HEPATITIS C VIRUS INHIBITORS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application Serial Number 61/485,224 filed May 12, 2011.

The present disclosure is generally directed to antiviral compounds, and more specifically directed to compounds which can inhibit the function of the NS5A protein encoded by Hepatitis C virus (HCV), compositions comprising such compounds, and methods for inhibiting the function of the NS5A protein.

HCV is a major human pathogen, infecting an estimated 170 million persons worldwide - roughly five times the number infected by human immunodeficiency virus type 1. A substantial fraction of these HCV infected individuals develop serious progressive liver disease, including cirrhosis and hepatocellular carcinoma.

The current standard of care for HCV, which employs a combination of pegylated-interferon and ribavirin, has a non-optimal success rate in achieving sustained viral response and causes numerous side effects. Thus, there is a clear and long-felt need to develop effective therapies to address this undermet medical need.

HCV is a positive-stranded RNA virus. Based on a comparison of the deduced amino acid sequence and the extensive similarity in the 5′ untranslated region, HCV has been classified as a separate genus in the Flaviviridae family. All members of the Flaviviridae family have enveloped virions that contain a positive stranded RNA genome encoding all known virus-specific proteins via translation of a single, uninterrupted, open reading frame.

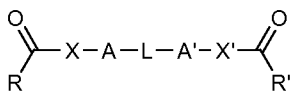
Considerable heterogeneity is found within the nucleotide and encoded amino acid sequence throughout the HCV genome due to the high error rate of the encoded RNA dependent RNA polymerase which lacks a proof-reading capability. At least six major genotypes have been characterized, and more than 50 subtypes have been described with distribution worldwide. The clinical significance of the genetic heterogeneity of HCV has demonstrated a propensity for mutations to arise during monotherapy treatment, thus additional treatment options for use are desired. The possible modulator effect of genotypes on pathogenesis and therapy remains elusive.

The single strand HCV RNA genome is approximately 9500 nucleotides in length and has a single open reading frame (ORF) encoding a single large polyprotein

of about 3000 amino acids. In infected cells, this polyprotein is cleaved at multiple sites by cellular and viral proteases to produce the structural and non-structural (NS) proteins. In the case of HCV, the generation of mature non-structural proteins (NS2, NS3, NS4A, NS4B, NS5A, and NS5B) is effected by two viral proteases. The first one is believed to be a metalloprotease and cleaves at the NS2-NS3 junction; the second one is a serine protease contained within the N-terminal region of NS3 (also referred to herein as NS3 protease) and mediates all the subsequent cleavages downstream of NS3, both in cis, at the NS3-NS4A cleavage site, and in trans, for the remaining NS4A-NS4B, NS4B-NS5A, NS5A-NS5B sites. The NS4A protein appears to serve multiple functions by both acting as a cofactor for the NS3 protease and assisting in the membrane localization of NS3 and other viral replicase components. The formation of a NS3-NS4A complex is necessary for proper protease activity resulting in increased proteolytic efficiency of the cleavage events. The NS3 protein also exhibits nucleoside triphosphatase and RNA helicase activities. NS5B (also referred to herein as HCV polymerase) is a RNA-dependent RNA polymerase that is involved in the replication of HCV with other HCV proteins, including NS5A, in a replicase complex.

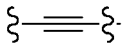
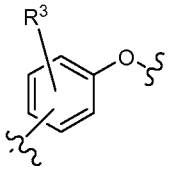
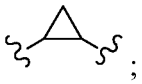
Compounds useful for treating HCV-infected patients are desired which selectively inhibit HCV viral replication. In particular, compounds which are effective to inhibit the function of the NS5A protein are desired. The HCV NS5A protein is described, for example, in the following references: S. L. Tan, et al., *Virology*, 284:1-12 (2001); K.-J. Park, et al., *J. Biol. Chem.*, 30711-30718 (2003); T. L. Tellinghuisen, et al., *Nature*, **435**, 374 (2005); R. A. Love, et al., *J. Virol*, **83**, 4395 (2009); N. Appel, et al., *J. Biol. Chem.*, **281**, 9833 (2006); L. Huang, *J. Biol. Chem.*, **280**, 36417 (2005); C. Rice, et al., WO2006093867.

In a first aspect the present disclosure provides a compound of Formula (I)

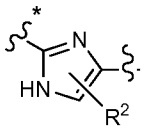
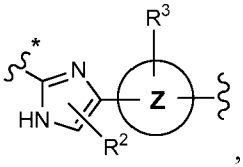
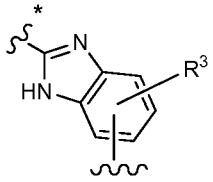
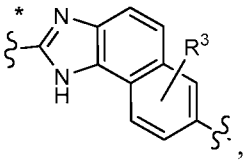
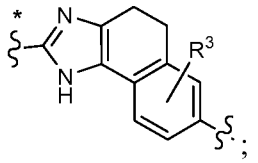


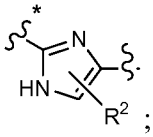
(I),

or a pharmaceutically acceptable salt thereof, wherein

L is selected from a bond,  ,  , and  ;

A and A' are independently selected from

 ;  ,  ,  , and  ;

provided at least one of A and A' is other than  ;

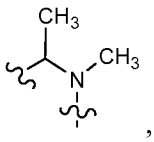
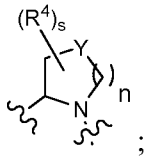
wherein "" represents the point of attachment to X and X' and "" represents the point of attachment to L; and wherein:

Z is a six-membered aromatic ring optionally containing one, two, or three nitrogen atoms;

R^2 is selected from hydrogen, alkyl, and halo; and

R^3 is selected from hydrogen, alkoxy, alkyl, cyano, halo, and haloalkoxy;

X and X' are independently selected from

 , and  ;

wherein each group is drawn with the carbon atom being attached to A or A' and with the nitrogen atom attached to the carbonyl group and wherein:

n is 0, 1, or 2;

s is 0, 1, 2, 3, or 4;

Y is selected from $Si(R^4)_2$, NR^4, O, S, S(O), SO_2, CH_2, CHR^4, and $C(R^4)_2$; provided that when n is 0, Y is selected from CH_2, CHR^4, and $C(R^4)_2$; and

each R^4 is independently selected from alkoxy, alkyl, aryl, cyano, halo, haloalkoxy, haloalkyl, hydroxy, $-NR^aR^b$, and thioalkyl, wherein the alkyl can optionally form a fused three- to six-membered ring or a bridged four- or five-membered ring with another carbon atom on the ring; or can optionally form a spirocyclic three- to six-membered ring with the carbon to which it is attached, wherein each formed ring system optionally contains one or two oxygen atoms, and wherein each formed ring system is optionally substituted with one or two groups independently selected from alkyl and halo; provided that when Y is NR^4, R^4 is other than halo, hydroxy, or $-NR^aR^b$;

R is (NR^cR^d)alkyl, wherein the alkyl part of the (NR^cR^d)alkyl is substituted with bicycloalkyl, fused bicycloheterocyclyl, cycloalkyl-substituted-heterocyclyl, ethenylcycloalkyl, heterocyclylethenyl, oxocycloalkyl, or spirocycloheterocyclyl, wherein the bicycloalkyl, bicycloheterocyclyl, oxocycloalkyl, and spirocycloheterocyclyl are optionally substituted with one or two groups independently selected from alkyl, halo, and haloalkyl;

R' is (NR^cR^d)alkyl, wherein the alkyl part of the (NR^cR^d)alkyl is optionally substituted with bicycloalkyl, fused bicycloheterocyclyl, cycloalkyl-substituted-heterocyclyl, ethenylcycloalkyl, heterocyclylethenyl, oxocycloalkyl, or spirocycloheterocyclyl, wherein the bicycloalkyl, bicycloheterocyclyl, oxocycloalkyl, and spirocycloheterocyclyl are optionally substituted with one or two groups independently selected from alkyl, halo, and haloalkyl;

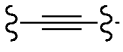
R^a and R^b are independently selected from hydrogen and alkyl;

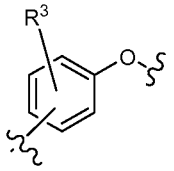
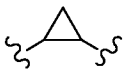
R^c and R^d are independently selected from hydrogen, alkenyloxycarbonyl, alkoxyalkylcarbonyl, alkoxycarbonyl, alkyl, alkylcarbonyl, alkylsulfonyl, aryl, arylalkoxycarbonyl, arylalkyl, arylalkylcarbonyl, arylcarbonyl, aryloxycarbonyl, arylsulfonyl, cycloalkyl, cycloalkyloxycarbonyl, cycloalkylsulfonyl, formyl, haloalkoxycarbonyl, heterocyclyl, heterocyclylalkoxycarbonyl, heterocyclylalkyl, heterocyclylalkylcarbonyl, heterocyclylcarbonyl, heterocyclyloxycarbonyl, hydroxyalkylcarbonyl, (NR^eR^f)alkyl, (NR^eR^f)alkylcarbonyl, (NR^eR^f)carbonyl, (NR^eR^f)sulfonyl, -C(NCN)OR'', and $-C(NCN)NR^xR^y$, wherein R'' is selected from alkyl and unsubstituted phenyl, and wherein the alkyl part of the arylalkyl, the arylalkylcarbonyl, the heterocyclylalkyl, and the heterocyclylalkylcarbonyl are further optionally substituted with one $-NR^eR^f$ group; and wherein the aryl, the aryl

part of the arylalkoxycarbonyl, the arylalkyl, the arylalkylcarbonyl, the arylcarbonyl, the aryloxycarbonyl, and the arylsulfonyl, the heterocyclyl, and the heterocyclyl part of the heterocyclylalkoxycarbonyl, the heterocyclylalkyl, the heterocyclylalkylcarbonyl, the heterocyclylcarbonyl, and the heterocyclyloxycarbonyl are further optionally substituted with one, two, or three substituents independently selected from alkoxy, alkyl, cyano, halo, haloalkoxy, haloalkyl, and nitro;

R^e and R^f are independently selected from hydrogen, alkyl, unsubstituted aryl, unsubstituted arylalkyl, unsubstituted cycloalkyl, unsubstituted (cyclolalkyl)alkyl, unsubstituted heterocyclyl, unsubstituted heterocyclylalkyl, (NR^xR^y)alkyl, and (NR^xR^y)carbonyl; and

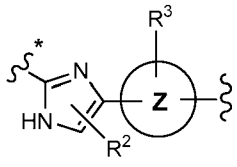
R^x and R^y are independently selected from hydrogen, alkoxycarbonyl, alkyl, alkylcarbonyl, unsubstituted aryl, unsubstituted arylalkoxycarbonyl, unsubstituted arylalkyl, unsubstituted cycloalkyl, unsubstituted heterocyclyl, and $(NR^{x'}R^{y'})$carbonyl, wherein $R^{x'}$ and $R^{y'}$ are independently selected from hydrogen and alkyl.

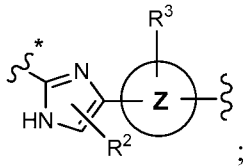
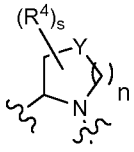
In a first embodiment of the first aspect the present disclosure provides a compound of formula (I), or a pharmaceutically acceptable salt thereof, wherein L is  .

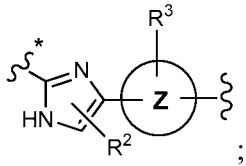
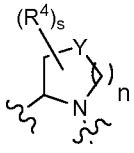
In a second embodiment of the first aspect the present disclosure provides a compound of formula (I), or a pharmaceutically acceptable salt thereof, wherein L is selected from  and  .

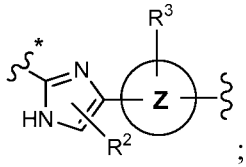
In a third embodiment of the first aspect the present disclosure provides a compound of formula (I), or a pharmaceutically acceptable salt thereof, wherein L is a bond.

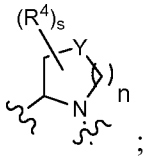
In a fourth embodiment of the first aspect the present disclosure provides a compound of formula (I), or a pharmaceutically acceptable salt thereof, wherein L is

a bond and A and A' are each  ; wherein Z is a six-membered aromatic ring optionally containing one nitrogen atom.

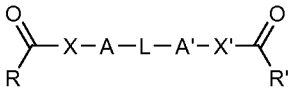
In a fifth embodiment of the first aspect the present disclosure provides a compound of formula (I), or a pharmaceutically acceptable salt thereof, wherein L is a bond; A and A' are each  ; wherein Z is a six-membered aromatic ring optionally containing one nitrogen atom; and X and X' are each  ; wherein n, s, and Y are as described for Formula (I).

In a sixth embodiment of the first aspect, the present disclosure provides a compound of formula (I), or a pharmaceutically acceptable salt thereof, wherein L is a bond; A and A' are each  ; wherein Z is a six-membered aromatic ring optionally containing one nitrogen atom; and X and X' are each  ; wherein n is 1 or 2; s is 1, 2, or 3; and Y is selected from O, CH_2, CHR^4, and $C(R^4)_2$.

In a seventh embodiment of the first aspect the present disclosure provides a compound of Formula (I), or a pharmaceutically acceptable salt thereof, wherein L is a bond; A and A' are each  ; wherein Z is a six-membered aromatic ring optionally containing one nitrogen atom; and X and X' are each

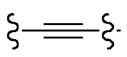
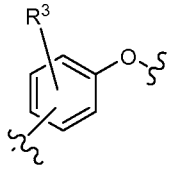
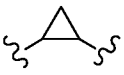

; wherein n is 1; s is 1, 2, or 3; and Y is selected from CH_2, CHR^4, and $C(R^4)_2$. In an eighth embodiment of the first aspect, R and R' are each (NR^cR^d)alkyl, wherein the alkyl part of each (NR^cR^d)alkyl is substituted with bicycloalkyl, fused bicycloheterocyclyl, cycloalkyl-substituted-heterocyclyl, or spirocycloheterocyclyl, wherein the bicycloalkyl and the bicycloheterocyclyl are optionally substituted with one or two halo groups. In a ninth embodiment of the first aspect, the alkyl part of each (NR^cR^d)alkyl is substituted with spirocycloheterocyclyl, wherein spirocycloheterocyclyl is a six-membered saturated ring containing one oxygen atom adjoined to a three-membered saturated carbocyclic ring via one single carbon atom.

In a second aspect the present disclosure provides a compound of Formula (II):

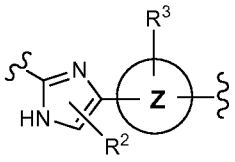
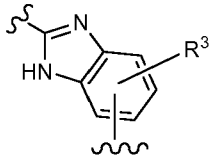
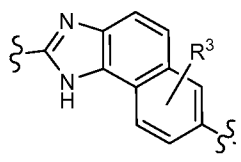
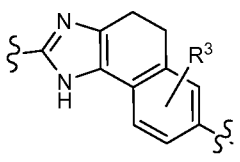


(II),

or a pharmaceutically acceptable salt thereof, wherein

L is selected from a bond,  ,  , and  ;

A and A' are independently selected from

 ,  ,  , and  ,

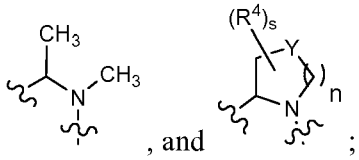
wherein each group is drawn with the imidazole ring being attached to X, and with the six-membered ring being attached to L, and wherein:

Z is a six-membered aromatic ring optionally containing one, two, or three nitrogen atoms;

R^2 is selected from hydrogen, alkyl, and halo; and

R^3 is selected from hydrogen, alkoxy, alkyl, cyano, halo, and haloalkoxy;

X and X' are independently selected from



wherein each group is drawn with the carbon atom being attached to A or A' and with the nitrogen atom attached to the carbonyl group and wherein:

n is 0, 1, or 2;

s is 0, 1, 2, 3, or 4;

Y is selected from NH, NR^4, O, S, S(O), SO_2, CH_2, CHR^4, and $C(R^4)_2$; provided that when n is 0, Y is selected from CH_2, CHR^4, and $C(R^4)_2$; and

each R^4 is independently selected from alkoxy, alkyl, aryl, cyano, halo, haloalkoxy, haloalkyl, hydroxy, and $-NR^aR^b$, wherein the alkyl can optionally form a fused three- to six-membered ring or a bridged four- or five-membered ring with another carbon atom on the ring; or can optionally form a spirocyclic three- to six-membered ring with the carbon to which it is attached, wherein the formed ring system is optionally substituted with one or two groups independently selected from alkyl and halo; provided that when Y is NR^4, R^4 is other than halo, hydroxy, or $-NR^aR^b$;

R is (NR^cR^d)alkyl, wherein the alkyl part of the (NR^cR^d)alkyl is substituted with bicycloalkyl, fused bicycloheterocyclyl, oxocycloalkyl, or spirocycloheterocyclyl, wherein the bicycloalkyl, bicycloheterocyclyl, oxocycloalkyl, and spirocycloheterocyclyl are optionally substituted with one or two groups independently selected from alkyl, halo, and haloalkyl;

R' is (NR^cR^d)alkyl, wherein the alkyl part of the (NR^cR^d)alkyl is optionally substituted with bicycloalkyl, fused bicycloheterocyclyl, oxocycloalkyl, or spirocycloheterocyclyl, wherein the bicycloalkyl, bicycloheterocyclyl, oxocycloalkyl, and spirocycloheterocyclyl are optionally substituted with one or two groups independently selected from alkyl, halo, and haloalkyl;

R^a and R^b are independently selected from hydrogen and alkyl;

R^c and R^d are independently selected from hydrogen, alkenyloxycarbonyl, alkoxyalkylcarbonyl, alkoxycarbonyl, alkyl, alkylcarbonyl, alkylsulfonyl, aryl, arylalkoxycarbonyl, arylalkyl, arylalkylcarbonyl, arylcarbonyl, aryloxycarbonyl, arylsulfonyl, cycloalkyl, cycloalkyloxycarbonyl, cycloalkylsulfonyl, formyl,

haloalkoxycarbonyl, heterocyclyl, heterocyclylalkoxycarbonyl, heterocyclylalkyl, heterocyclylalkylcarbonyl, heterocyclylcarbonyl, heterocyclyloxycarbonyl, hydroxyalkylcarbonyl, (NR^eR^f)alkyl, (NR^eR^f)alkylcarbonyl, (NR^eR^f)carbonyl, (NR^eR^f)sulfonyl, -C(NCN)OR'', and -C(NCN)NR^xR^y, wherein R'' is selected from alkyl and unsubstituted phenyl, and wherein the alkyl part of the arylalkyl, the arylalkylcarbonyl, the heterocyclylalkyl, and the heterocyclylalkylcarbonyl are further optionally substituted with one -NR^eR^f group; and wherein the aryl, the aryl part of the arylalkoxycarbonyl, the arylalkyl, the arylalkylcarbonyl, the arylcarbonyl, the aryloxycarbonyl, and the arylsulfonyl, the heterocyclyl, and the heterocyclyl part of the heterocyclylalkoxycarbonyl, the heterocyclylalkyl, the heterocyclylalkylcarbonyl, the heterocyclylcarbonyl, and the heterocyclyloxycarbonyl are further optionally substituted with one, two, or three substituents independently selected from alkoxy, alkyl, cyano, halo, haloalkoxy, haloalkyl, and nitro;

R^e and R^f are independently selected from hydrogen, alkyl, unsubstituted aryl, unsubstituted arylalkyl, unsubstituted cycloalkyl, unsubstituted (cyclolalkyl)alkyl, unsubstituted heterocyclyl, unsubstituted heterocyclylalkyl, (NR^xR^y)alkyl, and (NR^xR^y)carbonyl; and

R^x and R^y are independently selected from hydrogen, alkoxycarbonyl, alkyl, alkylcarbonyl, unsubstituted aryl, unsubstituted arylalkoxycarbonyl, unsubstituted arylalkyl, unsubstituted cycloalkyl, unsubstituted heterocyclyl, and ($NR^{x'}R^{y'}$)carbonyl, wherein $R^{x'}$ and $R^{y'}$ are independently selected from hydrogen and alkyl.

In a third aspect the present disclosure provides a composition comprising a compound of formula (I), or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier. In a first embodiment of the third aspect, the composition further comprises at least one additional compound having anti-HCV activity. In a second embodiment of the third aspect, at least one of the additional compounds is an interferon or a ribavirin. In a third embodiment of the third aspect, the interferon is selected from interferon alpha 2B, pegylated interferon alpha, pegylated interferon lambda, consensus interferon, interferon alpha 2A, and lymphoblastiod interferon tau.

In a fourth embodiment of the third aspect, the present disclosure provides a

composition comprising comprising a compound of formula (I), or a pharmaceutically acceptable salt thereof, a pharmaceutically acceptable carrier, and at least one additional compound having anti-HCV activity, wherein at least one of the additional compounds is selected from interleukin 2, interleukin 6, interleukin 12, a compound that enhances the development of a type 1 helper T cell response, interfering RNA, anti-sense RNA, Imiquimod, ribavirin, an inosine 5'-monophosphate dehydrogenase inhibitor, amantadine, and rimantadine.

In a fifth embodiment of the third aspect, the present disclosure provides a composition comprising comprising a compound of formula (I), or a pharmaceutically acceptable salt thereof, a pharmaceutically acceptable carrier, and at least one additional compound having anti-HCV activity, wherein at least one of the additional compounds is effective to inhibit the function of a target selected from HCV metalloprotease, HCV serine protease, HCV polymerase, HCV helicase, HCV NS4B protein, HCV entry, HCV assembly, HCV egress, HCV NS5A protein, and IMPDH for the treatment of an HCV infection.

In a fourth aspect the present disclosure provides a method of treating an HCV infection in a patient, comprising administering to the patient a therapeutically effective amount of a compound of formula (I), or a pharmaceutically acceptable salt thereof. In a first embodiment of the fourth aspect the method further comprises administering at least one additional compound having anti-HCV activity prior to, after or simultaneously with the compound of formula (I), or a pharmaceutically acceptable salt thereof. In a second embodiment of the fourth aspect, at least one of the additional compounds is an interferon or a ribavirin. In a third embodiment of the fourth aspect, the interferon is selected from interferon alpha 2B, pegylated interferon alpha, consensus interferon, interferon alpha 2A, and lymphoblastoid interferon tau.

In a fourth embodiment of the fourth aspect the present disclosure provides a method of treating an HCV infection in a patient, comprising administering to the patient a therapeutically effective amount of a compound of formula (I), or a pharmaceutically acceptable salt thereof and administering at least one additional compound having anti-HCV activity prior to, after or simultaneously with the compound of formula (I), or a pharmaceutically acceptable salt thereof, wherein at least one of the additional compounds is selected from interleukin 2, interleukin 6, interleukin 12, a compound that enhances the development of a type 1 helper T cell

response, interfering RNA, anti-sense RNA, Imiquimod, ribavirin, an inosine 5'-monophosphate dehydrogenase inhibitor, amantadine, and rimantadine.

In a fifth embodiment of the fourth aspect the present disclosure provides a method of treating an HCV infection in a patient, comprising administering to the patient a therapeutically effective amount of a compound of formula (I), or a pharmaceutically acceptable salt thereof and administering at least one additional compound having anti-HCV activity prior to, after or simultaneously with the compound of formula (I), or a pharmaceutically acceptable salt thereof, wherein at least one of the additional compounds is effective to inhibit the function of a target selected from HCV metalloprotease, HCV serine protease, HCV polymerase, HCV helicase, HCV NS4B protein, HCV entry, HCV assembly, HCV egress, HCV NS5A protein, and IMPDH for the treatment of an HCV infection.

Other aspects of the present disclosure may include suitable combinations of embodiments disclosed herein.

Yet other aspects and embodiments may be found in the description provided herein.

The description of the present disclosure herein should be construed in congruity with the laws and principals of chemical bonding. In some instances it may be necessary to remove a hydrogen atom in order to accommodate a substituent at any given location.

It should be understood that the compounds encompassed by the present disclosure are those that are suitably stable for use as pharmaceutical agent.

It is intended that the definition of any substituent or variable at a particular location in a molecule be independent of its definitions elsewhere in that molecule. For example, when s is 2, the two R^4 groups may be the same or different.

All patents, patent applications, and literature references cited in the specification are herein incorporated by reference in their entirety. In the case of inconsistencies, the present disclosure, including definitions, will prevail.

As used in the present specification, the following terms have the meanings indicated:

As used herein, the singular forms “a”, “an”, and “the” include plural reference unless the context clearly dictates otherwise.

Unless stated otherwise, all aryl, cycloalkyl, and heterocyclyl groups of the present disclosure may be substituted as described in each of their respective definitions. For example, the aryl part of an arylalkyl group may be substituted as described in the definition of the term "aryl".

The term "alkenyl," as used herein, refers to a straight or branched chain group of two to six carbon atoms containing at least one carbon-carbon double bond.

The term "alkenyloxy," as used herein, refers to an alkenyl group attached to the parent molecular moiety through an oxygen atom.

The term "alkenyloxycarbonyl," as used herein, refers to an alkenyloxy group attached to the parent molecular moiety through a carbonyl group.

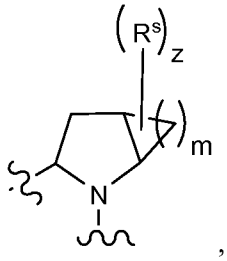
The term "alkoxy," as used herein, refers to an alkyl group attached to the parent molecular moiety through an oxygen atom.

The term "alkoxyalkyl," as used herein, refers to an alkyl group substituted with one, two, or three alkoxy groups.

The term "alkoxyalkylcarbonyl," as used herein, refers to an alkoxyalkyl group attached to the parent molecular moiety through a carbonyl group.

The term "alkoxycarbonyl," as used herein, refers to an alkoxy group attached to the parent molecular moiety through a carbonyl group.

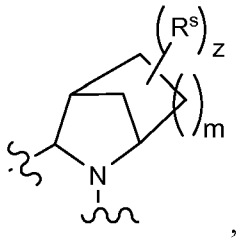
The term "alkyl," as used herein, refers to a group derived from a straight or branched chain saturated hydrocarbon containing from one to six carbon atoms. In the compounds of the present disclosure, when R^4 is alkyl, the alkyl can optionally form a fused three- to six-membered ring with an adjacent carbon atom to provide the structure shown below:



,

wherein m is selected from 1, 2, 3,and 4, wherein z is 0, 1, or 2, and wherein each R^s is independently selected from alkyl, halo, and haloalkyl;

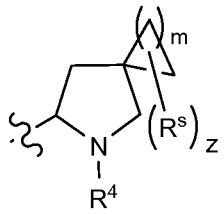
or wherein the alkyl can optionally form a bridged four-or five-membered ring with another carbon atom on the ring to provide the structure shown below:



,

wherein m is selected from 0 or 1, wherein z is 0, 1, or 2, and wherein each R^s is independently selected from alkyl, halo, and haloalkyl;

or wherein the alkyl can optionally form a a spirocyclic three- to six-membered ring with the carbon atom to which it is attached to provide the structure shown below:



wherein m is selected from 1, 2, 3, and 4, wherein z is 0, 1, or 2, and wherein each R^s is R^s is independently selected from alkyl, halo, and haloalkyl.

The term "alkylcarbonyl," as used herein, refers to an alkyl group attached to the parent molecular moiety through a carbonyl group.

The term "alkylcarbonyloxy," as used herein, refers to an alkylcarbonyl group attached to the parent molecular moiety through an oxygen atom.

The term "alkylsulfanyl," as used herein, refers to an alkyl group attached to the parent molecular moiety through a sulfur atom.

The term "alkylsulfonyl," as used herein, refers to an alkyl group attached to the parent molecular moiety through a sulfonyl group.

The term "aryl," as used herein, refers to a phenyl group, or a bicyclic fused ring system wherein one or both of the rings is a phenyl group. Bicyclic fused ring systems consist of a phenyl group fused to a four- to six-membered aromatic or non-aromatic carbocyclic ring. The aryl groups of the present disclosure can be attached to the parent molecular moiety through any substitutable carbon atom in the group. Representative examples of aryl groups include, but are not limited to, indanyl, indenyl, naphthyl, phenyl, and tetrahydronaphthyl. The aryl groups of the present disclosure are optionally substituted with one, two, three, four, or five substituents

independently selected from alkenyl, alkoxy, alkoxyalkyl, alkoxycarbonyl, alkyl, alkylcarbonyl, a second aryl group, arylalkoxy, arylalkyl, arylcarbonyl, cyano, halo, haloalkoxy, haloalkyl, heterocyclyl, heterocyclylalkyl, heterocyclylcarbonyl, hydroxy, hydroxyalkyl, nitro, $-NR^xR^y$, (NR^xR^y)alkyl, oxo, and $-P(O)OR_2$, wherein each R is independently selected from hydrogen and alkyl; and wherein the alkyl part of the arylalkyl and the heterocyclylalkyl are unsubstituted and wherein the second aryl group, the aryl part of the arylalkyl, the aryl part of the arylcarbonyl, the heterocyclyl, and the heterocyclyl part of the heterocyclylalkyl and the heterocyclylcarbonyl are further optionally substituted with one, two, or three substituents independently selected from alkoxy, alkyl, cyano, halo, haloalkoxy, haloalkyl, and nitro.

The term "arylalkoxy," as used herein, refers to an aryl group attached to the parent molecular moiety through an alkoxy group.

The term "arylalkoxycarbonyl," as used herein, refers to an arylalkoxy group attached to the parent molecular moiety through a carbonyl group.

The term "arylalkyl," as used herein, refers to an alkyl group substituted with one, two, or three aryl groups. The alkyl part of the arylalkyl is further optionally substituted with one or two additional groups independently selected from alkoxy, alkylcarbonyloxy, halo, haloalkoxy, haloalkyl, heterocyclyl, hydroxy, and $-NR^cR^d$, wherein the heterocyclyl is further optionally substitued with one or two substituents independently selected from alkoxy, alkyl, unsubstituted aryl, unsubstituted arylalkoxy, unsubstituted arylalkoxycarbonyl, halo, haloalkoxy, haloalkyl, hydroxy, $-NR^xR^y$, and oxo.

The term "arylalkylcarbonyl," as used herein, refers to an arylalkyl group attached to the parent molecular moiety through a carbonyl group.

The term "arylcarbonyl," as used herein, refers to an aryl group attached to the parent molecular moiety through a carbonyl group.

The term "aryloxy," as used herein, refers to an aryl group attached to the parent molecular moiety through an oxygen atom.

The term "aryloxycarbonyl," as used herein, refers to an aryloxy group attached to the parent molecular moiety through a carbonyl group.

The term "arylsulfonyl," as used herein, refers to an aryl group attached to the parent molecular moiety through a sulfonyl group.

The term "bicycloalkyl," as used herein, refers to a saturated, fused, bridged, or spirocyclic bicyclic hydrocarbon ring system having five to twelve carbon atoms and zero heteroatoms. The bicycloalkyl groups of the present disclosure are optionally substituted with one or two groups independently selected from alkyl, halo, and haloalkyl.

The term "carbonyl," as used herein, refers to -C(O)-.

The term "carboxy," as used herein, refers to $-CO_2H$.

The term "cyano," as used herein, refers to -CN.

The term "cycloalkyl," as used herein, refers to a saturated monocyclic, hydrocarbon ring system having three to seven carbon atoms and zero heteroatoms. Representative examples of cycloalkyl groups include, but are not limited to, cyclopropyl, cyclobutyl, cyclopentyl, and cyclohexyl. The cycloalkyl groups of the present disclosure are optionally substituted with one, two, three, four, or five substituents independently selected from alkoxy, alkyl, aryl, cyano, halo, haloalkoxy, haloalkyl, heterocyclyl, hydroxy, hydroxyalkyl, nitro, and $-NR^xR^y$, wherein the aryl and the heterocyclyl are futher optionally substituted with one, two, or three substituents independently selected from alkoxy, alkyl, cyano, halo, haloalkoxy, haloalkyl, hydroxy, and nitro.

The term "(cycloalkyl)alkyl," as used herein, refers to an alkyl group substituted with one, two, or three cycloalkyl groups.

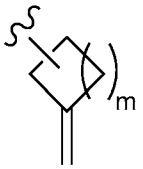
The term "cycloalkyloxy," as used herein, refers to a cycloalkyl group attached to the parent molecular moiety through an oxygen atom.

The term "cycloalkyloxycarbonyl," as used herein, refers to a cycloalkyloxy group attached to the parent molecular moiety through a carbonyl group.

The term "cycloalkylsulfonyl," as used herein, refers to a cycloalkyl group attached to the parent molecular moiety through a sulfonyl group.

The term "cycloalkyl-substituted-heterocyclyl," as used herein, refers to a saturated, monocyclic heterocyclyl group substituted with one or two cycloalkyl groups.

The term "ethenylcycloalkyl," as used herein, refers to:



;

wherein m is 1, 2, or 3.

The term "formyl," as used herein, refers to -CHO.

The term "fused bicycloheterocyclyl," as used herein, refers to a four-, five-, six-, or seven-membered saturated or unsaturated ring containing one, two, or three heteroatoms independently selected from nitrogen, oxygen, and sulfur, fused to a three- to five-membered saturated carbocyclic ring. The heterocyclyl groups of the present disclosure can be attached to the parent molecular moiety through any carbon atom or nitrogen atom in the group. The bicycloheterocyclyl groups of the present disclosure are optionally substituted with one or two groups independently selected from alkyl, spicrocyclyl, halo, and haloalkyl.

The term "halo," as used herein, refers to Cl, Br, F, or I.

The term "haloalkoxy," as used herein, refers to a haloalkyl group attached to the parent molecular moiety through an oxygen atom.

The term "haloalkoxycarbonyl," as used herein, refers to a haloalkoxy group attached to the parent molecular moiety through a carbonyl group.

The term "haloalkyl," as used herein, refers to an alkyl group substituted with one, two, three, or four halogen atoms.

The term "heterocyclyl," as used herein, refers to a four-, five-, six-, or seven-membered ring containing one, two, three, or four heteroatoms independently selected from nitrogen, oxygen, and sulfur. The four-membered ring has zero double bonds, the five-membered ring has zero to two double bonds, and the six- and seven-membered rings have zero to three double bonds. The term "heterocyclyl" also includes bicyclic groups in which the heterocyclyl ring is fused to another monocyclic heterocyclyl group, or a four- to six-membered aromatic or non-aromatic carbocyclic ring; as well as bridged bicyclic groups such as 7-azabicyclo[2.2.1]hept-7-yl, 2-azabicyclo[2.2.2]oct-2-yl, 2,5-diazabicyclo[2.2.1]heptan-2-yl, and 2-azabicyclo[2.2.2]oct-3-yl. The heterocyclyl groups of the present disclosure can be attached to the parent molecular moiety through any carbon atom or nitrogen atom in the group. Examples of heterocyclyl groups include, but are not limited to,

benzothienyl, furyl, imidazolyl, indolinyl, indolyl, isoquinolinyl, isothiazolyl, isoxazolyl, morpholinyl, oxazolyl, oxetanyl, piperazinyl, piperidinyl, pyrazolyl, pyridinyl, pyrrolidinyl, pyrrolopyridinyl, pyrrolyl, quinolinyl, tetrahydrofuranyl, tetrahydropyranyl, thiazolyl, thienyl, and thiomorpholinyl. The heterocyclyl groups of the present disclosure are optionally substituted with one, two, three, four, or five substituents independently selected from alkenyl, alkoxy, alkoxyalkyl, alkoxycarbonyl, alkyl, alkylcarbonyl, aryl, arylalkoxycarbonyl, arylalkyl, arylcarbonyl, cyano, halo, haloalkoxy, haloalkyl, a second heterocyclyl group, heterocyclylalkyl, heterocyclylcarbonyl, hydroxy, hydroxyalkyl, nitro, $-NR^xR^y$, (NR^xR^y)alkyl, and oxo, wherein the alkyl part of the arylalkyl and the heterocyclylalkyl are unsubstituted and wherein the aryl, the aryl part of the arylalkyl, the aryl part of the arylcarbonyl, the second heterocyclyl group, and the heterocyclyl part of the heterocyclylalkyl and the heterocyclylcarbonyl are further optionally substituted with one, two, or three substituents independently selected from alkoxy, alkyl, cyano, halo, haloalkoxy, haloalkyl, and nitro.

The term "heterocyclylalkoxy," as used herein, refers to a heterocylyl group attached to the parent molecular moiety through an alkoxy group.

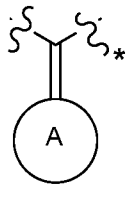
The term "heterocyclylalkoxycarbonyl," as used herein, refers to a heterocyclylalkoxy group attached to the parent molecular moiety through a carbonyl group.

The term "heterocyclylalkyl," as used herein, refers to an alkyl group substituted with one, two, or three heterocyclyl groups. The alkyl part of the heterocyclylalkyl is further optionally substituted with one or two additional groups independently selected from alkoxy, alkylcarbonyloxy, aryl, halo, haloalkoxy, haloalkyl, hydroxy, and $-NR^cR^d$, wherein the aryl is further optionally substitued with one or two substituents independently selected from alkoxy, alkyl, unsubstituted aryl, unsubstitued arylalkoxy, unsubstituted arylalkoxycarbonyl, halo, haloalkoxy, haloalkyl, hydroxy, and $-NR^xR^y$.

The term "heterocyclylalkylcarbonyl," as used herein, refers to a heterocyclylalkyl group attached to the parent molecular moiety through a carbonyl group.

The term "heterocyclylcarbonyl," as used herein, refers to a heterocyclyl group attached to the parent molecular moiety through a carbonyl group.

The term "heterocyclylethenyl," as used herein, refers to:



;

wherein A is a five- to seven-membered monocyclic heterocycle containing zero additional double bonds, and wherein " " and "" denote the point of attachment to the $-NR^cR^d$ group and the parent molecular moiety.

The term "heterocyclyloxy," as used herein, refers to a heterocyclyl group attached to the parent molecular moiety through an oxygen atom.

The term "heterocyclyloxycarbonyl," as used herein, refers to a heterocyclyloxy group attached to the parent molecular moiety through a carbonyl group.

The term "hydroxy," as used herein, refers to -OH.

The term "hydroxyalkyl," as used herein, refers to an alkyl group substituted with one, two, or three hydroxy groups.

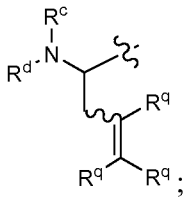
The term "hydroxyalkylcarbonyl," as used herein, refers to a hydroxyalkyl group attached to the parent molecular moiety through a carbonyl group.

The term "nitro," as used herein, refers to $-NO_2$.

The term "$-NR^cR^d$," as used herein, refers to two groups, R^c and R^d, which are attached to the parent molecular moiety through a nitrogen atom. R^c and R^d are independently selected from hydrogen, alkenyloxycarbonyl, alkoxyalkylcarbonyl, alkoxycarbonyl, alkyl, alkylcarbonyl, alkylsulfonyl, aryl, arylalkoxycarbonyl, arylalkyl, arylalkylcarbonyl, arylcarbonyl, aryloxycarbonyl, arylsulfonyl, cycloalkyl, cycloalkyloxy, cycloalkyloxycarbonyl, cycloalkylsulfonyl, formyl, haloalkoxycarbonyl, heterocyclyl, heterocyclylalkoxycarbonyl, heterocyclylalkyl, heterocyclylalkylcarbonyl, heterocyclylcarbonyl, heterocyclyloxycarbonyl, hydroxyalkylcarbonyl, (NR^eR^f)alkyl, (NR^eR^f)alkylcarbonyl, (NR^eR^f)carbonyl, (NR^eR^f)sulfonyl, -C(NCN)OR', and $-C(NCN)NR^xR^y$, wherein R' is selected from alkyl and unsubstituted phenyl, and wherein the alkyl part of the arylalkyl, the arylalkylcarbonyl, the heterocyclylalkyl, and the heterocyclylalkylcarbonyl are further optionally substituted with one $-NR^eR^f$ group; and wherein the aryl, the aryl

part of the arylalkoxycarbonyl, the arylalkyl, the arylalkylcarbonyl, the arylcarbonyl, the aryloxycarbonyl, and the arylsulfonyl, the heterocyclyl, and the heterocyclyl part of the heterocyclylalkoxycarbonyl, the heterocyclylalkyl, the heterocyclylalkylcarbonyl, the heterocyclylcarbonyl, and the heterocyclyloxycarbonyl are further optionally substituted with one, two, or three substituents independently selected from alkoxy, alkyl, cyano, halo, haloalkoxy, haloalkyl, and nitro.

The term "(NR^cR^d)alkenyl," as used herein, refers to



wherein R^c and R^d are as defined herein and each R^q is independently hydrogen or C_{1-3} alkyl.

The term "(NR^cR^d)alkyl," as used herein, refers to an alkyl group substituted with one, two, or three -NR^cR^d groups. The alkyl part of the (NR^cR^d)alkyl is further optionally substituted with one or two additional groups selected from alkoxy, alkoxyalkylcarbonyl, alkoxycarbonyl, alkylsulfanyl, arylalkoxycarbonyl, carboxy, cycloalkyl, heterocyclyl, heterocyclylcarbonyl, hydroxy, and (NR^eR^f)carbonyl; wherein the heterocyclyl is further optionally substituted with one, two, three, four, or five substituents independently selected from alkoxy, alkyl, cyano, halo, haloalkoxy, haloalkyl, and nitro.

The term "-NR^eR^f," as used herein, refers to two groups, R^e and R^f, which are attached to the parent molecular moiety through a nitrogen atom. R^e and R^f are independently selected from hydrogen, alkyl, unsubstituted aryl, unsubstituted arylalkyl, unsubstituted cycloalkyl, unsubstituted (cyclolalkyl)alkyl, unsubstituted heterocyclyl, unsubstituted heterocyclylalkyl, (NR^xR^y)alkyl, and (NR^xR^y)carbonyl.

The term "(NR^eR^f)alkyl," as used herein, refers to an alkyl group substituted with one, two, or three -NR^eR^f groups.

The term "(NR^eR^f)alkylcarbonyl," as used herein, refers to an (NR^eR^f)alkyl group attached to the parent molecular moiety through a carbonyl group.

The term "(NR^eR^f)carbonyl," as used herein, refers to an -NR^eR^f group attached to the parent molecular moiety through a carbonyl group.

The term "(NR^eR^f)sulfonyl," as used herein, refers to an -NR^eR^f group attached to the parent molecular moiety through a sulfonyl group.

The term "-NR^xR^y," as used herein, refers to two groups, R^x and R^y, which are attached to the parent molecular moiety through a nitrogen atom. R^x and R^y are independently selected from hydrogen, alkoxycarbonyl, alkyl, alkylcarbonyl, unsubstituted aryl, unsubstituted arylalkoxycarbonyl, unsubstituted arylalkyl, unsubstituted cycloalkyl, unsubstituted heterocyclyl, and ($NR^{x'}R^{y'}$)carbonyl, wherein $R^{x'}$ and $R^{y'}$ are independently selected from hydrogen and alkyl.

The term "(NR^xR^y)alkyl," as used herein, refers to an alkyl group substituted with one, two, or three -NR^xR^y groups.

