BIVALENT SMAC MIMETICS AND THE USES THEREOF

BACKGROUND OF THE INVENTION

The present application claims priority to U.S. Provisional Patent Application Serial No. 60/798,018, filed 05/05/2006, and U.S. Provisional Patent Application Serial No. 60/923,415, filed 04/13/2007, each of which are herein incorporated by reference in their entireties.

Field of the Invention

[0001] This invention is in the field of medicinal chemistry. In particular, the invention relates to bivalent mimetics of the N-terminal sequence of Smac which function as inhibitors of inhibitor of apoptosis proteins. The invention also relates to the use of these mimetics for inducing or sensitizing cells to the induction of apoptotic cell death.

Related Art

[0002] The aggressive cancer cell phenotype is the result of a variety of genetic and epigenetic alterations leading to deregulation of intracellular signaling pathways (Ponder, *Nature 411*:336 (2001)). The commonality for all cancer cells, however, is their failure to execute an apoptotic program, and lack of appropriate apoptosis due to defects in the normal apoptosis machinery is a hallmark of cancer (Lowe *et al., Carcinogenesis 21*:485 (2000)). Most current cancer therapies, including chemotherapeutic agents, radiation, and immunotherapy, work by indirectly inducing apoptosis in cancer cells. The inability of cancer cells to execute an apoptotic program due to defects in the normal apoptotic machinery is thus often associated with an increase in resistance to chemotherapy, radiation, or immunotherapy-induced apoptosis. Primary or acquired resistance of human cancer of different origins to current treatment protocols due to apoptosis defects is a major problem in current cancer therapy (Lowe *et al., Carcinogenesis 21*:485 (2000); Nicholson, *Nature 407*:810 (2000)). Accordingly, current and future efforts towards designing and developing new molecular target-specific anticancer therapies to improve survival and quality of life of cancer patients must include strategies that

specifically target cancer cell resistance to apoptosis. In this regard, targeting crucial negative regulators that play a central role in directly inhibiting apoptosis in cancer cells represents a highly promising therapeutic strategy for new anticancer drug design.

[0003] Two classes of central negative regulators of apoptosis have been identified. The first class of regulators is the Bcl-2 family of proteins, as exemplified by two potent anti-apoptotic molecules, Bcl-2 and Bcl-XL proteins (Adams *et al., Science 281*:1322 (1998); Reed, *Adv. Pharmacol. 41*:501 (1997); Reed *et al., J. Cell. Biochem. 60*:23 (1996)). Therapeutic strategies for targeting Bcl-2 and Bcl-XL in cancer to restore cancer cell sensitivity and overcome resistance of cancer cells to apoptosis have been extensively reviewed (Adams *et al., Science 281*:1322 (1998); Reed, *Adv. Pharmacol. 41*:501 (1997); Reed *et al., J. Cell. Biochem. 60*:23 (1996)). Several laboratories are interested in designing small molecule inhibitors of Bcl-2 and Bcl-XL.

[0004] The second class of central negative regulators of apoptosis is the inhibitor of apoptosis proteins (IAPs) (Deveraux *et al., Genes Dev. 13*:239 (1999); Salvesen *et al., Nat. Rev. Mol. Cell. Biol. 3*:401 (2002)). This class includes proteins such as XIAP, cIAP-1, cIAP-2, ML-IAP, HIAP, KIAP, TSIAP, NAIP, survivin, livin, ILP-2, apollon, and BRUCE. IAP proteins potently suppress apoptosis induced by a large variety of apoptotic stimuli, including chemotherapeutic agents, radiation, and immunotherapy in cancer cells.

[0005] X-linked IAP (XIAP) is the most potent inhibitor in suppressing apoptosis among all of the IAP members (Holcik *et al., Apoptosis 6*:253 (2001); LaCasse *et al., Oncogene 17*:3247 (1998); Takahashi *et al., J. Biol. Chem. 273*:7787 (1998); Deveraux *et al., Nature 388*:300 (1997); Sun *et al., Nature 401*:818 (1999); Deveraux *et al., EMBO J. 18*:5242 (1999); Asselin *et al., Cancer Res. 61*:1862 (2001)). XIAP plays a key role in the negative regulation of apoptosis in both the death receptor-mediated and the mitochondria-mediated pathways. XIAP functions as a potent endogenous apoptosis inhibitor by directly binding and potently inhibiting three members of the caspase family of enzymes, caspase-3, -7, and -9 (Takahashi *et al., J. Biol. Chem. 273*:7787 (1998); Deveraux *et al., Nature 388*:300 (1997); Sun *et al., Nature 401*:818 (1999); Deveraux *et al., EMBO J. 18*:5242 (1999); Asselin *et al., Cancer Res. 61*:1862 (2001); Riedl *et al., Cell 104*:791

(2001); Chai *et al., Cell 104*:769 (2001); Huang *et al., Cell 104*:781 (2001)). XIAP contains three baculovirus inhibitor of apoptosis repeat (BIR) domains as well as a C-terminal RING finger. The third BIR domain (BIR3) selectively targets caspase-9, the initiator caspase in the mitochondrial pathway, whereas the linker region between BIR1 and BIR2 inhibits both caspase-3 and caspase-7 (Salvesen *et al., Nat. Rev. Mol. Cell. Biol. 3*:401 (2002)). While binding to XIAP prevents the activation of all three caspases, it is apparent that the interaction with caspase-9 is the most critical for its inhibition of apoptosis (Ekert *et al., J. Cell Biol. 152*:483 (2001); Srinivasula *et al., Nature 410*:112 (2001)). Because XIAP blocks apoptosis at the down-stream effector phase, a point where multiple signaling pathways converge, strategies targeting XIAP may prove to be especially effective to overcome resistance of cancer cells to apoptosis (Fulda *et al., Nature Med. 8*:808 (2002); Arnt *et al., J. Biol. Chem. 277*:44236 (2002)).

[0006] Although the precise role of XIAP in each type of cancer is far from completely understood, evidence is mounting to indicate that XIAP is widely overexpressed in many types of cancer and may play an important role in the resistance of cancer cells to a variety of current therapeutic agents (Holcik *et al., Apoptosis 6*:253 (2001); LaCasse *et al., Oncogene 17*:3247 (1998)).

[0007] XIAP protein was found to be expressed in most of the NCI 60 human cancer cell lines (Tamm *et al., Clin. Cancer Res. 6*:1796 (2000)). Analysis of tumor samples in 78 previously untreated patients showed that those with lower levels of XIAP had significantly longer survival (Tamm *et al., Clin. Cancer Res. 6*:1796 (2000)). XIAP was found to be expressed in human malignant glioma (Wagenknecht *et al., Cell Death Differ. 6*:370 (1999); Fulda *et al., Nature Med. 8*:808 (2002)). XIAP was found to be expressed in human prostate cancer cells and blocks Apo2 ligand/tumor necrosis factor-related apoptosis inducing ligand-mediated apoptosis of prostate cancer cells in the presence of mitochondrial activation (McEleny *et al., Prostate 51*:133 (2002); Ng *et al., Mol. Cancer Ther. 1*:1051 (2002)). XIAP is overexpressed in non-small cell lung cancer (NSCLC) in patients and has been implicated in pathogenesis of NSCLC (Hofmann *et al., J. Cancer Res. Clin. Oncol. 128*:554 (2002)). Expression of XIAP and lack of down-regulation of XIAP upon treatment with cisplatin have been implicated in cisplatin resistance of human ovarian cancer (Li *et al., Endocrinology 142*:370 (2001); Cheng

et al., Drug Resist. Update 5:131 (2002)). Taken together, these data suggest that XIAP may play an important role in resistance of several human cancers to current therapeutic agents.

[0008] Apoptosis is not a single process, rather, it is involved with a number of different, sometimes interconnected, signaling pathways leading to cell degradation. The pathways involved in a particular form of apoptosis depend on many factors, such as the insult or insults that initiate the process. Other factors include the activation or overactivation of specific receptors, such as the activation of "death" receptors by tumor necrosis factor alpha (TNFα), tumor necrosis factor-related apoptosis-inducing ligand (TRAIL or Apo2L), or FAS ligand. Another determining factor is the type of cell which is involved, since different signaling pathways are shown for so called type I and type II cells after Fas or TNFα receptor activation.

[0009] TRAIL (Apo2L) has been shown to be a selective and potent inducer of apoptosis in cancer cells (but not normal cells) upon binding to either of two pro-apoptotic TRAIL receptors, TRAIL-R1 (or DR4) (Pan *et al., Science 276*:111 (1997)) or TRAIL-R2 (KILLER, or DR5) (Wu *et al., Nat. Genet. 17*:141-143 (1997); Pan *et al., Science 277*:815 (1997); Walczak *et al., EMBO J. 16*:5386 (1997)). Activation of the pro-apoptotic death receptors by TRAIL induces the formation of death inducing signaling complex (DISC), which consists of receptor FADD as an adaptor (Kischkel *et al., Immunity 12*:611 (2000); Kuang *et al., J. Biol. Chem. 275*:25065 (2000)), and caspase-8 as an initiator caspase. Once DISC is formed, caspase-8 is auto-processed and activated by induced proximity (Medema *et al., EMBO J. 16*:2794 (1997); Muzio *et al., J. Biol. Chem. 273*:2926 (1998)).

[0010] TRAIL has generated significant interest as a potential cancer therapeutic (French *et al., Nat. Med. 5*:146 (1999)) because of its selective targeting of cancer cells, whereas most normal cells appear to be resistant to TRAIL (Ashkenazi *et al., Science 281*:1305 (1998); Walczak *et al., Nat. Med. 5*:157 (1999)). Systemic administration of TRAIL has proven to be safe and effective at killing breast or colon xenografted tumors and prolonging survival in mice (Walczak *et al., Nat. Med.5*:157 (1999)). Although TRAIL can specifically kill many types of cancer cells, many others display TRAIL-resistance (Kim *et al., Clin. Cancer Res. 6*:335 (2000); Zhang *et al., Cancer Res. 59*:2747 (1999)). In addition, cancer cells have

been killed by application of antibodies (monoclonal or polyclonal) that specifically recognize either TRAIL-R1 or TRAIL-R2.

[0011] Numerous mechanisms have been identified as potential factors responsible for TRAIL-resistance. Such mechanisms exist at a number of levels, including at the receptor level, mitochondria level, post-mitochondria level, and at the DISC level. For example, loss of caspase-8 expression (Teitz *et al., Nat. Med. 6*:529 (2000); Griffith *et al., J. Immunol. 161*:2833 (1998)), or high expression of the cellular FLICE inhibitor protein (cFLIP) (Kim *et al., Clin. Cancer Res. 6*:335 (2000); Zhang *et al., Cancer Res. 59*:2747 1999; Kataoka *et al., J. Immunol. 161*:3936 (1998)) make cancer cells resistant to TRAIL. Yeh *et al.* have shown that cFLIP-deficient embryonic mouse fibroblasts are particularly sensitive to receptor-mediated apoptosis (Yeh *et al., Immunity 12*:533 (2000)). Several splice variants of cFLIP are known, including a short splice variant, cFLIP-S, and a longer splice variant, cFLIP-L. It has been shown that cFLIP-deficient embryonic mouse fibroblasts become resistant to TRAIL-induced apoptosis as a result of retroviral-mediated transduction of cFLIP-S (Bin *et al., FEBS Lett. 510*:37 (2002)).

[0012] Although TRAIL represents a potentially promising candidate for tumor-selective death receptor activation (i.e., it induces apoptosis preferentially in tumor cells but not in normal tissues), many cancer cells are resistant to apoptosis-inducing drugs, as discussed above. As a result, treatment with such drugs often requires co-treatment with irradiation and/or cytotoxic chemicals to achieve a therapeutic effect. However, both radiation and chemotherapy have significant side effects, and are generally avoided if possible.

[0013] Thus, a need exists for an agent that can selectively and efficiently sensitize tumor cells to selective, apoptosis-inducing drugs such as TRAIL or TRAIL receptor antibodies, without also sensitizing surrounding normal cells. Such an agent would also be useful for reducing or preventing the drug resistance commonly associated with the use of receptor-mediated apoptotic cancer drugs, thus improving their effectiveness and eliminating the need for combination therapies.

[0014] Recently, Smac/DIABLO (second mitochondria-derived activator of caspases) was identified as a protein released from mitochondria into the cytosol in response to apoptotic stimuli (Budihardjo *et al., Annu. Rev. Cell Dev. Biol. 15*:269 (1999); Du *et al., Cell 102*:33 (2000)). Smac is synthesized with an N-terminal

mitochondrial targeting sequence that is proteolytically removed during maturation to the mature polypeptide. Smac was shown to directly interact with XIAP and other IAPs and to disrupt their binding to caspases and facilitate caspase activation. Smac is a potent endogenous inhibitor of XIAP.

[0015] High resolution, experimental three-dimensional (3D) structures of the BIR3 domain of XIAP in complex with Smac protein and peptide have recently been determined (Sun *et al., J. Biol. Chem. 275*:36152 (2000); Wu *et al., Nature 408*:1008 (2000)) (Figure 1). The N-terminal tetrapeptide of Smac (Ala-Val-Pro-Ile, or AVPI (SEQ ID NO:1)) recognizes a surface groove on the BIR3 domain of XIAP through several hydrogen-bonding interactions and van der Waals contacts. The interaction between BIR3 and caspase-9 has also been shown to involve four residues (Ala-Thr-Pro-Phe, or ATPF (SEQ ID NO:2)) on the amino terminus of the small subunit of caspase-9 to the same surface groove on the BIR3 domain. Several recent studies have convincingly demonstrated that Smac promotes the catalytic activity of caspase-9 by competing with caspase-9 for the same binding groove on the surface of the BIR3 domain (Ekert *et al., J. Cell Biol. 152*:483 (2001); Srinivasula *et al., Nature 410*:112 (2001)).

[0016] Unlike most protein-protein interactions, the Smac-XIAP interaction is mediated by only four amino acid residues on the Smac protein and a well-defined surface groove on the BIR3 domain of XIAP. The K_d value of Smac peptide AVPI (SEQ ID NO:1) to XIAP (K_d = 0.4 μM) is essentially the same as the mature Smac protein (K_d = 0.42 μM). This well-defined interaction site is ideal for the design of non-peptide, drug-like small molecules that mimic the binding of Smac to XIAP.

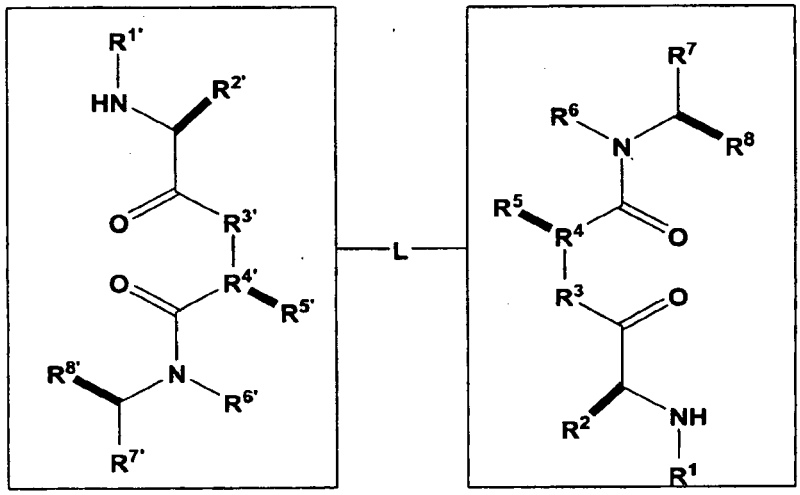
[0017] A cell permeable Smac peptide, which consists of the first four amino acid residues (AVPI (SEQ ID NO:1)) of the N-terminus of Smac tethered to a carrier peptide to facilitate intracellular delivery, was recently shown to sensitize various tumor cells *in vitro* and malignant glioma cells *in vivo* to apoptosis induced by death receptor ligation or cytotoxic drugs (Fulda *et al., Nature Med. 8*:808 (2002)). Importantly, this Smac peptide strongly enhanced the anti-tumor activity of Apo2L/TRAIL in an intracranial malignant glioma xenograft model *in vivo*. Complete eradication of established tumors and survival of mice was only achieved upon combined treatment with Smac peptides and Apo2L/TRAIL. Of significance, Smac peptide does not have detectable toxicity to normal brain tissue.

[0018] A second recent independent study also showed that peptides consisting of the first four to eight amino acid residues of the N-terminus of Smac tethered to a different carrier peptide enhanced the induction of apoptosis and the long term anti-proliferative effects of diverse chemotherapeutic drugs, including paclitaxel, etoposide, SN-38, and doxorubicin in MCF-7 and other human breast cancer cell lines (Arnt *et al., J. Biol. Chem. 277*:44236 (2002). This study conclusively showed that XIAP and cIAP-1 are the primary molecular targets for these peptides in cells.

[0019] A third study showed that a Smac peptide of the first seven N-terminal residues tethered to polyarginine restored the apoptosome activity and reversed the apoptosis resistance in non-small cell lung cancer H460 cells (Yang *et al., Cancer Res. 63*:831 (2003)). XIAP was shown to be responsible for the defect in apoptosome activity and suppression of caspase activity in H460 cells. When used in combination with chemotherapy, the cell-permeable Smac peptide regressed tumor growth *in vivo* with little murine toxicity. Taken together, these recent independent studies strongly suggest that a potent, stable, cell-permeable Smac mimetic may have great therapeutic potential for the treatment of human breast cancer and other types of cancer.

[0020] Peptide-based inhibitors are useful tools to elucidate the anti-apoptotic function of IAPs and the role of IAPs in response of cancer cells to chemotherapeutic agents. But peptide-based inhibitors in general have intrinsic limitations as potentially useful therapeutic agents. These limitations include their poor cell-permeability and poor *in vivo* stability. Indeed, in these three published studies using Smac-based peptide inhibitors, the peptides had to be fused to carrier peptides to make them relatively cell-permeable.

[0021] U.S. Published Application No. 2005/0197403 discloses dimeric Smac mimetic compounds of formula I:



I

wherein R^1 and $R^{1'}$ are selected from hydrogen, optionally substituted methyl, and hydroxyl;

R^2 and $R^{2'}$ are selected from optionally substituted methyl and optionally substituted ethyl;

R^3 and $R^{3'}$ are selected from CH_2, NH, O and S;

R_4 and R_4' are selected from CH and N;

R^5-R^8, and $R^{5'}$-$R^{8'}$ are selected from hydrogen, optionally hetero-, optionally substituted alkyl, optionally hetero-, optionally substituted alkenyl, optionally hetero-, optionally substituted alkynyl, optionally hetero-, optionally substituted aryl; and

L is a linker covalently linking R^2, R^5, R^6 or R^7, with $R^{2'}$, $R^{5'}$, $R^{6'}$ or $R^{7'}$,

or a pharmaceutically-acceptable salt thereof.

[0022] To overcome the intrinsic limitations of peptide-based inhibitors, the present invention involves the design of bivalent conformationally constrained Smac mimetics.

SUMMARY OF THE INVENTION

[0023] It is generally accepted that the inability of cancer cells or their supporting cells to undergo apoptosis in response to genetic lesions or exposure to inducers of apoptosis (such as anticancer agents and radiation) is a major factor in the onset and

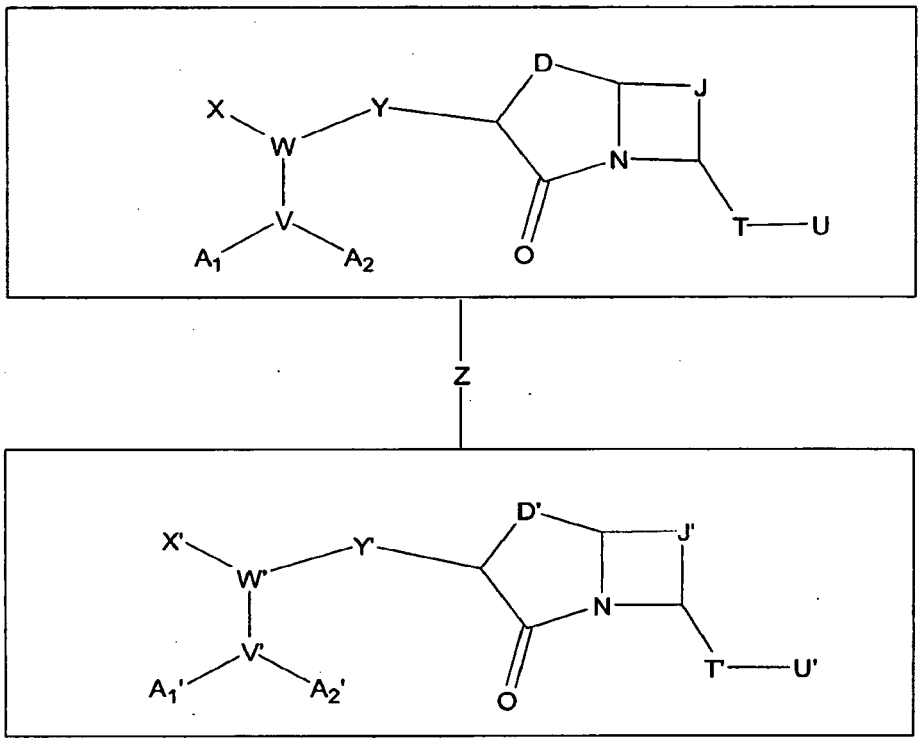
progression of cancer. The induction of apoptosis in cancer cells or their supporting cells (e.g., neovascular cells in the tumor vasculature) is thought to be a universal mechanism of action for virtually all of the effective cancer therapeutic drugs or radiation therapies on the market or in practice today. One reason for the inability of a cell to undergo apoptosis is increased expression and accumulation of IAPs.

