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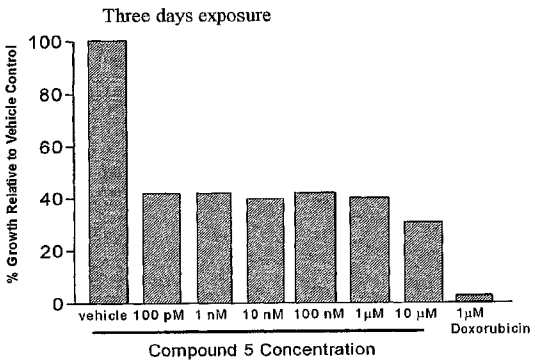

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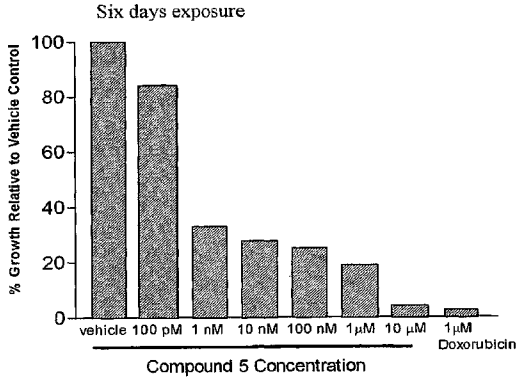

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(57) Abstract: The present invention provides angiogenesis inhibitor compounds comprising a MetAP-2 inhibitory core coupled to a peptide, as well as pharmaceutical compositions comprising the angiogenesis inhibitor compounds and a pharmaceutically acceptable carrier. The present invention also provides methods of inducing an immunosupressed condition and/or treating chronic allograft vasculopathy in a subject undergoing or who has undergone a transplant, by administering to the subject a therapeutically effective amount of one or more of the compounds of the invention.

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METHIONINE AMINOPEPTIDASE-2 INHIBITORS AND METHODS OF USE THEREOF

Related Application

This application claims priority to U.S. Patent Application Serial No. 11/490,967, filed July 21, 2006, which is a continuation-in-part of U.S. Patent Application Serial No. 10/429,174, filed on May 2, 2003, now U.S. Patent No. 7,105,482; which is a continuation-in-part of U.S. Patent Application Serial No. 10/138,935, filed on May 2, 2002, now U.S. Patent No. 6,919,307; which is a continuation-in-part of U.S. Patent Application Serial No. 10/001,945, filed on November 1, 2001, now U.S. Patent No. 7,084,108; which in turn is a continuation-in-part of U.S. Patent Application Serial No. 09/972,772, filed on October 5, 2001, now U.S. Patent No. 7,037,890; which in turn is a continuation-in-part of U.S. patent application Serial No. 09/704,251, filed on November 1, 2000, now U.S. Patent No. 6,548,477. The entire contents of each of the aforementioned applications are hereby incorporated herein by reference.

Background of the Invention

Lymphoma is a leading cause of death in the United States. Lymphoma is a type of cancer that can occur when an error occurs in the way a lymphocyte is produced, resulting in an abnormal cell. These abnormal cells can accumulate by two mechanisms: (a) they can duplicate faster than normal cells, or (b) they can live longer than normal lymphocytes. Like normal lymphocytes, the cancerous lymphocytes can grow in many parts of the body, including the lymph nodes, spleen, bone marrow, blood, or other organs. There are two main types of cancer of the lymphatic system. One is called Hodgkin's disease, while the other is called non-Hodgkin's lymphoma.

Autoimmune disorders also present a serious health issue in the United States. A progressive and maintained response by the immune system against self-components is termed autoimmunity. Normally self-tolerance mechanisms prevent the immune response from acting on self-components. However, all mechanisms have a risk of breakdown and occasionally the immune system turns on its host environment in an aggressive manner as to cause disease. This breakdown leads to the copious production of autoreactive B cells producing autoantibodies and/or autoreactive T cells leading to destructive autoimmune disease. The cellular mechanisms of autoimunity are the same as those involved in beneficial immune responses to foreign components which include antibody-dependent cell cytotoxicity, delayed-type hypersensitivity (DTH), and T-cell lympholysis.

Human autoimmune diseases can be divided into two categories: organ-specific and systemic. In organ-specific autoimmune disease, autoreactivity is directed to antigens unique to a single organ. In systemic autoimmune disease, autoreactivity is largely directed toward a broad range of antigens and involves a number of tissues. Disease in either type results from the generation of one or both autoreactive cell types (B or T cells). Autoreactive B cells lead to the generation of autoantibodies or immune complexes. Autoreactive T cells lead to the cellular DTH responses from T_DTh cells or cytotoxic responses from T_C cells.

Diseases caused by parasites are among the leading causes of death and disease in tropical and subtropical regions of the world. Efforts to control the invertebrate vector (carrier, such as the mosquito) of these diseases is, in many cases, difficult as a result of pesticide resistance, concerns regarding environmental damage and lack of adequate infrastructure to apply existing vector control methods. Thus, control of these diseases relies heavily on the availability of drugs. Unfortunately, most existing therapeutics are either incompletely effective or toxic to the human host. In a number of cases, even safe and effective drugs are failing as a result of the selection and spread of drug resistant variants of the parasites. This is best dramatized by the global spread of drug resistant Plasmodium falciparum, the organism responsible for the most lethal form of malaria.

Angiogenesis is the fundamental process by which new blood vessels are formed and is essential to a variety of normal body activities (such as reproduction, development and wound repair). Although the process is not completely understood, it is believed to involve a complex interplay of molecules which both stimulate and inhibit the growth of endothelial cells, the primary cells of the capillary blood vessels. Under normal conditions, these molecules appear to maintain the microvasculature in a quiescent state (*i.e.*, one of no capillary growth) for prolonged periods which may last for as long as weeks or in some cases, decades. When necessary, however, (such as during wound repair), these same cells can undergo rapid proliferation and turnover within a 5 day period (Folkman, J. and Shing, Y., *Journal of Biological Chemistry*, 267(16): 10931-10934, and Folkman, J. and Klagsbrun, M. (1987) *Science*, 235: 442-447).

Although angiogenesis is a highly regulated process under normal conditions, many diseases (characterized as "angiogenic diseases") are driven by persistent unregulated angiogenesis. Otherwise stated, unregulated angiogenesis may either cause a particular disease directly or exacerbate an existing pathological condition. For example, ocular neovacularization has been implicated as the most common cause of blindness and dominates approximately 20 eye diseases. In certain existing conditions

such as arthritis, newly formed capillary blood vessels invade the joints and destroy cartilage. In diabetes, new capillaries formed in the retina invade the vitreous, bleed, and cause blindness. Growth and metastasis of solid tumors are also angiogenesis-dependent (Folkman, J. (1986) *Cancer Research* 46: 467-473 and Folkman, J. (1989) *Journal of the National Cancer Institute* 82: 4-6). It has been shown, for example, that tumors which enlarge to greater than 2 mm, must obtain their own blood supply and do so by inducing the growth of new capillary blood vessels. Once these new blood vessels become embedded in the tumor, they provide a means for tumor cells to enter the circulation and metastasize to distant sites, such as the liver, lung or bone (Weidner, N., *et al.* (1991) *The New England Journal of Medicine* 324(1):1-8).

Fumagillin is a known compound which has been used as an antimicrobial and antiprotozoal. Its physicochemical properties and method of production are well known (U.S. Pat. No. 2,803,586 and *Proc. Nat. Acad. Sci. USA* (1962) 48:733-735). Fumagillin and certain types of Fumagillin analogs have also been reported to exhibit anti-angiogenic activity. However, the use of such inhibitors (*e.g.*, TNP-470) may be limited by their rapid metabolic degradation, erratic blood levels, and by dose-limiting central nervous system (CNS) side effects.

Accordingly, there is still a need for angiogenesis inhibitors which are more potent, less neurotoxic, more stable, and/or have longer serum half-lives.

Summary of the Invention

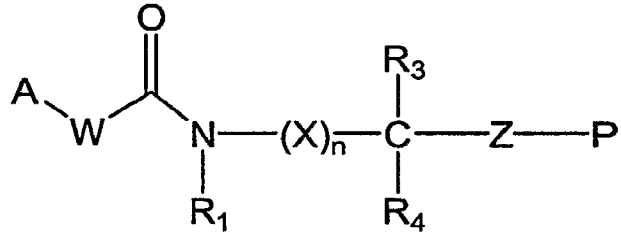
The present invention provides angiogenesis inhibitor compounds which comprise a core, *e.g.*, a Fumagillin core, that is believed to inhibit methionine aminopeptidase 2 (MetAP-2), coupled to a peptide. The present invention is based, at least in part, on the discovery that coupling the MetAP-2 inhibitory core to an amino acid residue or an amino acid derivative prevents the metabolic degradation of the angiogenesis inhibitor compound to ensure a superior pharmacokinetic profile and limits CNS side effects by altering the ability of the angiogenesis inhibitor compound to cross the blood brain barrier. The present invention is also based, at least in part, on the discovery that coupling the MetAP-2 inhibitory core to a peptide comprising a site-directed sequence allows for a cell specific delivery of the angiogenesis inhibitor compound and limits the toxicity of the angiogenesis inhibitor compound.

In one aspect the present invention provides a method for treating a subject (*e.g.*, a mammal, such as a human) suffering from a lymphoid malignancy. The method includes administering to a subject an effective amount of a MetAP-2 inhibitor, thereby treating a subject suffering from a lymphoid malignancy. Lymphoid malignancies which can be treated with a MetAP-2 inhibitor include lymphoid leukemias, such as chronic

lymphoid leukemia and acute lymphoid leukemia, and lymphomas, such as T cell lymphoma and B cell lymphoma.

In a preferred embodiment, the method further includes administering to the subject a second therapy suitable for treating a subject suffering from lymphoid malignancy. The second therapy may be administered to the subject subsequent to, simultaneously or prior to administration of the MetAP-2 inhibitor to the subject. The second therapy may include administration of a chemotherapeutic regimen or a vaccine to the subject.

Accordingly, the present invention provides compounds of Formula I,



In Formula I, A is a MetAP-2 inhibitory core,W is O or NR_2, and R_1 and R_2 are each, independently, hydrogen or alkyl; X is alkylene or substituted alkylene, preferably linear C_1-C_6-alkylene; n is 0 or 1; R_3 and R_4 are each, independently, hydrogen, substituted or unsubstituted alkyl, substituted or unsubstituted aryl or arylalkyl or substituted or unsubstituted heteroaryl or heteroalkyl. R_3 and R_4 can also, together with the carbon atom to which they are attached, form a carbocyclic or heterocyclic group; or R_1 and R_4 together can form an alkylene group; Z is -C(O)-, alkylene-C(O)- or alkylene; and P is a peptide comprising from 1 to about 100 amino acid residues attached at its amino terminus to Z or a group OR_5 or $N(R_6)R_7$, wherein R_5, R_6 and R_7 are each, independently, hydrogen, alkyl, substituted alkyl, azacycloalkyl or substituted azacycloalkyl. R_6 and R_7 can also form, together with the nitrogen atom to which they are attached, a substituted or unsubstituted heterocyclic ring structure.

In another embodiment of the compounds of Formula I, W, X, n, R_1, R_3 and R_4 have the meanings given above for these variables; Z is -O-, -NR_8-, alkylene-O- or alkylene-NR_8-, where R_8 is hydrogen or alkyl; and P is hydrogen, alkyl, preferably normal or branched C_1-C_4-alkyl or a peptide consisting of from 1 to about 100 amino acid residues attached at its carboxy terminus to Z.

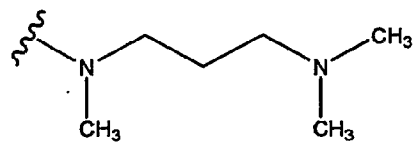
In compounds of Formula I, when any of R_1-R_8 is an alkyl group, preferred alkyl groups are substituted or unsubstituted normal, branched or cyclic C_1-C_6 alkyl groups. Particularly preferred alkyl groups are normal or branched C_1-C_4 alkyl groups. A

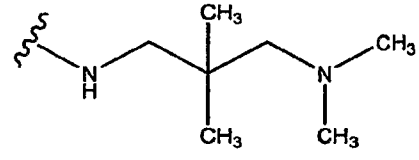
substituted alkyl group includes at least one non-hydrogen substituent, such as an amino group, an alkylamino group or a dialkylamino group; a halogen, such as a fluoro, chloro, bromo or iodo substituent; or hydroxyl.

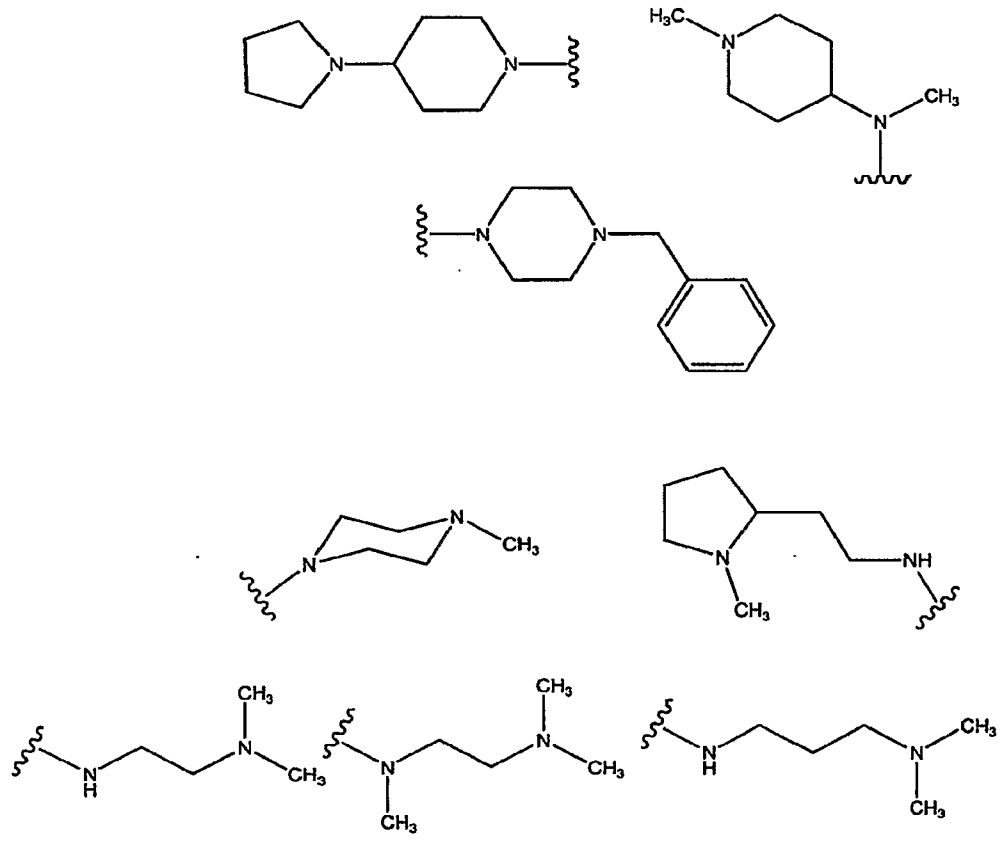
When at least one of R_3 and R_4 is a substituted or unsubstituted aryl or heteroaryl group, preferred groups include substituted and unsubstituted phenyl, naphthyl, indolyl, imidazoly and pyridyl. When at least one of R_3 and R_4 is substituted or unsubstituted arylalkyl or heteroarylalkyl, preferred groups include substituted and unsubstituted benzyl, naphthylmethyl, indolylmethyl, imidazolylmethyl and pyridylmethyl groups. Preferred substituents on aryl, heteroaryl, arylalkyl and heteroarylalkyl groups are independently selected from the group consisting of amino, alkyl-substituted amino, halogens, such as fluoro, chloro, bromo and iodo; hydroxyl groups and alkyl groups, preferably normal or branched C_1-C_6-alkyl groups, most preferably methyl groups. X is preferably linear C_1-C_6-alkylene, more preferably C_1-C_4-alkylene and most preferably methylene or ethylene. When Z is alkylene-C(O)-, alkylene-O- or alkylene-NR_8, the alkylene group is preferably linear C_1-C_6-alkylene, more preferably C_1-C_4-alkylene and most preferably methylene or ethylene.

R_6 and R_7, in addition to alkyl, substituted alkyl or hydrogen, can each also independently be a substituted or unsubstituted azacycloalkyl group or a substituted or unsubstituted azacycloalkylalkyl group. Suitable substituted azacycloalkyl groups include azacycloalkyl groups which have an N-alkyl substituent, preferably an N-C_1-C_4-alkyl substituent and more preferably an N-methyl substituent. R_6 and R_7 can also, together with the nitrogen atom to which they are attached, form a heterocyclic ring system, such as a substituted or unsubstituted five or six-membered aza- or diazacycloalkyl group. Preferably, the diazacycloalkyl group includes an N-alkyl substituent, such as an N-C_1-C_4-alkyl substituent or, more preferably, an N-methyl substituent.

In particularly preferred embodiments, $-N(R_6)R_7$ is NH_2 or one of the groups shown below:

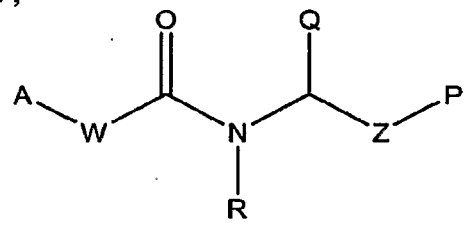






Preferably, the compounds of Formula I do not include compounds wherein Z is –O-, P is hydrogen, R_3 and R_4 are both hydrogen, n is 1 and X is methylene. Preferably, the compounds of Formula I further do not include compounds wherein Z is methylene-O-, R_3 and R_4 are both hydrogen, and n is 0.

In another aspect, the present invention is directed to angiogenesis inhibitor compounds of Formula XV,



(XV)

where A is a MetAP-2 inhibitory core and W is O or NR. In one embodiment, Z is –C(O)- or -alkylene-C(O)- and P is NHR, OR or a peptide consisting of one to about one hundred amino acid residues connected at the N-terminus to Z. In this embodiment, Q is hydrogen, linear, branched or cyclic alkyl or aryl, provided that when P is –OR, Q is not hydrogen.

In another embodiment, Z is –alkylene-O- or –alkylene-N(R)- and P is hydrogen or a peptide consisting of from one to about one hundred amino acid residues connected to Z at the carboxyl terminus. In this embodiment, Q is hydrogen, linear, branched or cyclic alkyl or aryl, provided that when P is hydrogen, Q is not hydrogen.

In the angiogenesis inhibitor compounds of Formula XV, each R is, independently, hydrogen or alkyl.

In another aspect, the invention features pharmaceutical compositions comprising the angiogenesis inhibitor compounds of Formula I or XV and a pharmaceutically acceptable carrier.

In yet another aspect, the invention features a method of treating an angiogenic disease, *e.g.*, cancer (such as lung cancer, brain cancer, kidney cancer, colon cancer, liver cancer, pancreatic cancer, stomach cancer, prostate cancer, breast cancer, ovarian cancer, cervical cancer, melanoma, and metastatic versions of any of the preceding cancers), in a subject. The method includes administering to the subject a therapeutically effective amount of one or more angiogenesis inhibitor compounds of Formula I or XV.

In one embodiment, the present invention provides a method of treating a subject suffering from a parasitic infection, such as an infection by Plasmodium species, such as Plasmodium falciparum, or an infection by Leishmania species, such as Leishmania donavani. The method comprises the step of administering to the subject a therapeutically effective amount of a compound of the invention. The subject can be an individual who is suffering from, or susceptible to, infection by a parasitic organism. In a preferred embodiment, the subject suffers from malaria or Leishmaniasis.

The invention further provides a method of treating a subject suffering from a lymphoid malignancy. The method comprises the step of administering to the subject a therapeutically effective amount of a compound of the invention. Suitable lymphoid malignancies which can be treated with a compound of the invention include lymphoid leukemias, such as chronic lymphoid leukemia and acute lymphoid leukemia, and lymphomas, such as Non-Hodgkin's lymphoma, including T cell lymphoma and B cell lymphoma.

In a further embodiment, the invention provides a method of treating a subject suffering from an autoimmune disorder, comprising the step of administering to the subject a therapeutically effective amount of a compound of the invention. The autoimmune disorder can be, for example, rheumatoid arthritis, lupus erythematosus, psoriasis, multiple sclerosis, myasthenia gravis, vasculitis, or diabetes mellitus.

Other features and advantages of the invention will be apparent from the following detailed description and claims.

Brief Description of the Drawings

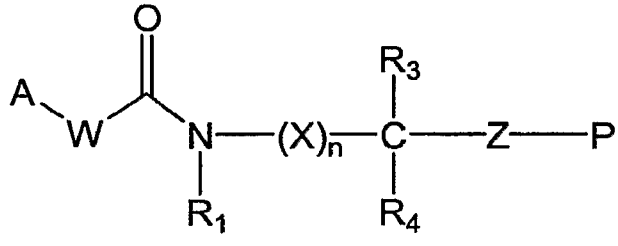
Figure 1 is a series of graphs depicting the inhibition of SR cell proliferation in culture following 3 or 6 days of exposure to Compound 5 (representative data).

Figure 2 is a graph depicting tumor volumes of SR lymphoma tumor-bearing mice treated with Compound 5.

Detailed Description of the Invention

The present invention provides compounds useful as angiogenesis inhibitors and methods for using these compounds in the treatment of angiogenic diseases. Without intending to be limited by theory, it is believed that the angiogenesis inhibitor compounds of the invention inhibit angiogenesis by inhibiting methionine aminopeptidase 2 (MetAP-2), an enzyme which cleaves the N-terminal methionine residue of newly synthesized proteins to produce the active form of the protein. At the same time, the presence of a peptide in the angiogenesis inhibitor compounds of the invention prevents the metabolic degradation of the angiogenesis inhibitor compounds and ensures a superior pharmacokinetic profile. The presence of the peptide in the angiogenesis inhibitor compounds of the invention also alters the ability of the angiogenesis inhibitor compound to cross the blood brain barrier to, for example, limit CNS side effects (such as CNS toxicity). The presence of peptides comprising a site-directed sequence in the angiogenesis inhibitor compounds of the invention allows for a site-specific delivery of the angiogenesis inhibitor compounds and, thus, limits the toxicity of the angiogenesis inhibitor compounds.

The angiogenesis inhibitor compounds of the invention comprise a MetAP-2 inhibitory core and a peptide attached, directly or indirectly, thereto. In one embodiment, the invention provides angiogenesis inhibitor compounds of Formula I



In Formula I, A is a MetAP-2 inhibitory core, W is O or NR_2, and R_1 and R_2 are each, independently, hydrogen or alkyl; X is alkylene or substituted alkylene, preferably

linear C_1-C_6-alkylene; n is 0 or 1; R_3 and R_4 are each, independently, hydrogen, substituted or unsubstituted alkyl, substituted or unsubstituted aryl or arylalkyl or substituted or unsubstituted heteroaryl or heteroalkyl. R_3 and R_4 can also, together with the carbon atom to which they are attached, form a carbocyclic or heterocyclic group; or R_1 and R_4 together can form an alkylene group; Z is -C(O)-, alkylene-C(O)- or alkylene; and P is a peptide comprising from 1 to about 100 amino acid residues attached at its amino terminus to Z or a group OR_5 or $N(R_6)R_7$, wherein R_5, R_6 and R_7 are each, independently, hydrogen, alkyl, substituted alkyl, azacycloalkyl or substituted azacycloalkyl. R_6 and R_7 can also form, together with the nitrogen atom to which they are attached, a substituted or unsubstituted heterocyclic ring structure.

In another embodiment of the compounds of Formula I, W, X, n, R_1, R_3 and R_4 have the meanings given above for these variables; Z is -O-, -NR_8-, alkylene-O- or alkylene-NR_8-, where R_8 is hydrogen or alkyl; and P is hydrogen, alkyl, preferably normal or branched C_1-C_4-alkyl or a peptide consisting of from 1 to about 100 amino acid residues attached at its carboxy terminus to Z.

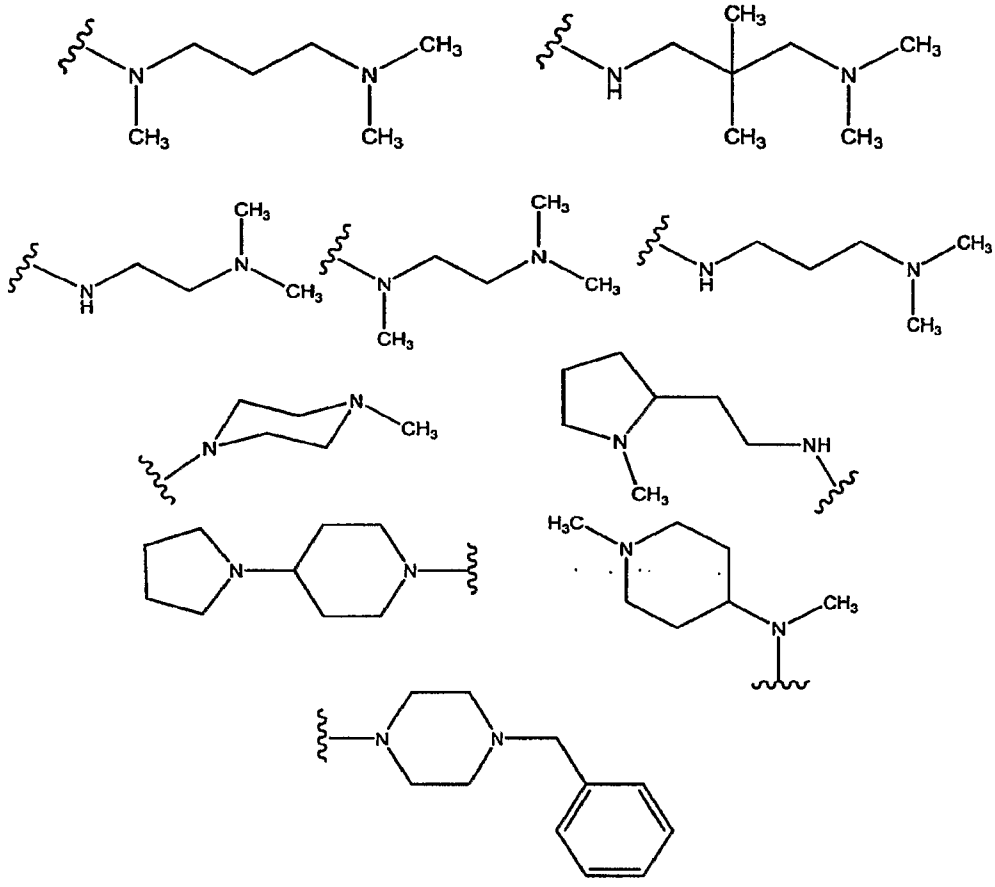
In compounds of Formula I, when any of R_1-R_8 is an alkyl group, preferred alkyl groups are substituted or unsubstituted normal, branched or cyclic C_1-C_6 alkyl groups. Particularly preferred alkyl groups are normal or branched C_1-C_4 alkyl groups. A substituted alkyl group includes at least one non-hydrogen substituent, such as an amino group, an alkylamino group or a dialkylamino group; a halogen, such as a fluoro, chloro, bromo or iodo substituent; or hydroxyl.