The term "(NR^xR^y)carbonyl," as used herein, refers to an -NR^xR^y group attached to the parent molecular moiety through a carbonyl group.

The term "($NR^{x'}R^{y'}$)carbonyl," as used herein, refers to an -$NR^{x'}R^{y'}$ group attached to the parent molecular moiety through a carbonyl group.

The term "oxo," as used herein, refers to =O.

The term "oxocycloalkyl," as used herein, refers to a cycloalkyl group substituted with an oxo group.

The term "spirocycloheterocyclyl," as used herein, refers to a four-, five-, six-, or seven-membered saturated or unsaturated ring containing one, two, or three heteroatoms independently selected from nitrogen, oxygen, and sulfur, adjoined to one or two three- to five-membered saturated rings optionally containing one oxygen atom, via one or two single carbon atoms, respectively. The heterocyclyl groups of the present disclosure can be attached to the parent molecular moiety through any carbon atom or nitrogen atom in the group. The spirocycloheterocyclyl groups of the present disclosure are optionally substituted with one or two gropus independently selected from alkyl, halo, and haloalkyl.

The term "spirocyclyl," as used herein, refers to a three-, four-, or five-membered saturated ring adjoined to the parent molecular moiety through a single carbon atom.

The term "sulfonyl," as used herein, refers to -SO_2-.

The term "thioalkyl," as used herein, represents an alkyl group attached to the parent molecular moiety through a sulfur atom.

Asymmetric centers exist in the compounds of the present disclosure. These centers are designated by the symbols "R" or "S", depending on the configuration of substituents around the chiral carbon atom. It should be understood that the disclosure encompasses all stereochemical isomeric forms, or mixtures thereof, which possess the ability to inhibit NS5A. Individual stereoisomers of compounds can be prepared synthetically from commercially available starting materials which contain chiral centers or by preparation of mixtures of enantiomeric products followed by separation such as conversion to a mixture of diastereomers followed by separation or recrystallization, chromatographic techniques, or direct separation of enantiomers on chiral chromatographic columns. Starting compounds of particular stereochemistry are either commercially available or can be made and resolved by techniques known in the art.

Certain compounds of the present disclosure may also exist in different stable conformational forms which may be separable. Torsional asymmetry due to restricted rotation about an asymmetric single bond, for example because of steric hindrance or ring strain, may permit separation of different conformers. The present disclosure includes each conformational isomer of these compounds and mixtures thereof.

The compounds of the present disclosure also exist as tautomers; therefore the present disclosure also encompasses all tautomeric forms.

The term "compounds of the present disclosure", and equivalent expressions, are meant to embrace compounds of Formula (I), and pharmaceutically acceptable enantiomers, diastereomers, and salts thereof. Similarly, references to intermediates are meant to embrace their salts where the context so permits.

The present disclosure is intended to include all isotopes of atoms occurring in the present compounds. Isotopes include those atoms having the same atomic number but different mass numbers. By way of general example and without limitation, isotopes of hydrogen include deuterium and tritium. Isotopes of carbon include ^{13}C and ^{14}C. Isotopically-labeled compounds of the invention can generally be prepared by conventional techniques known to those skilled in the art or by processes analogous to those described herein, using an appropriate isotopically-

labeled reagent in place of the non-labeled reagent otherwise employed. Such compounds may have a variety of potential uses, for example as standards and reagents in determining biological activity. In the case of stable isotopes, such compounds may have the potential to favorably modify biological, pharmacological, or pharmacokinetic properties.

The compounds of the present disclosure can exist as pharmaceutically acceptable salts. The term "pharmaceutically acceptable salt," as used herein, represents salts or zwitterionic forms of the compounds of the present disclosure which are water or oil-soluble or dispersible, which are, within the scope of sound medical judgment, suitable for use in contact with the tissues of patients without excessive toxicity, irritation, allergic response, or other problem or complication commensurate with a reasonable benefit/risk ratio, and are effective for their intended use. The salts can be prepared during the final isolation and purification of the compounds or separately by reacting a suitable nitrogen atom with a suitable acid. Representative acid addition salts include acetate, adipate, alginate, citrate, aspartate, benzoate, benzenesulfonate, bisulfate, butyrate, camphorate, camphorsulfonate; digluconate, glycerophosphate, hemisulfate, heptanoate, hexanoate, formate, fumarate, hydrochloride, hydrobromide, hydroiodide, 2-hydroxyethanesulfonate, lactate, maleate, mesitylenesulfonate, methanesulfonate, naphthylenesulfonate, nicotinate, 2-naphthalenesulfonate, oxalate, palmoate, pectinate, persulfate, 3-phenylproprionate, picrate, pivalate, propionate, succinate, tartrate, trichloroacetate, trifluoroacetate, phosphate, glutamate, bicarbonate, para-toluenesulfonate, and undecanoate. Examples of acids which can be employed to form pharmaceutically acceptable addition salts include inorganic acids such as hydrochloric, hydrobromic, sulfuric, and phosphoric, and organic acids such as oxalic, maleic, succinic, and citric.

Basic addition salts can be prepared during the final isolation and purification of the compounds by reacting a carboxy group with a suitable base such as the hydroxide, carbonate, or bicarbonate of a metal cation or with ammonia or an organic primary, secondary, or tertiary amine. The cations of pharmaceutically acceptable salts include lithium, sodium, potassium, calcium, magnesium, and aluminum, as well as nontoxic amine cations such as ammonium, tetramethylammonium, tetraethylammonium, methylamine, dimethylamine, trimethylamine, triethylamine,

diethylamine, ethylamine, tributylamine, pyridine, N,N-dimethylaniline, N-methylpiperidine, N-methylmorpholine, dicyclohexylamine, procaine, dibenzylamine, N,N-dibenzylphenethylamine, and N,N'-dibenzylethylenediamine. Other representative organic amines useful for the formation of base addition salts include ethylenediamine, ethanolamine, diethanolamine, piperidine, and piperazine.

When it is possible that, for use in therapy, therapeutically effective amounts of a compound of Formula (I), as well as pharmaceutically acceptable salts thereof, may be administered as the raw chemical, it is possible to present the active ingredient as a pharmaceutical composition. Accordingly, the disclosure further provides pharmaceutical compositions, which include therapeutically effective amounts of compounds of Formula (I) or pharmaceutically acceptable salts thereof, and one or more pharmaceutically acceptable carriers, diluents, or excipients. The term "therapeutically effective amount," as used herein, refers to the total amount of each active component that is sufficient to show a meaningful patient benefit, e.g., a sustained reduction in viral load. When applied to an individual active ingredient, administered alone, the term refers to that ingredient alone. When applied to a combination, the term refers to combined amounts of the active ingredients that result in the therapeutic effect, whether administered in combination, serially, or simultaneously. The compounds of Formula (I) and pharmaceutically acceptable salts thereof, are as described above. The carrier(s), diluent(s), or excipient(s) must be acceptable in the sense of being compatible with the other ingredients of the formulation and not deleterious to the recipient thereof. In accordance with another aspect of the present disclosure there is also provided a process for the preparation of a pharmaceutical formulation including admixing a compound of Formula (I), or a pharmaceutically acceptable salt thereof, with one or more pharmaceutically acceptable carriers, diluents, or excipients. The term "pharmaceutically acceptable," as used herein, refers to those compounds, materials, compositions, and/or dosage forms which are, within the scope of sound medical judgment, suitable for use in contact with the tissues of patients without excessive toxicity, irritation, allergic response, or other problem or complication commensurate with a reasonable benefit/risk ratio, and are effective for their intended use.

Pharmaceutical formulations may be presented in unit dose forms containing a predetermined amount of active ingredient per unit dose. Dosage levels of between

about 0.01 and about 250 milligram per kilogram ("mg/kg") body weight per day, preferably between about 0.05 and about 100 mg/kg body weight per day of the compounds of the present disclosure are typical in a monotherapy for the prevention and treatment of HCV mediated disease. Typically, the pharmaceutical compositions of this disclosure will be administered from about 1 to about 5 times per day or alternatively, as a continuous infusion. Such administration can be used as a chronic or acute therapy. The amount of active ingredient that may be combined with the carrier materials to produce a single dosage form will vary depending on the condition being treated, the severity of the condition, the time of administration, the route of administration, the rate of excretion of the compound employed, the duration of treatment, and the age, gender, weight, and condition of the patient. Preferred unit dosage formulations are those containing a daily dose or sub-dose, as herein above recited, or an appropriate fraction thereof, of an active ingredient. Generally, treatment is initiated with small dosages substantially less than the optimum dose of the compound. Thereafter, the dosage is increased by small increments until the optimum effect under the circumstances is reached. In general, the compound is most desirably administered at a concentration level that will generally afford antivirally effective results without causing any harmful or deleterious side effects.

When the compositions of this disclosure comprise a combination of a compound of the present disclosure and one or more additional therapeutic or prophylactic agent, both the compound and the additional agent are usually present at dosage levels of between about 10 to 150%, and more preferably between about 10 and 80% of the dosage normally administered in a monotherapy regimen.

Pharmaceutical formulations may be adapted for administration by any appropriate route, for example by the oral (including buccal or sublingual), rectal, nasal, topical (including buccal, sublingual, or transdermal), vaginal, or parenteral (including subcutaneous, intracutaneous, intramuscular, intra-articular, intrasynovial, intrasternal, intrathecal, intralesional, intravenous, or intradermal injections or infusions) route. Such formulations may be prepared by any method known in the art of pharmacy, for example by bringing into association the active ingredient with the carrier(s) or excipient(s). Oral administration or administration by injection are preferred.

Pharmaceutical formulations adapted for oral administration may be presented

as discrete units such as capsules or tablets; powders or granules; solutions or suspensions in aqueous or non-aqueous liquids; edible foams or whips; or oil-in-water liquid emulsions or water-in-oil emulsions.

For instance, for oral administration in the form of a tablet or capsule, the active drug component can be combined with an oral, non-toxic pharmaceutically acceptable inert carrier such as ethanol, glycerol, water, and the like. Powders are prepared by comminuting the compound to a suitable fine size and mixing with a similarly comminuted pharmaceutical carrier such as an edible carbohydrate, as, for example, starch or mannitol. Flavoring, preservative, dispersing, and coloring agent can also be present.

Capsules are made by preparing a powder mixture, as described above, and filling formed gelatin sheaths. Glidants and lubricants such as colloidal silica, talc, magnesium stearate, calcium stearate, or solid polyethylene glycol can be added to the powder mixture before the filling operation. A disintegrating or solubilizing agent such as agar-agar, calcium carbonate, or sodium carbonate can also be added to improve the availability of the medicament when the capsule is ingested.

Moreover, when desired or necessary, suitable binders, lubricants, disintegrating agents, and coloring agents can also be incorporated into the mixture. Suitable binders include starch, gelatin, natural sugars such as glucose or beta-lactose, corn sweeteners, natural and synthetic gums such as acacia, tragacanth or sodium alginate, carboxymethylcellulose, polyethylene glycol, and the like. Lubricants used in these dosage forms include sodium oleate, sodium chloride, and the like. Disintegrators include, without limitation, starch, methyl cellulose, agar, betonite, xanthan gum, and the like. Tablets are formulated, for example, by preparing a powder mixture, granulating or slugging, adding a lubricant and disintegrant, and pressing into tablets. A powder mixture is prepared by mixing the compound, suitable comminuted, with a diluent or base as described above, and optionally, with a binder such as carboxymethylcellulose, an aliginate, gelating, or polyvinyl pyrrolidone, a solution retardant such as paraffin, a resorption accelerator such as a quaternary salt and/or and absorption agent such as betonite, kaolin, or dicalcium phosphate. The powder mixture can be granulated by wetting with a binder such as syrup, starch paste, acadia mucilage, or solutions of cellulosic or polymeric materials and forcing through a screen. As an alternative to granulating,

the powder mixture can be run through the tablet machine and the result is imperfectly formed slugs broken into granules. The granules can be lubricated to prevent sticking to the tablet forming dies by means of the addition of stearic acid, a stearate salt, talc, or mineral oil. The lubricated mixture is then compressed into tablets. The compounds of the present disclosure can also be combined with a free flowing inert carrier and compressed into tablets directly without going through the granulating or slugging steps. A clear or opaque protective coating consisting of a sealing coat of shellac, a coating of sugar or polymeric material, and a polish coating of wax can be provided. Dyestuffs can be added to these coatings to distinguish different unit dosages.

Oral fluids such as solution, syrups, and elixirs can be prepared in dosage unit form so that a given quantity contains a predetermined amount of the compound. Syrups can be prepared by dissolving the compound in a suitably flavored aqueous solution, while elixirs are prepared through the use of a non-toxic vehicle. Solubilizers and emulsifiers such as ethoxylated isostearyl alcohols and polyoxyethylene sorbitol ethers, preservatives, flavor additive such as peppermint oil or natural sweeteners, or saccharin or other artificial sweeteners, and the like can also be added.

Where appropriate, dosage unit formulations for oral administration can be microencapsulated. The formulation can also be prepared to prolong or sustain the release as for example by coating or embedding particulate material in polymers, wax, or the like.

The compounds of Formula (I), and pharmaceutically acceptable salts thereof, can also be administered in the form of liposome delivery systems, such as small unilamellar vesicles, large unilamellar vesicles, and multilamellar vesicles. Liposomes can be formed from a variety of phopholipids, such as cholesterol, stearylamine, or phophatidylcholines.

The compounds of Formula (I) and pharmaceutically acceptable salts thereof may also be delivered by the use of monoclonal antibodies as individual carriers to which the compound molecules are coupled. The compounds may also be coupled with soluble polymers as targetable drug carriers. Such polymers can include polyvinylpyrrolidone, pyran copolymer, polyhydroxypropylmethacrylamidephenol, polyhydroxyethylaspartamidephenol, or polyethyleneoxidepolylysine substituted

with palitoyl residues. Furthermore, the compounds may be coupled to a class of biodegradable polymers useful in achieving controlled release of a drug, for example, polylactic acid, polepsilon caprolactone, polyhydroxy butyric acid, polyorthoesters, polyacetals, polydihydropyrans, polycyanoacrylates, and cross-linked or amphipathic block copolymers of hydrogels.

Pharmaceutical formulations adapted for transdermal administration may be presented as discrete patches intended to remain in intimate contact with the epidermis of the recipient for a prolonged period of time. For example, the active ingredient may be delivered from the patch by iontophoresis as generally described in *Pharmaceutical Research* **1986**, *3*(6), 318.

Pharmaceutical formulations adapted for topical administration may be formulated as ointments, creams, suspensions, lotions, powders, solutions, pastes, gels, sprays, aerosols, or oils.

For treatments of the eye or other external tissues, for example mouth and skin, the formulations are preferably applied as a topical ointment or cream. When formulated in an ointment, the active ingredient may be employed with either a paraffinic or a water-miscible ointment base. Alternatively, the active ingredient may be formulated in a cream with an oil-in-water cream base or a water-in oil base.

Pharmaceutical formulations adapted for topical administrations to the eye include eye drops wherein the active ingredient is dissolved or suspended in a suitable carrier, especially an aqueous solvent.

Pharmaceutical formulations adapted for topical administration in the mouth include lozenges, pastilles, and mouth washes.

Pharmaceutical formulations adapted for rectal administration may be presented as suppositories or as enemas.

Pharmaceutical formulations adapted for nasal administration wherein the carrier is a solid include a course powder having a particle size for example in the range 20 to 500 microns which is administered in the manner in which snuff is taken, *i.e.*, by rapid inhalation through the nasal passage from a container of the powder held close up to the nose. Suitable formulations wherein the carrier is a liquid, for administration as a nasal spray or nasal drops, include aqueous or oil solutions of the active ingredient.

Pharmaceutical formulations adapted for administration by inhalation include

fine particle dusts or mists, which may be generated by means of various types of metered, dose pressurized aerosols, nebulizers, or insufflators.

Pharmaceutical formulations adapted for vaginal administration may be presented as pessaries, tampons, creams, gels, pastes, foams, or spray formulations.

Pharmaceutical formulations adapted for parenteral administration include aqueous and non-aqueous sterile injection solutions which may contain anti-oxidants, buffers, bacteriostats, and soutes which render the formulation isotonic with the blood of the intended recipient; and aqueous and non-aqueous sterile suspensions which may include suspending agents and thickening agents. The formulations may be presented in unit-dose or multi-dose containers, for example sealed ampoules and vials, and may be stored in a freeze-dried (lyophilized) condition requiring only the addition of the sterile liquid carrier, for example water for injections, immediately prior to use. Extemporaneous injection solutions and suspensions may be prepared from sterile powders, granules, and tablets.

It should be understood that in addition to the ingredients particularly mentioned above, the formulations may include other agents conventional in the art having regard to the type of formulation in question, for example those suitable for oral administration may include flavoring agents.

The term "patient" includes both human and other mammals.

The term "treating" refers to: (i) preventing a disease, disorder or condition from occurring in a patient that may be predisposed to the disease, disorder, and/or condition but has not yet been diagnosed as having it; (ii) inhibiting the disease, disorder, or condition, i.e., arresting its development; and (iii) relieving the disease, disorder, or condition, i.e., causing regression of the disease, disorder, and/or condition.

The compounds of the present disclosure can also be administered with a cyclosporin, for example, cyclosporin A. Cyclosporin A has been shown to be active against HCV in clinical trials (*Hepatology* **2003**, *38*, 1282; *Biochem. Biophys. Res. Commun.* **2004**, *313*, 42; *J. Gastroenterol.* **2003**, *38*, 567).

Table 1 below lists some illustrative examples of compounds that can be administered with the compounds of this disclosure. The compounds of the disclosure can be administered with other anti-HCV activity compounds in combination therapy, either jointly or separately, or by combining the compounds

into a composition.

Table 1

Brand Name	*Physiological Class*	*Type of Inhibitor or Target*	*Source Company*
NIM811		Cyclophilin Inhibitor	Novartis
Zadaxin		Immuno-modulator	Sciclone
Suvus		Methylene blue	Bioenvision
Actilon (CPG10101)		TLR9 agonist	Coley
Batabulin (T67)	Anticancer	β-tubulin inhibitor	Tularik Inc., South San Francisco, CA
ISIS 14803	Antiviral	antisense	ISIS Pharmaceuticals Inc, Carlsbad, CA/Elan Phamaceuticals Inc., New York, NY
Summetrel	Antiviral	antiviral	Endo Pharmaceuticals Holdings Inc., Chadds Ford, PA
GS-9132 (ACH-806)	Antiviral	HCV Inhibitor	Achillion / Gilead
Pyrazolopyrimidine compounds and salts From WO-2005047288 26 May 2005	Antiviral	HCV Inhibitors	Arrow Therapeutics Ltd.
Levovirin	Antiviral	IMPDH inhibitor	Ribapharm Inc., Costa Mesa, CA
Merimepodib (VX-497)	Antiviral	IMPDH inhibitor	Vertex Pharmaceuticals Inc., Cambridge, MA

Brand Name	*Physiological Class*	*Type of Inhibitor or Target*	*Source Company*
XTL-6865 (XTL-002)	Antiviral	monoclonal antibody	XTL Biopharmaceuticals Ltd., Rehovot, Isreal
Telaprevir (VX-950, LY-570310)	Antiviral	NS3 serine protease inhibitor	Vertex Pharmaceuticals Inc., Cambridge, MA/ Eli Lilly and Co. Inc., Indianapolis, IN
HCV-796	Antiviral	NS5B Replicase Inhibitor	Wyeth / Viropharma
NM-283	Antiviral	NS5B Replicase Inhibitor	Idenix / Novartis
GL-59728	Antiviral	NS5B Replicase Inhibitor	Gene Labs / Novartis
GL-60667	Antiviral	NS5B Replicase Inhibitor	Gene Labs / Novartis
2'C MeA	Antiviral	NS5B Replicase Inhibitor	Gilead
PSI 6130	Antiviral	NS5B Replicase Inhibitor	Roche
R1626	Antiviral	NS5B Replicase Inhibitor	Roche
2'C Methyl adenosine	Antiviral	NS5B Replicase Inhibitor	Merck
JTK-003	Antiviral	RdRp inhibitor	Japan Tobacco Inc., Tokyo, Japan
Levovirin	Antiviral	ribavirin	ICN Pharmaceuticals, Costa Mesa, CA
Ribavirin	Antiviral	ribavirin	Schering-Plough Corporation, Kenilworth, NJ

Brand Name	*Physiological Class*	*Type of Inhibitor or Target*	*Source Company*
Viramidine	Antiviral	Ribavirin Prodrug	Ribapharm Inc., Costa Mesa, CA
Heptazyme	Antiviral	ribozyme	Ribozyme Pharmaceuticals Inc., Boulder, CO
BILN-2061	Antiviral	serine protease inhibitor	Boehringer Ingelheim Pharma KG, Ingelheim, Germany
SCH 503034	Antiviral	serine protease inhibitor	Schering Plough
Zadazim	Immune modulator	Immune modulator	SciClone Pharmaceuticals Inc., San Mateo, CA
Ceplene	Immunomodulator	immune modulator	Maxim Pharmaceuticals Inc., San Diego, CA
CellCept	Immunosuppressant	HCV IgG immuno-suppressant	F. Hoffmann-La Roche LTD, Basel, Switzerland
Civacir	Immunosuppressant	HCV IgG immuno-suppressant	Nabi Biopharmaceuticals Inc., Boca Raton, FL
Albuferon - α	Interferon	albumin IFN-α2b	Human Genome Sciences Inc., Rockville, MD
Infergen A	Interferon	IFN alfacon-1	InterMune Pharmaceuticals Inc., Brisbane, CA
Omega IFN	Interferon	IFN-ω	Intarcia Therapeutics
IFN-β and EMZ701	Interferon	IFN-β and EMZ701	Transition Therapeutics Inc., Ontario, Canada

Brand Name	*Physiological Class*	*Type of Inhibitor or Target*	*Source Company*
Rebif	Interferon	IFN-β1a	Serono, Geneva, Switzerland
Roferon A	Interferon	IFN-α2a	F. Hoffmann-La Roche LTD, Basel, Switzerland
Intron A	Interferon	IFN-α2b	Schering-Plough Corporation, Kenilworth, NJ
Intron A and Zadaxin	Interferon	IFN-α2b/α1-thymosin	RegeneRx Biopharma. Inc., Bethesda, MD/ SciClone Pharmaceuticals Inc, San Mateo, CA
Rebetron	Interferon	IFN-α2b/ribavirin	Schering-Plough Corporation, Kenilworth, NJ
Actimmune	Interferon	INF-γ	InterMune Inc., Brisbane, CA
Interferon-β	Interferon	Interferon-β-1a	Serono
Multiferon	Interferon	Long lasting IFN	Viragen/ Valentis
Wellferon	Interferon	Lympho-blastoid IFN-αn1	GlaxoSmithKline plc, Uxbridge, UK
Omniferon	Interferon	natural IFN-α	Viragen Inc., Plantation, FL
Pegasys	Interferon	PEGylated IFN-α2a	F. Hoffmann-La Roche LTD, Basel, Switzerland
Pegasys and Ceplene	Interferon	PEGylated IFN-α2a/ immune modulator	Maxim Pharmaceuticals Inc., San Diego, CA

Brand Name	*Physiological Class*	*Type of Inhibitor or Target*	*Source Company*
Pegasys and Ribavirin	Interferon	PEGylated IFN-α2a/ribavirin	F. Hoffmann-La Roche LTD, Basel, Switzerland
PEG-Intron	Interferon	PEGylated IFN-α2b	Schering-Plough Corporation, Kenilworth, NJ
PEG-Intron / Ribavirin	Interferon	PEGylated IFN-α2b/ribavirin	Schering-Plough Corporation, Kenilworth, NJ
IP-501	Liver protection	antifibrotic	Indevus Pharmaceuticals Inc., Lexington, MA
IDN-6556	Liver protection	caspase inhibitor	Idun Pharmaceuticals Inc., San Diego, CA
ITMN-191 (R-7227)	Antiviral	serine protease inhibitor	InterMune Pharmaceuticals Inc., Brisbane, CA
GL-59728	Antiviral	NS5B Replicase Inhibitor	Genelabs
ANA-971	Antiviral	TLR-7 agonist	Anadys
Boceprevir	Antiviral	serine protease inhibitor	Schering Plough
TMS-435	Antiviral	serine protease inhibitor	Tibotec BVBA, Mechelen, Belgium
BI-201335	Antiviral	serine protease inhibitor	Boehringer Ingelheim Pharma KG, Ingelheim, Germany
MK-7009	Antiviral	serine protease inhibitor	Merck
PF-00868554	Antiviral	replicase inhibitor	Pfizer

Brand Name	*Physiological Class*	*Type of Inhibitor or Target*	*Source Company*
ANA598	Antiviral	Non-Nucleoside NS5B Polymerase Inhibitor	Anadys Pharmaceuticals, Inc., San Diego, CA, USA
IDX375	Antiviral	Non-Nucleoside Replicase Inhibitor	Idenix Pharmaceuticals, Cambridge, MA, USA
BILB 1941	Antiviral	NS5B Polymerase Inhibitor	Boehringer Ingelheim Canada Ltd R&D, Laval, QC, Canada
PSI-7851	Antiviral	Nucleoside Polymerase Inhibitor	Pharmasset, Princeton, NJ, USA
PSI-7977	Antiviral	Nucleotide NS5B Polymerase Inhibitor	Pharmasset, Princeton, NJ, USA
VCH-759	Antiviral	NS5B Polymerase Inhibitor	ViroChem Pharma
VCH-916	Antiviral	NS5B Polymerase Inhibitor	ViroChem Pharma
GS-9190	Antiviral	NS5B Polymerase Inhibitor	Gilead
Peg-interferon lamda	Antiviral	Interferon	ZymoGenetics/Bristol-Myers Squibb

The compounds of the present disclosure may also be used as laboratory reagents. Compounds may be instrumental in providing research tools for designing of viral replication assays, validation of animal assay systems and structural biology studies to further enhance knowledge of the HCV disease mechanisms. Further, the compounds of the present disclosure are useful in establishing or determining the binding site of other antiviral compounds, for example, by competitive inhibition.

The compounds of this disclosure may also be used to treat or prevent viral contamination of materials and therefore reduce the risk of viral infection of

laboratory or medical personnel or patients who come in contact with such materials, e.g., blood, tissue, surgical instruments and garments, laboratory instruments and garments, and blood collection or transfusion apparatuses and materials.

This disclosure is intended to encompass compounds having Formula (I) when prepared by synthetic processes or by metabolic processes including those occurring in the human or animal body (*in vivo*) or processes occurring *in vitro*.

The abbreviations used in the present application, including particularly in the illustrative examples which follow, are well-known to those skilled in the art. Some of the abbreviations used are as follows: ca. for about; ACN or MECN for acetonitrile; TFA for trifluoroacetic acid; min or mins for minutes; EtOAc or EtOAc or EA for ethyl acetate; DCM for dichloromethane; Hex for hexanes; THF for tetrahydrofuran; DMSO for dimethylsulfoxide; Et_3N or TEA for triethylamine; TBS-Cl for tert-butyldimethylsilyl chloride; Et_2O for diethyl ether; MeOH for methanol; EtOH for ethanol; rt or RT for room temperature or retention time (context will dictate); R_t for retention time; Ts for para-tolylsulfonyl; Ph for phenyl; LiHMDS for lithium hexamethyldisilazide; Me for methyl; iPr_2EtN, DIEA, or DiPEA for diisopropylethylamine; h or hr or hrs for hours; ON for overnight; TBS for tert-butyldimethylsilyl; DMF for N,N-dimethylformamide; pTsOH for para-tolylsulfonic acid; AcOH for acetic acid; HATU for O-(7-azabenzotriazol-1-yl)-N,N,N′,N′-tetramethyluronium hexafluorophosphate; BOC for tert-butoxycarbonyl; DME for 1,2-dimethoxyethane; DMAP for N,N-dimethylaminopyridine; HOBT for 1-hydroxybenzotriazole; and EDC for 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide.

The present disclosure will now be described in connection with certain embodiments which are not intended to limit its scope. On the contrary, the present disclosure covers all alternatives, modifications, and equivalents as can be included within the scope of the claims. Thus, the following examples, which include specific embodiments, will illustrate one practice of the present disclosure, it being understood that the examples are for the purposes of illustration of certain embodiments and are presented to provide what is believed to be the most useful and readily understood description of its procedures and conceptual aspects.

Starting materials can be obtained from commercial sources or prepared by well-established literature methods known to those of ordinary skill in the art.

Condition 1

Start %B = 0

Final %B = 100

Gradient time = 2 min

Stop time = 3 min

Flow rate = 1 mL/min

Wavelength = 220 nm

Solvent A = 10% ACN / 90%H_2O / 0.1% TFA

Solvent B = 90% ACN / 10% H_2O / 0.1% TFA

Column = Phenomenex-Luna C18, 30x2, 3u

Condition 2

Start %B = 0

Final %B = 100

Gradient time = 2 min

Stop time = 3 min

Flow Rate = 4 mL/min

Wavelength = 220 nm

Solvent A = 0.1% TFA in 10% methanol/90%water

Solvent B = 0.1% TFA in 90% methanol/10% water

Column = Phenomenex-Luna 3.0X 50 mm S10

Condition 3

Start %B = 0

Final %B = 100

Gradient time = 4 min

Stop time = 5 min

Flow rate = 0.8 mL/min

Wavelength = 220 nm

Solvent A = 10% ACN / 90%H_2O / 0.1% TFA

Solvent B = 90% ACN / 10% H_2O / 0.1% TFA

Column = Phenomenex-Luna C18, 50x2, 3u

Condition 4

Start %B = 2

Final %B = 98

Gradient time = 1 min

Stop time = 1.5 min

Flow rate = 0.8 mL/min

Wavelength = 220 nm

Solvent A = 100% H_2O / 0.05% TFA

Solvent B = 100% ACN / 0.05% TFA

Column = Waters Acquity SDS

Condition 5

Start %B = 0

Final %B = 100

Gradient time = 2 min

Stop time = 3 min

Flow Rate = 1 mL/min

Wavelength = 220 nm

Solvent A = 0.1% TFA in 10% methanol/90%water

Solvent B = 0.1% TFA in 90% methanol/10% water

Column = Phenomenex-Luna 2.0X 30 mm 3um

Condition 6

Start %B = 10

Final %B = 100

Gradient time = 30 min

Stop time = 33 min

Flow Rate = 1 mL/min

Wavelength = 220 nm

Solvent A = 10mM amm. bicarb (pH=9.5)/95%water/5%methanol

Solvent B = 10mM amm. bicarb (pH=9.5)/5%water/95%methanol

Column = Xbridge Phenyl 3.5um, 3.0x150mm

Condition 7

Start %B = 10

Final %B = 100

Gradient time = 15 min

Stop time = 18 min

Flow Rate = 1 mL/min

Wavelength = 220 nm

Solvent A = 0.1%TFA/95%water/5%acetonitrile

Solvent B = 0.1%TFA/5%water/95%acetonitrile

Column = Xbridge C18 3.5um, 3.0x150mm

Condition 8

Start %B = 0

Final %B = 100

Gradient time = 4 min

Stop time = 5 min

Flow rate = 0.8 mL/min

Wavelength = 220 nm

Solvent A = 10% MeOH/ 90%H_2O / 0.1% TFA

Solvent B = 90% MeOH/ 10% H_2O / 0.1% TFA

Column = Phenomenex-Luna C18, 50x2, 3u

Oven Temp. = 40 °C

Condition 9

Start %B = 10

Final %B = 50

Gradient time = 20 min

Stop time = 25 min

Flow rate = 1 mL/min

Wavelength1 = 220 nm

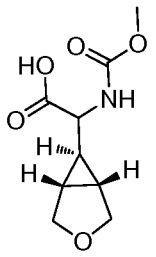
Wavelength2 = 254 nm

Solvent A = 5% ACN / 95%H_2O / 0.1% TFA

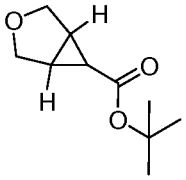
Solvent B = 95% ACN / 5% H_2O / 0.1% TFA

Column = Waters Sunfire C18, 150x4.6, 3.5u (low pH)

Cap-1

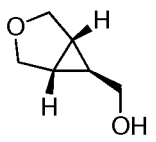


Cap-1 step a



A solution of tert-butyl diazoacetate (1.832 mL, 13.22 mmol) in 50 mL of CH_2Cl_2 was added into a mixture of 2,5-dihydrofuran (9.76 mL, 132 mmol), Rhodium(II) acetate dimer (0.058 g, 0.132 mmol) in 40 mL of CH_2Cl_2 dropwise by a syringe pump over 5 hours. The resulting mixture was then stirred at room temperature overnight. The solvent was removed under vacuum. The residue was purified by chromatography (silica gel, 0%-15% EtOAc/Hex) to afford *Cap-1 step a* (trans isomer) (720 mg) and *Cap-1 step a* (cis-isomer) (360 mg) as clear oil. *Cap-1 step a* (trans-isomer): ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 3.88 (2 H, d, *J*=8.55 Hz), 3.70 (2 H, d, *J*=8.55 Hz), 2.03 - 2.07 (2 H, m), 1.47 (1 H, t, *J*=3.20 Hz), 1.41 (9 H, s); *Cap-1 step a* (cis-isomer): ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 4.06 (2 H, d, *J*=8.53 Hz), 3.73 (2 H, d, *J*=8.03 Hz), 1.81 - 1.86 (2 H, m), 1.65 - 1.71 (1 H, m), 1.43 - 1.47 (9 H, m).

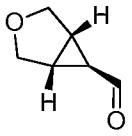
Cap-1 step b



To a solution of (*Cap-1 step a* (trans isomer)) (700 mg, 3.80 mmol) in 15 mL of diethyl ether at -10 °C was added LiAlH4 (7.60 mL, 7.60 mmol) (1 M in THF)

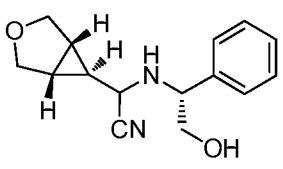
dropwise over 1 hour. The resulting mixture was stirred at -10 °C for 1 hour then at room temperature for 1 hour. The mixture was then cooled to -5 °C. 10 mL of Rochelle's salt (Potassium sodium tartrate) aqueous solution was added dropwise to quench the reaction. The mixture was stirred at room temperature for 30 min then extracted with EtOAc (3X). The combined organic layers were dried with $MgSO_4$ and concentrated to afford *Cap-1 step b* (380 mg) as light yellow oil. The product was used in the next step without purification. ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 3.85 (2 H, d, *J*=8.28 Hz), 3.68 (2 H, d, *J*=8.53 Hz), 3.45 - 3.55 (2 H, m), 1.50 - 1.56 (2 H, m), 1.02 - 1.11 (1 H, m).

Cap-1 step c



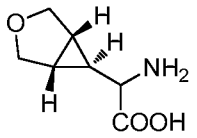
To a solution of DMSO (4.82 mL, 67.9 mmol) in CH_2Cl_2 (70 mL) was added oxalyl chloride (3.14 mL, 35.8 mmol) at -78 °C dropwise slowly. The resulting mixture was stirred at -78 °C for 15 min. A solution of *Cap-1 step b* (3.10 g, 27.2 mmol) in 35 mL of CH_2Cl_2 was added and the mixture was stirred at -78 °C for 1 hour. Et_3N (18.93 mL, 136 mmol) was then added dropwise. After 30 min, the cooling bath was removed and the reaction was quenched with cold 20% K_2HPO_4 aq. solution (10 mL) and water. The mixture was stirred at room temperature for 15 min then diluted with Et_2O. The layers were separated. The aqueous layer was extracted with Et_2O (2X). The combined organic layers were washed with brine, dried with $MgSO_4$ and concentrated. The residue was purified by flash chromatography (silica gel, 100% CH_2Cl_2) to afford *Cap-1 step c* (2.71 g) as light yellow oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 9.41 (1 H, d, *J*=4.27 Hz), 3.96 (2 H, d, *J*=8.85 Hz), 3.80 (2 H, d, *J*=8.55 Hz), 2.27 - 2.33 (2 H, m), 1.93 (1 H, m).

Cap-1 step d



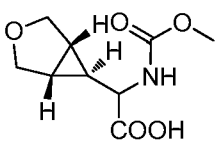
To a mixture of *Cap-1 step c* (2.7 g, 24.08 mmol) in 50 mL of water at 0 °C was added sodium bisulfite (2.506 g, 24.08 mmol) and KCN (1.631 g, 25.04 mmol), followed by a solution of (R)-2-amino-2-phenylethanol (3.30 g, 24.08 mmol) in 18 mL of MeOH. The resulting mixture was stirred at room temperature for 2 hours and then heated to reflux overnight. The mixture was cooled to room temperature. 100 mL of EtOAc was added. After mixing for 15 min the layers were separated. The aqueous layer was extracted with EtOAc (2X). The combined organic layers were washed with brine, dried with $MgSO_4$ and concentrated. The crude diastereomeric mixture was purified by reverse phase HPLC (Column: Water Sunfire 30 x 150 mm, acetonitrile/water/NH_4OAc) to afford a two diastereomers of *Cap-1 step d*. The absolute stereochemistry of each isomer was not determined. Diastereomer 1 (later fraction) (570 mg): LC (Cond. 1): RT = 0.97 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{15}H_{19}N_2O_2$ 259.14; found 259.2.

Cap-1 step e



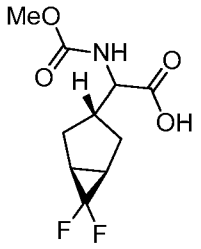
To a solution of *Cap-1 step d* (diastereomer 1) (570 mg, 2.207 mmol) in 20 mL of CH_2Cl_2 and 20 mL of MeOH at 0 °C was added lead tetraacetate (1174 mg, 2.65 mmol). The resulting orange mixture was stirred at 0 °C for 10 min. Water (20 mL) was then added into the mixture and the mixture was filtered through diatomaceous earth (Celite®). The filtrate was concentrated and diluted with 25 mL of 6 N HCl aq. solution. The resulting mixture was refluxed for 4 hours. The mixture was filtered off and washed with CH_2Cl_2. The aqueous layer was concentrated to afford *Cap-1 step e* (HCl salt). The crude product was used in the next step without further purification. ^1H NMR (500 MHz, *MeOD*) δ ppm 3.87 - 3.91 (2 H, m), 3.73 (2 H, dd, *J*=8.70, 2.90 Hz), 3.55 (1 H, d, *J*=10.07 Hz), 2.02 - 2.07 (1 H, m), 1.94 - 1.99 (1 H, m), 1.03 - 1.10 (1 H, m).

Cap-1



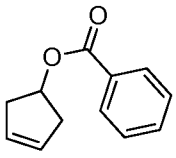
To a mixture of the above crude *Cap-1 step e* in 1 N NaOH aq. solution (10 mL) was added sodium bicarbonate (371 mg, 4.42 mmol). Methyl chloroformate (0.342 mL, 4.42 mmol) was then added dropwise. The resulting mixture was stirred at room temperature for 3 hours. The mixture was neutralized with 1 N HCl aq. solution then extracted with EtOAc (3X). The combined organic layers were dried with $MgSO_4$ and concentrated to afford *Cap-1* (100 mg, 21.1% over two steps) as light yellow oil. LC (Cond. 1): RT = 0.54 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_9H_{14}NO_5$ 216.09; found 216.1; 1H NMR (500 MHz, $CDCl_3$) δ ppm 5.29 (1 H, br. s.), 3.53 - 4.02 (8 H, m), 1.66 - 1.92 (2 H, m), 1.08 (1 H, br. s.).

Cap-2



Racemic mixture

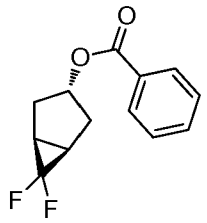
Cap-2 step a



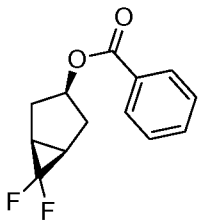
A solution of cyclopent-3-enol (5 g, 59.4 mmol) and Et_3N (9.94 mL, 71.3 mmol) in 50 mL of CH_2Cl_2 was stirred at room temperature for 15 min. Benzoyl chloride (8.28 mL, 71.3 mmol) was then added dropwise and the mixture was stirred at room temperature overnight. The mixture was then washed with water. The organic layer was dried with $MgSO_4$ and concentrated. The residue was purified by flash chromatography (silica gel, EtOAc/Hex 0 - 10%) to afford *Cap-2 step a* (9.25

g) as clear oil. LC (Cond. 1): RT = 1.77 min; ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 8.01 - 8.07 (2 H, m), 7.55 (1 H, t, *J*=7.40 Hz), 7.43 (2 H, t, *J*=7.65 Hz), 5.79 (2 H, s), 5.64 (1 H, tt, *J*=6.93, 2.60 Hz), 2.87 (2 H, dd, *J*=16.56, 6.78 Hz), 2.52 - 2.63 (2 H, m).

Cap-2 step b



isomer 1



isomer 2

To a round bottom flask with a magnetic stirring bar was added neat sodium fluoride (5.02 mg, 0.120 mmol) and *Cap-2 step a* (2.25 g, 11.95 mmol). The flask was heated up to 100 °C and neat trimethylsilyl 2,2-difluoro-2-(fluorosulfonyl)acetate (5.89 mL, 29.9 mmol) was added slowly by syringe pump over 5 hours. The mixture was stirred at 100 °C overnight. The mixture was then diluted with CH_2Cl_2, washed with water, sat. $NaHCO_3$ aq. solution and brine, dried with $MgSO_4$ and concentrated. The crude product was purified by flash chromatography (silica gel, 0-5% EtOAc/Hex) to afford *Cap-2 step b* (isomer 1) (750 mg) and *Cap-2 step b* (isomer 2) (480 mg) as clear oils. Relative stereochemical assignment was made by NOE study. *Cap-2 step b* (isomer 1): LC (Cond. 1): RT = 1.83 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{13}H_{13}F_2O_2$ 239.09; found 239.2; ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 7.99 - 8.04 (2 H, m), 7.56 (1 H, t, *J*=7.32 Hz), 7.43 (2 H, t, *J*=7.63 Hz), 5.25 - 5.33 (1 H, m), 2.50 (2 H, dd, *J*=14.04, 6.71 Hz), 2.14 - 2.22 (2 H, m), 2.08 - 2.14 (2 H, m); *Cap-2 step b* (isomer 2): LC (Cond. 1): RT = 1.79 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{13}H_{13}F_2O_2$ 239.09; found 239.2; ^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.98 - 8.08 (2 H, m), 7.53 - 7.59 (1 H, m), 7.41 - 7.48 (2 H, m), 5.53 - 5.62 (1 H, m), 2.59 - 2.70 (2 H, m), 2.01 - 2.11 (4 H, m).

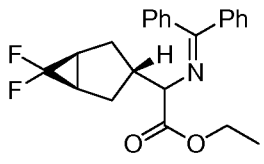
Cap-2 step c

To a solution of *Cap-2 step b* (isomer 2) (480 mg, 2.015 mmol) in 4 mL of MeOH was added KOH (4 mL, 2.015 mmol) (10% aq.). The resulting mixture was stirred at room temperature overnight. The mixture was then extracted with CH_2Cl_2 (3X). The combined organic layers were dried with $MgSO_4$ and concentrated to afford *Cap-2 step c* (220 mg) as a light yellow solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 4.41 - 4.54 (1 H, m), 2.38 - 2.50 (2 H, m), 1.89 - 1.99 (2 H, m), 1.81 (2 H, dd, *J*=14.50, 5.04 Hz).