[0024] The present invention contemplates that exposure of animals suffering from cancer or other hyperproliferative disorders or diseases associated with dysregulation of apoptosis to therapeutically effective amounts of drug(s) (e.g., small molecules) that inhibit the function(s) of IAPs will kill the diseased cells or supporting cells outright (those cells whose continued survival is dependent on the overactivity or overexpression of IAPs) and/or render such cells as a population more susceptible to the cell death-inducing activity of cancer therapeutic drugs or radiation therapies. The present invention contemplates that inhibitors of IAPs satisfy an unmet need for the treatment of multiple cancer types, either when administered as monotherapy to induce apoptosis in cancer cells dependent on IAP function, or when administered in a temporal relationship with other cell death-inducing cancer therapeutic drugs or radiation therapies so as to render a greater proportion of the cancer cells or supportive cells susceptible to executing the apoptosis program compared to the corresponding proportion of cells in an animal treated only with the cancer therapeutic drug or radiation therapy alone.

[0025] In certain embodiments of the invention, combination treatment of animals with a therapeutically effective amount of a compound of the present invention and a course of an anticancer agent or radiation produces a greater tumor response and clinical benefit in such animals compared to those treated with the compound or anticancer drugs/radiation alone. Put another way, because the compounds lower the apoptotic threshold of all cells that express IAPs, the proportion of cells that successfully execute the apoptosis program in response to the apoptosis inducing activity of anticancer drugs/radiation is increased. Alternatively, the compounds of the present invention can be used to allow administration of a lower, and therefore less toxic and more tolerable, dose of an anticancer agent and/or radiation to produce the same tumor response/clinical benefit as the conventional dose of the anticancer agent/radiation alone. Since the doses for all approved anticancer drugs and radiation treatments are known, the present invention contemplates the various

combinations of them with the compounds of the present invention. Also, since the compounds of the present invention act at least in part by inhibiting IAPs, the exposure of cancer cells and supporting cells to therapeutically effective amounts of the compounds can be temporally linked to coincide with the attempts of cells to execute the apoptosis program in response to the anticancer agent or radiation therapy. Thus, in some embodiments, administering the compositions of the present invention in connection with certain temporal relationships, provides especially efficacious therapeutic practices.

[0026] The present invention relates to Smac mimetics that are useful for inhibiting the activity of IAP proteins and increasing the sensitivity of cells to inducers of apoptosis. In one particular embodiment, the Smac mimetics are compounds of formula II:



II

wherein:

A_1 and A_1' are independently selected from the group consisting of hydrogen, optionally substituted alkyl and Z;

A_2 and A_2' are independently selected from the group consisting of hydrogen, optionally substituted alkyl and COR^1, wherein A_2 is absent when V is O and A_2' is absent when V' is O;

V and V' are independently selected from the group consisting of N, CH and O;

W and W' are independently selected from the group consisting of CH and N;

X and X' are independently optionally substituted C_{1-3} alkyl;

Y and Y' are independently selected from the group consisting of $CONR^1$, C(O)O, $(CR^1R^2)_{1-3}$, wherein one or more CH_2 groups can be replaced by O, S or NR^1, optionally substituted aryl and optionally substituted heteroaryl;

D and D' are independently selected from the group consisting of optionally substituted alkylenyl and $(CR^1R^2)_n$-R^{5a}-$(CR^3R^4)_m$;

J and J' are independently selected from the group consisting of optionally substituted alkylenyl and $(CR^1R^2)_p$-R^{5b}-$(CR^3R^4)_q$;

T and T' are independently selected from the group consisting of C=O, C=S, $C=NR^1$, S, O, NR^1, CR^1R^2, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

U and U' are independently selected from the group consisting of hydrogen, NR^1R^2, OR^1, SR^1, optionally substituted alkyl and optionally substituted aryl;

n, m, p and q are independently 0-5;

each R^1 is selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl, optionally substituted heteroaryl and Z;

each R^2, R^3 and R^4 are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

R^{5a} and R^{5b} are independently selected from the group consisting of C=O, C=S, $C=NR^1$, S, O, NR^1 and CR^1R^2; and

Z is a linker covalently linking one of A_1, Y, D, J, T and U with one of A_1', Y', D', J', T' and U';

or pharmaceutically acceptable salts or prodrugs thereof.

[0027] The invention relates to compounds represented by Formula II, which are inhibitors of IAP proteins. The invention relates to the use if the compounds of the invention to induce apoptosis in cells. The invention also relates to the use of the compounds of the invention for sensitizing cells to inducers of apoptosis. The compounds are useful for the treatment, amelioration, or prevention of disorders responsive to induction of apoptotic cell death, e.g., disorders characterized by dysregulation of apoptosis, including hyperproliferative diseases such as cancer. In certain embodiments, the compounds can be used to treat, ameliorate, or prevent cancer that is characterized by resistance to cancer therapies (e.g., those which are chemoresistant, radiation resistant, hormone resistant, and the like). In other embodiments, the compounds can be used to treat hyperproliferative diseases characterized by overexpression of IAPs.

[0028] The present invention provides pharmaceutical compositions comprising a compound of Formula II in a therapeutically effective amount to induce apoptosis in cells or to sensitize cells to inducers of apoptosis.

[0029] The invention further provides kits comprising a compound of Formula II and instructions for administering the compound to an animal. The kits may optionally contain other therapeutic agents, e.g., anticancer agents or apoptosis-modulating agents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] Figure 1 show the competitive binding of Smac mimetics to XIAP BIR3 protein.

[0031] Figure 2 shows the inhibition of cell growth in MDA-MB-231, MAMLE-3M, SK-OV-3 and OVCAR-4 cells by SH-164.

[0032] Figure 3 shows the induction of cell death in MDA-MB-231, MAMLE-3M, and OVCAR-4 cells by SH-164.

[0033] Figures 4A-4C show the inhibition of cell growth in MDA-MB-231 (A), MDA-MB-453 (B), and PC-3 (C) cells by SH-164 in combination with TRAIL.

[0034] Figure 5 shows the inhibition of cell growth in MDA-MB-231 cells by SH-164 in combination with cisplatin or mitoxantrone.

[0035] Figure 6 shows induction of apoptosis by SH-164 in the MDA-MB-231 breast cancer cell line.

DETAILED DESCRIPTION OF THE INVENTION

[0036] The present invention relates to bivalent conformationally constrained compounds represented by Formula II, which are mimetics of Smac and function as inhibitors of IAPs. These compounds sensitize cells to inducers of apoptosis and, in some instances, themselves induce apoptosis by inhibiting IAPs. Therefore, the invention relates to methods of sensitizing cells to inducers of apoptosis and to methods of inducing apoptosis in cells, comprising contacting the cells with a compound of Formula II alone or in combination with an inducer of apoptosis. The invention further relates to methods of treating, ameliorating, or preventing disorders in an animal that are responsive to induction of apoptosis comprising administering to the animal a compound of Formula II and an inducer of apoptosis. Such disorders include those characterized by a dysregulation of apoptosis and those characterized by overexpression of IAPs.

[0037] The term "IAP proteins," as used herein, refers to any known member of the Inhibitor of Apoptosis Protein family, including, but not limited to, XIAP, cIAP-1, cIAP-2, ML-IAP, HIAP, TSIAP, KIAP, NAIP, survivin, livin, ILP-2, apollon, and BRUCE.

[0038] The term "overexpression of IAPs," as used herein, refers to an elevated level (e.g., aberrant level) of mRNAs encoding for an IAP protein(s), and/or to elevated levels of IAP protein(s) in cells as compared to similar corresponding non-pathological cells expressing basal levels of mRNAs encoding IAP proteins or having basal levels of IAP proteins. Methods for detecting the levels of mRNAs encoding IAP proteins or levels of IAP proteins in a cell include, but are not limited to, Western blotting using IAP protein antibodies, immunohistochemical methods, and methods of nucleic acid amplification or direct RNA detection. As important as the absolute level of IAP proteins in cells is to determining that they overexpress IAP proteins, so also is the relative level of IAP proteins to other pro-apoptotic signaling molecules (e.g., pro-apoptotic Bcl-2 family proteins) within such cells. When the balance of these two are such that, were it not for the levels of the IAP proteins, the pro-apoptotic signaling molecules would be sufficient to cause the cells to execute the apoptosis program and die, said cells would be dependent on the IAP proteins for their survival. In such cells, exposure to an inhibiting effective amount of an IAP protein inhibitor will be sufficient to cause the cells to execute the

apoptosis program and die. Thus, the term "overexpression of an IAP protein" also refers to cells that, due to the relative levels of pro-apoptotic signals and anti-apoptotic signals, undergo apoptosis in response to inhibiting effective amounts of compounds that inhibit the function of IAP proteins.

[0039] The terms "anticancer agent" and "anticancer drug," as used herein, refer to any therapeutic agents (e.g., chemotherapeutic compounds and/or molecular therapeutic compounds), radiation therapies, or surgical interventions, used in the treatment of hyperproliferative diseases such as cancer (e.g., in mammals).

[0040] The term "prodrug," as used herein, refers to a pharmacologically inactive derivative of a parent "drug" molecule that requires biotransformation (e.g., either spontaneous or enzymatic) within the target physiological system to release, or to convert (e.g., enzymatically, physiologically, mechanically, electromagnetically) the prodrug into the active drug. Prodrugs are designed to overcome problems associated with stability, toxicity, lack of specificity, or limited bioavailability. Exemplary prodrugs comprise an active drug molecule itself and a chemical masking group (e.g., a group that reversibly suppresses the activity of the drug). Some preferred prodrugs are variations or derivatives of compounds that have groups cleavable under metabolic conditions. Exemplary prodrugs become pharmaceutically active *in vivo* or *in vitro* when they undergo solvolysis under physiological conditions or undergo enzymatic degradation or other biochemical transformation (e.g., phosphorylation, hydrogenation, dehydrogenation, glycosylation). Prodrugs often offer advantages of solubility, tissue compatibility, or delayed release in the mammalian organism. (See e.g., Bundgard, Design of Prodrugs, pp. 7-9, 21-24, Elsevier, Amsterdam (1985); and Silverman, The Organic Chemistry of Drug Design and Drug Action, pp. 352-401, Academic Press, San Diego, CA (1992)). Common prodrugs include acid derivatives such as esters prepared by reaction of parent acids with a suitable alcohol (e.g., a lower alkanol), amides prepared by reaction of the parent acid compound with an amine, or basic groups reacted to form an acylated base derivative (e.g., a lower alkylamide).

[0041] The term "pharmaceutically acceptable salt," as used herein, refers to any salt (e.g., obtained by reaction with an acid or a base) of a compound of the present invention that is physiologically tolerated in the target animal (e.g., a mammal). Salts of the compounds of the present invention may be derived from inorganic or

organic acids and bases. Examples of acids include, but are not limited to, hydrochloric, hydrobromic, sulfuric, nitric, perchloric, fumaric, maleic, phosphoric, glycolic, lactic, salicylic, succinic, toluene-p-sulfonic, tartaric, acetic, citric, methanesulfonic, ethanesulfonic, formic, benzoic, malonic, sulfonic, naphthalene-2-sulfonic, benzenesulfonic acid, and the like. Other acids, such as oxalic, while not in themselves pharmaceutically acceptable, may be employed in the preparation of salts useful as intermediates in obtaining the compounds of the invention and their pharmaceutically acceptable acid addition salts.

[0042] Examples of bases include, but are not limited to, alkali metal (e.g., sodium) hydroxides, alkaline earth metal (e.g., magnesium) hydroxides, ammonia, and compounds of formula NW_4^+, wherein W is C_{1-4} alkyl, and the like.

[0043] Examples of salts include, but are not limited to: acetate, adipate, alginate, aspartate, benzoate, benzenesulfonate, bisulfate, butyrate, citrate, camphorate, camphorsulfonate, cyclopentanepropionate, digluconate, dodecylsulfate, ethanesulfonate, fumarate, flucoheptanoate, glycerophosphate, hemisulfate, heptanoate, hexanoate, chloride, bromide, iodide, 2-hydroxyethanesulfonate, lactate, maleate, mesylate, methanesulfonate, 2-naphthalenesulfonate, nicotinate, oxalate, palmoate, pectinate, persulfate, phenylpropionate, picrate, pivalate, propionate, succinate, tartrate, thiocyanate, tosylate, undecanoate, and the like. Other examples of salts include anions of the compounds of the present invention compounded with a suitable cation such as Na^+, NH_4^+, and NW_4^+ (wherein W is a C_{1-4} alkyl group), and the like. For therapeutic use, salts of the compounds of the present invention are contemplated as being pharmaceutically acceptable. However, salts of acids and bases that are non-pharmaceutically acceptable may also find use, for example, in the preparation or purification of a pharmaceutically acceptable compound.

[0044] The term "therapeutically effective amount," as used herein, refers to that amount of the therapeutic agent sufficient to result in amelioration of one or more symptoms of a disorder, or prevent advancement of a disorder, or cause regression of the disorder. For example, with respect to the treatment of cancer, a therapeutically effective amount preferably refers to the amount of a therapeutic agent that decreases the rate of tumor growth, decreases tumor mass, decreases the number of metastases, increases time to tumor progression, or increases survival time by at least 5%, preferably at least 10%, at least 15%, at least 20%, at least 25%,

at least 30%, at least 35%, at least 40%, at least 45%, at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, or at least 100%.

[0045] The terms "sensitize" and "sensitizing," as used herein, refer to making, through the administration of a first agent (e.g., a compound of Formula II), an animal or a cell within an animal more susceptible, or more responsive, to the biological effects (e.g., promotion or retardation of an aspect of cellular function including, but not limited to, cell division, cell growth, proliferation, invasion, angiogenesis, or apoptosis) of a second agent. The sensitizing effect of a first agent on a target cell can be measured as the difference in the intended biological effect (e.g., promotion or retardation of an aspect of cellular function including, but not limited to, cell growth, proliferation, invasion, angiogenesis, or apoptosis) observed upon the administration of a second agent with and without administration of the first agent. The response of the sensitized cell can be increased by at least 10%, at least 20%, at least 30%, at least 40%, at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, at least 100%, at least 150%, at least 200%, at least 350%, at least 300%, at least 350%, at least 400%, at least 450%, or at least 500% over the response in the absence of the first agent.

[0046] The term "dysregulation of apoptosis," as used herein, refers to any aberration in the ability of (e.g., predisposition) a cell to undergo cell death via apoptosis. Dysregulation of apoptosis is associated with or induced by a variety of conditions, including for example, autoimmune disorders (e.g., systemic lupus erythematosus, rheumatoid arthritis, graft-versus-host disease, myasthenia gravis, or Sjögren's syndrome), chronic inflammatory conditions (e.g., psoriasis, asthma or Crohn's disease), hyperproliferative disorders (e.g., tumors, B cell lymphomas, or T cell lymphomas), viral infections (e.g., herpes, papilloma, or HIV), and other conditions such as osteoarthritis and atherosclerosis. It should be noted that when the dysregulation is induced by or associated with a viral infection, the viral infection may or may not be detectable at the time dysregulation occurs or is observed. That is, viral-induced dysregulation can occur even after the disappearance of symptoms of viral infection.

[0047] The term "hyperproliferative disease," as used herein, refers to any condition in which a localized population of proliferating cells in an animal is not governed by

the usual limitations of normal growth. Examples of hyperproliferative disorders include, but are not restricted to tumors, neoplasms, lymphomas and the like. A neoplasm is said to be benign if it does not undergo invasion or metastasis and malignant if it does either of these. A "metastatic" cell means that the cell can invade and destroy neighboring body structures. Hyperplasia is a form of cell proliferation involving an increase in cell number in a tissue or organ without significant alteration in structure or function. Metaplasia is a form of controlled cell growth in which one type of fully differentiated cell substitutes for another type of differentiated cell.

[0048] The pathological growth of activated lymphoid cells often results in an autoimmune disorder or a chronic inflammatory condition. As used herein, the term "autoimmune disorder" refers to any condition in which an organism produces antibodies or immune cells which recognize the organism's own molecules, cells or tissues. Non-limiting examples of autoimmune disorders include autoimmune hemolytic anemia, autoimmune hepatitis, Berger's disease or IgA nephropathy, celiac sprue, chronic fatigue syndrome, Crohn's disease, dermatomyositis, fibromyalgia, graft versus host disease, Grave's disease, Hashimoto's thyroiditis, idiopathic thrombocytopenia purpura, lichen planus, multiple sclerosis, myasthenia gravis, psoriasis, rheumatic fever, rheumatic arthritis, scleroderma, Sjögren's syndrome, systemic lupus erythematosus, type 1 diabetes, ulcerative colitis, vitiligo, and the like.

[0049] The term "neoplastic disease," as used herein, refers to any abnormal growth of cells being either benign (non-cancerous) or malignant (cancerous).

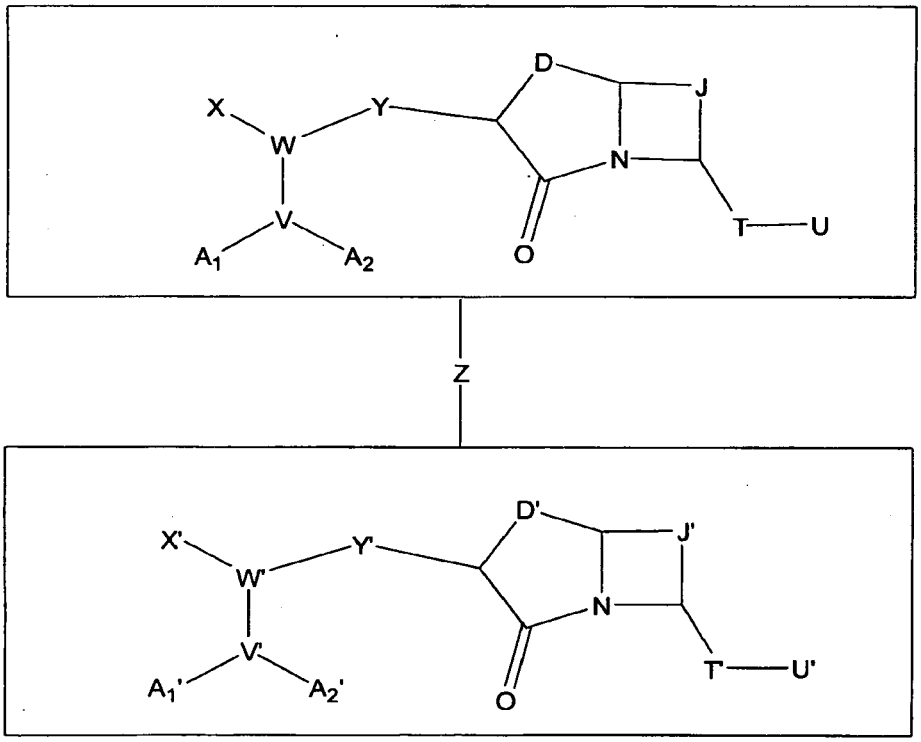
[0050] The term "anti-neoplastic agent," as used herein, refers to any compound that retards the proliferation, growth, or spread of a targeted (e.g., malignant) neoplasm.

[0051] The terms "prevent," "preventing," and "prevention," as used herein, refer to a decrease in the occurrence of pathological cells (e.g., hyperproliferative or neoplastic cells) in an animal. The prevention may be complete, e.g., the total absence of pathological cells in a subject. The prevention may also be partial, such that the occurrence of pathological cells in a subject is less than that which would have occurred without the present invention.

[0052] The term "apoptosis-modulating agents," as used herein, refers to agents which are involved in modulating (e.g., inhibiting, decreasing, increasing,

promoting) apoptosis. Examples of apoptosis-modulating agents include proteins which comprise a death domain such as, but not limited to, Fas/CD95, TRAMP, TNF RI, DR1, DR2, DR3, DR4, DR5, DR6, FADD, and RIP. Other examples of apoptotic-modulating agents include, but are not limited to, TNFα, Fas ligand, antibodies to Fas/CD95 and other TNF family receptors, TRAIL (also known as Apo2 Ligand or Apo2L/TRAIL), agonists (*e.g.*, monoclonal or polyclonal agonistic antibodies) of TRAIL-R1 or TRAIL-R2, Bcl-2, p53, BAX, BAD, Akt, CAD, PI3 kinase, PP1, and caspase proteins. Modulating agents broadly include agonists and antagonists of TNF family receptors and TNF family ligands. Apoptosis-modulating agents may be soluble or membrane bound (e.g. ligand or receptor). Preferred apoptosis-modulating agents are inducers of apoptosis, such as TNF or a TNF-related ligand, particularly a TRAMP ligand, a Fas/CD95 ligand, a TNFR-1 ligand, or TRAIL

[0053] The inhibitors of IAPs of the present invention are compounds having the general Formula II:



II

wherein:

A_1 and A_1' are independently selected from the group consisting of hydrogen, optionally substituted alkyl and Z;

A_2 and A_2' are independently selected from the group consisting of hydrogen, optionally substituted alkyl and COR^1, wherein A_2 is absent when V is O and A_2' is absent when V' is O;

V and V' are independently selected from the group consisting of N, CH and O;

W and W' are independently selected from the group consisting of CH and N;

X and X' are independently optionally substituted C_{1-3} alkyl;

Y and Y' are independently selected from the group consisting of $CONR^1$, C(O)O, $(CR^1R^2)_{1-3}$, wherein one or more CH_2 groups can be replaced by O, S or NR^1, optionally substituted aryl and optionally substituted heteroaryl;

D and D' are independently selected from the group consisting of optionally substituted alkylenyl and $(CR^1R^2)_n$-R^{5a}-$(CR^3R^4)_m$;

J and J' are independently selected from the group consisting of optionally substituted alkylenyl and $(CR^1R^2)_p$-R^{5b}-$(CR^3R^4)_q$;

T and T' are independently selected from the group consisting of C=O, C=S, $C=NR^1$, S, O, NR^1, CR^1R^2, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

U and U' are independently selected from the group consisting of hydrogen, NR^1R^2, OR^1, SR^1, optionally substituted alkyl and optionally substituted aryl;

n, m, p and q are independently 0-5;

each R^1 is selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl, optionally substituted heteroaryl and Z;

each R^2, R^3 and R^4 are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

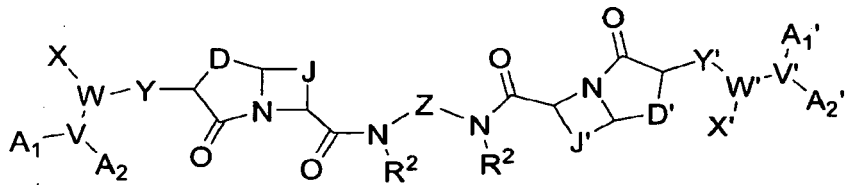
R^{5a} and R^{5b} are independently selected from the group consisting of C=O, C=S, $C=NR^1$, S, O, NR^1 and CR^1R^2; and

Z is a linker covalently linking one of A_1, Y, D, J, T and U with one of A_1', Y', D', J', T' and U';

or pharmaceutically acceptable salts or prodrugs thereof.

