is performed at 48 °C for 30 minutes followed by PCR. Thermal
cycler parameters used for the PCR reaction on the ABI Prism 7700 Sequence Detection
System are: one cycle at 95 °C, 10 minutes followed by 35 cycles each of which include
10 one incubation at 95 °C for 15 seconds and a second incubation for 60 °C for 1 minute.

To normalize the data to an internal control molecule within the cellular RNA,
RT-PCR is performed on the cellular messenger RNA glyceraldehydes-3-phosphate
dehydrogenase (GAPDH). The GAPDH copy number is very stable in the cell lines
15 used. GAPDH RT-PCR is performed on the same exact RNA sample from which the
HCV copy number is determined. The GAPDH primers and probes, as well as the
standards with which to determine copy number, are contained in the ABI Pre-
Developed TaqMan Assay Kit (catalog no. 4310884E). The ratio of HCV/GAPDH RNA
is used to calculate the activity of compounds evaluated for inhibition of HCV RNA
20 replication.

Activity of compounds as inhibitors of HCV replication (Cell based Assay) in replicon containing Huh-7 cell lines.

25 The effect of a specific anti-viral compound on HCV replicon RNA levels in
Huh-11-7 or 9-13 cells is determined by comparing the amount of HCV RNA
normalized to GAPDH (e.g. the ratio of HCV/GAPDH) in the cells exposed to
compound versus cells exposed to the 0% inhibition and the 100% inhibition controls.
Specifically, cells are seeded at 5×10^3 cells/well in a 96 well plate and are incubated
30 either with: 1) media containing 1% DMSO (0% inhibition control), 2) 100 international
units, IU/ml Interferon-alpha 2b in media/1%DMSO or 3) media/1%DMSO containing a
fixed concentration of compound. 96 well plates as described above are then incubated at
37 °C for 3 days (primary screening assay) or 4 days (IC50 determination). Percent
inhibition is defined as:

% Inhibition= $[100 - ((S - C2) / (C1 - C2))] \times 100$ where:

S= the ratio of HCV RNA copy number/GAPDH RNA copy number in the sample;

5 C1= the ratio of HCV RNA copy number/GAPDH RNA copy number in the 0% inhibition control (media/1%DMSO); and

C2= the ratio of HCV RNA copy number/GAPDH RNA copy number in the 100% inhibition control (100 IU/ml Interferon-alpha 2b).

The dose-response curve of the inhibitor is generated by adding compound in serial, three-fold dilutions over three logs to wells starting with the highest concentration of a specific compound at 10uM and ending with the lowest concentration of 0.01uM. Further dilution series (1uM to 0.001uM for example) is performed if the IC50 value is not in the linear range of the curve. IC50 is determined based on the IDBS Activity Base program using Microsoft Excel "XL Fit" in which A=100% inhibition value (100IU/ml Interferon-alpha 2b), B= 0% inhibition control value (media/1%DMSO) and C= midpoint of the curve as defined as $C = (B - A / 2) + A$. A, B and C values are expressed as the ratio of HCV RNA/GAPDH RNA as determined for each sample in each well of a 96 well plate as described above. For each plate the average of 4 wells are used to define the 100% and 0% inhibition values.

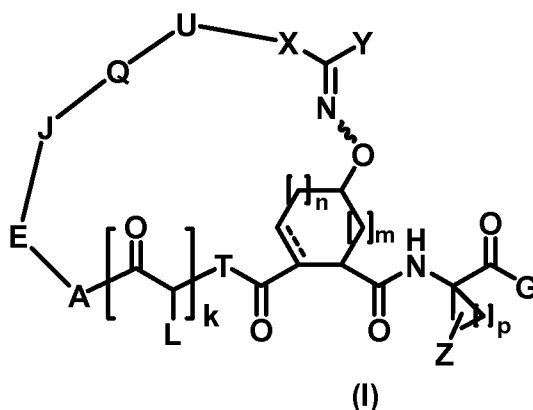
20 In the above assays, representative compounds of the present invention were found to have HCV replication inhibitory activity and HCV NS3 protease inhibitory activity. These compounds were also effective in inhibiting HCV NS3 proteases of different HCV genotypes including genotypes 1, 2, 3 and 4.

25 Representative compounds were tested in the above assays. Exemplary compounds disclosed herein were found to have activities in the ranges of ≤ 0.2 nM-3000 nM in the NS3/NS4a Protease Enzyme Assay.