Cap-2 step d

Tosyl-Cl (625 mg, 3.28 mmol) was added to a solution of *Cap-2 step c* (220 mg, 1.640 mmol) and pyridine (0.531 mL, 6.56 mmol) in 7 mL of CH_2Cl_2. The mixture was stirred at room temperature overnight and then diluted with CH_2Cl_2, washed with water and 1 N HCl aq. solution. The organic layer was dried ($MgSO_4$) and concentrated. The residue was purified by flash chromatography (silica gel, 0-15% EtOAc/Hexane) to afford *Cap-2 step d* (325 mg) as a clear oil. LC (Cond. 1): RT = 1.72 min; LC/MS: Anal. Calcd. For $[M+Na]^+$ $C_{13}H_{14}F_2NaO_3S$ 311.05; found 311.2; ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 7.76 (2 H, d, *J*=8.24 Hz), 7.34 (2 H, d, *J*=8.24 Hz), 4.99 – 5.08 (1 H, m), 2.45 (3 H, s), 2.31 – 2.41 (2 H, m), 1.84 – 1.94 (4 H, m).

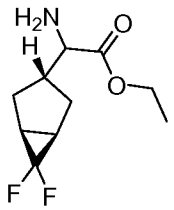
Cap-2 step e



Racemic mixture

To a microwave tube was added N-(diphenylmethylene)glycine ethyl ester (241 mg, 0.902 mmol) and *Cap-2 step d* (260 mg, 0.902 mmol) in 2 mL of toluene. The tube was sealed and LiHMDS (1.082 mL, 1.082 mmol) (1 N in THF) was added dropwise under N_2. The resulting dark brown solution was heated at 100 °C in microwave for 5 hours. The mixture was then quenched with water, and extracted with EtOAc (3X). The combined organic layers were washed with water, dried with $MgSO_4$ and concentrated. The crude product was purified by flash chromatography (silica gel, 0-5% EtOAc/Hex) to afford a racemic mixture of *Cap-2 step e* (240 mg) as light yellow oil. The mixture was submitted to the next step without separation. LC (Cond. 2): RT = 1.91 min; LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{23}H_{24}F_2NO_2$ 384.18, found 384.35. ^1H NMR (500 MHz, $CDCl_3$) δ ppm 7.63 - 7.70 (2 H, m), 7.43 - 7.51 (3 H, m), 7.38 - 7.43 (1 H, m), 7.31 - 7.38 (2 H, m), 7.13 - 7.22 (2 H, m), 4.13 - 4.22 (2 H, m), 3.95 (1 H, d, *J*=6.41 Hz), 2.67 - 2.79 (1 H, m), 2.07 - 2.16 (1 H, m), 1.97 - 2.07 (2 H, m), 1.90 (2 H, m), 1.65 - 1.76 (1 H, m), 1.25 (3 H, t, *J*=7.17 Hz).

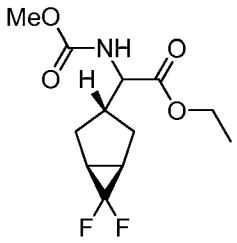
Cap-2 step f



Racemic mixture

To a solution of *Cap-2 step e* (240 mg, 0.626 mmol) in 4 mL of THF was added HCl (1 mL, 2.0 mmol) (2 N aq.). The resulting mixture was stirred at room temperature for 2 hours. The mixture was then washed with EtOAc, neutralized with sat. $NaHCO_3$ aq. solution then extracted with EtOAc (3x). The combined organic layers were dried with $MgSO_4$ and concentrated to afford *Cap-2 step f* (120 mg) as clear oil. LC (Cond. 2): RT = 0.85 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{10}H_{16}F_2NO_2$ 220.11; found 220.26; ^1H NMR (500 MHz, $CDCl_3$) δ ppm 4.14 - 4.25 (2 H, m), 3.26 (1 H, d, *J*=6.71 Hz), 2.22 - 2.35 (1 H, m), 1.90 - 2.11 (5 H, m), 1.79 - 1.90 (1 H, m), 1.22 - 1.34 (3 H, m).

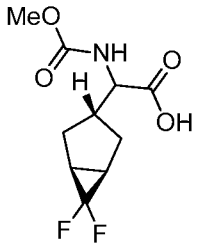
Cap-2 step g



Racemic mixture

To a solution of *Cap-2 step f* (120 mg, 0.547 mmol) in 2 mL of CH_2Cl_2 was added methyl chloroformate (0.085 mL, 1.095 mmol). The resulting mixture was stirred at room temperature for 1 hour. The mixture was diluted with CH_2Cl_2 and washed with water. The organic layer was dried with Na_2SO_4 and concentrated to afford *Cap-2 step g* (150 mg) as a white solid. LC (Cond. 1): RT = 1.45 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{12}H_{18}F_2NO_4$ 278.12; found 278.2; ^1H NMR (500 MHz, $CDCl_3$) δ ppm 5.23 (1 H, d, *J*=8.24 Hz), 4.29 (1 H, t, *J*=7.48 Hz), 4.15 - 4.23 (2 H, m), 3.68 (3 H, s), 2.37 (1 H, br. s.), 2.02 - 2.10 (1 H, m), 1.85 - 2.00 (4 H, m), 1.75 - 1.84 (1 H, m), 1.27 (3 H, t, *J*=7.02 Hz).

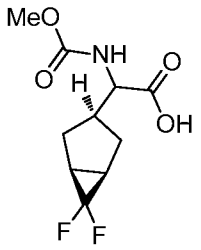
Cap-2



Racemic mixture

To a mixture of *Cap-2 step g* (150 mg, 0.541 mmol) in 2 mL of THF and 1 mL of water was added LiOH (0.811 mL, 1.623 mmol) (2 N aq.). The resulting mixture was stirred at room temperature overnight. The mixture was neutralized with 1 N HCl aq. solution and extracted with EtOAc (3X). The combined organic layers were dried with $MgSO_4$ and concentrated to afford *Cap-2* (133 mg) as a white solid. LC (Cond. 2): RT = 1.07 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{10}H_{14}F_2NO_4$ 250.09; found 250.13; ^1H NMR (500 MHz, $CDCl_3$) δ ppm 5.18 - 5.36 (1 H, m), 4.28 - 4.44 (1 H, m), 3.70 (3 H, s), 2.37 - 2.56 (1 H, m), 1.74 - 2.31 (6 H, m).

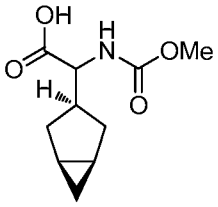
Cap-3



Racemic mixture

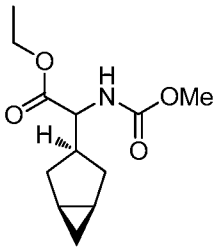
Cap-3 was synthesized from *Cap-2 step b* (isomer 1) according to the procedure described for *Cap-2*. LC (Cond. 2): RT = 1.08 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{10}H_{14}F_2NO_4$ 250.09, found 249.86. ^1H NMR (500 MHz, $CDCl_3$) δ ppm 5.15 (1 H, d, *J*=8.24 Hz), 4.32 (1 H, t, *J*=7.48 Hz), 3.69 (3 H, s), 2.83 - 2.99 (1 H, m), 1.96 - 2.26 (4 H, m), 1.70 (1 H, t, *J*=11.75 Hz), 1.59 (1 H, t, *J*=12.05 Hz).

Cap-4



Racemic mixture

Cap-4 step a

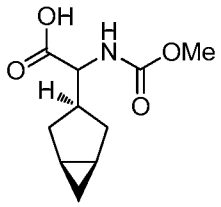


Racemic mixture

A mixture of ethyl 2-amino-2-((1R,3r,5S)-bicyclo[3.1.0]hexan-3-yl)acetate (prepared from commercially available (1R,3r,5S)-bicyclo[3.1.0]hexan-3-ol by employing the same procedures described for the preparation of *Cap*-2; 350 mg, 1.910 mmol), DiPEA (0.667 mL, 3.82 mmol), methyl chloroformate (0.296 mL, 3.82 mmol) in 5 mL of CH_2Cl_2 was stirred at room temperature for 1 hour. The mixture

was then diluted with CH_2Cl_2 and washed with water. The organic layer was dried with $MgSO_4$ and concentrated to afford *Cap-4 step a* (461 mg) as yellow oil. LC (Cond. 1): RT = 1.43 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{12}H_{20}NO_4$ 242.14; found 242.2; ^1H NMR (500 MHz, $CDCl_3$) δ ppm 5.04 (1 H, d, *J*=7.63 Hz), 4.09 - 4.20 (2 H, m), 4.05 (1 H, t, *J*=8.39 Hz), 3.63 (3 H, s), 2.55 - 2.70 (1 H, m), 1.96 - 2.09 (2 H, m), 1.37 - 1.60 (4 H, m), 1.24 (3 H, t, *J*=7.17 Hz), 0.66 - 0.76 (1 H, m), -0.03 - 0.06 (1 H, m).

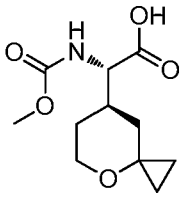
Cap-4



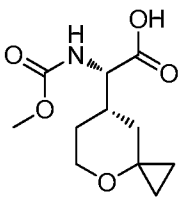
Racemic mixture

To a mixture of ethyl ester *Cap-4 step a* (461 mg, 1.911 mmol) in 5 mL of THF and 2 mL of water was added LiOH (2.87 mL, 5.73 mmol) (2 N aq.). The resulting mixture was stirred at room temperature overnight. The mixture was then neutralized with 1 N HCl aqueous solution, and extracted with EtOAc (3X). The combined organic layers were dried with $MgSO_4$ and concentrated to afford *Cap-4* (350 mg) as clear oil. LC (Cond. 1): RT = 1.04 min; LC/MS: Anal. Calcd. for $[2M+Na]^+$ $C_{20}H_{30}N_2NaO_8$ 449.19; found 449.3; ^1H NMR (500 MHz, $CDCl_3$) δ ppm 5.07 (1 H, d, *J*=8.85 Hz), 4.13 (1 H, t, *J*=8.24 Hz), 3.68 (3 H, s), 2.64 - 2.79 (1 H, m), 2.04 - 2.21 (2 H, m), 1.23 - 1.49 (4 H, m), 0.71 - 0.81 (1 H, m), 0.03 - 0.12 (1 H, m).

Cap 5.1 & Cap 5.2

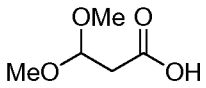


(Cap 5.1)



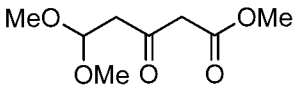
(Cap 5.2)

Cap 5, step a



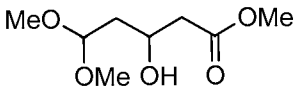
A mixture of methyl 3,3-dimethoxypropanoate (10 g, 68 mmol) and LiOH (8.08 g, 337 mmol) in MeOH (40 mL), THF (40 mL) and water (40 mL) was heated at 80 °C for 2 hours. The mixture was then cooled down to room temperature and acidified with 1 N HCl aqueous solution (pH>3). The mixture was then extracted with CH_2Cl_2 (3X). The combined organic layers were dried with $MgSO_4$ and concentrated to give *Cap 5, step a* as a clear oil (6.3 g). The product was used in the next reaction without further purification. ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.82 (t, *J*=5.8 Hz, 1H), 3.36 (s, 6H), 2.69 (d, *J*=5.8 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 175.22, 101.09, 53.68, 38.76.

Cap 5, step b



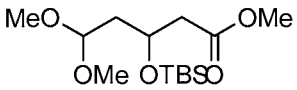
To a solution of *Cap 5, step a* (4.55 g, 33.9 mmol) in THF (40 mL) was added the suspension of N,N'-carbonyldiimidazole (6.60 g, 40.7 mmol) in THF (40 mL) dropwise. The solution turned yellow and gas evolution was observed. The mixture was stirred at room temperature for 2 hours. At the same time, another flask with monomethyl monopotassium malonate (7.95 g, 50.9 mmol) and magnesium chloride (3.55 g, 37.3 mmol) in THF (80 mL) was stirred at room temperature for 2 hours. The imidazolide solution was then transferred into the $Mg(OOCCH_2COOMe)_2$ solution by syringe and the resulting mixture was stirred at room temperature for 16 h. The mixture was then acidified with 2M $NaHSO_4$ (60 mL) and extracted with EtOAc (3X). The combined organic layers were washed with sat. $NaHCO_3$ aqueous solution, brine, dried with $MgSO_4$ and concentrated to give *Cap 5, step b* as a light purple colored oil (4.9 g). The oil was used in the next step without further purification. ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.75 (t, *J*=5.5 Hz, 1H), 3.72 (s, 3H), 3.50 (s, 2H), 3.35 (s, 6H), 2.84 (d, *J*=5.5 Hz, 2H).

Cap 5, step c



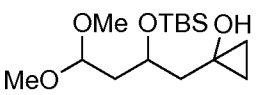
To a solution of *Cap 5, step b* (4.9 g, 26 mmol) in MeOH (70 mL) was slowly added sodium borohydride (1.07 g, 28.3 mmol). The resulting mixture was stirred at room temperature for 3 hours and then quenched with 1N HCl (15 mL). The mixture was extracted with EtOAc (3X). The combined organic layers were dried with $MgSO_4$ and concentrated to give *Cap 5, step c* as a light yellow oil (4.4 g). The product was used in the next step without further purification. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.60 (t, *J*=5.5 Hz, 1H), 4.25 - 4.16 (m, 1H), 3.70 (s, 3H), 3.38 (s, 3H), 3.37 (s, 3H), 2.52 - 2.48 (m, 2H), 1.83 - 1.77 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.21, 102.73, 64.61, 53.22, 52.95, 51.30, 41.00, 38.65.

Cap 5, step d



To a solution of *Cap 5, step c* (4.4 g, 22.89 mmol) in DMF (50 mL) was added imidazole (3.12 g, 45.8 mmol) and TBS-Cl (5.52 g, 36.6 mmol). The resulting mixture was stirred at room temperature for 3 days. The reaction was then diluted with CH_2Cl_2 and washed with water. The organic phase was washed with brine, dried with $MgSO_4$ and concentrated. The crude product was purified by flash chromatography (silica gel, 0-15% EtOAc/Hex) to give *Cap 5, step d* as a clear oil (5.0 g). ^{1}H NMR (400MHz, $CDCl_3$) δ 4.55 - 4.50 (m, 1H), 4.30 - 4.21 (m, 1H), 3.67 (s, 3H), 3.32 (s, 3H), 3.31 (s, 3H), 2.51 (d, *J*=6.3 Hz, 2H), 1.89 - 1.77 (m, 2H), 0.88 (s, 9H), 0.08 (s, 3H), 0.06 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.41, 101.24, 65.85, 52.35, 52.09, 51.04, 42.40, 39.92, 25.37, 25.27, 17.55, -3.95, -5.15.

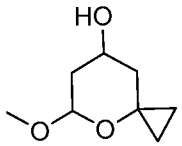
Cap 5, step e



To a solution of *Cap 5, step d* (5.0 g, 16 mmol) in ether (50 mL) in a ice/water bath was added a solution of tetraisopropyl titanate (0.971 mL, 3.26 mmol) in ether (10 mL). Ethylmagnesium bromide (48.9 mL, 48.9 mmol) (1 M in THF) was then

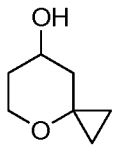
added dropwise by a syringe pump over 1 hour. The mixture was then stirred in ice/water bath for 2 hours. The mixture was diluted with ether and quenched with sat. NH_4Cl aqueous solution slowly. The resulting white precipitate was filtered off. The filtrate was extracted with Et_2O (3X). The combined organic layers were dried with $MgSO_4$ and concentrated. The crude product was then purified by flash chromatography (silica gel, 0-20% EtOAc/Hex) to give *Cap 5, step e* as a clear oil (4.02 g). ^1H NMR (500MHz, $CDCl_3$) δ 4.47 (t, *J*=5.6 Hz, 1H), 4.21 - 4.14 (m, 1H), 3.71 (s, 1H), 3.32 (s, 3H), 3.31 (s, 3H), 2.05 - 1.88 (m, 3H), 1.66 - 1.58 (m, 1H), 0.90 (s, 9H), 0.83 - 0.76 (m, 1H), 0.71 - 0.65 (m, 1H), 0.47 (m, 1H), 0.40 - 0.34 (m, 1H), 0.14 (s, 3H), 0.11 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 102.09, 69.97, 54.44, 52.97, 52.84, 43.27, 40.00, 25.92, 17.96, 14.04, 12.06, -4.32, -4.61.

Cap 5, step f



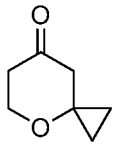
A solution of *Cap 5, step e* (4.02 g, 13.2 mmol) and *p*-toluenesulfonic acid monohydrate (3.01 g, 15.8 mmol) in MeOH (120 mL) was stirred at room temperature overnight. To the mixture was added aq. sat. $NaHCO_3$ (100 mL) and the mixture was extracted with CH_2Cl_2 (3X). The combined organic layers were dried with $MgSO_4$ and concentrated. The crude product was purified by passing it through a silica gel bed with 70% EtOAc/Hex to give *Cap 5, step f* as as a mixture of diastereomers (1.7 g; clear oil) and. ^1H NMR (500MHz, $CDCl_3$) δ 4.79 (t, *J*=3.7 Hz, 1H), 4.59 (dd, *J*=5.3, 2.9 Hz, 1H), 4.30 - 4.22 (m, 1H), 4.03 (br. s., 1H), 3.37 (s, 3H), 3.31 (s, 3H), 2.09 - 2.03 (m, 1H), 2.00 (dtd, *J*=13.1, 4.0, 1.5 Hz, 1H), 1.86 (dd, *J*=13.1, 3.7 Hz, 1H), 1.81 - 1.61 (m, 7H), 0.94 - 0.87 (m, 1H), 0.83 - 0.77 (m, 1H), 0.74 - 0.69 (m, 1H), 0.65 - 0.56 (m, 2H), 0.48 - 0.40 (m, 2H), 0.37 - 0.30 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 100.86, 100.27, 65.75, 64.35, 56.24, 55.92, 53.80, 52.35, 40.86, 39.92, 39.28, 38.05, 12.10, 12.06, 9.91, 9.37.

Cap 5, step g



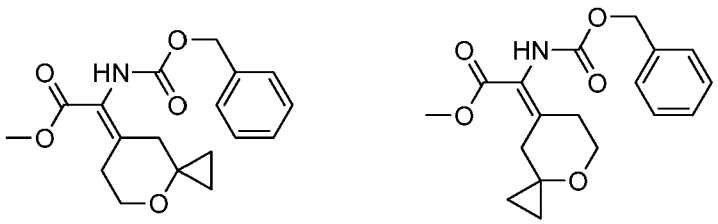
To a solution of *Cap 5, step f* (1.7 g, 11 mmol) in CH_2Cl_2 (20 mL) was added bis(trimethylsilyl)trifluoroacetamide (2.14 mL, 8.06 mmol). The mixture was stirred at room temperature for 2 hours. The mixture was then cooled to -10 °C and triethylsilane (6.87 mL, 43.0 mmol) and then boron trifluoride ether complex (3.40 mL, 26.9 mmol) were added dropwise. The mixture was then allowed to warm to 0 °C slowly and stirred at 0 °C for 30 min. The reaction was then quenched with water and extracted with EtOAc (3X). The combined organic layers were dried with $MgSO_4$ and concentrated. The crude product was purified by passing it through a silica gel bed with 70% EtOAc/Hex give *Cap 5, step g* as a clear oil (1.5 g). ^1H NMR (500MHz, $CDCl_3$) δ 6.43 (br. s., 1H), 3.96 (tt, *J*=9.5, 4.7 Hz, 1H), 3.86 (dt, *J*=11.5, 4.0 Hz, 1H), 3.51 (td, *J*=11.1, 2.7 Hz, 1H), 1.98 - 1.84 (m, 2H), 1.66 - 1.50 (m, 2H), 0.86 - 0.79 (m, 1H), 0.66 - 0.59 (m, 1H), 0.53 - 0.46 (m, 1H), 0.34 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 67.41, 64.37, 57.99, 41.28, 35.22, 11.74, 11.32.

Cap 5, step h



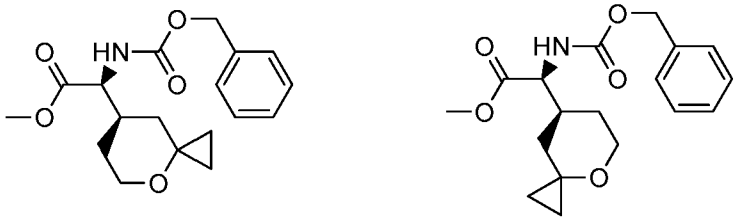
To a solution of oxalyl chloride (1.090 mL, 12.45 mmol) in CH_2Cl_2 (30 mL) at -78 °C was added dropwise a solution of DMSO (1.767 mL, 24.90 mmol) in CH_2Cl_2 (20 mL). The mixture was stirred for 20 min, and *Cap 5, step g* (1.33 g, 10.4 mmol) in CH_2Cl_2 (20 mL) was added dropwise. The mixture was stirred at -78 °C for 20 min. Et_3N (7.52 mL, 54.0 mmol) was then added and the mixture was warmed slowly to room temperature over 30 min. The mixture was then quenched with water and extracted with CH_2Cl_2 (3X). The organic layers were combined and dried with $MgSO_4$ and concentrated to give *Cap 5, step h* as a clear oil (1.3 g). The crude product was used in the next step without purification. ^1H NMR (500MHz, $CDCl_3$) δ 3.95 (t, *J*=6.0 Hz, 2H), 2.55 - 2.50 (m, 2H), 2.46 (s, 2H), 0.84 (m, 2H), 0.50 (m, 2H).

Cap 5, step i



To a solution of methyl 2-(((benzyloxy)carbonyl)amino)-2-(dimethoxyphosphoryl)acetate (3.41 g, 10.3 mmol) in of THF (20 mL) at -20 °C was added 1,1,3,3-tetramethylguanidine (2.85 mL, 22.7 mmol). The resulting mixture was stirred at -20 °C for 1 hour. *Cap 5, step h* (1.3 g, 10.30 mmol) in THF (10 mL) was then added. The resulting brown mixture was stirred at room temperature for 6 days. The reaction was then concentrated and the crude product was purified by flash chromatography (silica gel, 0-25% EtOAc/Hex) to give *Cap 5, step i* (mixture of isomers) as a white solid (850 mg. LC (Cond. 2): RT = 1.88 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{18}H_{22}NO_5$ 332.15; found 332.14; ^1H NMR (500MHz, $CDCl_3$) δ 7.45 - 7.29 (m, 5H), 6.09 - 5.81 (m, 1H), 5.18 - 5.08 (m, 2H), 3.88 - 3.49 (m, 5H), 3.06 - 2.82 (m, 2H), 2.52 - 2.36 (m, 2H), 0.82 - 0.64 (m, 2H), 0.58 - 0.32 (m, 2H).

Cap 5.1 and Cap 5.2, step j



(5.1) **(5.2)**

A solution of *Cap 5, step i* (mixture of isomers) (730 mg, 2.20 mmol) in MeOH (5 mL) in a 500 mL hydrogenation pressure bottle was bubbled with N_2 for 30 min. To the mixture was added (-)-1,2-bis((2S,5S)-2,5-dimethylphospholano)ethane(cyclooctadiene) rhodium (I) tetrafluoroborate (24.5 mg, 0.044 mmol) and the bottle was then put onto a Parr shaker and hydrogenated at 60 psi for 3 days. The mixture was concentrated and the crude product was separated by chiral HPLC (Chiralpak AD column, 21 x 250 mm, 10 um, eluting with 85% 0.1%diethylamine/Heptane-15% EtOH at 15 mL/min) to give *Cap 5.1, step j* (220

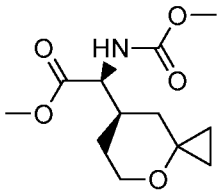
mg) (first eluting fraction) and *Cap 5.2, step j* (290 mg) (second eluting fraction) as clear oils. The absolute stereochemistry of the isomers was not determined.

Cap 5.1, step j: LC (Cond. 2): RT = 1.89 min; LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{18}H_{23}NNaO_5$ 356.15; found 356.16; ^1H NMR (500MHz, $CDCl_3$) δ 7.41 - 7.28 (m, 5H), 5.34 (d, *J*=8.9 Hz, 1H), 5.10 (s, 2H), 4.37 (dd, *J*=9.0, 5.0 Hz, 1H), 3.89 - 3.82 (m, 1H), 3.75 (s, 3H), 3.48 (td, *J*=11.1, 3.1 Hz, 1H), 2.29 - 2.17 (m, 1H), 1.96 (t, *J*=12.7 Hz, 1H), 1.57 - 1.43 (m, 2H), 1.07 - 0.98 (m, 1H), 0.87 - 0.78 (m, 1H), 0.66 - 0.56 (m, 1H), 0.56 - 0.47 (m, 1H), 0.37 - 0.27 (m, 1H);

Cap 5.2, step j: LC (Cond. 2): RT = 1.90 min; LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{18}H_{23}NNaO_5$ 356.15; found 356.17; ^1H NMR (500MHz, $CDCl_3$) δ 7.40 - 7.28 (m, 5H), 5.33 (d, *J*=8.5 Hz, 1H), 5.10 (s, 2H), 4.36 (dd, *J*=8.9, 5.8 Hz, 1H), 3.86 (dd, *J*=11.0, 3.1 Hz, 1H), 3.74 (s, 3H), 3.53 - 3.43 (m, 1H), 2.25 - 2.14 (m, 1H), 1.94 (t, *J*=12.5 Hz, 1H), 1.67 - 1.44 (m, 2H), 0.97 - 0.90 (m, 1H), 0.86 - 0.79 (m, 1H), 0.66 - 0.57 (m, 1H), 0.53 - 0.44 (m, 1H), 0.33 - 0.24 (m, 1H).

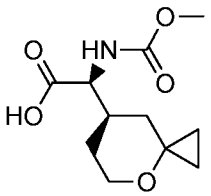
[Note: see below for absolute stereochemical assignment]

Cap 5.1, step k



To a solution of *Cap 5.1, step j* (210 mg, 0.630 mmol) in MeOH (10 mL) in a hydrogenation flask was added dimethyl dicarbonate (0.135 mL, 1.26 mmol) and 10% Pd/C (33.5 mg, 0.031 mmol). The flask was put on a Parr shaker and the mixture was hydrogenated at 50 psi for 4 hours. The mixture was then filtered through diatomaceous earth (Celite®) and the filtrate was concentrated to afford *Cap 5.1, step k* as a clear oil (165 mg). LC (Cond. 2): RT = 1.56 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{12}H_{20}NO_5$ 258.13; found 258.16; ^1H NMR (500MHz, $CDCl_3$) δ 5.39 (d, *J*=8.5 Hz, 1H), 4.30 (dd, *J*=8.9, 5.2 Hz, 1H), 3.84 - 3.78 (m, 1H), 3.70 (s, 3H), 3.63 (s, 3H), 3.47 - 3.39 (m, 1H), 2.23 - 2.12 (m, 1H), 1.91 (t, *J*=12.5 Hz, 1H), 1.49 - 1.39 (m, 2H), 0.97 (dd, *J*=13.1, 2.4 Hz, 1H), 0.81 - 0.74 (m, 1H), 0.61 - 0.52 (m, 1H), 0.46 (dt, *J*=10.1, 6.0 Hz, 1H), 0.32 - 0.24 (m, 1H).

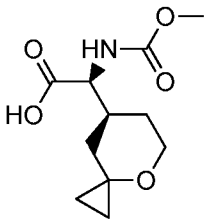
Cap 5.1



To a mixture of *Cap 5.1, step k* (165 mg, 0.641 mmol) in THF (2 mL) and water (1 mL) was added 2 M LiOH (1 mL, 2.0 mmol) (aqueous). The resulting mixture was stirred at room temperature overnight. The mixture was then washed with ether (1 mL). The aqueous phase was acidified with 1 N HCl aq. and extracted with ether (6 X). The combined organic layers were dried with $MgSO_4$ and concentrated to give *Cap 5.1* as a white solid (150 mg). LC (Cond. 2): RT = 1.10 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{11}H_{18}NO_5$ 244.12; found 244.09; ^1H NMR (500MHz, $CDCl_3$-*d*) δ 5.27 (d, *J*=8.9 Hz, 1H), 4.39 (dd, *J*=8.5, 4.9 Hz, 1H), 3.94 - 3.86 (m, 1H), 3.70 (s, 3H), 3.56 - 3.46 (m, 1H), 2.36 - 2.24 (m, 1H), 2.01 (t, *J*=12.7 Hz, 1H), 1.63 - 1.48 (m, 2H), 1.14 - 1.05 (m, 1H), 0.92 - 0.80 (m, 1H), 0.69 - 0.60 (m, 1H), 0.58 - 0.49 (m, 1H), 0.40 - 0.31 (m, 1H).

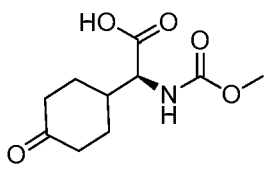
Note: *Cap 5.1* was coupled to (S)-1-(naphthalen-2-yl)ethanamine via a HATU coupling and the resutling amide was crystallized. X-ray crystal ananlysis of this analog established the relative and absolute sterochemistry of *Cap 5.1* to be as shown.

Cap 5.2

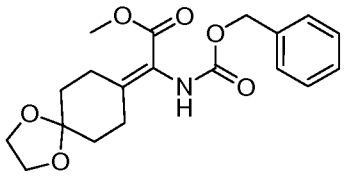


Cap 5.2 was prepared from *Cap 5.2, step j* according to the procedure described for *Cap 5.1*. LC (Cond. 2): RT = 1.12 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{11}H_{18}NO_5$ 244.12; found 244.09; ^1H NMR (500MHz, $CDCl_3$) δ 5.27 (d, *J*=8.9 Hz, 1H), 4.38 (dd, *J*=8.2, 4.9 Hz, 1H), 3.91 (dd, *J*=11.1, 3.2 Hz, 1H), 3.69 (s, 3H), 3.52 (t, *J*=11.0 Hz, 1H), 2.34 - 2.23 (m, 1H), 2.07 - 1.97 (m, 1H), 1.72 - 1.61 (m, 1H), 1.54 (qd, *J*=12.6, 4.7 Hz, 1H), 1.04 - 0.96 (m, 1H), 0.90 - 0.82 (m, 1H), 0.68 - 0.61 (m, 1H), 0.56 - 0.49 (m, 1H), 0.39 - 0.30 (m, 1H).

Cap-6

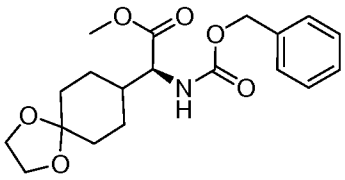


Cap-6, step a



A solution of 1,4-dioxaspiro[4.5]decan-8-one (15 g, 96 mmol) in EtOAc (150 mL) was added to a solution of methyl 2-(benzyloxycarbonylamino)-2-(dimethoxyphosphoryl)acetate (21.21 g, 64.0 mmol) in 1,1,3,3-tetramethylguanidine (10.45 mL, 83 mmol) and EtOAc (150 mL). The resulting solution was the stirred at ambient temperature for 72 h and then it was diluted with EtOAc (25 mL). The organic layer was washed with 1N HCl (75 mL), H_2O (100 mL) and brine (100 mL), dried ($MgSO_4$), filtered and concentrated. The residue was purified via Biotage (5% to 25 % EtOAc/Hexanes; 300g column). The combined fractions containing the product were then concentrated under vacuum and the residue was re-crystallized from hexanes/EtOAc to give white crystals that corresponded to methyl 2-(benzyloxycarbonylamino)-2-(1,4-dioxaspiro[4.5]decan-8-ylidene)acetate (6.2 g) ^{1}H NMR (400 MHz, $CDCl_3$-*d*) δ ppm 7.30 - 7.44 (5 H, m), 6.02 (1 H, br. s.), 5.15 (2 H, s), 3.97 (4 H, s), 3.76 (3 H, br. s.), 2.84 - 2.92 (2 H, m), 2.47 (2 H, t, *J*=6.40 Hz), 1.74 - 1.83 (4 H, m). LC (Cond. OL1): R_t = 2.89 min. LC/MS: Anal. Calcd. For $[M+Na]^+$ $C_{19}H_{23}NNaO_6$: 745.21; found: 745.47.

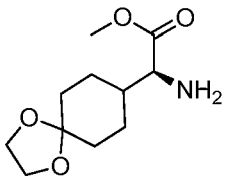
Cap-6, step b



Ester *Cap-176, step b* was prepared from alkene *Cap-176, step a* according to the method of Burk, M. J.; Gross, M. F. and Martinez J. P. (*J. Am. Chem. Soc.,*

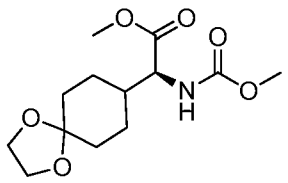
1995, *117*, 9375-9376 and references therein): A 500 mL high-pressure bottle was charged with alkene *Cap-176, step a* (3.5 g, 9.68 mmol) in degassed MeOH (200 mL) under a blanket of N_2. The solution was then charged with (-)-1,2-Bis((2S,5S)-2,5-dimethylphospholano)ethane(cyclooctadiene)rhodium (I) tetrafluoroborate (0.108 g, 0.194 mmol) and the resulting mixture was flushed with N_2 (3x) and charged with H_2 (3x). The solution was shaken vigorously under 70 psi of H_2 at ambient temperature for 72 h. The solvent was removed under reduced pressure and the remaining residue was taken up in EtOAc. The brownish solution was then filtered through a plug of Silica Gel and eluted with EtOAc. The solvent was concentrated under vacuum to afford a clear oil corresponding to ester *Cap-176, step b* (3.4 g) .^{1}H NMR (500 MHz, $CDCl_3$-*d*) δ ppm 7.28 - 7.43 (5 H, m), 5.32 (1 H, d, *J*=9.16 Hz), 5.06 - 5.16 (2 H, m), 4.37 (1 H, dd, *J*=9.00, 5.04 Hz), 3.92 (4 H, t, *J*=3.05 Hz), 3.75 (3 H, s), 1.64 - 1.92 (4 H, m), 1.37 - 1.60 (5 H, m). LC (Cond. OL1): R_t = 1.95 min. LC/MS: Anal. Calcd. For $[M+H]^+$ $C_{19}H_{26}NO_6$: 364.18; found: 364.27.

Cap-6, step c



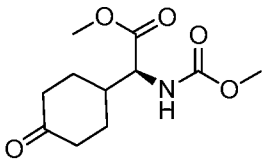
Cap-6, step b (6.68 g, 18.38 mmol) was dissolved in MeOH (150 mL) and charged with Pd/C (0.039 g, 0.368 mmol) and the suspension was placed under 1 atm of H_2. The reaction mixture was stirred at rt for 6 h and filtered though a plug of diatomaceous earth (Celite®) and volatiles were removed under reduced pressure. An amber oil corresponding to *Cap-6, step c* (3.8 g, 16.57 mmol, 90 % yield) was recovered and used without further purification. ^{1}H NMR (400MHz, $CDCl_3$-*d*) δ 3.92 (br. s., 4H), 3.71 (s, 3H), 3.31 (d, *J*=4.0 Hz, 1H), 1.87 - 1.44 (m, 9H). ^{13}C NMR (101MHz, $CDCl_3$-*d*) δ 176.1, 108.7, 64.5 (2C), 59.1 , 52.0, 41.1, 34.7, 34.6 , 27.2, 25.4.

Cap-6, step d



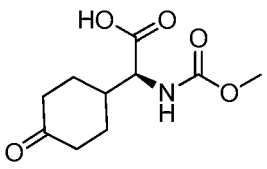
Methyl chloroformate (2.57 mL, 33.1 mmol) was added to a solution of *Cap 6, step c* (3.8 g, 16.57 mmol) and DIEA (23.16 mL, 133 mmol) in CH_2Cl_2 (200 mL). The resulting solution was stirred at rt for 3 h and volatiles were removed under reduced pressure. The residue was purified via Biotage (30% EtOAc/Hex; 160g column). An amber oil corresponding to *Cap-6, step d* (3 g, 10.44 mmol, 63.0 % yield) was recovered. ^{1}H NMR (500MHz, $CDCl_3$-*d*) δ 5.24 (d, *J*=8.5 Hz, 1H), 4.34 (dd, *J*=8.9, 4.9 Hz, 1H), 3.92 (s, 4H), 3.74 (s, 3H), 3.67 (s, 3H), 1.89 - 1.73 (m, 3H), 1.67 (d, *J*=12.5 Hz, 1H), 1.62 - 1.33 (m, 5H). ^{13}C NMR (126MHz, $CDCl_3$-*d*) 172.4, 156.7, 108.1, 64.2, 64.2, 57.7, 52.3, 52.2, 39.6, 34.2 (2C), 26.5, 25.0.

Cap-6, step e



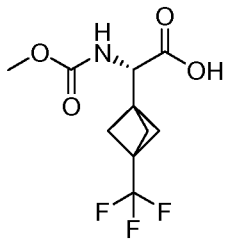
Cap-6, step d (1.15 g, 4.00 mmol) was dissolved in THF (50 mL) followed by sequential addition of water (30 mL), glacial AcOH (8.02 mL, 140 mmol) and dichloroacetic acid (1.985 mL, 24.02 mmol). The mixture was stirred overnight at room temperature and the reaction was quenched by slow addition of solid sodium carbonate with vigorous stirring until the release of gas was no longer visible. Crude product was extracted into 10% ethyl acetate-dichloromethane and the organic layers were combined, dried (MgSO4), filtered and concentrated. The residue was purified via Biotage (0 to 30% EtOAc/Hex; 40g column) and a clear oil corresponding to *Cap-6, step e* (0.72 g, 2.96 mmol, 73.9 % yield) was recovered. ^{1}H NMR (500MHz, $CDCl_3$-*d*) δ 5.36 (d, *J*=8.2 Hz, 1H), 4.46 (dd, *J*=8.4, 5.0 Hz, 1H), 3.77 (s, 3H), 3.68 (s, 3H), 2.46 - 2.39 (m, 2H), 2.38 - 2.29 (m, 2H), 2.09 - 2.03 (m, 1H), 1.96 - 1.88 (m, 1H), 1.64 - 1.51 (m, 2H). ^{13}C NMR (126MHz, $CDCl_3$-*d*) δ 210.1, 171.9, 156.7, 57.2, 52.5 (2C), 40.2, 40.2, 39.4, 28.7, 27.6.

Cap-6



A solution of *Cap-6, step e* (0.68 g, 2.80 mmol) in THF (7.5 mL) and MeOH (7.50 mL) was cooled to 0 °C. 2N aq. NaOH (1.9 mL, 3.80 mmol) was added dropwise and the resulting solution was stirred at room temperature for 2 h. A 1:1 mixture of hexanes:Et_2O (20 mL) was added and the organic layer was discarded. The aqueous layer was then acidified to pH ~1 with 10% aq. $KHSO_4$ and the mixture was extracted with EtOAc (2X). The combined organic layers were dried ($MgSO_4$), filtered and concentrated. A white foam corresponding to *Cap-6* (0.55 g)) was recovered and used without further purification. ^{1}H NMR (500MHz, DMSO-d_6) δ 12.70 (br. s., 1H), 7.49 (d, *J*=8.5 Hz, 1H), 4.01 (dd, *J*=8.2, 6.7 Hz, 1H), 3.54 (s, 3H), 2.45 - 2.30 (m, 2H), 2.23 - 2.13 (m, 3H), 1.94 - 1.79 (m, 3H), 1.57 (qd, *J*=12.7, 4.1 Hz, 1H), 1.47 (qd, *J*=12.7, 4.4 Hz, 1H). ^{13}C NMR (126MHz, DMSO-d_6) 210.2, 173.0, 156.8, 57.6, 51.5, 39.7 (2C), 36.9, 28.6, 27.5.

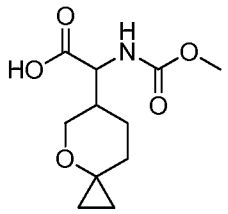
Cap-7



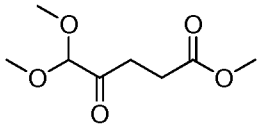
To a mixture of (S)-2-amino-2-(3-(trifluoromethyl)bicyclo[1.1.1]pentan-1-yl)acetic acid (obtained from a commercial source; 0.5151 g, 2.463 mmol) and sodium carbonate (0.131 g, 1.231 mmol) in sodium hydroxide, 1M aq (2.4 ml, 2.400 mmol) at 0 °C was added methyl carbonochloridate (0.2 ml, 2.59 mmol) dropwise. The reaction was then stirred at room temperature for 4 hr. It was then cooled in an ice/water bath, and diethyl ether (25 mL) was added and stirred and the layers were separated. The aqueous layer was washed with diethyl ether (2 x 25 mL). The aqueous layer was cooled with an ice-water bath and acidified with 12N HCl to a pH region of 1-2. It was extracted with CH_2Cl_2 (3 x 50 mL), dried over MgSO4, and

concentrated in vacuo to afford Cap-7 as an off-white solid (480.7 mg) and was used without further purification. ^{1}H NMR (400MHz, DMSO-d_6) δ 12.86 (br s, 1H), 7.61 (br d, *J*=8.0 Hz, 1H), 4.16 (d, *J*=8.0 Hz, 1H), 3.57 (s, 3H), 2.00 (d, J = 8.3 Hz, 3H), 1.93 (d, J = 9.3, 3H).

Cap 8.1 & Cap 8.2 (two stereoisomers)

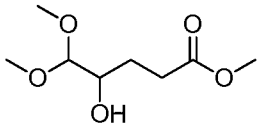


Cap 8, step a



A mixture of 4-oxovaleric acid methyl ester (6 g, 46.1 mmol), diphenyl diselenide (14.39 g, 46.1 mmol) and ammonium persulfate (15.92 mL, 138 mmol) in MeOH (200 mL) was stirred at reflux temperature for 3 hours. The mixture was then poured into water and extracted with CH_2Cl_2 (3 X 75 mL). The combined organic layers were washed with brine, dried with $MgSO_4$ and concentrated. The crude product was purified by flash chromatography (silica gel, 0 - 15% EtOAc/Hex) to give *Cap 8, step a* (7.1g) as a yellow oil. ^{1}H NMR (500MHz, $CDCl_3$) δ 4.53 (s, 1H), 3.67 (s, 3H), 3.42 (s, 6H), 2.89 (t, *J*=6.6 Hz, 2H), 2.60 (t, *J*=6.6 Hz, 2H).