When at least one of R_3 and R_4 is a substituted or unsubstituted aryl or heteroaryl group, preferred groups include substituted and unsubstituted phenyl, naphthyl, indolyl, imidazolyl and pyridyl. When at least one of R_3 and R_4 is substituted or unsubstituted arylalkyl or heteroarylalkyl, preferred groups include substituted and unsubstituted benzyl, naphthylmethyl, indolylmethyl, imidazolylmethyl and pyridylmethyl groups. Preferred substituents on aryl, heteroaryl, arylalkyl and heteroarylalkyl groups are independently selected from the group consisting of amino, alkyl-substituted amino, halogens, such as fluoro, chloro, bromo and iodo; hydroxyl groups and alkyl groups, preferably normal or branched C_1-C_6-alkyl groups, most preferably methyl groups. X is preferably linear C_1-C_6-alkylene, more preferably C_1-C_4-alkylene and most preferably methylene or ethylene. When Z is alkylene-C(O)-, alkylene-O- or alkylene-NR_8, the alkylene group is preferably linear C_1-C_6-alkylene, more preferably C_1-C_4-alkylene and most preferably methylene or ethylene.

R_6 and R_7, in addition to alkyl, substituted alkyl or hydrogen, can each also independently be a substituted or unsubstituted azacycloalkyl group or a substituted or unsubstituted azacycloalkylalkyl group. Suitable substituted azacycloalkyl groups

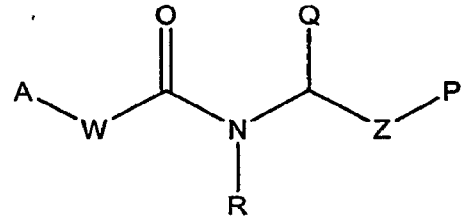
include azacycloalkyl groups which have an N-alkyl substituent, preferably an N-C_1-C_4-alkyl substituent and more preferably an N-methyl substituent. R_6 and R_7 can also, together with the nitrogen atom to which they are attached, form a heterocyclic ring system, such as a substituted or unsubstituted five or six-membered aza- or diazacycloalkyl group. Preferably, the diazacycloalkyl group includes an N-alkyl substituent, such as an N-C_1-C_4-alkyl substituent or, more preferably, an N-methyl substituent.

In particularly preferred embodiments, $-N(R_6)R_7$ is NH_2 or one of the groups shown below:



Preferably, the compounds of Formula I do not include compounds wherein Z is –O-, P is hydrogen, R_3 and R_4 are both hydrogen, n is 1 and X is methylene. Preferably, the compounds of Formula I further do not include compounds wherein Z is methylene-O-, R_3 and R_4 are both hydrogen, and n is 0.

In another embodiment, the invention provides angiogenesis inhibitor compounds of Formula XV,



(XV)

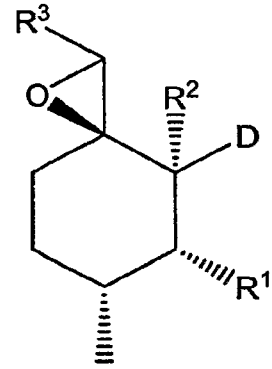
where A is a MetAP-2 inhibitory core and W is O or NR. In one embodiment, Z is –C(O)- or -alkylene-C(O)- and P is NHR, OR or a peptide consisting of one to about one hundred amino acid residues connected at the N-terminus to Z. In this embodiment, Q is hydrogen, linear, branched or cyclic alkyl or aryl, provided that when P is –OR, Q is not hydrogen. Z is preferably –C(O)- or C_1-C_4-alkylene-C(O)-, and, more preferably, -C(O)- or C_1-C_2-alkylene-C(O)-. Q is preferably linear, branched or cyclic C_1-C_6-alkyl, phenyl or naphthyl. More preferably, Q is isopropyl, phenyl or cyclohexyl.

In another embodiment, Z is –alkylene-O- or –alkylene-N(R)-, where alkylene is, preferably, C_1-C_6-alkylene, more preferably C_1-C_4-alkylene and, most preferably, C_1-C_2-alkylene. P is hydrogen or a peptide consisting of from one to about one hundred amino acid residues connected to Z at the carboxyl terminus.. In this embodiment, Q is hydrogen, linear, branched or cyclic alkyl or aryl, provided that when P is hydrogen, Q is not hydrogen. Q is preferably linear, branched or cyclic C_1-C_6-alkyl , phenyl or naphthyl. More preferably, Q is isopropyl, phenyl or cyclohexyl.

In the compounds of Formula XV, each R is, independently, hydrogen or alkyl. In one embodiment, each R is, independently, hydrogen or linear, branched or cyclic C_1-C_6-alkyl. Preferably, each R is, independently, hydrogen or linear or branched C_1-C_4-alkyl. More preferably, each R is, independently, hydrogen or methyl. In the most preferred embodiments, each R is hydrogen.

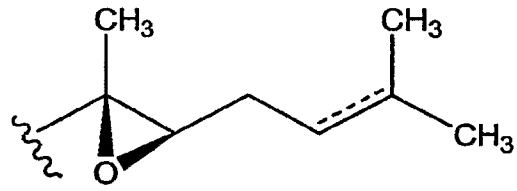
In Formulas I and XV, A is a MetAP-2 inhibitory core. As used herein, a "MetAP-2 inhibitory core" includes a moiety able to inhibit the activity of methionine aminopeptidase 2 (MetAP-2), *e.g.*, the ability of MetAP-2 to cleave the N-terminal methionine residue of newly synthesized proteins to produce the active form of the protein. Preferred MetAP-2 inhibitory cores are Fumagillin derived structures.

Suitable MetAP-2 inhibitory cores include the cores of Formula II,



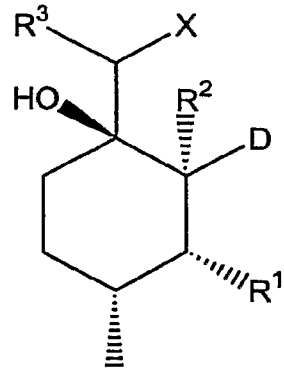
(II)

where R^1 is hydrogen or alkoxy, preferably C_1-C_4-alkoxy and more preferably, methoxy. R^2 is hydrogen or hydroxy; and R^3 is hydrogen or alkyl, preferably C_1-C_4-alkyl and more preferably, hydrogen. D is linear or branched alkyl, preferably C_1-C_6-alkyl; arylalkyl, preferably aryl-C_1-C_4-alkyl and more preferably phenyl-C_1-C_4-alkyl; or D is of the structure



where the dashed line represents a single bond or a double bond.

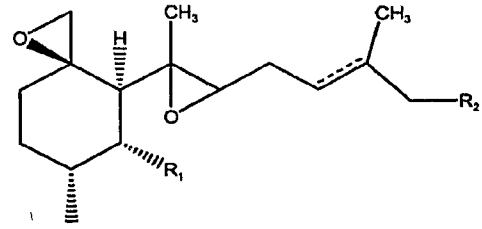
A can also be a MetAP-2 inhibitory core of Formula III,



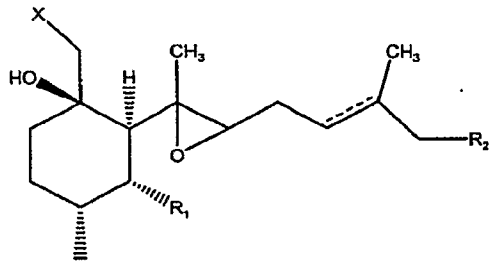
(III)

Where R^1, R^2, R^3 and D have the meanings given above for Formula II, and X is a leaving group, such as a halogen.

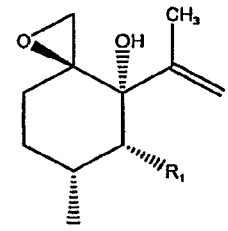
Examples of suitable MetAP-2 inhibitory cores include, but are not limited to, the following.



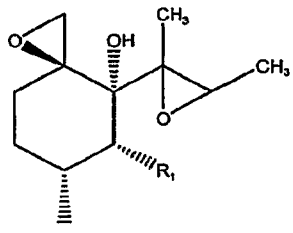
(IV)



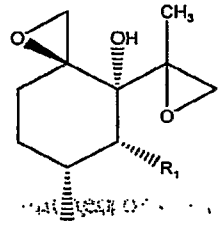
(V)



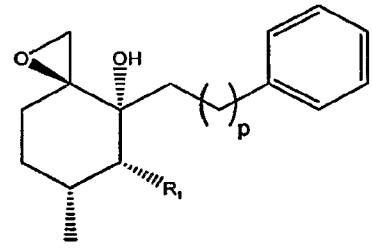
(VI)



(VII)



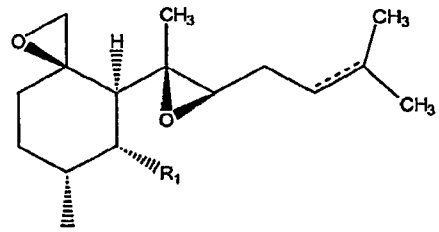
(VIII)



(IX)

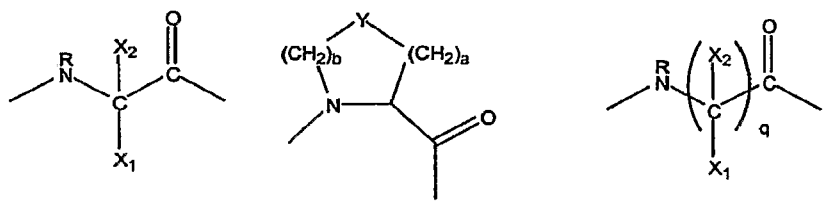
In each of Formulas IV-X, the indicated valence on the ring carbon is the point of attachment of the structural variable W, as set forth in Formulas I-XV. In Formula IX, p is an integer from 0 to 10, preferably 1-4. In Formulas IV, V and VI-IX, R_1 is hydrogen or C_1-C_4-alkoxy, preferably methoxy. In Formulas IV and V, the dashed line indicates that the bond can be a double bond or a single bond. In Formula V, X represents a leaving group, such as a thioalkoxy group, a thioaryloxy group, a halogen or a dialkylsulfinium group. In Formulas IV and V, R_2 is H, OH, amino, C_1-C_4-alkylamino or di(C_1-C_4-alkyl)amino), preferably H. In formulas in which the stereochemistry of a particular stereocenter is not indicated, that stereocenter can have either of the possible stereochemistries, consistent with the ability of the angiogenesis inhibitor compound to inhibit the activity of MetAP-2.

In particularly preferred embodiments, A is the MetAP-2 inhibitory core of Formula X below.



(X)

As used herein, the terms "P" and "peptide" include compounds comprising from 1 to about 100 amino acid residues (*e.g.*, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 or more amino acid residues). In preferred embodiments, the peptide includes compounds comprising less than about 90, 80, 70, 60, 50, 40, 30, 20, or 10 amino acid residues, preferably about 1-10, 1-20, 1-30, 1-40, 1-50, 1-60, 1-70, 1-80, or 1-90 amino acid residues. The peptides may be natural or synthetically made. The amino acid residues are preferably α-amino acid residues. For example, the amino acid residues can be independently selected from among the twenty naturally occurring amino acid residues, the D-enantiomers of the twenty natural amino acid residues, and may also be non-natural amino acid residues (*e.g.*, norleucine, norvaline, phenylglycine, β-alanine, or a peptide mimetic such as 3-amino-methylbenzoic acid). In one embodiment, the amino acid residues are independently selected from residues of Formula XI, Formula XII, and Formula XIII.



XI XII XIII

In Formula XI, X_1 is hydrogen, a side chain of one of the twenty naturally-occurring amino acid residues, a linear, branched or cyclic C_1-C_8-alkyl group, an aryl group, such as a phenyl or naphthyl group, an aryl-C_1-C_4-alkyl group, a heteroaryl group, such as a pyridyl, thienyl, pyrrolyl, or furyl group, or a heteroaryl-C_1-C_4-alkyl

group; and X_2 is hydrogen a linear, branched or cyclic C_1-C_8-alkyl group, an aryl group, such as a phenyl or naphthyl group, an aryl-C_1-C_4-alkyl group or a heteroaryl group as described above for X_1. Preferably, X_2 is hydrogen. In Formula XII, Y is methylene, oxygen, sulfur or NH, and a and b are each, independently, 0-4, provided that the sum of a and b is between 1 and 4. Formulas XI and XII encompass α–amino acid residues having either a D or an L stereochemistry at the alpha carbon atom. One or more of the amino acid residues can also be an amino acid residue other than an α-amino acid residue, such as a β-, γ- or ε-amino acid residue. Suitable examples of such amino acid residues are of Formula XIII, wherein q is an integer of from 2 to about 6, and each X_1 and X_2 independently have the meanings given above for these variables in Formula XI.

In a preferred embodiment, the peptide used in the angiogenesis inhibitor compounds of the invention may include a site-directed sequence in order to increase the specificity of binding of the angiogenesis inhibitor compound to a cell surface of interest. As used herein, the term "site-directed sequence" is intended to include any amino acid sequence (*e.g.*, comprised of natural or non natural amino acid residues) which serves to limit exposure of the angiogenesis inhibitor compound to the periphery and/or which serves to direct the angiogenesis inhibitor compound to a site of interest, *e.g.*, a site of angiogenesis or aberrant cellular proliferation.

The peptide contained within the angiogenesis inhibitor compounds of the invention may include a peptide cleavage site for an enzyme which is expressed at sites of angiogenesis or aberrant cell proliferation, allowing tissue-selective delivery of a cell-permeable active angiogenesis inhibitor compound or fragment thereof (*e.g.*, a fragment containing the MetAP-2 inhibitory core of the angiogenesis inhibitor compound). The peptide may also include a sequence which is a ligand for a cell surface receptor which is expressed at a site of angiogenesis or aberrant cell proliferation, thereby targeting angiogenesis inhibitor compounds to a cell surface of interest. For example, a peptide contained within the angiogenesis inhibitor compounds of the invention can include a cleavage site for a matrix metalloproteinase, or an integrin binding RGD (Arg-Gly-Asp) sequence, or a combination of both an enzyme "cleavage" sequence and a cell surface "ligand" which serve to target the angiogenesis inhibitor compound to the membrane of an endothelial cell. However, the selection of a peptide sequence must be such that the active angiogenesis inhibitor compound is available to be delivered to the cells in which MetAP-2 inhibition is desired.

For example, a sequence that is cleaved by a matrix matalloproteinase produces a product that contains the MetAP-2 inhibitory core, a coupling group, and a peptide fragment. Sequences are selected so that the active angiogenesis inhibitor compound, *e.g.*, the active angiogenesis inhibitor compound generated by the matrix

matalloproteinase cleavage, is cell permeable. Preferably, the active angiogenesis inhibitor compound does not contain a free acid after the cleavage.

In one embodiment, the peptide includes a cleavage site for a matrix metalloprotease, such as matrix metalloprotease-2 (MMP-2), MMP-1, MMP-3, MMP-7, MMP-8, MMP-9, MMP-12, MMP-13 or MMP-26. Preferably, the peptide includes a cleavage site for MMP-2 or MMP-9. For example, the peptide can comprise the sequence -Pro-Leu-Gly-Xaa- (SEQ ID NO:1), where Xaa is any naturally occurring amino acid residue consistent with matrix metalloprotease (MMP) cleavage at the Gly-Xaa bond. Xaa is preferably a hydrophobic amino acid residue, such as tryptophan, phenylalanine, methionine, leucine, isoleucine, proline, and valine.

Other suitable sequences include sequences comprising one or more of Pro-Cha-Gly-Cys(Me)-His (SEQ ID NO:2); Pro-Gln-Gly-Ile-Ala-Gly-Gln-D-Arg (SEQ ID NO:3); Pro-Gln-Gly-Ile-Ala-Gly-Trp (SEQ ID NO:4); Pro-Leu-Gly-Cys(Me)-His-Ala-D-Arg (SEQ ID NO:5); Pro-Leu-Gly-Met-Trp-Ser-Arg (SEQ ID NO:35); Pro-Leu-Gly-Leu-Trp-Ala-D-Arg (SEQ ID NO:6); Pro-Leu-Ala-Leu-Trp-Ala-Arg (SEQ ID NO:7); Pro-Leu-Ala-Leu-Trp-Ala-Arg (SEQ ID NO:8); Pro-Leu-Ala-Tyr-Trp-Ala-Arg (SEQ ID NO:9); Pro-Tyr-Ala-Tyr-Trp-Met-Arg (SEQ ID NO:10); Pro-Cha-Gly-Nva-His-Ala (SEQ ID NO:11); Pro-Leu-Ala-Nva (SEQ ID NO:12); Pro-Leu-Gly-Leu (SEQ ID NO:13); Pro-Leu-Gly-Ala (SEQ ID NO:14); Arg-Pro-Leu-Ala-Leu-Trp-Arg-Ser (SEQ ID NO:15); Pro-Cha-Ala-Abu-Cys(Me)-His-Ala (SEQ ID NO:16); Pro-Cha-Ala-Gly-Cys(Me)-His-Ala (SEQ ID NO:17); Pro-Lys-Pro-Gln-Gln-Phe-Phe-Gly-Leu (SEQ ID NO:18); Pro-Lys-Pro-Leu-Ala-Leu (SEQ ID NO:19); Arg-Pro-Lys-Pro-Tyr-Ala-Nva-Trp-Met (SEQ ID NO:20); Arg-Pro-Lys-Pro-Val-Glu-Nva-Trp-Arg (SEQ ID NO:21); Arg-Pro-Lys-Pro-Val-Glu-Nva-Trp-Arg (SEQ ID NO:22); and Arg-Pro-Lys-Pro-Leu-Ala-Nva-Trp (SEQ ID NO:23). These sequences identify the natural amino acid residues using the customary three-letter abbreviations; the following abbreviations represent the indicated non-natural amino acids: Abu = L-a-aminobutyryl; Cha = L-cyclohexylalanine; Nva = L-norvaline.

In certain embodiments, P is an amino acid sequence selected from the group consisting of Ac-Pro-Leu-Gly-Met-Trp-Ala (SEQ ID NO:24); Gly-Pro-Leu-Gly-Met-His-Ala-Gly (SEQ ID NO:25); Gly-Pro-Leu-(Me)Gly (SEQ ID NO:26); Gly-Pro-Leu-Gly (SEQ ID NO:27); Gly-Met-Gly-Leu-Pro (SEQ ID NO:28); Ala-Met-Gly-Ile-Pro (SEQ ID NO:29); Gly-Arg-Gly-Asp-(O-Me-Tyr)-Arg-Glu (SEQ ID NO:30); Gly-Arg-Gly-Asp-Ser-Pro (SEQ ID NO:31); Gly-Arg-Gly-Asp (SEQ ID NO:32); Asp-Gly-Arg; Ac-Pro-Leu-Gly-Met-Ala (SEQ ID NO:34); Ac-Arg-Gly-Asp-Ser-Pro-Leu-Gly-Met-Trp-Ala (SEQ ID NO:33); Ac-Pro-Leu-Gly-Met-Gly (SEQ ID NO:36); Met-Trp-Ala

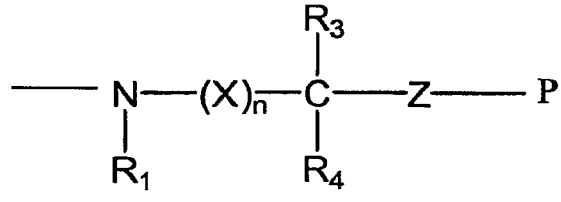
(SEQ ID NO:37); Met-Gly (SEQ ID NO:38); Gly-Pro-Leu-Gly-Met-Trp-Ala-Gly (SEQ ID NO:39); and Gly-Arg-Gly-(3-amino-3-pyridylpropionic acid) (SEQ ID NO:40). (Ac in the foregoing sequences represents an Acetyl group).

The peptide can be attached to the MetAP-2 inhibitory core at either its N-terminus or C-terminus. When the peptide is attached to the MetAP-2 inhibitory core at its C-terminus, the N-terminus of the peptide can be $-NR_2R_3$, where R_2 is hydrogen, alkyl or arylalkyl and R_3 is hydrogen, alkyl, arylalkyl or acyl. When the peptide is attached to the MetAP-2 inhibitory core at its N-terminus, the C-terminus can be $-C(O)R_4$, where R_4 is -OH, -O-alkyl, –O-arylalkyl, or $-NR_2R_3$, where R_2 is hydrogen, alkyl or arylalkyl and R_3 is hydrogen, alkyl, arylalkyl or acyl. In this embodiment, the C-terminal residue can also be present in a reduced form, such as the corresponding primary alcohol.

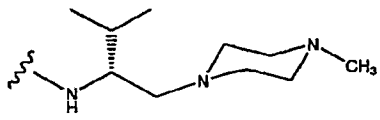
The present invention also includes pharmaceutically acceptable salts of the angiogenesis inhibitor compounds of the invention. A "pharmaceutically acceptable salt" includes a salt that retains the desired biological activity of the parent angiogenesis inhibitor compound and does not impart any undesired toxicological effects. Examples of such salts are salts of acids such as hydrochloric acid, hydrobromic acid, sulfuric acid, phosporic acid, nitric acid, and the like; acetic acid, oxalic acid, tartaric acid, succinic acid, malic acid, benzoic acid, pamoic acid, alginic acid, methanesulfonic acid, naphthalenesulfonic acid, and the like. Also included are salts of cations such as sodium, potassium, lithium, zinc, copper, barium, bismuth, calcium, and the like; or organic cations such as trialkylammonium. Combinations of the above salts are also useful.

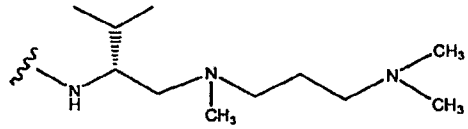
Preferred Angiogenesis Inhibitor Compounds of Formula I

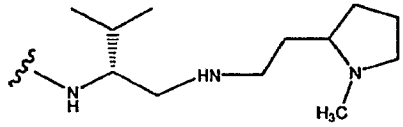
One set of particularly preferred angiogenesis inhibitor compounds of the invention includes compounds in which A is the MetAP-2 inhibitory core of Formula X, W is O or NR_2, and the structure

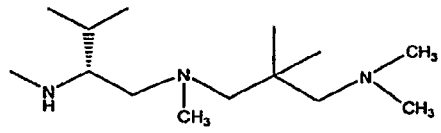


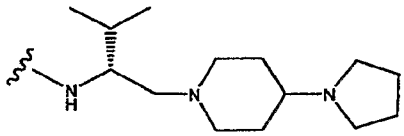
is represented by the structures set forth below.