[0054] In a further embodiment, Z links D with U'. In a further embodiment, Z links D with D'. In a further embodiment, Z links U with U'. In a further embodiment, n and m are independently selected from 0-4 such that n + m is 3 or 4. In a further embodiment, p and q are independently selected from 0 and 1 such that p + q is 1. In a further embodiment, n and m are independently selected from 0-4 such that n + m is 3 or 4 and p and q are independently selected from 0 and 1 such that p + q is 1. In a further embodiment, T is C=O. In a further embodiment, U is NR^1R^2. In a further embodiment, R^{5b} is CH_2. In a further embodiment, Y is CONH, W is CH and V is N. In a further embodiment, A^2 and $A^{2'}$ are independently selected from the group consisting of hydrogen and optionally substituted alkyl.

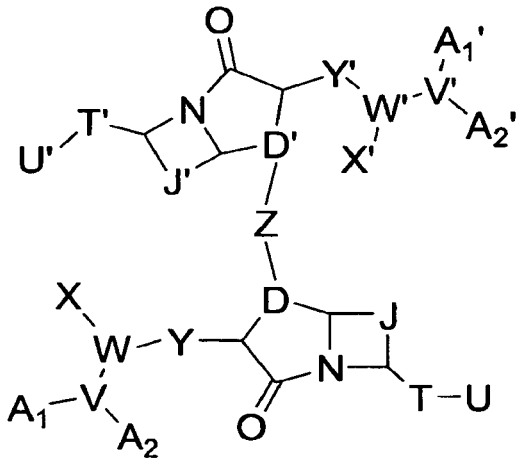
[0055] In another particular embodiment, the inhibitors of IAPs of the present invention are compounds of formula III:



III

wherein A_1, A_2, V, W, X, Y, D, J, Z, A_1', A_2', V', W', X', Y', D', J' and R^2 have the meanings as above; or pharmaceutically acceptable salts or prodrugs thereof.

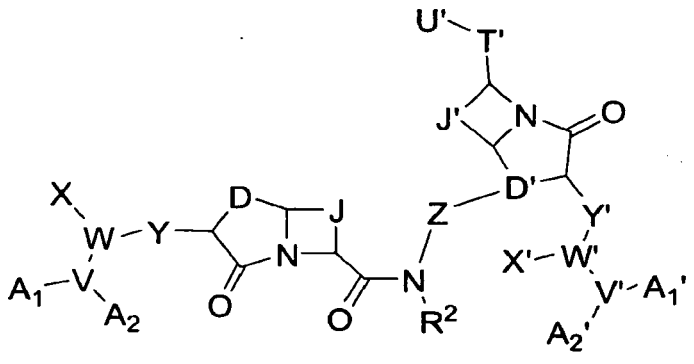
[0056] In another particular embodiment, the inhibitors of IAPs of the present invention are compounds of formula IV:



IV

wherein A_1, A_2, V, W, X, Y, D, J, Z, T, U, A_1', A_2', V', W', X', Y', D', J', T' and U' have the meanings as above; or pharmaceutically acceptable salts or prodrugs thereof.

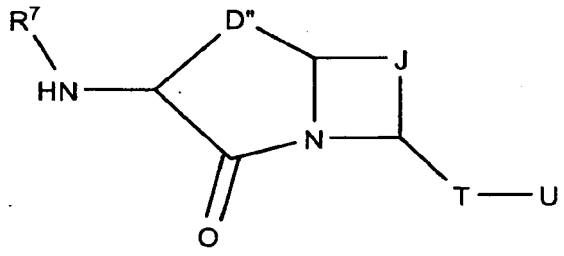
[0057] In another particular embodiment, the inhibitors of IAPs of the present invention are compounds of formula V:



V

wherein A_1, A_2, V, W, X, Y, D, J, Z, A_1', A_2', V', W', X', Y', D', J', T', U' and R^2 have the meanings as above; or pharmaceutically acceptable salts or prodrugs thereof.

[0058] In another particular embodiment, intermediates useful for making IAPs of the present invention are compounds of formula XIII:



XIII

wherein:

D" is $(CR^1R^2)_n$-R^{5c}-$(CR^3R^4)_m$;

J is selected from the group consisting of optionally substituted alkylenyl and $(CR^1R^2)_p$-R^{5b}-$(CR^3R^4)_q$;

T is selected from the group consisting of C=O, C=S, C=NR^1, S, O, NR^1, CR^1R^2, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

U is selected from the group consisting of hydrogen, NR^1R^2, OR^1, SR^1, optionally substituted alkyl and optionally substituted aryl;

n, m, p and q are independently selected from 0-5;

each R^1, R^2, R^3 and R^4 are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

R^{5c} is selected from the group consisting of C=O, C=S, C=NR^1, S, O, NR^1, $CR^{1a}R^{2a}$, $NCOR^8$ and NCO_2R^8;

R^{1a} and R^{2a} are independently selected from the group consisting of hydrogen, hydroxy, azido, optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

R^{5b} is selected from the group consisting of O, S, NR^1, CR^1R^2, C=O, C=S and C=NR^1;

R^7 is selected from the group consisting of hydrogen, CO_2R^{7a} and $COCH(R^{7b})N(R^{7c})CO_2R^{7a}$;

R^{7a} is selected from the group consisting of optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

R^{7b} is optionally substituted C_{1-3} alkyl;

R^{7c} is selected from the group consisting of hydrogen and optionally substituted alkyl;

and,

R^8 is selected from the group consisting of optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl.

[0059] In a further embodiment, R^{7a} is t-butyl. In a further embodiment, n is 1, m is 2, R^{5c} is NCO_2R^8 and R^8 is benzyl. In a further embodiment, R^{5c} is $CR^{1a}R^{2a}$, R^{1a} is selected from the group consisting of hydroxy, azido and optionally substituted heteroaryl and R^{2a} is hydrogen.

[0060] Useful alkyl groups include straight-chained or branched C_{1-18} alkyl groups, especially methyl, ethyl, propyl, isopropyl, t-butyl, sec-butyl, 3-pentyl and 3-hexyl groups. The term "alkylenyl" refers to a divalent alkyl radical containing 1, 2, 3 or 4 joined methylene groups as exemplified by $-(CH_2)_4-$.

[0061] Useful alkenyl groups include straight-chained or branched C_{2-18} alkyl groups, especially ethenyl, propenyl, isopropenyl, butenyl, isobutenyl, and hexenyl.

[0062] The term "alkenylene" as used herein refers to a divalent radical derived from an alkene as exemplified by $-CH_2CH=CHCH_2-$.

[0063] Useful alkynyl groups are C_{2-18} alkynyl groups, especially ethynyl, propynyl, butynyl, and 2-butynyl groups

[0064] Useful cycloalkyl groups are C_{3-8} cycloalkyl. Typical cycloalkyl groups include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, adamantyl and norbornyl.

[0065] Useful aryl groups include C_{6-14} aryl, especially phenyl, naphthyl, phenanthrenyl, anthracenyl, indenyl, azulenyl, biphenyl, biphenylenyl, and fluorenyl groups.

[0066] Useful heteroaryl groups include thienyl, benzo[b]thienyl, naphtho[2,3-b]thienyl, thianthrenyl, furyl, pyranyl, isobenzofuranyl, chromenyl, xanthenyl, phenoxanthenyl, 2H-pyrrolyl, pyrrolyl, imidazolyl, triazolyl, pyrazolyl, pyridyl, pyrazinyl, pyrimidinyl, pyridazinyl, indolizinyl, isoindolyl, 3H-indolyl, indolyl, indazolyl, purinyl, 4H-quinolizinyl, isoquinolyl, quinolyl, phthalzinyl, naphthyridinyl, quinozalinyl, cinnolinyl, pteridinyl, carbazolyl, β-carbolinyl,

phenanthridinyl, acridinyl, perimidinyl, phenanthrolinyl, phenazinyl, isothiazolyl, phenothiazinyl, isoxazolyl, furazanyl, phenoxazinyl, 1,4-dihydroquinoxaline-2,3-dione, 7-aminoisocoumarin, pyrido[1,2-a]pyrimidin-4-one, 1,2-benzoisoxazol-3-yl, benzimidazolyl, 2-oxindolyl, and 2-oxobenzimidazolyl. Where the heteroaryl group contains a nitrogen atom in a ring, such nitrogen atom may be in the form of an N-oxide, e.g., a pyridyl N-oxide, pyrazinyl N-oxide, pyrimidinyl N-oxide, and the like.

[0067] Optional substituents include one or more alkyl; halo; azido; haloalkyl; hydroxyl; alkynyl; cycloalkyl; heteroalkyl; heteroalkynyl; aryl optionally substituted with one or more lower alkyl, halo, haloalkyl or heteroaryl groups; aryloxy optionally substituted with one or more lower alkyl, haloalkyl, or heteroaryl groups; aralkyl; heteroaryl optionally substituted with one or more lower alkyl, haloalkyl, and aryl groups; heteroaryloxy optionally substituted with one or more lower alkyl, haloalkyl, and aryl groups; alkoxy; alkylthio; arylthio; amido; amino; acyloxy; arylacyloxy optionally substituted with one or more lower alkyl, haloalkyl, and aryl groups; diphenylphosphinyloxy optionally substituted with one or more lower alkyl, halo or haloalkyl groups; heterocyclo optionally substituted with one or more lower alkyl, haloalkyl, and aryl groups; heterocycloalkoxy optionally substituted with one or more lower alkyl, haloalkyl, and aryl groups; partially unsaturated heterocycloalkyl optionally substituted with one or more lower alkyl, haloalkyl, and aryl groups; partially unsaturated heterocycloalkyloxy optionally substituted with one or more lower alkyl, haloalkyl, and aryl groups; and any covalent linker (*vide infra*).

[0068] Useful saturated or partially saturated carbocyclic groups are cycloalkyl groups as defined above, as well as cycloalkenyl groups, such as cyclopentenyl, cycloheptenyl and cyclooctenyl. Carbocyclic groups also include groups having fused optionally substituted aryl groups such as tetralin.

[0069] Useful halo or halogen groups include fluorine, chlorine, bromine and iodine.

[0070] Useful alkylaryl and alkylheteroaryl groups include any of the above-mentioned C_{1-18} alkyl groups substituted by any of the above-mentioned C_{6-14} aryl groups or heteroaryl groups. Useful values include benzyl, phenethyl and naphthylmethyl.

[0071] Useful haloalkyl groups include C_{1-10} alkyl groups substituted by one or more fluorine, chlorine, bromine or iodine atoms, e.g., fluoromethyl, difluoromethyl,

trifluoromethyl, pentafluoroethyl, 1,1-difluoroethyl, chloromethyl, chlorofluoromethyl and trichloromethyl groups.

[0072] Useful heteroalkyl groups include C_{1-10} alkyl groups containing one or more nitrogen, oxygen or sulfur atoms, e.g., $-CH_2CH_2OCH_3$, $-CH_2OH$, $-CH_2CH_2NH_2$ and $-CH_2CH_2NHCH_3$ groups.

[0073] Useful heteroalkynyl groups include C_{2-18} alkynyl groups containing one or more nitrogen, oxygen or sulfur atoms, e.g., $-CH_2OCH_2CCH$.

[0074] Useful alkoxy groups include oxygen substituted by one of the C_{1-10} alkyl groups mentioned above.

[0075] Useful alkylthio groups include sulfur substituted by one of the C_{1-10} alkyl groups mentioned above. Also included are the sulfoxides and sulfones of such alkylthio groups.

[0076] Useful amido groups include carbonylamido as well as any C_{1-6} acyl (alkanoyl) attached to an amino nitrogen, e.g., acetamido, propionamido, butanoylamido, pentanoylamido, hexanoylamido as well as aryl-substituted C_{2-6} substituted acyl groups.

[0077] Useful acyloxy groups are any C_{1-6} acyl (alkanoyl) attached to an oxy (-O-) group, e.g., formyloxy, acetoxy, propionoyloxy, butanoyloxy, pentanoyloxy, hexanoyloxy and the like.

[0078] Useful arylacyloxy groups include any of the aryl groups mentioned above substituted on any of the acyloxy groups mentioned above, e.g., 2,6-dichlorobenzoyloxy, 2,6-difluorobenzoyloxy and 2,6-di-(trifluoromethyl)-benzoyloxy groups.

[0079] Useful amino groups include $-NH_2$, $-NHR^{11}$, and $-NR^{11}R^{11}$, wherein R^{11} and R^{12} are C_{1-10} alkyl or cycloalkyl groups as defined above.

[0080] Useful saturated or partially saturated heterocyclic groups include tetrahydrofuranyl, pyranyl, piperidinyl, piperizinyl, pyrrolidinyl, imidazolidinyl, imidazolinyl, indolinyl, isoindolinyl, quinuclidinyl, morpholinyl, isochromanyl, chromanyl, pyrazolidinyl, pyrazolinyl, tetronoyl and tetramoyl groups.

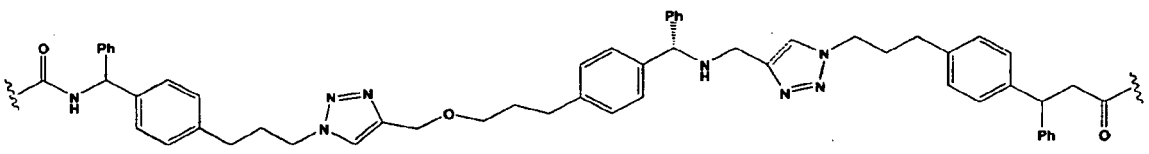
[0081] Useful arylene groups include C_{6-14} arylene, especially phenylene, naphthylene, phenanthrenylene, anthracenylene, indenylene, azulenylene, biphenylene, biphenylenylene, and fluorenylene groups.

[0082] Useful heteroarylene groups include disubstituted heteroaryl groups such as 2,5-thienylene, 2,4-imidazoylene, and 1,3-triazolylene.

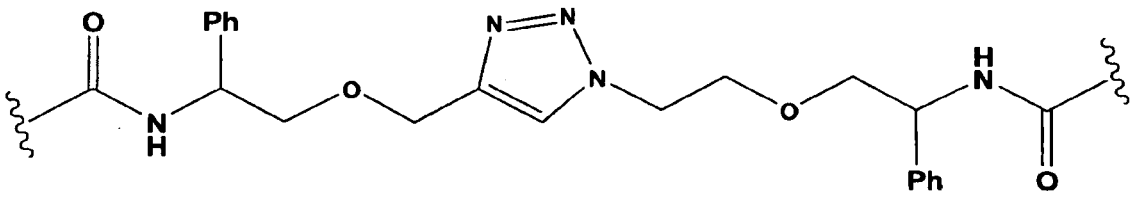
[0083] Throughout the specification, groups an optional substituents thereof are chosen to provide stable moieties and compounds.

[0084] Covalent linkers that may be used in the invention include any bivalent covalent linker. In some embodiments, the linker is a contiguous chain of between 5 and 50 atoms. The linker typically has a length of from about 5 angstroms to about 100 angstroms using standard bond lengths and angles. More preferably, the linker has a length of from about 10 angstroms to about 50 angstroms. In certain embodiments, the linker comprises at least one aryl, heteroaryl, or heterocyclic moiety. In other embodiments, the linker is symmetrical. In other embodiments, the linker is non-symmetrical. The linker may be any one of the many known homobifunctional and heterobifunctional linkers. *See, e.g.*, U.S. Patent Nos. 7,001,989, 6,967,107, 6,921,669, 6,906,182, 6,887,952, 6,759,509, 6,521,431, 6,512,101, 5,880,270, 5,856,571, 5,824,805, 5,262,524, 5,258,498, 5,212,075, 5,165,923, 5,141,648, each if which is incorporated by reference in its entirety

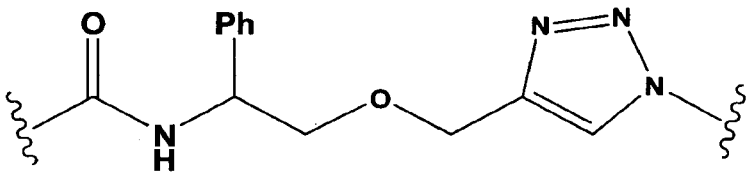
[0085] In another embodiment, the linker may comprise a $-COR^{9a}-$ or $-R^{9a}CO-$ group bound to any one of A_1, Y, D, J, T or U and any one of A_1', Y', D', J', T' or U' wherein R^{7a} is O, S or NR^{10a} and R^{10a} is hydrogen or lower alkyl. In this embodiment, the linker further comprises a group bound to $R^{9a}-$ of the first group and CO- of the second group which may include an optionally substituted alkylene group wherein any one of the carbon atoms of the alkylene group may be substituted by one or more O, S, NR^{10a}, arylene, and heteroarylene groups. Examples of such linkers include, without limitation:



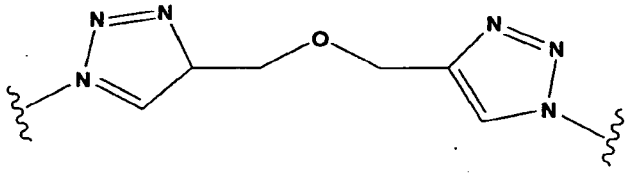
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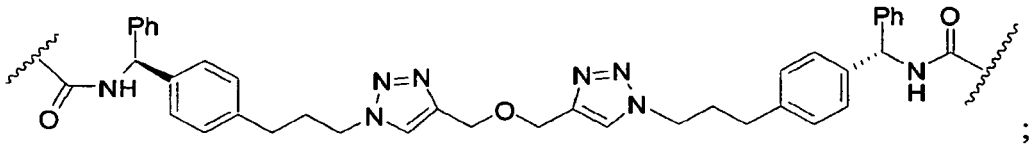
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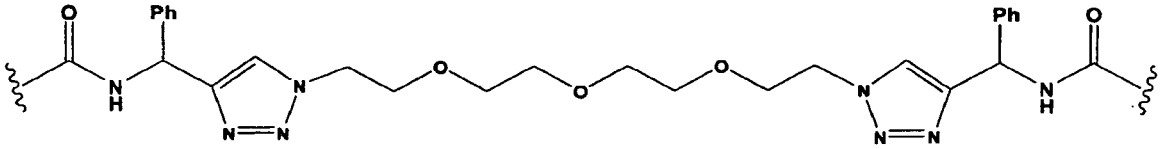
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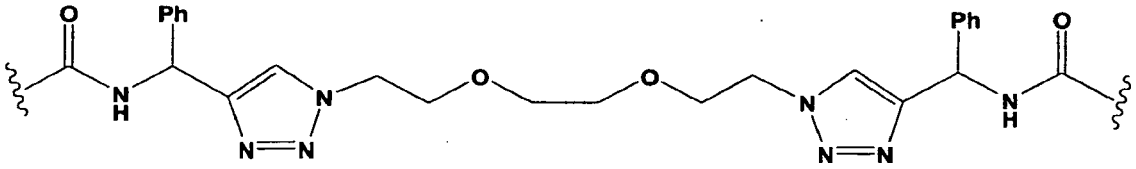
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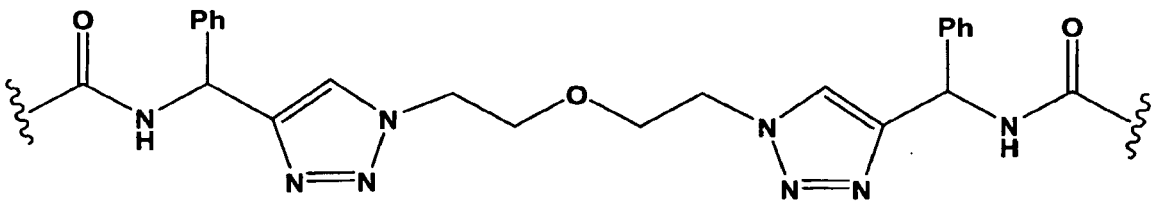
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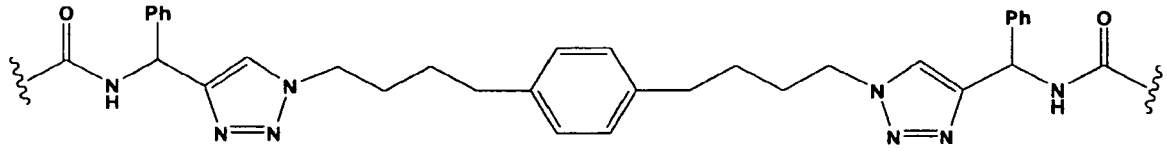
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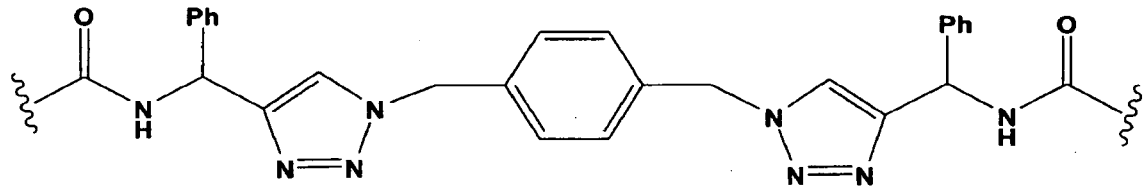