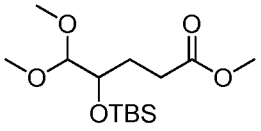
Cap 8, step b



To a solution of *Cap 8, step a* (7.1 g, 37.3 mmol) in MeOH (100 mL) was slowly added sodium borohydride (1.554 g, 41.1 mmol). The resulting mixture was stirred at room temperature for 2 hours. To the mixture was added a 1 N HCl aqueous solution until acidic and then extracted with CH_2Cl_2 (3 x 50 mL). The combined organic layers were washed with brine, dried with $MgSO_4$ and concentrated to give *Cap 8, step b* as an orange oil (7.1 g) which was contaminated in

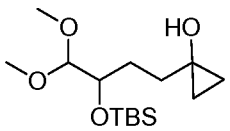
a 1:1.7 ratio with the corresponding cyclized byproduct, 5-(dimethoxymethyl)dihydrofuran-2(3H)-one. The mixture was used without further purification.

Cap 8, step c



To a solution of *Cap 8, step b* (7.1 g, 36.9 mmol) in DMF (50 mL) was added imidazole (5.03 g, 73.9 mmol) and TBS-Cl (8.91 g, 59.1 mmol). The resulting mixture was stirred at room temperature for 16 h. The reaction was then diluted with CH_2Cl_2, washed with water and brine, dried with $MgSO_4$ and concentrated. The crude product was purified by flash chromatography (silica gel, 0-5% then 10% EtOAc/Hex) to give *Cap 8, step c* as a clear oil. ^{1}H NMR (500MHz, $CDCl_3$) δ 4.07 (d, *J*=5.5 Hz, 1H), 3.72 - 3.67 (m, 1H), 3.66 (s, 3H), 3.40 (s, 3H), 3.39 (s, 3H), 2.48 - 2.35 (m, 2H), 1.92 (dddd, *J*=13.8, 9.3, 6.9, 4.1 Hz, 1H), 1.82 - 1.71 (m, 1H), 0.88 (s, 9H), 0.07 (s, 3H), 0.05 (s, 3H).

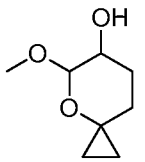
Cap 8, step d



To a solution of *Cap 8, step c* (4.4 g, 14.36 mmol) in Et_2O (50 mL) in a water bath was added tetraisopropyl titanate (0.855 mL, 2.87 mmol) in ether (10 mL) and the solution turned yellow. Ethylmagnesium bromide (14.36 mL, 43.1 mmol, 1 M in THF) was then added dropwise by syringe pump over 1 hour. The solution turned dark brown with some precipitate. The mixture was then stirred in a water bath for 2 hours. The mixture was diluted with ether and quenched by slow addition of a saturated NH_4Cl aqueous solution. The mixture was filtered to remove the formed white precipitate. The two layers were separated and the aqueous layer was extracted with Et_2O (3 x 50 mL). The combined organic layers were dried with $MgSO_4$ and concentrated. The crude product was then purified by flash chromatography (silica gel, 0 - 20% EtOAc/Hex) to give *Cap 8, step d* as a clear oil (2.9 g). ^{1}H NMR

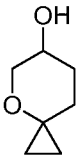
(500MHz, $CDCl_3$) δ 4.26 (d, *J*=6.1 Hz, 1H), 3.81 - 3.72 (m, 1H), 3.46 (s, 3H), 3.43 (s, 3H), 1.90 - 1.75 (m, 3H), 1.52 - 1.43 (m, 1H), 0.90 (s, 9H), 0.82 - 0.74 (m, 1H), 0.73 - 0.67 (m, 1H), 0.47 - 0.40 (m, 2H), 0.11 - 0.10 (m, 6H).

Cap 8, step e



A solution of *Cap 8, step d* (2.9 g, 9.52 mmol) and *p*-TsOH.H_2O (2.174 g, 11.43 mmol) in MeOH (40 mL) was stirred at room temperature for 16 h. To the mixture was added 200 mL of a sat. $NaHCO_3$ solution and the mixture was extracted with CH_2Cl_2 (3 x 50 mL). The combined organic layers were dried with $MgSO_4$ and concentrated. The crude product was filtered through a plug of silica gel (eluted with 70% EtOAc/Hex) to give *Cap 8, step e* (1 g) as a clear oil which consisted of a mixture of diastereomers and were not separated. ^1H NMR (500MHz, $CDCl_3$) δ 4.16 (d, *J*=7.3 Hz, 1H), 3.55 - 3.46 (m, 1H), 3.44 - 3.38 (m, 2H), 2.50 - 2.22 (m, 1H), 2.13 - 2.00 (m, 1H), 1.71 - 1.59 (m, 1H), 1.22 - 1.14 (m, 1H), 0.99 - 0.77 (m, 1H), 0.70 - 0.59 (m, 1H), 0.57 - 0.46 (m, 1H), 0.45 - 0.30 (m, 1H).

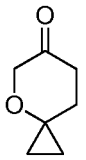
Cap 8, step f



To a solution of *Cap 8, step e* (1 g, 6.32 mmol) in CH_2Cl_2 (15 mL) was added bis(trimethylsilyl)trifluoroacetamide (1.26 mL, 4.74 mmol). The mixture was stirred at room temperature for 2 hours during which time it turned orange. The mixture was then cooled down to -10 °C and triethylsilane (4.04 mL, 25.3 mmol) was added dropwise, followed by boron trifluoride ether complex (2.00 mL, 15.80 mmol). The mixture turned light purple immediately upon adding the boron trifluoride ether complex. The mixture was then allowed to slowly warm to 0 °C and stirred at 0 °C for 30 mins. The reaction was then quenched with water and extracted with EtOAc

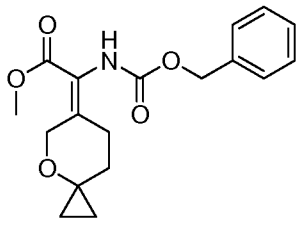
(3 X 20 mL). The combined organic layers were dried with $MgSO_4$ and concentrated. The crude product was filtered through a plug of silica gel (eluted with 70% EtOAc/Hex) and the filtrate was concentrated to give *Cap 8, step f* (0.8 g) as a clear oil. ^{1}H NMR (400MHz, $CDCl_3$) δ 4.19 (d, *J*=6.8 Hz, 1H), 3.77 (dd, *J*=11.3, 2.5 Hz, 1H), 3.55 (d, *J*=6.0 Hz, 1H), 2.14 - 2.06 (m, 2H), 1.75 - 1.62 (m, 1H), 1.44 (dd, *J*=12.4, 7.2 Hz, 1H), 0.97 - 0.88 (m, 2H), 0.65 (dddd, *J*=10.8, 6.2, 4.8, 1.5 Hz, 1H), 0.59 - 0.51 (m, 1H), 0.48 - 0.40 (m, 2H).

Cap 8, step g



To a solution of oxalyl chloride (0.664 mL, 7.58 mmol) in CH_2Cl_2 (10 mL) at -78 °C was added dropwise DMSO (1.076 mL, 15.17 mmol) in CH_2Cl_2 (7 mL). The mixture was stirred for 20 min, and *Cap 8, step f* (810 mg, 6.32 mmol) in CH_2Cl_2 (7 mL) was added dropwise. The mixture was stirred at -78 °C for 20 min. Et_3N (4.58 mL, 32.9 mmol) was then added and the mixture was slowly warmed to room temperature over 30 min. The mixture was then quenched with water and extracted with CH_2Cl_2 (3 x 10 mL). The organic layers were combined and dried with $MgSO_4$ and concentrated to give *Cap 8, step g* (0.8g) as a clear oil. The product was used without further purification. ^{1}H NMR (500MHz, $CDCl_3$) δ 4.56 (s, 1H), 4.00 (s, 1H), 2.53 - 2.46 (m, 1H), 2.40 - 2.32 (m, 1H), 2.08 (t, *J*=6.9 Hz, 1H), 1.82 (dt, *J*=13.5, 5.8 Hz, 1H), 1.09 - 0.99 (m, 1H), 0.89 - 0.82 (m, 1H), 0.70 (ddd, *J*=10.2, 6.9, 5.8 Hz, 1H), 0.54 (ddd, *J*=10.2, 6.7, 5.6 Hz, 1H).

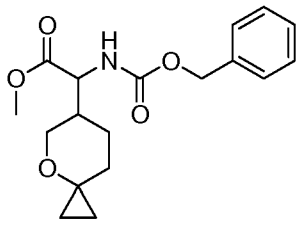
Cap 8, step h



To a solution of methyl 2-(((benzyloxy)carbonyl)amino)-2-(dimethoxyphosphoryl)acetate (3.19 g, 9.63 mmol) in THF (10 mL) at -20 °C was

added 1,1,3,3-tetramethylguanidine (2.42 mL, 19.26 mmol). The resulting mixture was stirred at -20 °C for 1 hour and the mixture turned milky white. A solution of *Cap 8, step g* (810 mg, 6.42 mmol) in THF (5 mL) was added and the resulting brown mixture was then stirred at room temperature for two days. The reaction was then concentrated and the crude product was purified by flash chromatography (silica gel, 0 - 5% EtOAc/CH_2Cl_2) to give *Cap 8, step h* (mixture of *cis-trans* isomers) as a clear oil (400 mg). LC (Cond. 3): RT = 1.74 min; LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{18}H_{21}NNaO_5$ 354.13; found 354.04. ^1H NMR (500MHz, $CDCl_3$) δ 7.42 - 7.31 (m, 10H), 5.19 - 5.10 (m, 4H), 4.66 (br. s., 1H), 4.23 (s, 1H), 3.84 - 3.70 (m, 5H), 3.39 (s, 3H), 2.68 - 2.53 (m, 2H), 1.81 - 1.74 (m, 2H), 1.30 - 1.21 (m, 2H), 0.96 - 0.80 (m, 4H), 0.76 (dt, *J*=11.1, 5.7 Hz, 1H), 0.56 - 0.39 (m, 4H).

Cap 8, step i



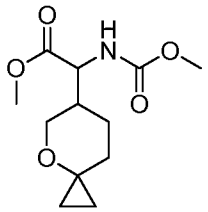
A solution of *Cap 8, step h* (mixture of isomers) (400 mg, 1.207 mmol) in MeOH (10 mL) in a 500 mL hydrogenation pressure tube was bubbled with N_2 for 30 mins. To the mixture was added (-)-1,2-bis((2S,5S)-2,5-dimethylphospholano)ethane(cyclooctadiene)rhodium (I) tetrafluoroborate (13.43 mg, 0.024 mmol) and the mixture was then put on Parr shaker and hydrogenated at 60 psi for 3 days. The mixture was then concentrated. The crude product was then separated by chiral HPLC (Chiralpak OJ column, 21 x 250 mm, 10 um) eluting with 90% 0.1% diethylamine/Heptane-10% EtOH at 15 mL/min to give *Cap 8, step i.1* (55 mg; first eluting fraction) and *Cap 8, step i.2* (65 mg; second eluting fraction) as clear oils. The absolute stereochemistry of the isomers was not determined.

Cap 8, step i.1: LC (Cond. 3): RT = 1.93 min; LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{18}H_{23}NNaO_5$ 356.15; found 356.04; ^1H NMR (500MHz, $CDCl_3$) δ 7.45 - 7.30 (m, 5H), 5.38 - 5.30 (m, 1H), 5.18 - 5.06 (m, 2H), 4.41 (dd, *J*=8.9, 5.8 Hz, 1H), 3.83 (d, *J*=11.0 Hz, 1H), 3.77 (s, 3H), 3.35 (t, *J*=10.8 Hz, 1H), 2.21 - 2.09 (m, 1H), 2.07 - 1.98 (m, 1H), 1.70 (d, *J*=11.0 Hz, 2H), 1.54 (qd, *J*=12.1, 4.1 Hz, 1H), 1.19 (dt,

J=13.6, 3.4 Hz, 1H), 0.83 (dt, *J*=11.1, 5.7 Hz, 1H), 0.63 (dt, *J*=10.5, 5.1 Hz, 1H), 0.49 (dt, *J*=10.1, 6.0 Hz, 1H), 0.36 - 0.29 (m, 1H).

Cap 8, step i.2: LC (Cond. 5): RT = 1.55 min; LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{18}H_{23}NNaO_5$ 356.15; found 356.06; ^1H NMR (500MHz, $CDCl_3$) δ 7.40 - 7.32 (m, 5H), 5.31 (d, *J*=8.5 Hz, 1H), 5.12 (s, 2H), 4.39 - 4.33 (m, 1H), 3.77 (s, 3H), 3.74 (d, *J*=2.1 Hz, 1H), 3.39 (t, *J*=10.5 Hz, 1H), 2.07 (d, *J*=4.0 Hz, 1H), 2.04 - 1.95 (m, 1H), 1.82 (d, *J*=10.7 Hz, 1H), 1.34 - 1.21 (m, 2H), 0.82 (dt, *J*=11.0, 5.8 Hz, 1H), 0.68 - 0.61 (m, 1H), 0.49 (dt, *J*=9.9, 5.9 Hz, 1H), 0.34 (ddd, *J*=10.1, 6.4, 4.9 Hz, 1H).

Cap 8, step j.1



To a solution of *Cap 8, step i.1* (55 mg, 0.165 mmol) in 10 mL of MeOH in a hydrogenation flask was added dimethyl dicarbonate (0.035 mL, 0.33 mmol) and Pd/C (8.78 mg, 08.25 μmol). The flask was put on a Parr shaker and the mixture was hydrogenated at 50 psi for 4 hours. The mixture was then filtered through diatomaceous earth (Celite®) and the filtrate was concentrated to afford *Cap 8, step j.1* as a clear oil (50 mg). LC (Cond. 1): RT = 1.09 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{12}H_{20}NO_5$ 258.13; found 258.05; ^1H NMR (500MHz, $CDCl_3$) δ 4.39 (dd, *J*=8.7, 6.0 Hz, 1H), 3.85 - 3.80 (m, 1H), 3.79 - 3.76 (m, 3H), 3.71 (s, 3H), 3.36 (t, *J*=10.8 Hz, 1H), 2.14 (d, *J*=4.9 Hz, 1H), 2.03 (t, *J*=13.0 Hz, 1H), 1.71 (ddd, *J*=12.7, 3.7, 2.0 Hz, 1H), 1.55 (td, *J*=12.1, 4.1 Hz, 1H), 1.20 (d, *J*=13.4 Hz, 1H), 0.83 (dt, *J*=11.0, 5.8 Hz, 1H), 0.67 - 0.60 (m, 1H), 0.49 (dt, *J*=9.9, 6.0 Hz, 1H), 0.37 - 0.29 (m, 1H). Benzyl carbamate *Cap 8, step i.2* was elaborated similarly to its methyl carbamate, *Cap 8, step j.2*.

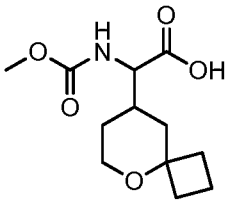
Cap 8.1 & Cap 8.2

To a mixture of *Cap 8, step j.1* (50 mg, 0.194 mmol) in THF (1 mL) and water (0.5 mL) was added LiOH (0.292 mL, 0.583 mmol) (2 M aqueous). The resulting mixture was stirred at room temperature overnight. The mixture was

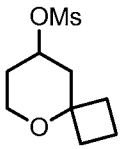
extracted with Et_2O (5 mL). The aqueous phase was acidified with 1 N HCl aq. solution and extracted with Et_2O (6 x). The combined organic layers were dried with $MgSO_4$ and concentrated to give *Cap 8.1* as a white solid (35 mg). LC (Cond. 1): RT = 0.95 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{11}H_{18}NO_5$ 244.12; found 244.02; ^1H NMR (400MHz, $CDCl_3$) δ 5.24 (d, *J*=7.5 Hz, 1H), 4.43 (br. s., 1H), 3.89 (d, *J*=12.0 Hz, 1H), 3.73 (s, 3H), 3.41 (t, *J*=10.8 Hz, 1H), 2.22 (d, *J*=4.3 Hz, 1H), 2.11 - 2.00 (m, 1H), 1.78 (dt, *J*=12.6, 1.9 Hz, 1H), 1.65 - 1.54 (m, 1H), 1.30 - 1.18 (m, 2H), 0.85 (dt, *J*=11.1, 5.9 Hz, 1H), 0.70 - 0.61 (m, 1H), 0.50 (dt, *J*=10.0, 5.9 Hz, 1H), 0.40 - 0.31 (m, 1H).

Cap 8.2 was synthesized from *Cap 8, step j.2* according to the procedure described for *Cap-8.1*. LC (Cond. 1): RT = 0.96 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{11}H_{18}NO_5$ 244.12; found 244.02; ^1H NMR (500MHz, $CDCl_3$) δ 5.44 (d, *J*=8.5 Hz, 1H), 4.35 (t, *J*=7.6 Hz, 1H), 3.81 (d, *J*=8.9 Hz, 1H), 3.71 (s, 3H), 3.49 - 3.41 (m, 1H), 2.14 (br. s., 1H), 2.04 - 1.86 (m, 2H), 1.69 - 1.55 (m, 1H), 1.34 - 1.25 (m, 2H), 0.83 (dt, *J*=11.0, 5.8 Hz, 1H), 0.67 (dt, *J*=10.5, 5.1 Hz, 1H), 0.54 - 0.45 (m, 1H), 0.40 - 0.34 (m, 1H).

Cap 9.1 to Cap 9.4 (four stereoisomers)



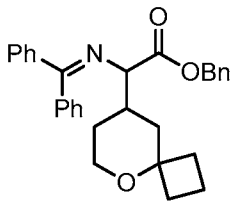
Cap 9, step a



Methanesulfonic acid (3.89 mL, 59.9 mmol) was added to a stirred solution of but-3-en-1-ol (2.06 g, 28.5 mmol) and cyclobutanone (2.00 g, 28.5 mmol) in DCM (20 mL) and the reaction mixture was stirred overnight. The reaction was quenched slowly with sat. $NaHCO_3$ (aq) (until basic), the layers were separated and the aqueous layer extracted with DCM (20 mL). The combined organics were dried ($MgSO_4$)

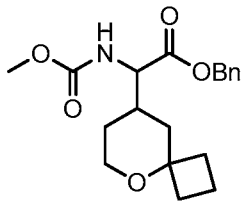
filtered and concentrated to a crude yellow oil. The crude oil was purified with a Biotage Horizon (90g SiO_2, 0-40% EtOAc/hexanes) to yield *Cap 9, step a* (5.3 g) as an orange oil. ^{1}H NMR (400MHz, $CDCl_3$) δ 4.93 - 4.81 (m, 1H), 3.84 (dt, *J*=12.1, 4.1 Hz, 1H), 3.50 (ddd, *J*=12.1, 10.9, 2.6 Hz, 1H), 3.05 (s, 3H), 2.28 (ddd, *J*=12.7, 4.4, 1.8 Hz, 1H), 2.22 - 2.12 (m, 1H), 2.09 - 1.96 (m, 4H), 1.90 - 1.64 (m, 4H).

Cap 9, Step b



In a 35 mL pressure vessel, benzyl 2-((diphenylmethylene)amino)acetate (972 mg, 2.95 mmol) and *Cap 9, step a* (500 mg, 2.270 mmol) were dissolved into toluene (10 mL) and THF (2 mL) and the clear colorless solution was stirred under nitrogen for 5 min. Then, 1M LiHMDS/THF (2.95 mL, 2.95 mmol) was added and the vessel was sealed and then heated at 100 °C for 9h. The reaction was allowed to cool and was poured into 1/2 sat NH_4Cl (aq) (~40 mL) and then extracted with EtOAc (~40 mL). The organic phase was washed with brine (~40 mL), dried ($MgSO_4$), filtered and concentrated. The crude orange oil was purified with a Biotage Horizon (0-30% EtOAc/hex, 40g SiO_2) to yield *Cap 9, step b* (a mixture of four stereoisomers) (350 mg) as an orange-yellow oil. LC-MS retention time 1.920 min; m/z 454.32 (MH+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x50mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0% solvent B to 0% solvent A / 100% solvent B, a gradient time of 2 min, a hold time of 1 min, and an analysis time of 3 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode.

Cap 9, Step c



Cap 9, step b (345 mg, 0.761 mmol) in THF (8 mL) was treated with 1.5M HCl (3.04 mL, 4.56 mmol) (aq) and stirred for 1.5h. The reaction mixture was then concentrated under high vacuum. The residue was dissolved into DCM (4 mL), treated with DIPEA (0.531 mL, 3.04 mmol) and methyl chloroformate (0.088 mL, 1.14 mmol) and stirred at rt ON. The reaction was diluted with water (~10 mL) and DCM (10 mL), separated and the aqueous layer extracted with DCM (10 mL). The combined organic layer was dried ($MgSO_4$), filtered and concentrated. The residue was purified by prep HPLC (water/ACN with TFA buffer) to yield *Cap 9, step c* (a mixture of four stereoisomers; 108 mg) as an orange glass. LC-MS retention time 2.833 min; m/z 348.3 (MH^+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x50mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0% solvent B to 0% solvent A / 100% solvent B, a gradient time of 4 min, a hold time of 1 min, and an analysis time of 5 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode.

The mixture of stereoisomers was separated by chiral preparative SFC purification:

Chiralpak AD-H preparative column, 30 x 250 mm, 5μm

Mobile Phase: 15% 2:1 heptane:EtOH in CO_2 @ 150bar

Temp: 35 ^{0}C

Flow rate: 70.0 mL/min. for 14 min.

UV monitored @ 220nm

Injection: 0.35mL of ~27 mg/mL in EtOH (~108 mg total via stacked injection)

to yield:

Cap 9, step c.1: First eluting peak: 22.3 mg; ^{1}H NMR (400MHz, $CDCl_3$) δ 7.47 - 7.32 (m, 5H), 5.37 - 5.21 (m, 2H), 5.10 (d, *J*=12.0 Hz, 1H), 4.42 (dd, *J*=9.0, 4.8 Hz, 1H), 3.79 - 3.65 (m, 4H), 3.38 (td, *J*=11.5, 3.3 Hz, 1H), 2.15 - 2.01 (m, 2H), 1.98 - 1.65 (m, 4H), 1.56 - 1.14 (m, 5H).

Cap 9, step c.2: Seond eluting peak: 20.6 mg; ^{1}H NMR (400MHz, $CDCl_3$) δ 7.45 - 7.32 (m, 5H), 5.26 (d, *J*=9.0 Hz, 1H), 5.20 (s, 2H), 4.37 (dd, *J*=9.0, 5.0 Hz, 1H), 3.77 - 3.67 (m, 4H), 3.41 - 3.29 (m, 1H), 2.16 - 1.99 (m, 2H), 1.96 - 1.68 (m, 4H), 1.58 - 1.19 (m, 5H).

Cap 9, step c.3: Third eluting peak: 25.0 mg; ^{1}H NMR (400MHz, $CDCl_3$) δ 7.44 - 7.31 (m, 5H), 5.27 (d, *J*=8.8 Hz, 1H), 5.20 (s, 2H), 4.37 (dd, *J*=9.0, 5.0 Hz, 1H), 3.77 - 3.66 (m, 4H), 3.40 - 3.28 (m, 1H), 2.14 - 2.00 (m, 2H), 1.97 - 1.69 (m, 4H), 1.62 - 1.23 (m, 5H).

Cap 9, step c.4: Fourth eluting peak: 22.4 mg; ^{1}H NMR (400MHz, $CDCl_3$) δ 7.45 - 7.32 (m,5H), 5.37 - 5.21 (m, 2H), 5.10 (d, *J*=12.0 Hz, 1H), 4.42 (dd, *J*=9.0, 4.8 Hz, 1H), 3.78 - 3.66 (m, 4H), 3.38 (td, *J*=11.5, 3.3 Hz, 1H), 2.06 (q, *J*=10.1 Hz, 2H), 1.96 - 1.67 (m, 4H), 1.56 - 1.14 (m, 5H).

Based on ^{1}H NMR analyses, *Cap 9, step c.1*and *Cap 9, step c.4* are enantiomers as are *Cap 9, step c.2* and *Cap 9, step c.3*. Each single stereoisomer was elaborated independently.

Cap 9.1 to Cap 9.4

Cap 9, step c.1 (22.3 mg, 0.064 mmol) was dissolved in MeOH (3 mL) and added to 10% Pd/C (5.46 mg, 5.14 μmol). The reaction was vacuum flushed with nitrogen (4X) and then with hydrogen (4X) and allowed to stir under a balloon of hydrogen ON. The reaction was treated with diatomaceous earth (Celite®) and then filtered through diatomaceous earth (Celite®) and concentrated to yield *Cap 9.1* (16.8 mg) as a colorless glass. LC-MS retention time 1.008 min; m/z 258.2 (MH+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x50mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0% solvent B to 0% solvent A / 100%

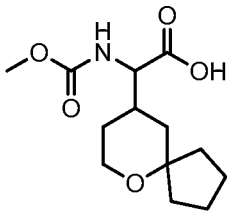
solvent B, a gradient time of 2 min, a hold time of 1 min, and an analysis time of 3 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode. The other related stereosiomers *Cap 9, step c.2 to c.4* were all independently debenylated using the procedure described above.

Cap 9.2: LC-MS retention time 1.011 min; m/z 258.15 (MH^+).

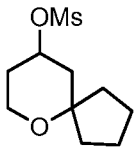
Cap 9.3: LC-MS retention time 1.054 min; m/z 258.2 (MH^+).

Cap 9.4: LC-MS retention time 1.045 min; m/z 258.2 (MH^+).

Cap 10.1 to 10.4 (four stereoisomers)

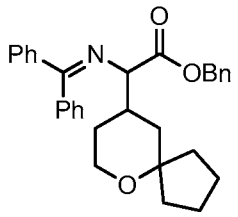


Cap 10, step a



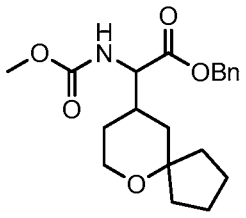
Methanesulfonic acid (3.89 mL, 59.9 mmol) was added to a stirred solution of but-3-en-1-ol (2.058 g, 28.5 mmol) and cyclopentanone (2.40 g, 28.5 mmol) in DCM (20 mL) and the reaction mixture was stirred ON. The reaction was quenched slowly with sat $NaHCO_3$ (aq) (until basic), the layers were separated and the aqueous layer extracted with DCM (20 mL). The combined organics were dried ($MgSO_4$) filtered and concententrated to a crude orange oil. The crude oil was purified with a Biotage Horizon (90g SiO_2, 0-40% EtOAc/hexanes) to yield *Cap 10, step a* (4.68 g) as an orange oil. ^1H NMR (400MHz, $CDCl_3$) δ 5.02 - 4.82 (m, 1H), 3.85 (dt, *J*=12.4, 4.2 Hz, 1H), 3.60 (ddd, *J*=12.4, 10.7, 3.0 Hz, 1H), 3.04 (s, 3H), 2.11 - 1.97 (m, 2H), 1.95 - 1.54 (m, 9H), 1.52 - 1.40 (m, 1H).

Cap 10, step b



In a 48 mL pressure vessel, benzyl 2-((diphenylmethylene)amino)acetate (1.46 g, 4.44 mmol) and *Cap 10, step a* (800 mg, 3.41 mmol) were dissolved into toluene (15 mL) and THF (3 mL) and the clear colorless solution was stirred under nitrogen for 5 min. Then 1M LiHMDS (4.44 mL, 4.44 mmol) in THF was added and the vessel was sealed and then heated at 100 °C for 9h. The reaction was allowed to cool and was then poured into 1/2 sat NH_4Cl (aq) (~60 mL) and extracted with EtOAc (~60 mL). The organic phase was washed with brine (~40 mL), dried ($MgSO_4$), filtered and concentrated. The crude orange oil was purified with a Biotage Horizon (0-40% EtOAc/hex, 90g SiO_2) to yield *Cap 10, step b* (mixture of four stereoisomers) (480 mg) as a viscous orange oil. LC-MS retention time 1.991 min; m/z 468.4 (MH+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x50mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0% solvent B to 0% solvent A / 100% solvent B, a gradient time of 2 min, a hold time of 1 min, and an analysis time of 3 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode.

Cap 10, step c



Cap 10, step b (475 mg, 1.02 mmol) was dissolved into THF (12 mL) and then treated with 1.5M HCl (4.06 mL, 6.09 mmol) (aq) and stirred 1.5h. The reaction

was concentrated under high vacuum. The residue was then dissolved in DCM (6 mL) and treated with DIPEA (0.710 mL, 4.06 mmol) and methyl chloroformate (0.118 mL, 1.52 mmol) and stirred at rt 1.5d. The reaction was diluted with water (~10 mL) and DCM (10 mL) separated and the aqueous layer was further extracted with DCM (10 mL). The combined organics were dried ($MgSO_4$), filtered and concentrated. The residue was purified with a Biotage Horizon (12g SiO_2, 0-25% EtOAc/hex) to yield 284 mg of an orange oil. This material was further purified by prep HPLC (water/ACN with a TFA buffer) to yield *Cap 10, step c* (mixture of four stereoisomers) (200 mg) as a clear nearly colorless glass. LC-MS retention time 3.025 min; m/z 362.3 (MH+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x50mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0% solvent B to 0% solvent A / 100% solvent B, a gradient time of 4 min, a hold time of 1 min, and an analysis time of 5 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode.

The mixture of stereoisomers was separated by chiral semi-preparative purification:

Chiralpak AD-H preparative column, 30 x 250 mm, 5μm

Mobile Phase: 8% EtOH/heptane with 0.1% Et_2NH

UV monitored @ 220nm

Injection: 0.5 mL of ~30mg/mL in EtOH (~200 mg total)

to yield:

Cap 10, step c.1: First eluting peak: 30.5 mg; ^{1}H NMR (400MHz, $CDCl_3$) δ 7.45 - 7.31 (m, 5H), 5.34 - 5.19 (m, 2H), 5.10 (d, *J*=12.0 Hz, 1H), 4.39 (dd, *J*=9.0, 4.8 Hz, 1H), 3.78 - 3.66 (m, 4H), 3.51 (td, *J*=12.0, 2.6 Hz, 1H), 2.20 - 2.06 (m, 1H), 1.92 - 1.79 (m, 1H), 1.76 - 1.11 (m, 11H).

Cap 10, step c.2: Second eluting peak: 29.6 mg; ^{1}H NMR (400MHz, $CDCl_3$) δ 7.43 - 7.31 (m, 5H), 5.28 - 5.15 (m, 3H), 4.34 (dd, *J*=9.0, 5.3 Hz, 1H), 3.78 - 3.66

(m, 4H), 3.53 - 3.40 (m, 1H), 2.10 (td, *J*=10.6, 5.4 Hz, 1H), 1.94 - 1.82 (m, 1H), 1.76 - 1.62 (m, 3H), 1.59 - 1.24 (m, 8H).

Cap 10, step c.3: Third eluting peak: 27.8 mg; ^{1}H NMR (400MHz, $CDCl_3$) δ 7.46 - 7.31 (m, 5H), 5.30 - 5.14 (m, 3H), 4.34 (dd, *J*=8.9, 5.1 Hz, 1H), 3.79 - 3.63 (m, 4H), 3.53 - 3.40 (m, 1H), 2.10 (td, *J*=10.4, 5.5 Hz, 1H), 1.95 - 1.82 (m, 1H), 1.76 - 1.63 (m, 3H), 1.60 - 1.22 (m, 8H).

Cap 10, step c.4: Fourth eluting peak: 21.7 mg; ^{1}H NMR (400MHz, $CDCl_3$) δ 7.45 - 7.32 (m, 5H), 5.36 - 5.18 (m, 2H), 5.10 (d, *J*=12.0 Hz, 1H), 4.39 (dd, *J*=9.0, 4.8 Hz, 1H), 3.79 - 3.67 (m, 4H), 3.51 (td, *J*=12.0, 2.6 Hz, 1H), 2.19 - 2.06 (m, 1H), 1.92 - 1.79 (m, 1H), 1.77 - 1.10 (m, 11H).

By ^{1}H NMR *Cap 10, step c.1* and *Cap 10, step c.4* are an enantiomeric pair as are *Cap 10, step c.2* and *Cap 10, step c.3*. Each single stereoisomer was carried forward independently.

Cap 10.1-10.4

Cap 10, step c.1 (24.4 mg, 0.068 mmol) was dissolved in MeOH (3 mL) and added to 10% Pd/C (5.8 mg, 5.40 μmol). The reaction was vacuum flushed with nitrogen (4X) and then with hydrogen (4X) and allowed to stir under a balloon of hydrogen ON. The reaction was treated with diatomaceous earth (Celite®) and then filtered through diatomaceous earth (Celite®) and concentrated to yield *Cap 10.1* (16.3 mg) as a colorless glass. LC-MS retention time 1.139 min; m/z 272.2 (MH+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x50mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0% solvent B to 0% solvent A / 100% solvent B, a gradient time of 2 min, a hold time of 1 min, and an analysis time of 3 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode. ^{1}H NMR (400MHz, MeOH-d_4) δ 4.11 - 4.03 (m, 1H), 3.77 - 3.70 (m, 1H), 3.66 (s, 3H), 3.65 - 3.56 (m, 1H), 3.37 - 3.34 (m, 1H), 2.22 - 2.08 (m, 1H), 2.02 - 1.93 (m, 1H), 1.77 - 1.28 (m, 11H).

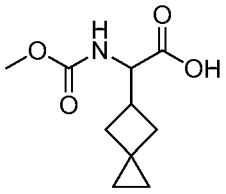
The other three stereoisomers *Cap 10, step c.2* to *c.4* were all independently debenylated using the procedure described above:

Cap 10.2 (colorless glass): LC-MS retention time 1.018 min; m/z 272.2 (MH+). ^{1}H NMR (400MHz, MeOH -d_4) δ 4.10 - 4.03 (m, 1H), 3.78 - 3.71 (m, 1H), 3.66 (s, 3H), 3.59 (td, *J*=12.1, 2.4 Hz, 1H), 3.38 - 3.34 (m, 1H), 2.22 - 2.09 (m, 1H), 2.06 - 1.96 (m, 1H), 1.79 - 1.27 (m, 11H).

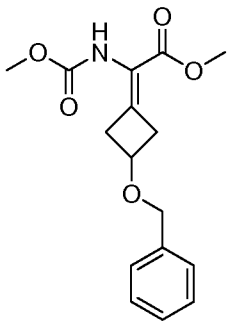
Cap 10.3 (colorless glass): ^{1}H NMR (400MHz, MeOH -d_4) δ 4.10 - 4.03 (m, 1H), 3.78 - 3.70 (m, 1H), 3.66 (s, 3H), 3.59 (td, *J*=12.1, 2.4 Hz, 1H), 3.38 - 3.35 (m, 1H), 2.23 - 2.09 (m, 1H), 2.05 - 1.94 (m, 1H), 1.79 - 1.26 (m, 11H).

Cap 10.4 (colorless glass): ^{1}H NMR (400MHz, MeOH -d_4) δ 4.06 (d, *J*=6.0 Hz, 1H), 3.77 - 3.70 (m, 1H), 3.69 - 3.57 (m, 4H), 3.36 (s, 1H), 2.22 - 2.06 (m, 1H), 2.02 - 1.92 (m, 1H), 1.79 - 1.26 (m, 11H).

Cap-11 (racemix mixture)



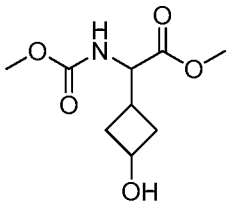
Cap-11, step a



To a solution of 3-(benzyloxy)cyclobutanone (5 g, 28.4 mmol) in CH_2Cl_2 (200 ml) at 0 °C under nitrogen was added methyl 2-(dimethoxyphosphoryl)-2-(methoxycarbonylamino)acetate (14.48 g, 56.7 mmol) followed by the addition of 1,1,3,3-tetramethylguanidine (7.33 ml, 62.4 mmol). The reaction was removed from the cold bath and allowed to stir at ~25 °C under nitrogen for 24.5h. The reaction was treated with saturated NH_4Cl (aq, 100 mL). The layers were separated and the

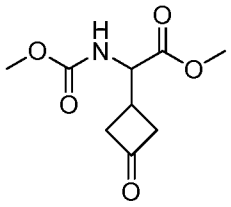
aqueous layer was extracted with CH_2Cl_2 (2 x 100 mL). The combined organic layers were washed with brine (50 mL), dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The viscous oil was diluted with chloroform (5mL) and loaded on a Thomson's silica gel cartridge eluting with 25% ethyl acetate/hexanes to afford *Cap-11, step a* (6.84 g) as a light yellow viscous oil. LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{16}H_{19}NNaO_5$ 328.12; found 328.00. ^1H NMR (400MHz, DMSO-d_6) δ 8.49 (br. s., 1H), 7.41 - 7.26 (m, 5H), 4.43 (s, 2H), 4.20 - 4.10 (m, 1H), 3.65 (s, 3H), 3.56 (s, 3H), 3.35 - 3.24 (m, 1H), 3.01 (ddt, *J*=17.4, 6.8, 3.5 Hz, 1H), 2.96 - 2.84 (m, 1H), 2.72 - 2.62 (m, 1H).

Cap-11, step b



To a solution of *Cap-11, step a* (6.84 g, 22.40 mmol) in MeOH (100 mL) under nitrogen was added a suspension of palladium on carbon, 10% (2.384 g, 2.240 mmol) in MeOH (20 mL) under nitrogen. The mixture was then exposed to hydrogen under a balloon for 26h. The reaction was filtered over diatomaceous earth (Celite®) and concentrated *in vacuo* to afford *Cap-11, step b* (4.84 g) as a light yellow viscous oil. LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_9H_{15}NNaO_5$ 240.08; found 240.01. ^1H NMR (400MHz, MeOH-d_4) δ 7.40 - 7.25 (m, 1H), 4.91 (s, 2H), 4.19 - 3.99 (m, 2H), 3.72 (s, 3H), 3.67 (s, 3H), 2.42 - 2.25 (m, 2H), 2.24 - 2.02 (m, 1H), 1.91 - 1.61 (m, 1H).

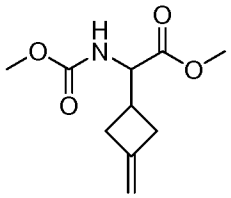
Cap-11, step c



To a solution of DMSO (4.0 ml, 56.4 mmol) in CH_2Cl_2 (70 ml) at -78 °C under nitrogen was added oxalyl chloride, 2M solution in CH_2Cl_2 (15.3 ml, 30.6

mmol) dropwise. The reaction was stirred for 1h. A solution of *Cap-11, step b* (4.814 g, 22.16 mmol) in CH_2Cl_2 (35.0 ml) was added to the reaction maintaining to stir at -78 °C under nitrogen. The reaction mixture was stirred for 1.5h. Triethylamine (15.5 ml, 111 mmol) was added to the reaction dropwise with the reaction maintaining to stir at -78 °C under nitrogen. The reaction was stirred for 16h. The reaction was quenched with cold 20% K_2HPO_4 (aq) (50 mL) and water (50 mL). The mixture was stirred at ~25 °C for 15 min. The reaction was diluted with ethyl acetate (50 mL) and the layers were separated. The aqueous layer was extracted with ethyl acetate (2 x 50 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The residue was loaded on a Thomson's silica gel cartridge eluting with 40% ethyl acetate/hexanes to afford *Cap-11, step c* (3.71 g) as a light yellow viscous oil. ^{1}H NMR (400MHz, DMSO-d_6) δ 7.86 (d, *J*=8.0 Hz, 1H), 4.27 (t, *J*=8.4 Hz, 1H), 3.65 (s, 3H), 3.57 (s, 3H), 3.16, 2.86 (m, 4H), 2.82 - 2.61 (m, 1H).

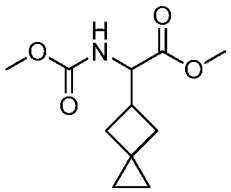
Cap-11, step d



A mixture of methyltriphenylphosphonium bromide (3 g, 8.40 mmol) and potassium *tert*-butoxide (1 g, 8.91 mmol) in 1,4-dioxane (35 mL) was heated at 40 °C under nitrogen for 3h. The reaction was removed from the heat and cooled in a cold bath to 10 °C. A solution of *Cap-11, step c* (1.48 g, 6.88 mmol) in 1,4-dioxane (7 mL) was added dropwise and the reaction continued to stir at 10 °C under nitrogen for 45h. All solvents were removed *in vacuo*. The residue was taken up in ethyl acetate (50 mL) and saturated NH_4Cl (aq, 50 mL). The layers were separated and the aqueous layer was extracted further with ethyl acetate (2 x 50 mL). The combined organic layers were washed with saturated NaCl (aq, 50 mL), dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The residue was taken up in $CHCl_3$ (1 mL) and loaded on a Thomson's silica gel cartridge eluting with 5% to 15% ethyl acetate/hexanes over ~4L to afford *Cap-11, step d* (533 mg) as a colorless viscous oil

which solidified into a white solid upon standing. ^{1}H NMR (400MHz, $CDCl_3$) δ 5.21 (d, *J*=7.8 Hz, 1H), 4.83 - 4.74 (m, 2H), 4.41 (t, *J*=7.7 Hz, 1H), 3.74 (s, 3H), 3.70 (s, 3H), 2.82 - 2.52 (m, 5H).

Cap-11, step e



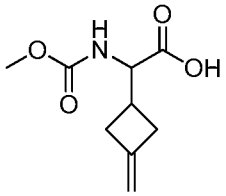
To CH_2Cl_2 (2.5 ml) at 0 °C under nitrogen was added diethylzinc, 1M in hexanes (6.69 ml, 6.69 mmol) followed by the addition of triflouroacetic acid (in 1 mL CH_2Cl_2) (0.516 ml, 6.69 mmol) dropwise over 10 min. After 1h, diiodomethane (in 1 mL CH_2Cl_2) (0.540 ml, 6.69 mmol) was added dropwise over 10 min. followed by the the addition of *Cap-11, step d* (in 1 mL CH_2Cl_2) (0.2378 g, 1.115 mmol) dropwise. After the addition, the reaction was removed from the cold bath and allowed to stir at ~25 °C under nitrogen 12.5 h. The reaction was quenched with 0.1N HCl (aq, 50 mL). The product was extracted with ethyl acetate (3 x 50 mL). The combined organic layers were dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The residue was loaded on a Thomson's silica gel cartridge eluting with 15% ethyl acetate/hexanes to afford *Cap-11, step e* (206.1 mg, 81% yield) as a white solid. ^{1}H NMR (400MHz, DMSO-d_6) δ 7.65 (d, *J*=7.8 Hz, 1H), 4.08 (dd, *J*=9.5, 8.0 Hz, 1H), 3.62 (s, 3H), 3.56 (s, 3H), 2.76 - 2.57 (m, 1H), 2.11 - 2.00 (m, 3H), 2.00 - 1.90 (m, 1H), 0.48 - 0.28 (m, 4H).