Although the invention has been described with respect to various preferred embodiments, it is not intended to be limited thereto, but rather those skilled in the art will recognize that variations and modifications may be made therein which are within the spirit of the invention and the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A compound of Formula I:



5 wherein:

A is absent or NR_1 ;

R_1 is selected from the group consisting of: H, substituted or unsubstituted C_1 - C_8 alkyl,
 10 substituted or unsubstituted C_2 - C_8 alkenyl or substituted or unsubstituted -C_3 - C_8
 cycloalkyl;

E is absent or selected from the group consisting of -(C=O)- , -S(O)- , -S(O)_2 -, -
 15 $\text{(C=N-OR}_2\text{)-}$, (C=N-CN)- , and $\text{(C=N-R}_2\text{)-}$;

R_2 is selected from the group consisting of:

- (i) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
- (ii) heterocycloalkyl or substituted heterocycloalkyl; and
- (iii) -C_1 - C_8 alkyl, -C_2 - C_8 alkenyl, or -C_2 - C_8 alkynyl each containing 0, 1, 2, or
 20 3 heteroatoms selected from O, S, or N; substituted -C_1 - C_8 alkyl,
 substituted -C_2 - C_8 alkenyl, or substituted -C_2 - C_8 alkynyl each containing
 0, 1, 2, or 3 heteroatoms selected from O, S or N; -C_3 - C_{12} cycloalkyl, or
 substituted -C_3 - C_{12} cycloalkyl; -C_3 - C_{12} cycloalkenyl, or substituted -C_3 -
 C_{12} cycloalkenyl;

25

J is selected from the group consisting of $\text{-C(R}_3\text{R}_4\text{)-}$, -O- , or -NR_5 -;

R₃, R₄, and R₅ are independently selected from the group consisting of:

- (i) hydrogen;
- (ii) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
- (iii) heterocycloalkyl or substituted heterocycloalkyl; and
- 5 (iv) -C₁-C₈ alkyl, -C₂-C₈ alkenyl, or -C₂-C₈ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S, or N; substituted -C₁-C₈ alkyl, substituted -C₂-C₈ alkenyl, or substituted -C₂-C₈ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N; -C₃-C₁₂ cycloalkyl, or substituted -C₃-C₁₂ cycloalkyl; -C₃-C₁₂ cycloalkenyl, or substituted -C₃-C₁₂ cycloalkenyl;
- 10

Q is selected from the group consisting of:

- (i) -C₁-C₈ alkyl, -C₂-C₈ alkenyl, or -C₂-C₈ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S, or N;
- 15 (ii) substituted -C₁-C₈ alkyl, substituted -C₂-C₈ alkenyl, or substituted -C₂-C₈ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- (iii) -C₃-C₁₂ cycloalkyl, or substituted -C₃-C₁₂ cycloalkyl;
- (iv) -C₃-C₁₂ cycloalkenyl, or substituted -C₃-C₁₂ cycloalkenyl; and
- (v) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
- 20

U is absent or selected from O, S, SO, CO, SO₂, NR₁, NH(CO), NH(CO)NH, NHSO₂, NHSO₂NH, O(CO), O(CO)NH;

X and Y are independently selected from the group consisting of:

- 25 (i) absent for X or hydrogen for Y;
- (ii) aryl;
- (iii) substituted aryl;
- (iv) heteroaryl;
- (v) substituted heteroaryl;
- 30 (vi) heterocyclic or substituted heterocyclic;
- (vii) -C₁-C₈ alkyl, -C₂-C₈ alkenyl, or -C₂-C₈ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;

- (viii) substituted $-C_1-C_8$ alkyl, substituted $-C_2-C_8$ alkenyl, or substituted $-C_2-C_8$ alkynyl containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- (ix) $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- 5 (x) $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- (xi) $-W-R_6$, where W is (CO), (CO)O, (CO)NH, (SO), (SO₂), (SO₂)NH, and R₆ are independently selected from the group consisting of:
- (a) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
- 10 (b) heterocyclic; substituted heterocyclic;
- (c) $-C_1-C_8$ alkyl; $-C_2-C_8$ alkenyl, or $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- (d) substituted $-C_1-C_8$ alkyl; substituted $-C_2-C_8$ alkenyl; or substituted $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- 15 (e) $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- (f) $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N;
- 20

or X and Y taken together with the carbon atom to which they are attached form a cyclic moiety selected from: substituted or unsubstituted cycloalkyl, cycloalkenyl, or heterocyclic; substituted or unsubstituted cycloalkyl, cycloalkenyl, and heterocyclic fused with one or more aryl, substituted aryl, heteroaryl, substituted heteroaryl, heterocyclic, substituted heterocyclic, cycloalkyl, substituted cycloalkyl, cycloalkenyl or substituted cycloalkenyl;