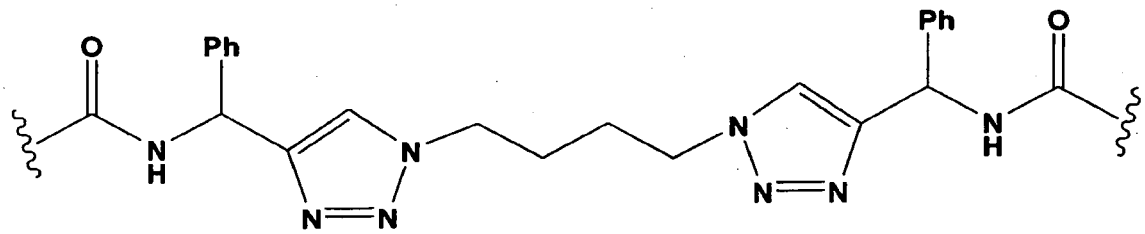
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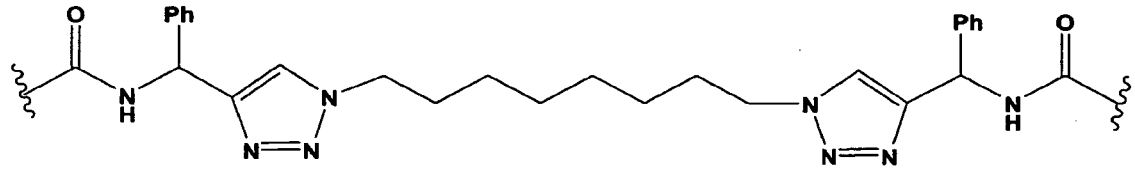


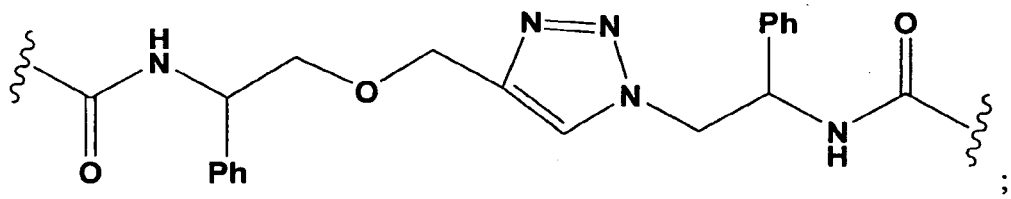
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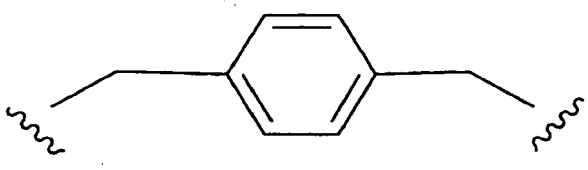

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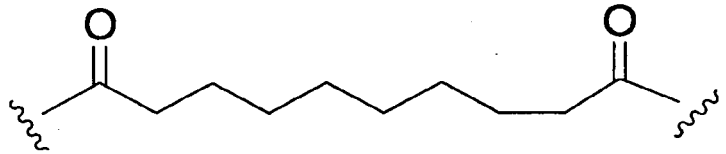

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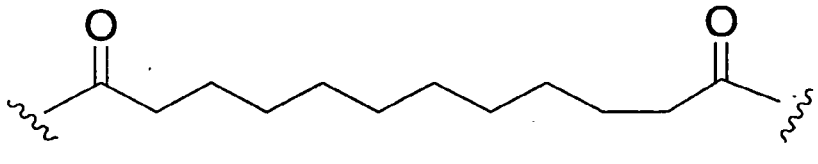

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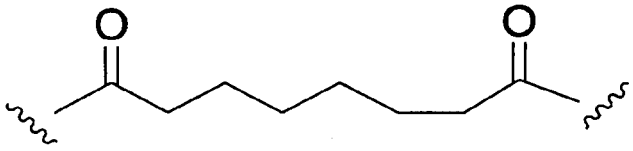

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; and



[0086] In another embodiment, the linker may comprise a carbonyl group bound to any one of A_1, Y, D, J, T or U and any one of A_1', Y', D', J', T' or U', and further comprise an alkylene, polyalkylene or aralkyl glycol group bound to the carbonyl groups. Examples of such glycols include polyoxyethylene, polyoxypropylene, and block copolymers of polyoxyethylene and polyoxypropylene glycol, diethylene glycol, triethylene glycol, tetraethylene glycol, dipropylene glycol, thioethylene glycol, and pentaethylene, hexaethylene, heptaethylene, octaethylene, nonaethylene, and decaethylene glycols. Particular examples of these glycols include ethylene glycol; 1,2-propylene glycol; 1,3-propanediol; 2,4-dimethyl-2-ethylhexane-1,3,diol; 2,2-dimethyl-1,3-propanediol; 2-ethyl-2-butyl-1,3-propanediol; 2-ethyl-2-isobutyl-1,3-propanediol; 1,3-butanediol; 1,4-butanediol: 1,5-pentanediol; 1,6-hexanediol; 2,2-4-trimethyl-1,6-hexanediol; thiodiethanol. 1,2-cyclohexanedimethanol; 1,3-cyclohexanedimethanol; 1,4-cyclohexanedimethanol; 2,2,4,4-tetramethyl-1,3-cyclobutanediol; p-xylylenediol, 2,3-naphthalenediol and 2,7-naphthalenediol. Examples of diamino compounds include 1,3-bis-(2,4-diaminophenoxy)propane; 2,4-diamino-5-methylphenetol; 2,4-diamino-5-methylphenoxyethanol; 2,4-diaminodiphenylamine; 2,4-diaminophenol; 2,4-diaminophenol; 2,4-diaminophenoxyethanol; 2,6-bis(2-hydroxyethoxy)-3,5-

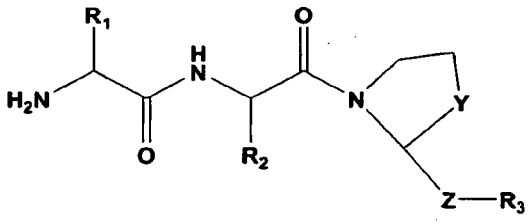
pyridinediamine; 2,6-diaminopyridine; 2,6-dimethoxy-3,5-pyridinediamine, 2-chloro-5-nitro-n-hydroxyethyl p-phenylenediamine, 2-chloro-p-phenylenediamine, 2-aminomethyl-p-aminophenol and 4,5-diamino-1-methylpyrazole. Examples of amino-hydroxy compounds include 2-amino-3-hydroxypyridine; 2-amino-3-nitrophenol; 2-amino-4-hydroxyethylaminoanisole; 2-amino-4-hydroxyethylaminoanisole sulfate; and 2-amino-6-chloro-4-nitrophenol.

[0087] In another embodiment, the linker may comprise an oxygen or amino group bound to any one of A_1, Y, D, J, T or U and any one of A_1', Y', D', J', T' or U', and further comprise a diacid thereby giving a diester, diamide or ester amide. Examples of such diacids include succinic acid, fumaric acid, adipic acid and the like.

[0088] In another embodiment, the linker comprises a 1,2,3-triazol-4,5-ene group which is introduced by cycloaddition of a propargyl group with an azide group.

[0089] The linker is used to join two Smac mimetic compounds into a bivalent structure. The Smac mimetic compounds joined together may be the same or different, and may be any Smac mimetic compound known to bind to IAPs and inhibit the interaction of IAPs and caspases. In one embodiment, the Smac mimetics are conformationally constrained. In another embodiment, the Smac mimetics do not contain any naturally occurring amino acids. In a further embodiment, the Smac mimetics do not contain any peptide bonds. Examples of known Smac mimetic compounds that are useful as starting materials in the present invention include the following:

[0090] WO 2005/069888 discloses Smac peptidomimetic compounds of formula VI:



VI

or a pharmaceutically acceptable salt or prodrug thereof, wherein:

R_1 is C_{1-2} alkyl or C_{1-2} haloalkyl;

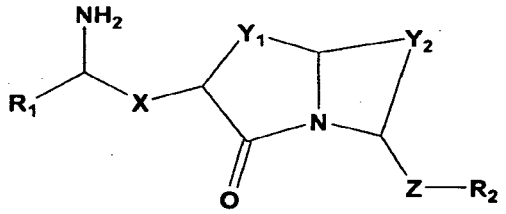
R_2 is branched or unbranched alkyl or cycloalkyl or substituted or unsubstituted aryl, alkylaryl, heteroaryl, or alkylheteroaryl;

R_3 is branched or unbranched alkyl or cycloalkyl or substituted or unsubstituted aryl, alkylaryl, heteroaryl, or alkylheteroaryl;

Y is $(CH_2)_{0-3}$, wherein one or more carbon can be replaced by one or more heteroatoms selected from oxygen, sulfur, and nitrogen, and one or more hydrogens in CH_2 groups can be replaced by a branched or unbranched alkyl or cyclic alkyl or substituted or unsubstituted aryl, alkylaryl, heteroaryl, or alkylheteroaryl; and

Z is CONH, CH_2O, NHCO, $(CH_2)_{1-4}$, $(CH_2)_{1-3}CONH(CH_2)_{0-3}$, $(CH_2)_{1-3}S(CH_2)_{0-3}$, $(CH_2)_{1-3}NH(CH_2)_{0-3}$, $(CH_2)_{1-3}NHCO(CH_2)_{0-3}$, $(CH_2)_{1-3}NHSO_2(CH_2)_{0-3}$, $(CH_2)_{1-3}NHC(O)NH(CH_2)_{0-3}$, $(CH_2)_{1-3}NHC(S)NH(CH_2)_{0-3}$, or $(CH_2)_{1-3}NR'(CH_2)_{0-3}$, wherein R' is branched or unbranched alkyl or cycloalkyl or substituted or unsubstituted aryl, alkylaryl, heteroaryl, or alkylheteroaryl.

[0091] WO 2005/069894 discloses Smac mimetic compounds of formula VII:



VII

or a pharmaceutically acceptable salt or prodrug thereof, wherein:

R_1 is C_{1-2} alkyl or C_{1-2} haloalkyl;

R_2 is branched or unbranched alkyl or cycloalkyl or substituted or unsubstituted aryl, alkylaryl, heteroaryl, or alkylheteroaryl;

X is CONH, CH_2O, CH_2NH, CH_2S, or $(CH_2)_{1-3}$;

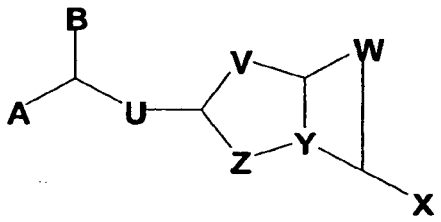
Y_1 is $(CH_2)_{1-5}$, wherein one or more carbon can be replaced by one or more heteroatoms selected from oxygen, sulfur, and nitrogen, and one or more hydrogens in CH_2 groups can be replaced by a branched or unbranched alkyl or cyclic alkyl or substituted or unsubstituted aryl, alkylaryl, heteroaryl, or alkylheteroaryl;

Y_2 is $(CH_2)_{1-5}$, wherein one or more carbon can be replaced by one or more heteroatoms selected from oxygen, sulfur, and nitrogen, and one or more hydrogens in CH_2 groups can be replaced by a branched or unbranched alkyl or cyclic alkyl or substituted or unsubstituted aryl, alkylaryl, heteroaryl, or alkylheteroaryl; and

Z is CONH, CH_2O, NHCO, $(CH_2)_{1-4}$, $(CH_2)_{1-3}CONH(CH_2)_{0-3}$, $(CH_2)_{1-3}S(CH_2)_{0-3}$, $(CH_2)_{1-3}NH(CH_2)_{0-3}$, $(CH_2)_{1-3}NHCO(CH_2)_{0-3}$, $(CH_2)_{1-3}NHSO_2(CH_2)_{0-3}$, $(CH_2)_{1-3}NHC(O)NH(CH_2)_{0-3}$, $(CH_2)_{1-3}NHC(S)NH(CH_2)_{0-3}$, or $(CH_2)_{1-3}NR'(CH_2)_{0-3}$, wherein

R' is branched or unbranched alkyl or cycloalkyl or substituted or unsubstituted aryl, alkylaryl, heteroaryl, or alkylheteroaryl

[0092] WO 2006/010118 discloses Smac mimetics compounds of formula VIII:



VIII

or a pharmaceutically acceptable salt or prodrug thereof, wherein:

A is NR_1R_2, or $N^+R_1R_2R_3$;

R_1, R_2, and R_3 are independently hydrogen or optionally substituted C_{1-8} alkyl, C_{2-8} alkenyl, or C_{2-8} alkynyl, in which one or more carbons can be replaced by C=O, C=S, or a heteroatom selected from O, S, and N, and one or more hydrogens in CH, CH_2 or CH_3 groups can be replaced by fluorine, a branched or unbranched alkyl or cycloalkyl, an optionally substituted aryl, alkylaryl, heteroaryl, or alkylheteroaryl, or OR_4, SR_4, or NR_4R_5;

R_4, and R_5 are independently hydrogen or optionally substituted C_{1-4} alkyl, C_{2-5} alkenyl, or C_{2-5} alkynyl, in which one or more carbons can be replaced by a heteroatom selected from O, S, and N, or optionally substituted aryl, alkylaryl, heteroaryl, or alkylheteroaryl; or

any two of R_1, R_2, and R_3 taken together with the nitrogen to which they are attached form a heterocyclic group, in which one or more carbon atom can be replaced by C=O, C=S, or a heteroatom selected from O, S, and N, with the proviso that the heteroatom is separated from the nitrogen atom by at least two carbons;

B is optionally substituted C_{1-4} alkyl, C_{2-4} alkenyl, or C_{2-4} alkynyl, wherein one or more hydrogens can be replaced by fluorine;

U is CONH, C(O)O, C(S)O, C(S)NH, C(NH)NH, or $(CH_2)_{1-5}$, wherein one or more carbons can be replaced by a heteroatom selected from O, S, and N;

V and W are independently $(CH_2)_{1-5}$, wherein one or more carbons can be replaced by C=O, C=S, or a heteroatom selected from O, S, and N, and one or more

hydrogens in CH_2 groups can be replaced by a branched or unbranched alkyl or cycloalkyl, an optionally substituted aryl, alkylaryl, heteroaryl, or alkylheteroaryl, or OR_4, SR_4, or NR_4R_5;

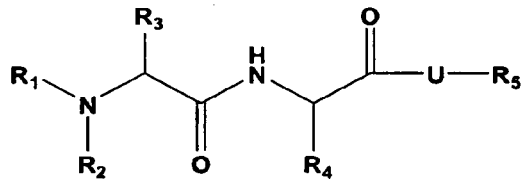
X is optionally substituted C_{1-18} alkyl, C_{2-18} alkenyl, C_{2-18} alkynyl, aryl, or heteroaryl, wherein one or more carbons can be replaced by C=O, C=S, or a heteroatom selected from O, S, and N, and one or more hydrogens in CH, CH_2 or CH_3 groups can be replaced by a branched or unbranched alkyl or cycloalkyl, an optionally substituted aryl, alkylaryl, heteroaryl, or alkylheteroaryl, or OR_4, SR_4, or NR_4R_5;

Y is CH or N;

Z is CH_2, C=O, C=S, CHSR, CHOR, or CHNR; and

R is hydrogen or optionally substituted C_{1-4} alkyl, C_{2-4} alkenyl, or C_{2-4} alkynyl.

[0093] U.S. Published Application No. 2005/0234042 discloses compounds according to formula IX:



IX

wherein R_1 is H; C_1-C_4 alkyl; C_1-C_4 alkenyl; C_1-C_4 alkynyl or C_3-C_{10} cycloalkyl which are unsubstituted or substituted;

R_2 is H; C_1-C_4 alkyl; C_1-C_4 alkenyl; C_1-C_4 alkynyl or C_3-C_{10} cycloalkyl which are unsubstituted or substituted;

R_3 is H; $-CF_3$; $-C_2F_5$; C_1-C_4 alkyl; C_1-C_4 alkenyl; C_1-C_4 alkynyl; $-CH_2$-Z or R_2 and R_3 together with the nitrogen form a het ring;

Z is H; -OH; F; Cl; $-CH_3$; $-CF_3$; $-CH_2Cl$; $-CH_2F$ or $-CH_2OH$;

R_4 is C_1-C_{16} straight or branched alkyl; C_1-C_{16} alkenyl; C_1-C_{16} alkynyl; or $-C_3$-C_{10} cycloalkyl; $-(CH_2)_{1-6}$-Z_1; $-(CH_2)_{0-6}$-aryl; and $-(CH_2)_{0-6}$-het; wherein alkyl, cycloalkyl and phenyl are unsubstituted or substituted;

Z_1 is $-N(R_8)$-C(O)-C_1-C_{10} alkyl; $-N(R_8)$-C(O)-$(CH_2)_{1-6}$-C_3-C_7 cycloalkyl; $-N(R_8)$-C(O)-$(CH_2)_{0-6}$-phenyl; $-N(R_8)$-C(O)-$(CH_2)_{1-6}$-het; -C(O)-$N(R_9)(R_{10})$; -C(O)-O-C_1-C_{10} alkyl; -C(O)-O-$(CH_2)_{1-6}$-C_3-C_7 cycloalkyl; -C(O)-O-$(CH_2)_{0-6}$-phenyl; -C(O)-O-$(CH_2)_{1-6}$-het; -O-C(O)-C_1-C_{10} alkyl; -O-C(O)-$(CH_2)_{1-6}$-C_3-C_7 cycloalkyl; -O-C(O)-

$(CH_2)_{0-6}$-phenyl; -O-C(O)-$(CH_2)_{1-6}$-het; wherein alkyl, cycloalkyl and phenyl are unsubstituted or substituted;

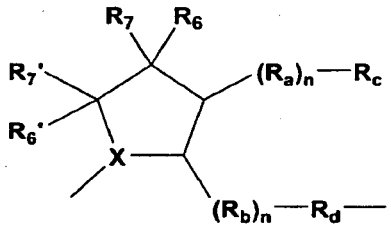
het is a 5-7 membered heterocyclic ring containing 1-4 heteroatoms selected from N, O and S, or an 8-12 membered fused ring system including at least one 5-7 membered heterocyclic ring containing 1, 2 or 3 heteroatoms selected from N, O, and S, which heterocyclic ring or fused ring system is unsubstituted or substituted on a carbon or nitrogen atom;

R_8 is H; $-CH_3$; $-CF_3$; $-CH_2OH$ or $-CH_2Cl$;

R_9 and R_{10} are each independently H; C_1-C_4 alkyl; C_3-C_7 cycloalkyl; -$(CH_2)_{1-6}$-C_3-C_7 cycloalkyl; -$(CH_2)_{0-6}$-phenyl; wherein alkyl, cycloalkyl and phenyl are unsubstituted or substituted, or R_9 and R_{10} together with the nitrogen form het;

R_5 is H; C_1-C_{10}-alkyl; aryl; phenyl; C_3-C_7 cycloalkyl; -$(CH_2)_{1-6}$-C_3-C_7 cycloalkyl; -C_1-C_{10} alkyl-aryl; -$(CH_2)_{0-6}$-C_3-C_7 cycloalkyl-$(CH_2)_{0-6}$-phenyl; -$(CH_2)_{0-4}$CH-$((CH_2)_{1-4}$-phenyl$)_2$; -$(CH_2)_{0-6}$-CH(phenyl$)_2$; -indanyl; -C(O)-C_1-C_{10} alkyl; -C(O)-$(CH_2)_{1-6}$-C_3-C_7-cycloalkyl; -C(O)-$(CH_2)_{0-6}$-phenyl; -$(CH_2)_{0-6}$-C(O)-phenyl; -$(CH_2)_{0-6}$-het; -C(O)-$(CH_2)_{1-6}$-het; or R_5 is a residue of an amino acid, wherein the alkyl, cycloalkyl, phenyl and aryl substituents are unsubstituted or substituted;

U is as shown in structure X:



X

wherein n=0-5;

X is -CH or N;

Ra and Rb are independently an O, S, or N atom or C_{0-8} alkyl wherein one or more of the carbon atoms in the alkyl chain may be replaced by a heteroatom selected from O, S or N, and where the alkyl may be unsubstituted or substituted;

Rd is selected from: (a) -Re-Q-$(Rf)_p(Rg)_q$; or (b) Ar_1-D-Ar_2;

Rc is H or Rc and Rd may together form a cycloalkyl or het; where if Rd and Rc form a cycloalkyl or het, R_5 is attached to the formed ring at a C or N atom;

p and q are independently 0 or 1;

Re is C_{1-8} alkyl or alkylidene, and Re which may be unsubstituted or substituted;

Q is N, O, S, S(O), or $S(O)_2$;

Ar_1 and Ar_2 are substituted or unsubstituted aryl or het;

Rf and Rg are each independently H; -C_1-C_{10} alkyl; C_1-C_{10} alkylaryl; -OH; -O-C_1-C_{10} alkyl; -$(CH_2)_{0-6}$-C_3-C_7 cycloalkyl; -O-$(CH_2)_{0-6}$-aryl; phenyl; aryl; phenyl-phenyl; -$(CH_2)_{1-6}$-het; -O-$(CH_2)_{1-6}$-het; -OR_{11}; -C(O)-R_{11}; -C(O)-N(R_{11})(R_{12}); -N(R_{11})(R_{12}); -S-R_{11}; -S(O)-R_{11}; -$S(O)_2$-R_{11}; -$S(O)_2$-N$R_{11}R_{12}$; -NR_{11}-$S(O)_2$-R_{12}; S-C_1-C_{10} alkyl; aryl-C_1-C_4 alkyl; het-C_1-C_4-alkyl wherein alkyl, cycloalkyl, het and aryl are unsubstituted or substituted; -SO_2-C_1-C_2 alkyl; -SO_2-C_1-C_2 alkylphenyl; -O-C_1-C_4 alkyl; or Rg and Rf form a ring selected from het or aryl;