Cap-11 (racemic mixture)

To a solution of *Cap-11, step e* (0.2804 g, 1.234 mmol) in MeOH (4 mL) at ~25 °C was added a solution of lithium hydroxide (0.035 g, 1.481 mmol) in water (2 mL). The reaction was stirred for 4h, all volatile components were removed *in vacuo*. The residue was diluted with water (25 mL) and acidfied with 6N HCl to pH ~1-2. The product was extracted with ethyl acetate (3 x 25 mL), dried over $MgSO_4$, filtered, and concentrated *in vacuo* to afford *Cap-11* (258.1 mg) as a white solid. ^{1}H NMR (400MHz, DMSO-d_6) δ 12.52 (s, 1H), 7.48 (d, *J*=8.3 Hz, 1H), 3.99 (dd, *J*=9.3,

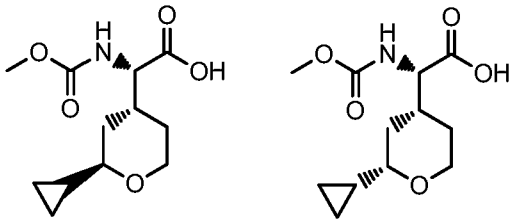
8.3 Hz, 1H), 3.55 (s, 3H), 2.74 - 2.57 (m, 1H), 2.17 - 1.89 (m, 4H), 0.49 - 0.25 (m, 4H).

Cap-12 (racemic mixture)

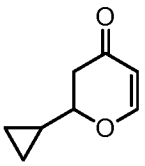


To a solution of *Cap-11, step d* (0.200 g, 0.938 mmol) in MeOH (3 mL) was added a solution of lithium hydroxide (0.027 g, 1.126 mmol) in water (1.5 mL) dropwise. The reaction was stirred at ~25 °C for 6 h. All volatile components were removed *in vacuo*. The residue was diluted with water (10 mL) and acidified with 6N HCl to pH ~ 1-2. The product was extracted with ethyl acetate (3 x 25 mL). The combined organic layers were dried over $MgSO_4$, filtered, and concentrated *in vacuo* to afford *Cap-12* (178 mg) as a white solid. ^{1}H NMR (400MHz, DMSO-d_6) δ 12.59 (s, 1H), 7.54 (d, *J*=8.0 Hz, 1H), 4.75 (br. s., 2H), 3.95 (t, *J*=8.2 Hz, 1H), 3.55 (s, 3H), 2.76 - 2.51 (m, 4H), 2.51 - 2.42 (m, 1H).

Cap 13.1 and 13.2



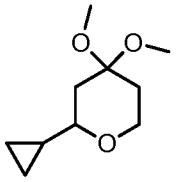
Cap 13, step a



(Diethyloxonio)trifluoroborate (3.64 mL, 29.0 mmol) was added dropwise (over 10 min.) to a solution of cyclopropanecarbaldehyde (4.25 mL, 56.9 mmol) and (E)-((4-methoxybuta-1,3-dien-2-yl)oxy)trimethylsilane (4.90 g, 28.4 mmol) in Et_2O

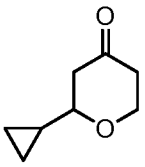
(100 mL) which had been cooled to -78 °C under nitrogen. The reaction was stirred at -78 °C for 2.5h and then sat $NaHCO_3$ (aq) (50 mL) was added and the reaction was allowed to come to rt slowly and stirred ON. The layers were separated, the aqueous layer was extracted with Et_2O (100 mL) and the combined orgainic layers were washed with brine (~50 mL), dried ($MgSO_4$), filtered and concentrated to a crude orange oil. The crude oil was purified with a Biotage Horizon (80g SiO_2, 0-30% EtOAC/hexanes) to yield *Cap13, step a* (2.826 g) as a yellow oil. The material was used without further purification. ^{1}H NMR (400MHz, $CDCl_3$) δ 7.37 (d, *J*=6.0 Hz, 1H), 5.40 (dd, *J*=6.0, 1.0 Hz, 1H), 3.70 (ddd, *J*=13.1, 8.8, 3.8 Hz, 1H), 2.74 - 2.63 (m, 1H), 2.60 - 2.52 (m, 1H), 1.24 - 1.14 (m, 1H), 0.75 - 0.61 (m, 2H), 0.54 - 0.46 (m, 1H), 0.35 - 0.28 (m, 1H).

Cap 13, step b



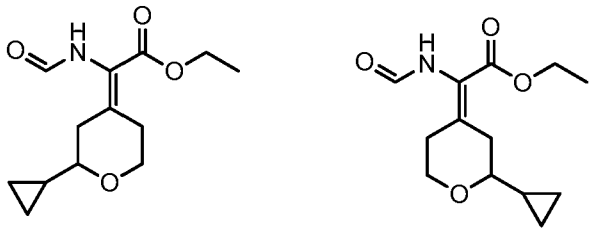
Cap 13, step a (800 mg, 5.79 mmol) was dissolved into methanol (50 mL) and then treated with 10% Pd/C (185 mg, 0.174 mmol). The reaction mixture was stirred and vacuum flushed with nitrogen (4X) and then with hydrogen (4X). The reaction was then allowed to stir under a balloon of hydrogen for 2h. Diatomaceous earth (Celite®) was added to the reaction mixture and stirred, and then the reaction was filtered through diatomaceous earth (Celite®) and concentrated to a crude oil. The crude oil was purified with a Biotage Horizon (25g SiO_2, 0-50% EtOAc/hexanes) to yield *Cap 13, step b* (650 mg contaminated with 25% w/w EtOAc) as a colorless nonviscous oil. ^{1}H NMR (400MHz, $CDCl_3$) δ 3.92 (ddd, *J*=11.5, 5.1, 1.8 Hz, 1H), 3.56 - 3.45 (m, 1H), 3.23 (s, 3H), 3.16 (s, 3H), 2.70 (ddd, *J*=11.2, 8.7, 2.1 Hz, 1H), 2.10 (dt, *J*=13.4, 2.6 Hz, 1H), 1.93 - 1.84 (m, 1H), 1.68 - 1.57 (m, 1H), 1.46 (dd, *J*=13.3, 11.5 Hz, 1H), 0.96 - 0.85 (m, 1H), 0.63 - 0.45 (m, 2H), 0.37 (dq, *J*=9.4, 4.8 Hz, 1H), 0.19 (dq, *J*=9.5, 4.8 Hz, 1H).

Cap 13, step c



Cap 13, step b (650 mg, 2.65 mmol, contaminated with 25% w/w EtOAc) was dissolved into THF (7 mL) and then treated with 1.5M HCl (aq) (7.07 mL, 10.61 mmol) and stirred for 30 min. The reaction was diluted with brine (~30 mL), extracted with DCM (3x25 mL) and the combined organics were dried ($MgSO_4$), filtered and concentrated to yield *Cap 13, step c* (543 mg, contaminated with 12% w/w THF and other minor impruities) as a clear colorless oil. The material was used without further purification. ^{1}H NMR (400MHz, $CDCl_3$) δ 4.31 (ddd, *J*=11.5, 7.4, 1.6 Hz, 1H), 3.67 - 3.57 (m, 1H), 2.98 - 2.88 (m, 1H), 2.68 - 2.42 (m, 3H), 2.37 - 2.28 (m, 1H), 1.03 (qt, *J*=8.1, 4.8 Hz, 1H), 0.69 - 0.52 (m, 2H), 0.49 - 0.40 (m, 1H), 0.30 - 0.21 (m, 1H).

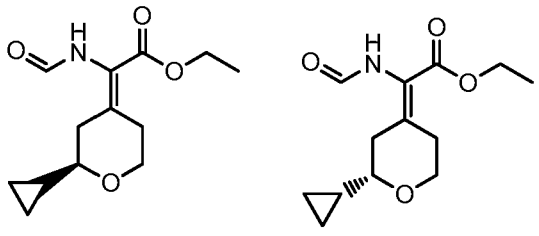
Cap 13, step d.1 and d.2



Ethyl 2-isocyanoacetate (390 mg, 3.45 mmol) was diluted with Et_2O (15 mL) and then treated with cuprous oxide (76 mg, 0.530 mmol). The slurry was stirred 10 min and then *Cap 13, step c* (371 mg, 2.65 mmol) in Et_2O (10 mL) was added and the reaction was stirred at rt for 3h. The reaction was then cooled to 0 °C, treated dropwise with 1M potassium *tert*-butoxide (3.45 mL, 3.45 mmol) in THF and stirred for 1h at 0 °C. Acetic acid (0.197 mL, 3.45 mmol) in DCM (2 mL) was added and the reaction was allowed to warm to rt and stirred ON. The crude reaction mixture was diluted with water (~20 mL) and extracted with EtOAc (3x25 mL). The combined organics were dried ($MgSO_4$), filtered and concentrated to a dark red oil. The oil was purified with a Biotage Horizon (25g SiO_2, 50-75% EtOAc,hexanes) to yield racemic *Cap 13, step d.1* ((Z)-isomer; 250 mg) and *Cap 13, step d.2* ((*E*)-

isomer; 243 mg), each as an off-white solid. The *E/Z* assignment was based on nOe studies. *Cap 13, step d.1*: LC-MS retention time 1.007 min; m/z 254.2 (MH+). ^{1}H NMR (400MHz, MeOH-d_4) δ 8.10 (s, 1H), 4.20 (q, *J*=7.0 Hz, 2H), 4.08 (ddd, *J*=11.2, 5.6, 1.8 Hz, 1H), 3.45 - 3.36 (m, 1H), 3.35 - 3.29 (m, 1H), 2.75 - 2.67 (m, 2H), 2.30 (ddd, *J*=13.9, 12.4, 5.5 Hz, 1H), 2.07 (dd, *J*=14.1, 11.0 Hz, 1H), 1.34 - 1.22 (m, 3H), 0.95 (qt, *J*=8.1, 4.8 Hz, 1H), 0.57 - 0.47 (m, 2H), 0.40 - 0.23 (m, 2H). *Cap 13, step d.2*: LC-MS retention time 1.067 min; m/z 254.2 (MH+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x30mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0% solvent B to 0% solvent A / 100% solvent B, a gradient time of 2 min, a hold time of 1 min, and an analysis time of 3 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode. ^{1}H NMR (400MHz, METHANOL-d_4) δ 8.08 (s, 1H), 4.21 (q, *J*=7.0 Hz, 2H), 4.08 (ddd, *J*=11.1, 5.6, 1.9 Hz, 1H), 3.51 (dt, *J*=14.0, 2.0 Hz, 1H), 3.42 (td, *J*=11.5, 2.5 Hz, 1H), 2.70 (ddd, *J*=10.6, 8.2, 2.3 Hz, 1H), 2.49 (dq, *J*=14.1, 2.2 Hz, 1H), 2.26 - 2.12 (m, 2H), 1.34 - 1.24 (m, 3H), 0.96 (qt, *J*=8.1, 4.9 Hz, 1H), 0.58 - 0.49 (m, 2H), 0.37 (dddd, *J*=7.8, 6.3, 3.0, 1.3 Hz, 1H), 0.26 (dddd, *J*=5.2, 4.0, 2.9, 1.4 Hz, 1H).

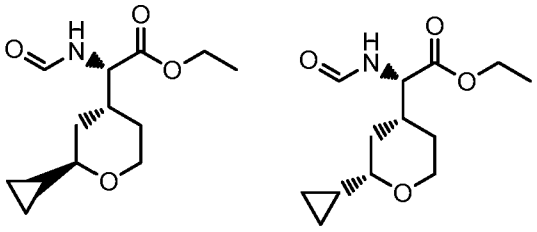
Cap 13, step e.1 and e.2



Racemic *Cap 13, step d.1* (625 mg) was dissolved into 16 mL of EtOH and seperated in multiple injections by prep chiral HPLC (ChiralPak AS column, 10% EtOH/Heptane 0.1% diethyl amine) to yield *Cap 13, step e.1* (450 mg, first eluting peak) and *Cap 13, step e.2* (360 mg, second eluting peak), each as an off-white solid. The enantiomers separated cleanly, and although each sample was clean by LC/MS and chiral analytical HPLC, an unidentified contaminate was present according to ^{1}H

NMR. Each material was used without further purification. ^{1}H NMR (400MHz, MeOH-d_4) δ 8.08 (s, 1H), 4.21 (q, *J*=7.0 Hz, 2H), 4.08 (ddd, *J*=11.1, 5.6, 1.9 Hz, 1H), 3.51 (dt, *J*=13.9, 2.1 Hz, 1H), 3.46 - 3.38 (m, 1H), 2.70 (ddd, *J*=10.7, 8.2, 2.3 Hz, 1H), 2.49 (dq, *J*=14.1, 2.2 Hz, 1H), 2.26 - 2.12 (m, 2H), 1.34 - 1.22 (m, 3H), 0.96 (qt, *J*=8.2, 5.0 Hz, 1H), 0.58 - 0.48 (m, 2H), 0.37 (dddd, *J*=7.7, 6.3, 2.9, 1.4 Hz, 1H), 0.28 - 0.22 (m, 1H).

Cap 13, step f.1 and f.2

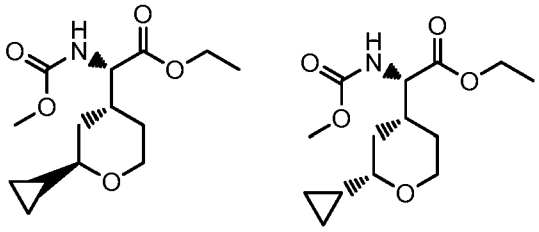


In a Parr Shaker 500 mL reaction vessel, *Cap 13, step e.1* (310 mg, contaminated with an unknown impurity) was dissolved into MeOH (20 mL) and then (-)-1,2-bis((2S,5S)-2,5-dimethylphospholano)ethane(cyclooctadiene)rhodium (I) tetrafluoroborate (17.0 mg, 0.031 mmol) was added. Nitrogen was bubbled through the reaction mixture for 10 min, and then the reaction was vacuum flushed with nitrogen (4X) and then with hydrogen (4X). The reaction was then shaken under 60 psi of hydrogen for 2.5 days. The reaction was concentrated to a brown-yellow oil and then purified with a Biotage Horizon (12g SiO_2, 60-80% EtOAc/hex) to yield *Cap 13, step f.1* (201 mg) as a clear colorless oil. LC-MS retention time 1.681 min; m/z 256.25 (MH+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x50mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0% solvent B to 0% solvent A / 100% solvent B, a gradient time of 4 min, a hold time of 1 min, and an analysis time of 5 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode. By ^{1}H NMR the material presents as a 12:1 mixture of amide rotamers. For the major rotamer: ^{1}H NMR (400MHz, $CDCl_3$) δ 8.26 (s, 1H), 6.09 (d, *J*=7.8 Hz, 1H), 4.88 (t, *J*=8.7 Hz, 1H), 4.25 (q, *J*=7.0 Hz, 2H), 3.89 - 3.72 (m,

2H), 2.89 (ddd, *J*=9.5, 6.2, 3.9 Hz, 1H), 2.32 - 2.20 (m, 1H), 1.80 - 1.70 (m, 1H), 1.69 - 1.58 (m, 2H), 1.50 (dt, *J*=6.8, 3.4 Hz, 1H), 1.33 (t, *J*=7.2 Hz, 3H), 1.13 - 1.03 (m, 1H), 0.63 - 0.49 (m, 2H), 0.44 - 0.35 (m, 1H), 0.18 - 0.10 (m, 1H).

Cap 13, step f.2 (a colorless oil) was prepared from *Cap 13, step e.2* according to the procedure described above. LC-MS retention time 1.753 min; m/z 256.25 (MH+). ^{1}H NMR (400MHz, $CDCl_3$) δ 8.28 (s, 1H), 6.16 (d, *J*=8.8 Hz, 1H), 4.72 (dd, *J*=8.9, 4.6 Hz, 1H), 4.25 (q, *J*=7.1 Hz, 2H), 4.09 - 4.02 (m, 1H), 3.41 - 3.29 (m, 1H), 2.54 (ddd, *J*=10.9, 8.5, 2.0 Hz, 1H), 2.15 - 2.04 (m, 1H), 1.80 (dd, *J*=13.2, 1.9 Hz, 1H), 1.49 - 1.42 (m, 2H), 1.32 (t, *J*=7.2 Hz, 3H), 0.94 - 0.82 (m, 1H), 0.60 - 0.45 (m, 2H), 0.39 - 0.31 (m, 1H), 0.21 - 0.13 (m, 1H). The tentative assignment of the trans (*Cap 13, step f.1*) and cis (*Cap 13, step f.2*) stereoisomers were made based on the magnitude of the ^{1}H NMR couplings on select THP protons.

Cap 13, step g



Cap 13, step f.1 (213 mg, 0.834 mmol) was dissolved in MeOH (5 mL) and then 1.5M HCl (1.11 mL, 1.67 mmol) was added and the reaction was sealed with a septum which was then pierced with a needle and left open to air. The reaction was then heated at 50 °C ON. The reaction was concentrated, dissolved in DCM (5 mL) and then treated with DIPEA (0.583 mL, 3.34 mmol) and methyl chloroformate (0.13 mL, 1.7 mmol) and stirred at rt for 3h. The reaction was quenched with water (~5 mL), stirred, separated and the water layer was further extracted with DCM (3x5 mL). The combined organics were dried ($MgSO_4$) filtered and concentrated. The crude light brown oil was purified with a Biotage Horizon (12g SiO_2, 25-25% EtOAc/hexanes) to yield *Cap 13, step g.1* (131 mg). LC-MS retention time 2.020 min; m/z 286.2 (MH+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x50mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0%

solvent B to 0% solvent A / 100% solvent B, a gradient time of 4 min, a hold time of 1 min, and an analysis time of 5 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode. ^{1}H NMR (400MHz, $CDCl_3$) δ 5.17 (d, *J*=9.3 Hz, 1H), 4.49 (t, *J*=8.7 Hz, 1H), 4.30 - 4.18 (m, 2H), 3.89 - 3.80 (m, 1H), 3.79 - 3.67 (m, 1H), 3.69 (s, 3H), 2.94 - 2.83 (m, 1H), 2.26 - 2.16 (m, 1H), 1.78 - 1.47 (m, 4H), 1.33 (t, *J* = 7.2 Hz, 3H), 1.08 (dt, *J*=8.6, 4.4 Hz, 1H), 0.63 - 0.47 (m, 2H), 0.44 - 0.36 (m, 1H), 0.18 - 0.09 (m, 1H).

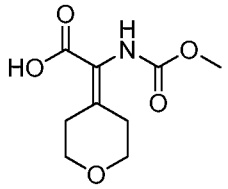
Cap 13, step g.2 was prepared from *Cap 13, step f.2* according to the above procedure. LC-MS retention time 2.053 min; m/z 286.25 (MH+). ^{1}H NMR (400MHz, CHLOROFORM-d) δ 5.27 (d, *J*=8.8 Hz, 1H), 4.34 (dd, *J*=9.0, 4.8 Hz, 1H), 4.23 (q, *J*=7.3 Hz, 2H), 4.05 (dt, *J*=11.2, 3.2 Hz, 1H), 3.71 (s, 3H), 3.41 - 3.30 (m, 1H), 2.55 (ddd, *J*=10.7, 8.5, 1.9 Hz, 1H), 2.09 - 1.96 (m, 1H), 1.77 (d, *J*=12.8 Hz, 1H), 1.48 - 1.38 (m, 2H), 1.35 - 1.22 (m, 1H), 1.31 (t, *J*=7.3 Hz, 3H), 0.89 (qt, *J*=8.2, 4.9 Hz, 1H), 0.61 - 0.44 (m, 2H), 0.39 - 0.30 (m, 1H), 0.17 (dq, *J*=9.4, 4.7 Hz, 1H).

Cap 13.1 and 13.2

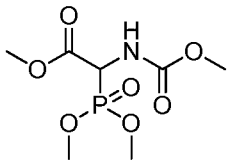
Cap 13, step g.1 (131 mg, 0.459 mmol) was dissolved in THF (5.5 mL) and then treated with 0.5 M aq LiOH (3.67 mL, 1.836 mmol) and stirred for 5h. The reaction was quenched with 1N HCl (1.9 mL) and then concentrated under a stream of nitrogen. The material was diluted with water (~4 mL) and then extracted with DCM:MeOH (~5:1, 3X3 mL). The combined organics were concentrated to yield *Cap 13.1* (117 mg) as a colorless glass. The material was used without further purification. LC-MS retention time 2.441 min; m/z 258.2 (MH+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x50mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0% solvent B to 0% solvent A / 100% solvent B, a gradient time of 4 min, a hold time of 1 min, and an analysis time of 5 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode.

Cap 13.2 was prepared from *Cap 13, step g.2* using the above procedure. LC-MS retention time 2.553 min; m/z 258.2 (MH+).

Cap 14

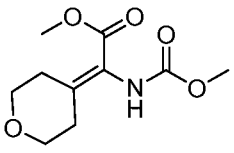


Cap 14, step a



A solution of methyl 2-(benzyloxycarbonylamino)-2-(dimethoxyphosphoryl)acetate (300 mg, 0.906 mmol) in MeOH (10 mL) in a 500 mL hydrogenation pressure tube was bubbled with N_2 for 30 mins. To the mixture was added dimethyl dicarbonate (0.146 mL, 1.358 mmol) and Pd/C (48.2 mg, 0.045 mmol) (10%) and then put on Parr shaker and hydrogenated at 60 psi for 5 h. The mixture was filtered through a pad of diatomaceous earth (Celite®) and the filtrate was concentrated to give *Cap 14, step a* (230 mg) as a light yellow oil which was used without further purification. LC (Cond. 1): RT = 1.60 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_7H_{15}NO_7P$ 256.06; found 256.20. ^1H NMR (400MHz, $CDCl_3$) δ 5.54 (d, *J*=8.0 Hz, 1H), 5.00 - 4.86 (m, 1H), 3.87 - 3.82 (m, 9H), 3.73 (s, 3H).

Cap 14, step b



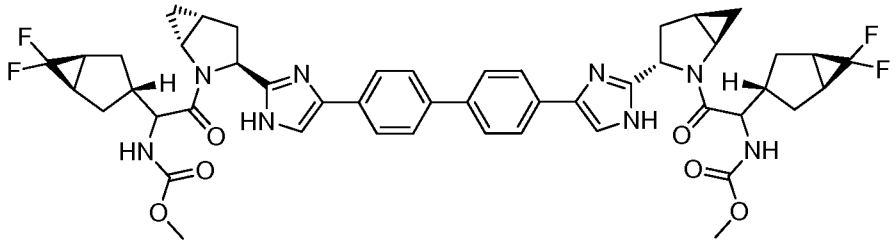
To a solution of *Cap 14, step a* (230 mg, 0.901 mmol) in THF (1 mL) at -20 °C was added 1,1,3,3-tetramethylguanidine (0.125 mL, 0.992 mmol). The resulting light yellow mixture was stirred at -20 °C for 1 h. Dihydro-2H-pyran-4(3H)-one (99 mg, 0.992 mmol) in THF (0.5 mL) was then added and the resulting mixture was stirred at room temperature for 16 h. The reaction mixture was diluted with EtOAc (5 mL) and washed with 0.1 N HCl solution. The aqueous layer was extracted with

EtOAc (2 x 10 mL) and the combined organic layers were dried with MgSO4 and concentrated. The crude product was purified by flash chromatography (silica gel, 50% EtOAc/Hex) to give *Cap 14, step b* as a white solid. ^{1}H NMR (500MHz, $CDCl_3$) δ 5.93 (br. s., 1H), 3.81 - 3.75 (m, 7H), 3.73 (s, 3H), 2.95 (t, *J*=5.5 Hz, 2H), 2.44 (t, *J*=5.2 Hz, 2H).

Cap 14

To a mixture of *Cap 14, step b* (150 mg, 0.654 mmol) in THF (2 mL) and water (1 mL) was added LiOH (0.982 mL, 1.963 mmol) (2 M aqueous). The resulting mixture was stirred at room temperature overnight. The mixture was extracted with Et_2O (5 mL). The aqueous phase was acidified with 1 N HCl aq. solution and extracted with EtOAc (6 x). The combined organic layers were dried with $MgSO_4$ and concentrated to give *Cap 14* as a white solid (100 mg). ^{1}H NMR (400MHz, CD_3OD) δ 8.34 (br. s., 1H), 3.73 - 3.67 (m, 4H), 3.65 (s, 3H), 3.29 (dt, *J*=3.3, 1.7 Hz, 2H), 2.38 (t, *J*=5.3 Hz, 2H).

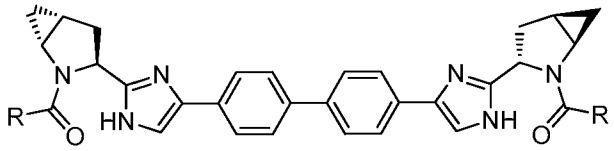
Examples QC-1.1, QC-1.2 & QC-1.3



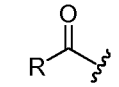
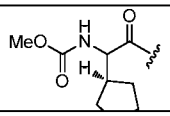
To a solution of 4,4'-bis(2-((1R,3S,5R)-2-azabicyclo[3.1.0]hexan-3-yl)-1H-imidazol-4-yl)biphenyl, 4 HCl (50 mg, 0.084 mmol), and *Cap-2* (racemic mixture) (41.9 mg, 0.168 mmol) in 2 mL of DMF was added DiPEA (0.088 ml, 0.505 mmol). To the resulting mixture was added HATU (64.0 mg, 0.168 mmol) and the mixture was stirred at room temperature for 2 hours. The solvent was then removed to afford a crude mixture of 3 diastereomers with a ratio of ~ 1:2:1 when analyzed under LC (Cond. 3). The mixture was then purified by reverse phase HPLC (Column: Water Sunfire 30 x 150 mm; acetonitrile/water/NH_4OAc) to afford the free bases of three diastereomers (*Example QC-1.1, QC-1.2 & QC-1.3*) as white solids. *Example QC-1.1* (9.1 mg): LC (Cond. 1): RT = 1.15 min; >95%; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{51}F_4N_8O_6$ 911.39; found 456.5 (M/2+1); HRMS: Anal. Calcd. for

$[M+H]^+$ $C_{48}H_{51}F_4N_8O_6$ 911.3862; found 911.3869; ^1H NMR (500 MHz, CD_3OD) δ ppm 7.61 - 7.88 (8 H, m), 7.36 (2 H, br. s.), 5.09 - 5.21 (2 H, m), 4.66 - 4.77 (2 H, m), 3.69 (6 H, s), 2.36 - 2.62 (6 H, m), 1.86 - 2.14 (16 H, m), 1.03 - 1.17 (2 H, m), 0.70 - 0.84 (2 H, m). *Example QC-1.2* (24.5 mg,): LC (Cond. 1): RT = 1.19 min; >97% pure. LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{51}F_4N_8O_6$ 911.39; found 456.5 (M/2+1); HRMS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{51}F_4N_8O_6$ 911.3862; found 911.3865; 1H NMR (500 MHz, CD_3OD) δ ppm 7.59 - 7.89 (8 H, m), 7.36 (2 H, d, *J*=4.88 Hz), 5.08 - 5.24 (2 H, m), 4.60 - 4.76 (2 H, m), 3.69 (6 H, s), 2.36 - 2.71 (6 H, m), 1.82 - 2.20 (16 H, m), 1.16 - 1.25 (1 H, m), 1.03 - 1.14 (1 H, m), 0.66 - 0.83 (2 H, m). *Example QC-1.3* (14.7 mg): LC (Cond. 1): RT = 1.22 min; >99% pure. LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{51}F_4N_8O_6$ 911.39; found 456.5 (M/2+1); HRMS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{51}F_4N_8O_6$ 911.3862; found 911.3864. ^1H NMR (500 MHz, CD_3OD) δ ppm 7.61 - 7.88 (8 H, m), 7.36 (2 H, br. s.), 5.09 - 5.21 (2 H, m), 4.66 - 4.77 (2 H, m), 3.69 (6 H, s), 2.36 - 2.62 (6 H, m), 1.86 - 2.14 (16 H, m), 1.03 - 1.17 (2 H, m), 0.70 - 0.84 (2 H, m).

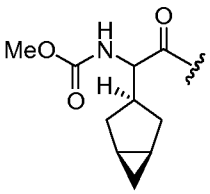
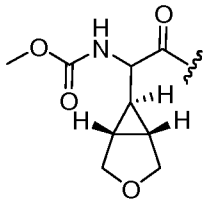
Examples QC-2.1 to QC-4.3



Examples QC-2.1 to QC-3.3 were prepared according to the procedure described for *Example QC-1* by using appropriate caps. *Example QC-4.1* to *QC-4.3* were also prepared similarly with the exception that a MeOH/water/TFA solvent system (Column: WATERS Atlantis OBD 30 X 100 mm 5u) was employed for the reverse phase HPLC purification. Even though only one compound was expected when using *Cap-1,* 3 different diastereomers were obtained, indicating that racemization might have occurred during the synthesis of Cap-1.

Example		**Isomer**	**RT (LC-Cond); % homogeneity index; MS data**
QC-2.1 to QC-2.3		1	RT = 1.99 minutes (Cond. 3); 100%; LC/MS: Anal. Calcd. for $[M+H]^+$

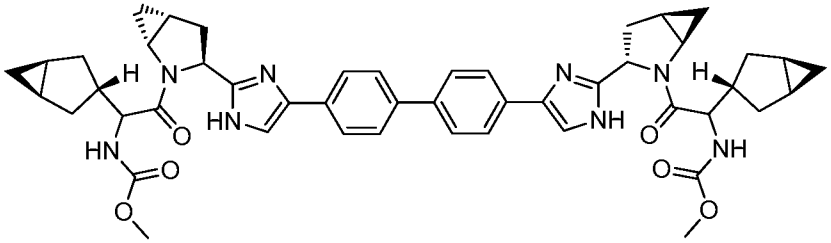
			$C_{48}H_{51}F_4N_8O_6$ 911.39; found 456.2 (M/2+1); HRMS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{51}F_4N_8O_6$ 911.3862; found 911.3873
		2	RT = 2.06 minutes (Cond. 3); >97%; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{51}F_4N_8O_6$ 911.39; found 456.2 (M/2+1); HRMS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{51}F_4N_8O_6$ 911.3862; found 911.3868
		3	RT = 2.14 minutes (Cond. 3); >99%; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{51}F_4N_8O_6$ 911.39; found 456.2 (M/2+1); HRMS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{51}F_4N_8O_6$ 911.3862; found 911.3866

QC-3.1 to QC3.3		1	RT = 1.17 minutes (Cond. 1); >98%; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_6$ 839.42; found 839.8; HRMS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_6$ 839.4239; found 839.4243
		2	RT = 1.21 minutes (Cond. 1); 100%; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_6$ 839.42; found 839.8
		3	RT = 1.25 minutes (Cond. 1); >97%; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_6$ 839.42; found 839.8; HRMS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_6$ 839.4239; found 839.4242
QC-4.1 to QC4.3		1	RT = 0.93 minutes (Cond. 1); >96%; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{46}H_{51}N_8O_8$ 843.38; found 843.7; HRMS: Anal. Calcd. for $[M+H]^+$ $C_{46}H_{51}N_8O_8$ 843.3824; found 843.3834
		2	RT = 1.18 minutes (Cond. 2); >93%; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{46}H_{51}N_8O_8$ 843.38; found 843.53; HRMS: Anal. Calcd. for $[M+H]^+$ $C_{46}H_{51}N_8O_8$ 843.3824; found 843.3823
		3	RT = 0.99 minutes (Cond. 1); LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{46}H_{51}N_8O_8$ 843.38; found 843.6.

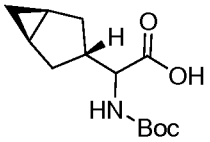
5

Example QC-5.1, QC-5.2 & QC-5.3

(Three diastereomers regarding the non-specified stereogenic center)



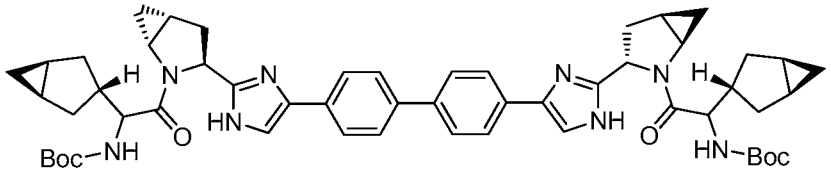
Example QC-5 step a



Racemic mixture

2-((1R,3s,5S)-bicyclo[3.1.0]hexan-3-yl)-2-(tert-butoxycarbonylamino) acetic acid (*Example QC-5 step a*) was prepared from commercially available (cis)-bicyclo[3.1.0]hexan-3-ol, which was first converted to its (trans)-bicyclo[3.1.0]hexan-3-ol isomer using standard Mitsubobu's protocol and then elaborated to ethyl 2-amino-2-((1R,3s,5S)-bicyclo[3.1.0]hexan-3-yl)acetate following the reaction sequence described from *Cap-2 step d* through *Cap-2 step f.* The amine was then protected as it's BOC derivative followed by the hydrolysis of the ethyl ester under standard protocols to afford acid *Example QC-5 step a.*

Example QC-5 step b

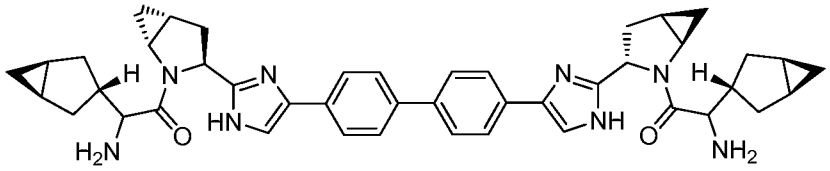


Diastereomeric mixture

To a solution of 4,4'-bis(2-((1R,3S,5R)-2-azabicyclo[3.1.0]hexan-3-yl)-1H-imidazol-4-yl)biphenyl, 4 HCl (50 mg, 0.084 mmol), and acid *Example QC-5 step a* (43.0 mg, 0.168 mmol) in 2 mL of DMF was added DiPEA (0.088 ml, 0.505 mmol) and HATU (64.0 mg, 0.168 mmol). The mixture was stirred at room temperature for 2 hours. The solvent was then removed in vacuo and the crude product was purified

by reverse phase HPLC (Column: WATERS Atlantis OBD 30 X 100 mm 5u, MeOH/water/THF) to afford the TFA salt of *Example QC-5 step b* as a white solid (97 mg). LC (Cond. 1): RT = 1.47 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{54}H_{67}N_8O_6$ 923.52; found 462.8 (M/2+1); 1H NMR (500 MHz, CD_3OD) δ ppm 7.82 - 7.91 (10 H, m), 5.08 - 5.18 (2 H, m), 4.57 (1 H, d, *J*=7.63 Hz), 4.48 (1 H, d, *J*=8.24 Hz), 4.06 - 4.12 (1 H, m), 3.79 - 3.86 (1 H, m), 3.02 (3 H, s), 2.88 (3 H, s), 2.66 - 2.75 (2 H, m), 2.43 - 2.54 (2 H, m), 2.01 - 2.16 (4 H, m), 1.88 - 1.97 (2 H, m), 1.68 - 1.82 (4 H, m), 1.57 - 1.68 (2 H, m), 1.47 (9 H, s), 1.41 (9 H, s), 1.25 - 1.36 (6 H, m), 1.16 - 1.24 (1 H, m), 1.04 - 1.11 (1 H, m), 0.81 - 0.93 (2 H, m), 0.29 - 0.39 (2 H, m), 0.19 - 0.27 (2 H, m).

Example QC-5 step c



Diastereomeric mixture

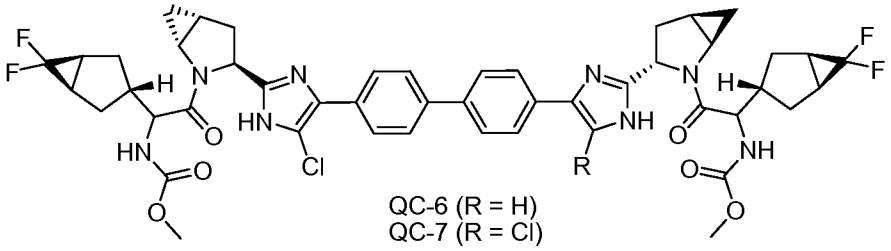
To a mixture of *Example QC-5 step b* (97 mg, 0.084 mmol) in 1 mL of CH_2Cl_2 was added HCl (2 mL, 4.00 mmol) (2 N in diethyl ether). The resulting mixture was stirred at room temperature for 2 hours. The solvent was then removed to afford the HCl salt of *Example QC-5 step c* as a yellow solid (73 mg). LC (Cond. 1): RT = 0.84 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{44}H_{51}N_8O_2$ 723.41; found 723.6.

Example QC-5.1, QC-5.2 & QC-5.3

To a mixture of the HCl salt of *Example QC-5 step b* (73 mg, 0.084 mmol) in 2 mL of CH_2Cl_2 was added DiPEA (0.117 mL, 0.672 mmol) and methyl chloroformate (0.026 mL, 0.336 mmol). The resulting mixture was stirred at room temperature for 1 hour. Ammonia (2 mL, 4.00 mmol) (2 N in Methanol) was added and the resulting mixture was stirred for 2 hours. The solvent was then removed in vacuo and the crude material was purified by a reverse phase HPLC (Column: Water Sunfire 30 x 150 mm, acetonitrile/water/NH_4OAc) to afford the free bases of three

diastereomers (*Example QC-5.1, QC-5.2 & QC-5.3*) as white to light yellow solids. *Example QC-5.1* (8.5 mg): LC (Cond. 3): RT = 2.05 min, >95% pure; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_6$ 839.42; found 839.7. HRMS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_6$ 839.4239; found 839.4243. ^{1}H NMR (500 MHz, CD_3OD) δ ppm 7.64 - 7.87 (8 H, m), 7.37 (2 H, br. s.), 5.10 - 5.22 (2 H, m), 4.57 - 4.72 (2 H, m), 3.68 (6 H, s), 2.38 - 2.58 (4 H, m), 1.90 - 2.31 (6 H, m), 1.55 - 1.87 (6 H, m), 1.20 - 1.38 (6 H, m), 1.04 - 1.19 (2 H, m), 0.72 - 0.85 (2 H, m), 0.28 - 0.37 (2 H, m), 0.22 - 0.28 (2 H, m). *Example QC-5.2* (18 mg): LC (Cond. 3): RT = 2.14 min; >99% pure; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_6$ 839.42; found 839.7; HRMS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_6$ 839.4239; found 839.4243; ^{1}H NMR (500 MHz, CD_3OD) δ ppm 7.63 - 7.86 (8 H, m), 7.37 (2 H, d), 5.11 - 5.22 (2 H, m), 4.51 - 4.70 (2 H, m), 3.68 (6 H, d), 2.38 - 2.59 (4 H, m), 1.90 - 2.15 (6 H, m), 1.57 - 1.84 (6 H, m), 1.18 - 1.38 (6 H, m), 1.03 - 1.16 (2 H, m), 0.72 - 0.83 (2 H, m), 0.28 - 0.39 (2 H, m), 0.22 - 0.28 (2 H, m). *Example QC-5.3* (9.1 mg): LC (Cond. 3): RT = 2.23 min; >95% pure. LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_6$ 839.42; found 839.7; HRMS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_6$ 839.4239; found 839.4242. ^{1}H NMR (500 MHz, CD_3OD) δ ppm 7.63 - 7.93 (8 H, m), 7.36 (2 H, s), 5.17 - 5.29 (2 H, m), 4.55 (2 H, d, *J*=8.5 Hz), 3.69 (6 H, s), 2.39 - 2.64 (4 H, m), 1.92 - 2.20 (6 H, m), 1.58 - 1.86 (6 H, m), 1.27 - 1.45 (6 H, m), 1.17 - 1.27 (2 H, m), 0.70 - 0.84 (2 H, m), 0.31 - 0.45 (2 H, m), 0.20 - 0.30 (2 H, m).

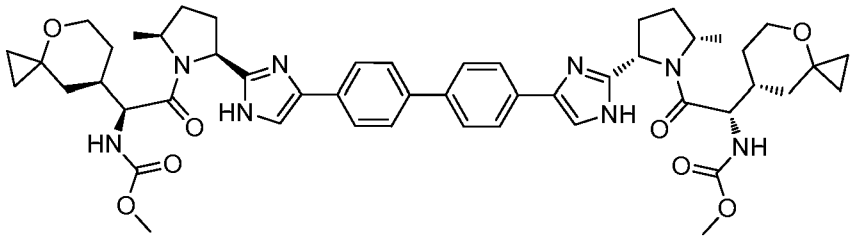
Example QC-6 to QC-7



To a mixture of *Example QC-2.1* (50 mg, 0.044 mmol) in 1 mL of DMF was added NCS (7.03 mg, 0.053 mmol). The resulting mixture was stirred at 50 °C overnight. The solvent was then removed and the crude product was purified by reverse phase HPLC (Column: WATERS Sunfire C18 OBD 30 X 100 mm 5u, MeOH/water/TFA) to afford the TFA salts of *Example QC-6* and *Example CQ-7* as

white and light yellow solids, respectively. *Example QC-6* (20 mg): LC (Cond. 2): RT = 1.72 min, >99% pure; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{50}ClF_4N_8O_6$ 945.35; found 473.16 (M/2+1); HRMS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{50}ClF_4N_8O_6$ 945.3472; found 945.3440; 1H NMR (500 MHz, CD_4OD) δ ppm 7.77 - 7.92 (9 H, m), 5.06 - 5.13 (1 H, m), 4.97 - 5.04 (1 H, m), 4.61 - 4.70 (2 H, m), 3.78 - 3.85 (1 H, m), 3.71 - 3.75 (1 H, m), 3.69 (6 H, d), 2.63 - 2.74 (1 H, m), 2.39 - 2.55 (5 H, m), 1.83 - 2.14 (14 H, m), 1.00 - 1.12 (2 H, m), 0.81 - 0.89 (1 H, m), 0.72 - 0.79 (1 H, m). *Example QC-7* (19 mg): LC (Cond. 2): RT = 2.03 min, >96% pure; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{49}Cl_2F_4N_8O_6$ 979.31; found 490.17 (M/2+1); HRMS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{49}Cl_2F_4N_8O_6$ 979.3083; found 979.3043; 1H NMR (500 MHz, CD_3OD) δ ppm 7.74 - 7.88 (8 H, m), 4.97 - 5.05 (2 H, m), 4.63 - 4.71 (2 H, m), 3.71 - 3.78 (2 H, m), 3.69 (6 H, s), 2.39 - 2.55 (6 H, m), 1.87 - 2.11 (14 H, m), 1.01 - 1.11 (2 H, m), 0.73 - 0.81 (2 H, m).