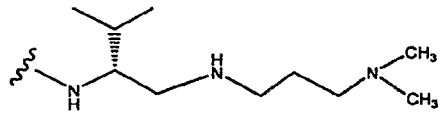


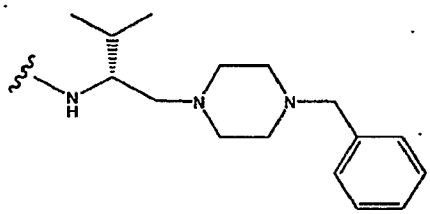


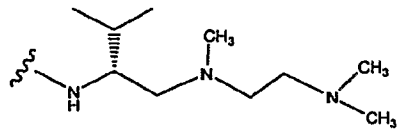


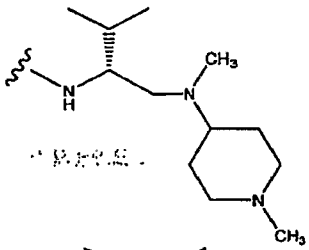


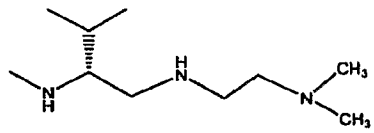


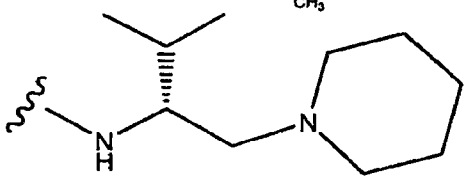


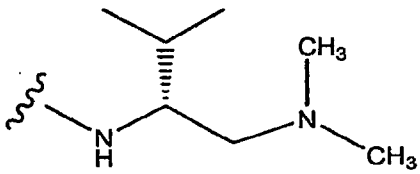


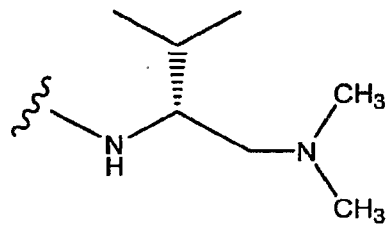


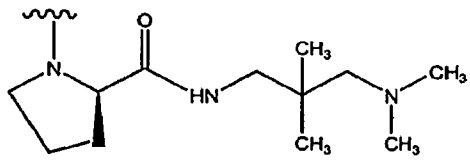


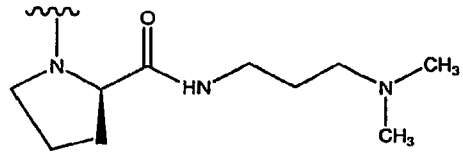


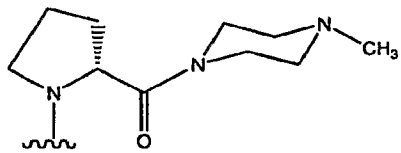


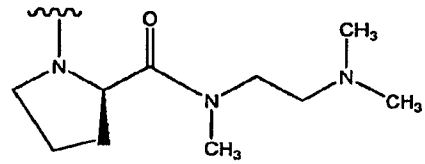


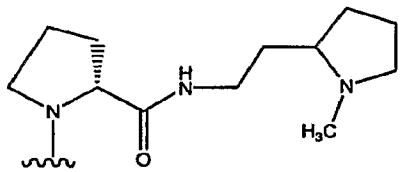


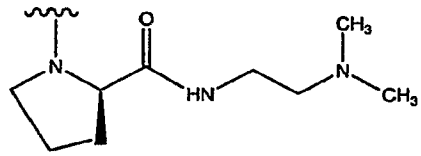


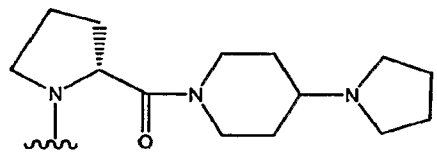


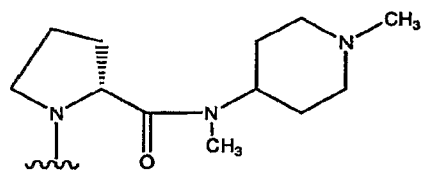


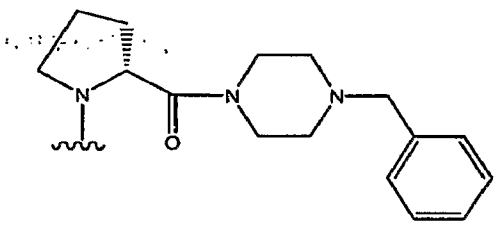


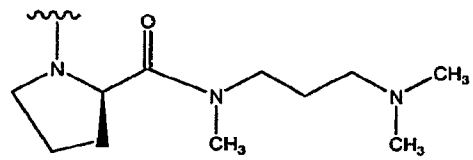


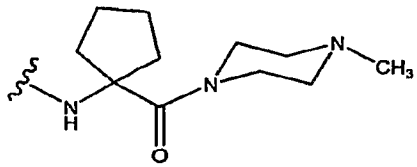


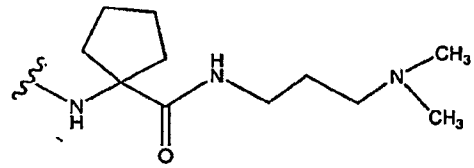


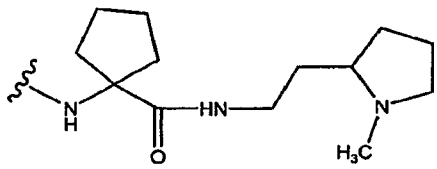


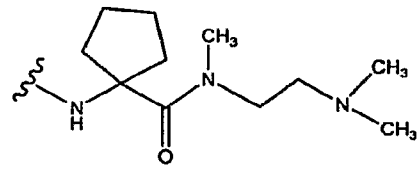


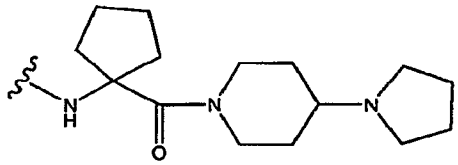


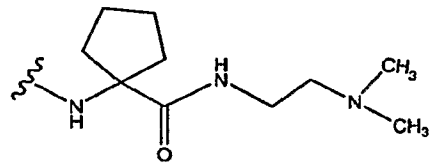


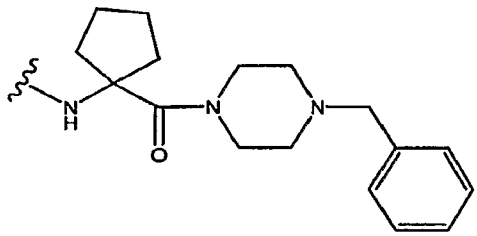


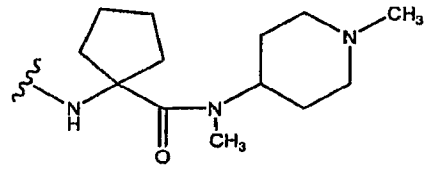


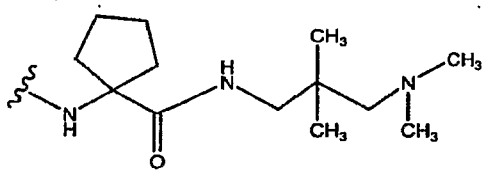


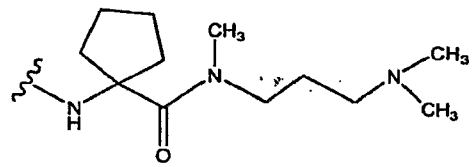


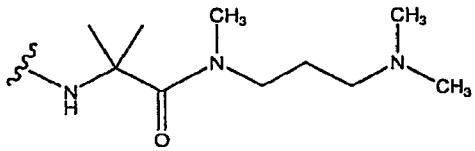


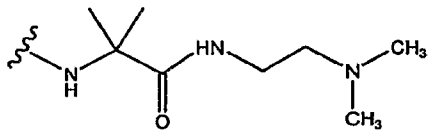


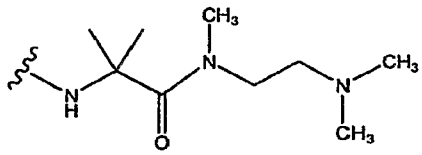


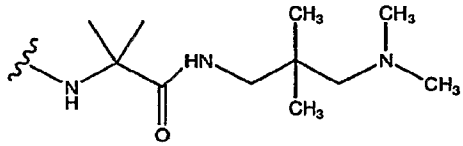


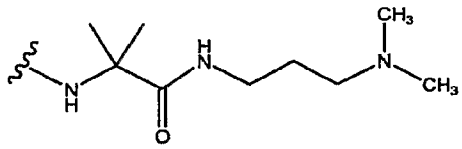


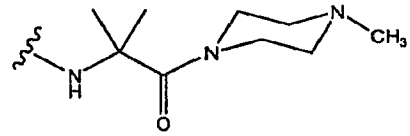


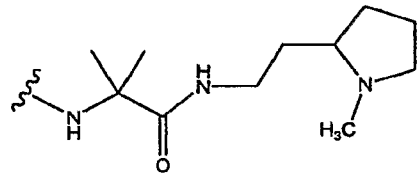


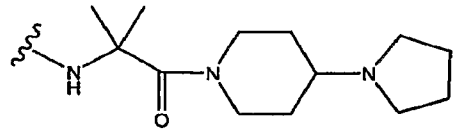


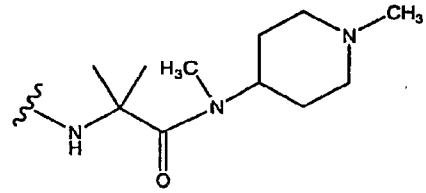


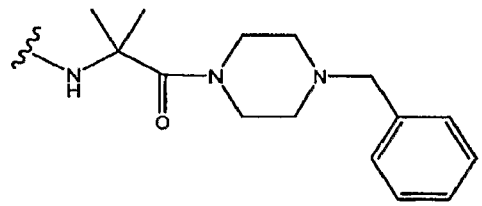


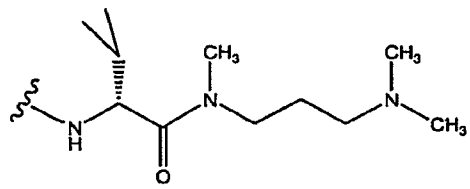


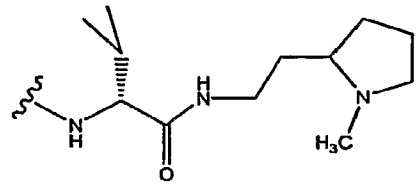


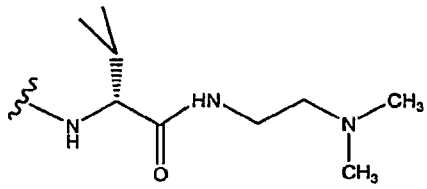


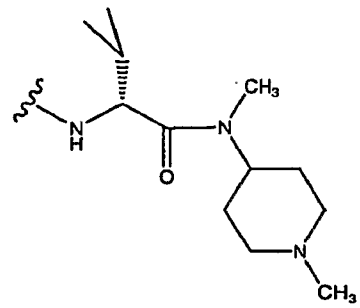


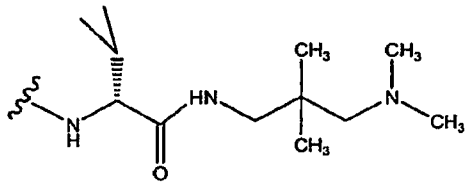


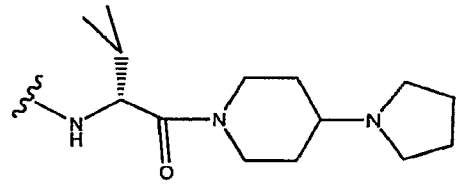


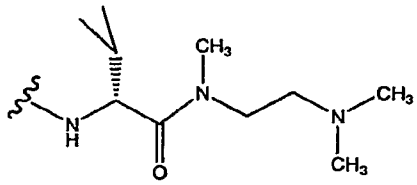


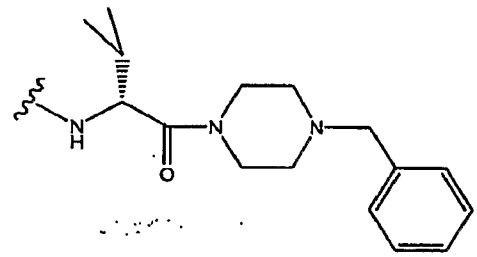


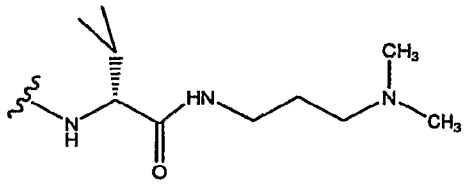


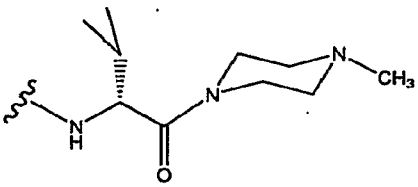


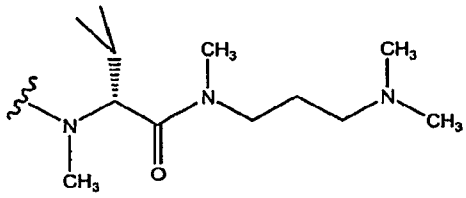


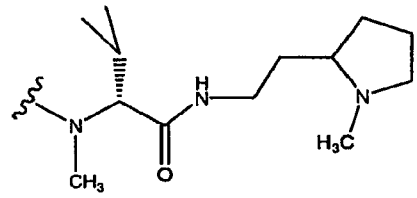


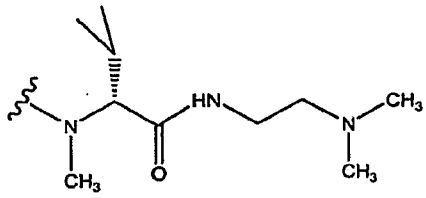


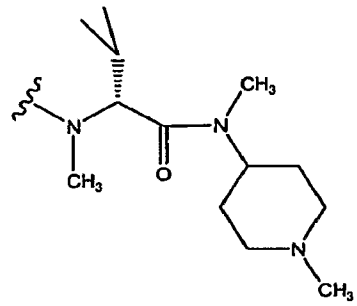


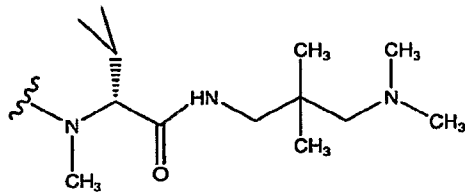


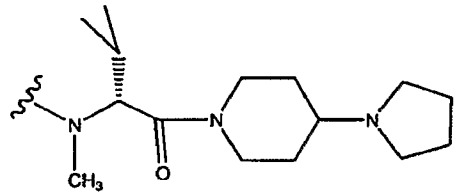


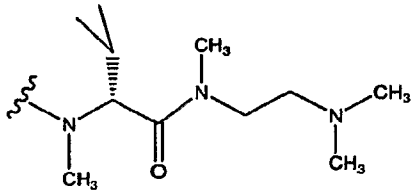


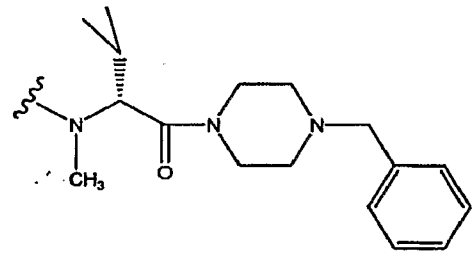


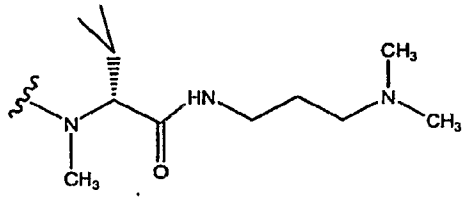


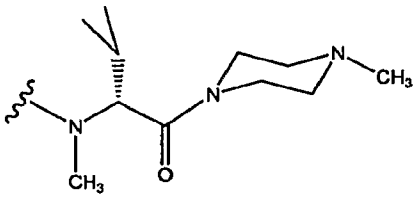


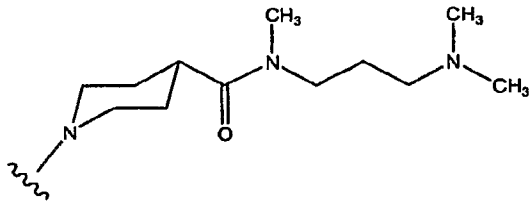


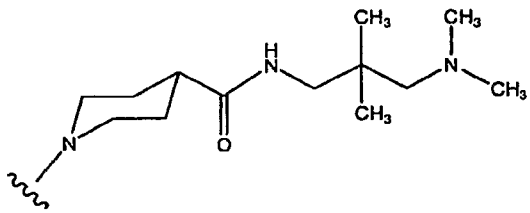


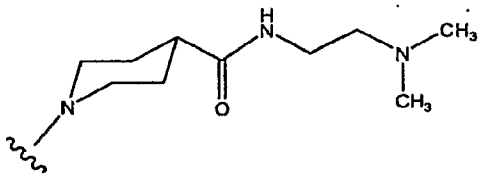


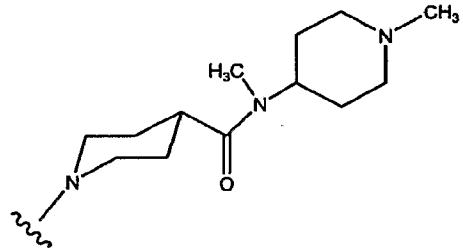


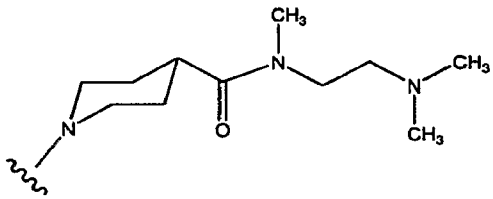


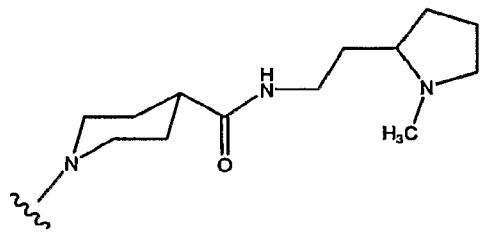


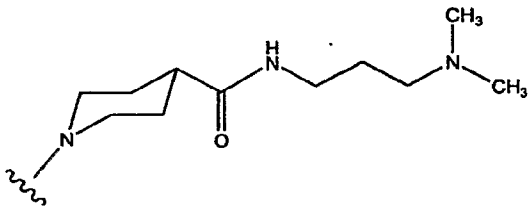


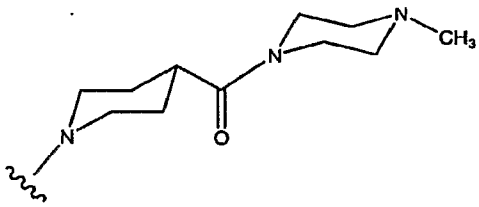


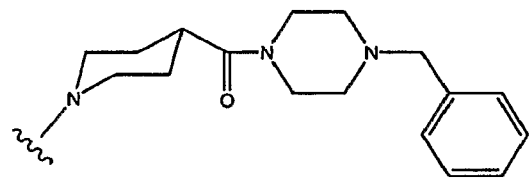


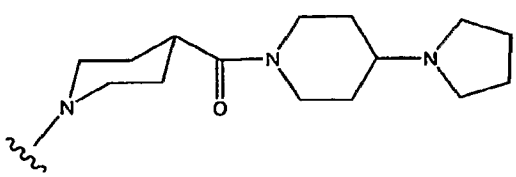


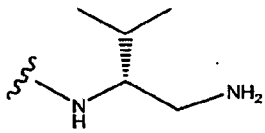


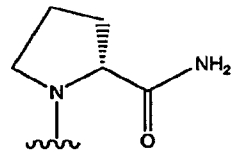


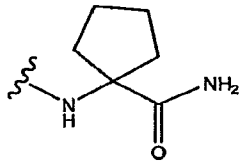


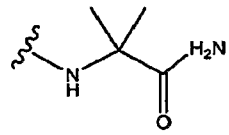


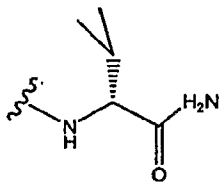


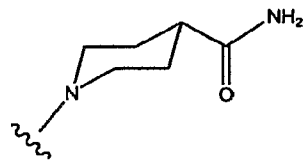


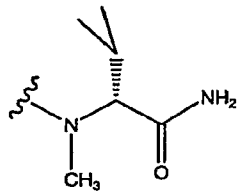


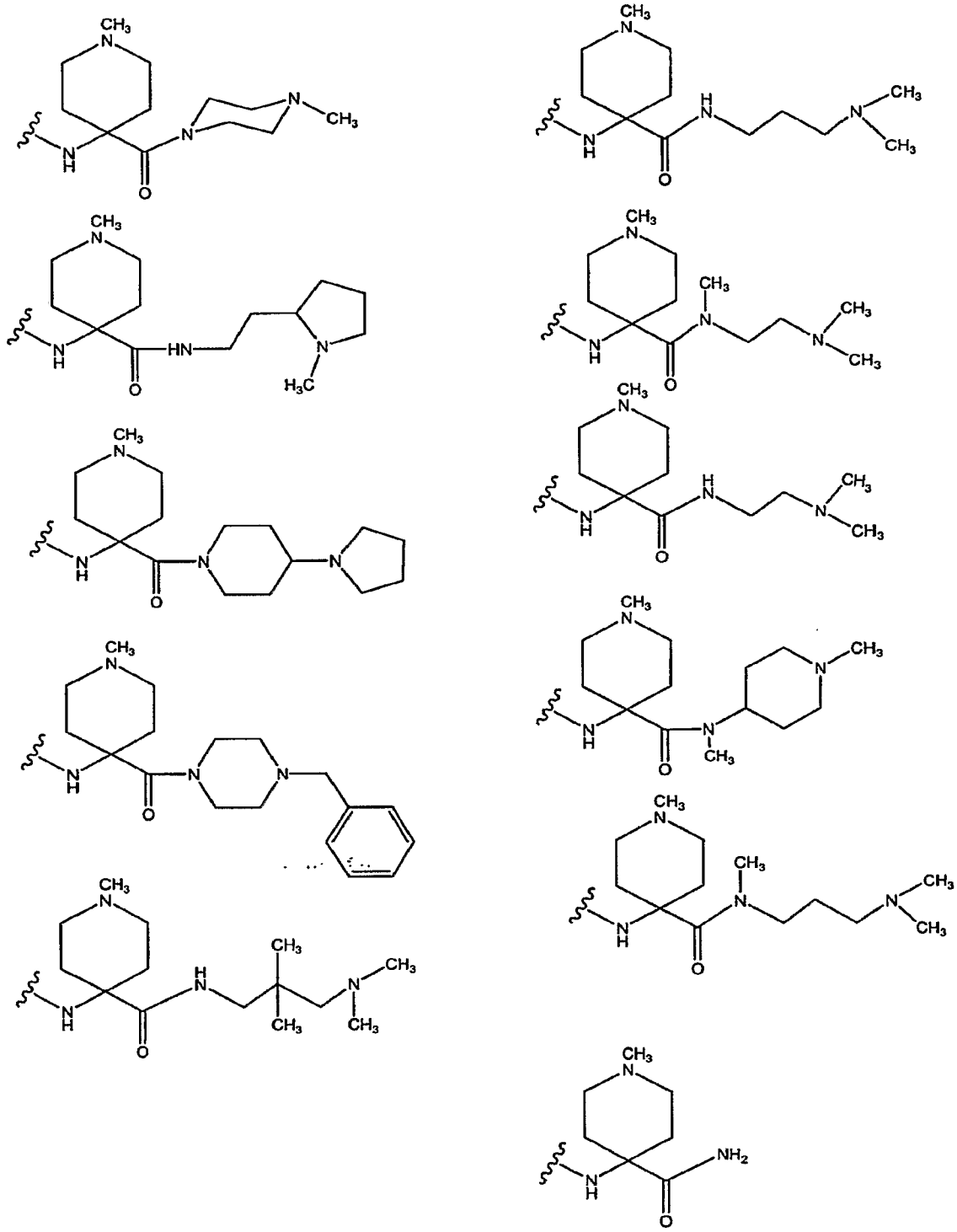






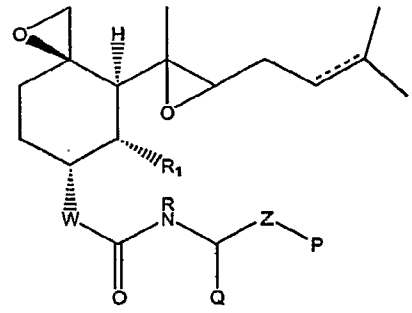






Preferred Angiogenesis Inhibitor Compounds of Formula XV

A preferred subset of the angiogenesis inhibitor compounds of Formula XV comprises Formula XIV shown below.

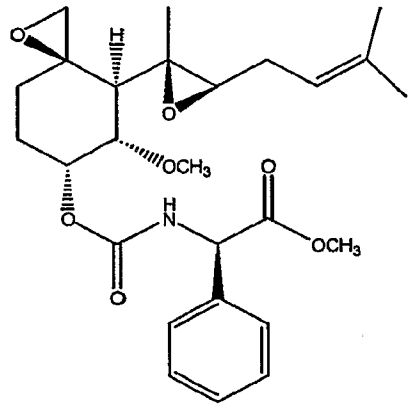


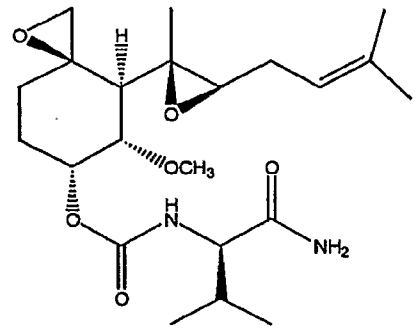
(XIV)

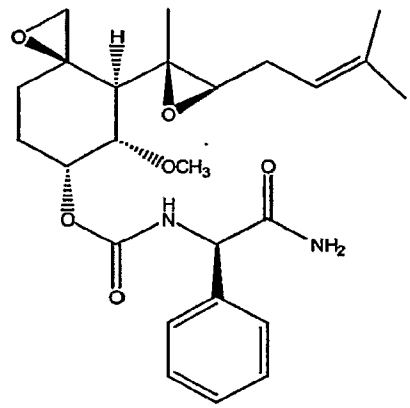
In one embodiment, W is O or NR. Z is –C(O) or -alkylene-C(O)-, preferably C_1-C_4-alkylene-C(O)-. R is hydrogen or a C_1-C_4-alkyl. Q is hydrogen; linear, branched or cyclic C_1-C_6-alkyl; or aryl. R_1 is hydroxy, C_1-C_4-alkoxy or halogen. P is NH_2, OR or a peptide attached to Z at its N-terminus and comprising from 1 to 100 amino acid residues independently selected from naturally occurring amino acid residues, D-enantiomers of the naturally occurring amino acid residues and non-natural amino acid residues. When Q is H, P is not NH_2 or OR. In preferred embodiments, W is O or NH; Q is isopropyl; R_1 is methoxy; P comprises from 1 to 15 amino acid residues; and the dashed line present in Formula XIV represents a double bond. In particularly preferred embodiments, W is O, and P comprises 10 or fewer amino acid residues.

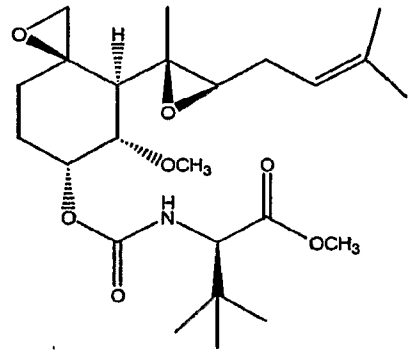
In another embodiment of the compounds of Formula XIV, W is O or NR. Z is alkylene-O or alkylene-NR, preferably C1-C4-alkylene-O or C1-C4-alkylene-NR-. R is hydrogen or a C_1-C_4-alkyl. Q is hydrogen; linear, branched or cyclic C_1-C_6-alkyl; or aryl. R_1 is hydroxy, C_1-C_4-alkoxy or halogen. P is hydrogen or a peptide attached to Z at its C-terminus and comprising from 1 to 100 amino acid residues independently selected from naturally occurring amino acid residues, D-enantiomers of the naturally occurring amino acid residues and non-natural amino acid residues. When Q is H, P is not H. In preferred embodiments, W is O or NH; Q is isopropyl; R_1 is methoxy; P comprises from 1 to 15 amino acid residues; and the dashed line present in Formula XIV represents a double bond. In particularly preferred embodiments, W is O, and P comprises 10 or fewer amino acid residues or P is hydrogen.

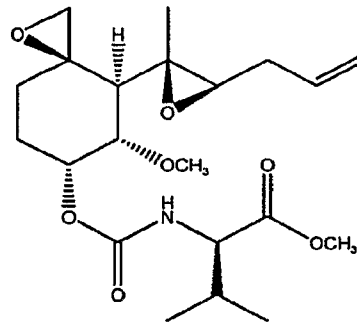
One set of particularly preferred angiogenesis inhibitor compounds of the invention is represented by the structures set forth below.