D is -CO-; -C(O)-C_{1-7} alkylene or arylene; -CF_2-; -O-; -$S(O)_r$ where r is 0-2; 1,3dioaxolane; or C_{1-7} alkyl-OH; where alkyl, alkylene or arylene may be unsubstituted or substituted with one or more halogens, OH, -O-C_1-C_6 alkyl, -S-C_1-C_6 alkyl or -CF_3; or D is -N(Rh) wherein Rh is H; C_{1-7} alkyl (unsubstituted or substituted); aryl; -O(C_{1-7} cycloalkyl) (unsubstituted or substituted); C(O)-C_1-C_{10} alkyl; C(O)-C_0-C_{10} alkyl-aryl; C-O-C_1-C_{10} alkyl; C-O-C_0-C_{10} alkyl-aryl or SO_2-C_1-C_{10}-alkyl; SO_2-(C_0-C_{10}-alkylaryl);

R_6, R_7, R'_6 and R'_7 are each independently H; -C_1-C_{10} alkyl; -C_1-C_{10} alkoxy; aryl-C_1-C_{10} alkoxy; -OH; -O-C_1-C_{10} alkyl; -$(CH_2)_{0-6}$-C_3-C_7 cycloalkyl; -O-$(CH_2)_{0-6}$-aryl; phenyl; -$(CH_2)_{1-6}$-het; -O-$(CH_2)_{1-6}$-het; -OR_{11}; -C(O)-R_{11}; -C(O)-N(R_{11})(R_{12}); -N(R_{11})(R_{12}); -S-R_{11}; -S(O)-R_{11}; -$S(O)_2$-R_{11}; -$S(O)_2$-N$R_{11}R_{12}$; -NR_{11}-$S(O)_2$-R_{12}; wherein alkyl, cycloalkyl and aryl are unsubstituted or substituted; and R_6, R_7, R'_6 and R'_7 can be united to form a ring system;

R_{11} and R_{12} are independently H; C_1-C_{10} alkyl; -$(CH_2)_{0-6}$-C_3-C_7 cycloalkyl; -$(CH_2)_{0-6}$-$(CH)_{0-1}$$(aryl)_{1-2}$; -C(O)-$C_1$-$C_{10}$ alkyl; -C(O)-$(CH_2)_{1-6}$-C_3-C_7 cycloalkyl; -C(O)-O-$(CH_2)_{0-6}$-aryl; -C(O)-$(CH_2)_{0-6}$-O-fluorenyl; -C(O)-NH-$(CH_2)_{0-6}$-aryl; -C(O)-$(CH_2)_{0-6}$-aryl; -C(O)-$(CH_2)_{1-6}$-het; -C(S)-C_1-C_{10}alkyl; -C(S)-$(CH_2)_{1-6}$-C_3-C_7 cycloalkyl; -C(S)-O-$(CH_2)_{0-6}$-aryl; -C(S)-$(CH_2)_{0-6}$-O-fluorenyl; -C(S)-NH-$(CH_2)_{0-6}$-aryl; -C(S)-$(CH_2)_{0-6}$-aryl; -C(S)-$(CH_2)_{1-6}$-het; wherein alkyl, cycloalkyl and aryl are unsubstituted or substituted; or R_{11} and R_{12} are a substituent that facilitates transport of the molecule across a cell membrane; or R_{11} and R_{12} together with the nitrogen atom form het;

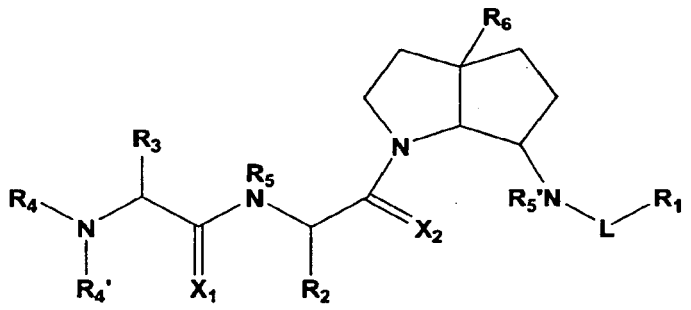
wherein the alkyl substituents of R_{11} and R_{12} may be unsubstituted or substituted by one or more substituents selected from C_1-C_{10} alkyl, halogen, OH, -O-C_1-C_6 alkyl, -S-C_1-C_6 alkyl or -CF_3;

substituted cycloalkyl substituents of R_{11} and R_{12} are substituted by one or more substituents selected from a C_1-C_{10} alkene; C_1-C_6 alkyl; halogen; OH; -O-C_1-C_6 alkyl; -S-C_1-C_6 alkyl or -CF_3; and

substituted phenyl or aryl of R_{11} and R_{12} are substituted by one or more substituents selected from halogen; hydroxy; C_1-C_4 alkyl; C_1-C_4 alkoxy; nitro; -CN; -O-C(O)-C_1-C_4 alkyl and -C(O)-O-C_1-C_4-aryl,

or pharmaceutically acceptable salts thereof.

[0094] U.S. Published Application No. 2005/0261203 discloses compounds of formula XI:



XI

wherein X_1 and X_2 are independently O or S;

L is a bond, -C(X_3)-, -C(X_3)NR_{12} or –C(X_3)O- wherein X_3 is O or S and R_{12} is H or R_1;

R_1 is alkyl, a carbocycle, carbocycle-substituted alkyl, a heterocycle or heterocycle-substituted alkyl, wherein each is optionally substituted with halogen, hydroxyl, mercapto, carboxyl, alkyl, haloalkyl, alkoxy, alkylsulfonyl, amino, nitro, aryl and heteroaryl;

R_2 is alkyl, cycloalkyl, cycloalkylalkyl, aryl, aralkyl, a heterocycle or heterocyclylalkyl;

R_3 is H or alkyl;

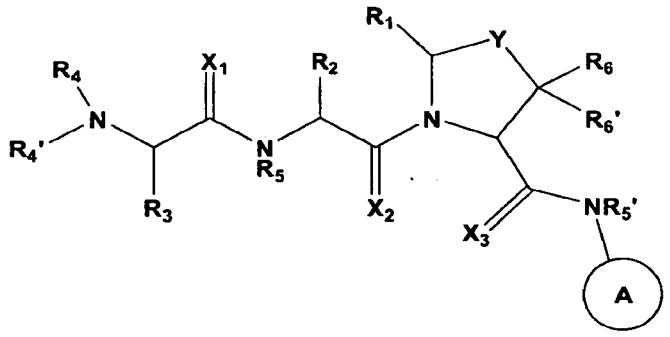
R_4 and $R_{4'}$ are independently H, alkyl, aryl, aralkyl, cycloalkyl, cycloalkylalkyl, heteroaryl, or heteroaralkyl wherein each is optionally substituted with halogen, hydroxyl, mercapto, carboxyl, alkyl, alkoxy, amino and nitro;

R_5 and $R_{5'}$ are each independently H or alkyl;

R_6 is H or alkyl;

and salts and solvates thereof.

[0095] U.S. Published Application No. 2006/0014700 discloses compounds of formula XII:



XII

wherein X_1, X_2 and X_3 are independently O or S;

Y is $(CHR_7)_n$, O or S; wherein n is 1 or 2 and R_7 is H, halogen, alkyl, aryl, aralkyl, amino, arylamino, alkylamino, aralkylamino, alkoxy, aryloxy or aralkyloxy;

A is a 5-member heterocycle comprising 1 to 4 heteroatoms optionally substituted with amino, hydroxyl, mercapto, halogen, carboxyl, amidino, guanidino, alkyl, alkoxy, aryl, aryloxy, acyl, acyloxy, acylamino, alkoxycarbonylamino, cycloalkyl, alkylthio, alkylsulfinyl, alkylsulfonyl, aminosulfonyl, alkylaminosulfonyl, alkylsulfonylamino or a heterocycle; wherein each alkyl, alkoxy, aryl, aryloxy, acyl, acyloxy, acylamino, cycloalkyl and heterocycle substitution is optionally substituted with hydroxyl, halogen, mercapto, carboxyl, alkyl, alkoxy, haloalkyl, amino, nitro, cyano, cycloalkyl, aryl or a heterocycle;

R_1 is H or R_1 and R_2 together form a 5-8 member ring;

R_2 is alkyl, cycloalkyl, cycloalkylalkyl, aryl, aralkyl, a heterocycle or heterocyclylalkyl; each optionally substituted with hydroxyl, mercapto, halogen, amino, carboxyl, alkyl, haloalkyl, alkoxy or alkylthio;

R_3 is H or alkyl;

R_4 and $R_{4'}$ are independently H, hydroxyl, amino, alkyl, aryl, aralkyl, cycloalkyl, cycloalkylalkyl, heteroaryl, or heteroarylalkyl wherein each alkyl, aryl, aralkyl, cycloalkyl, cycloalkylalkyl, heteroaryl and heteroarylalkyl is optionally substituted with halogen, hydroxyl, mercapto, carboxyl, alkyl, alkoxy, amino and nitro;

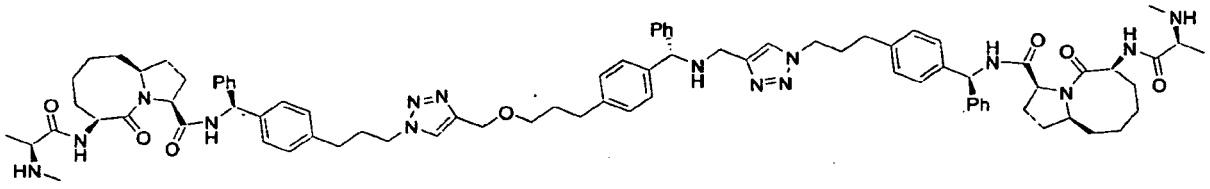
R_5, and $R_{5'}$ are each independently H or alkyl;

R_6, and $R_{6'}$ are each independently H, alkyl, aryl or aralkyl;

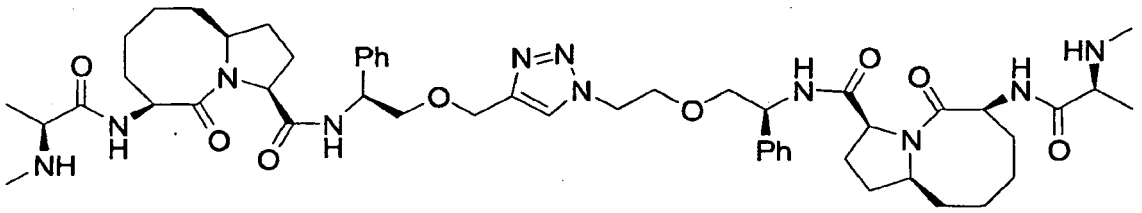
and salts and solvates thereof.

[0096] Certain of the compounds of the present invention may exist as stereoisomers including optical isomers. The invention includes all stereoisomers, both as pure individual stereoisomer preparations and enriched preparations of each, and both the racemic mixtures of such stereoisomers as well as the individual enantiomers that may be separated according to methods that are well known to those of skill in the art.

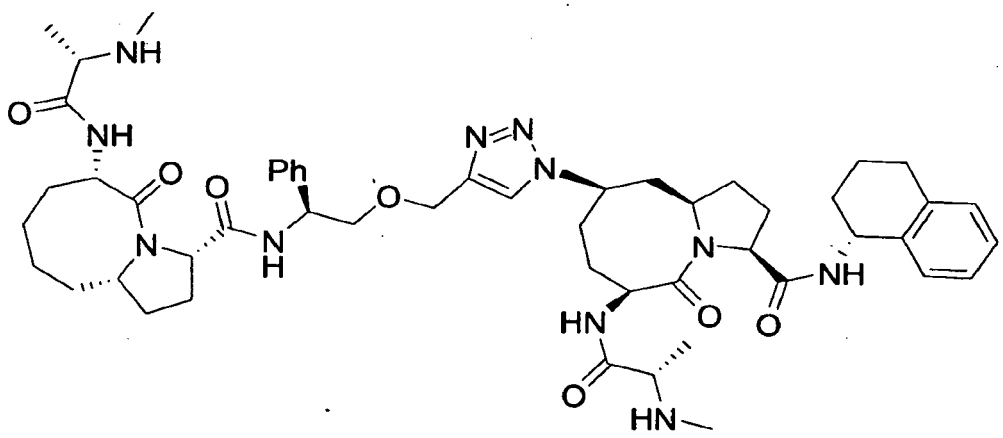
[0097] In certain embodiments of the invention the compound of Formula II is selected from the group consisting of:



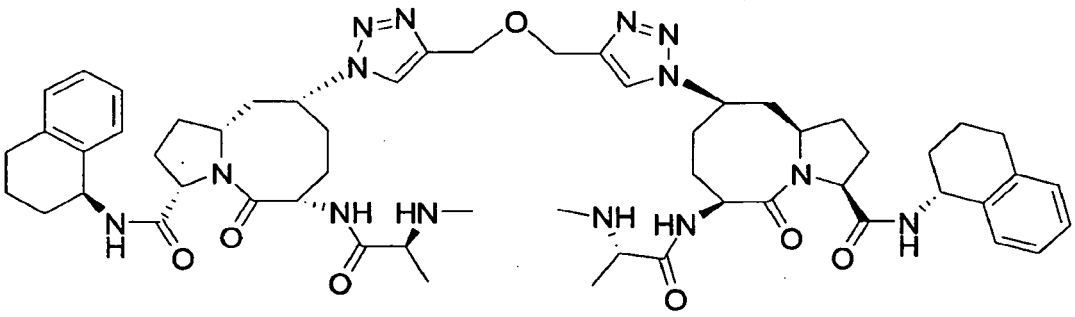
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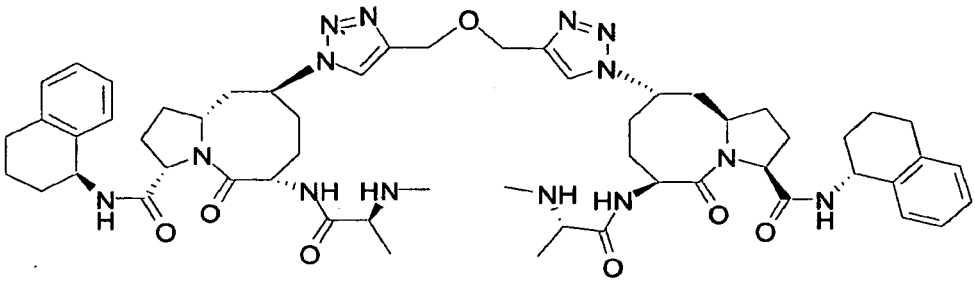


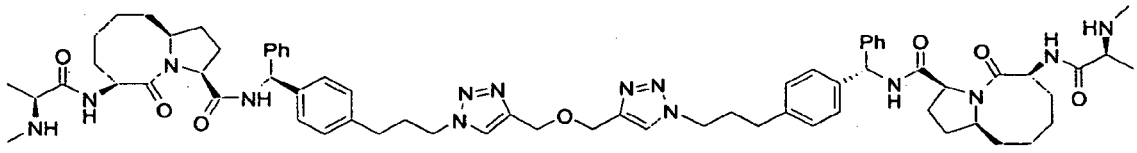
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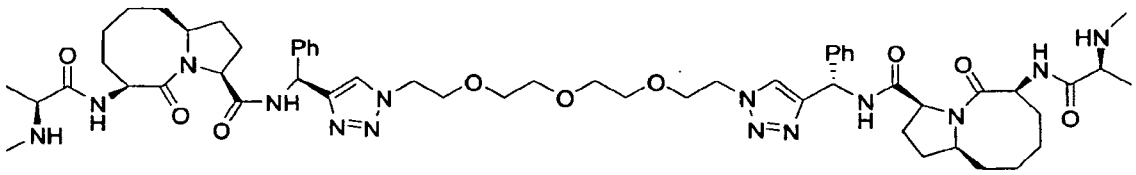


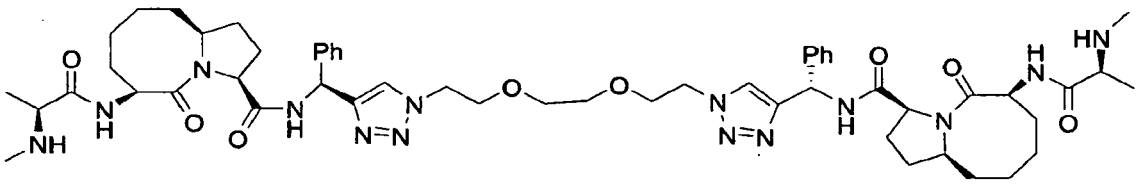
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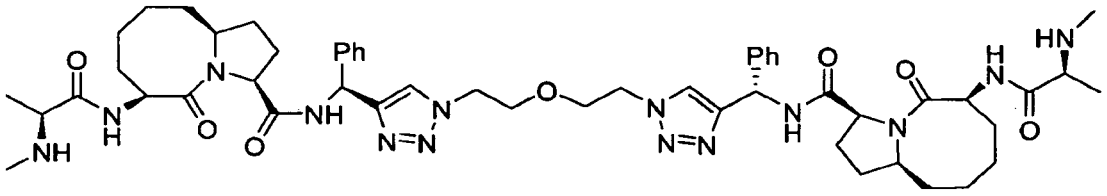

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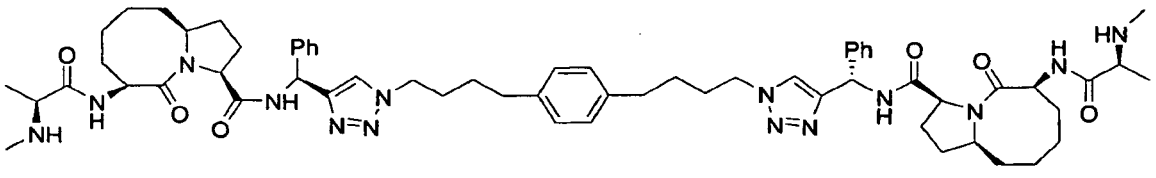

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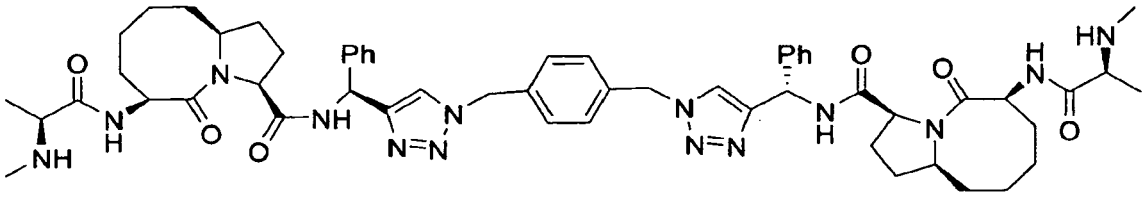

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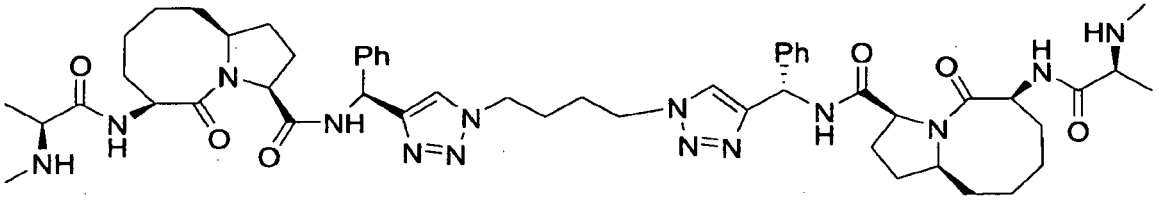

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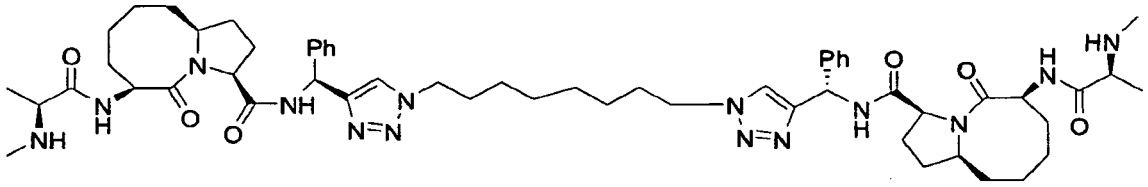

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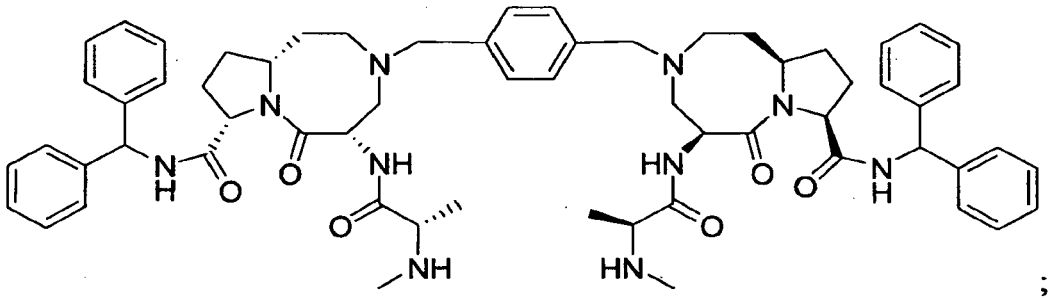

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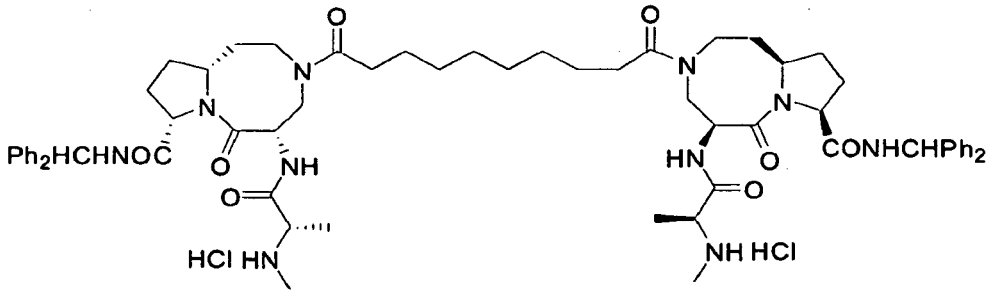