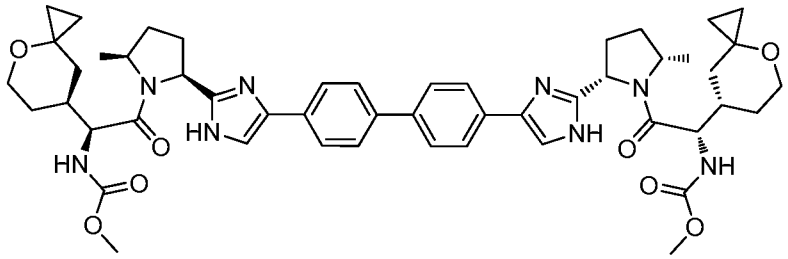
Example QC-8.1



To a solution of 4,4'-bis(2-((2S,5S)-5-methylpyrrolidin-2-yl)-1H-imidazol-4-yl)-1,1'-biphenyl, 4 HCl (25 mg, 0.042 mmol), and *Cap 5.1* (20.32 mg, 0.084 mmol) in 2 mL of DMF was added DiPEA (0.044 mL, 0.251 mmol). To the resulting mixture was added HATU (31.8 mg, 0.084 mmol) and the mixture was stirred at room temperature for 2 hours. The solvent was removed under vacuum. The crude product was purified by a reverse phase HPLC (Column: WATERS Sunfire C18 OBD 30 X 100 mm 5u, methanol/water/TFA) to give the TFA salt of *Example QC-8.1* as a white solid (32 mg, 64.3%). LC (Cond. 1): RT = 1.04 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{63}N_8O_8$ 903.48; found: 903.7; HRMS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{63}N_8O_8$ 903.4763; found: 903.4753; ^1H NMR (500MHz, CD_3OD) δ 8.03 - 7.78 (m, 10H), 5.16 (dd, *J*=10.5, 7.2 Hz, 2H), 4.84-4.73 (m, 2H), 4.33 - 4.18 (m, 2H), 3.92 - 3.78 (m, 2H), 3.74 - 3.63 (m, 6H), 3.61 - 3.43 (m, 2H), 2.69 - 2.47 (m, 2H), 2.43 - 2.07 (m, 6H), 2.06 - 1.95 (m, 2H), 1.95 - 1.74 (m, 4H), 1.56 (d, *J*=6.4 Hz,

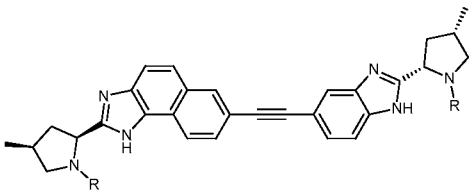
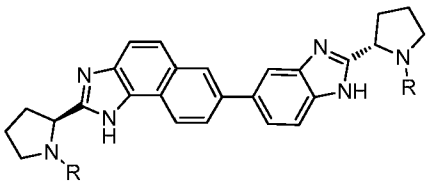
6H), 1.42 (m, 2H), 0.83 - 0.70 (m, 2H), 0.67 - 0.49 (m, 4H), 0.45 - 0.33 (m, 2H), 0.21 - 0.10 (m, 2H).

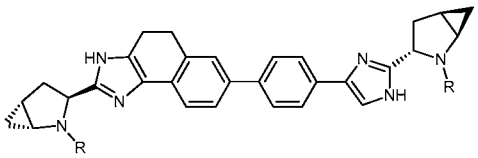
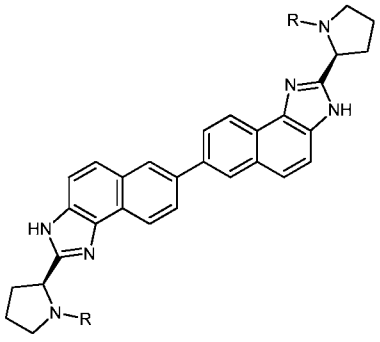
Example QC-8.2

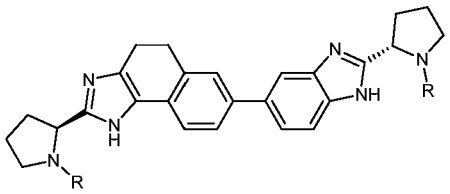
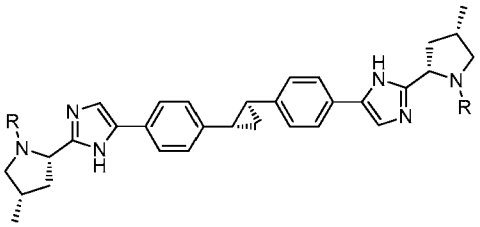


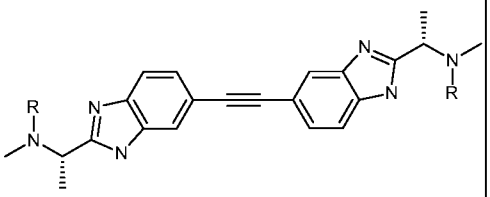
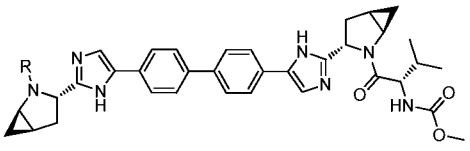
The TFA salt of *Example QC-8.2* was prepared by substituting *Cap 5.2* for *Cap 5.1* using the same procedure described for *Example QC-8.1*. LC (Cond. 1): RT = 1.01 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{63}N_8O_8$ 903.48; found: 903.7; HRMS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{63}N_8O_8$ 903.4763; found: 903.4761; ^{1}H NMR (500MHz, CD_3OD) δ 8.05 - 7.78 (m, 10H), 5.16 (dd, *J*=10.4, 7.0 Hz, 2H), 4.83 - 4.75 (m, 2H), 4.36 - 4.18 (m, 2H), 3.92 - 3.75 (m, 2H), 3.74 - 3.61 (m, 6H), 3.57 - 3.37 (m, 2H), 2.72 - 2.47 (m, 2H), 2.44 - 2.24 (m, 4H), 2.24 - 2.07 (m, 2H), 1.99 (m, 2H), 1.95 - 1.77 (m, 2H), 1.58 (d, *J*=6.4 Hz, 6H), 1.52 - 1.40 (m, 2H), 1.39 - 1.19 (m, 4H), 0.76 (m, 2H), 0.67 - 0.44 (m, 4H), 0.38 (m, 2H).

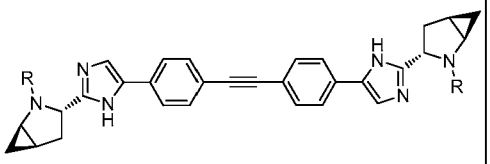
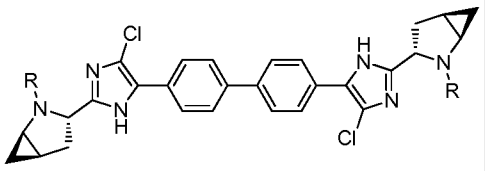
Example QC-9 to QC16 and *Example OL1 to OL10* were prepared using the same procedure described for *Example QC-1.1,* combining the corresponding core (see references within the table) with either *Cap 5.1* or *Cap 5.2* and the products were purified with a reverse phase HPLC condition and obtained as TFA salts *Example OL10* was prepared from appropriate core and Cap 6 by using standard EDC/CH_2Cl_2 coupling condition, and the product was purified with a reverse phase HPLC condition and obtained as free base. Example OL11 to OL12 were prepared from appropriate core and Cap 7 by using standard HATU/DIEA/DMF coupling condition, and the products were purified with a reverse phase HPLC condition and obtained as TFA salts.

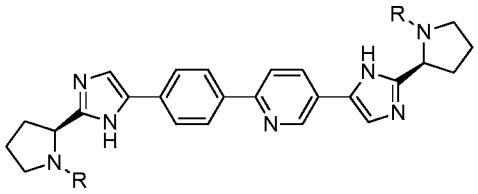
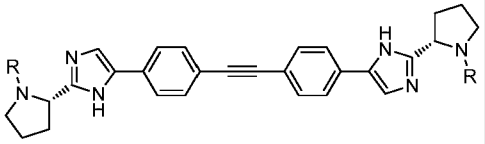
Example	*Structure*	*Ref. for penultimate precursor*	*R-OH*	*LCMS analysis*
QC9		WO2010/096302	*Cap 5.2*	LC (Cond. 4): RT = 0.81 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{52}H_{61}N_8O_8$ 925.46; found 926.12; HPLC (Cond. 6): RT = 27.33; 100%
QC10		WO2010/096302	*Cap 5.2*	LC (Cond. 5): RT = 1.66 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{57}N_8O_8$ 873.43; found 873.51; HPLC (Cond.

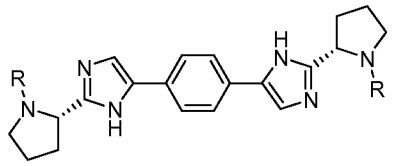
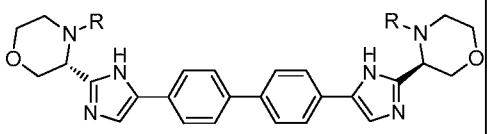
				6): RT = 24.01; 99%
QC11		WO2009/ 102633	*Cap 5.2*	LC (Cond. 4): RT = 0.75 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{52}H_{61}N_8O_8$ 925.46; found 925.87; HPLC (Cond. 6): RT = 25.22; 97%
QC12		WO2009/ 102633	*Cap 5.2*	LC (Cond. 4): RT = 0.76 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{52}H_{59}N_8O_8$ 923.45; found 923.82; HPLC (Cond.

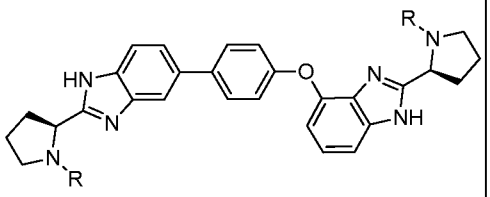
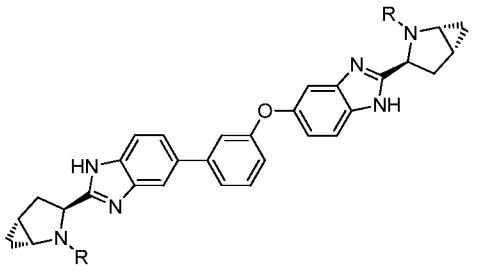
				6): RT = 26.01; 100%
QC13		WO2010/096302	*Cap 5.2*	LC (Cond. 5): RT = 1.52 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{59}N_8O_8$ 875.45; found 875.47; HPLC (Cond. 6): RT = 23.98; 99%
OL1		WO2010/117635	*Cap 5.1*	LC (Cond. 4): RT = 0.8 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{53}H_{66}N_8O_8$ 943.51; found 943.88; HPLC (Cond.

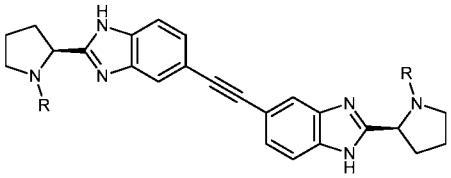
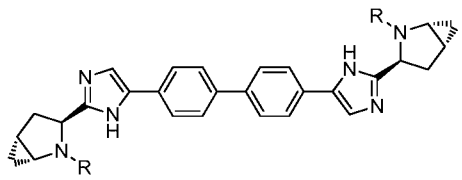
				7): RT = 11.32; 94%
OL2		WO2010/017401	*Cap 5.2*	LC (Cond. 5): RT = 1.77 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{44}H_{55}N_8O_8$ 823.41; found 823.40; HPLC (Cond. 7): RT = 11.34; 95%
OL3		WO2008/021927	*Cap 5.2*	LC (Cond. 5): RT = 1.62 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_7$ 831.43; found 831.40; HPLC (Cond.

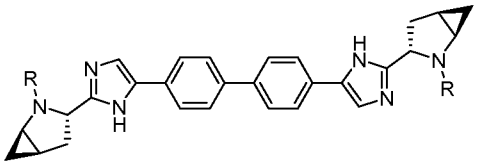
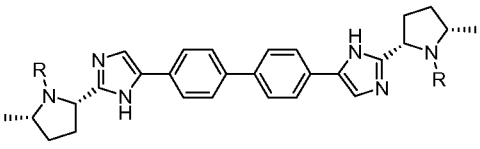
				7): RT = 10.76; 93%
OL4		WO2010/ 117635	*Cap 5.2*	LC (Cond. 4): RT = 0.78 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{52}H_{59}N_8O_8$ 923.45; found 923.77; HPLC (Cond. 7): RT = 11.65; 93%
OL5			*Cap 5.2*	LC (Cond. 4): RT = 0.98 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{57}Cl_2N_8O_8$ 967.37; found 967.32; HPLC

				(Cond. 7): RT = 13.44; 95%
OL6		WO2008/021928	*Cap 5.2*	LC (Cond. 5): RT = 1.55 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{47}H_{58}N_9O_8$ 876.44; found 876.39; HPLC (Cond. 7): RT = 4.93; 93%
OL7		WO2010/117635	*Cap 5.2*	LC (Cond. 5): RT = 1.65 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{59}N_8O_8$ 899.45; found 899.51; HPLC (Cond.

				7): RT = 5.79; 95%
QC14		See the note below the Table	*Cap 5.2*	LC (Cond. 4): RT = 0.65 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{42}H_{55}N_8O_8$ 799.41; found 799.50; HPLC (Cond. 6): RT = 20.85; 97%
OL8		See WO2008/021927 for a relevant procedure	*Cap 5.2*	LC (Cond. 5): RT = 1.61 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{59}N_8O_{10}$ 907.44; found 907.26; HPLC (Cond.

				7): RT = 5.49; 93%
QC15		WO2010/017401	*Cap 5.2*	LC (Cond. 4): RT = 0.76 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{59}N_8O_9$ 915.44; found 915.68; HPLC (Cond. 6): RT = 25.90; 99%
QC16		WO2010/017401	*Cap 5.2*	LC (Cond. 4): RT = 0.78 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{52}H_{59}N_8O_9$ 939.44; found 939.73; HPLC (Cond. 6): RT =

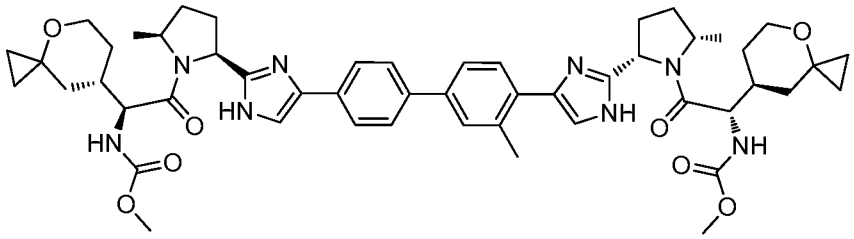
				26.17; 93%
OL9		WO2010/017401	*Cap 5.2*	LC (Cond. 5): RT = 1.67 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{46}H_{55}N_8O_8$ 847.41; found 847.6; HPLC (Cond. 7): RT = 5.38; 95%
OL10		WO2008/021927	*Cap 6*	LC (Cond. 3): RT = 2.37 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{55}N_8O_8$ 871.41; found 871.6; HPLC (Cond. 7): RT = 7.29; 95%

OL11		WO2008/021927	*Cap 7*	LC/MS (Cond. 8): RT = 3.36 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{49}F_6N_8O_6$ 947.37; found 947.39; HPLC (Cond. 9): RT = 16.28; 100%
OL12		WO2009/102325	*Cap 7*	LC/MS (Cond. 8): RT = 3.446 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{53}F_6N_8O_6$ 951.40; found 951.41; HPLC

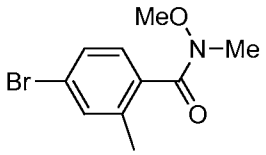
				(Cond. 9): RT = 17.44; 100%

* The penultimate precursor of Example QC14 was prepared starting from 1,1'-(1,4-phenylene)bis(2-aminoethanone) dihydrochloride (see TL, **1986**, p. 5759 for a preparative procedure) and Boc-L-proline according to a three-step protocol (amide coupling, cyclization of ketoamide to imidazole, and Boc-deprotection) described in WO2008/021927.

Example QC-17.1

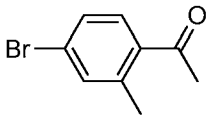


Example QC-17.1, step a



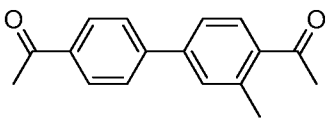
To a solution of 4-bromo-2-methylbenzoic acid (10 g, 46.5 mmol) in DMF (150 mL) was added N, O-dimethylhydroxylamine hydrochloride (5.44 g, 55.8 mmol) at RT followed by HOBT (8.55 g, 55.8 mmol). Then EDC (10.7 g, 55.8 mmol) was added followed by DIPEA (24.4 mL, 140 mmol) and the reaction mixture was stirred at RT for 12 h. The reaction mixture was then diluted with EtOAc (150 mL), washed with water (3 x 250 mL) and brine (150 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude *QC-17.1, step a* (9.5 g), which was submitted to the next step as such. ^{1}H NMR ($CDCl_3$, δ = 7.26 ppm, 400 MHz): δ 7.37 (d, J = 1.6 Hz, 1H), 7.34 (dd, J = 8.0, 1.6 Hz, 1H), 7.14 (d, J = 8.0 Hz, 1H), 3.47 (s, 3H), 3.30 (s, 3H), 2.31 (s, 3H). LC/MS: Anal. Calcd. For $[M+H]^+$ $C_{10}H_{13}{}^{81}BrNO_2$: 260.01; found 260.0.

Example QC-17.1, step b



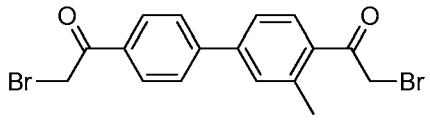
QC-17.1, step a (9.5 g, 36.8 mmol) was dissolved in diethyl ether (150 mL) and cooled to 0°C. Then methylmagnesium iodide (3.0 M in diethyl ether, 24.54 mL, 73.6 mmol) was added drop wise over 10 minutes. The reaction was stirred for 6 h at 40 °C and then brought to room temperature and stirred for 12 h. The reaction mixture was cooled to 0 °C, quenched with ice and then with 1.5N HCl (50 mL). The organic layer was separated and the aqueous layer was extracted with methyl tert-butyl ether (2 x 100 mL), dried over Na_2SO_4 and concentrated under reduced pressure. The crude was purified by flash chromatography (Silica gel, 60-120, EtOAc: petroleum ether, 2:98) to afford *QC-17.1, step b* (6.25 g) as pale yellow liquid. ^{1}H NMR ($CDCl_3$, δ = 7.26 ppm, 400 MHz): δ 7.55 (d, *J* = 8.0 Hz, 1H), 7.41 (s, 1H), 7.40 (d, *J* = 8.0 Hz, 1H), 2.55 (s, 3H), 2.50 (s, 3H).

Example QC-17.1, step c



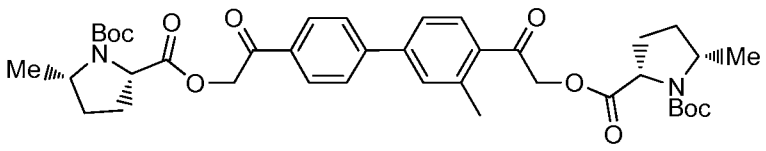
4-Acetylphenylboronic acid (5.39 g, 32.9 mmol) was added to a sealed tube containing *QC-17.1, step b* (7.0 g, 32.9 mmol) in MeOH (75.0 mL) and the reaction mixture was purged with nitrogen for 10 minutes. Then K_2CO_3 (9.08 g, 65.7 mmol) was added followed by $Pd(Ph_3P)_4$ (1.139 g, 0.986 mmol) and the reaction mixture was purged with nitrogen for further 10 minutes. The reaction mixture was heated to 75 °C for 12 h. Then the reaction mixture was concentrated under reduced pressure and the residue was diluted with EtOAc (100 mL) and washed with water (2 x 100 mL), brine (50 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by combiflash (Silicycle, SiO_2, 10-15% EtOAc/petroleum ether) to afford *QC-17.1, step c* (6.5 g) as a white solid. ^{1}H NMR ($CDCl_3$, δ = 7.26 ppm, 400 MHz): δ 8.06-8.04 (m, 2H), 7.81 (d, *J* = 8.0 Hz, 1H), 7.72-7.70 (m, 2H), 7.54-7.49 (m, 2H), 2.65 (s, 3H), 2.63 (s, 6H).

Example QC-17.1, step d



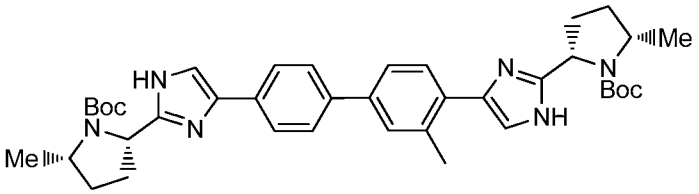
Bromine (1.12 mL, 21.8 mmol) (diluted in 10 mL of dioxane) was added slowly (over 10 minutes) to a solution of *QC-17.1, step c* (2.75 g, 10.90 mmol) in dioxane (50 mL) at 10 °C, and the mixture was stirred at RT for 2 h. The reaction was quenched with 10%$NaHCO_3$ (25 mL) and extracted with DCM (50 mL). The organic phase was dried over Na_2SO_4 and concentrated under reduced pressure to afford crude *QC-17.1, step d* (5.0 g) which was used as such in the next step without purification. LC/MS: Anal. Calcd. For $[M+H]^+$ $C_{17}H_{15}{}^{79/81}Br_2O_2$: 410.94; found 411.0.

Example QC-17.1, step e



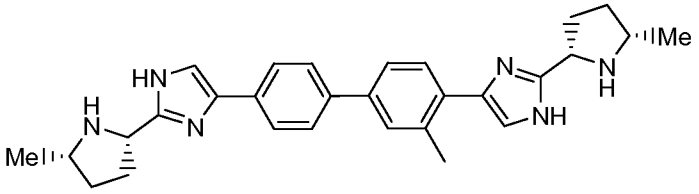
To a solution of crude *QC-17.1, step d* (5.1 g, 12 mmol) in acetonitrile (75 mL) was added *QC-17.1, step a* (5.70 g, 24.9 mmol) followed by DIPEA (8.69 mL, 49.7 mmol) at 0 °C. After 10 minutes, the temperature was raised to RT and stirred for 2 h. Then the reaction mixture was diluted with EtOAc (100 mL) and washed with 10% $NaHCO_3$ (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by combiflash (Silicycle, SiO_2, 25-30% EtOAc/petroleum ether) to afford *QC-17.1, step e* (5.8 g) as a pale yellow oil. ^1H NMR ($CDCl_3$, δ = 7.26 ppm, 400 MHz): δ 8.00 (app bd, 2H), 7.71 (app d, 3H), 7.53-7.51 (m, 2H), 5.61-5.34 (m, 2H), 5.29-5.04 (m, 2H), 4.51-4.36 (m, 2H), 4.09-3.91 (m, 2H), 2.59 (s, 3H), 2.35-2.21 (m, 4H), 2.15-2.04 (m, 2H), 1.80-1.63 (m, 2H), 1.47/1.44 (s, 18H), 1.35-1.27 (m, 6H). LC/MS: Anal. Calcd. for $[M-H]^-$ $C_{39}H_{49}N_2O_{10}$: 705.35; found 705.30.

Example QC-17.1, step f



To a solution of *QC-17.1, step e* (5.6 g, 7.92 mmol) in xylenes (75 mL) was added NH_4OAc (12.21 g, 158 mmol), and the reaction mixture was purged with nitrogen for 10 minutes. After heating for 18 h at 130 °C, the reaction mixture was cooled to room temperature and the volatile components were removed under reduced pressure. Then the reaction mixture was diluted with EtOAc (100 mL) and washed with 10% $NaHCO_3$ (50 mL), brine (50 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by combiflash (Redi Sep, C-18 column , 30-40% acetonitrile :10 mM ammonium bicarbonate) to afford *QC-17.1, step f* (2.3 g) as pale yellow solid. ^1H NMR (DMSO-d_6, δ = 2.50 ppm, 400 MHz): δ 12.27/12.0/11.77/11.71 (s, 2H), 7.92-7.63 (m, 5H), 7.58-7.47 (m, 3H), 7.24 (br s, 1H), 4.90-4.75 (m, 2H), 3.92-3.84 (m, 2H), 2.54 (s, 3H), 2.20-2.01 (m, 6H), 1.73-1.65 (m, 2H), 1.48-1.12 (m, 24H). LC/MS: Anal. Calcd. For $[M-H]^-$ $C_{39}H_{49}N_6O_4$: 665.39; found 665.4.

Example QC-17.1, step g



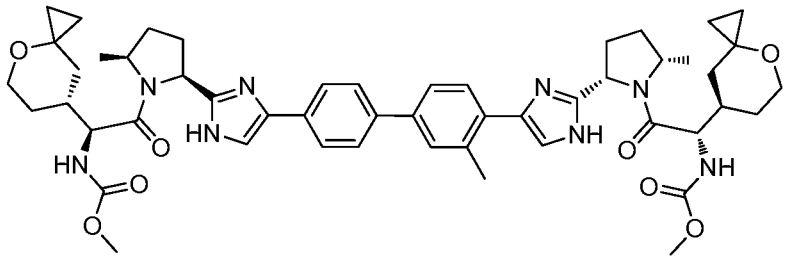
To a solution of *QC-17.1, step f* (1.55 g, 2.32 mmol) in MeOH (10 mL) was added in HCl/MeOH (4N, 58.1 mL) and stirred at room temperature for 2 h. The volatile components were removed *in vacuo*, and the residue was co-evaporated with dry DCM (3 x 25 mL). The resulting solid was exposed to high vacuum to afford the HCl salt of *QC-17.1, step e* (1.3 g) as a pale yellow solid. ^1H NMR (MeOD, δ = 3.34 ppm, 400 MHz): δ 8.06 (br s, 1H), 7.98 (d, *J* = 8.4 Hz, 2H), 7.90 (d, *J* = 8.4 Hz, 2H), 7.86 (br s, 1H), 7.78 (br s, 1H), 7.74 (d, *J* = 8.4 Hz, 1H), 7.71 (d, *J* = 8.4 Hz, 1H), 5.27-5.20 (m, 2H), 4.04-4.00 (m, 2H), 2.80-2.67 (m, 4H), 2.59 (s, 3H), 2.55-2.46

(m, 2H), 2.15-2.06 (m, 2H), 1.60 (d, *J* = 6.4, 6H). LC/MS: Anal. Calcd. For [[M+H]$^+$ $C_{29}H_{35}N_6$: 467.28; found 467.2.

Example QC-17.1

HATU (37.2 mg, 0.098 mmol) was added to a stirred solution of *Cap 5.2* (26.2 mg, 0.108 mmol) and *Example QC-17.1, step g* (30 mg, 0.049 mmol) in DMF (2 mL) and DIPEA (0.051 ml, 0.294 mmol). The reaction mixture was stirred at RT for 2h and concentrated under vacuum. The residue was diluted with MeOH, filtered and purified by prep HPLC (Waters Sunfire C18 OBD 30 X 100 mm 5u; MeOH/water w/ TFA buffer) to afford the TFA salt of *Example QC-17.1* (34 mg) as an off-white solid. LC/MS (Cond. 1): RT = 1.743 min; LC/MS: Anal. Calcd. for [M+H]$^+$ $C_{51}H_{65}N_8O_8$ 917.12; found 917.9; HPLC (Cond. 6): RT = 26.27; 97% homogeneity. ^{1}H NMR (500MHz, CD_3OD) δ 8.05 - 7.92 (m, 1H), 7.90 - 7.83 (m, 4H), 7.75 (s, 1H), 7.72 - 7.65 (m, 1H), 7.63 (s, 1H), 7.56 (d, *J*=8.2 Hz, 1H), 5.25 - 5.10 (m, 2H), 4.84 - 4.78 (m, 2H), 4.27 - 4.15 (m, 2H), 3.79 (d, *J*=7.9 Hz, 2H), 3.65 (s, 4H), 3.49 - 3.38 (m, 2H), 2.59 - 2.51 (m, 2H), 2.47 (s, 3H), 2.42 - 2.33 (m, 2H), 2.33 - 2.23 (m, 2H), 2.16 (d, *J*=17.7 Hz, 2H), 2.04 - 1.95 (m, 2H), 1.82 (t, *J*=12.2 Hz, 2H), 1.67 - 1.52 (m, 6H), 1.51 - 1.38 (m, 2H), 1.36 - 1.21 (m, 5H), 0.83 - 0.72 (m, 2H), 0.63 - 0.45 (m, 4H), 0.43 - 0.30 (m, 2H).

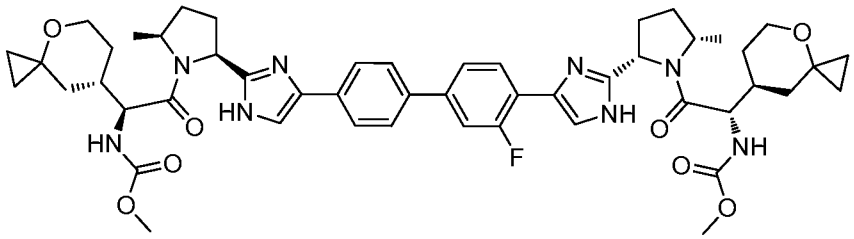
Example QC-17.2



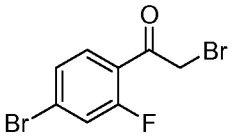
The TFA salt of *Example QC-17.2* was prepared by substituting *Cap 5.1* for *Cap 5.2* and using the same procedure described for *Example QC-17.1*. LC/MS (Cond. 1): RT = 1.710 min; LC/MS: Anal. Calcd. for [M+H]$^+$ $C_{51}H_{65}N_8O_8$ 917.12; found 917.6; HPLC (Cond. 6): RT = 26.05; 98% homogeneity. ^{1}H NMR (500MHz, CD_3OD) δ 8.01 - 7.95 (m, 1H), 7.90 (s, 1H), 7.88 - 7.80 (m, 5H), 7.75 (s, 1H), 7.72 - 7.66 (m, 2H), 7.63 (s, 1H), 7.54 (d, *J*=7.9 Hz, 1H), 5.16 (dd, *J*=10.1, 7.3 Hz, 2H),

4.82 - 4.74 (m, 2H), 4.22 (d, *J*=8.9 Hz, 2H), 3.89 - 3.81 (m, 2H), 3.67 (s, 6H), 3.53 - 3.45 (m, 2H), 2.58 - 2.50 (m, 3H), 2.47 (s, 3H), 2.42 - 2.33 (m, 3H), 2.27 (br. s., 2H), 2.15 (dd, *J*=19.5, 10.1 Hz, 2H), 1.98 (dd, *J*=11.7, 5.3 Hz, 2H), 1.89 (t, *J*=12.4 Hz, 2H), 1.79 (d, *J*=12.2 Hz, 2H), 1.55 (t, *J*=6.7 Hz, 6H), 1.46 - 1.38 (m, 2H), 1.35 - 1.27 (m, 3H), 0.76 (dt, *J*=11.1, 5.3 Hz, 2H), 0.69 - 0.50 (m, 5H), 0.38 (d, *J*=5.5 Hz, 2H), 0.25 - 0.12 (m, 2H).

Example QC-18.1

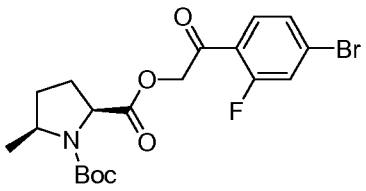


Example QC-18.1, step a



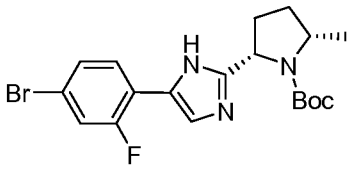
To a solution of 1-(4-bromo-2-fluorophenyl)ethanone (5.0 g, 23 mmol) in dioxane (150 mL) and ether (150 mL) in a ice-water bath at 0 °C was added bromine (1.18 mL, 23.0 mmol) dropwise. The reaction was stirred for 1 hr, allowed to warm to RT and stirred for 16 hrs. The mixture was partitioned between EtOAc (50 mL) and sat. $NaHCO_3$ (50 mL), and the organic layer was washed with water and dried over Na_2SO_4. The volatile component was evaporated *in vacuo* and the solid was dried under vacuum overnight to afford *Example 18.1, step a* (6.94 g) as white solid. ^1H NMR (DMSO-d_6, δ = 2.5 ppm, 400 MHz): 7.87-7.79 (m, 2H), 7.62-7.60 (m, 1H), 4.84 (s, 2H).

Example QC-18.1, step b



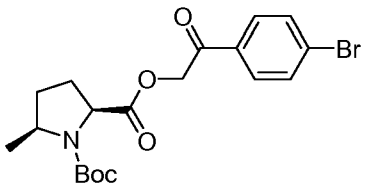
To a solution of *Example 18.1, step a* (2.58 g, 8.72 mmol) and (2S,5S)-1-(tert-butoxycarbonyl)-5-methylpyrrolidine-2-carboxylic acid (2.00 g, 8.72 mmol) in acetonitrile (50 mL) was added DIEA (2.285 mL, 13.08 mmol), and the mixture was stirred at room temperature for 64 hrs. Solvent was removed *in vacuo* and the residue was partitioned between EtOAc (40 mL) and water (30 mL). The organic layer was washed with sat. $NaHCO_3$ and brine, dried with Na_2SO_4 and evaporated *in vacuo* to afford *Example 18.1, step b* (3.8 g) as yellow solid. ^1H NMR ($CDCl_3$, 400 MHz): 7.87 (m, 1H), 7.44 (m, 2H), 5.42-5.09 (m, 2H), 4.53-4.40 (m, 1H), 4.10-3.95 (m, 1H), 2.31 (m, 2H), 2.09 (m, 1H), 1.75 (m, 1H), 1.49-1.46 (two singlet, 9H), 1.33 (m, 3H). LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{19}H_{24}BrNNaO_5$: 466.06; found: 466.03.

Example QC-18.1, step c



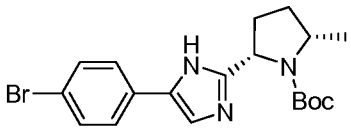
To a pressure tube containing a solution of *Example 18.1, step b* (3.8 g, 8.6 mmol) in xylenes (40 mL) was added ammonium acetate (6.59 g, 86 mmol), and the reaction vessel was capped and heated at 140 °C for 6 hrs. The volatile component was evaporated *in vacuo* and the residue was partitioned between DCM (80 mL) and water (50 mL). The organic layer was separated and washed with sat. $NaHCO_3$, and dried with Na_2SO_4. Removal of the solvent *in vacuo* resulted in a red oil which was purified by flash chromatograph (0-40% EtOAc/Hexane) to afford *Example 18.1, step c* (2.3 g) as brown solid. ^1H NMR (DMSO-d_6, δ = 2.5 ppm, 400 MHz): 7.98 (app. t, J =8.4 Hz, 1H), 7.65 (dd, J = 11, 1.9 Hz, 1H), 7.45 (dd, J = 8.3, 2, 1H), 7.36 (m, 1H), 4.85 (m, 1H), 3.90 (m, 1H), 2.15-2.07 (m, 3H), 1.73 (m, 1H), 1.40-1.17 (m, 12H). LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{19}H_{23}{}^{79}BrFN_3NaO_2$: 446.09; found: 446.00.

Example QC-18.1, step d



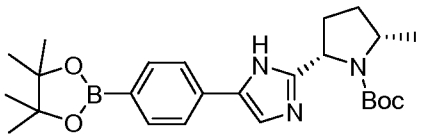
To a solution of 2-bromo-1-(4-bromophenyl)ethanone (2.425 g, 8.72 mmol) and (2S,5S)-1-(tert-butoxycarbonyl)-5-methylpyrrolidine-2-carboxylic acid (2 g, 8.72 mmol) in acetonitrile (50 mL) was added DIEA (1.524 mL, 8.72 mmol), and the mixture was stirred at room temperature for 16 hrs. Solvent was removed *in vacuo* and the residue was partitioned between EtOAc (40 mL) and water (30 mL). The organic phase was washed with sat. $NaHCO_3$ and brine, and dried with Na_2SO_4. Removal of the volatile component *in vacuo* afforded *Example 18.1, step d* (1.74 g) as light yellow solid, which was used without further purification. ^1H NMR (DMSO-d_6, δ = 2.5 ppm, 400 MHz): 7.95-7.90 (m, 2H), 7.81 (m, 1H), 7.79 (m, 1H), 5.63-5.44 (m, 2H), 4.36 (m, 1H), 3.99 (m, 1H), 2.27 (m, 1H), 2.09 (m, 2H), 1.63 (m, 1H), 1.41-1.37 (two singlet, 9H), 1.19 (m, 3H). LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{19}H_{24}BrNNaO_5$: 448.07; found: 448.06.

Example QC-18.1, step e



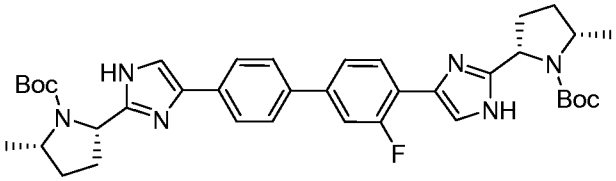
To a pressure tube containing a solution of *Example 18.1, step d* (3.4 g, 8.0 mmol) in xylenes (40 mL) was added ammonium acetate (6.15 g, 80 mmol), and the mixture was heated at 140 °C for 6 hrs. The volatile component was removed *in vacuo,* the residue was partitioned carefully between DCM (60 mL) and sat. $NaHCO_3$ (30 mL), and the organic layer was separated and dried with Na_2SO_4. The solvent was removed *in vacuo* to give red solid, which was purified by flash chromatograph (5-50% EtOAc/Hexane) to afford *Example 18.1, step e* (2.65 g) as light brown solid. ^1H NMR (DMSO-d_6, δ = 2.5 ppm, 400 MHz): 7.73-7.71 (m, 2H), 7.59-7.50 (m, 3H), 4.80 (m, 1H), 3.89 (m, 1H), 2.10 (m, 3H), 1.71 (m, 1H), 1.40-1.17 (m, 12H). LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{19}H_{24}BrN_3NaO_2$: 428.09; found: 428.07.

Example QC-18.1, step f



To a solution of *Example 18.1, step e* (2.64 g, 6.50 mmol) and 4,4,4',4',5,5,5',5'-octamethyl-2,2'-bi(1,3,2-dioxaborolane) (3.30 g, 13.0 mmol) in dioxane (40 mL) was added potassium acetate (1.594 g, 16.24 mmol). The mixture was degassed by bubbling nitrogen for 10 min, $Pd(Ph_3P)_4$ (0.375 g, 0.325 mmol) was added and degassing was continued for an additional 15 min. The reaction vessel was then sealed and heated at 80 °C for 16 hrs. The volatile component was evaporated *in vacuo* and the residue was partitioned between DCM (100 mL) and half sat. $NaHCO_3$ (50 mL). The organic layer was separated, dried with Na_2SO_4, and evaporated *in vacuo* to afford a crude red oil which was purified by flash chromatograph (10-90% EtOAc/hexanes). *Example 18.1, step f* (2.7g) was obtained as yellow foam. ^1H NMR (DMSO-d_6, δ = 2.5 ppm, 400 MHz): 7.77 (d, J = 8.3 Hz, 2H), 7.64-7.53 (m, 3H), 4.80 (m, 1H), 3.88 (m, 1H), 2.09 (m, 3H), 1.73 (m, 1H), 1.43-1.08 (m, 24H). LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{25}H_{37}BrBN_3O_4$: 454.29; found: 454.23.

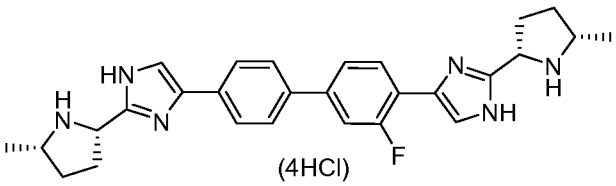
Example QC-18.1, step g



To a pressure tube containing a solution of *Example 18.1, step f* (2.70 g, 5.96 mmol) and Example 4, step c (2.30 g, 5.42 mmol) in DME (70 mL) were added water (17.50 mL) and sodium bicarbonate (2.27 g, 27.1 mmol). The mixture was degassed by bubbling nitrogen for 15 min and $Pd(Ph_3P)_4$ (0.313 g, 0.271 mmol) was added and degassing was continued for an additional 15 min. The reaction vessel was sealed and heated at 80 °C for 15 hrs. The solvent was evaporated *in vacuo* and the residue was partitioned between DCM (100 mL) and water (50 mL). The organic layer was separated, dried with Na_2SO_4 and the volatile component was removed *in vacuo* and the resultant red crude solid was purified by flash chromatograph (30-100%

EtOAc/Hexane). *Example 18.1, step g* (1.95g) was obtained as yellow solid. ^{1}H NMR (DMSO-d_6, δ = 2.5 ppm, 400 MHz): 8.10 (m, 1H), 7.87-7.71 (m, 4H), 7.61-7.55 (m, 3H), 7.37 (m, 1H), 4.85 (m, 2H), 3.91 (m, 2H), 2.11 (m, 6H), 1.76 (m, 2H), 1.42-1.08 (m, 24H). LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{35}H_{48}FN_6O_4$: 671.37; found: 671.35.

Example QC-18.1, step h



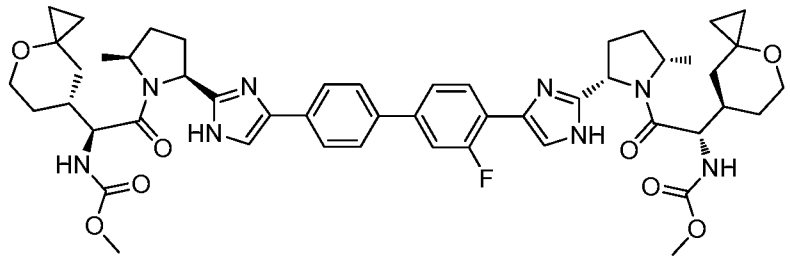
To a suspension of *Example 18.1, step g* (1.95 g, 2.91 mmol) in dioxane (10 mL) was added 4N HCl in dioxane (9.72 mL, 320 mmol), and the mixture was stirred at room temperature for 6 hrs. Methanol (1 mL) was added and stirring was continued for 1 hr. The volatile component was removed *in vacuo* and the residue was dried under vacuum overnight. The HCl salt of *Example 18.1, step h* (1.7 g) was retrieved as yellow solid. ^{1}H NMR (DMSO-d_6), δ = 2.5 ppm, 400 MHz): 10.34/10.29/9.43/9.08 (four broad S, ~4H), 8.16 (t, *J* = 8.3 Hz, 1H), 8.10 (br s, 1H), 8.00 (d, *J* = 8.3 Hz, 2H), 7.92 (d, *J* = 8.3 Hz, 2H), 7.78-7.72 (m, 3H), 4.99-4.89 (m, 2H), 3.80 (m, 2H), 2.53-2.42 (m, 4H), 2.25 (m, 2H), 1.87 (m, 2H), 1.44 (d, *J* = 6.5, 3H), 1.43 (d, *J* = 6.5, 3H). LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{28}H_{32}FN_6$: 471.27; found: 471.17.