25

L is selected from the group consisting of:

- (i) hydrogen;
- 30 (ii) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
- (iii) heterocycloalkyl or substituted heterocycloalkyl; and
- (iv) $-C_1-C_8$ alkyl, $-C_2-C_8$ alkenyl, or $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S, or N; substituted $-C_1-C_8$ alkyl,

substituted $-C_2-C_8$ alkenyl, or substituted $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N; $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl; $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl;

5

Z is selected from the group consisting of:

- (i) hydrogen;
- (ii) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
- (iii) heterocycloalkyl or substituted heterocycloalkyl; and
- 10 (iv) $-C_1-C_8$ alkyl, $-C_2-C_8$ alkenyl, or $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S, or N; substituted $-C_1-C_8$ alkyl, substituted $-C_2-C_8$ alkenyl, or substituted $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N; $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl; $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl;

15

G is selected from the group consisting of $-NHS(O)_2-R_7$; $-NH(SO_2)NR_8R_9$; OR_8 , and NR_8R_9 ; where:

R_7 is selected from the group consisting of:

- 20 (i) aryl; substituted aryl; heteroaryl; substituted heteroaryl
- (ii) heterocycloalkyl or substituted heterocycloalkyl; and
- (iii) $-C_1-C_8$ alkyl, $-C_2-C_8$ alkenyl, or $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N, substituted $-C_1-C_8$ alkyl, substituted $-C_2-C_8$ alkenyl, or substituted $-C_2-C_8$ alkynyl each containing
- 25 0, 1, 2, or 3 heteroatoms selected from O, S or N; $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl; $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl;

25

R_8 and R_9 are independently selected from the group consisting of:

- 30 (i) hydrogen;
- (ii) aryl; substituted aryl; heteroaryl; substituted heteroaryl;
- (iii) heterocycloalkyl or substituted heterocycloalkyl; and

- (iv) $-C_1-C_8$ alkyl, $-C_2-C_8$ alkenyl, or $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S, or N; substituted $-C_1-C_8$ alkyl, substituted $-C_2-C_8$ alkenyl, or substituted $-C_2-C_8$ alkynyl each containing 0, 1, 2, or 3 heteroatoms selected from O, S or N; $-C_3-C_{12}$ cycloalkyl, or substituted $-C_3-C_{12}$ cycloalkyl; $-C_3-C_{12}$ cycloalkenyl, or substituted $-C_3-C_{12}$ cycloalkenyl;

T is absent or is selected from the group consisting of NR_8 , $NR_1(CO)$ and $NR_1(CO)O$;

- 10 \equiv denotes a carbon-carbon single or double bond;

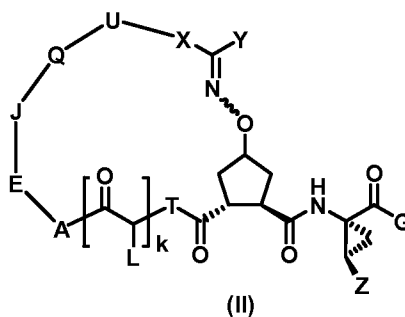
$k = 0$ or 1 ;

$m = 0, 1, 2$ or 3 ;

$n = 0, 1, 2$ or 3 ; and

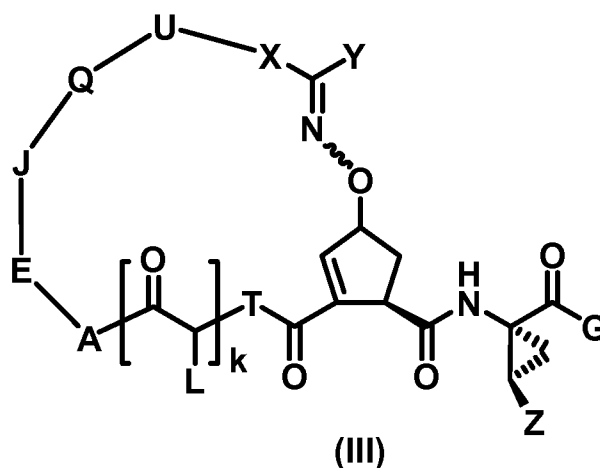
- 15 $p = 1, 2$ or 3 .