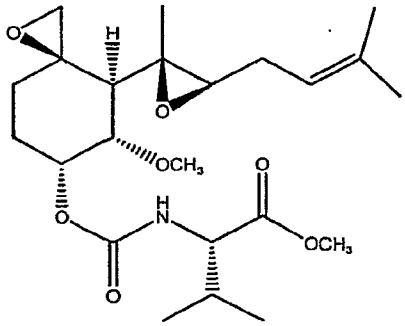


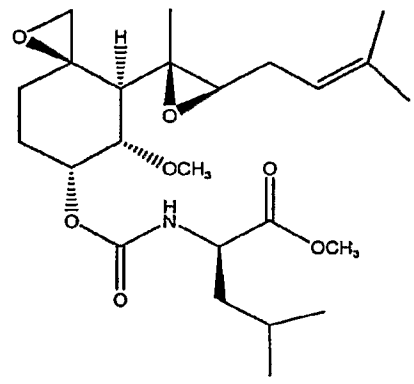


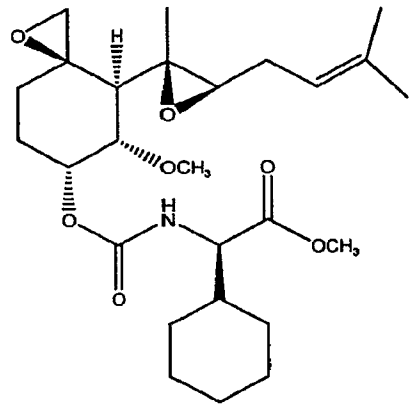


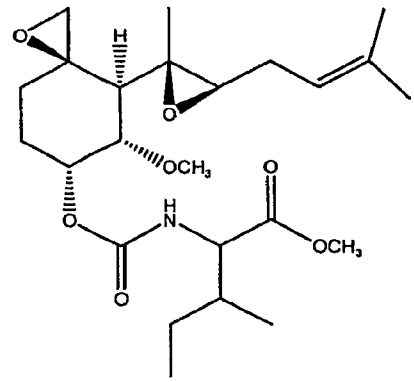


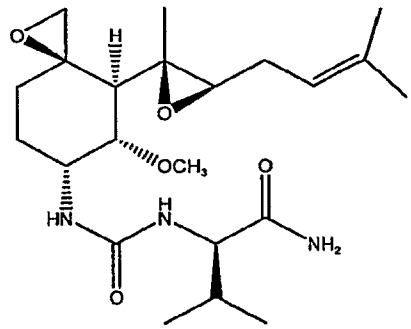


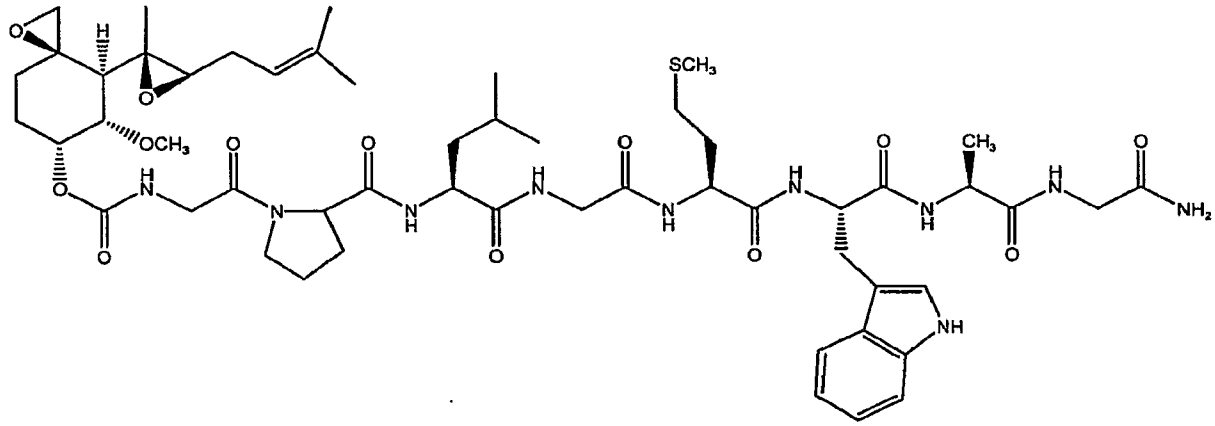


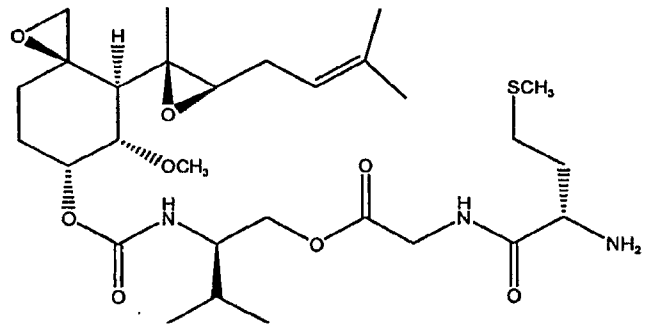


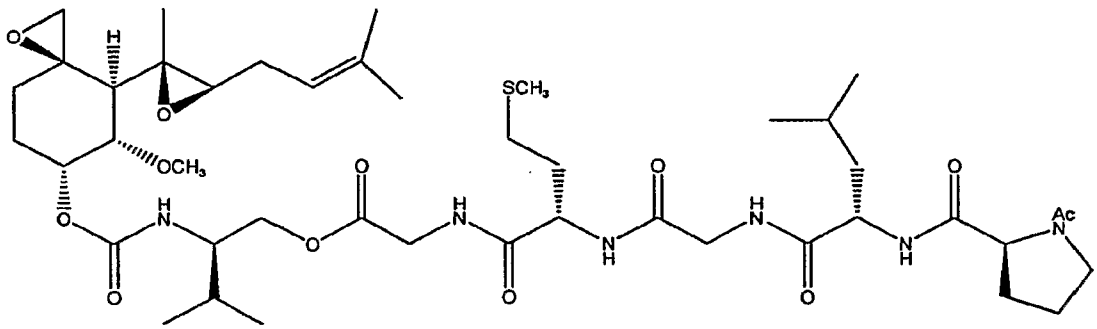


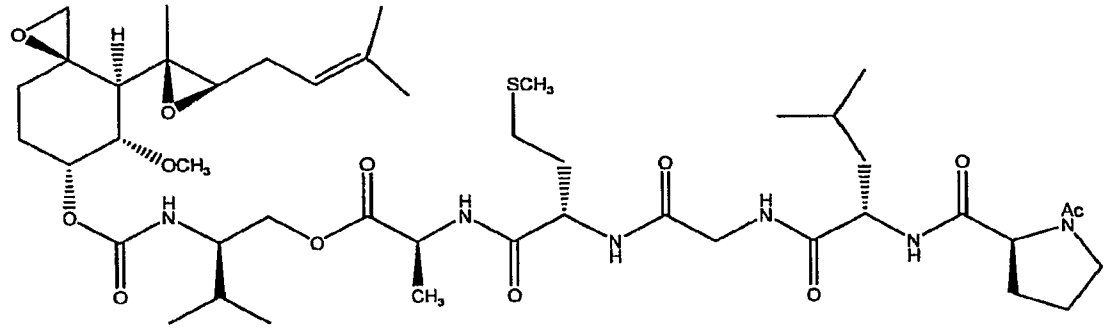


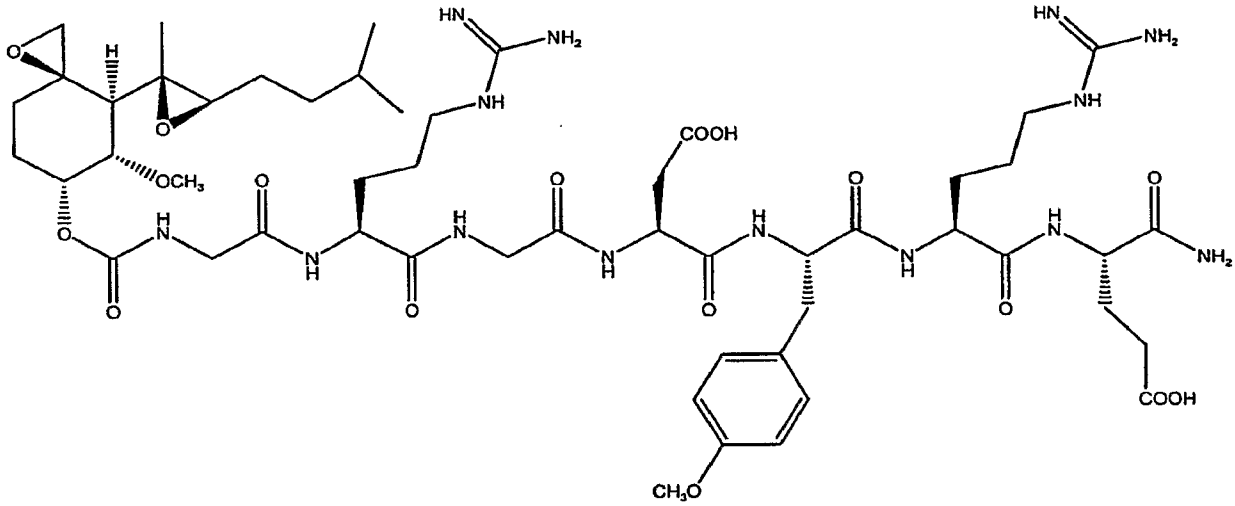


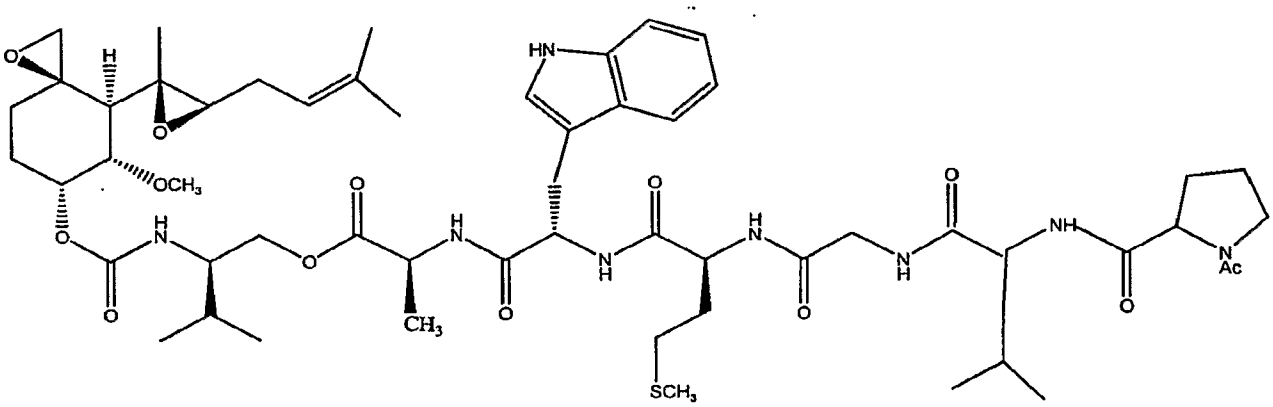












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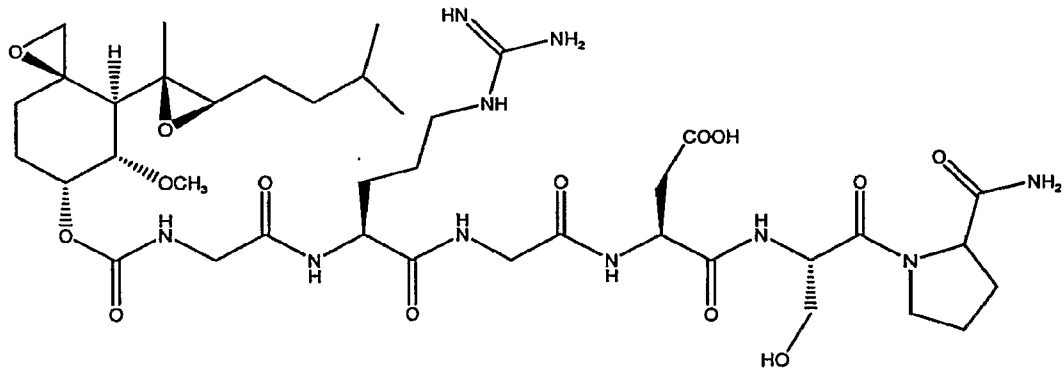

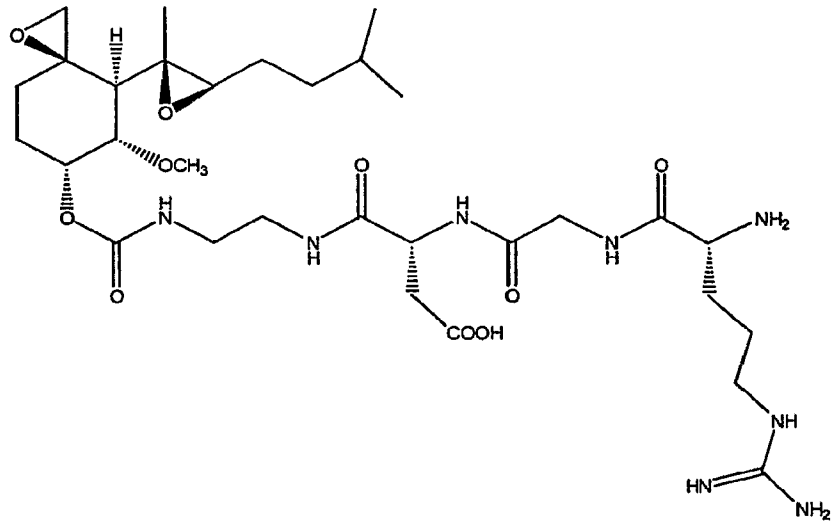

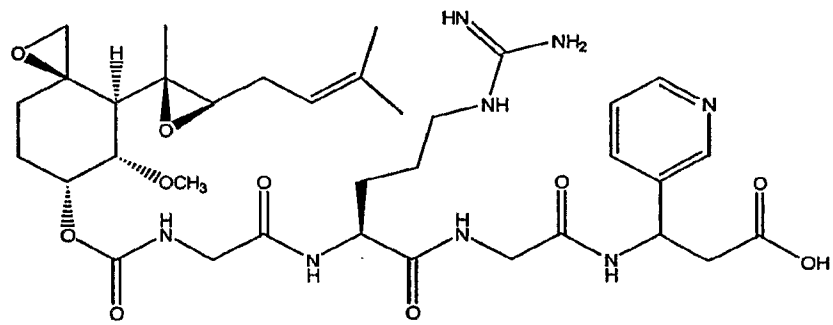

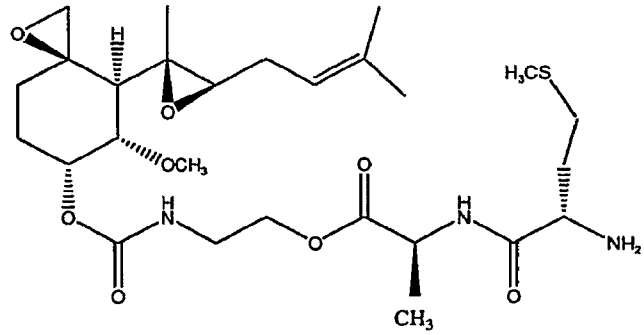

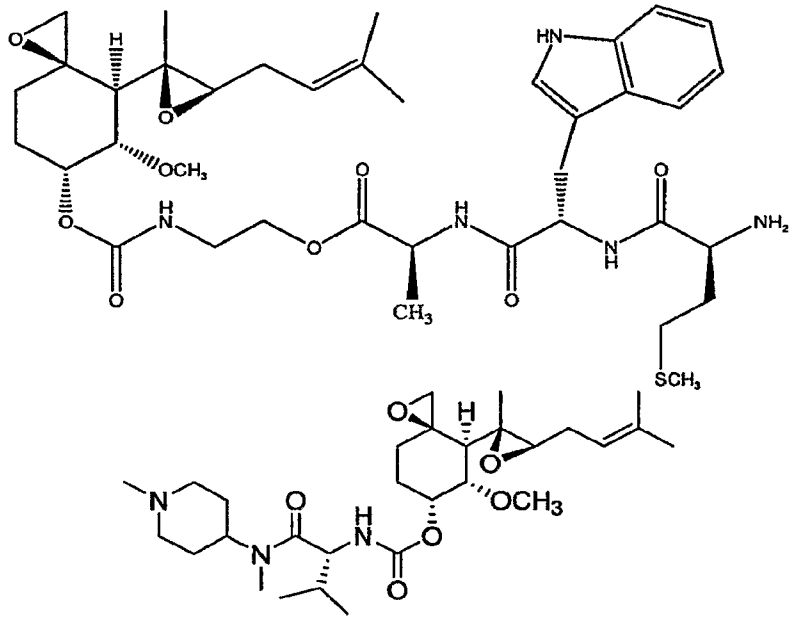

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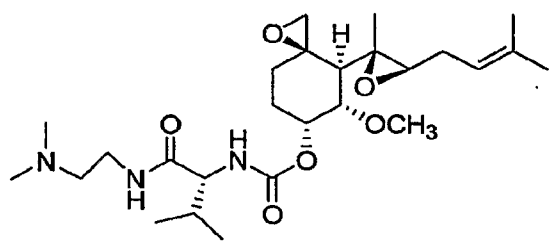
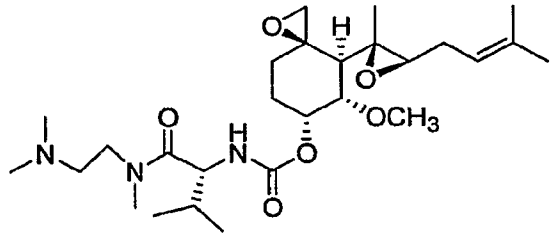
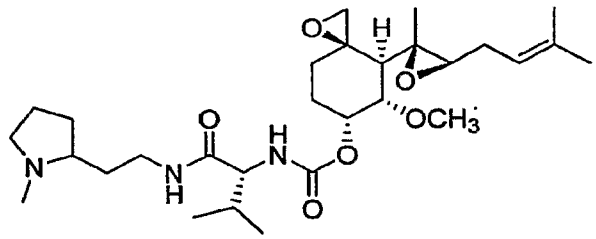
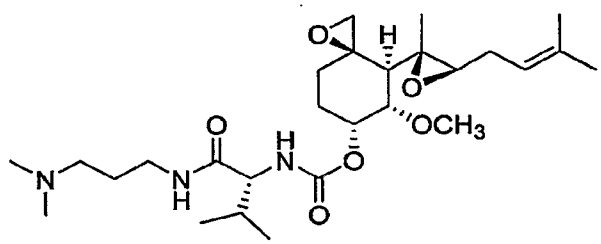
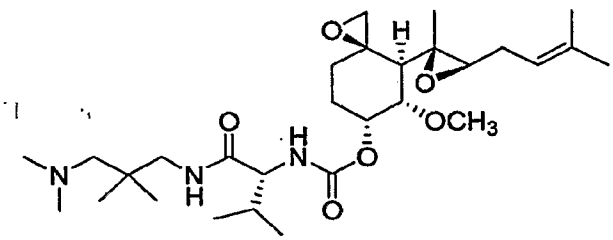
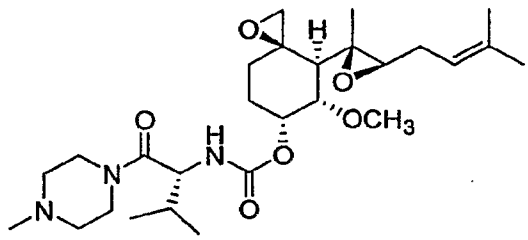


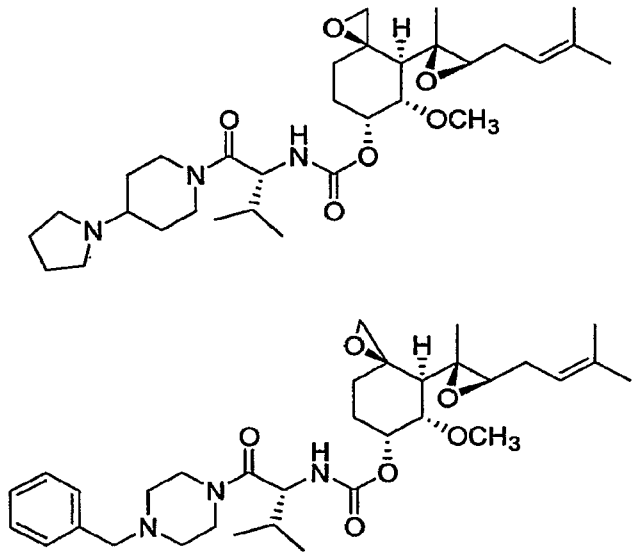












Methods of Using the Angiogenesis Inhibitor Compounds for the Treatment of Angiogenic Disease

In another embodiment, the present invention provides a method of treating an angiogenic disease in a subject. The method includes administering to the subject a therapeutically effective amount of an angiogenesis inhibitor compound of the present invention, thereby treating the angiogenic disease in the subject.

As used herein, the term "angiogenic disease" includes a disease, disorder, or condition characterized or caused by aberrant or unwanted, *e.g.*, stimulated or suppressed, formation of blood vessels (angiogenesis). Aberrant or unwanted angiogenesis may either cause a particular disease directly or exacerbate an existing pathological condition. Examples of angiogenic diseases include ocular disorders, *e.g.*, diabetic retinopathy, retinopathy of prematurity, corneal graft rejection, retrolental fibroplasia, neovascular glaucoma, rubeosis, retinal neovascularization due to macular degeneration, hypoxia, angiogenesis in the eye associated with infection or surgical intervention, ocular tumors and trachoma, and other abnormal neovascularization conditions of the eye, where neovascularization may lead to blindness; disorders affecting the skin, *e.g.*, psoriasis and pyogenic granuloma; cancer, *e.g.*, carcinomas and sarcomas, where progressive growth is dependent upon the continuous induction of angiogenesis by these tumor cells, lung cancer, brain cancer, kidney cancer, colon cancer, liver cancer, pancreatic cancer, stomach cancer, prostate cancer, breast cancer, ovarian cancer, cervical cancer, melanoma, and metastatic versions of any of the preceding cancers; lymphoid malignancies, *e.g.*, lymphoid leukemias, such as chronic lymphoid leukemia and acute lymphoid leukemia, and lymphomas, such as T cell

lymphoma and B cell lymphoma; pediatric disorders, *e.g.*, angiofibroma, and hemophiliac joints; blood vessel diseases such as hemangiomas, and capillary proliferation within atherosclerotic plaques; disorders associated with surgery, *e.g.*, hypertrophic scars, wound granulation and vascular adhesions; and autoimmune diseases such as rheumatoid, immune and degenerative arthritis, where new vessels in the joint may destroy articular cartilage and scleroderma; lupus erythematosus, psoriasis, multiple sclerosis, myasthenia gravis, vasculitis, or diabetes mellitus.

The term angiogenic disease also includes diseases characterized by excessive or abnormal stimulation of endothelial cells, including but not limited to intestinal adhesions, Crohn's disease, atherosclerosis, scleroderma, and hypertrophic scars, *i.e.*, keloids; diseases that have angiogenesis as a pathologic consequence such as cat scratch disease (Rochele ninalia quintosa) and ulcers (Helicobacter pylori). In addition, the angiogenesis inhibitor compounds of the present invention are useful as birth control agents (by virtue of their ability to inhibit the angiogenesis dependent ovulation and establishment of the placenta) and may also be used to reduce bleeding by administration to a subject prior to surgery.

The compounds of the invention may also be used to treat a subject suffering from a parasitic infection, such as an infection by Plasmodium species, such as Plasmodium falciparum, or an infection by Leishmania species, such as Leishmania donavani. The method comprises the step of administering to the subject a therapeutically effective amount of a compound of the invention. The subject can be an individual who is suffering from, or susceptible to, infection by a parasitic organism. In a preferred embodiment, the subject suffers from malaria or Leishmaniasis.

The compounds of the invention can also be used to treat a subject suffering from a thymoma. Thus the invention provides a method of treating a thymoma in a patient, comprising the step of administering to the patient a therapeutically effective amount of a compound of the invention.

The compounds of the invention can also be used as immunosuppressive agents in clinical protocols in which suppression of the immune system is desired. Thus, the present invention provides a method of inducing an immunosupressed condition in a subject, comprising the step of administering to the subject an immunosupressive amount of a compound of the invention. For example, the compounds of the invention can be used to suppress immune function in subjects undergoing, or who have undergone, an organ, tissue or cell transplant from a donor. In one embodiment, the transplanted tissue, organ or cell is bone marrow, stem cells, pancreatic cells, such as islet cells, or cornea. In another embodiment, the transplanted organ is a solid organ, such as a liver, a kidney, a heart or a lung.

The compounds of the invention may also be used to treat a subject suffering from chronic allograft vasculopathy (CAV). Cardiac allograft vasculopathy (CAV) remains a troublesome long-term complication of transplantation, *e.g.*, heart transplantation. CAV is characterized by vascular injury induced by an immune system response to the allograft, ischemia-reperfusion injury, viral infection, immunosuppressive drugs, and classic risk factors such as hyperlipidemia, insulin resistance, and hypertension. Chronic allograft vasculopathy describes the long term loss of function in organ transplants associated with the excess development of fibrous connective tissue of the internal blood vessels of the transplant.

The compounds of the invention may also be used to treat a subject (*e.g.*, a mammal, such as a human) suffering from a lymphoid malignancy. The method includes administering to a subject an effective amount of a MetAP-2 inhibitor, thereby treating a subject suffering from a lymphoid malignancy.

The compounds of the invention may also be used to treat rheumatic diseases, such as rheumatoid arthritis, lupus, akylosing spondylitis, psoriatic arthritis, scleroderma, Kawasaki syndrome and other rheumatic diseases as set forth in Primer on the Rheumatic Diseases, 11th Edition (John H. Klippel, MD, editor; Arthritis Foundation:Atlanta GA (1997)).

As used herein, the term "lymphoid malignancy" includes any malignancy of a lymphoid cell. Examples of lymphoid malignancies include lymphoid leukemias, such as chronic lymphoid leukemia and acute lymphoid leukemia, and lymphomas, such as Non-Hogkins lymphoma. The term "Non-Hodgkins lymphoma" includes T cell lymphomas, such as Precursor (peripheral) T-cell lymphoblastic, Adult T-cell, extranodal Natural Killer/T-cell, nasal type, enteropathy type T-cell, hepatosplenic T-cell, subcutaneous panniculitis like T-cell, skin (cutaneous) lymphomas, anaplastic large cell, peripheral T-cell, and angioimmunoblastic T-cell lymphomas; and B cell lymphomas, such as precursor B lymphoblastic, small lymphocytic, B-cell prolymphocytic, lymphoplasmacytic, splenic marginal zone, extranodal marginal zone – MALT, nodal marginal zone, follicular, mantle cell, diffuse large B-cell, primary mediastinal large B-cell, primary effusion and Burkitt's lymphomas. Non-Hodgkins lymphoma also includes AIDS-related lymphoma and central nervous system lymphoma.

As used herein, the term "subject" includes warm-blooded animals, preferably mammals, including humans. In a preferred embodiment, the subject is a primate. In an even more preferred embodiment, the primate is a human.

As used herein, the term "administering" to a subject includes dispensing, delivering or applying an angiogenesis inhibitor compound, *e.g.*, an angiogenesis

inhibitor compound in a pharmaceutical formulation (as described herein), to a subject by any suitable route for delivery of the compound to the desired location in the subject, including delivery by either the parenteral or oral route, intramuscular injection, subcutaneous/intradermal injection, intravenous injection, buccal administration, transdermal delivery and administration by the rectal, colonic, vaginal, intranasal or respiratory tract route.

As used herein, the term "effective amount" includes an amount effective, at dosages and for periods of time necessary, to achieve the desired result, *e.g.*, sufficient to treat an angiogenic disease in a subject. An effective amount of an angiogenesis inhibitor compound, as defined herein may vary according to factors such as the disease state, age, and weight of the subject, and the ability of the angiogenesis inhibitor compound to elicit a desired response in the subject. Dosage regimens may be adjusted to provide the optimum therapeutic response. An effective amount is also one in which any toxic or detrimental effects (*e.g.*, side effects) of the angiogenesis inhibitor compound are outweighed by the therapeutically beneficial effects.

A therapeutically effective amount of an angiogenesis inhibitor compound (*i.e.*, an effective dosage) may range from about 0.001 to 30 mg/kg body weight, preferably about 0.01 to 25 mg/kg body weight, more preferably about 0.1 to 20 mg/kg body weight, and even more preferably about 1 to 10 mg/kg, 2 to 9 mg/kg, 3 to 8 mg/kg, 4 to 7 mg/kg, or 5 to 6 mg/kg body weight. The skilled artisan will appreciate that certain factors may influence the dosage required to effectively treat a subject, including but not limited to the severity of the disease or disorder, previous treatments, the general health and/or age of the subject, and other diseases present. Moreover, treatment of a subject with a therapeutically effective amount of an angiogenesis inhibitor compound can include a single treatment or, preferably, can include a series of treatments. In one example, a subject is treated with an angiogenesis inhibitor compound in the range of between about 0.1 to 20 mg/kg body weight, one time per week for between about 1 to 10 weeks, preferably between 2 to 8 weeks, more preferably between about 3 to 7 weeks, and even more preferably for about 4, 5, or 6 weeks. It will also be appreciated that the effective dosage of an angiogenesis inhibitor compound used for treatment may increase or decrease over the course of a particular treatment.