Example QC-18.1

HATU (37.0 mg, 0.097 mmol) was added to a stirred solution of *Cap 5.2* (26.0 mg, 0.107 mmol) and *Example QC-18.1, step f* (30 mg, 0.049 mmol) in DMF (2 mL) and DIPEA (0.051 ml, 0.294 mmol). The reaction mixture was stirred at RT for 2h and concentrated under vacuum. The residue was diluted with MeOH, filtered and purified by prep HPLC (Waters Sunfire C18 OBD 30 X 100 mm 5u; MeOH/water w/ TFA buffer) to afford the TFA salt of *Example QC-17.1* (34 mg) as an off-white solid. LC/MS (Cond. 1): RT = 1.77 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{62}FN_8O_8$ 921.47; found 921.11; HPLC (Cond. 6): RT = 26.39; 99% homogeneity. ^{1}H NMR (500MHz, CD_3OD) δ 8.13 - 7.98 (m, 1H), 7.95 - 7.84 (m,

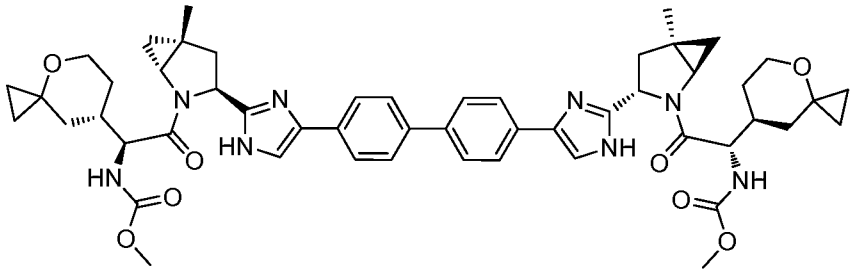
5H), 7.82 (s, 1H), 7.75 - 7.67 (m, 2H), 5.24 - 5.12 (m, 2H), 4.82 - 4.76 (m, 2H), 4.28 - 4.17 (m, 2H), 3.87 - 3.75 (m, 2H), 3.72 - 3.61 (m, 6H), 3.42 (t, *J*=11.6 Hz, 2H), 2.52 (d, *J*=3.4 Hz, 2H), 2.44 - 2.23 (m, 4H), 2.18 - 2.08 (m, 2H), 2.03 - 1.94 (m, 2H), 1.82 (t, *J*=12.2 Hz, 2H), 1.58 (d, *J*=6.7 Hz, 6H), 1.47 (td, *J*=12.1, 8.2 Hz, 2H), 1.33 - 1.18 (m, 5H), 0.84 - 0.74 (m, 2H), 0.57 (br. s., 2H), 0.50 (br. s., 2H), 0.37 (d, *J*=4.0 Hz, 2H).

Example QC-18.2

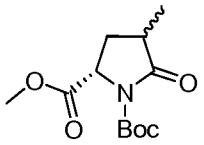


The TFA salt of *Example QC-18.2* was prepared by substituting *Cap 5.1* for *Cap 5.2* using the same procedure described for *Example QC-18.1*. LC/MS (Cond. 1): RT = 1.75 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{62}FN_8O_8$ 921.47; found 921.25; HPLC (Cond. 6): RT = 26.02; 98% homogeneity. ^{1}H NMR (400MHz, CD_3OD) δ 7.96 (d, *J*=9.3 Hz, 1H), 7.92 - 7.80 (m, 6H), 7.79 - 7.64 (m, 4H), 5.26 - 5.12 (m, 2H), 4.22 (d, *J*=6.5 Hz, 3H), 3.84 (d, *J*=7.8 Hz, 3H), 3.73 - 3.64 (m, 7H), 3.48 (t, *J*=11.8 Hz, 3H), 2.56 - 2.48 (m, 2H), 2.45 - 2.23 (m, 5H), 2.18 - 2.09 (m, 2H), 2.04 - 1.94 (m, 3H), 1.94 - 1.74 (m, 5H), 1.55 (d, *J*=6.3 Hz, 6H), 1.47 - 1.35 (m, 3H), 1.29 (br. s., 4H), 1.03 - 0.84 (m, 3H), 0.81 - 0.70 (m, 3H), 0.63 (t, *J*=13.6 Hz, 3H), 0.54 (d, *J*=4.8 Hz, 2H), 0.38 (d, *J*=5.3 Hz, 2H), 0.24 - 0.08 (m, 2H).

Example QC-19

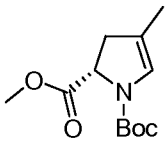


Example QC-19, step a



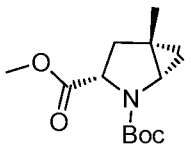
The above ester was prepared as a diastereomeric mixture from (S)-1-tert-butyl 2-methyl 5-oxopyrrolidine-1,2-dicarboxylate according to the procedure described in *Tetrahedon Letters*, ***2003***, 3203-3205.

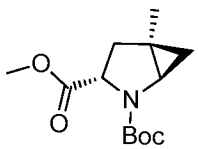
Example QC-19, step b



To a cooled (-50 °C) toluene (45 mL) solution of *Example QC-19, step a* (4.75g, 18.5 mmol) was added Superhydride (19.20 mL of 1M/THF, 19.20 mmol) dropwise over 10 min. Hunig's base (13.6 mL, 78 mmol) was added, and stirred for 10 min; DMAP (0.122 g, 0.997 mmol) was added as a solid, stirred for 15 min; and, trifluoroacetic anhydride (2.98 mL, 21.1 mmol) was added dropwise over 15 min, the cooling bath was removed, and stirring was continued for 4 hr while allowing it to warm to room temperature. The reaction mixture was washed with water (50 mL), sat. NaCl (30 mL), and the organic phase was concentrated *in vacuo*. The resulting crude material was purified with flash chromatography (8-60% EtOAc/Hexane) to afford *Example QC-19, step b* as yellow oil (2.85 g). ^{1}H NMR ($CDCl_3$, 400 MHz): 6.36 (s, 0.5H), 6.25 (s, 0.5H), 4.70-4.57 (m, 1H), 3.78 (s, 3H), 2.96 (m, 1H), 2.54 (m, 1H), 1.70 (s, 3H), 1.50 (s, 4.5H), 1.44 (s, 4.5H).

Example QC-19, step c



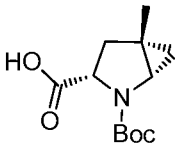


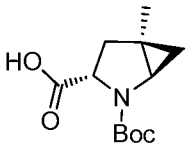
Example QC-19 , step c.1 *Example QC-19, step c.2*

Diethylzinc (1.1 M in toluene, 59.1 mL, 65.0 mmol) was added dropwise over 20 min to a cooled (-23 °C) toluene (60 mL) solution of *Example QC-19, step b* (5.23

g, 21.7 mmol), and stirred for 10 min. Chloroiodomethane (9.44 mL, 130 mmol) was added dropwise over 10 min, and the reaction mixture was stirred at -21 °C for 16 hr. Sat. $NaHCO_3$ (60 mL) was added to the reaction mixture, the cooling bath was removed, and the mixture was stirred for 10 min. It was then filtered, and the filter cake was washed with toluene (50 mL). The filtrate was partitioned, and the organic layer was dried with Na_2SO_4, and concentrated *in vacuo*. The resulting crude material was purified with flash chromatography (2-10% EtOAc/Hexane) to afford *Example QC-19 , step c.1* (first elute; colorless oil; 2.88 g) and *Example QC-19 , step c.2* (second elute; colorless oil; 1.01g). Relative stereochemical assignment was made based on NOE studies. *Example QC-19 , step c.1*: ^{1}H NMR ($CDCl_3$, 400 MHz): 4.65-4.52 (m, 1H), 3.72 (s, 3H), 3.28-3.17 (m, 1H), 2.44-2.32 (m, 1H), 2.16-2.10 (m, 1H), 1.51-1.42 (two s, 9H), 1.24 (s, 3H), 1.07 (m, 1H), 0.69-0.60 (m, 1H). *Example QC-19 , step c.2*: ^{1}H NMR ($CDCl_3$, 400 MHz): 4.0 (m, 1H), 3.76 (s, 3H), 3.32-3.16 (m, 1H), 2.43 (m, 1H), 2.01 (m, 1H), 1.44 (s, 9H), 1.35 (s, 3H), 0.76-0.66 (m, 2H).

Example QC-19, step d



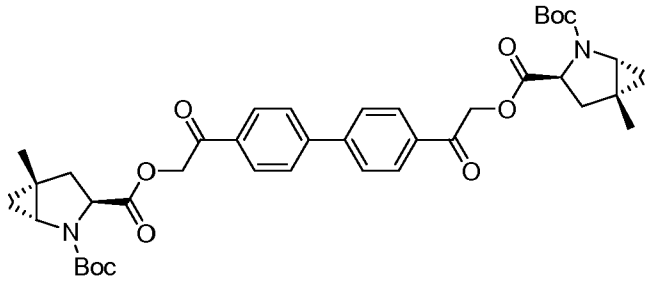


Example QC-19, step d.1 *Example QC-19, step d.2*

To a solution of *Example QC-19 , step c.1* (2.88 g, 11.3 mmol) in ethanol (20 mL) was added a solution of LiOH (0.324 g, 13.5 mmol) in water (10.00 mL), and the reaction mixture was stirred at room temperature for 6 hr. Most of the volatile component was removed *in vacuo,* and the residue was partitioned between water (20 mL) and ether (20 mL). The aqueous layer was chilled in an ice-water bath, acidified with a 1N HCl to a pH region of 2, and extracted with EtOAc (30 mL, 4X). The combined organic phase was dried with Na_2SO_4 and evaporated *in vacuo* to afford *Example QC-19 , step d.1* as a sticky solid (2.55g). ^{1}H NMR ($CDCl_3$, 400 MHz): 4.64 (m, 1H), 3.25 (appt s, 1H), 2.70-2.40 (m, 1H), 2.14 (m, 1H), 1.54-1.44 (m, 9H), 1.27 (s, 3H), 1.10-0.80 (m, 1H), 0.67 (m, 1H). *Example QC-19 , step d.2* was prepared similarly from *Example QC-19 , step c.2*. ^{1}H NMR ($CDCl_3$, 400 MHz):

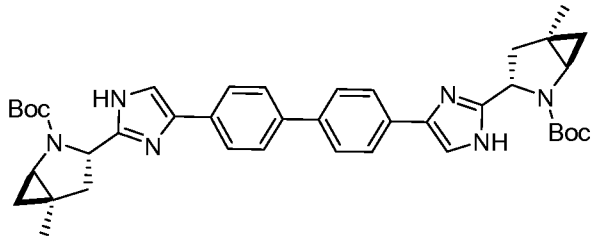
4.13 (app br s, 1H), 3.06 (app br s, 1H), 2.55/2.41 (overlapping app br s, 2H), 1.51 (s, 9H), 1.27 (s, 3H), 0.76 (app t, J = 5.6 Hz, 1H), 0.60 (app br s, 1H).

Example QC-19, step e



To a suspension of *Example QC-19 , step d.2* (1.09 g, 4.52 mmol) and 1,1'-(biphenyl-4,4'-diyl)bis(2-bromoethanone) (0.869 g, 2.19 mmol) in acetonitrile (40 mL) was added DIEA (0.789 mL, 4.52 mmol), and the mixture was stirred at room temperature for 4 hrs. The volatile component was removed *in vacuo*, and the residue was partitioned between EtOAc (70 mL) and water (50 mL). The organic layer was washed with sat. $NaHCO_3$ (50 mL), dried with Na_2SO_4, evaporated *in vacuo* and dried under vacuum to give *Example QC-19 , step e* (1.54 g) as white foam. ^{1}H NMR (DMSO-d_6, δ = 2.5 ppm, 400 MHz): 8.13 (d, J=8.3 Hz, 4H), 7.99 (d, J=8.5 Hz, 4H), 5.70-5.54 (m, 4H), 4.17 (m, 2H), 3.13-3.11 (m, 2H), 2.58-2.46 (m, 2H), 2.19 (m, 2H), 1.42-1.37 (two s, 18H), 1.24 (s, 6H), 0.76-0.70 (m, 4H). LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{40}H_{48}N_2NaO_{10}$: 739.32; found: 739.52.

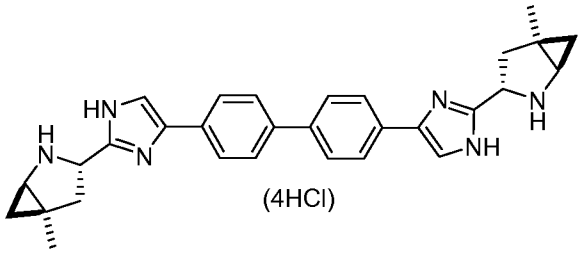
Example QC-19, step f



To a pressure tube containing a solution of *Example QC-19 , step e* (1.54 g, 2.15 mmol) in xylenes (40 mL) was added ammonium acetate (1.656 g, 21.48 mmol), and the vessel was capped and heated at 140 °C for 5 hrs. The volatile component was removed *in vacuo* and the residue was carefully partitioned between DCM (50 mL) and water (50 mL) while adding sufficient saturated $NaHCO_3$ solution so that at

the end of partitioning, the aqueous phase is neutral or basic. The organic layer was dried with Na_2SO_4, evaporated *in vacuo*, and the resulting crude material was purified by flash chromatograph (10-100% EtOAc/Hexane) to afford *Example QC-19 , step f* (0.65 g) as brown solid. ^{1}H NMR (DMSO-d_6, δ = 2.5 ppm, 400 MHz): 7.84-7.65 (m, 8H), 7.55-7.54 (m, 1.7H), 7.32-7.30 (m, 0.3H), 4.60 (m, 2H), 3.20 (m, 2H), 2.48-2.43 (m, 2H), 2.12 (m, 2H), 1.45-1.07 (m, 24H), 0.77 (m, 2H), 0.69 (m, 2H). LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{40}H_{49}N_6O_4$: 677.38; found: 677.45.

Example QC-19, step g



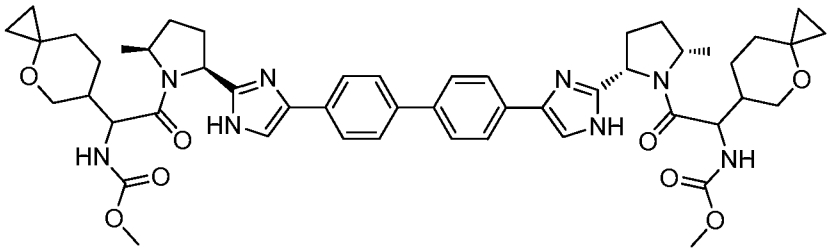
To a solution of *Example QC-19 , step f* (0.65 g, 0.960 mmol) in dioxane (5 mL) was added 4N HCl in dioxane (5.84 mL, 192 mmol), and the mixture was stirred at room temperature for 6 hrs. The volatile component was removed *in vacuo* and dried under vacuum overnight to afford the HCl salt of *Example QC-19 , step g* (0.6 g) as brown solid. ^{1}H NMR (DMSO-d_6, δ = 2.5 ppm, 400 MHz): 10.5-10 (br s, ~3.2H), 7.99 (br s, 2H), 7.95 (d, *J* = 8.5, 4H), 7.85 (d, *J* = 8.5 Hz, 4H), 4.76 (m, 2H), 3.18 (m, 2H), 2.61-2.46 (m, 4H; overlapped with solvent signal), 1.35 (s, 6H), 1.30 (m, 2H), 0.82 (app br t, *J* = 7.1, 2H). LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{30}H_{33}N_6$: 477.28; found: 477.22.

Example QC-19

HATU (37.0 mg, 0.097 mmol) was added to a stirred solution of *Cap 5.2* (23.5 mg, 0.096 mmol) and *Example QC-19, step g,* (30 mg, 0.048 mmol) in DMF (2 mL) and DIPEA (0.051 ml, 0.294 mmol). The reaction mixture was stirred at RT for 2h and concentrated under vacuum. The residue was diluted with MeOH, filtered and purified by prep HPLC (Waters Sunfire C18 OBD 30 X 100 mm 5u; MeOH/water w/ TFA buffer) to afford the TFA salt of *Example QC-191* (31 mg) as an off-white solid. LC/MS (Cond. 1): RT = 1.72 min; LC/MS: Anal. Calcd. for

$[M+H]^+$ $C_{52}H_{63}N_8O_8$ 927.48; found 927.05; HPLC (Cond. 6): RT = 26.32; 100% homogeneity. ^1H NMR (500MHz, CD_3OD) δ 7.96 - 7.74 (m, 10H), 5.02 (t, *J*=8.5 Hz, 2H), 4.56 (d, *J*=7.9 Hz, 2H), 3.82 (d, *J*=10.7 Hz, 2H), 3.66 (s, 5H), 3.60 (d, *J*=3.4 Hz, 2H), 3.54 - 3.44 (m, 2H), 2.77 (dd, *J*=13.3, 9.3 Hz, 2H), 2.32 - 2.15 (m, 4H), 1.88 (t, *J*=12.5 Hz, 2H), 1.53 (br. s., 4H), 1.41 (s, 6H), 1.11 (d, *J*=11.9 Hz, 2H), 1.00 (d, *J*=5.5 Hz, 2H), 0.95 (d, *J*=5.5 Hz, 2H), 0.76 (dt, *J*=10.8, 5.5 Hz, 2H), 0.64 - 0.58 (m, 2H), 0.52 - 0.45 (m, 2H), 0.42 - 0.32 (m, 2H).

Example 1.1 and 1.2

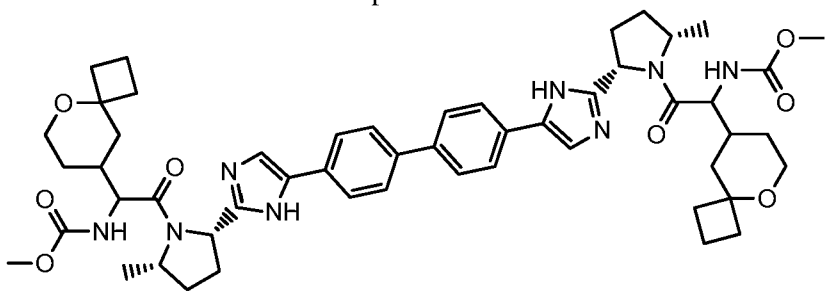


The TFA salt of *Example 1.1* was prepared from *Cap 8.2* according to the procedure described for *Example QC-8.1*. LC (Cond. 1): RT = 1.15 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{63}N_8O_8$ 903.48; found: 903.50; HRMS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{63}N_8O_8$ 903.4763; found: 903.4755; ^1H NMR (500MHz, DMSO-d_6) δ 7.89 (br. s., 8H), 7.73 (d, *J*=7.9 Hz, 2H), 5.02 (t, *J*=8.5 Hz, 2H), 4.71 - 4.61 (m, 2H), 4.11 (t, *J*=8.7 Hz, 2H), 3.78 - 3.67 (m, 3H), 3.55 (s, 6H), 3.24 (t, *J*=10.5 Hz, 2H), 2.36 (br. s., 2H), 2.30 - 2.06 (m, 4H), 1.98 (d, *J*=9.8 Hz, 2H), 1.89 - 1.72 (m, 3H), 1.49 (d, *J*=6.4 Hz, 6H), 1.23 (d, *J*=5.8 Hz, 1H), 1.09 (d, *J*=13.4 Hz, 2H), 0.68 (dt, *J*=10.6, 5.2 Hz, 2H), 0.56 - 0.40 (m, 4H), 0.36 - 0.27 (m, 2H).

The TFA salt of *Example 1.2* was prepared by using *Cap 8.1* according to the procedure described for *Example QC-8.1*. LC (Cond. 1): RT = 1.19 min; LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{63}N_8O_8$ 903.48; found: 903.50; ^1H NMR (500MHz, DMSO-d_6) δ 8.02 - 7.87 (m, 8H), 7.71 (d, *J*=8.5 Hz, 2H), 5.09 - 4.97 (m, 2H), 4.62 (t, *J*=6.7 Hz, 2H), 4.30 (t, *J*=9.0 Hz, 2H), 3.56 (s, 6H), 3.38 (d, *J*=8.9 Hz, 2H), 3.17 (dd, *J*=10.8, 8.1 Hz, 2H), 2.36 (br. s., 2H), 2.29 - 2.08 (m, 4H), 1.99 (d, *J*=3.4 Hz, 2H), 1.86 - 1.75 (m, 3H), 1.54 (d, *J*=9.2 Hz, 2H), 1.47 (d, *J*=6.7 Hz, 6H), 1.42 (br. s.,

2H), 1.26 (d, *J*=6.1 Hz, 1H), 0.68 - 0.59 (m, 2H), 0.57 - 0.48 (m, 2H), 0.45 - 0.31 (m, 4H).

Example 2.1 to 2.4



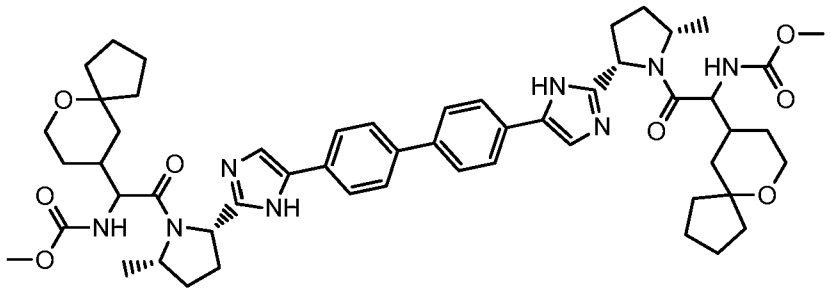
HATU (24.38 mg, 0.064 mmol) was added to a stirred solution of 4,4'-bis(2-((2S,5S)-5-methylpyrrolidin-2-yl)-1H-imidazol-5-yl)-1,1'-biphenyl, 4 HCl (18.3 mg, 0.031 mmol) and *Cap 9.1* (16.5 mg, 0.064 mmol) in DMF (0.8 mL) and DIPEA (0.037 mL, 0.21 mmol). The reaction was flushed with nitrogen, sealed and then stirred at rt for 2h. The reaction was partially concentrated under a stream of nitrogen and then purified by prep HPLC (ACN/water with a TFA buffer) to yield the TFA salt of Example 2.1 as an off-white solid (23.1 mg). LC-MS retention time 2.205 min; ½ m/z 466.55 (MH^+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x50mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0% solvent B to 0% solvent A / 100% solvent B, a gradient time of 4 min, a hold time of 1 min, and an analysis time of 5 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode.

The TFA salt of Example 2.2 to 2.4 were prepared and characterized in a similar manner to the procedure described for Example 2.1 unless noted otherwise.

Example #	Starting acid	Ret.time	½ m/z (MH+)
Example 2.2	*Cap 9.2*	2.183	466.55
Example 2.3	*Cap 9.3*	1.145*	466.55
Example 2.4	*Cap 9.4*	1.183*	466.55

* A gradient time of 2 min, a hold time of 1 min, and an analysis time of 3 min

Example 3.1 to 3.4



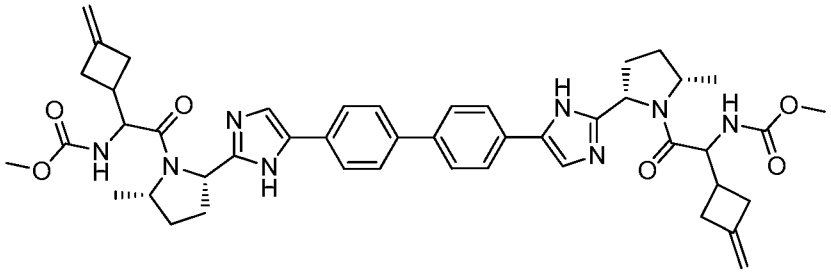
HATU (22.8 mg, 0.060 mmol) was added to a stirred clear solution of 4,4'-bis(2-((2S,5S)-5-methylpyrrolidin-2-yl)-1H-imidazol-5-yl)-1,1'-biphenyl, 4 HCl (17.1 mg, 0.029 mmol) and *Cap10.1* (16.3 mg, 0.060 mmol) in DMF (0.8 mL) and DIPEA (0.035 mL, 0.200 mmol). The reaction was flushed with nitrogen, sealed and then stirred at rt for 2h. The reaction was partially concentrated under a stream of nitrogen and then purified by prep HPLC (ACN/water with a TFA buffer) to yield the TFA salt of Example 3.1 (23.4 mg) as a a white solid. LC-MS retention time 2.425 min; ½ m/z 480.55 (MH+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x50mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0% solvent B to 0% solvent A / 100% solvent B, a gradient time of 4 min, a hold time of 1 min, and an analysis time of 5 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode. ^{1}H NMR (400MHz, MeOH-d_4) δ 7.96 - 7.83 (m, 10H), 5.32 (t, *J*=8.4 Hz, 2H), 4.56 (t, *J*=6.4 Hz, 2H), 4.34 (d, *J*=8.3 Hz, 2H), 3.81 - 3.53 (m, 10H), 2.70 - 2.59 (m, 2H), 2.42 - 2.21 (m, 4H), 2.12 - 1.91 (m, 6H), 1.81 - 1.42 (m, 28H).

The TFA salt of Example 3.2 to 3.4 were prepared and characterized in a similar manner to the procedure described for Example 10.1 unless noted otherwise.

Example #	Starting acid	Ret.time	½ m/z (MH+)
Example 3.2	*Cap 10, step d.2*	1.332*	480.5
Example 3.3	*Cap 10, step d.3*	2.126	480.6
Example 3.4	*Cap 10, step d.4*	2.273	480.6

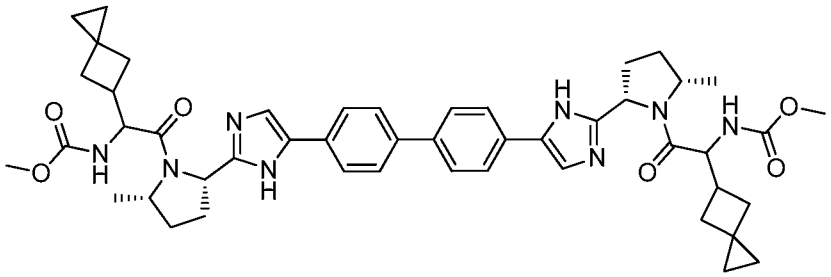
* A gradient time of 2 min, a hold time of 1 min, and an analysis time of 3 min

Example 4.1 and 4.2 (two symmetrical diastereomers)



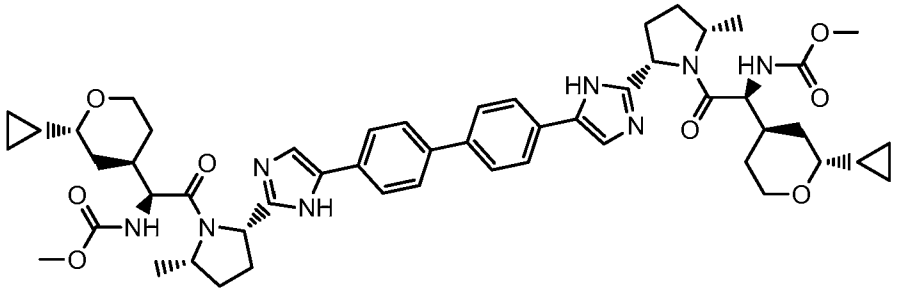
To a solution of 4,4'-bis(2-((2S,5S)-5-methylpyrrolidin-2-yl)-1H-imidazol-5-yl)-1,1'-biphenyl tetrahydrochloride (0.134 g, 0.224 mmol), *Cap-12* (0.1034 g, 0.519 mmol), and *N,N*-diisopropylethylamine (0.313 mL, 1.791 mmol) in DMF (1.5 mL) was added HATU (0.179 g, 0.470 mmol). The reaction was stirred at ~25 °C for 3.5h. The reaction was diluted with MeOH (3.5 mL) and the product was purified by prep-HPLC (injection volume: 2000 μL; gradient time: 15 min; start %B: 30, final %B: 100; flow rate: 30 mL/min; stop time: 15 min; Solvent A: 10% MeOH – 90% H_2O – 0.1% TFA, Solvent B: 90% MeOH – 10% H_2O – 0.1% TFA; Column: XTERRA 30 x 100 mm S5; Collect by UV: 220 nm) to afford a mixture of diastereomers. The mixture of diastereomers was further separated by prep-HPLC (injection volume: 2000 μL; gradient time: 30 min; start %B: 10, final %B: 50; flow rate: 30 mL/min; stop time: 30 min; Solvent A: 10% Acetonitrile – 90% H_2O – 0.1% TFA, Solvent B: 90% Acetonitrile – 10% H_2O – 0.1% TFA; Column: Waters-SunFire 30 x 100 mm S5; Collect by UV: 220 nm) to isolate the two symmetrical diastereomers: *Example 4.1* (first elute) (35.5 mg) as an off-white foam. LC (Cond. 1): RT = 13.696 min. LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{46}H_{55}N_8O_6$ 815.42; found 815.49; *Example 4.2* (last elute) (38.3 mg) as an off-white foam. LC (Cond. 1): RT = 14.492 min. LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{46}H_{55}N_8O_6$ 815.42; found 815.49.

Example 5.1 and 5.2 (two symmetrical diastereomers)



Example 5.1 and 5.2 were prepared from 4,4'-bis(2-((2S,5S)-5-methylpyrrolidin-2-yl)-1H-imidazol-5-yl)-1,1'-biphenyl tetrahydrochloride and *Cap-11* according to the procedure described for *Example 4.1 and 4.2*. *Example 5.1*(first elute) (56.4 mg) as a light yellow foam: LC (Cond. 1): RT = 15.124 min. LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{59}N_8O_6$ 843.46; found 843.40; *and Example 5.2* (last elute) (50.7 mg) as a white foam. LC (Cond. 1): RT = 16.559 min. LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{48}H_{59}N_8O_6$ 843.46; found 843.40.

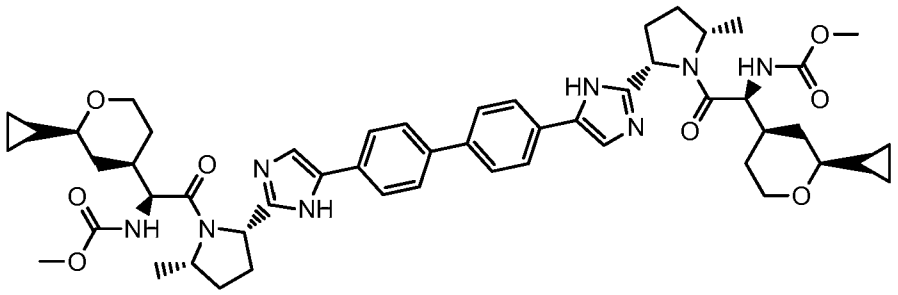
Example 6



HATU (173 mg, 0.455 mmol) was added to a stirred clear solution of 4,4'-bis(2-((2S,5S)-5-methylpyrrolidin-2-yl)-1H-imidazol-5-yl)-1,1'-biphenyl, 4 HCl (109 mg, 0.182 mmol) and *Cap 13.1* (117 mg, 0.455 mmol) in DMF (2.0 mL) and DIPEA (0.222 mL, 1.27 mmol). The reaction was flushed with nitrogen, sealed and then stirred at rt overnight. The reaction was partially concentrated under a stream of nitrogen and then purified by prep HPLC (ACN/water with a TFA buffer) to yield the TFA salt of Example 6 (135 mg) as an off-white solid. LC-MS retention time 2.196 min; m/z 931.7 (MH+). LC data was recorded on a Shimadzu LC-10AS liquid chromatograph equipped with a Phenomenex-Luna 3u C18 2.0x50mm column using a SPD-10AV UV-Vis detector at a detector wave length of 220 nM. The elution conditions employed a flow rate of 0.8 mL/min, a gradient of 100% solvent A / 0%

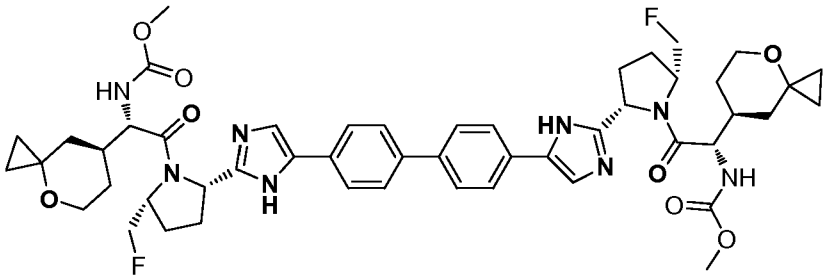
solvent B to 0% solvent A / 100% solvent B, a gradient time of 4 min, a hold time of 1 min, and an analysis time of 5 min where solvent A was 10% acetonitrile/ 90% H_2O / 0.1% trifluoroacetic acid and solvent B was 10% H_2O / 90% acetonitrile / 0.1% trifluoroacetic acid. MS data was determined using a Micromass Platform for LC in electrospray mode. ^{1}H NMR (400MHz, MeOH-d_4) δ 7.96 (s, 2H), 7.88 (s, 8H), 5.20 (dd, *J*=10.7, 7.2 Hz, 2H), 4.79 (t, *J*=6.8 Hz, 2H), 4.31 - 4.24 (m, 2H), 3.85 - 3.76 (m, 2H), 3.74 - 3.69 (m, 2H), 3.67 (s, 6H), 2.91 - 2.83 (m, 2H), 2.55 (dt, *J*=12.8, 6.7 Hz, 2H), 2.47 - 2.23 (m, 6H), 2.00 (dd, *J*=12.3, 5.8 Hz, 2H), 1.79 (d, *J*=12.3 Hz, 2H), 1.69 - 1.27 (m, 12H), 1.15 (dd, *J*=8.3, 4.3 Hz, 2H), 0.47 (td, *J*=8.5, 3.9 Hz, 2H), 0.34 - 0.21 (m, 4H), -0.01 - -0.09 (m, 2H).

Example 7

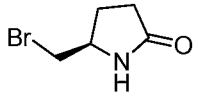


The TFA salt of Example 7 was prepared from *Cap 13.2* and characterized in a similar manner to the procedure described for Example 6. LC-MS retention time 2.208 min; m/z 931.7 (MH+).

Example 8



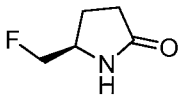
Example 8, Step a



To a suspension of (R)-5-(hydroxymethyl)pyrrolidin-2-one (5 g, 43.4 mmol) and triphenylphosphine (17.09 g, 65.1 mmol) in acetonitrile (300 mL) at 0 ^{0}C in an

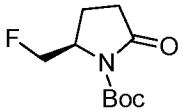
ice-water bath was added dropwise a solution of carbontetrabromide (21.60 g, 65.1 mmol) in acetonitrile (80 mL). The suspension gradually changed to clear solution in 1 hour and the bath was removed and stirred at room temperature for 23 hrs. The solvent was removed in vacuo and the resultant crude material was submitted to flash chromatography (30-100% EtOAc/Hexane, 10-20% MeOH/EtOAc) to afford *Example 8, Step a* as brown oil (6.3 g). LC (Cond. II): RT = 1.29 min; LC/MS: Anal. Calcd. for $[M+H]^+$ C_5H_9BrNO: 179.99; found: 178.11. ^1H NMR ($CDCl_3$, δ = 7.26 ppm, 400 MHz) δ 6.09 (br. s., 1H), 4.07 - 3.92 (m, 1H), 3.46 (dd, *J*=10.3, 4.8 Hz, 1H), 3.36 (dd, *J*=10.3, 7.5 Hz, 1H), 2.55 - 2.30 (m, 3H), 1.99 - 1.81 (m, 1H).

Example 8, Step b



To a mixture solid of *Example 8, Step a* (6.33 g, 35.6 mmol) and Silver(I) fluoride (14.21 g, 112 mmol) was added acetonitrile (500 mL) slowly by syringe while the reaction flask was covered with aluminum foil. The reaction mixture was stirred at room temperature for 40 hrs. It was filtrated through diatomaceous earth (Celite®) and the solvent was removed in vacuo. The resultant crude material was submitted to flash chromatography (50-100% EtOAc/Hex, EtOAc, 10-20% MeOH/EtOAc) to afford *Example 8, Step b* as colorless oil (1.96 g). LC (Cond. II): RT = 0.78 min; LC/MS: Anal. Calcd. for $[M+H]^+$ C_5H_9FNO: 118.07; found: 118.0. ^1H NMR ($CDCl_3$, δ = 7.26 ppm, 400 MHz) δ 6.07 (br. s., 1H), 4.51 (dd, *J*=9.5, 3.5 Hz, 0.5H), 4.43 - 4.31 (m, 1H), 4.23 (dd, *J*=9.5, 7.3 Hz, 0.5H), 4.06 - 3.91 (m, 1H), 2.48 - 2.34 (m, 2H), 2.32 - 2.18 (m, 1H), 1.84 (m, 1H).

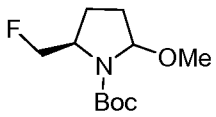
Example 8, Step c



To a solution of *Example 8, Step b* (2.61 g, 22.28 mmol) and DMAP (0.109 g, 0.891 mmol) in DCM (110 mL) was added di-*tert*-butyl dicarbonate (5.11 g, 23.40 mmol) in three portions in an ice-water bath at 0 ^0C in 10 mins. The bath was removed and it was stirred at room temperature for 20 hrs. 50% sat. $NaHCO_3$ (30 mL) was added and stirred for 10 mins. Organic layer was separated and dried with Na_2SO_4. The solvent was evaporated in vacuo to afford crude product as yellow oil.

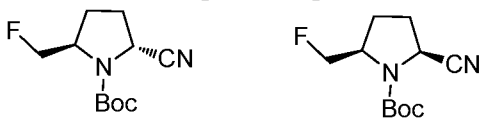
The resultant crude material was submitted to flash chromatography (0-80% EtOAc/Hexane) to afford *Example 8, Step c* as colorless oil (3.87 g). LC (Cond. II): RT = 2.64 min; LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{10}H_{16}FNNaO_3$: 240.10; found: 240.14. ^1H NMR ($CDCl_3$, δ = 7.26 ppm, 500 MHz) δ 4.68 (ddd, *J*=48.2, 9.8, 3.5 Hz, 1 H), 4.50 (ddd, *J*=45.7, 9.8, 2.5 Hz, 1H), 4.31 (ddm, *J*=27.7, 8.8 Hz, 1H), 2.69 (dtd, *J*=17.7, 9.8, 1.9 Hz, 1H), 2.44 (ddq, *J*=17.7, 9.8, 1.1 Hz, 1 H), 2.20 (m, 1H), 2.06 (m, 1H), 1.51 (s, 9H).

Example 8, Step d



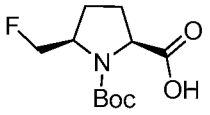
To a solution of *Example 8, Step c* (2.67 g, 12.29 mmol) in THF (50 mL) in a dry ice-acetone bath at - 78 ^0C was added dropwise Superhydride (14.75 mL, 14.75 mmol). The reaction mixture was stirred at - 78 ^0C for 40 mins. Sat. $NaHCO_3$ aq. solution (15 mL) was added and the dry ice-acetone bath was removed and temperature raised to room temperature. 20 drops of 50% H_2O_2 was added drop wise and it was stirred for 20 mins. The organic layer was separated and aqueous layer was extracted with Ether (2 X 40 mL), the combined organic layer was dried with Na_2SO_4, evaporated the solvent in vacuo to afford a crude intermediate (2.34 g) as clear oil. This crude intermediate was dissolved in methanol (30 mL) and *p*-toluenesulfonic acid monohydrate (0.223 g, 1.174 mmol) was added, it was stirred at room temperature for 16 hrs. Aq. sat. $NaHCO_3$ (5 mL) was added, extracted with ether (3 X 35 mL), dried with Na_2SO_4, evaporated in vacuo to afford a clear oil as crude product. The resultant crude material was submitted to flash chromatography (0-40% EtOAc/Hexane) to afford *Example 8, Step d* as colorless oil (1.97 g). LC (Cond. II): RT = 3.43 min; LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{11}H_{20}FNNaO_3$: 256.13; found: 256.19. ^1H NMR ($CDCl_3$, δ = 7.26 ppm, 400 MHz) δ 5.27-5.16 (m, 1H), 4.59-4.26 (m, 2H), 4.03 (br. s., 1H), 3.29 (br. s., 3H), 2.17 - 1.96 (m, 2H), 1.96 - 1.85 (m, 1H), 1.85 - 1.70 (m, 1H), 1.55 - 1.39 (m, 9H).

Example 8, Step e



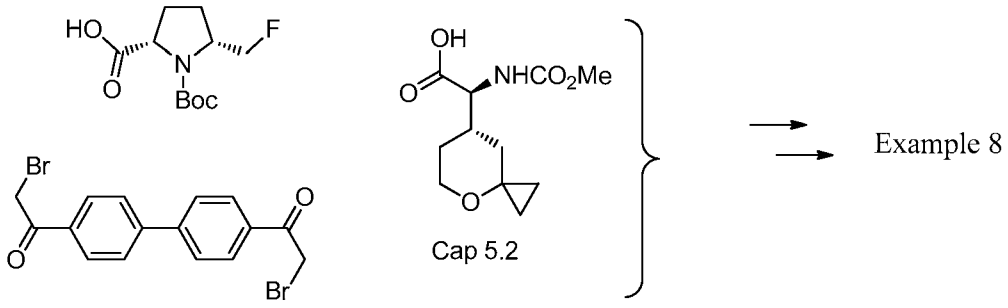
To a solution of *Example 8, Step d* (1.97 g, 8.44 mmol) in DCM (50 mL) cooled with - 78 ^{0}C dry ice-acetone bath was added trimethylsilyl cyanide (1.698 mL, 12.67 mmol), followed by boron trifluoride ether complex (1.605 mL, 12.67 mmol). It was stirred for 1 hr. Sat. $NaHCO_3$ (20 mL) was added and the bath was removed, and it was stirred at room temperature for 2 hrs. The organic layer was separated and extracted with DCM (40 mL X 2), dried with Na_2SO_4, evaporated in vacuo. The resultant crude material was submitted to flash chromatography (0-40%, 40-55% EtOAc/Hexane) to afford first elute *Example 8, Step e.1* (trans; 1.12 g) and second elute *Example 8, Step e.2* (cis; 0.63 g) as white solids. LC (Cond. II): RT = 3.04 min; LC/MS: Anal. Calcd. for $[M+Na]^+$ $C_{11}H_{17}FN_2NaO_2$: 251.12; found: 251.16. ^{1}H NMR ($CDCl_3$, δ = 7.26 ppm, 400 MHz): d 4.67-4.44 (m, 3H), 4.12-4.06 (m, 1H), 2.32 (br s, 2H), 2.18 (br s, 2H), 1.52 (s, 9H).

Example 8, Step f



To a solution of 8e-*cis* (0.51 g, 2.234 mmol) in dioxane (3 mL) was added HCl (12M, 3 mL, 99 mmol). It was heated to 80 °C for 8 hrs. The solvent was evaporated in vacuo and dried under vacuum for 16 hrs to give crude intermediate (0.55 g) as yellow solid. This crude intermediate (0.55g) was dissolved in THF (4 mL), NaOH (2M, 3.44 mL, 6.89 mmol) and di-tert-butyl dicarbonate (0.719 g, 3.30 mmol) were added and it was stirred at room temperature for 17 hrs. The solvent was evaporated in vacuo and water (5 mL) and ether (5 mL) were added. The aqueous layer was separated and acidified by 10% HCl to pH 3 in an ice-water bath, EtOAc (15 mL, 3x) extracted and dried with Na_2SO_4, evaporated the solvent in vacuo to afford *Example 8, step f* as yellow solid (0.50g). ^{1}H NMR ($CDCl_3$, δ = 7.26 ppm, 400 MHz): δ 4.69-4.14 (m, 4H), 2.29-2.07 (m, 4H), 1.50-1.48 (two s, 9H).