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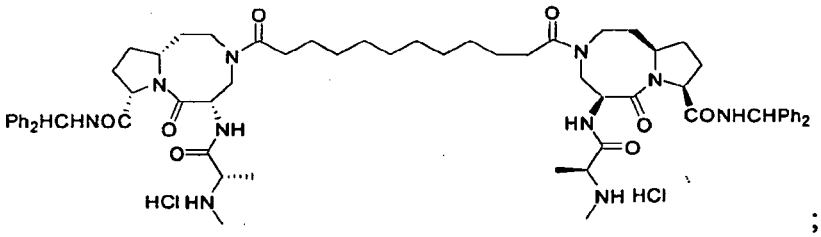

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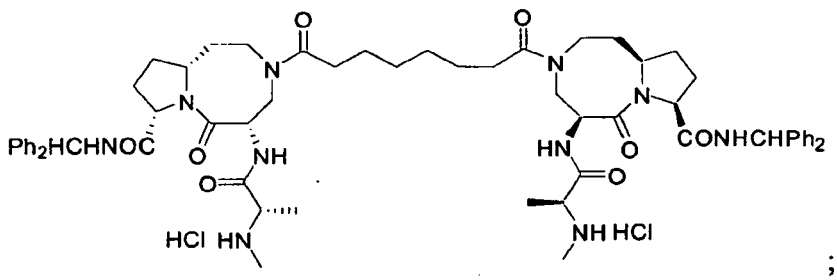

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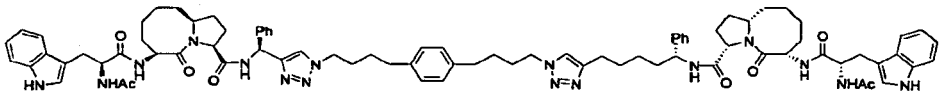

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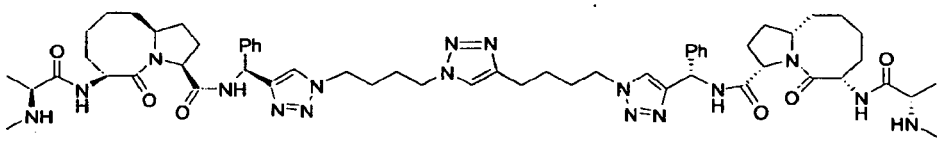

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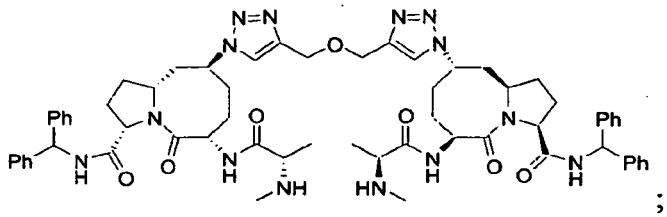
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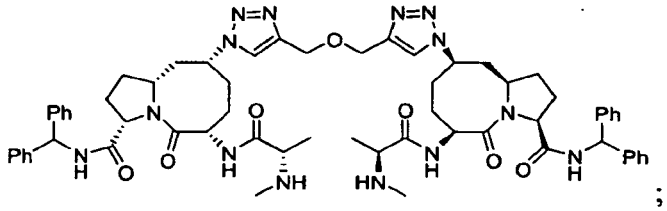
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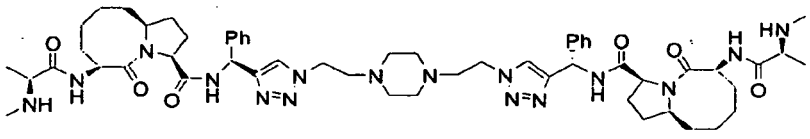
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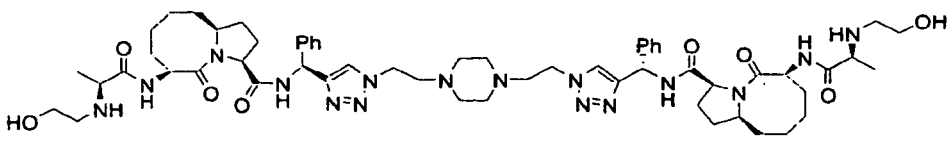
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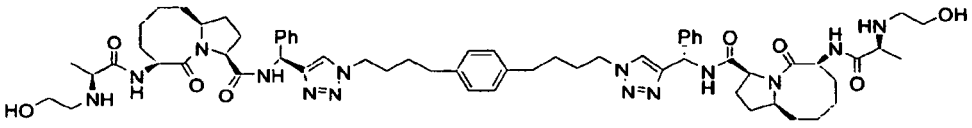
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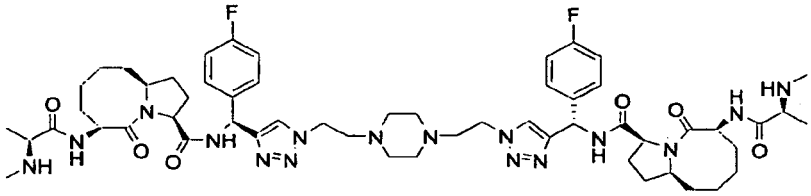
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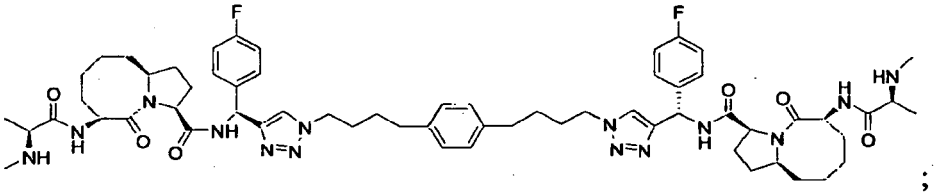
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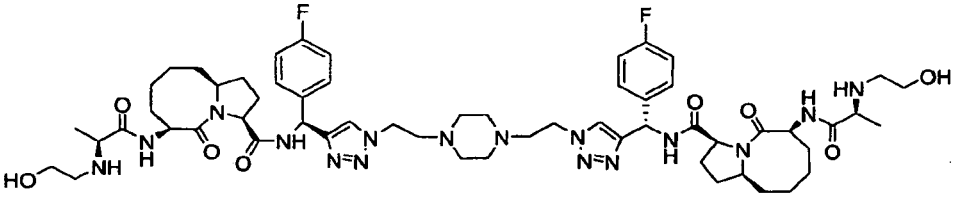
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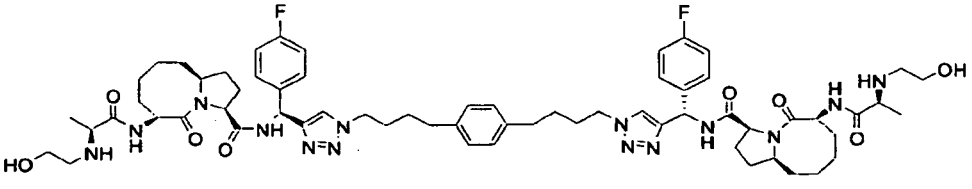
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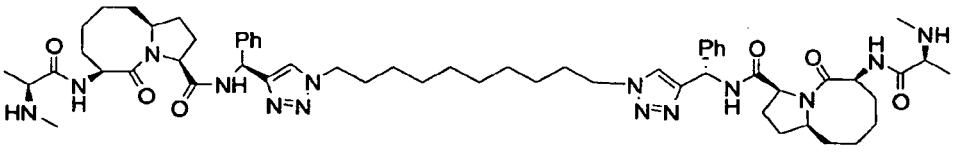
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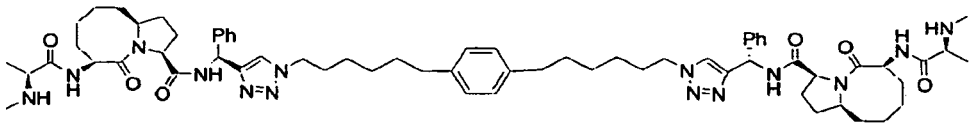
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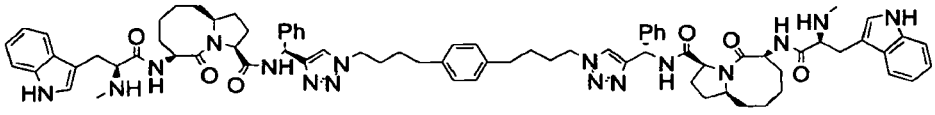
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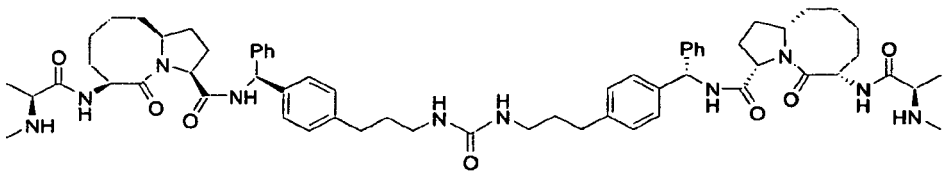
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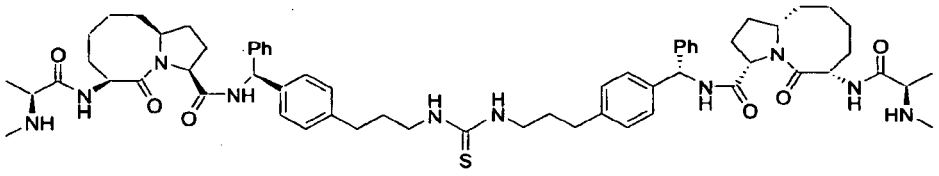
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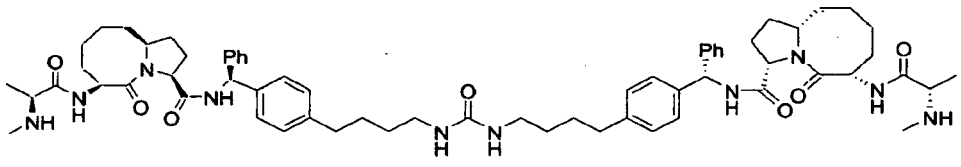
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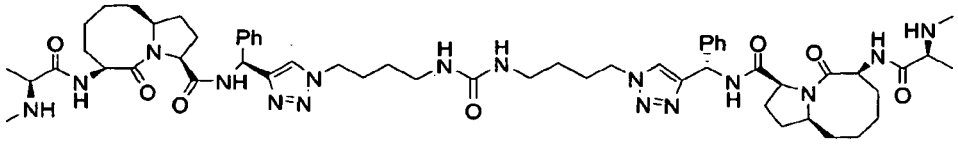
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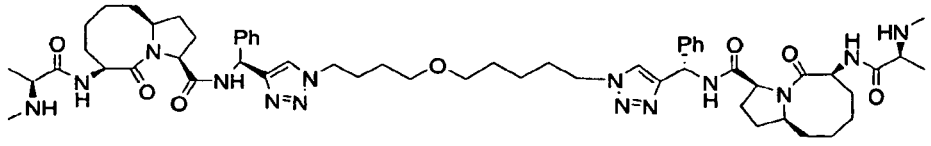
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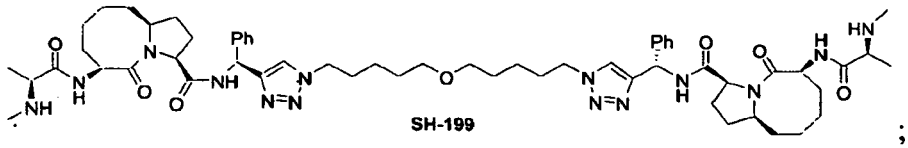
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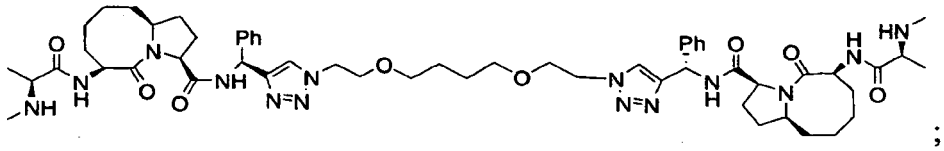
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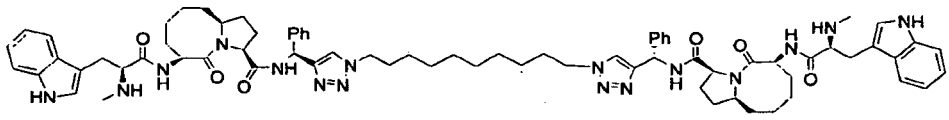
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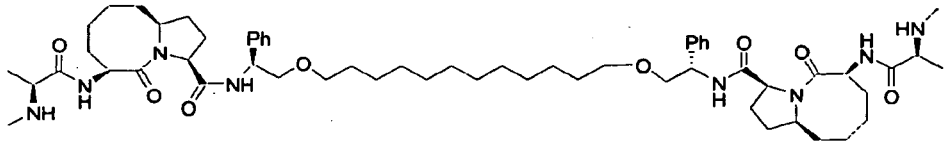
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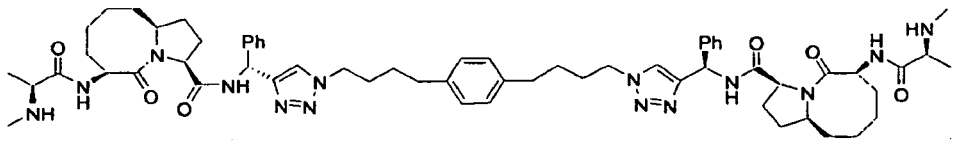
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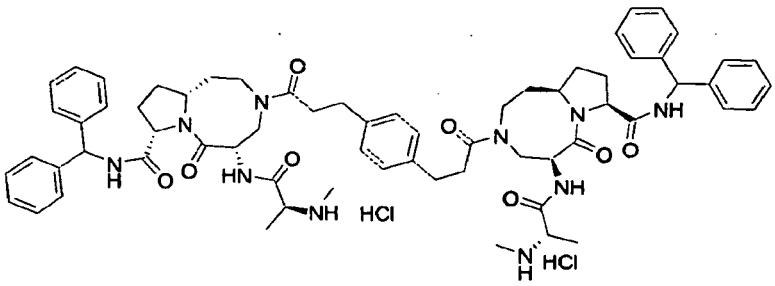


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and



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or the free base thereof or another pharmaceutically acceptable salt thereof.

[0098] The compounds of this invention may be prepared using methods known to those of skill in the art. Specifically, compounds with Formula II can be prepared as illustrated by the exemplary reactions in the Examples.

[0099] An important aspect of the present invention is that compounds of Formula II induce apoptosis and also potentiate the induction of apoptosis in response to apoptosis induction signals. Therefore, it is contemplated that these compounds sensitize cells to inducers of apoptosis, including cells that are resistant to such inducers. The IAP inhibitors of the present invention can be used to induce apoptosis in any disorder that can be treated, ameliorated, or prevented by the induction of apoptosis. Thus, the present invention provides compositions and methods for targeting animals characterized as overexpressing an IAP protein. In some of the embodiments, the cells (e.g., cancer cells) show elevated expression levels of IAP proteins as compared to non-pathological samples (e.g., non-cancerous cells). In other embodiments, the cells operationally manifest elevated expression levels of IAP proteins by virtue of executing the apoptosis program and dying in response to an inhibiting effective amount of a compound of Formula I, said response occurring, at least in part, due to the dependence in such cells on IAP protein function for their survival.

[0100] In another embodiment, the invention pertains to modulating an apoptosis-associated state which is associated with one or more apoptosis-modulating agents. Examples of apoptosis-modulating agents include, but are not limited to, Fas/CD95, TRAMP, TNF RI, DR1, DR2, DR3, DR4, DR5, DR6, FADD, RIP, TNFα, Fas ligand, TRAIL, antibodies to TRAIL-R1 or TRAIL-R2, Bcl-2, p53, BAX, BAD, Akt, CAD, PI3 kinase, PP1, and caspase proteins. Other agents involved in the initiation, decision and degradation phase of apoptosis are also included. Examples of apoptosis-modulating agents include agents, the activity, presence, or change in concentration of which, can modulate apoptosis in a subject. Preferred apoptosis-modulating agents are inducers of apoptosis, such as TNF or a TNF-related ligand, particularly a TRAMP ligand, a Fas/CD95 ligand, a TNFR-1 ligand, or TRAIL.

[0101] In some embodiments, the compositions and methods of the present invention are used to treat diseased cells, tissues, organs, or pathological conditions and/or disease states in an animal (e.g., a mammalian subject including, but not limited to, humans and veterinary animals). In this regard, various diseases and

pathologies are amenable to treatment or prophylaxis using the present methods and compositions. A non-limiting exemplary list of these diseases and conditions includes, but is not limited to, breast cancer, prostate cancer, lymphoma, skin cancer, pancreatic cancer, colon cancer, melanoma, malignant melanoma, ovarian cancer, brain cancer, primary brain carcinoma, head–neck cancer, glioma, glioblastoma, liver cancer, bladder cancer, non-small cell lung cancer, head or neck carcinoma, breast carcinoma, ovarian carcinoma, lung carcinoma, small-cell lung carcinoma, Wilms' tumor, cervical carcinoma, testicular carcinoma, bladder carcinoma, pancreatic carcinoma, stomach carcinoma, colon carcinoma, prostatic carcinoma, genitourinary carcinoma, thyroid carcinoma, esophageal carcinoma, myeloma, multiple myeloma, adrenal carcinoma, renal cell carcinoma, endometrial carcinoma, adrenal cortex carcinoma, malignant pancreatic insulinoma, malignant carcinoid carcinoma, choriocarcinoma, mycosis fungoides, malignant hypercalcemia, cervical hyperplasia, leukemia, acute lymphocytic leukemia, chronic lymphocytic leukemia, acute myelogenous leukemia, chronic myelogenous leukemia, chronic granulocytic leukemia, acute granulocytic leukemia, hairy cell leukemia, neuroblastoma, rhabdomyosarcoma, Kaposi's sarcoma, polycythemia vera, essential thrombocytosis, Hodgkin's disease, non-Hodgkin's lymphoma, soft-tissue sarcoma, osteogenic sarcoma, primary macroglobulinemia, and retinoblastoma, and the like, T and B cell mediated autoimmune diseases; inflammatory diseases; infections; hyperproliferative diseases; AIDS; degenerative conditions, vascular diseases, and the like. In some embodiments, the cancer cells being treated are metastatic. In other embodiments, the cancer cells being treated are resistant to anticancer agents.

[0102] In some embodiments, infections suitable for treatment with the compositions and methods of the present invention include, but are not limited to, infections caused by viruses, bacteria, fungi, mycoplasma, prions, and the like.

[0103] Some embodiments of the present invention provide methods for administering an effective amount of a compound of Formula I and at least one additional therapeutic agent (including, but not limited to, chemotherapeutic antineoplastics, apoptosis-modulating agents, antimicrobials, antivirals, antifungals, and anti-inflammatory agents) and/or therapeutic technique (e.g., surgical intervention, and/or radiotherapies).

[0104] A number of suitable anticancer agents are contemplated for use in the methods of the present invention. Indeed, the present invention contemplates, but is not limited to, administration of numerous anticancer agents such as: agents that induce apoptosis; polynucleotides (e.g., anti-sense, ribozymes, siRNA); polypeptides (e.g., enzymes and antibodies); biological mimetics (e.g., gossypol or BH3 mimetics); agents that bind (e.g., oligomerize or complex) with a Bcl-2 family protein such as Bax; alkaloids; alkylating agents; antitumor antibiotics; antimetabolites; hormones; platinum compounds; monoclonal or polyclonal antibodies (e.g., antibodies conjugated with anticancer drugs, toxins, defensins), toxins; radionuclides; biological response modifiers (e.g., interferons (e.g., IFN-α) and interleukins (e.g., IL-2)); adoptive immunotherapy agents; hematopoietic growth factors; agents that induce tumor cell differentiation (e.g., all-trans-retinoic acid); gene therapy reagents (e.g., antisense therapy reagents and nucleotides); tumor vaccines; angiogenesis inhibitors; proteosome inhibitors: NF-KB modulators; anti-CDK compounds; HDAC inhibitors; and the like. Numerous other examples of chemotherapeutic compounds and anticancer therapies suitable for co-administration with the disclosed compounds are known to those skilled in the art.

[0105] In preferred embodiments, anticancer agents comprise agents that induce or stimulate apoptosis. Agents that induce apoptosis include, but are not limited to, radiation (e.g., X-rays, gamma rays, UV); tumor necrosis factor (TNF)-related factors (e.g., TNF family receptor proteins, TNF family ligands, TRAIL, antibodies to TRAIL-R1 or TRAIL-R2); kinase inhibitors (e.g., epidermal growth factor receptor (EGFR) kinase inhibitor, vascular growth factor receptor (VGFR) kinase inhibitor, fibroblast growth factor receptor (FGFR) kinase inhibitor, platelet-derived growth factor receptor (PDGFR) kinase inhibitor, and Bcr-Abl kinase inhibitors (such as GLEEVEC)); antisense molecules; antibodies (e.g., HERCEPTIN, RITUXAN, ZEVALIN, and AVASTIN); anti-estrogens (e.g., raloxifene and tamoxifen); anti-androgens (e.g., flutamide, bicalutamide, finasteride, aminoglutethamide, ketoconazole, and corticosteroids); cyclooxygenase 2 (COX-2) inhibitors (e.g., celecoxib, meloxicam, NS-398, and non-steroidal anti-inflammatory drugs (NSAIDs)); anti-inflammatory drugs (e.g., butazolidin, DECADRON, DELTASONE, dexamethasone, dexamethasone intensol, DEXONE, HEXADROL, hydroxychloroquine, METICORTEN, ORADEXON, ORASONE,

oxyphenbutazone, PEDIAPRED, phenylbutazone, PLAQUENIL, prednisolone, prednisone, PRELONE, and TANDEARIL); and cancer chemotherapeutic drugs (e.g., irinotecan (CAMPTOSAR), CPT-11, fludarabine (FLUDARA), dacarbazine (DTIC), dexamethasone, mitoxantrone, MYLOTARG, VP-16, cisplatin, carboplatin, oxaliplatin, 5-FU, doxorubicin, gemcitabine, bortezomib, gefitinib, bevacizumab, TAXOTERE or TAXOL); cellular signaling molecules; ceramides and cytokines; staurosporine, and the like.