The methods of the invention further include administering to a subject a therapeutically effective amount of an angiogenesis inhibitor compound in combination with another pharmaceutically active compound known to treat an angiogenic disease, *e.g.*, a chemotherapeutic agent such as Taxol, Paclitaxel, or Actinomycin D, or an antidiabetic agent such as Tolbutamide; or a compound that may potentiate the angiogenesis inhibitory activity of the angiogenesis inhibitor compound, such as heparin

or a sulfated cyclodextrin. Other pharmaceutically active compounds that may be used can be found in Harrison's Principles of Internal Medicine, Thirteenth Edition, Eds. T.R. Harrison et al. McGraw-Hill N.Y., NY; and the Physicians Desk Reference 50th Edition 1997, Oradell New Jersey, Medical Economics Co., the complete contents of which are expressly incorporated herein by reference. The angiogenesis inhibitor compound and the pharmaceutically active compound may be administered to the subject in the same pharmaceutical composition or in different pharmaceutical compositions (at the same time or at different times).

Pharmaceutical Compositions of the Angiogenesis Inhibitor Compounds

The present invention also provides pharmaceutically acceptable formulations comprising one or more angiogenesis inhibitor compounds. Such pharmaceutically acceptable formulations typically include one or more angiogenesis inhibitor compounds as well as a pharmaceutically acceptable carrier(s) and/or excipient(s). As used herein, "pharmaceutically acceptable carrier" includes any and all solvents, dispersion media, coatings, antibacterial and anti fungal agents, isotonic and absorption delaying agents, and the like that are physiologically compatible. The use of such media and agents for pharmaceutically active substances is well known in the art. Except insofar as any conventional media or agent is incompatible with the angiogenesis inhibitor compounds, use thereof in the pharmaceutical compositions is contemplated.

Supplementary pharmaceutically active compounds known to treat an angiogenic disease, *e.g.*, a chemotherapeutic agent such as Taxol, Paclitaxel, or Actinomycin D, or an antidiabetic agent such as Tolbutamide; or compounds that may potentiate the angiogenesis inhibitory activity of the angiogenesis inhibitor compound, such as heparin or a sulfated cyclodextrin, can also be incorporated into the compositions of the invention. Suitable pharmaceutically active compounds that may be used can be found in Harrison's Principles of Internal Medicine (*supra*).

A pharmaceutical composition of the invention is formulated to be compatible with its intended route of administration. Examples of routes of administration include parenteral, *e.g.*, intravenous, intradermal, subcutaneous, oral (*e.g.*, inhalation), transdermal (topical), transmucosal, and rectal administration. Solutions or suspensions used for parenteral, intradermal, or subcutaneous application can include the following components: a sterile diluent such as water for injection, saline solution, fixed oils, polyethylene glycols, glycerine, propylene glycol or other synthetic solvents; antibacterial agents such as benzyl alcohol or methyl parabens; antioxidants such as ascorbic acid or sodium bisulfite; chelating agents such as ethylenediaminetetraacetic acid; buffers such as acetates, citrates or phosphates and agents for the adjustment of

tonicity such as sodium chloride or dextrose. pH can be adjusted with acids or bases, such as hydrochloric acid or sodium hydroxide. The parenteral preparation can be enclosed in ampoules, disposable syringes or multiple dose vials made of glass or plastic.

Pharmaceutical compositions suitable for injectable use include sterile aqueous solutions (where water soluble) or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersion. For intravenous administration, suitable carriers include physiological saline, bacteriostatic water, Cremophor EL™ (BASF, Parsippany, NJ) or phosphate buffered saline (PBS). In all cases, the pharmaceutical composition must be sterile and should be fluid to the extent that easy syringability exists. It must be stable under the conditions of manufacture and storage and must be preserved against the contaminating action of microorganisms such as bacteria and fungi. The carrier can be a solvent or dispersion medium containing, for example, water, ethanol, polyol (for example, glycerol, propylene glycol, and liquid polyetheylene glycol, and the like), and suitable mixtures thereof. The proper fluidity can be maintained, for example, by the use of a coating such as lecithin, by the maintenance of the required particle size in the case of dispersion and by the use of surfactants. Prevention of the action of microorganisms can be achieved by various antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, ascorbic acid, thimerosal, and the like. In many cases, it will be preferable to include isotonic agents, for example, sugars, polyalcohols such as manitol, sorbitol, sodium chloride in the composition. Prolonged absorption of the injectable compositions can be brought about by including in the composition an agent which delays absorption, for example, aluminum monostearate and gelatin.

Sterile injectable solutions can be prepared by incorporating the angiogenesis inhibitor compound in the required amount in an appropriate solvent with one or a combination of the ingredients enumerated above, as required, followed by filtered sterilization. Generally, dispersions are prepared by incorporating the angiogenesis inhibitor compound into a sterile vehicle which contains a basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, the preferred methods of preparation are vacuum drying and freeze-drying which yields a powder of the angiogenesis inhibitor compound plus any additional desired ingredient from a previously sterile-filtered solution thereof.

Oral compositions generally include an inert diluent or an edible carrier. They can be enclosed in gelatin capsules or compressed into tablets. For the purpose of oral therapeutic administration, the angiogenesis inhibitor compound can be incorporated

with excipients and used in the form of tablets, troches, or capsules. Oral compositions can also include an enteric coating. Oral compositions can also be prepared using a fluid carrier for use as a mouthwash, wherein the angiogenesis inhibitor compound in the fluid carrier is applied orally and swished and expectorated or swallowed.

Pharmaceutically compatible binding agents, and/or adjuvant materials can be included as part of the composition. The tablets, pills, capsules, troches and the like can contain any of the following ingredients, or compounds of a similar nature: a binder such as microcrystalline cellulose, gum tragacanth or gelatin; an excipient such as starch or lactose, a disintegrating agent such as alginic acid, Primogel, or corn starch; a lubricant such as magnesium stearate or Sterotes; a glidant such as colloidal silicon dioxide; a sweetening agent such as sucrose or saccharin; or a flavoring agent such as peppermint, methyl salicylate, or orange flavoring.

For administration by inhalation, the angiogenesis inhibitor compounds are delivered in the form of an aerosol spray from pressured container or dispenser which contains a suitable propellant, *e.g.*, a gas such as carbon dioxide, or a nebulizer.

Systemic administration can also be by transmucosal or transdermal means. For transmucosal or transdermal administration, penetrants appropriate to the barrier to be permeated are used in the formulation. Such penetrants are generally known in the art, and include, for example, for transmucosal administration, detergents, bile salts, and fusidic acid derivatives. Transmucosal administration can be accomplished through the use of nasal sprays or suppositories. For transdermal administration, the angiogenesis inhibitor compounds are formulated into ointments, salves, gels, or creams as generally known in the art.

The angiogenesis inhibitor compounds can also be prepared in the form of suppositories (*e.g.*, with conventional suppository bases such as cocoa butter and other glycerides) or retention enemas for rectal delivery.

In one embodiment, the angiogenesis inhibitor compounds are prepared with carriers that will protect the compound against rapid elimination from the body, such as a controlled release formulation, including implants and microencapsulated delivery systems. Biodegradable, biocompatible polymers can be used, such as ethylene vinyl acetate, polyanhydrides, polyglycolic acid, collagen, polyorthoesters, and polylactic acid. Methods for preparation of such formulations will be apparent to those skilled in the art. The materials can also be obtained commercially from Alza Corporation and Nova Pharmaceuticals, Inc. Liposomal suspensions can also be used as pharmaceutically acceptable carriers. These can be prepared according to methods known to those skilled in the art, for example, as described in U.S. Patent No. 4,522,811,

U.S. Patent No. 5,455,044 and U.S. Patent No. 5,576,018, and U.S. Patent No. 4,883,666, the contents of all of which are incorporated herein by reference.

The angiogenesis inhibitor compounds of the invention can also be incorporated into pharmaceutical compositions which allow for the sustained delivery of the angiogenesis inhibitor compounds to a subject for a period of at least several weeks to a month or more. Such formulations are described in U.S. Patent 5,968,895, the contents of which are incorporated herein by reference.

It is especially advantageous to formulate oral or parenteral compositions in dosage unit form for ease of administration and uniformity of dosage. Dosage unit form as used herein refers to physically discrete units suited as unitary dosages for the subject to be treated; each unit containing a predetermined quantity of angiogenesis inhibitor compounds calculated to produce the desired therapeutic effect in association with the required pharmaceutical carrier. The specification for the dosage unit forms of the invention are dictated by and directly dependent on the unique characteristics of the angiogenesis inhibitor compound and the particular therapeutic effect to be achieved, and the limitations inherent in the art of compounding such angiogenesis inhibitor compounds for the treatment of individuals.

Toxicity and therapeutic efficacy of such angiogenesis inhibitor compounds can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, *e.g.*, for determining the LD50 (the dose lethal to 50% of the population) and the ED50 (the dose therapeutically effective in 50% of the population). The dose ratio between toxic and therapeutic effects is the therapeutic index and it can be expressed as the ratio LD50/ED50. Angiogenesis inhibitor compounds which exhibit large therapeutic indices are preferred. While angiogenesis inhibitor compounds that exhibit toxic side effects may be used, care should be taken to design a delivery system that targets such angiogenesis inhibitor compounds to the site of affected tissue in order to minimize potential damage to uninfected cells and, thereby, reduce side effects.

The data obtained from the cell culture assays and animal studies can be used in formulating a range of dosage for use in humans. The dosage of such angiogenesis inhibitor compounds lies preferably within a range of circulating concentrations that include the ED50 with little or no toxicity. The dosage may vary within this range depending upon the dosage form employed and the route of administration utilized. For any angiogenesis inhibitor compounds used in the methods of the invention, the therapeutically effective dose can be estimated initially from cell culture assays. A dose may be formulated in animal models to achieve a circulating plasma concentration range that includes the IC50 (*i.e.*, the concentration of the angiogenesis inhibitor compound which achieves a half-maximal inhibition of symptoms) as determined in cell culture.

Such information can be used to more accurately determine useful doses in humans. Levels in plasma may be measured, for example, by high performance liquid chromatography.

Assays for Detecting the Activity of the Angiogenesis Inhibitor Compounds

The angiogenesis inhibitor compounds of the invention may be tested for their ability to modulate (*e.g.*, inhibit or stimulate) angiogenesis in a variety of well known assays, *e.g.*, the rat aortic ring angiogenesis inhibition assay or in a chorioallantoic membrane (CAM) assay.

The CAM assay may be performed essentially as described in Liekens S. et al. (1997) *Oncology Research* 9: 173-181, the contents of which are incorporated herein by reference. Briefly, fresh fertilized eggs are incubated for 3 days at 37°C. On the third day, the shell is cracked and the egg is placed into a tissue culture plate and incubated at 38°C. For the assay, the angiogenesis inhibitor compound to be tested is attached on a matrix of collagen on a nylon mesh. The mesh is then used to cover the chorioallantoic membrane and the eggs are incubated at 37°C. If angiogenesis occurs, new capillaries form and grow through the mesh within 24 hours. The ability of the angiogenesis inhibitor compound (at various concentrations) to modulate, *e.g.*, inhibit, angiogenesis, *e.g.*, FGF-induced angiogenesis, may then be determined.

The angiogenesis inhibitor compounds of the invention may also be tested for their ability to modulate (*e.g.*, inhibit or stimulate) human endothelial cell growth. Human umbilical vein endothelial cells (HUVE) may be isolated by perfusion of an umbilical vein with a trypsin-containing medium. HUVE may then be cultured in GIT medium (Diago Eiyou Kagaku, Co., Japan) supplemented with 2.5% fetal bovine serum and 2.0 ng/ml of recombinant human basic fibroblast growth factor (rbFGF, Biotechnology Research Laboratories, Takeda, Osaka, Japan) at 37°C under 5% CO_2 and 7% O_2. HUVE are then plated on 96-well microtiter plates (Nunc, 1-67008) at a cell density of $2x10^3$ /100 µl of medium. The following day, 100 µl of medium containing rbFGF (2 ng/ml at the final concentration) and each angiogenesis inhibitor compound at various concentrations may be added to each well. The angiogenesis inhibitor compounds are dissolved in dimethylsulfoxide (DMSO) and then diluted with culture medium so that the final DMSO concentration does not exceed 0.25%. After a 5-day culture, medium is removed, 100 µl of 1 mg/ml of MTT (3-(4,5-dimethyl-2-thiazolyl)- 2,5-diphenyl-2 H-tetrazolium bromide) solution is added to the wells, and microtiters are kept at 37°C for 4 hours. Then, 100 µl of 10% sodium dodecyl sulfate (SDS) solution is added to wells, and the microtiters are kept at 37°C for 5-6 hours. To

determine the effects of the angiogenesis inhibitor compound on cell number, the optical density (590 μm) of each well is measured using an optical densitometer.

The ability of the angiogenesis inhibitor compounds of the invention to modulate capillary endothelial cell migration *in vitro* may also be tested using the Boyden chamber assay (as described in Falk *et al.* (1980) *J. Immunol. Meth.* 33:239-247, the contents of which are incorporated herein by reference). Briefly, bovine capillary endothelial cells are plated at $1.5x10^4$ cells per well in serum-free DMEM (Dulbecco's Modified Eagle's Medium) on one side of nucleopore filters pre-coated with fibronectin (7.3 μg fibronectin/ml PBS). An angiogenesis inhibitor compound is dissolved in ethanol and diluted in DMEM so that the final concentration of ethanol does not exceed 0.01%. Cells are exposed to endothelial mitogen (Biomedical Technologies, Mass.) at 200 μg/ml and different concentrations of the angiogenesis inhibitor compound in serum-free DMEM for 4 hours at 37°C. At the end of this incubation, the number of cells that migrate through 8μ pores in the filters is determined by counting cells with an ocular grid at 100x in quadruplicate.

The ability of the angiogenesis inhibitor compounds of the invention to modulate tumor growth may be tested *in vivo*. An animal model , *e.g.*, a C57BL/6N mouse with a mouse reticulum cell sarcoma (M 5076) intraperitoneally transplantated therein, may be used. The tumor cells in ascites can be collected by centrifugation, and suspended in saline. The cell suspension ($2x10^6$ cells/100 μl/mouse) is inoculated into the right flanks of mice. Tumor-bearing mice are then subcutaneously treated with the angiogenesis inhibitor compound (at various concentrations suspended in 5% arabic gum solution containing 1% of ethanol) for 12 days beginning one day after the tumor inoculation. The tumor growth may be determined by measuring tumor size in two directions with calipers at intervals of a few days.

Finally, the ability of the angiogenesis inhibitor compounds of the invention to modulate the activity of MetAP2 may be tested as follows. Recombinant human MetAP2 may be expressed and purified from insect cells as described in Li and Chang, (1996) *Biochem. Biophys. Res. Commun.* 227:152-159. Various amounts of angiogenesis inhibitor compound is then added to buffer H (10 mM Hepes, pH 7.35, 100 mM KCl, 10% glycerol, and 0.1 M Co^{2+}) containing 1nM purified recombinant human MetAP2 and incubated at 37°C for 30 minutes. To start the enzymatic reaction a peptide containing a methionine residue, *e.g.*, Met-Gly-Met, is added to the reaction mixture (to a concentration of 1 mM). Released methionine is subsequently quantified at different time points (*e.g.*, at 0, 2, 3, and 5 minutes) using the method of Zou *et al.* (1995) *Mol. Gen Genetics* 246:247-253).

This invention is further illustrated by the following examples which should not be construed as limiting. The contents of all references, patents and published patent applications cited throughout this application, as well as the Figures and the Sequence Listing, are hereby incorporated by reference.

EXAMPLES

Synthetic methods

Compounds of the invention can be prepared using one or more of the following general methods.

General Procedure A: To a mixture of carbonic acid-(3*R*, 4*S*, 5*S*, 6*R*)-5-methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester 4-nitro-phenyl ester[1] (**1**, 0.47 mmol; Han, C. K.; Ahn, S. K.; Choi, N. S.; Hong, R. K.; Moon, S. K.; Chun, H. S.; Lee, S. J.; Kim, J. W.; Hong, C. I.; Kim, D.; Yoon, J. H.; No, K. T. *Biorg. Med. Chem. Lett.* 2000, *10*, 39-43) and amine (2.35 mmol) in EtOH (9 mL) was added dropwise, diisopropyl ethyl amine (2.35 mmol). After 3-18 hours, the ethanol was removed in vacuo and the crude material was dissolved into EtOAc (10 mL) and washed with H_2O (2 x 5 mL), and then brine (5 mL). The organic phase was dried over Na_2SO_4 and the solvent removed in vacuo. Purification via flash chromatography (2-5% MeOH/CH_2Cl_2) afforded product.

General Procedure B, Part I: A solution of (3*R*, 4*S*, 5*S*, 6*R*) -5-Methoxy-4-[(2*R*, 3*R*)- 2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino)-acetic acid[2] (**2**, 0.11 mmol; U.S. Patent No. 6,017,954) in DMF (1 mL) was added to a 10 mL round bottomed flask containing swelled PS-DCC (0.28 mmol). In a separate vessel, the peptide (0.04 mmol) was dissolved into DMF (0.5 mL) and neutralized with NMM (0.04 mmol). After 1 hour, the solution of peptide was added to the pre-activated acid, and the reaction was continued for 5-18 hours. The resin was removed by filtration, washed with DMF (0.5 mL) and the solvent removed in vacuo. Purification via HPLC (CH_3CN/H_2O) afforded the product.

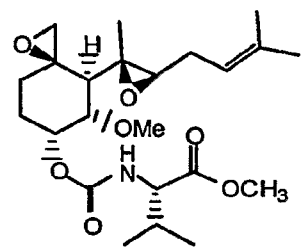
General Procedure B, Part II: A solution of the product in Part I (0.009 mmol) was dissolved into MeOH (1 mL) and was treated with Pd/C (2 mg), then subjected to a H_2 atmosphere (38 psi) for 24 hours. The mixture was then filtered through Celite, washed

with MeOH (0.5 mL) and the solvent removed in vacuo. Purification via HPLC (CH_3CN/H_2O) afforded the product as a white solid.

General Procedure C: (1-Hydroxymethyl-methyl-propyl)-carbamic acid (3*R*, 4*S*, 5*S*, 6*R*)-5-methoxy-4-[(2*R*, 3*R*)- 2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester (Example7, 189 mg, 0.46 mmol), acid (0.46 mmol) and DMAP (0.69 mmol) were dissolved into anhydrous CH_2Cl_2 (5 mL) and treated with diisopropylcarbodiimide (0.46 mmol). After 7-18 hours, the solvent was removed in vacuo and purification via flash chromatography ($MeOH/CH_2Cl_2$) afforded the product.

Example 1

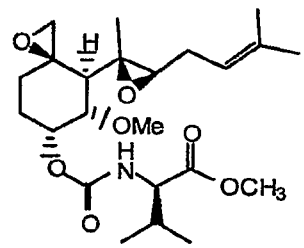
2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-3-methyl-butyric acid methyl ester



General procedure A was followed using **1** (31 mg, 0.07 mmol), L-valine methyl ester hydrochloride (58 mg, 0.35 mmol), and DIEA (60 μL, 0.35 mmol) in EtOH (2 mL). Purification via flash chromatography (1% $MeOH/CH_2Cl_2$) afforded the product as a clear oil (10 mg, 0.02 mmol, 33% yield); $R_f = 0.60$ (20% $EtOAc/CH_2Cl_2$); LRMS (*m/z*) $[M+1]^+$ 440.3 (calculated for $C_{23}H_{38}NO_7$, 440.3).

Example 2

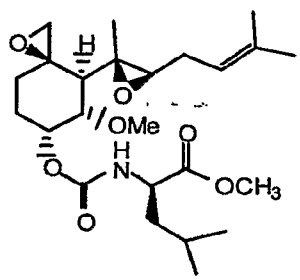
2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-3-methyl-butyric acid methyl ester



General procedure A was followed using **1** (41 mg, 0.09 mmol) and D-valine methyl ester hydrochloride (77 mg, 0.45 mmol), and DIEA (80 μL, 0.45 mmol) in EtOH (2 mL). Purification via flash chromatography (1% MeOH/CH_2Cl_2) afforded the product as a clear oil (18 mg, 0.04 mmol, 45% yield); $R_f = 0.39$ (20% EtOAc/CH_2Cl_2; LRMS (*m/z*) $[M+1]^+$ 440.3 (calculated for $C_{23}H_{38}NO_7$, 440.3).

Example 3

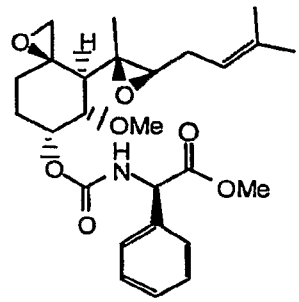
2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-4-methyl-pentanoic acid methyl ester



General procedure A was followed using **1** (23 mg, 0.05 mmol), D-leucine methyl ester hydrochloride (47 mg, 0.25 mmol), and DIEA (45 μL, 0.25 mmol) in EtOH (2 mL). Purification via flash chromatography (1% MeOH/CH_2Cl_2) afforded the product as a clear oil (19 mg, 0.04 mmol, 83% yield); $R_f = 0.22$ (15% EtOAc/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 454.3 (calculated for $C_{24}H_{40}NO_7$, 454.3).

Example 4

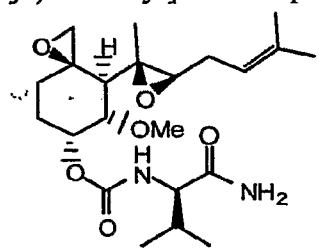
{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-phenyl-acetic acid methyl ester



General procedure A was followed using **1** (37 mg, 0.08 mmol), D-phenyl glycine methyl ester hydrochloride (83 mg, 0.40 mmol), and DIEA (72 μL, 0.40 mmol) in EtOH (2 mL). Purification via flash chromatography (1% MeOH/CH_2Cl_2) afforded the product as a clear oil (32 mg, 0.07 mmol, 82% yield); $R_f = 0.41$ (2% MeOH/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 474.3 (calculated for $C_{26}H_{36}NO_7$, 474.3).

Example 5

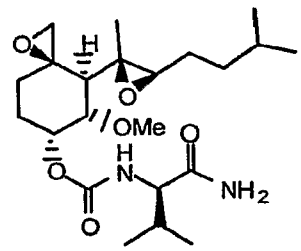
(1-Carbamoyl-2-methyl-propyl)-carbamic acid-(3*R*, 4*S*, 5*S*, 6*R*)-5-methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester



General procedure A was followed using **1** (55 mg, 0.12 mmol), D-valine amide hydrochloride (93 mg, 0.62 mmol), and DIEA (110 μL, 0.62 mmol) in EtOH (2 mL). Purification via flash chromatography (2% MeOH/CH_2Cl_2) afforded the product as a clear oil (42 mg, 0.10 mmol, 80% yield); $R_f = 0.19$ (2% MeOH/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 425.5 (calculated for $C_{22}H_{37}N_2O_6$, 425.5).

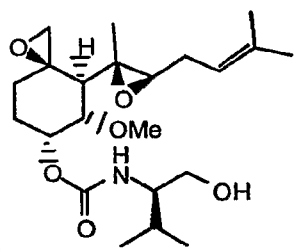
Example 6

(1-Carbamoyl-2-methyl-propyl)-carbamic acid-(3*R*, 4*S*, 5*S*, 6*R*)-5-methoxy-4-[(2*R*, 3*R*) -2-methyl-3-(3-methyl-butyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester



The compound in Example 4 (18 mg, 0.04 mmol) was dissolved into anhydrous MeOH (1.5 mL) and treated with Pd-C (2 mg) under a H_2 atmosphere. After 12 hours, the reaction was filtered through Celite and the solvent removed in vacuo to afford the product as a clear oil (18 mg, 0.04 mmol, 100% yield); $R_f = 0.21$ (2% MeOH/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 427.5 (calculated for $C_{22}H_{39}N_2O_6$, 427.5).

Example 7

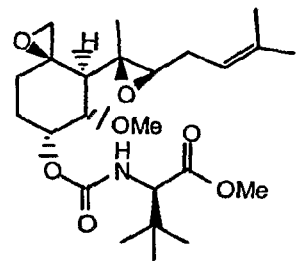


(1-Hydroxymethyl-2-methyl-propyl)-carbamic acid-(3*R*, 4*S*, 5*S*, 6*R*)-5-methoxy-4-[(2*R*,3*R*)- 2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester

General procedure A was followed using 1 (290 mg, 0.65 mmol), D-valinol (337 mg, 3.25 mmol), and DIEA (560 µL, 3.25 mmol) in EtOH (5 mL). Purification via flash chromatography (2% MeOH/CH_2Cl_2) afforded the product as a clear oil (200 mg, 0.49 mmol, 75% yield); $R_f = 0.26$ (2% MeOH/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 412.5 (calculated for $C_{22}H_{38}NO_6$, 412.5).

Example 8

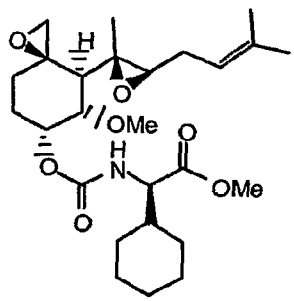
2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-3,3-dimethyl-butyric acid methyl ester



General procedure A was followed using 1 (65 mg, 0.15 mmol), D-tBu glycine methyl ester hydrochloride (132 mg, 0.73 mmol), and DIEA (127 μL, 0.73 mmol) in EtOH (8 mL). Purification via flash chromatography (10% EtOAc/CH_2Cl_2) afforded the product as a clear oil (10 mg, 0.02 mmol, 15% yield); R_f = 0.22 (10% EtOAc/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 454.5 (calculated for $C_{24}H_{40}NO_7$, 454.5).

Example 9

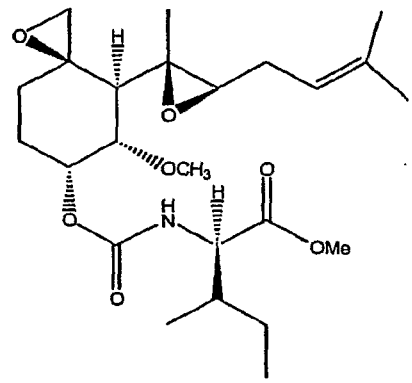
Cyclohexyl-2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-acetic acid methyl ester



General procedure A was followed using 1 (65 mg, 0.15 mmol), D-cyclohexyl glycine methyl ester hydrochloride (207 mg, 0.73 mmol), and DIEA (127 μL, 0.73 mmol) in EtOH (7 mL). Purification via flash chromatography (10% EtOAc/CH_2Cl_2) afforded the product as a clear oil (20 mg, 0.04 mmol, 28% yield); R_f = 0.22 (10% EtOAc/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 480.3 (calculated for $C_{26}H_{42}NO_7$, 480.3).