Example 8



Example 8, step f was elaborated to Example 8 according to the procedure described for the synthesis of Example QC17.1 by using indicated and other appropriate precursors. LC/MS: Anal. Calcd. for $[M+H]^+$ $C_{50}H_{61}F_2N_8O_8$: 939.46; found: 939.77. RT = 15.99 min under the following LC condition: Start %B = 10; Final %B = 98; Gradient time = 35 min; Stop time = 35 min; Flow Rate = 0.35 mL/min; Wavelength = 306 nm; Solvent A = Water with 0.05% TFA ; Solvent B = Acetonitrile with 0.05% TFA; Column = Waters Acquity BEH C18; 1.7um; 150 X 2.1 mm ID; (at 35^0C).

BIOLOGICAL ACTIVITY

An HCV Replicon assay was utilized in the present disclosure, and was prepared, conducted and validated as described in commonly owned PCT/US2006/022197 and in O'Boyle et. al. *Antimicrob Agents Chemother.* **2005** Apr;49(4):1346-53. Assay methods incorporating luciferase reporters have also been used as described (Apath.com).

HCV-neo replicon cells and replicon cells containing resistance substitutions in the NS5A region were used to test the currently described family of compounds. The compounds were determined to have differing degrees of reduced inhibitory activity on cells containing mutations vs. the corresponding inhibitory potency against wild-type cells. Thus, the compounds of the present disclosure can be effective in inhibiting the function of the HCV NS5A protein and are understood to be as effective in combinations as previously described in application PCT/US2006/022197 and commonly owned WO/04014852. It should be understood that the compounds of the present disclosure can inhibit multiple genotypes of HCV. Table 2 shows the EC_{50} (Effective 50% inhibitory concentration) values of representative compounds of the present disclosure against the HCV 1b genotype.

The compounds of the present disclosure may inhibit HCV by mechanisms in addition to or other than NS5A inhibition. In one embodiment the compounds of the present disclosure inhibit HCV replicon and in another embodiment the compounds of the present disclosure inhibit NS5A. Compounds of the present disclosure may inhibit multiple genotypes of HCV. EC_{50} ranges against HCV 1b are as follows: A (900.01 pM - 140 nM); B (100.01 pM - 900 pM); C (5.01 pM - 100 pM); D (0.5 pM - 5 pM).

Table 2

Example	*1b (μM)*	*Range*	*Name*
QC1.1		D	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1)
QC1.2	4.90E-06	D	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2)
QC1.3		B	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 3)
QC2.1		D	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3r,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1)
QC2.2		C	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-

			3,2-diyl(1-((1R,3r,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2)
QC2.3	1.08E-03	A	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3r,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 3)
QC3.1		D	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3r,5S)-bicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1)
QC3.2		C	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3r,5S)-bicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2)
QC3.3		B	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3r,5S)-bicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 3)
QC4.1		C	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,5S,6s)-3-oxabicyclo[3.1.0]hex-6-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1)
QC4.2		B	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,5S,6s)-3-oxabicyclo[3.1.0]hex-6-yl)-2-oxo-2,1-ethanediyl)))biscarbamate

			(diastereomer 2)
QC4.3			dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,5S,6s)-3-oxabicyclo[3.1.0]hex-6-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 3)
QC5.1	5.93E-07	D	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-bicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1)
QC5.2		D	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-bicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2)
QC5.3	5.55E-06	C	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-bicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 3)
QC6		D	methyl (2-((1R,3S,5R)-3-(4-(4'-(4-chloro-2-((1R,3S,5R)-2-(((1R,3s,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)((methoxycarbonyl)amino)acetyl)-2-azabicyclo[3.1.0]hex-3-yl)-1H-imidazol-5-yl)-4-biphenylyl)-1H-imidazol-2-yl)-2-azabicyclo[3.1.0]hex-2-yl)-1-((1R,3s,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxoethyl) carbamate
QC7		D	dimethyl (4,4'-biphenyldiylbis((4-chloro-1H-imidazole-5,2-diyl)(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-

			6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate
QC8.1		D	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1)
QC8.2		D	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2)
QC9		C	methyl (2-((2S,4S)-2-(7-((2-((2S,4S)-1-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)-4-methyl-2-pyrrolidinyl)-1H-benzimidazol-5-yl)ethynyl)-1H-naphtho[1,2-d]imidazol-2-yl)-4-methyl-1-pyrrolidinyl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate
QC10	2.59E-04	B	methyl (2-((2S)-2-(7-(2-((2S)-1-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)-2-pyrrolidinyl)-1H-benzimidazol-5-yl)-1H-naphtho[1,2-d]imidazol-2-yl)-1-pyrrolidinyl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate
QC11		C	methyl (2-((1*R*,3*S*,5*R*)-3-(4-(4-(2-((1*R*,3*S*,5*R*)-2-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)-2-azabicyclo[3.1.0]hex-3-yl)-4,5-dihydro-3*H*-naphtho[1,2-*d*]imidazol-7-yl)phenyl)-1*H*-imidazol-2-yl)-2-azabicyclo[3.1.0]hex-2-yl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate
QC12		B	methyl (2-((2S)-2-(7-(2-((2S)-1-

			(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)-2-pyrrolidinyl)-1H-benzimidazol-5-yl)-4,5-dihydro-1H-naphtho[1,2-d]imidazol-2-yl)-1-pyrrolidinyl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate
QC13		C	dimethyl (1H,1'H-7,7'-binaphtho[1,2-d]imidazole-2,2'-diylbis((2S)-2,1-pyrrolidinediyl(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate
OL1		C	dimethyl (((3S,3'S,5S,5'S)-5,5'-(5,5'-((1S,2S)-cyclopropane-1,2-diylbis(4,1-phenylene))bis(1H-imidazole-5,2-diyl))bis(3-methylpyrrolidine-5,1-diyl))bis(2-oxo-1-(4-oxaspiro[2.5]octan-7-yl)ethane-2,1-diyl))dicarbamate
OL2		C	methyl (2-(((1S)-1-(5-((2-((1S)-1-((((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)(methyl)amino)ethyl)-1H-benzimidazol-6-yl)ethynyl)-1H-benzimidazol-2-yl)ethyl)(methyl)amino)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate
OL3		C	methyl ((2S)-1-((1R,3S,5R)-3-(5-(4'-(2-((1R,3S,5R)-2-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)-2-azabicyclo [3.1.0]hex-3-yl)-1H-imidazol-5-yl)biphenyl-4-yl)-1H-imidazol-2-yl)-2-azabicyclo[3.1.0]hex-2-yl)-3-methyl-1-oxobutan-2-yl)carbamate
OL4		C	dimethyl (((1R,1'R,3S,3'S,5R,5'R)-3,3'-(5,5'-(ethyne-1,2-diylbis(4,1-phenylene))bis(1H-imidazole-5,2-diyl))bis(2-azabicyclo [3.1.0]hexane-3,2-diyl))bis(2-oxo-1-(4-oxaspiro [2.5]octan-7-yl)ethane-2,1-diyl))dicarbamate
OL5		C	dimethyl (((1R,1'R,3S,3'S,5R,5'R)-3,3'-(5,5'-

			([1,1'-biphenyl]-4,4'-diyl)bis(4-chloro-1H-imidazole-5,2-diyl))bis(2-azabicyclo[3.1.0]hexane-3,2-diyl))bis(2-oxo-1-(4-oxaspiro[2.5]octan-7-yl)ethane-2,1-diyl))dicarbamate
OL6		B	methyl (2-((2S)-2-(5-(6-(4-(2-((2S)-1-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)pyrrolidin-2-yl)-1H-imidazol-5-yl)phenyl)pyridin-3-yl)-1H-imidazol-2-yl)pyrrolidin-1-yl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate
OL7		C	dimethyl (((2S,2'S)-2,2'-(5,5'-(ethyne-1,2-diylbis(4,1-phenylene))bis(1H-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(2-oxo-1-(4-oxaspiro[2.5]octan-7-yl)ethane-2,1-diyl))dicarbamate
QC14	1.45E-02	A	dimethyl (benzene-1,4-diylbis(1*H*-imidazole-4,2-diyl(2*S*)pyrrolidine-2,1-diyl(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethane-2,1-diyl)))biscarbamate
OL8		B	dimethyl (((3R,3'R)-3,3'-(5,5'-([1,1'-biphenyl]-4,4'-diyl)bis(1H-imidazole-5,2-diyl))bis(morpholine-4,3-diyl))bis(2-oxo-1-(4-oxaspiro[2.5]octan-7-yl)ethane-2,1-diyl))dicarbamate
QC15		C	methyl (2-((2*S*)-2-(5-(4-((2-((2*S*)-1-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)pyrrolidin-2-yl)-1*H*-benzimidazol-4-yl)oxy)phenyl)-1*H*-benzimidazol-2-yl)pyrrolidin-1-yl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate
QC16		B	methyl (2-((2S)-2-(7-(2-((2S)-1-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-

			7-yl)acetyl)-2-pyrrolidinyl)-1H-benzimidazol-5-yl)-4,5-dihydro-1H-naphtho[1,2-d]imidazol-2-yl)-1-pyrrolidinyl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate
OL9		B	dimethyl (((2S,2'S)-2,2'-(5,5'-(ethyne-1,2-diyl)bis(1H-benzo[d]imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(2-oxo-1-(4-oxaspiro[2.5]octan-7-yl)ethane-2,1-diyl))dicarbamate
OL10		B	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl((1S)-2-oxo-1-(4-oxocyclohexyl)-2,1-ethanediyl)))biscarbamate
OL11		C	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl((1S)-2-oxo-1-(3-(trifluoromethyl)bicyclo [1.1.1]pent-1-yl)-2,1-ethanediyl)))biscarbamate
OL12		B	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)((1S)-2-oxo-1-(3-(trifluoromethyl)bicyclo[1.1.1]pent-1-yl)-2,1-ethanediyl)))biscarbamate
QC17.1		D	dimethyl ((3-methyl-4,4'-biphenyldiyl)bis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1)
QC17.2		D	dimethyl ((3-methyl-4,4'-biphenyldiyl)bis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer

			2)
QC18.1		D	dimethyl ((3-fluoro-4,4'-biphenyldiyl)bis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1)
QC18.2		D	dimethyl ((3-fluoro-4,4'-biphenyldiyl)bis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2)
QC19		C	dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl((1R,3S,5R)-5-methyl-2-azabicyclo[3.1.0]hexane-3,2-diyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate
1.1		C	
1.2		C	
2.1		A	
2.2		A	
2.3	4.88E-06	D	
2.4		C	
3.1		A	
3.2		A	
3.3	5.04E-06	C	
3.4		C	
4.1		D	
4.2	2.43E-04	B	
5.1		D	
5.2	9.07E-03	A	
6		C	
7		C	

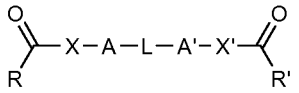
8		C	

It will be evident to one skilled in the art that the present disclosure is not limited to the foregoing illustrative examples, and that it can be embodied in other specific forms without departing from the essential attributes thereof. It is therefore desired that the examples be considered in all respects as illustrative and not restrictive, reference being made to the appended claims, rather than to the foregoing examples, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

CLAIMS

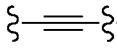
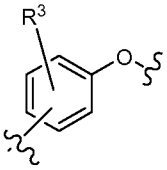
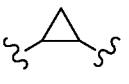
WHAT IS CLAIMED IS:

1. A compound of Formula (I)

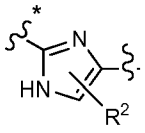
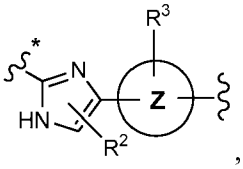
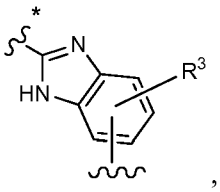
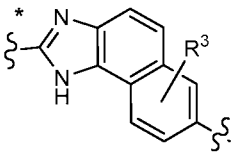
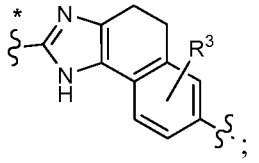


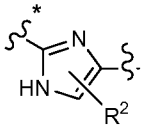
(I),

or a pharmaceutically acceptable salt thereof, wherein

L is selected from a bond,  ,  , and  ;

A and A' are independently selected from

 ;  ,  ,  , and  ;

provided at least one of A and A' is other than  ;

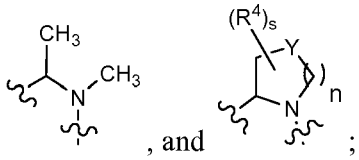
wherein " " represents the point of attachment to X and X' and " " represents the point of attachment to L; and wherein:

Z is a six-membered aromatic ring optionally containing one, two, or three nitrogen atoms;

R^2 is selected from hydrogen, alkyl, and halo; and

R^3 is selected from hydrogen, alkoxy, alkyl, cyano, halo, and haloalkoxy;

X and X' are independently selected from



, and ;

wherein each group is drawn with the carbon atom being attached to A or A' and with the nitrogen atom attached to the carbonyl group and wherein:

n is 0, 1, or 2;

s is 0, 1, 2, 3, or 4;

Y is selected from $Si(R^4)_2$, NR^4, O, S, S(O), SO_2, CH_2, CHR^4, and $C(R^4)_2$; provided that when n is 0, Y is selected from CH_2, CHR^4, and $C(R^4)_2$; and

each R^4 is independently selected from alkoxy, alkyl, aryl, cyano, halo, haloalkoxy, haloalkyl, hydroxy, $-NR^aR^b$, and thioalkyl, wherein the alkyl can optionally form a fused three- to six-membered ring or a bridged four- or five-membered ring with another carbon atom on the ring; or can optionally form a spirocyclic three- to six-membered ring with the carbon to which it is attached, wherein each formed ring system optionally contains one or two oxygen atoms, and wherein each formed ring system is optionally substituted with one or two groups independently selected from alkyl and halo; provided that when Y is NR^4, R^4 is other than halo, hydroxy, or $-NR^aR^b$;

R is (NR^cR^d)alkyl, wherein the alkyl part of the (NR^cR^d)alkyl is substituted with bicycloalkyl, fused bicycloheterocyclyl, cycloalkyl-substituted-heterocyclyl, ethenylcycloalkyl, heterocyclylethenyl, oxocycloalkyl, or spirocycloheterocyclyl, wherein the bicycloalkyl, bicycloheterocyclyl, oxocycloalkyl, and spirocycloheterocyclyl are optionally substituted with one or two groups independently selected from alkyl, halo, and haloalkyl;

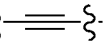
R' is (NR^cR^d)alkyl, wherein the alkyl part of the (NR^cR^d)alkyl is optionally substituted with bicycloalkyl, fused bicycloheterocyclyl, cycloalkyl-substituted-heterocyclyl, ethenylcycloalkyl, heterocyclylethenyl, oxocycloalkyl, or spirocycloheterocyclyl, wherein the bicycloalkyl, bicycloheterocyclyl, oxocycloalkyl, and spirocycloheterocyclyl are optionally substituted with one or two groups independently selected from alkyl, halo, and haloalkyl;

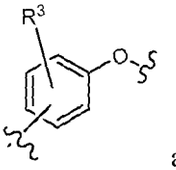
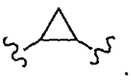
R^a and R^b are independently selected from hydrogen and alkyl;

R^c and R^d are independently selected from hydrogen, alkenyloxycarbonyl, alkoxyalkylcarbonyl, alkoxycarbonyl, alkyl, alkylcarbonyl, alkylsulfonyl, aryl, arylalkoxycarbonyl, arylalkyl, arylalkylcarbonyl, arylcarbonyl, aryloxycarbonyl, arylsulfonyl, cycloalkyl, cycloalkyloxycarbonyl, cycloalkylsulfonyl, formyl, haloalkoxycarbonyl, heterocyclyl, heterocyclylalkoxycarbonyl, heterocyclylalkyl, heterocyclylalkylcarbonyl, heterocyclylcarbonyl, heterocyclyloxycarbonyl, hydroxyalkylcarbonyl, (NR^eR^f)alkyl, (NR^eR^f)alkylcarbonyl, (NR^eR^f)carbonyl, (NR^eR^f)sulfonyl, -C(NCN)OR'', and -C(NCN)NR^xR^y, wherein R'' is selected from alkyl and unsubstituted phenyl, and wherein the alkyl part of the arylalkyl, the arylalkylcarbonyl, the heterocyclylalkyl, and the heterocyclylalkylcarbonyl are further optionally substituted with one -NR^eR^f group; and wherein the aryl, the aryl part of the arylalkoxycarbonyl, the arylalkyl, the arylalkylcarbonyl, the arylcarbonyl, the aryloxycarbonyl, and the arylsulfonyl, the heterocyclyl, and the heterocyclyl part of the heterocyclylalkoxycarbonyl, the heterocyclylalkyl, the heterocyclylalkylcarbonyl, the heterocyclylcarbonyl, and the heterocyclyloxycarbonyl are further optionally substituted with one, two, or three substituents independently selected from alkoxy, alkyl, cyano, halo, haloalkoxy, haloalkyl, and nitro;

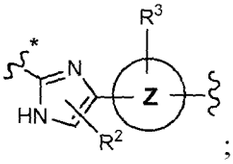
R^e and R^f are independently selected from hydrogen, alkyl, unsubstituted aryl, unsubstituted arylalkyl, unsubstituted cycloalkyl, unsubstituted (cyclolalkyl)alkyl, unsubstituted heterocyclyl, unsubstituted heterocyclylalkyl, (NR^xR^y)alkyl, and (NR^xR^y)carbonyl; and

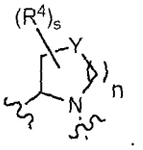
R^x and R^y are independently selected from hydrogen, alkoxycarbonyl, alkyl, alkylcarbonyl, unsubstituted aryl, unsubstituted arylalkoxycarbonyl, unsubstituted arylalkyl, unsubstituted cycloalkyl, unsubstituted heterocyclyl, and $(NR^{x'}R^{y'})$carbonyl, wherein $R^{x'}$ and $R^{y'}$ are independently selected from hydrogen and alkyl.

2. A compound of claim 1, or a pharmaceutically acceptable salt thereof, wherein L is  .

3. A compound of claim 1, or a pharmaceutically acceptable salt thereof, wherein L is selected from  and  .

4. A compound of claim 1, or a pharmaceutically acceptable salt thereof, wherein L is a bond.

5. A compound of claim 4, or a pharmaceutically acceptable salt thereof, wherein A and A' are each  ; wherein Z is a six-membered aromatic ring optionally containing one nitrogen atom.

6. A compound of claim 5, or a pharmaceutically acceptable salt thereof, wherein X and X' are each  .

7. A compound of claim 6, or a pharmaceutically acceptable salt thereof, wherein:

n is 1 or 2;

s is 1, 2, or 3; and

Y is selected from O, CH_2, CHR^4, and $C(R^4)_2$.

8. A compound of claim 6, or a pharmaceutically acceptable salt thereof, wherein:

n is 1;

s is 1, 2, or 3; and

Y is selected from CH_2, CHR^4, and $C(R^4)_2$.

9. A compound of claim 8, or a pharmaceutically acceptable salt thereof, wherein R and R' are each (NR^cR^d)alkyl, wherein the alkyl part of each (NR^cR^d)alkyl is substituted with bicycloalkyl, fused bicycloheterocyclyl, cycloalkyl-substituted-heterocyclyl, or spirocycloheterocyclyl, wherein the bicycloalkyl and the bicycloheterocyclyl are optionally substituted with one or two halo groups.

10. A compound of claim 9, or a pharmaceutically acceptable salt thereof, wherein the alkyl part of each (NR^cR^d)alkyl is substituted with spirocycloheterocyclyl, wherein spirocycloheterocyclyl is a six-membered saturated ring containing one oxygen atom adjoined to a three-membered saturated carbocyclic ring via one single carbon atom.

11. A compound selected from

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 3);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3r,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3r,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3r,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 3);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3r,5S)-bicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3r,5S)-bicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3r,5S)-bicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 3);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,5S,6s)-3-oxabicyclo[3.1.0]hex-6-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,5S,6s)-3-oxabicyclo[3.1.0]hex-6-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,5S,6s)-3-oxabicyclo[3.1.0]hex-6-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 3);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-bicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-bicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-bicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 3);

methyl (2-((1R,3S,5R)-3-(4-(4'-(4-chloro-2-((1R,3S,5R)-2-(((1R,3s,5S)-6,6-difluorobicyclo [3.1.0]hex-3-yl)((methoxycarbonyl)amino) acetyl)-2-azabicyclo[3.1.0]hex-3-yl)-1H-imidazol-5-yl)-4-biphenylyl)-1H-imidazol-2-yl)-2-azabicyclo[3.1.0]hex-2-yl)-1-((1R,3s,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxoethyl) carbamate;

dimethyl (4,4'-biphenyldiylbis((4-chloro-1H-imidazole-5,2-diyl)(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl(1-((1R,3s,5S)-6,6-difluorobicyclo[3.1.0]hex-3-yl)-2-oxo-2,1-ethanediyl)))biscarbamate;

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1);

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2);

methyl (2-((2S,4S)-2-(7-((2-((2S,4S)-1-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)-4-methyl-2-pyrrolidinyl)-1H-benzimidazol-5-yl)ethynyl)-1H-naphtho[1,2-d]imidazol-2-yl)-4-methyl-1-pyrrolidinyl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate;

methyl (2-((2S)-2-(7-(2-((2S)-1-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)-2-pyrrolidinyl)-1H-benzimidazol-5-yl)-1H-naphtho[1,2-d]imidazol-2-yl)-1-pyrrolidinyl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate;

methyl (2-((1*R*,3*S*,5*R*)-3-(4-(4-(2-((1*R*,3*S*,5*R*)-2-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)-2-azabicyclo[3.1.0]hex-3-yl)-4,5-dihydro-3*H*-naphtho[1,2-*d*]imidazol-7-yl)phenyl)-1*H*-imidazol-2-yl)-2-azabicyclo[3.1.0]hex-2-yl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate;

methyl (2-((2S)-2-(7-(2-((2S)-1-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)-2-pyrrolidinyl)-1H-benzimidazol-5-yl)-4,5-dihydro-1H-naphtho[1,2-d]imidazol-2-yl)-1-pyrrolidinyl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate;

dimethyl (1H,1'H-7,7'-binaphtho[1,2-d]imidazole-2,2'-diylbis((2S)-2,1-pyrrolidinediyl(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate;

dimethyl (((3S,3'S,5S,5'S)-5,5'-(5,5'-((1S,2S)-cyclopropane-1,2-diylbis(4,1-phenylene))bis(1H-imidazole-5,2-diyl))bis(3-methylpyrrolidine-5,1-diyl))bis(2-oxo-1-(4-oxaspiro[2.5]octan-7-yl)ethane-2,1-diyl))dicarbamate;

methyl (2-(((1S)-1-(5-((2-((1S)-1-((((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)(methyl)amino)ethyl)-1H-benzimidazol-6-yl)ethynyl)-

1H-benzimidazol-2-yl)ethyl)(methyl)amino)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate;

methyl ((2S)-1-((1R,3S,5R)-3-(5-(4'-(2-((1R,3S,5R)-2-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)-2-azabicyclo [3.1.0]hex-3-yl)-1H-imidazol-5-yl)biphenyl-4-yl)-1H-imidazol-2-yl)-2-azabicyclo[3.1.0]hex-2-yl)-3-methyl-1-oxobutan-2-yl)carbamate;

dimethyl (((1R,1'R,3S,3'S,5R,5'R)-3,3'-(5,5'-(ethyne-1,2-diylbis(4,1-phenylene))bis(1H-imidazole-5,2-diyl))bis(2-azabicyclo [3.1.0]hexane-3,2-diyl))bis(2-oxo-1-(4-oxaspiro [2.5]octan-7-yl)ethane-2,1-diyl))dicarbamate;

dimethyl (((1R,1'R,3S,3'S,5R,5'R)-3,3'-(5,5'-([1,1'-biphenyl]-4,4'-diyl)bis(4-chloro-1H-imidazole-5,2-diyl))bis(2-azabicyclo[3.1.0] hexane-3,2-diyl))bis(2-oxo-1-(4-oxaspiro [2.5]octan-7-yl)ethane-2,1-diyl))dicarbamate;

methyl (2-((2S)-2-(5-(6-(4-(2-((2S)-1-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)pyrrolidin-2-yl)-1H-imidazol-5-yl)phenyl)pyridin-3-yl)-1H-imidazol-2-yl)pyrrolidin-1-yl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate;

dimethyl (((2S,2'S)-2,2'-(5,5'-(ethyne-1,2-diylbis(4,1-phenylene))bis(1H-imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(2-oxo-1-(4-oxaspiro[2.5]octan-7-yl)ethane-2,1-diyl))dicarbamate;

dimethyl (benzene-1,4-diylbis(1*H*-imidazole-4,2-diyl(2*S*)pyrrolidine-2,1-diyl(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethane-2,1-diyl)))biscarbamate;

dimethyl (((3R,3'R)-3,3'-(5,5'-([1,1'-biphenyl]-4,4'-diyl)bis(1H-imidazole-5,2-diyl))bis(morpholine-4,3-diyl))bis(2-oxo-1-(4-oxaspiro[2.5]octan-7-yl)ethane-2,1-diyl))dicarbamate;

methyl (2-((2*S*)-2-(5-(4-((2-((2*S*)-1-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)pyrrolidin-2-yl)-1*H*-benzimidazol-4-yl)oxy)phenyl)-1*H*-benzimidazol-2-yl)pyrrolidin-1-yl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate;

methyl (2-((2S)-2-(7-(2-((2S)-1-(((methoxycarbonyl)amino)(4-oxaspiro[2.5]oct-7-yl)acetyl)-2-pyrrolidinyl)-1H-benzimidazol-5-yl)-4,5-dihydro-1H-naphtho[1,2-d]imidazol-2-yl)-1-pyrrolidinyl)-1-(4-oxaspiro[2.5]oct-7-yl)-2-oxoethyl)carbamate;

dimethyl (((2S,2'S)-2,2'-(5,5'-(ethyne-1,2-diyl)bis(1H-benzo[d]imidazole-5,2-diyl))bis(pyrrolidine-2,1-diyl))bis(2-oxo-1-(4-oxaspiro[2.5]octan-7-yl)ethane-2,1-diyl))dicarbamate;

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl((1S)-2-oxo-1-(4-oxocyclohexyl)-2,1-ethanediyl)))biscarbamate;

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl(1R,3S,5R)-2-azabicyclo[3.1.0]hexane-3,2-diyl((1S)-2-oxo-1-(3-(trifluoromethyl)bicyclo[1.1.1]pent-1-yl)-2,1-ethanediyl)))biscarbamate;

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)((1S)-2-oxo-1-(3-(trifluoromethyl)bicyclo[1.1.1]pent-1-yl)-2,1-ethanediyl)))biscarbamate;

dimethyl ((3-methyl-4,4'-biphenyldiyl)bis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1);

dimethyl ((3-methyl-4,4'-biphenyldiyl)bis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2);

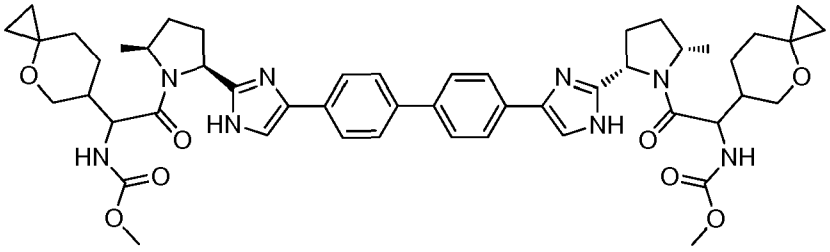
dimethyl ((3-fluoro-4,4'-biphenyldiyl)bis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 1)

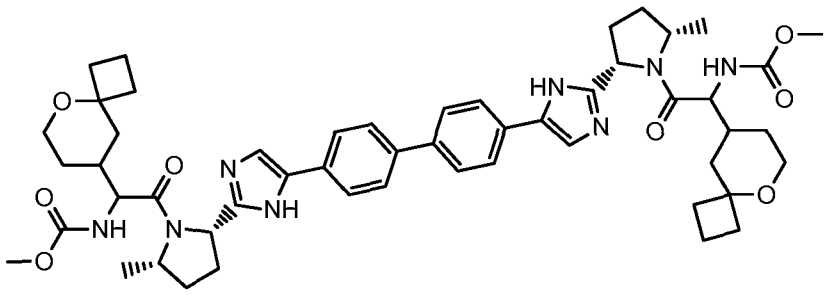
dimethyl ((3-fluoro-4,4'-biphenyldiyl)bis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate (diastereomer 2); and

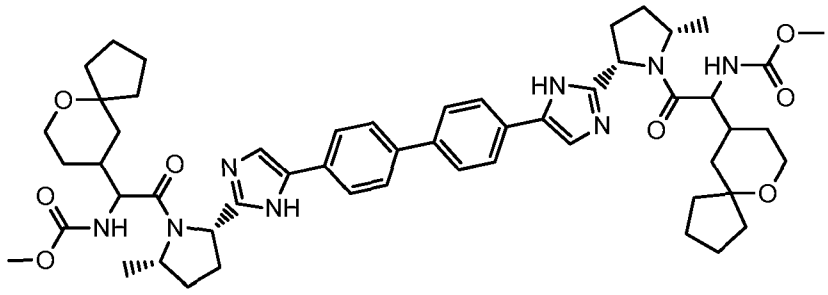
dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl((1R,3S,5R)-5-methyl-2-azabicyclo[3.1.0]hexane-3,2-diyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate;

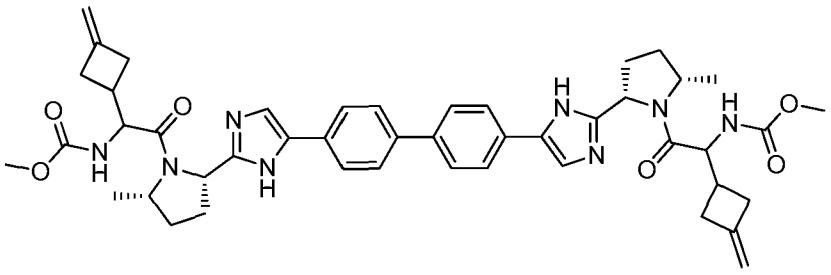
or a pharmaceutically acceptable salt thereof.

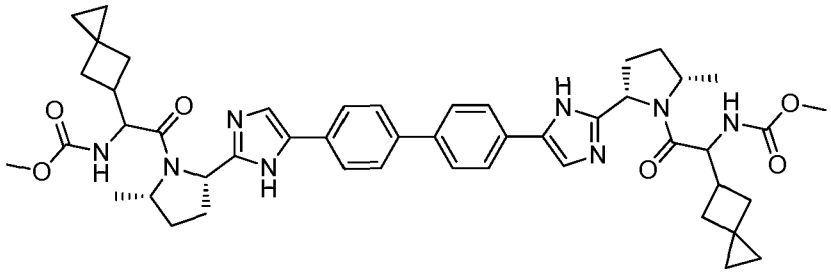
12. A compound selected from:

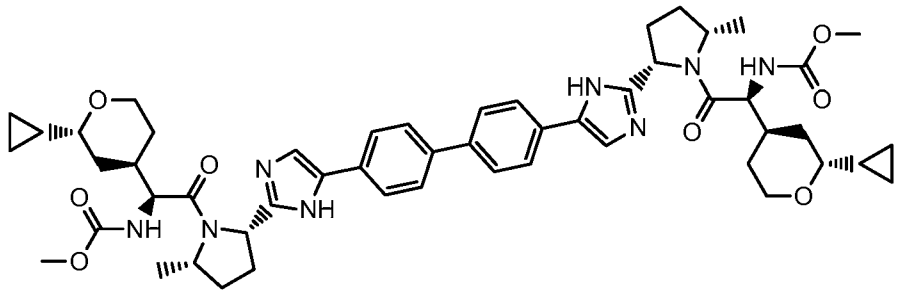

;


;

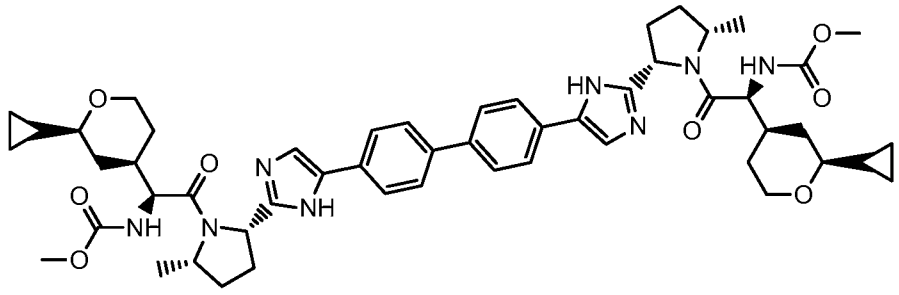

;


;

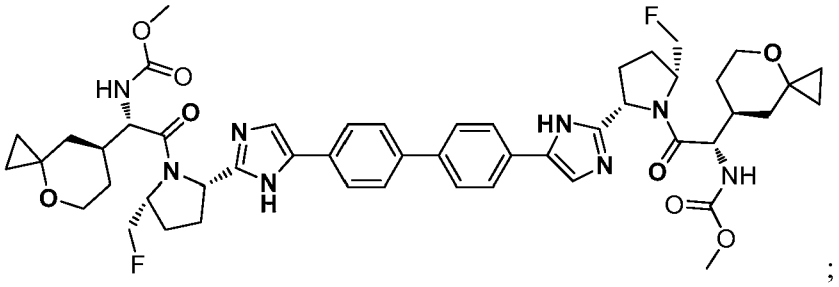

;



;



; and



;

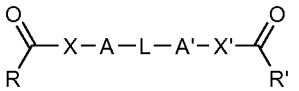
or a pharmaceutically acceptable salt thereof.

13. A compound which is

dimethyl (4,4'-biphenyldiylbis(1H-imidazole-4,2-diyl((2S,5S)-5-methyl-2,1-pyrrolidinediyl)(1-(4-oxaspiro[2.5]oct-7-yl)-2-oxo-2,1-ethanediyl)))biscarbamate;

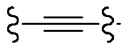
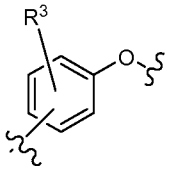
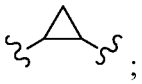
or a pharmaceutically acceptable salt thereof.

14. A compound of Formula (II)

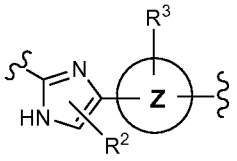
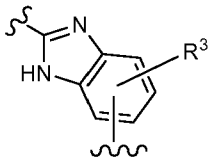
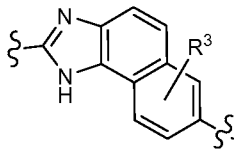
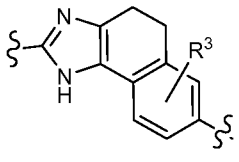


(II),

or a pharmaceutically acceptable salt thereof, wherein

L is selected from a bond,  ,  , and  ;

A and A' are independently selected from

 ,  ,  , and  ,

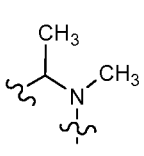
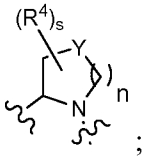
wherein each group is drawn with the imidazole ring being attached to X, and with the six-membered ring being attached to L, and wherein:

Z is a six-membered aromatic ring optionally containing one, two, or three nitrogen atoms;

R^2 is selected from hydrogen, alkyl, and halo; and

R^3 is selected from hydrogen, alkoxy, alkyl, cyano, halo, and haloalkoxy;

X and X' are independently selected from

 , and  ;

wherein each group is drawn with the carbon atom being attached to A or A' and with the nitrogen atom attached to the carbonyl group and wherein:

n is 0, 1, or 2;

s is 0, 1, 2, 3, or 4;

Y is selected from NH, NR^4, O, S, S(O), SO_2, CH_2, CHR^4, and $C(R^4)_2$; provided that when n is 0, Y is selected from CH_2, CHR^4, and $C(R^4)_2$; and

each R^4 is independently selected from alkoxy, alkyl, aryl, cyano, halo, haloalkoxy, haloalkyl, hydroxy, and $-NR^aR^b$, wherein the alkyl can optionally form a fused three- to six-membered ring or a bridged four- or five-membered ring with another carbon atom on the ring; or can optionally form a spirocyclic three- to six-membered ring with the carbon to which it is attached, wherein the formed ring system is optionally substituted with one or two groups independently selected from alkyl and halo; provided that when Y is NR^4, R^4 is other than halo, hydroxy, or $-NR^aR^b$;

R is (NR^cR^d)alkyl, wherein the alkyl part of the (NR^cR^d)alkyl is substituted with bicycloalkyl, fused bicycloheterocyclyl, oxocycloalkyl, or spirocycloheterocyclyl, wherein the bicycloalkyl, bicycloheterocyclyl, oxocycloalkyl, and spirocycloheterocyclyl are optionally substituted with one or two groups independently selected from alkyl, halo, and haloalkyl;

R' is (NR^cR^d)alkyl, wherein the alkyl part of the (NR^cR^d)alkyl is optionally substituted with bicycloalkyl, fused bicycloheterocyclyl, oxocycloalkyl, or spirocycloheterocyclyl, wherein the bicycloalkyl, bicycloheterocyclyl, oxocycloalkyl, and spirocycloheterocyclyl are optionally substituted with one or two groups independently selected from alkyl, halo, and haloalkyl;

R^a and R^b are independently selected from hydrogen and alkyl;

R^c and R^d are independently selected from hydrogen, alkenyloxycarbonyl, alkoxyalkylcarbonyl, alkoxycarbonyl, alkyl, alkylcarbonyl, alkylsulfonyl, aryl, arylalkoxycarbonyl, arylalkyl, arylalkylcarbonyl, arylcarbonyl, aryloxycarbonyl, arylsulfonyl, cycloalkyl, cycloalkyloxycarbonyl, cycloalkylsulfonyl, formyl, haloalkoxycarbonyl, heterocyclyl, heterocyclylalkoxycarbonyl, heterocyclylalkyl, heterocyclylalkylcarbonyl, heterocyclylcarbonyl, heterocyclyloxycarbonyl, hydroxyalkylcarbonyl, (NR^eR^f)alkyl, (NR^eR^f)alkylcarbonyl, (NR^eR^f)carbonyl, (NR^eR^f)sulfonyl, -C(NCN)OR'', and -C(NCN)NR^xR^y, wherein R'' is selected from alkyl and unsubstituted phenyl, and wherein the alkyl part of the arylalkyl, the arylalkylcarbonyl, the heterocyclylalkyl, and the heterocyclylalkylcarbonyl are further optionally substituted with one -NR^eR^f group; and wherein the aryl, the aryl part of the arylalkoxycarbonyl, the arylalkyl, the arylalkylcarbonyl, the arylcarbonyl, the aryloxycarbonyl, and the arylsulfonyl, the heterocyclyl, and the heterocyclyl part of the heterocyclylalkoxycarbonyl, the heterocyclylalkyl, the heterocyclylalkylcarbonyl, the heterocyclylcarbonyl, and the heterocyclyloxycarbonyl are further optionally substituted with one, two, or three substituents independently selected from alkoxy, alkyl, cyano, halo, haloalkoxy, haloalkyl, and nitro;

R^e and R^f are independently selected from hydrogen, alkyl, unsubstituted aryl, unsubstituted arylalkyl, unsubstituted cycloalkyl, unsubstituted (cyclolalkyl)alkyl, unsubstituted heterocyclyl, unsubstituted heterocyclylalkyl, (NR^xR^y)alkyl, and (NR^xR^y)carbonyl; and

R^x and R^y are independently selected from hydrogen, alkoxycarbonyl, alkyl, alkylcarbonyl, unsubstituted aryl, unsubstituted arylalkoxycarbonyl, unsubstituted arylalkyl, unsubstituted cycloalkyl, unsubstituted heterocyclyl, and $(NR^{x'}R^{y'})$carbonyl, wherein $R^{x'}$ and $R^{y'}$ are independently selected from hydrogen and alkyl.

15. A composition comprising a compound of claim 1, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

16. The composition of claim 15 further comprising at least one additional compound having anti-HCV activity.

17. The composition of claim 16 wherein at least one of the additional compounds is an interferon or a ribavirin.

18. The composition of claim 17 wherein the interferon is selected from interferon alpha 2B, pegylated interferon alpha, pegylated interferon lambda, consensus interferon, interferon alpha 2A, and lymphoblastiod interferon tau.

19. The composition of claim 16 wherein at least one of the additional compounds is selected from interleukin 2, interleukin 6, interleukin 12, a compound that enhances the development of a type 1 helper T cell response, interfering RNA, anti-sense RNA, Imiquimod, ribavirin, an inosine 5'-monophosphate dehydrogenase inhibitor, amantadine, and rimantadine.

20. The composition of claim 16 wherein at least one of the additional compounds is effective to inhibit the function of a target selected from HCV metalloprotease, HCV serine protease, HCV polymerase, HCV helicase, HCV NS4B protein, HCV entry, HCV assembly, HCV egress, HCV NS5A protein, and IMPDH for the treatment of an HCV infection.

21. A method of treating an HCV infection in a patient, comprising administering to the patient a therapeutically effective amount of a compound of claim 1, or a

pharmaceutically acceptable salt thereof.

22. The method of claim 21 further comprising administering at least one additional compound having anti-HCV activity prior to, after or simultaneously with the compound of claim 1, or a pharmaceutically acceptable salt thereof.

23. The method of claim 22 wherein at least one of the additional compounds is an interferon or a ribavirin.

24. The method of claim 23 wherein the interferon is selected from interferon alpha 2B, pegylated interferon alpha, pegylated interferon lambda, consensus interferon, interferon alpha 2A, and lymphoblastiod interferon tau.

25. The method of claim 22 wherein at least one of the additional compounds is selected from interleukin 2, interleukin 6, interleukin 12, a compound that enhances the development of a type 1 helper T cell response, interfering RNA, anti-sense RNA, Imiquimod, ribavirin, an inosine 5'-monophosphate dehydrogenase inhibitor, amantadine, and rimantadine.

26. The method of claim 22 wherein at least one of the additional compounds is effective to inhibit the function of a target selected from HCV metalloprotease, HCV serine protease, HCV polymerase, HCV helicase, HCV NS4B protein, HCV entry, HCV assembly, HCV egress, HCV NS5A protein, and IMPDH for the treatment of an HCV infection.