[0106] In still other embodiments, the compositions and methods of the present invention provide a compound of Formula II and at least one anti-hyperproliferative or antineoplastic agent selected from alkylating agents, antimetabolites, and natural products (e.g., herbs and other plant and/or animal derived compounds).

[0107] Alkylating agents suitable for use in the present compositions and methods include, but are not limited to: 1) nitrogen mustards (e.g., mechlorethamine, cyclophosphamide, ifosfamide, melphalan (L-sarcolysin); and chlorambucil); 2) ethylenimines and methylmelamines (e.g., hexamethylmelamine and thiotepa); 3) alkyl sulfonates (e.g., busulfan); 4) nitrosoureas (e.g., carmustine (BCNU); lomustine (CCNU); semustine (methyl-CCNU); and streptozocin (streptozotocin)); and 5) triazenes (e.g., dacarbazine (DTIC; dimethyltriazenoimid-azolecarboxamide).

[0108] In some embodiments, antimetabolites suitable for use in the present compositions and methods include, but are not limited to: 1) folic acid analogs (e.g., methotrexate (amethopterin)); 2) pyrimidine analogs (e.g., fluorouracil (5-fluorouracil; 5-FU), floxuridine (fluorode-oxyuridine; FudR), and cytarabine (cytosine arabinoside)); and 3) purine analogs (e.g., mercaptopurine (6-mercaptopurine; 6-MP), thioguanine (6-thioguanine; TG), and pentostatin (2'-deoxycoformycin)).

[0109] In still further embodiments, chemotherapeutic agents suitable for use in the compositions and methods of the present invention include, but are not limited to: 1) vinca alkaloids (e.g., vinblastine (VLB), vincristine); 2) epipodophyllotoxins (e.g., etoposide and teniposide); 3) antibiotics (e.g., dactinomycin (actinomycin D), daunorubicin (daunomycin; rubidomycin), doxorubicin, bleomycin, plicamycin (mithramycin), and mitomycin (mitomycin C)); 4) enzymes (e.g., L-asparaginase); 5) biological response modifiers (e.g., interferon-alfa); 6) platinum coordinating complexes (e.g., cisplatin (cis-DDP) and carboplatin); 7) anthracenediones (e.g.,

mitoxantrone); 8) substituted ureas (e.g., hydroxyurea); 9) methylhydrazine derivatives (e.g., procarbazine (N-methylhydrazine; MIH)); 10) adrenocortical suppressants (e.g., mitotane (o,p'–DDD) and aminoglutethimide); 11) adrenocorticosteroids (e.g., prednisone); 12) progestins (e.g., hydroxyprogesterone caproate, medroxyprogesterone acetate, and megestrol acetate); 13) estrogens (e.g., diethylstilbestrol and ethinyl estradiol); 14) antiestrogens (e.g., tamoxifen); 15) androgens (e.g., testosterone propionate and fluoxymesterone); 16) antiandrogens (e.g., flutamide): and 17) gonadotropin-releasing hormone analogs (e.g., leuprolide).

[0110] Any oncolytic agent that is routinely used in a cancer therapy context finds use in the compositions and methods of the present invention. For example, the U.S. Food and Drug Administration maintains a formulary of oncolytic agents approved for use in the United States. International counterpart agencies to the U.S.F.D.A. maintain similar formularies. Table 1 provides a list of exemplary antineoplastic agents approved for use in the U.S. Those skilled in the art will appreciate that the "product labels" required on all U.S. approved chemotherapeutics describe approved indications, dosing information, toxicity data, and the like, for the exemplary agents.

Table 1

Aldesleukin (des-alanyl-1, serine-125 human interleukin-2)	Proleukin	Chiron Corp., Emeryville, CA
Alemtuzumab (IgG1κ anti CD52 antibody)	Campath	Millennium and ILEX Partners, LP, Cambridge, MA
Alitretinoin (9-cis-retinoic acid)	Panretin	Ligand Pharmaceuticals, Inc., San Diego CA
Allopurinol (1,5-dihydro-4 H -pyrazolo[3,4-d]pyrimidin-4-one monosodium salt)	Zyloprim	GlaxoSmithKline, Research Triangle Park, NC
Altretamine (N,N,N',N',N",N",- hexamethyl-1,3,5-triazine-2, 4, 6-triamine)	Hexalen	US Bioscience, West Conshohocken, PA
Amifostine (ethanethiol, 2-[(3-aminopropyl)amino]-, dihydrogen phosphate (ester))	Ethyol	US Bioscience
Anastrozole (1,3-Benzenediacetonitrile, a, a, a', a'-tetramethyl-5-(1H-1,2,4-triazol-1-ylmethyl))	Arimidex	AstraZeneca Pharmaceuticals, LP, Wilmington, DE
Arsenic trioxide	Trisenox	Cell Therapeutic, Inc., Seattle, WA
Asparaginase (L-asparagine amidohydrolase, type EC-2)	Elspar	Merck & Co., Inc., Whitehouse Station, NJ

BCG Live (lyophilized preparation of an attenuated strain of *Mycobacterium bovis* (*Bacillus Calmette-Gukin* [BCG], substrain Montreal)	TICE BCG	Organon Teknika, Corp., Durham, NC
bexarotene capsules (4-[1-(5,6,7,8-tetrahydro-3,5,5,8,8-pentamethyl-2-napthalenyl) ethenyl] benzoic acid)	Targretin	Ligand Pharmaceuticals
bexarotene gel	Targretin	Ligand Pharmaceuticals
Bleomycin (cytotoxic glycopeptide antibiotics produced by *Streptomyces verticillus*; bleomycin A_2 and bleomycin B_2)	Blenoxane	Bristol-Myers Squibb Co., NY, NY
Capecitabine (5'-deoxy-5-fluoro-N-[(pentyloxy)carbonyl]-cytidine)	Xeloda	Roche
Carboplatin (platinum, diammine [1,1-cyclobutanedicarboxylato(2-)-0, 0']-,(SP-4-2))	Paraplatin	Bristol-Myers Squibb
Carmustine (1,3-bis(2-chloroethyl)-1-nitrosourea)	BCNU, BiCNU	Bristol-Myers Squibb
Carmustine with Polifeprosan 20 Implant	Gliadel Wafer	Guilford Pharmaceuticals, Inc., Baltimore, MD
Celecoxib (as 4-[5-(4-methylphenyl)-3- (trifluoromethyl)-1H-pyrazol-1-yl] benzenesulfonamide)	Celebrex	Searle Pharmaceuticals, England
Chlorambucil (4-[bis(2chlorethyl)amino]benzenebutanoic acid)	Leukeran	GlaxoSmithKline
Cisplatin ($PtCl_2H_6N_2$)	Platinol	Bristol-Myers Squibb
Cladribine (2-chloro-2'-deoxy-b-D-adenosine)	Leustatin, 2-CdA	R.W. Johnson Pharmaceutical Research Institute, Raritan, NJ
Cyclophosphamide (2-[bis(2-chloroethyl)amino] tetrahydro-2H-13,2-oxazaphosphorine 2-oxide monohydrate)	Cytoxan, Neosar	Bristol-Myers Squibb
Cytarabine (1-b-D-Arabinofuranosylcytosine, $C_9H_{13}N_3O_5$)	Cytosar-U	Pharmacia & Upjohn Company
cytarabine liposomal	DepoCyt	Skye Pharmaceuticals, Inc., San Diego, CA
Dacarbazine (5-(3,3-dimethyl-l-triazeno)-imidazole-4-carboxamide (DTIC))	DTIC-Dome	Bayer AG, Leverkusen, Germany
Dactinomycin, actinomycin D (actinomycin produced by *Streptomyces parvullus*, $C_{62}H_{86}N_{12}O_{16}$)	Cosmegen	Merck
Darbepoetin alfa (recombinant peptide)	Aranesp	Amgen, Inc., Thousand Oaks, CA
daunorubicin liposomal ((8S-cis)-8-acetyl-10-[(3-amino-2,3,6-trideoxy-á-L-lyxo-hexopyranosyl)oxy]-7,8,9,10-tetrahydro-6,8,11-trihydroxy-1-methoxy-5,12-naphthacenedione hydrochloride)	DanuoXome	Nexstar Pharmaceuticals, Inc., Boulder, CO
Daunorubicin HCl, daunomycin ((1 *S*,3 *S*)-3-Acetyl-1,2,3,4,6,11-hexahydro-3,5,12-trihydroxy-10-methoxy-6,11-dioxo-1-naphthacenyl 3-amino-2,3,6-trideoxy-(alpha)-L- *lyxo* -hexopyranoside hydrochloride)	Cerubidine	Wyeth Ayerst, Madison, NJ

Denileukin diftitox (recombinant peptide)	Ontak	Seragen, Inc., Hopkinton, MA
Dexrazoxane ((S)-4,4'-(1-methyl-1,2-ethanediyl)bis-2,6-piperazinedione)	Zinecard	Pharmacia & Upjohn Company
Docetaxel ((2R,3S)-N-carboxy-3-phenylisoserine, N-tert-butyl ester, 13-ester with 5b-20-epoxy-12a,4,7b,10b,13a-hexahydroxytax- 11-en-9-one 4-acetate 2-benzoate, trihydrate)	Taxotere	Aventis Pharmaceuticals, Inc., Bridgewater, NJ
Doxorubicin HCl (8S,10S)-10-[(3-amino-2,3,6-trideoxy-a-L-lyxo-hexopyranosyl)oxy] -8-glycolyl-7,8,9,10-tetrahydro-6,8,11- trihydroxy-1-methoxy-5,12-naphthacenedione hydrochloride)	Adriamycin, Rubex	Pharmacia & Upjohn Company
doxorubicin	Adriamycin PFS Intravenous injection	Pharmacia & Upjohn Company
doxorubicin liposomal	Doxil	Sequus Pharmaceuticals, Inc., Menlo park, CA
dromostanolone propionate (17b-Hydroxy-2a-methyl-5a-androstan-3-one propionate)	Dromostanolone	Eli Lilly & Company, Indianapolis, IN
dromostanolone propionate	Masterone injection	Syntex, Corp., Palo Alto, CA
Elliott's B Solution	Elliott's B Solution	Orphan Medical, Inc
Epirubicin ((8S-cis)-10-[(3-amino-2,3,6-trideoxy-a-L-arabino-hexopyranosyl)oxy]-7,8,9,10-tetrahydro-6,8,11-trihydroxy-8- (hydroxyacetyl)-1-methoxy-5,12-naphthacenedione hydrochloride)	Ellence	Pharmacia & Upjohn Company
Epoetin alfa (recombinant peptide)	Epogen	Amgen, Inc
Estramustine (estra-1,3,5(10)-triene-3,17-diol(17(beta))-, 3-[bis(2-chloroethyl)carbamate] 17-(dihydrogen phosphate), disodium salt, monohydrate, or estradiol 3-[bis(2-chloroethyl)carbamate] 17-(dihydrogen phosphate), disodium salt, monohydrate)	Emcyt	Pharmacia & Upjohn Company
Etoposide phosphate (4'-Demethylepipodophyllotoxin 9-[4,6-O-(R)-ethylidene-(beta)-D-glucopyranoside], 4'-(dihydrogen phosphate))	Etopophos	Bristol-Myers Squibb
etoposide, VP-16 (4'-demethylepipodophyllotoxin 9-[4,6-0-(R)-ethylidene-(beta)-D-glucopyranoside])	Vepesid	Bristol-Myers Squibb
Exemestane (6-methylenandrosta-1,4-diene-3, 17-dione)	Aromasin	Pharmacia & Upjohn Company
Filgrastim (r-metHuG-CSF)	Neupogen	Amgen, Inc
floxuridine (intraarterial) (2'-deoxy-5-fluorouridine)	FUDR	Roche
Fludarabine (fluorinated nucleotide analog of the antiviral agent vidarabine, 9-b -D-arabinofuranosyladenine (ara-A))	Fludara	Berlex Laboratories, Inc., Cedar Knolls, NJ
Fluorouracil, 5-FU (5-fluoro-2,4(1H,3H)-pyrimidinedione)	Adrucil	ICN Pharmaceuticals, Inc., Humacao, Puerto Rico

Fulvestrant (7-alpha-[9-(4,4,5,5,5-penta fluoropentylsulphinyl) nonyl]estra-1,3,5-(10)- triene-3,17-beta-diol)	Faslodex	IPR Pharmaceuticals, Guayama, Puerto Rico
Gemcitabine (2'-deoxy-2', 2'-difluorocytidine monohydrochloride (b-isomer))	Gemzar	Eli Lilly
Gemtuzumab Ozogamicin (anti-CD33 hP67.6)	Mylotarg	Wyeth Ayerst
Goserelin acetate (acetate salt of [D-Ser(But)^6,Azgly^{10}]LHRH; pyro-Glu-His-Trp-Ser-Tyr-D-Ser(But)-Leu-Arg-Pro-Azgly-NH2 acetate [$C_{59}H_{84}N_{18}O_{14}$ •$(C_2H_4O_2)_x$	Zoladex Implant	AstraZeneca Pharmaceuticals
Hydroxyurea	Hydrea	Bristol-Myers Squibb
Ibritumomab Tiuxetan (immunoconjugate resulting from a thiourea covalent bond between the monoclonal antibody Ibritumomab and the linker-chelator tiuxetan [N-[2-bis(carboxymethyl)amino]-3-(p-isothiocyanatophenyl)-propyl]-[N-[2-bis(carboxymethyl)amino]-2-(methyl) -ethyl]glycine)	Zevalin	Biogen IDEC, Inc., Cambridge MA
Idarubicin (5, 12-Naphthacenedione, 9-acetyl-7-[(3-amino-2,3,6-trideoxy-(alpha)-L- lyxo -hexopyranosyl)oxy]-7,8,9,10-tetrahydro-6,9,11-trihydroxyhydrochloride, (7S- cis))	Idamycin	Pharmacia & Upjohn Company
Ifosfamide (3-(2-chloroethyl)-2-[(2-chloroethyl)amino]tetrahydro-2H-1,3,2-oxazaphosphorine 2-oxide)	IFEX	Bristol-Myers Squibb
Imatinib Mesilate (4-[(4-Methyl-1-piperazinyl)methyl]-N-[4-methyl-3-[[4-(3-pyridinyl)-2-pyrimidinyl]amino]-phenyl]benzamide methanesulfonate)	Gleevec	Novartis AG, Basel, Switzerland
Interferon alfa-2a (recombinant peptide)	Roferon-A	Hoffmann-La Roche, Inc., Nutley, NJ
Interferon alfa-2b (recombinant peptide)	Intron A (Lyophilized Betaseron)	Schering AG, Berlin, Germany
Irinotecan HCl ((4S)-4,11-diethyl-4-hydroxy-9-[(4- piperi-dinopiperidino)carbonyloxy]-1H-pyrano[3', 4': 6,7] indolizino[1,2-b] quinoline-3,14(4H, 12H) dione hydrochloride trihydrate)	Camptosar	Pharmacia & Upjohn Company
Lenalidomide 3-(4-amino-1-oxo 1,3-dihydro-2H-isoindol-2-yl) piperidine-2,6-dione	Revlimid	Celgene
Letrozole (4,4'-(1H-1,2,4 -Triazol-1-ylmethylene) dibenzonitrile)	Femara	Novartis
Leucovorin (L-Glutamic acid, N[4[[(2amino-5-formyl1,4,5,6,7,8 -hexahydro4oxo6-pteridinyl)methyl]amino]benzoyl], calcium salt (1:1))	Wellcovorin, Leucovorin	Immunex, Corp., Seattle, WA
Levamisole HCl ((-)-(S)-2,3,5, 6-tetrahydro-6-phenylimidazo [2,1-b] thiazole monohydrochloride $C_{11}H_{12}N_2S$·HCl)	Ergamisol	Janssen Research Foundation, Titusville, NJ
Lomustine (1-(2-chloro-ethyl)-3-cyclohexyl-1-nitrosourea)	CeeNU	Bristol-Myers Squibb

Meclorethamine, nitrogen mustard (2-chloro-N-(2-chloroethyl)-N-methylethanamine hydrochloride)	Mustargen	Merck
Megestrol acetate 17α(acetyloxy)- 6- methylpregna- 4,6- diene- 3,20- dione	Megace	Bristol-Myers Squibb
Melphalan, L-PAM (4-[bis(2-chloroethyl) amino]-L-phenylalanine)	Alkeran	GlaxoSmithKline
Mercaptopurine, 6-MP (1,7-dihydro-6 H -purine-6-thione monohydrate)	Purinethol	GlaxoSmithKline
Mesna (sodium 2-mercaptoethane sulfonate)	Mesnex	Asta Medica
Methotrexate (N-[4-[[(2,4-diamino-6-pteridinyl)methyl]methylamino]benzoyl]-L-glutamic acid)	Methotrexate	Lederle Laboratories
Methoxsalen (9-methoxy-7H-furo[3,2-g][1]-benzopyran-7-one)	Uvadex	Therakos, Inc., Way Exton, Pa
Mitomycin C	Mutamycin	Bristol-Myers Squibb
mitomycin C	Mitozytrex	SuperGen, Inc., Dublin, CA
Mitotane (1,1-dichloro-2-(o-chlorophenyl)-2-(p-chlorophenyl) ethane)	Lysodren	Bristol-Myers Squibb
Mitoxantrone (1,4-dihydroxy-5,8-bis[[2- [(2-hydroxyethyl)amino]ethyl]amino]-9,10-anthracenedione dihydrochloride)	Novantrone	Immunex Corporation
Nandrolone phenpropionate	Durabolin-50	Organon, Inc., West Orange, NJ
Nofetumomab	Verluma	Boehringer Ingelheim Pharma KG, Germany
Oprelvekin (IL-11)	Neumega	Genetics Institute, Inc., Alexandria, VA
Oxaliplatin (cis-[(1R,2R)-1,2-cyclohexanediamine-N,N'] [oxalato(2-)-O,O'] platinum)	Eloxatin	Sanofi Synthelabo, Inc., NY, NY
Paclitaxel (5ß, 20-Epoxy-1,2a, 4,7ß, 10ß, 13a-hexahydroxytax-11-en-9-one 4,10-diacetate 2- benzoate 13-ester with (2R, 3 S)- N-benzoyl-3-phenylisoserine)	TAXOL	Bristol-Myers Squibb
Pamidronate (phosphonic acid (3-amino-1-hydroxypropylidene) bis-, disodium salt, pentahydrate, (APD))	Aredia	Novartis
Pegademase ((monomethoxypolyethylene glycol succinimidyl) 11 - 17 -adenosine deaminase)	Adagen (Pegademase Bovine)	Enzon Pharmaceuticals, Inc., Bridgewater, NJ
Pegaspargase (monomethoxypolyethylene glycol succinimidyl L-asparaginase)	Oncaspar	Enzon
Pegfilgrastim (covalent conjugate of recombinant methionyl human G-CSF (Filgrastim) and monomethoxypolyethylene glycol)	Neulasta	Amgen, Inc
Pentostatin	Nipent	Parke-Davis Pharmaceutical Co., Rockville, MD
Pipobroman	Vercyte	Abbott Laboratories, Abbott Park, IL
Plicamycin, Mithramycin (antibiotic produced by *Streptomyces plicatus*)	Mithracin	Pfizer, Inc., NY, NY

Porfimer sodium	Photofrin	QLT Phototherapeutics, Inc., Vancouver, Canada
Procarbazine (N-isopropyl-μ-(2-methylhydrazino)-p-toluamide monohydrochloride)	Matulane	Sigma Tau Pharmaceuticals, Inc., Gaithersburg, MD
Quinacrine (6-chloro-9-(1 –methyl-4-diethyl-amine) butylamino-2-methoxyacridine)	Atabrine	Abbott Labs
Rasburicase (recombinant peptide)	Elitek	Sanofi-Synthelabo, Inc.,
Rituximab (recombinant anti-CD20 antibody)	Rituxan	Genentech, Inc., South San Francisco, CA
Sargramostim (recombinant peptide)	Prokine	Immunex Corp
Streptozocin (streptozocin 2 –deoxy - 2 - [[(methylnitrosoamino)carbonyl]amino] - a(and b) - D - glucopyranose and 220 mg citric acid anhydrous)	Zanosar	Pharmacia & Upjohn Company
Talc ($Mg_3Si_4O_{10}(OH)_2$)	Sclerosol	Bryan, Corp., Woburn, MA
Tamoxifen ((Z)2-[4-(1,2-diphenyl-1-butenyl) phenoxy]-N, N-dimethylethanamine 2-hydroxy-1,2,3-propanetricarboxylate (1:1))	Nolvadex	AstraZeneca Pharmaceuticals
Temozolomide (3,4-dihydro-3-methyl-4-oxoimidazo[5,1-d]-as-tetrazine-8-carboxamide)	Temodar	Schering
teniposide, VM-26 (4'-demethylepipodophyllotoxin 9-[4,6-0-(R)-2-thenylidene-(beta)-D-glucopyranoside])	Vumon	Bristol-Myers Squibb
Testolactone (13-hydroxy-3-oxo-13,17-secoandrosta-1,4-dien-17-oic acid [dgr]-lactone)	Teslac	Bristol-Myers Squibb
Thioguanine, 6-TG (2-amino-1,7-dihydro-6 H - purine-6-thione)	Thioguanine	GlaxoSmithKline
Thiotepa (Aziridine, 1,1',1"-phosphinothioylidynetris-, or Tris (1-aziridinyl) phosphine sulfide)	Thioplex	Immunex Corporation
Topotecan HCl ((S)-10-[(dimethylamino) methyl]-4-ethyl-4,9-dihydroxy-1H-pyrano[3', 4': 6,7] indolizino [1,2-b] quinoline-3,14-(4H,12H)-dione monohydrochloride)	Hycamtin	GlaxoSmithKline
Toremifene (2-(p-[(Z)-4-chloro-1,2-diphenyl-1-butenyl]-phenoxy)-N,N-dimethylethylamine citrate (1:1))	Fareston	Roberts Pharmaceutical Corp., Eatontown, NJ
Tositumomab, I 131 Tositumomab (recombinant murine immunotherapeutic monoclonal IgG_{2a} lambda anti-CD20 antibody (I 131 is a radioimmunotherapeutic antibody))	Bexxar	Corixa Corp., Seattle, WA
Trastuzumab (recombinant monoclonal IgG_1 kappa anti-HER2 antibody)	Herceptin	Genentech, Inc
Tretinoin, ATRA (all-trans retinoic acid)	Vesanoid	Roche
Uracil Mustard	Uracil Mustard Capsules	Roberts Labs