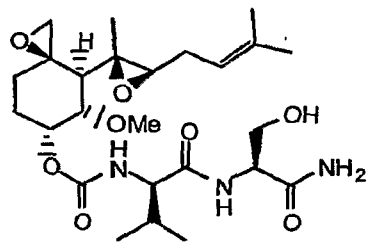
Example 10

2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-3-methyl-pentanoic acid methyl ester



General procedure A was followed using **1** (65 mg, 0.15 mmol), D-isoleucine methyl ester hydrochloride (132 mg, 0.73 mmol), and DIEA (127 μL, 0.73 mmol) in EtOH (7 mL). Purification via flash chromatography (10% EtOAc/CH_2Cl_2) afforded the product as a clear oil (20 mg, 0.04 mmol, 30% yield); R_f = 0.20 (10% EtOAc/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 454.5 (calculated for $C_{24}H_{40}NO_7$, 454.5).

Example 11

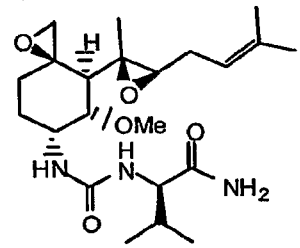


[1-(1-Carbamoyl-2-hydroxy-ethylcarbamoyl)-2-methyl-propyl]-carbamic acid-(3*R*, 4*S*, 5*S*, 6*R*)-5-methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl]-oxiranyl-1-oxa-spiro[2.5]oct-6-yl ester

General procedure A was followed using **1** (74 mg, 0.17 mmol), H-D-vS-NH_2•TFA (262 mg, 0.83 mmol), and DIEA (140 μL, 0.83 mmol) in EtOH (5 mL). Purification via HPLC (60% CH_3CN/H_2O) afforded the as a white solid (34 mg, 0.07 mmol, 40% yield); R_f = 0.21 (5% MeOH/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 512.5 (calculated for $C_{25}H_{42}N_3O_8$, 512.3).

Example 12

2-(3-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl}-ureido)-3-methyl-butyramide

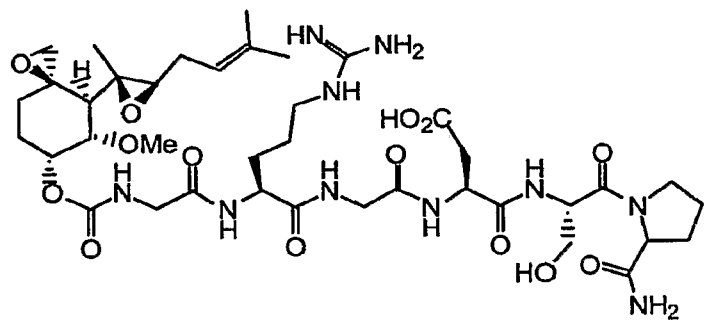


(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-ylamine (**3**; PCT Publication No. WO 99/59987) was prepared according to the published procedure. To a solution of crude **3** (29 mg, 0.1 mmol), DIEA (21 mL, 0.1 mmol) and DMAP (2 mg) in CH_2Cl_2 (1.5 mL) cooled to 0 °C was added p-NO_2 phenyl chloroformate (25 mg, 0.12 mmol). After 45 minutes, the reaction was warmed to room temperature and a solution of H-D-val-NH_2•HCl (40 mg, 0.15 mmol) in EtOH (1 mL) and DIEA (35 μL, 0.2 mmol) was added.

The reaction was continued for 1 hour, then was concentrated in vacuo, taken up into EtOAc (15 mL), and washed with dilute HCl_{aq}(2 x 15 mL), H_2O (2 x 15 mL) and brine (15 mL). Purification via flash chromatography (5% MeOH/CH_2Cl_2) afforded the product as a white solid (6 mg, 0.014 mmol, 13% yield from **3**); R_f = 0.12 (5% MeOH/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 424.4 (calculated for $C_{22}H_{38}N_3O_5$, 424.4).

Example 13

N-Carbamoyl (ID#31) 3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-butyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester



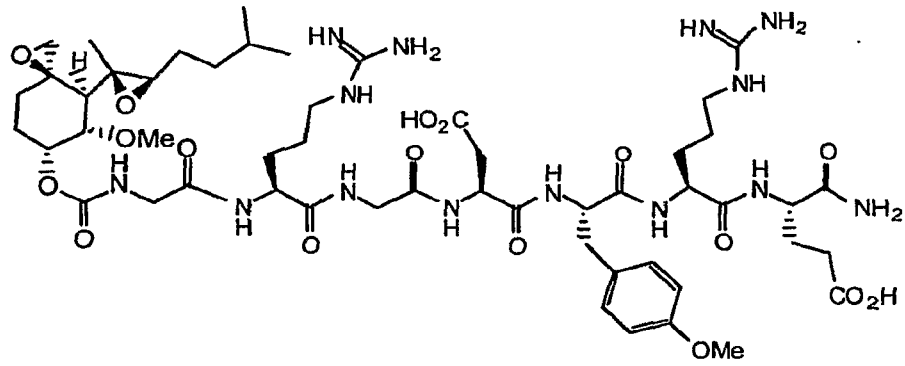
General Procedure B, Part I was followed using **2** (41 mg, 0.11 mmol), PS-DCC (256 mg, 0.28 mmol) in DMF (1 mL) and H-RGD(Bn)S(OBn)P-NH_2•2TFA (37 mg, 0.04 mmol), NMM (4 μL, 0.04 mmol) in DMF (0.5 mL). Purification via HPLC (70%CH_3CN/H_2O/0.075% TFA) afforded the product as a white floculent solid (9.3 mg,

0.009 mmol, 17%yield); LRMS (*m/z*) $[M+1]^+$ 1075.4 (calculated for $C_{53}H_{75}N_{10}O_{14}$, 1075.5).

General Procedure, Part II was followed using the product in Part I (9.3 mg, 0.009 mmol) and Pd/C (2 mg) in MeOH (1 mL), and a H_2 atmosphere (38 psi) for 24 hours. Purification via HPLC (55%CH_3CN/H_2O/0.075% TFA) afforded the product as a white solid (5 mg, 0.006 mmol, 65% yield); LRMS (*m/z*) $[M+1]^+$ 897.3 (calculated for $C_{39}H_{65}N_{10}O_{14}$, 897.5).

Example 14

N-Carbamoyl (ID#30) 3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-butyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester

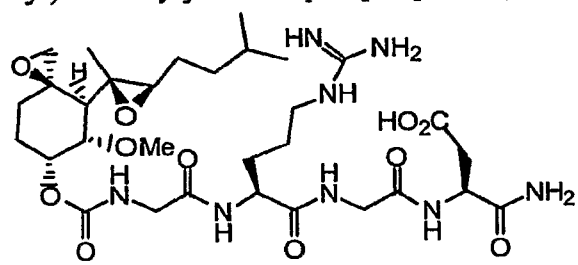


General Procedure, Part I was followed using **2** (38 mg, 0.10 mmol) and PS-DCC (238 mg, 0.25 mmol) in DMF (1 mL), H-RGD(Bn)Y(OMe)RE(Bn)-NH_2•3TFA (35 mg, 0.03 mmol) and NMM (3 μL, 0.03 mmol) in DMF (0.5 mL). Purification via HPLC (70%CH_3CN/H_2O/0.075% TFA) afforded the product as a white floculent solid (4.0 mg, 0.002 mmol, 8%yield); LRMS (*m/z*) $[M+2/2]^+$ 677.6 (calculated for $C_{66}H_{92}N14O_{17}$, 677.8).

General Procedure, Part II was followed using the product in Part I (3.0 mg, 0.002 mmol) and Pd/C (2 mg) in MeOH (1 mL), under a H_2 atmosphere (38 psi) for 24 hours. Purification via HPLC (55%CH_3CN/H_2O/0.075% TFA) afforded the product as a white solid (3.3 mg, 0.0027 mmol, 94% yield); LRMS (*m/z*) $[M+2/2]^+$ 588.5 (calculated for $C_{52}H_{82}N14O_{17}$, 588.7).

Example 15

N-Carbamoyl (ID#32) 3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-butyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester

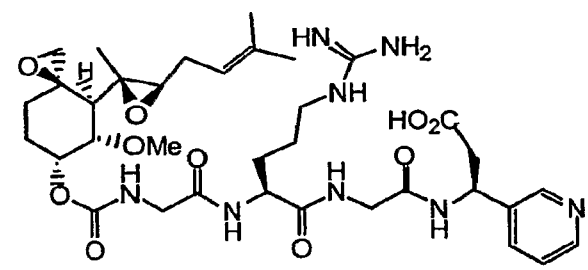


General Procedure B, Part I was followed using **2** (38 mg, 0.10 mmol), PS-DCC (238 mg, 0.25 mmol), and HOBt (29 mg, 0.25mmol) in DMF (1 mL), and H-RGD(Bn)NH_2•TFA (29 mg, 0.04 mmol) and NMM (4.8 μL, 0.04 mmol) in DMF (0.5 mL). Purification via HPLC (60%CH_3CN/H_2O/0.075% TFA) afforded the product as a white solid (35 mg, 0.04 mmol, 44%yield); LRMS (*m/z*) 801.2 (calculated for $C_{38}H_{57}N_8O_{11}$, 801.4).

General Procedure, Part II was followed using the product in Part I (35 mg, 0.04 mmol) and Pd/C (2 mg) in MeOH (1 mL), under a H_2 atmosphere (38 psi) for 24 hours. Purification via HPLC (50%CH_3CN/H_2O/0.075% TFA) afforded the product as a white solid (22 mg, 0.03 mmol, 71% yield); LRMS (*m/z*) 713.2 (calculated for $C_{31}H_{53}N_8O_{11}$, 713.4).

Example 16

N-Carbamoyl (ID#40) (3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester



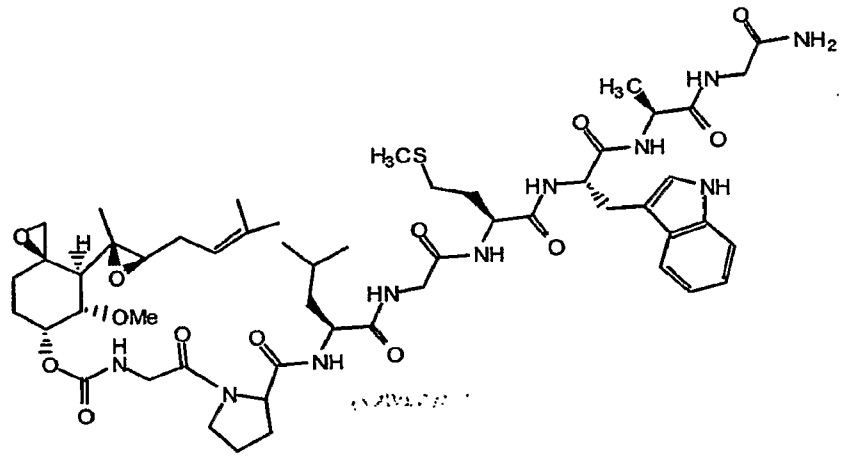
General Procedure B, Part I was followed using **2** (65 mg, 0.17 mmol), PS-DCC (405 mg, 0.43 mmol), and HOBt (34 mg, 0.26 mmol) in DMF (1 mL), and H-RG(pyridyl)D-OMe (43 mg, 0.06 mmol) and NMM (7 μL, 0.06 mmol) in DMF (0.5 mL). Purification via HPLC (50% CH_3CN/H_2O/0.075% TFA) afforded the product as a

white solid (15 mg, 0.02 mmol, 34%yield); LRMS (*m/z*) 773.2 (calculated for $C_{34}H_{55}N_4O_{10}$, 773.4).

The product of Part I (11 mg, 0.01 mmol) was dissolved into THF:MeOH:H_2O (2:1:1, 500 μL) and treated with LiOH•H_2O (1.2 mg, 0.02 mmol) for 2 hours. The crude material was diluted with EtOAc (5 mL) and acidified with dilute HCl (10 mL). The aqueous phase was washed with additional EtOAc (2 x 5 mL), the combined organic extracts dried over Na_2SO_4 and the solvent removed in vacuo. Purification via HPLC (30% CH_3CN/H_2O/0.075% TFA) afforded the product as a white solid (2 mg, 0.003 mmol, 19% yield). LRMS (*m/z*) 745.3 (calculated for $C_{33}H_{53}N_4O_{10}$, 745.4).

Example 17

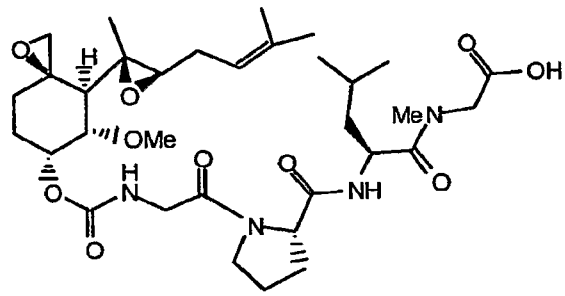
N-Carbamoyl (ID#39) (3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester



General procedure B, Part I was followed using **2** (25 mg, 0.07 mmol) and PS-DCC (155 mg, 0.16 mmol) in DMF (1 mL), and H-PLGMWAG-NH_2 (20 mg, 0.03 mmol) and NMM (3 μL, 0.03 mmol) in DMF (0.5 mL). Purification via HPLC (70%CH_3CN/H_2O/0.075% TFA) afforded the product as a white solid (1.4 mg, 0.001 mmol, 5%yield); LRMS (*m/z*) [M+1]+ 1095.6 (calculated for $C_{53}H_{79}N_{10}O_{13}S$, 1095.6).

Example 18

N-Carbamoyl (ID#26) (3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester

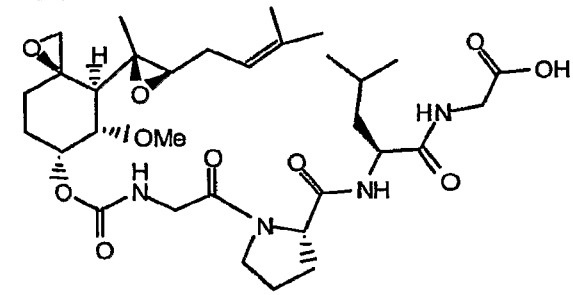


General Procedure B, Part I was followed using **2** (69 mg, 0.18 mmol), PS-DCC (429 mg, 0.45 mmol) and HOBt (21 mg, 0.18 mmol) in DMF (1 mL), and H-PL(N-Me)G-OMe (31 mg, 0.07 mmol) and NMM (8 μL, 0.07 mmol) in DMF (0.5 mL). Purification via HPLC (70%CH_3CN/H_2O/0.075% TFA) afforded the product as a white solid (27 mg, 0.04 mmol, 59%yield); LRMS (*m/z*) [M+1]+ 679.4 (calculated for $C_{34}H_{55}N_4O_{10}$, 679.4).

The product of Part I (27 mg, 0.04 mmol) was dissolved into THF:MeOH:H_2O (2:1:1, 1.5 mL) and treated with LiOH•H_2O (4 mg, 0.10 mmol) for 1 hour. The solution was acidified to pH 3 using 0.1 N HCl, and the MeOH and THF removed in vacuo. Purification via HPLC (60% CH_3CN/H_2O/0.075% TFA) afforded the product as a white solid (6 mg, 0.01 mmol, 23% yield). LRMS (*m/z*) 665.4 (calculated for $C_{33}H_{53}N_4O_{10}$, 665.4).

Example 19

N-Carbamoyl (ID#27) (3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester



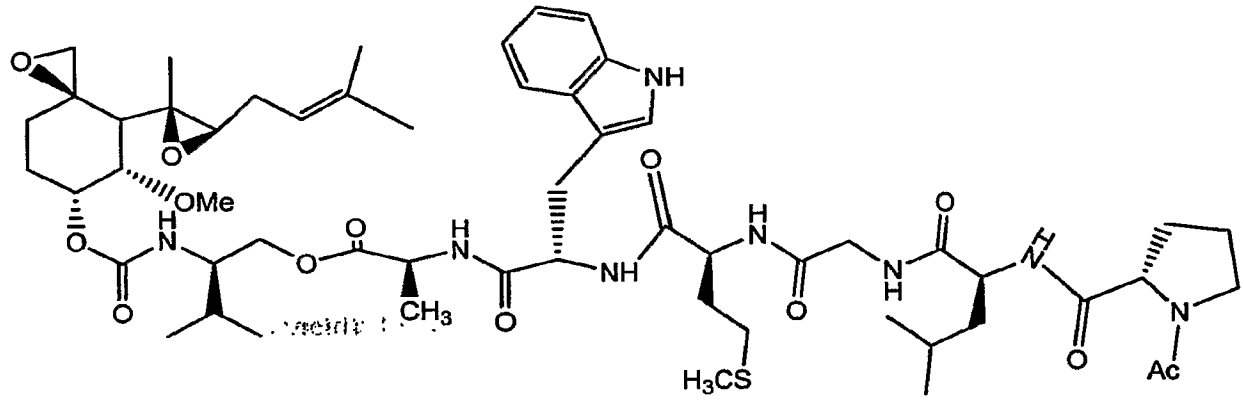
General Procedure B, Part I was followed using **2** (44 mg, 0.12 mmol), PS-DCC (276 mg, 0.29 mmol) and HOBt (27 mg, 0.23 mmol) in DMF (1 mL), and H-PLG-OMe

(20 mg, 0.05 mmol) and NMM (5 μL, 0.05 mmol) in DMF (0.5 mL). Purification via HPLC (90%CH_3CN/H_2O/0.075% TFA) afforded the product as a white solid (13 mg, 0.02 mmol, 43%yield); LRMS (*m/z*) [M+1]+ 664.4 (calculated for $C_{34}H_{52}N_4O_{10}$, 664.4).

The product in Part I (27 mg, 0.04 mmol) was dissolved into THF:MeOH:H_2O (2:1:1, 790 μL) and treated with $LiOH•H_2O$ (1.2 mg, 0.03 mmol) for 2 hours. The solution was acidified to pH 3 using 0.1 N HCl, and the MeOH and THF removed in vacuo. Purification via HPLC (90% CH_3CN/H_2O/0.075% TFA) afforded the product as a white solid (1.8 mg, 0.003 mmol, 15% yield). LRMS (*m/z*) 650.4 (calculated for $C_{32}H_{50}N_4O_{10}$, 650.4).

Example 20

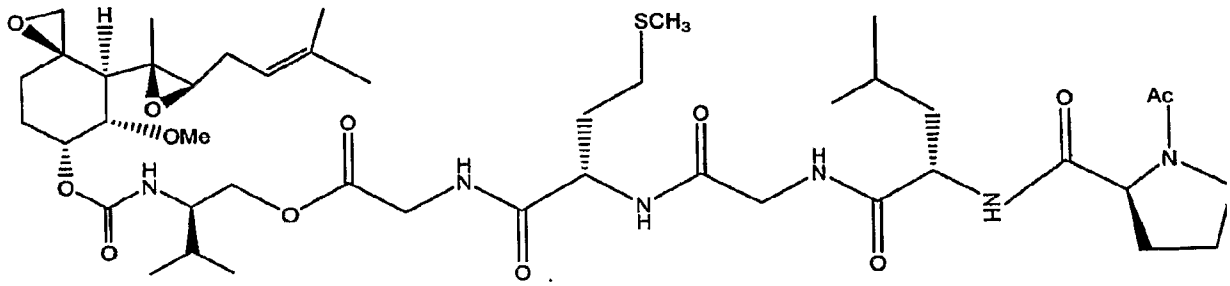
(ID#24)-(2*R*-{(3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonyl}. amino-3-methyl-butanol) ester



General Procedure C was followed using the compound in Example 7 (189 mg, 0.46 mmol), Ac-PLGMWA-OH (329 mg, 0.46 mmol), DMAP (84 mg, 0.69 mmol) and DIC (72 μL, 0.46 mmol) in CH_2Cl_2 (5 mL). After 18 hours, the solvent was removed in vacuo and purification via flash chromatography (2% MeOH/CH_2Cl_2) afforded the product as a white solid (357 mg, 0.32 mmol, 70% yield); R_f = 0.18 (5% MeOH/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 1110.3 (calculated for $C_{56}H_{85}N_8O_{13}S$, 1110.3).

Example 21

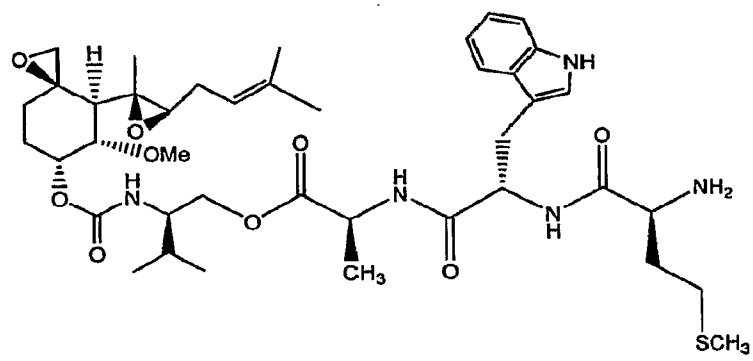
(ID#36)-(2*R*-{(3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonyl} amino-3-methyl-butanol) ester



General Procedure C was followed using the compound in Example 7 (61 mg, 0.15 mmol), Ac-PLGMG-OH (92 mg, 0.18 mmol), DMAP (22 mg, 0.18 mmol) and DIC (28 μL, 0.18 mmol) in CH_2Cl_2 (2 mL). After 7 hours, the solvent was removed in vacuo and purification via flash chromatography (3% MeOH/CH_2Cl_2) afforded the product as a white solid (61 mg, 0. mmol, 45% yield); R_f = 0.20 (5% MeOH/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 909.7 (calculated for $C_{44}H_{73}N_6O_{12}S$, 909.5).

Example 22

(ID#37)-(2*R*-{(3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonyl} amino-3-methyl-butanol) ester



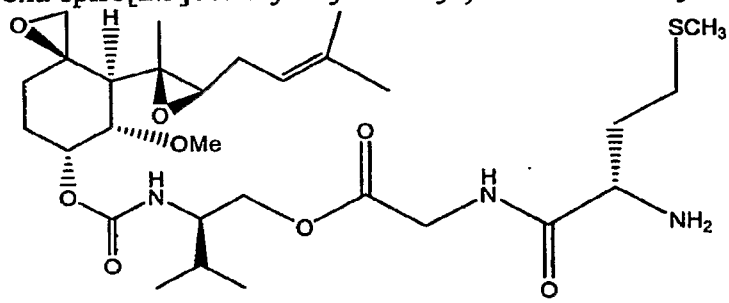
General Procedure C was followed using the compound in Example 7 (79 mg, 0.19 mmol), Fmoc-MWA-OH (121 mg, 0.19 mmol) and DMAP (4 mg, 0.03 mmol) and DIC (30 μL, 0.19 mmol) in CH_2Cl_2 (2 mL). After 11 hours, the solvent was removed in vacuo and purification via flash chromatography (2% MeOH/CH_2Cl_2) afforded the

product as a white solid (128 mg, 0.12 mmol, 65% yield); LRMS (*m/z*) $[M+1]^+$ 1022.9 (calculated for $C_{44}H_{73}N_6O_{12}S$, 1022.5).

The product from General Procedure C (above) (54 mg, 0.05 mmol) was dissolved into anhydrous CH_2Cl_2 (3 mL) cooled to 0 °C, then treated with a gentle stream of $NH_{3(g)}$ for 15 minutes. The reaction was sealed and continued at 0 °C for 36 hours. The solvent was removed in vacuo, and the crude residue acidified with CH_3CN/H_2O(0.075% TFA) (5 mL). Purification via HPLC (70% CH_3CN/H_2O/0,075% TFA) afforded the product as a white solid (2 mg, 0.003 mmol, 5% yield); LRMS (*m/z*) $[M+1]^+$ 800.6 (calculated for $C_{41}H_{62}N_5O_9S$, 800.5).

Example 23

(ID#38)-(2*R*-{(3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonyl} amino-3-methyl-butanol) ester

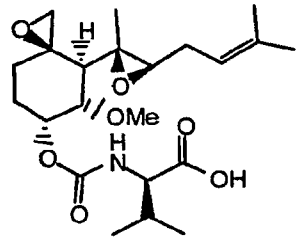


General Procedure C was followed using the compound in Example 7 (76 mg, 0.18 mmol), Fmoc-MG-OH (79 mg, 0.18 mmol) and DMAP (4 mg, 0.03 mmol) and VDIC (29 µL, 0.18 mmol) in CH_2Cl_2 (2 mL). After 10 hours, the solvent was removed in vacuo and purification via flash chromatography (2% MeOH/CH_2Cl_2) afforded the product as a white solid (128 mg, 0.12 mmol, 65% yield); LRMS (*m/z*) $[M+1]^+$ 822.6 (calculated for $C_{44}H_{60}N_3O_{10}S$, 822.5).

The product from General Procedure C (above) (42 mg, 0.05 mmol) was dissolved into anhydrous CH_2Cl_2 (3 mL) cooled to 0 °C, then treated with a gentle stream of $NH_{3(g)}$ for 15 minutes. The reaction was sealed and continued at 0 °C for 36 hours. The solvent was removed in vacuo, and the crude residue acidified with CH_3CN/H_2O(0.075% TFA) (5 mL). Purification via HPLC (70% CH_3CN/H_2O/0.075% TFA) afforded the product as a white solid (2 mg, 0.003 mmol, 5% yield); LRMS (*m/z*) $[M+1]^+$ 600.4 (calculated for $C_{29}H_{50}N_3O_8S$, 600.4).

Example 24

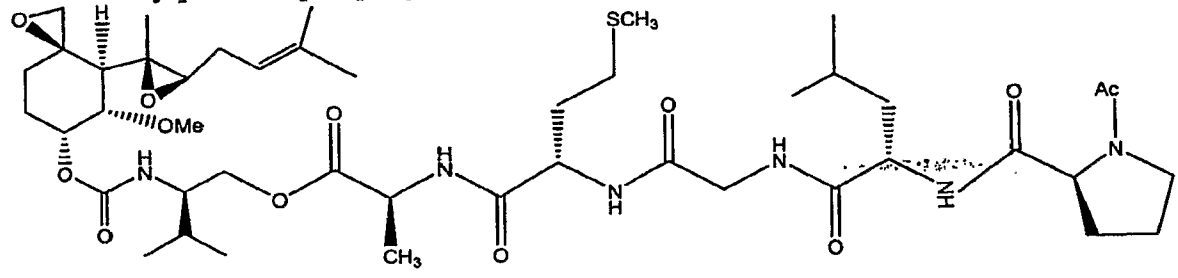
2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-3-methyl-butyric acid



The compound in Example 2 (9 mg, 0.02 mmol) was dissolved into THF:MeOH:H_2O (1 mL) and treated with LiOH•H_2O (2 mg, 0.05 mmol). After 2 hours, the reaction was partitioned between EtOAc (5 mL) and dilute HCl (5 mL). The organic phase was dried over Na_2SO_4 and the solvent removed in vacuo. Purification via HPLC (85% CH_3CN/H_2O/0.075% TFA) afforded the product as a white solid (0.58 mg, 0.001 mmol, 6% yield); LRMS (*m/z*) $[M+1]^+$ 426.4 (calculated for $C_{22}H_{36}NO_7$, 426.5).