2. The compound of claim 1, wherein the compound is of Formula II:



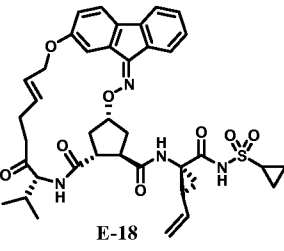
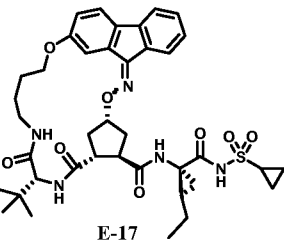
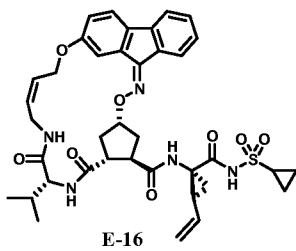
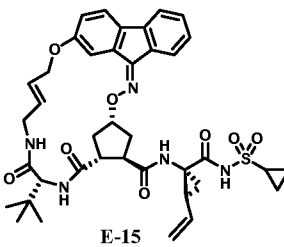
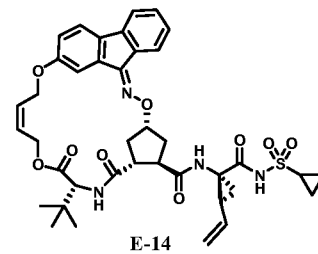
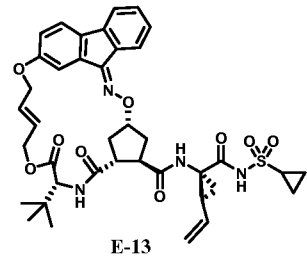
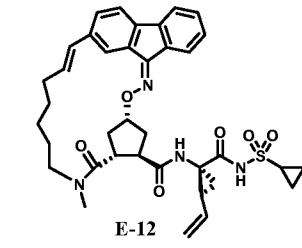
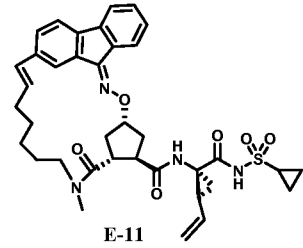
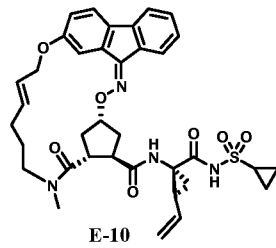
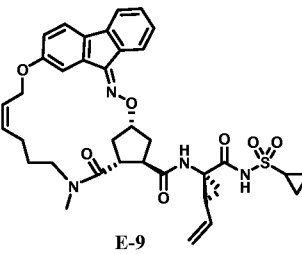
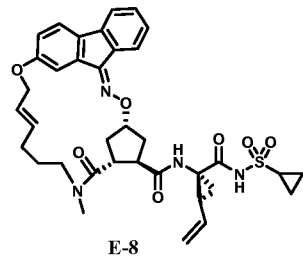
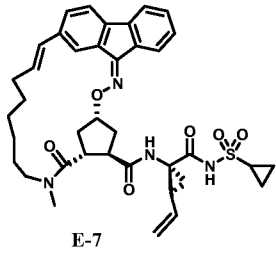
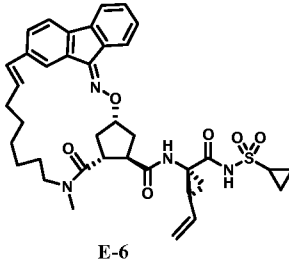
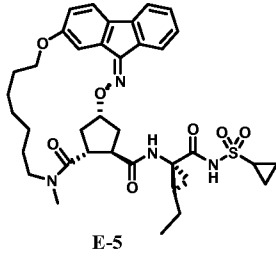
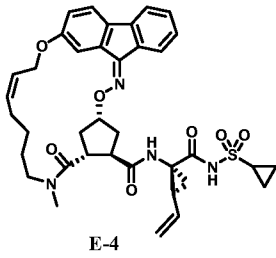
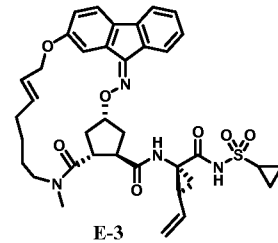
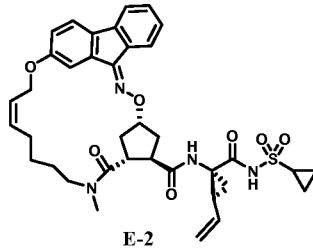
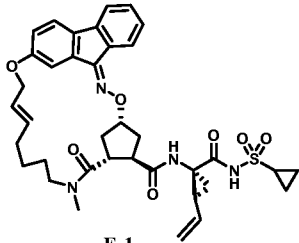
- 20 or a pharmaceutically acceptable salt, ester or prodrug thereof, alone or in combination with a pharmaceutically acceptable carrier or excipient, where A, E, J, L, U, Q, X, Y, Z, G and k are as previously defined in claim 1.