Example 25

(ID#34)-(2*R*-{(3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonyl}. amino-3-methyl-butanol) ester



General Procedure C was followed using the compound in Example 7 (41 mg, 0.10 mmol), Ac-PLGMG-OH (63 mg, 0.12 mmol), DMAP (15 mg, 0.12 mmol) and DIC (19 μL, 0.12 mmol) in CH_2Cl_2 (2 mL). After 7 hours, the solvent was removed in vacuo and purification via flash chromatography (3% MeOH/CH_2Cl_2) afforded the product as a white solid (43 mg, 0.05 mmol, 47% yield); R_f = 0.21 (5% MeOH/CH_2Cl_2); LRMS (*m/z*) $[M+1]^+$ 923.7 (calculated for $C_{45}H_{75}N_6O_{12}S$, 923.5).

Example 26

The angiogenesis inhibitor compounds of the invention were tested for their ability to modulate human endothelial cell growth and for their ability to modulate the activity of MetAP2. The MetAP2 enzyme assay was performed essentially as described in Turk, B. *et al.* (1999) *Chem. & Bio.* 6: 823-833, the entire contents of which are

incorporated herein by reference. The bovine aortic endothelial cell growth assay (Baec assay) was performed essentially as described in Turk, B. *et al.* (*supra*), the entire contents of which are incorporated herein by reference.

For the human endothelial cell growth assay, human umbilical vein endothelial cells (HUVEC) were maintained in Clonetics endothelial growth medium (EGM) in a 37 °C humidified incubator. Cells were detached with trypsin and pelleted by centrifugation at 300 x g for 5 minutes at room temperature. HUVEC were added to 96-well plates at 5,000 cells/well. After incubating for 6 hours, the medium was replaced with 0.2 ml fresh EGM supplemented with 0.5 nM bFGF and the desired concentration of test angiogenesis inhibitor compound. Test angiogenesis inhibitor compounds were initially dissolved in ethanol at stock concentrations of either 10 mM or 0.1 mM, and subsequently diluted in EGM to obtain concentrations from 1 pM to 10 μM. After 48 hours at 37 °C, the medium was replaced with fresh bFGF-supplemented EGM and test angiogenesis inhibitor compound. Following incubation for an additional 48 hours at 37 °C MTT (3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyl-tetrazolium bromide) was added to 1 mg/ml. After 2-4 hours at 37 °C the medium was replaced with 0.1 ml/well isopropanol. The plates were placed on a shaker for 15 minutes at room temperature and analyzed in a Labsystems Multiskan plate spectrophotometer at an optical density of 570 nm.

The results of the assays, set forth below in Tables I-III, demonstrate that the angiogeness inhibitor compounds of the invention have excellent MetAP2 inhibitory activity and are able to inhibit endothelial cell growth at the picomolar range.

Table I. MetAP2 Assay

Example	IC_{50} (nM)
1	4.7
2	2
3	5.5
4	2.7
13	2.9
14	4000
17	16.7

Table II. Huvec Assay

Example	IC_{50} (pM)
1	18
2	40
3	38
4	36
5	93
13	(>10 μM)
14	(>10 μM)
15	(>10 μM)
17	(95 nM)
18	(>100 nM)
19	(>100 nM)
24	5444

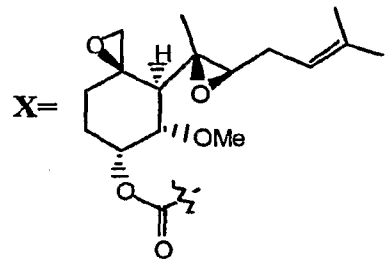
Table III. Baec Assay

Example	IC_{50} (pM)
1	17
2	48
3	118
4	35
5	46
6	220
7	128
8	313
9	165
10	179
11	(>100 nM)
16	(>100 nM)
19	(>100 nM)
22	326
23	207

The identity of the angiogenesis inhibitor compounds used in each of the experiments is shown in Tables IV and V below.

Table IV.

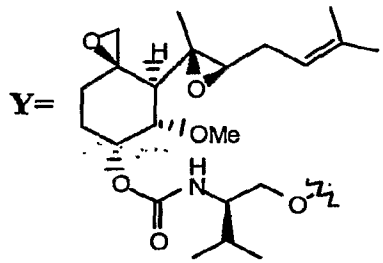
X=



Example	ID#	Sequence
13	31	X-GlyArgGlyAspSerPro-NH_2
14	30	X-GlyArgGlyAspTyr(OMe)Arg Glu-NH_2
15	32	X-GlyArgGlyAsp-NH_2
16	40	X-Gly-Arg-Gly-(3-amino-3-pyridylpropionic acid)
17	39	X-GlyProLeuGlyMetTrpAlaGly-NH_2
18	26	X-GlyProLeuSar-OH
19	27	X-GlyProLeuGly-OH

Table V.

Y=



Example	ID#	Sequence
20	24	Ac-ProLeuGly-MetTrpAla-Y
21	36	Ac-ProLeuGlyMetGly-Y
22	37	H-MetTrpAla-Y
23	38	H-MetGly-Y
25	34	Ac-ProLeuGlyMetAla-Y

Example 27

The compound of example 5 was also evaluated against a panel of cancer cell lines (Alley, M.C. *et al.* (1998) *Cancer Research* 48: 589-601; Grever, M.R., *et al.* (1992) *Seminars in Oncology*, Vol. 19, No. 6, pp 622-638; Boyd, M.R., and Paull, K.D. (1995) *Drug Development Research* 34: 91-109). The human tumor cell lines of the cancer screening panel were grown in RPMI 1640 medium containing 5% fetal bovine serum and 2 mM L-glutamine. Cells were inoculated into 96 well microtiter plates in 100 µL at plating densities ranging from 5,000 to 40,000 cells/well depending on the doubling time of individual cell lines. After cell inoculation, the microtiter plates were incubated at 37° C, 5 % CO_2, 95 % air and 100 % relative humidity for 24 hours prior to addition of experimental drugs.

After the 24 hour incubation period, two plates of each cell line were fixed *in situ* with TCA, to represent a measurement of the cell population for each cell line at the time of drug addition (Tz). Experimental drugs were solubilized in dimethyl sulfoxide at 400-fold the desired final maximum test concentration and stored frozen prior to use. At the time of drug addition, an aliquot of frozen concentrate was thawed and diluted to twice the desired final maximum test concentration with complete medium containing 50 µg/ml gentamicin. Additional four, 10-fold or ½ log serial dilutions were made to provide a total of five drug concentrations plus control. Aliquots of 100 µl of these different drug dilutions were added to the appropriate microtiter wells already containing 100 µl of medium, resulting in the required final drug concentrations.

Following drug addition, the plates were incubated for an additional 48 hours at 37°C, 5 % CO_2, 95 % air, and 100 % relative humidity. For adherent cells, the assay was terminated by the addition of cold TCA. Cells were fixed *in situ* by the gentle addition of 50 µl of cold 50 % (w/v) TCA (final concentration, 10 % TCA) and incubated for 60 minutes at 4°C. The supernatant was discarded, and the plates were washed five times with tap water and air dried. Sulforhodamine B (SRB) solution (100 µl) at 0.4 % (w/v) in 1 % acetic acid were added to each well, and plates were incubated for 10 minutes at room temperature. After staining, unbound dye was removed by washing five times with 1 % acetic acid and the plates were air dried. Bound stain was subsequently solubilized with 10 mM trizma base, and the absorbance was read on an automated plate reader at a wavelength of 515 nm. For suspension of the cells, the methodology used was the same except that the assay was terminated by fixing settled cells at the bottom of the wells by gently adding 50 µl of 80 % TCA (final concentration, 16 % TCA). Using the seven absorbance measurements [time zero, (Tz), control growth, (C), and test growth in the presence of drug at the five concentration levels (Ti)], the percentage growth was calculated at each of the drug concentrations levels.

Percentage growth inhibition was calculated as:

[(Ti-Tz)/(C-Tz)] x 100 for concentrations for which Ti>/=Tz

[(Ti-Tz)/Tz] x 100 for concentrations for which Ti<Tz.

Growth inhibition of 50 % (GI_{50}) was calculated from [(Ti-Tz)/(C-Tz)] x 100 = 50, which is the drug concentration resulting in a 50% reduction in the net protein increase (as measured by SRB staining) in control cells during the drug incubation. The GI_{50} was calculated for each of the cell lines if the level of activity is reached; however, if the effect was not reached or is exceeded, the value for that parameter is expressed as greater or less than the maximum (10^{-4} M) or minimum (10^{-8} M) concentration tested.

Table VIII: Effect of the compound of example 5 on tumor cell line panel

Cell line	Tumor type	GI_{50} (moles liter^{-1})
HL-60(TB)	Leukemia	2.17×10^{-5}
K-562	Leukemia	6.44×10^{-5}
MOLT-4	Leukemia	3.56×10^{-5}
RPMI-8226	Leukemia	$<1 \times 10^{-8}$
SR	Leukemia	$<1 \times 10^{-8}$
EKVX	Non-Small Cell Lung	2.08×10^{-5}
HOP-62	Non-Small Cell Lung	$<1 \times 10^{-8}$
HOP-92	Non-Small Cell Lung	3.39×10^{-5}
NCI-H226	Non-Small Cell Lung	7.91×10^{-7}
NCI-H23	Non-Small Cell Lung	6.34×10^{-6}
NCI-H322M	Non-Small Cell Lung	4.68×10^{-8}
NCI-H460	Non-Small Cell Lung	$<1 \times 10^{-8}$
NCI-H522	Non-Small Cell Lung	1.29×10^{-5}
COLO 205	Colon	$<1 \times 10^{-8}$
HCT-116	Colon	$<1 \times 10^{-8}$
HCT-15	Colon	7.13×10^{-6}
HT29	Colon	1.61×10^{-5}
KM12	Colon	$<1 \times 10^{-8}$
SW-620	Colon	$>1 \times 10^{-4}$
SF-268	CNS	2.61×10^{-5}
SF-295	CNS	$<1 \times 10^{-8}$
SF-539	CNS	2.06×10^{-5}
SNB-19	CNS	$<1 \times 10^{-8}$

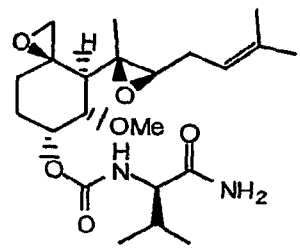
SNB-75	CNS	9.09×10^{-5}
MALME-3M	Melanoma	5.31×10^{-8}
M14	Melanoma	$<1 \times 10^{-8}$
SK-MEL-2	Melanoma	$>1 \times 10^{-4}$
SK-MEL-28	Melanoma	5.96×10^{-6}
SK-MEL-5	Melanoma	$>1 \times 10^{-4}$
UACC-257	Melanoma	1.48×10^{-6}
UACC-62	Melanoma	$<1 \times 10^{-8}$
IGR-OV1	Ovarian	$<1 \times 10^{-8}$
OVCAR-3	Ovarian	4.18×10^{-5}
OVCAR-4	Ovarian	3.66×10^{-5}
OVCAR-5	Ovarian	1.35×10^{-8}
OVCAR-8	Ovarian	1.84×10^{-5}
SK-OV-3	Ovarian	7.37×10^{-6}
786-0	Renal	1.61×10^{-5}
A498	Renal	$>1 \times 10^{-4}$
ACHN	Renal	$< 1 \times 10^{-8}$
CAKI-1	Renal	$<1 \times 10^{-8}$
RXF 393	Renal	4.02×10^{-5}
SN12C	Renal	$<1 \times 10^{-8}$
TK-10	Renal	5.43×10^{-8}
PC-3	Prostate	1.80×10^{-5}
DU-145	Prostate	$<1 \times 10^{-8}$
MCF7	Breast	1.24×10^{-5}
NCI/ADR-RES	Breast	3.42×10^{-5}
MDA-MB-231/ATCC	Breast	$<1 \times 10^{-8}$
HS 578T	Breast	1.15×10^{-6}
MDA-N	Breast	1.58×10^{-6}

Results

The results of the cell line screen, presented in Table VIII, show that the compound of example 5 has a significant inhibitory effect on a wide variety of tumor cell lines. The results also show that certain cell lines are much more sensitive to the compound of example 5 than are others, indicating that this compound is selective for certain cell lines.

In Examples 28-31, the compound of Example 5 (hereinafter "Compound 5") was used:

(1-Carbamoyl-2-methyl-propyl)-carbamic acid-(3*R*, 4*S*, 5*S*, 6*R*)-5-methoxy-4-[(2*R*, 3*R*) -2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester



EXAMPLE 28

INHIBITION OF B-CELL LYMPHOMA CELL LINE IN CULTURE

Objective:

To determine the inhibition of germinal center derived B cell lymphoma lines by Compound 5.

Experimental Design:

Compound 5 was incubated at final concentrations ranging from 0.01-100 nM with 50,000 cells/mL of germinal center derived B cell lymphoma lines. Incubations lasted for five or six days after which cell numbers were determined from triplicate flasks at each concentration.

Results:

Compound A inhibited the proliferation of all lymphoma lines tested except for the Ramos line, a Burkitt's lymphoma cell line. Table IX shows the maximum growth inhibition and estimated concentration producing a 50% decrease in cell proliferation ($GI_{50\%}$) in Compound A treated cultures relative to growth observed in vehicle control cultures.

Table IX: Inhibition of GC Derived B Cell Lymphoma Lines

B Lymphoma Cell Line	Classification[1]	Growth Inhibition by Compound A Relative to Vehicle Control	
		Maximum Inhibition	$GI_{50\%}$
SU-DHL-16	DLBCL	60%[2]	1.9 nM
Pfeiffer	DLBCL	54%	0.27 nM
DB	DLBCL	42%[2]	-
D10	FL	59%	0.42 nM
H2	FL	59%	0.16 nM
Ramos	BL	-	-
ST486	BL	53%	0.22 nM

1) DLBCL – diffuse large B cell lymphoma, FL – follicular lymphoma, BL – Burkitt's lymphoma.

2) Cell number determined at day 5 due to rapid growth of vehicle treated cultures

Conclusion:

Compound 5 inhibited the proliferation of all DLBCL and FL cell lines tested at low nanomolar concentrations.

EXAMPLE 29

INHIBITION OF SR CELL LINE IN CULTURE

Objective:

To evaluate the dose response inhibition of the human SR lymphoblast cell line in culture

Experimental Design:

Compound 5 was incubated at final concentrations ranging from 0.1 nM to 10 μM with 25,000 cells/mL of human lymphoblast SR cells. Incubations were conducted for 3, 5 or 6 days after which cell proliferation relative to vehicle treatment was determined using a ^{3}H-thymidine incorporation assay. Medium was replaced and fresh drug was added on day 3 for the 5 and 6 day assays.

Results:

Figure 1 shows representative data from these cell proliferation assays. Compound 5 inhibited proliferation of the SR cell line by 59-75% at concentrations from 1-100 nM with a mean GI_{50} of 0.5 nM in the 5 and 6 day assays.

Conclusion:

These results demonstrate that Compound 5 can inhibit proliferation of the SR cell line in culture at nM concentrations. Maximal inhibition by Compound 5 was greater than 90% with a mean $GI_{50\%}$ of 0.5 nM following five or six days of exposure to Compound 5.

EXAMPLE 30

EVALUATION OF IN VIVO EFFICACY OF COMPOUND 5 IN SR LYMPHOMA CELL TUMORS GROWN IN MICE

Objective:

This study was performed to determine the *in vivo* efficacy for Compound A administered either subcutaneously or orally in SR tumor-bearing mice

Experimental Design:

SR lymphoma tumor cells were injected subcutaneously into SCID/NCr female mice. Tumors were measured using a caliper every 3-4 days beginning on day 12 post-implantation of tumor cells. Animals were weighed routinely on the same days as tumor measurments and monitored for clinical signs of any adverse, drug-related side effects. Treatment with Compound 5 or vehicle began on Day 12 for 5 weeks and ended on Day 44. The endpoints evaluated were optimal percent treated/control (%T/C) and tumor growth delay measured at multiple timepoints during the study.

Results:

In SR tumor xenografts both oral and subcutaneous routes of administration of Compound 5 significantly suppressed tumor growth in a dose-dependent manner and the oral route appeared to be slightly superior to the subcutaneous route in this model (Figure 2). Compound 5 administered subcutaneously at 15 or 30 mg/kg produced optimal % T/C values of 70 or 50, respectively, whereas administration by the oral route achieved optimal % T/C values of 48 or 43 at the 15 or 30 mg/kg dose, respectively. Moreover, oral administration of Compound 5 was more efficacious than subcutaneous administration, as determined by tumor growth delay. Compound 5 produced tumor

growth delays of 29 or 28% when administered orally (15 or 30 mg/kg, respectively) compared to 18 or 19% when administered by the subcutaneous route (15 or 30 mg/kg, respectively).

Conclusion:

Compound 5 produces a dose-dependent inhibition of growth of SR lymphoma tumors growing in mice with maximal efficacy observed in this study at 30 mg/kg administered by the oral route.

EXAMPLE 31

EVALUATION OF THE EFFICACY OF COMPOUND 5 IN TREATING ALLOGRAFT VASCULAR DISEASE

Donor hearts from B6.C-H2 mice were heterotopically implanted intra-abdominally into C57BL/6 recipients using a standard microvascular technique. The study was comprised of four groups; 2 vehicle-treated groups (1-4 weeks and 5-8 weeks) and 2 groups treated with the compound of Example 5 (1-4 weeks and 5-8 weeks) to distinguish between a therapeutic benefit of early and/or late stage disease attenuation. The study was terminated at the end of 8 weeks and hearts were grossly examined for overall graft health (healthy tissue color, abdominal adhesions, and heart beat intensity) and then fixed in formalin and processed for histological examination. The graft sections were stained with H & E and elastin and scored blindly for the following parameters: inflammatory cell infiltrate within the allograft myocardium, myocyte necrosis and allograft vascular disease (CAV).

Results

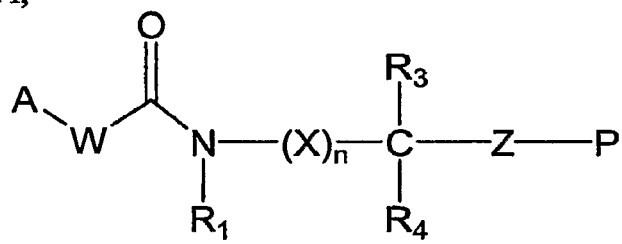
When compared to vehicle treated mice, there was an overall improvement in graft health in the 5-8 week group treated with the compound of Example 5 at the time of harvest. Histologically, there was a reduction in inflammatory cell infiltrates, less myocyte necrosis and a decreased incidence of CAV when the compound of Example 5 was administered from 5-8 weeks as compared to vehicle. However, when the compound of Example 5 was dosed from 1-4 weeks there was no histological or gross visual improvement when compared to vehicle. Based on the foregoing results, it is evident that there is a general therapeutic benefit when the compound of Example 5 is administered to an animal suffering from CAV disease, *e.g.*, during late stage CAV disease.

Equivalents

Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments of the invention described herein. Such equivalents are intended to be encompassed by the following claims.

We claim:

1. A method of inducing an immunosupressed condition and/or treating chronic allograft vasculopathy in a subject undergoing or who has undergone a transplant, the method comprising administering to said subject an effective amount of a compound comprising Formula I,



wherein

A is a Met-AP2 inhibitory core;

W is O or NR_2;

R_1 and R_2 are each, independently, hydrogen or alkyl;

X is alkylene or substituted alkylene;

n is 0 or 1;

R_3 and R_4 are each, independently, hydrogen, substituted or unsubstituted alkyl, substituted or unsubstituted aryl or substituted or unsubstituted heteroaryl; or R_3 and R_4, together with the carbon atom to which they are attached, form a carbocyclic or heterocyclic group; or R_3 and R_4 together form an alkylene group;

Z is -C(O)- or alkylene-C(O)-; and

P is a peptide comprising from 1 to about 100 amino acid residues attached at its amino terminus to Z or a group OR_5 or $N(R_6)R_7$, wherein

R_5, R_6 and R_7 are each, independently, hydrogen, alkyl, substituted alkyl, azacycloalkyl or substituted azacycloalkyl; or R_6 and R_7, together with the nitrogen atom to which they are attached, form a substituted or unsubstituted heterocyclic ring structure;

or

Z is -O-, $-NR_8$-, alkylene-O- or alkylene-NR_8-, where R_8 is hydrogen or alkyl; and

P is hydrogen, alkyl or a peptide consisting of from 1 to about 100 amino acid residues attached at its carboxy terminus to Z and pharmaceutically acceptable salts thereof,

thereby inducing an immunosupressed condition and/or treating chronic allograft vasculopathy in a subject undergoing or who has undergone a transplant.

2. The method of claim 1, wherein at least one of R_1, R_3 and R_4 is a substituted or unsubstituted alkyl group.

3. The method of claim 2, wherein at least one of R_1, R_3 and R_4 is a substituted or unsubstituted normal, branched or cyclic C_1-C_6 alkyl group.

4. The method of claim 3, wherein at least one of R_1, R_3 and R_4 is a normal or branched C_1-C_4 alkyl group.

5. The method of claim 1, wherein one of R_3 and R_4 is a substituted or unsubstituted aryl group, a substituted or unsubstituted heteroaryl group, a substituted or unsubstituted heteroarylalkyl group, or a substituted or unsubstituted aryl alkyl group.

6. The method of claim 5, wherein one of R_3 and R_4 is selected from the group consisting of phenyl, naphthyl, indolyl, imidazolyl, pyridyl, benzyl, naphthylmethyl, indolylmethyl, imidazolylmethyl and pyridylmethyl.

7. The method of claim 1, wherein n is 1 and X is C_1-C_6-alkylene.

8. The method of claim 7, wherein X is methylene or ethylene.

9. The method of claim 1, wherein Z is C_1-C_6-alkylene-C(O)-.

10. The method of claim 9, wherein Z is methylene-C(O)- or ethylene-C(O)-.

11. The method of claim 1, wherein at least one of R_6 and R_7 is alkyl, substituted alkyl, substituted or unsubstituted azacycloalkyl or substituted or unsubstituted azacycloalkyl.

12. The method of claim 11, wherein at least one of R_6 and R_7 is an azacycloalkyl group having an N-alkyl substituent.

13. The method of claim 12, wherein the N-alkyl substituent is a C_1-C_4-alkyl group.

14. The method of claim 13, wherein the N-alkyl substituent is a methyl group.

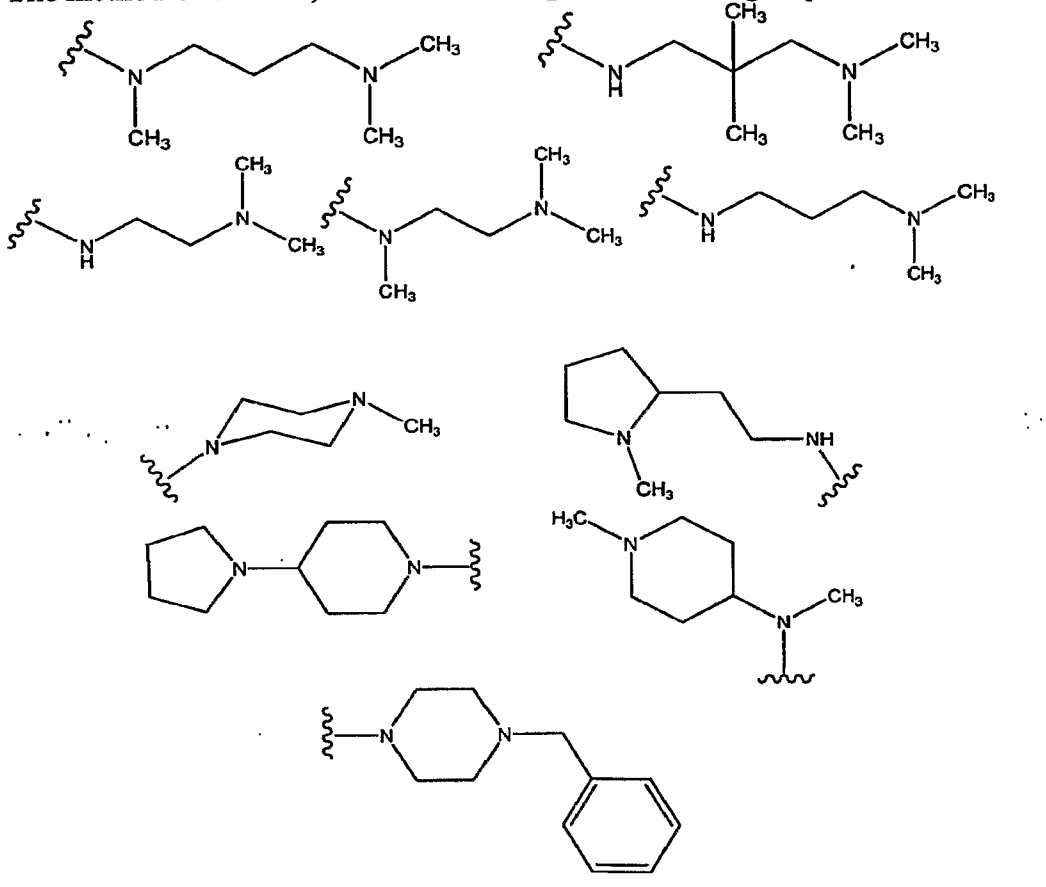
15. The method of claim 1, wherein R_6 and R_7, together with the nitrogen atom to which they are attached, form a substituted or unsubstituted five or six-membered aza- or diazacycloalkyl group.

16. The method of claim 15, wherein R_6 and R_7, together with the nitrogen atom to which they are attached, form a substituted or unsubstituted five or six-membered diazacycloalkyl group which includes an N-alkyl substituent.

17. The method of claim 16, wherein the N-alkyl substituent is a C_1-C_4-alkyl group.

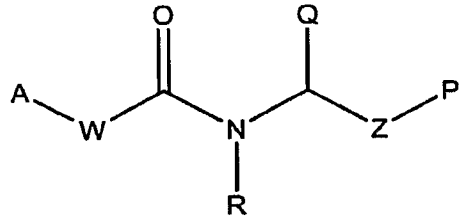
18. The method of claim 17, wherein the N-alkyl substituent is a methyl group.

19. The method of claim 1, wherein P is NH_2 or one of the groups shown below:



20. A method of inducing an immunosupressed condition and/or treating chronic allograft vasculopathy in a subject undergoing or who has undergone a transplant, the

method comprising administering to said subject an effective amount of a compound comprising Formula XV,



(XV)

wherein

A is a MetAP-2 inhibitory core;

W is O or NR;

each R is, independently, hydrogen or alkyl;

Z is –C(O)- or -alkylene-C(O)-;

P is NHR, OR or a peptide consisting of one to about one hundred amino acid residues connected at the N-terminus to Z;

Q is hydrogen, linear, branched or cyclic alkyl or aryl, provided that when P is –OR, Q is not hydrogen;

or

Z is –alkylene-O- or –alkylene-N(R)-;

P is hydrogen or a peptide consisting of from one to about one hundred amino acid residues connected to Z at the carboxyl terminus;

Q is hydrogen, linear, branched or cyclic alkyl or aryl, provided that when P is hydrogen, Q is not hydrogen;

and pharmaceutically acceptable salts thereof, thereby inducing an immunosupressed condition and/or treating chronic allograft vasculopathy in a subject undergoing or who has undergone a transplant.