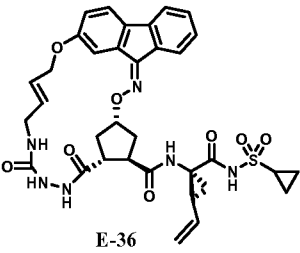
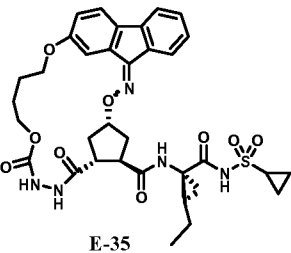
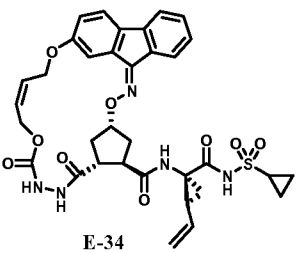
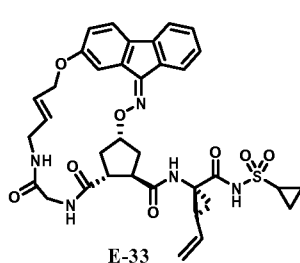
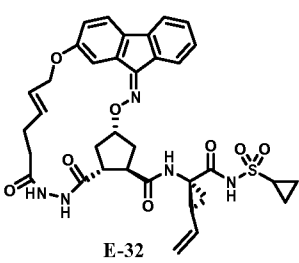
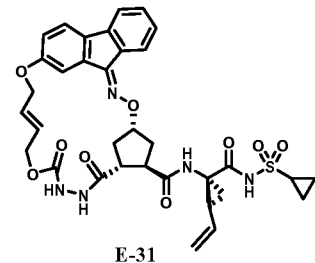
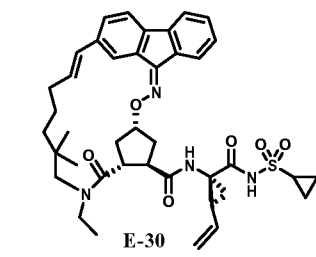
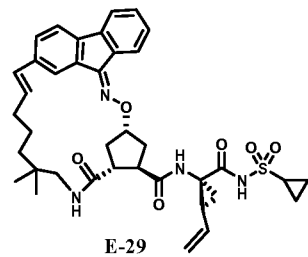
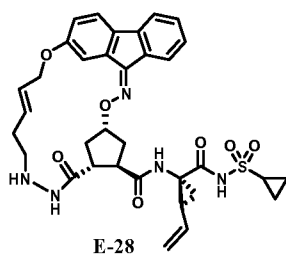
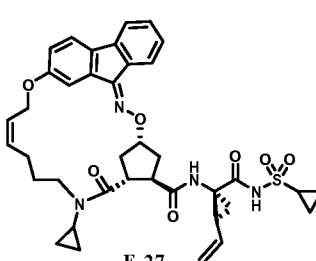
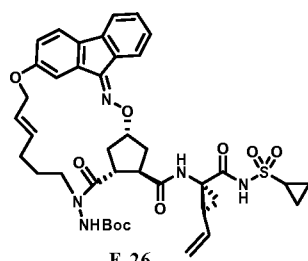
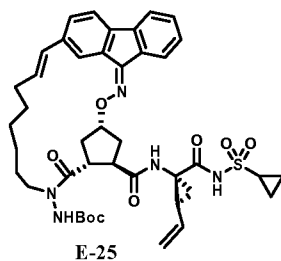
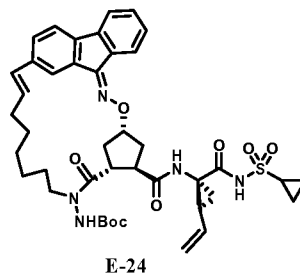
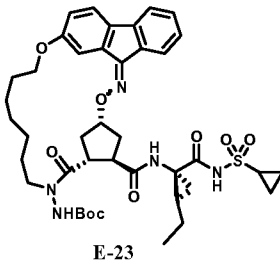
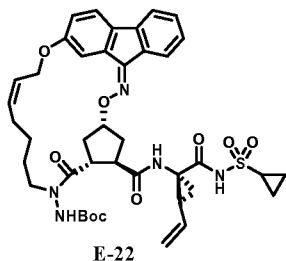
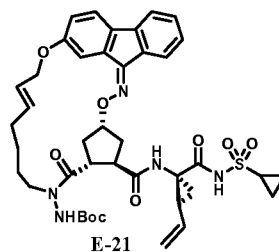
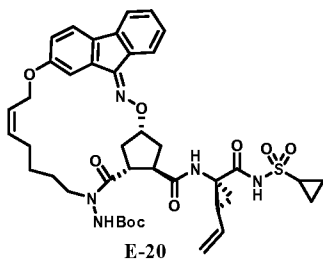
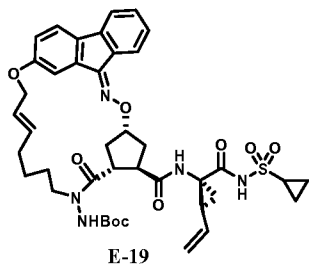
3. The compound of claim 1, wherein the compound is of Formula III:



or a pharmaceutically acceptable salt, ester or prodrug thereof, alone or in combination with a pharmaceutically acceptable carrier or excipient, where A, E, J, L, U, 5 Q, X, Y, Z, G and k are as previously defined in claim 1.

4. A compound according to claim 1, which is selected from compounds (E1-E36):





5. A pharmaceutical composition comprising an inhibitory amount of a compound according to claim 1 in combination with a pharmaceutically acceptable carrier or excipient.
- 5 6. A method of treating a viral infection in a subject, comprising administering to the subject an inhibitory amount of a pharmaceutical composition according to claim 5.
7. The method of claim 6, wherein the viral infection is hepatitis C.
- 10 8. A method of inhibiting the replication of hepatitis C virus, the method comprising supplying a hepatitis C viral NS3 protease inhibitory amount of the pharmaceutical composition of claim 5.
9. The method of claim 6 further comprising administering concurrently an additional
15 anti-hepatitis C virus agent.
10. The method of claim 9, wherein said additional anti-hepatitis C virus agent is selected from the group consisting of: α -interferon, β -interferon, ribavirin, and adamantine.
20
11. The method of claim 9, wherein said additional anti-hepatitis C virus agent is an inhibitor of hepatitis C virus helicase, polymerase, metalloprotease, or IRES.
12. The pharmaceutical composition of claim 5, further comprising another anti-HCV
25 agent.
13. The pharmaceutical composition of claim 5, further comprising an agent selected from interferon, ribavirin, amantadine, another HCV protease inhibitor, an HCV polymerase inhibitor, an HCV helicase inhibitor, or an internal ribosome entry site
30 inhibitor.
14. The pharmaceutical composition of claim 5, further comprising pegylated interferon.

15. The pharmaceutical composition of claim 5, further comprising another anti-viral, anti-bacterial, anti-fungal or anti-cancer agent, or an immune modulator.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 08/87470

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - A01N 33/24; A61K 31/15 (2009.01) USPC - 514/640 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) USPC: 514/640 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched USPC: 514/19, 411, 633, 747, 763 (see search terms below) Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) PubWEST(USPT,PGPB,EPAB,JPAB); GoogleScholar Search viral hepatitis C, pyrrolidine, macrocyclic, NS3 protease inhibition, combination therapy		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,869,964 B2 (CAMPBELL et al.) 22 March 2005 (22.03.2005) Abstract; col 2, ln 25-45; col 3, ln 10-15; ln 50-55; col 24, ln 5-15; col 28, ln 10-25	1-15
Y	US 2007/0281885 A1 (SUN et al.) 6 December 2007 (06.12.2007) para [0012]-[0013], [0043], [0046], [0066], [0472]	1-15
Y	US 2007/0203072 A1 (ROSENQUIST et al.) 30 August 2007 (30.08.2007) para [0033]	1-15
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/>		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 25 February 2009 (25.02.2009)		Date of mailing of the international search report 03 MAR 2009
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201		Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774