21. The method of claim 20, wherein Z is Z is –C(O)- or C_1-C_4-alkylene-C(O)-.

22. The method of claim 21, wherein Z is -C(O)- or C_1-C_2-alkylene-C(O)-.

23. The method of claim 21, wherein Q is linear, branched or cyclic C_1-C_6-alkyl, phenyl or naphthyl.

24. The method of claim 23, wherein Q is isopropyl, phenyl or cyclohexyl.

25. The method of claim 1, wherein Z is C_1-C_6-alkylene-O- or C_1-C_6-alkylene-NR-.

26. The method of claim 25, wherein Z is C_1-C_4-alkylene-O- or C_1-C_4-alkylene-NH-.

27. The method of claim 26, wherein Z is C_1-C_2-alkylene-O- or C_1-C_2-alkylene-NH.

28. The method of claim 25, wherein Q is linear, branched or cyclic C_1-C_6-alkyl , phenyl or naphthyl.

29. The method of claim 28, wherein Q is isopropyl, phenyl or cyclohexyl.

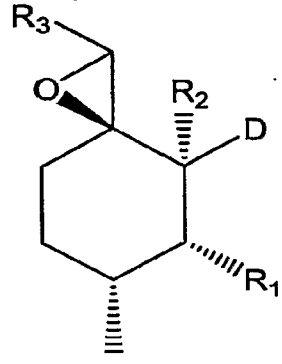
30. The method of claim 20, wherein each R is, independently, hydrogen or linear, branched or cyclic C_1-C_6-alkyl.

31. The method of claim 30, wherein each R is, independently, hydrogen or linear or branched C_1-C_4-alkyl.

32. The method of claim 31, wherein each R is, independently, hydrogen or methyl.

33. The method of claim 32, wherein each R is hydrogen.

34. The method of claim 20, wherein A is of Formula II,



(II)

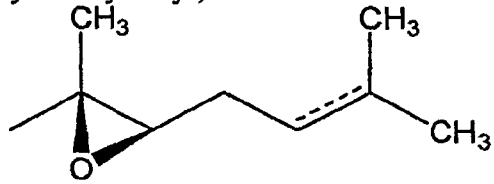
wherein

R_1 is hydrogen or alkoxy;

R_2 is hydrogen or hydroxy;

R_3 is hydrogen or alkyl; and

D is linear or branched alkyl or arylalkyl; or D is of the structure



35. The method of claim 34, wherein R_1 is C_1-C_4-alkoxy.

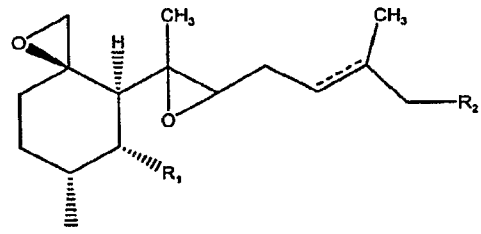
36. The method of claim 35, wherein R_1 is methoxy.

37. The method of claim 34, wherein R_3 is hydrogen or C_1-C_4-alkyl.

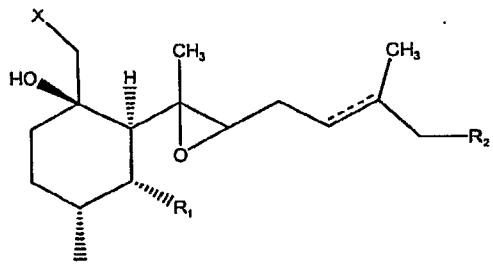
38. The method of claim 37, wherein R_3 is methyl.

39. The method of claim 34, wherein D is linear, branched or cyclic C_1-C_6-alkyl; or aryl-C_1-C_4-alkyl.

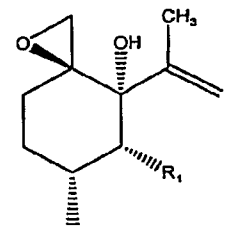
40. The method of claim 20, wherein A is selected from the group consisting of



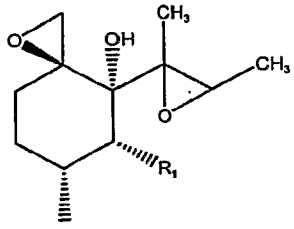
(IV)



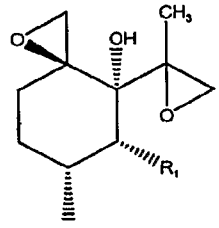
(V)



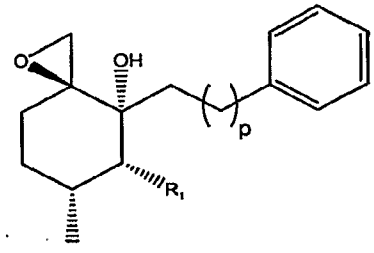
(VI)



(VII)



(VIII)



(IX)

wherein

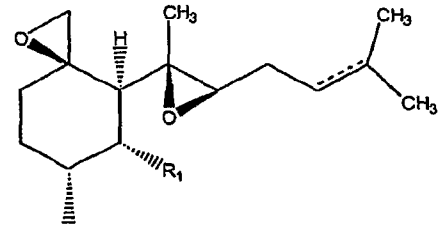
p is an integer from 0 to 10;

R_1 is hydrogen, -OH or C_1-C_4-alkoxy;

X is a leaving group; and

R_2 is H, OH, amino, C_1-C_4-alkylamino or di(C_1-C_4-alkyl)amino).

41. The method of claim 40, wherein A is of the formula



42. The method of claim 20, wherein P comprises from 1 to about 20 amino acid residues.

43. The method of claim 42, wherein P comprises an amino acid sequence which is a substrate for a matrix metalloprotease.

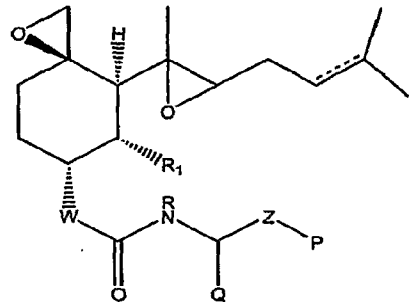
44. The method of claim 43, wherein the matrix metalloprotease is selected from the group consisting of MMP-2, MMP-1, MMP-3, MMP-7, MMP-8, MMP-9, MMP-12, MMP-13 and MMP-26.

45. The method of claim 44, wherein the matrix metalloprotease is MMP-2 or MMP-9.

46. The method of claim 45, wherein P comprises the sequence -Pro-Leu-Gly-Xaa-, wherein Xaa is a naturally occurring amino acid residue.

47. The method of claim 46, wherein P comprises the a sequence selected from the group consisting of Pro-Cha-Gly-Cys(Me)-His (SEQ ID NO:2); Pro-Gln-Gly-Ile-Ala-Gly-Gln-D-Arg (SEQ ID NO:3); Pro-Gln-Gly-Ile-Ala-Gly-Trp (SEQ ID NO:4); Pro-Leu-Gly-Cys(Me)-His-Ala-D-Arg (SEQ ID NO:5); Pro-Leu-Gly-Met-Trp-Ser-Arg (SEQ ID NO:35); Pro-Leu-Gly-Leu-Trp-Ala-D-Arg (SEQ ID NO:6); Pro-Leu-Ala-Leu-Trp-Ala-Arg (SEQ ID NO:7); Pro-Leu-Ala-Leu-Trp-Ala-Arg (SEQ ID NO:8); Pro-Leu-Ala-Tyr-Trp-Ala-Arg (SEQ ID NO:9); Pro-Tyr-Ala-Tyr-Trp-Met-Arg (SEQ ID NO:10); Pro-Cha-Gly-Nva-His-Ala (SEQ ID NO:11); Pro-Leu-Ala-Nva (SEQ ID NO:12); Pro-Leu-Gly-Leu (SEQ ID NO:13); Pro-Leu-Gly-Ala (SEQ ID NO:14); Arg-Pro-Leu-Ala-Leu-Trp-Arg-Ser (SEQ ID NO:15); Pro-Cha-Ala-Abu-Cys(Me)-His-Ala (SEQ ID NO:16); Pro-Cha-Ala-Gly-Cys(Me)-His-Ala (SEQ ID NO:17); Pro-Lys-Pro-Gln-Gln-Phe-Phe-Gly-Leu (SEQ ID NO:18); Pro-Lys-Pro-Leu-Ala-Leu (SEQ ID NO:19); Arg-Pro-Lys-Pro-Tyr-Ala-Nva-Trp-Met (SEQ ID NO:20); Arg-Pro-Lys-Pro-Val-Glu-Nva-Trp-Arg (SEQ ID NO:21); Arg-Pro-Lys-Pro-Val-Glu-Nva-Trp-Arg (SEQ ID NO:22); and Arg-Pro-Lys-Pro-Leu-Ala-Nva-Trp (SEQ ID NO:23).

48. A method of inducing an immunosupressed condition and/or treating chronic allograft vasculopathy in a subject undergoing or who has undergone a transplant, the method comprising administering to said subject an effective amount of a compound comprising a compound of the formula



wherein

W is O or NR;

each R is, independently hydrogen or a C_1-C_4-alkyl;

Q is hydrogen; linear, branched or cyclic C_1-C_6-alkyl; or aryl;

R_1 is hydroxy, C_1-C_4-alkoxy or halogen;

Z is –C(O)- or C_1-C_4-alkylene;

P is NHR, OR, or a peptide comprising 1 to 100 amino acid residues attached to Z at the N-terminus; or

Z is alkylene-O or alkylene-NR; and

P is hydrogen or peptide comprising 1 to 100 amino acid residues attached to Z at the C-terminus;

or a pharmaceutically acceptable salt thereof; provided that when P is hydrogen, NHR or OR, Q is not hydrogen, thereby inducing an immunosupressed condition and/or treating chronic allograft vasculopathy in a subject undergoing or who has undergone a transplant.

49. The method of claim 48, wherein

W is O or NH;

Z is alkylene-O or alkylene-NH;

Q is isopropyl;

R_1 is methoxy; and

P comprises from 1 to 15 amino acid residues.

50. The method of claim 49, wherein
W is O; and
P comprises 10 or fewer amino acid residues.

51. The method of claim 48, wherein P comprises from 1 to about 20 amino acid residues.

52. The method of claim 51, wherein P comprises an amino acid sequence which is a substrate for a matrix metalloprotease.

53. The method of claim 52, wherein the matrix metalloprotease is selected from the group consisting of MMP-2, MMP-1, MMP-3, MMP-7, MMP-8, MMP-9, MMP-12, MMP-13 and MMP-26.

54. The method of claim 53, wherein the matrix metalloprotease is MMP-2 or MMP-9.

55. The method of claim 54, wherein P comprises the sequence -Pro-Leu-Gly-Xaa-, wherein Xaa is a naturally occurring amino acid residue.

56. The method of claim 55, wherein P comprises the a sequence selected from the group consisting of Pro-Cha-Gly-Cys(Me)-His (SEQ ID NO:2); Pro-Gln-Gly-Ile-Ala-Gly-Gln-D-Arg (SEQ ID NO:3); Pro-Gln-Gly-Ile-Ala-Gly-Trp (SEQ ID NO:4); Pro-Leu-Gly-Cys(Me)-His-Ala-D-Arg (SEQ ID NO:5); Pro-Leu-Gly-Met-Trp-Ser-Arg (SEQ ID NO:35); Pro-Leu-Gly-Leu-Trp-Ala-D-Arg (SEQ ID NO:6); Pro-Leu-Ala-Leu-Trp-Ala-Arg (SEQ ID NO:7); Pro-Leu-Ala-Leu-Trp-Ala-Arg (SEQ ID NO:8); Pro-Leu-Ala-Tyr-Trp-Ala-Arg (SEQ ID NO:9); Pro-Tyr-Ala-Tyr-Trp-Met-Arg (SEQ ID NO:10); Pro-Cha-Gly-Nva-His-Ala (SEQ ID NO:11); Pro-Leu-Ala-Nva (SEQ ID NO:12); Pro-Leu-Gly-Leu (SEQ ID NO:13); Pro-Leu-Gly-Ala (SEQ ID NO:14); Arg-Pro-Leu-Ala-Leu-Trp-Arg-Ser (SEQ ID NO:15); Pro-Cha-Ala-Abu-Cys(Me)-His-Ala (SEQ ID NO:16); Pro-Cha-Ala-Gly-Cys(Me)-His-Ala (SEQ ID NO:17); Pro-Lys-Pro-Gln-Gln-Phe-Phe-Gly-Leu (SEQ ID NO:18); Pro-Lys-Pro-Leu-Ala-Leu (SEQ ID NO:19); Arg-Pro-Lys-Pro-Tyr-Ala-Nva-Trp-Met (SEQ ID NO:20); Arg-Pro-Lys-Pro-Val-Glu-Nva-Trp-Arg (SEQ ID NO:21); Arg-Pro-Lys-Pro-Val-Glu-Nva-Trp-Arg (SEQ ID NO:22); and Arg-Pro-Lys-Pro-Leu-Ala-Nva-Trp (SEQ ID NO:23).

57. A method of inducing an immunosupressed condition and/or treating chronic allograft vasculopathy in a subject undergoing or who has undergone a transplant, the method comprising administering to said subject an effective amount of a compound comprising a structure selected from the group consisting of

{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-3-methyl-butyric acid methyl ester;

2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-3-methyl-butyric acid methyl ester;

2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-4-methyl-pentanoic acid methyl ester;

{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-phenyl-acetic acid methyl ester;

(1-Carbamoyl-2-methyl-propyl)-carbamic acid-(3*R*, 4*S*, 5*S*, 6*R*)-5-methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

(1-Carbamoyl-2-methyl-propyl)-carbamic acid-(3*R*, 4*S*, 5*S*, 6*R*)-5-methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-butyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

(1-Hydroxymethyl-2-methyl-propyl)-carbamic acid-(3*R*, 4*S*, 5*S*, 6*R*)-5-methoxy-4-[(2*R*, 3*R*)- 2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-3,3-dimethyl-butyric acid methyl ester;

Cyclohexyl-2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-acetic acid methyl ester;

2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-3-methyl-pentanoic acid methyl ester;

[1-(1-Carbamoyl-2-hydroxy-ethylcarbamoyl)-2-methyl-propyl]-carbamic acid-(3*R*, 4*S*, 5*S*, 6*R*)-5-methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl]-oxiranyl-1-oxa-spiro[2.5]oct-6-yl ester;

2-(3-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl}-ureido)-3-methyl-butyramide;

2-{(3*R*, 4*S*, 5*S*, 6*R*)-5-Methoxy-4-[(2*R*, 3*R*)-2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonylamino}-3-methyl-butyric acid;

N-Carbamoyl (ID#31) (3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-butyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

N-Carbamoyl (ID#30) (3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-butyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

N-Carbamoyl (ID#32) (3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-butyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

N-Carbamoyl (ID#40) (3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

N-Carbamoyl (ID#39) (3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

N-Carbamoyl (ID#26) (3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

N-Carbamoyl (ID#27) (3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

(ID#24)-(2*R*-{(3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonyl} amino-3-methyl-butanol) ester;

(ID#36)-(2*R*-{(3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonyl} amino-3-methyl-butanol) ester;

(ID#37)-(2*R*-{(3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonyl} amino-3-methyl-butanol) ester;

(ID#38)-(2*R*-{(3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonyl} amino-3-methyl-butanol) ester;

(ID#34)-(2*R*-{(3*R*, 4*S*, 5*S*, 6*R*) 5-methoxy-4-[(2R,3R)2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yloxycarbonyl} amino-3-methyl-butanol) ester;

{2-Methyl-1-[methyl-(1-methyl-piperidin-4-yl)-carbamoyl]-propyl}-carbamic acid 5-methoxy-4-[2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

[1-(2-Dimethylamino-ethylcarbamoyl)-2-methyl-propyl]-carbamic acid 5-methoxy-4-[2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

{1-[(2-Dimethylamino-ethyl)-methyl-carbamoyl]-2-methyl-propyl}-carbamic acid 5-methoxy-4-[2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

[1-(3-Dimethylamino-propylcarbamoyl)-2-methyl-propyl]-carbamic acid 5-methoxy-4-[2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

[1-(3-Dimethylamino-2,2-dimethyl-propylcarbamoyl)-2-methyl-propyl]-carbamic acid 5-methoxy-4-[2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

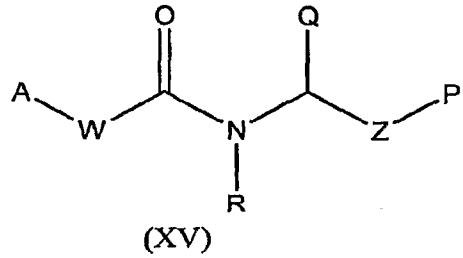
[2-Methyl-1-(4-methyl-piperazine-1-carbonyl)-propyl]-carbamic acid 5-methoxy-4-[2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

{2-Methyl-1-[2-(1-methyl-pyrrolidin-2-yl)-ethylcarbamoyl]-propyl}-carbamic acid 5-methoxy-4-[2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester;

[2-Methyl-1-(4-pyrrolidin-1-yl-piperidine-1-carbonyl)-propyl]-carbamic acid 5-methoxy-4-[2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester; and

[1-(4-Benzyl-piperazine-1-carbonyl)-2-methyl-propyl]-carbamic acid 5-methoxy-4-[2-methyl-3-(3-methyl-but-2-enyl)-oxiranyl]-1-oxa-spiro[2.5]oct-6-yl ester, thereby inducing an immunosupressed condition and/or treating chronic allograft vasculopathy in a subject undergoing or who has undergone a transplant.

58. A method of inducing an immunosupressed condition and/or treating chronic allograft vasculopathy in a subject undergoing or who has undergone a transplant, the method comprising administering to said subject an effective amount of a compound comprising the structure



(XV)

wherein
A is a MetAP-2 inhibitory core;
W is O or NR;
each R is, independently, hydrogen or alkyl;
Z is –C(O)- or -alkylene-C(O)-;
P is NHR, OR or a peptide consisting of one to about one hundred amino acid residues connected at the N-terminus to Z;
Q is hydrogen, linear, branched or cyclic alkyl or aryl, provided that when P is –OR, Q is not hydrogen;
or
Z is –alkylene-O- or –alkylene-N(R)-;
P is hydrogen or a peptide consisting of from one to about one hundred amino acid residues connected to Z at the carboxyl terminus;
Q is hydrogen, linear, branched or cyclic alkyl or aryl, provided that when P is hydrogen, Q is not hydrogen; and a pharmaceutically acceptable salt thereof, thereby inducing an immunosupressed condition and/or treating chronic allograft vasculopathy in a subject undergoing or who has undergone a transplant.

59. The method of claim 58, wherein said transplant is an organ transplant.

60. The method of claim 59, wherein said organ transplant is a heart transplant.

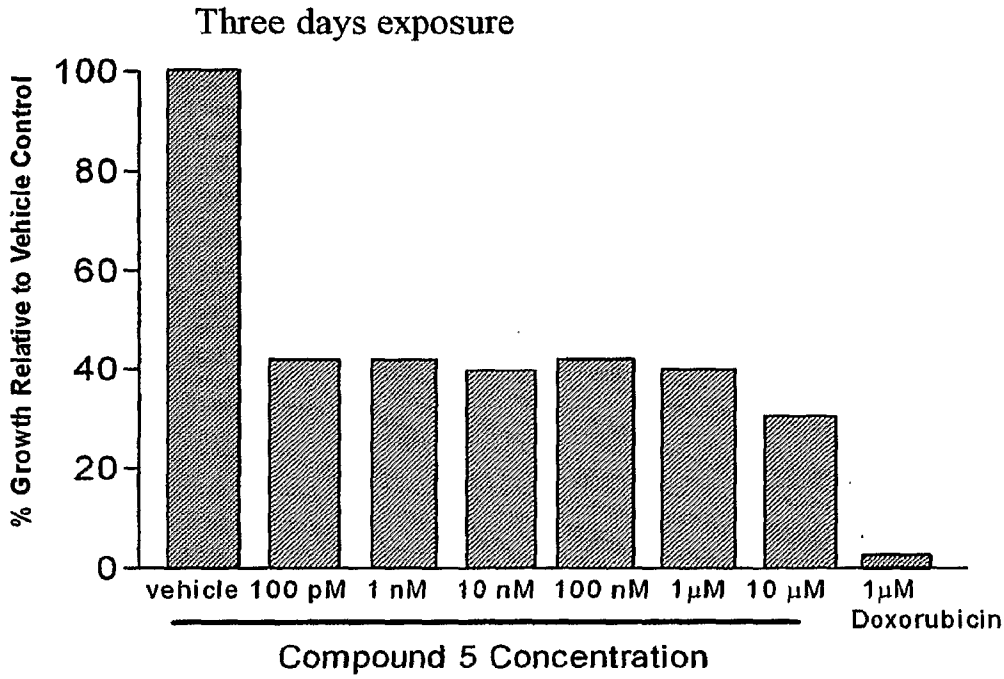

Three days exposure
% Growth Relative to Vehicle Control
100
80
60
40
20
0
vehicle
100 pM
1 nM
10 nM
100 nM
1μM
10 μM
1μM Doxorubicin
Compound 5 Concentration

Fig. 1A

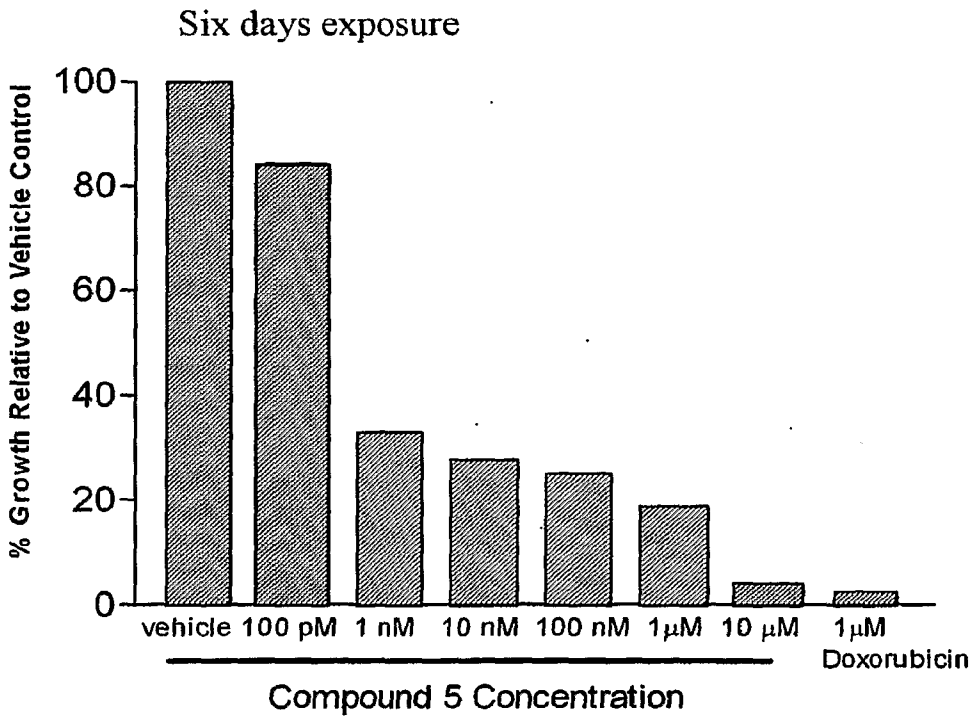

Six days exposure
% Growth Relative to Vehicle Control
100
80
60
40
20
0
vehicle
100 pM
1 nM
10 nM
100 nM
1μM
10 μM
1μM Doxorubicin
Compound 5 Concentration

Fig. 1B

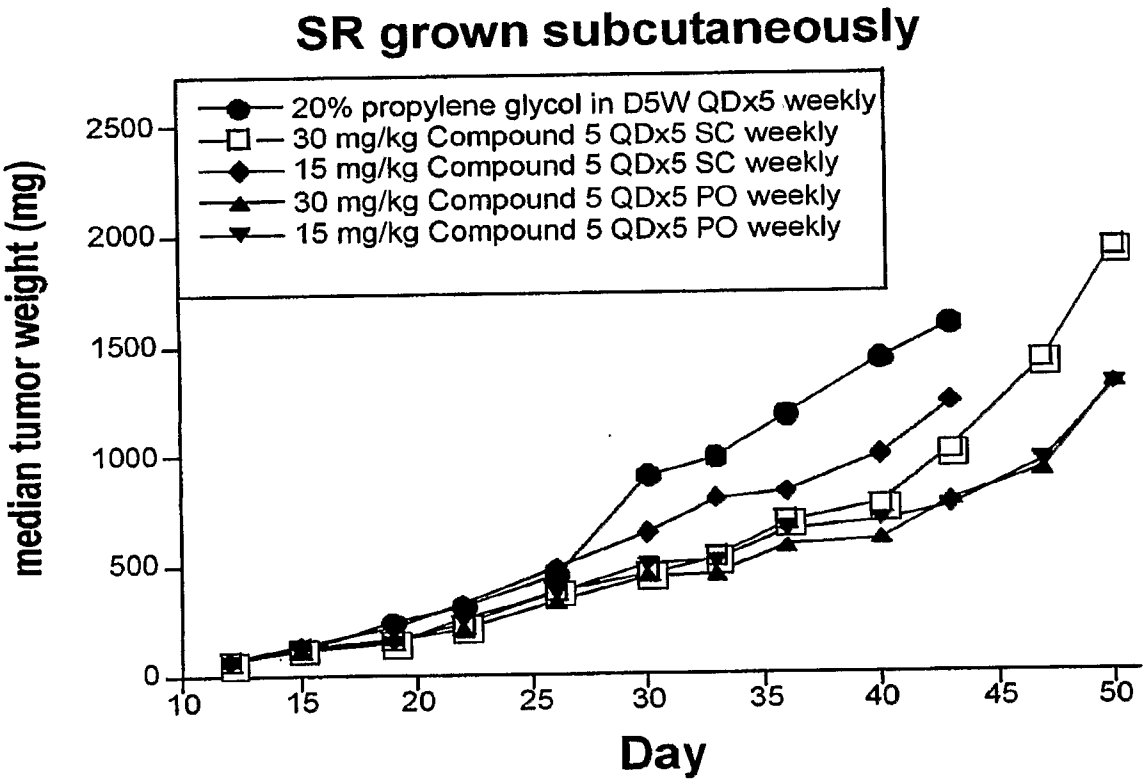

SR grown subcutaneously
20% propylene glycol in D5W QDx5 weekly
30 mg/kg Compound 5 QDx5 SC weekly
15 mg/kg Compound 5 QDx5 SC weekly
30 mg/kg Compound 5 QDx5 PO weekly
15 mg/kg Compound 5 QDx5 PO weekly
median tumor weight (mg)
2500
2000
1500
1000
500
0
10
15
20
25
30
35
40
45
50
Day

Fig. 2