Valrubicin, N-trifluoroacetyladriamycin-14-valerate ((2S-cis)-2- [1,2,3,4,6,11-hexahydro-2,5,12-trihydroxy-7 methoxy-6,11-dioxo-[[4 2,3,6-trideoxy-3-[(trifluoroacetyl)-amino-α-L-*lyxo*-hexopyranosyl]oxyl]-2-naphthacenyl]-2-oxoethyl pentanoate)	Valstar	Anthra --> Medeva
Vinblastine, Leurocristine ($C_{46}H_{56}N_4O_{10}$•H_2SO_4)	Velban	Eli Lilly
Vincristine ($C_{46}H_{56}N_4O_{10}$•H_2SO_4)	Oncovin	Eli Lilly
Vinorelbine (3',4'-didehydro-4'-deoxy-C'-norvincaleukoblastine [R-(R*,R*)-2,3-dihydroxybutanedioate (1:2)(salt)])	Navelbine	GlaxoSmithKline
Zoledronate, Zoledronic acid ((1-Hydroxy-2-imidazol-1-yl-phosphonoethyl) phosphonic acid monohydrate)	Zometa	Novartis

[0111] Anticancer agents further include compounds which have been identified to have anticancer activity but are not currently approved by the U.S. Food and Drug Administration or other counterpart agencies or are undergoing evaluation for new uses. Examples include, but are not limited to, 3-AP, 12-O-tetradecanoylphorbol-13-acetate, 17AAG, 852A, ABI-007, ABR-217620, ABT-751, ADI-PEG 20, AE-941, AG-013736, AGRO100, alanosine, AMG 706, antibody G250, antineoplastons, AP23573, apaziquone, APC8015, atiprimod, ATN-161, atrasenten, azacitidine, BB-10901, BCX-1777, bevacizumab, BG00001, bicalutamide, BMS 247550, bortezomib, bryostatin-1, buserelin, calcitriol, CCI-779, CDB-2914, cefixime, cetuximab, CG0070, cilengitide, clofarabine, combretastatin A4 phosphate, CP-675,206, CP-724,714, CpG 7909, curcumin, decitabine, DENSPM, doxercalciferol, E7070, E7389, ecteinascidin 743, efaproxiral, eflornithine, EKB-569, enzastaurin, erlotinib, exisulind, fenretinide, flavopiridol, fludarabine, flutamide, fotemustine, FR901228, G17DT, galiximab, gefitinib, genistein, glufosfamide, GTI-2040, histrelin, HKI-272, homoharringtonine, HSPPC-96, hu14.18-interleukin-2 fusion protein, HuMax-CD4, iloprost, imiquimod, infliximab, interleukin-12, IPI-504, irofulven, ixabepilone, lapatinib, lestaurtinib, leuprolide, LMB-9 immunotoxin, lonafarnib, luniliximab, mafosfamide, MB07133, MDX-010, MLN2704, monoclonal antibody 3F8, monoclonal antibody J591, motexafin, MS-275, MVA-MUC1-IL2, nilutamide, nitrocamptothecin, nolatrexed dihydrochloride, nolvadex, NS-9, O6-benzylguanine, oblimersen sodium, ONYX-015, oregovomab, OSI-774, panitumumab, paraplatin, PD-0325901, pemetrexed, PHY906, pioglitazone, pirfenidone, pixantrone, PS-341, PSC 833, PXD101, pyrazoloacridine, R115777,

RAD001, ranpirnase, rebeccamycin analogue, rhuAngiostatin protein, rhuMab 2C4, rosiglitazone, rubitecan, S-1, S-8184, satraplatin, SB-, 15992, SGN-0010, SGN-40, sorafenib, SR31747A, ST1571, SU011248, suberoylanilide hydroxamic acid, suramin, talabostat, talampanel, tariquidar, temsirolimus, TGFa-PE38 immunotoxin, thalidomide, thymalfasin, tipifarnib, tirapazamine, TLK286, trabectedin, trimetrexate glucuronate, TroVax, UCN-1, valproic acid, vinflunine, VNP40101M, volociximab, vorinostat, VX-680, ZD1839, ZD6474, zileuton, and zosuquidar trihydrochloride.

[0112] For a more detailed description of anticancer agents and other therapeutic agents, those skilled in the art are referred to any number of instructive manuals including, but not limited to, the Physician's Desk Reference and to Goodman and Gilman's "Pharmaceutical Basis of Therapeutics" tenth edition, Eds. Hardman et al., 2002.

[0113] The present invention provides methods for administering a compound of Formula II with radiation therapy. The invention is not limited by the types, amounts, or delivery and administration systems used to deliver the therapeutic dose of radiation to an animal. For example, the animal may receive photon radiotherapy, particle beam radiation therapy, other types of radiotherapies, and combinations thereof. In some embodiments, the radiation is delivered to the animal using a linear accelerator. In still other embodiments, the radiation is delivered using a gamma knife.

[0114] The source of radiation can be external or internal to the animal. External radiation therapy is most common and involves directing a beam of high-energy radiation to a tumor site through the skin using, for instance, a linear accelerator. While the beam of radiation is localized to the tumor site, it is nearly impossible to avoid exposure of normal, healthy tissue. However, external radiation is usually well tolerated by animals. Internal radiation therapy involves implanting a radiation-emitting source, such as beads, wires, pellets, capsules, particles, and the like, inside the body at or near the tumor site including the use of delivery systems that specifically target cancer cells (e.g., using particles attached to cancer cell binding ligands). Such implants can be removed following treatment, or left in the body inactive. Types of internal radiation therapy include, but are not limited to,

brachytherapy, interstitial irradiation, intracavity irradiation, radioimmunotherapy, and the like.

[0115] The animal may optionally receive radiosensitizers (e.g., metronidazole, misonidazole, intra-arterial Budr, intravenous iododeoxyuridine (IudR), nitroimidazole, 5-substituted-4-nitroimidazoles, 2H-isoindolediones, [[(2-bromoethyl)-amino]methyl]-nitro-1H-imidazole-1-ethanol, nitroaniline derivatives, DNA-affinic hypoxia selective cytotoxins, halogenated DNA ligand, 1,2,4 benzotriazine oxides, 2-nitroimidazole derivatives, fluorine-containing nitroazole derivatives, benzamide, nicotinamide, acridine-intercalator, 5-thiotretrazole derivative, 3-nitro-1,2,4-triazole, 4,5-dinitroimidazole derivative, hydroxylated texaphrins, cisplatin, mitomycin, tiripazamine, nitrosourea, mercaptopurine, methotrexate, fluorouracil, bleomycin, vincristine, carboplatin, epirubicin, doxorubicin, cyclophosphamide, vindesine, etoposide, paclitaxel, heat (hyperthermia), and the like), radioprotectors (e.g., cysteamine, aminoalkyl dihydrogen phosphorothioates, amifostine (WR 2721), IL-1, IL-6, and the like). Radiosensitizers enhance the killing of tumor cells. Radioprotectors protect healthy tissue from the harmful effects of radiation.

[0116] Any type of radiation can be administered to an animal, so long as the dose of radiation is tolerated by the patient without unacceptable negative side-effects. Suitable types of radiotherapy include, for example, ionizing (electromagnetic) radiotherapy (e.g., X-rays or gamma rays) or particle beam radiation therapy (e.g., high linear energy radiation). Ionizing radiation is defined as radiation comprising particles or photons that have sufficient energy to produce ionization, i.e., gain or loss of electrons (as described in, for example, U.S. 5,770,581 incorporated herein by reference in its entirety). The effects of radiation can be at least partially controlled by the clinician. The dose of radiation is preferably fractionated for maximal target cell exposure and reduced toxicity.

[0117] The total dose of radiation administered to an animal preferably is about .01 Gray (Gy) to about 100 Gy. More preferably, about 10 Gy to about 65 Gy (e.g., about 15 Gy, 20 Gy, 25 Gy, 30 Gy, 35 Gy, 40 Gy, 45 Gy, 50 Gy, 55 Gy, or 60 Gy) are administered over the course of treatment. While in some embodiments a complete dose of radiation can be administered over the course of one day, the total dose is ideally fractionated and administered over several days. Desirably,

radiotherapy is administered over the course of at least about 3 days, e.g., at least 5, 7, 10, 14, 17, 21, 25, 28, 32, 35, 38, 42, 46, 52, or 56 days (about 1-8 weeks). Accordingly, a daily dose of radiation will comprise approximately 1-5 Gy (e.g., about 1 Gy, 1.5 Gy, 1.8 Gy, 2 Gy, 2.5 Gy, 2.8 Gy, 3 Gy, 3.2 Gy, 3.5 Gy, 3.8 Gy, 4 Gy, 4.2 Gy, or 4.5 Gy), preferably 1-2 Gy (e.g., 1.5-2 Gy). The daily dose of radiation should be sufficient to induce destruction of the targeted cells. If stretched over a period, radiation preferably is not administered every day, thereby allowing the animal to rest and the effects of the therapy to be realized. For example, radiation desirably is administered on 5 consecutive days, and not administered on 2 days, for each week of treatment, thereby allowing 2 days of rest per week. However, radiation can be administered 1 day/week, 2 days/week, 3 days/week, 4 days/week, 5 days/week, 6 days/week, or all 7 days/week, depending on the animal's responsiveness and any potential side effects. Radiation therapy can be initiated at any time in the therapeutic period. Preferably, radiation is initiated in week 1 or week 2, and is administered for the remaining duration of the therapeutic period. For example, radiation is administered in weeks 1-6 or in weeks 2-6 of a therapeutic period comprising 6 weeks for treating, for instance, a solid tumor. Alternatively, radiation is administered in weeks 1-5 or weeks 2-5 of a therapeutic period comprising 5 weeks. These exemplary radiotherapy administration schedules are not intended, however, to limit the present invention.

[0118] Antimicrobial therapeutic agents may also be used as therapeutic agents in the present invention. Any agent that can kill, inhibit, or otherwise attenuate the function of microbial organisms may be used, as well as any agent contemplated to have such activities. Antimicrobial agents include, but are not limited to, natural and synthetic antibiotics, antibodies, inhibitory proteins (e.g., defensins), antisense nucleic acids, membrane disruptive agents and the like, used alone or in combination. Indeed, any type of antibiotic may be used including, but not limited to, antibacterial agents, antiviral agents, antifungal agents, and the like.

[0119] In some embodiments of the present invention, a compound of Formula II and one or more therapeutic agents or anticancer agents are administered to an animal under one or more of the following conditions: at different periodicities, at different durations, at different concentrations, by different administration routes, etc. In some embodiments, the compound is administered prior to the therapeutic or

anticancer agent, e.g., 0.5, 1, 2 3, 4, 5, 10, 12, or 18 hours, 1, 2, 3, 4, 5, or 6 days, 1, 2, 3, or 4 weeks prior to the administration of the therapeutic or anticancer agent. In some embodiments, the compound is administered after the therapeutic or anticancer agent, e.g., 0.5, 1, 2 3, 4, 5, 10, 12, or 18 hours, 1, 2, 3, 4, 5, or 6 days, 1, 2, 3, or 4 weeks after the administration of the anticancer agent. In some embodiments, the compound and the therapeutic or anticancer agent are administered concurrently but on different schedules, e.g., the compound is administered daily while the therapeutic or anticancer agent is administered once a week, once every two weeks, once every three weeks, or once every four weeks. In other embodiments, the compound is administered once a week while the therapeutic or anticancer agent is administered daily, once a week, once every two weeks, once every three weeks, or once every four weeks.

[0120] Compositions within the scope of this invention include all compositions wherein the compounds of the present invention are contained in an amount which is effective to achieve its intended purpose. While individual needs vary, determination of optimal ranges of effective amounts of each component is within the skill of the art. Typically, the compounds may be administered to mammals, e.g. humans, orally at a dose of 0.0025 to 50 mg/kg, or an equivalent amount of the pharmaceutically acceptable salt thereof, per day of the body weight of the mammal being treated for disorders responsive to induction of apoptosis. Preferably, about 0.01 to about 25 mg/kg is orally administered to treat, ameliorate, or prevent such disorders. For intramuscular injection, the dose is generally about one-half of the oral dose. For example, a suitable intramuscular dose would be about 0.0025 to about 25 mg/kg, and most preferably, from about 0.01 to about 5 mg/kg.

[0121] The unit oral dose may comprise from about 0.01 to about 1000 mg, preferably about 0.1 to about 100 mg of the compound. The unit dose may be administered one or more times daily as one or more tablets or capsules each containing from about 0.1 to about 10, conveniently about 0.25 to 50 mg of the compound or its solvates.

[0122] In a topical formulation, the compound may be present at a concentration of about 0.01 to 100 mg per gram of carrier. In a preferred embodiment, the compound is present at a concentration of about 0.07-1.0 mg/ml, more preferably, about 0.1-0.5 mg/ml, most preferably, about 0.4 mg/ml.

[0123] In addition to administering the compound as a raw chemical, the compounds of the invention may be administered as part of a pharmaceutical preparation containing suitable pharmaceutically acceptable carriers comprising excipients and auxiliaries which facilitate processing of the compounds into preparations which can be used pharmaceutically. Preferably, the preparations, particularly those preparations which can be administered orally or topically and which can be used for the preferred type of administration, such as tablets, dragees, slow release lozenges and capsules, mouth rinses and mouth washes, gels, liquid suspensions, hair rinses, hair gels, shampoos and also preparations which can be administered rectally, such as suppositories, as well as suitable solutions for administration by intravenous infusion, injection, topically or orally, contain from about 0.01 to 99 percent, preferably from about 0.25 to 75 percent of active compound(s), together with the excipient.

[0124] The pharmaceutical compositions of the invention may be administered to any animal which may experience the beneficial effects of the compounds of the invention. Foremost among such animals are mammals, e.g., humans, although the invention is not intended to be so limited. Other animals include veterinary animals (cows, sheep, pigs, horses, dogs, cats and the like).

[0125] The compounds and pharmaceutical compositions thereof may be administered by any means that achieve their intended purpose. For example, administration may be by parenteral, subcutaneous, intravenous, intramuscular, intraperitoneal, transdermal, buccal, intrathecal, intracranial, intranasal or topical routes. Alternatively, or concurrently, administration may be by the oral route. The dosage administered will be dependent upon the age, health, and weight of the recipient, kind of concurrent treatment, if any, frequency of treatment, and the nature of the effect desired.

[0126] The pharmaceutical preparations of the present invention are manufactured in a manner which is itself known, for example, by means of conventional mixing, granulating, dragee-making, dissolving, or lyophilizing processes. Thus, pharmaceutical preparations for oral use can be obtained by combining the active compounds with solid excipients, optionally grinding the resulting mixture and processing the mixture of granules, after adding suitable auxiliaries, if desired or necessary, to obtain tablets or dragee cores.

[0127] Suitable excipients are, in particular, fillers such as saccharides, for example lactose or sucrose, mannitol or sorbitol, cellulose preparations and/or calcium phosphates, for example tricalcium phosphate or calcium hydrogen phosphate, as well as binders such as starch paste, using, for example, maize starch, wheat starch, rice starch, potato starch, gelatin, tragacanth, methyl cellulose, hydroxypropylmethylcellulose, sodium carboxymethylcellulose, and/or polyvinyl pyrrolidone. If desired, disintegrating agents may be added such as the above-mentioned starches and also carboxymethyl-starch, cross-linked polyvinyl pyrrolidone, agar, or alginic acid or a salt thereof, such as sodium alginate. Auxiliaries are, above all, flow-regulating agents and lubricants, for example, silica, talc, stearic acid or salts thereof, such as magnesium stearate or calcium stearate, and/or polyethylene glycol. Dragee cores are provided with suitable coatings which, if desired, are resistant to gastric juices. For this purpose, concentrated saccharide solutions may be used, which may optionally contain gum arabic, talc, polyvinyl pyrrolidone, polyethylene glycol and/or titanium dioxide, lacquer solutions and suitable organic solvents or solvent mixtures. In order to produce coatings resistant to gastric juices, solutions of suitable cellulose preparations such as acetylcellulose phthalate or hydroxypropylmethyl-cellulose phthalate, are used. Dye stuffs or pigments may be added to the tablets or dragee coatings, for example, for identification or in order to characterize combinations of active compound doses.

[0128] Other pharmaceutical preparations which can be used orally include push-fit capsules made of gelatin, as well as soft, sealed capsules made of gelatin and a plasticizer such as glycerol or sorbitol. The push-fit capsules can contain the active compounds in the form of granules which may be mixed with fillers such as lactose, binders such as starches, and/or lubricants such as talc or magnesium stearate and, optionally, stabilizers. In soft capsules, the active compounds are preferably dissolved or suspended in suitable liquids, such as fatty oils, or liquid paraffin. In addition, stabilizers may be added.

[0129] Possible pharmaceutical preparations which can be used rectally include, for example, suppositories, which consist of a combination of one or more of the active compounds with a suppository base. Suitable suppository bases are, for example, natural or synthetic triglycerides, or paraffin hydrocarbons. In addition, it is also possible to use gelatin rectal capsules which consist of a combination of the active

compounds with a base. Possible base materials include, for example, liquid triglycerides, polyethylene glycols, or paraffin hydrocarbons.

[0130] Suitable formulations for parenteral administration include aqueous solutions of the active compounds in water-soluble form, for example, water-soluble salts and alkaline solutions. In addition, suspensions of the active compounds as appropriate oily injection suspensions may be administered. Suitable lipophilic solvents or vehicles include fatty oils, for example, sesame oil, or synthetic fatty acid esters, for example, ethyl oleate or triglycerides or polyethylene glycol-400. Aqueous injection suspensions may contain substances which increase the viscosity of the suspension include, for example, sodium carboxymethyl cellulose, sorbitol, and/or dextran. Optionally, the suspension may also contain stabilizers.

[0131] The topical compositions of this invention are formulated preferably as oils, creams, lotions, ointments and the like by choice of appropriate carriers. Suitable carriers include vegetable or mineral oils, white petrolatum (white soft paraffin), branched chain fats or oils, animal fats and high molecular weight alcohol (greater than C12). The preferred carriers are those in which the active ingredient is soluble. Emulsifiers, stabilizers, humectants and antioxidants may also be included as well as agents imparting color or fragrance, if desired. Additionally, transdermal penetration enhancers can be employed in these topical formulations. Examples of such enhancers can be found in U.S. Pat. Nos. 3,989,816 and 4,444,762.

[0132] Creams are preferably formulated from a mixture of mineral oil, self-emulsifying beeswax and water in which mixture the active ingredient, dissolved in a small amount of an oil such as almond oil, is admixed. A typical example of such a cream is one which includes about 40 parts water, about 20 parts beeswax, about 40 parts mineral oil and about 1 part almond oil.

[0133] Ointments may be formulated by mixing a solution of the active ingredient in a vegetable oil such as almond oil with warm soft paraffin and allowing the mixture to cool. A typical example of such an ointment is one which includes about 30% almond oil and about 70% white soft paraffin by weight.

[0134] Lotions may be conveniently prepared by dissolving the active ingredient, in a suitable high molecular weight alcohol such as propylene glycol or polyethylene glycol.

[0135] The following examples are illustrative, but not limiting, of the method and compositions of the present invention. Other suitable modifications and adaptations of the variety of conditions and parameters normally encountered in clinical therapy and which are obvious to those skilled in the art are within the spirit and scope of the invention.

EXAMPLE 1

Synthesis of Bivalent Smac Mimetics

[0136] General Methods: NMR spectra were acquired at a proton frequency of 300 MHz. ^{1}H chemical shifts are reported with Me_4Si (0.00 ppm), $CHCl_3$ (7.26 ppm), CD_2HOD (3.31 ppm), or DHO 04.79 ppm) as internal standards. ^{13}C chemical shifts are reported with $CDCl_3$ (77.00 ppm), CD_3OD (49.00 ppm), or 1,4-dioxane (67.16 ppm) as internal standards. Optical rotations were measured at room temperature.

General procedure A (condensation):

[0137] To a solution of the two substrates in CH_2Cl_2 (20 mg/mL for the minor substrate) was added EDC (1.1 eq per amino group), HOBt (1.1 eq per amino group) and N,N-diisopropylethyl amine (4 eq per amino group) at 0 °C with stirring. The mixture was stirred at room temperature for eight hours and then condensed. The residue was purified by chromatography to give the product.

General procedure B (click chemistry):

[0138] To a solution of $CuSO_4$ (10 mg/mL) was added (+)-sodium L-ascorbate (2 eq). The mixture was shaken until the color turned to bright yellow. To a solution of the two substrates in acetonotrile or 2-methylpropanol (20 mg/mL for the minor substrate) was added the pre-made mixture of $CuSO_4$-sodium L-ascorbate (0.1 eq of $CuSO_4$ per 1 eq of the minor substrate). The mixture was stirred at room temperature overnight and then extracted with dichloromethane three times. The combined organic layer was washed with brine, dried over Na_2SO_4 and condensed. The residue was purified by chromatography to give the product.

General procedure C (deprotection of Boc):

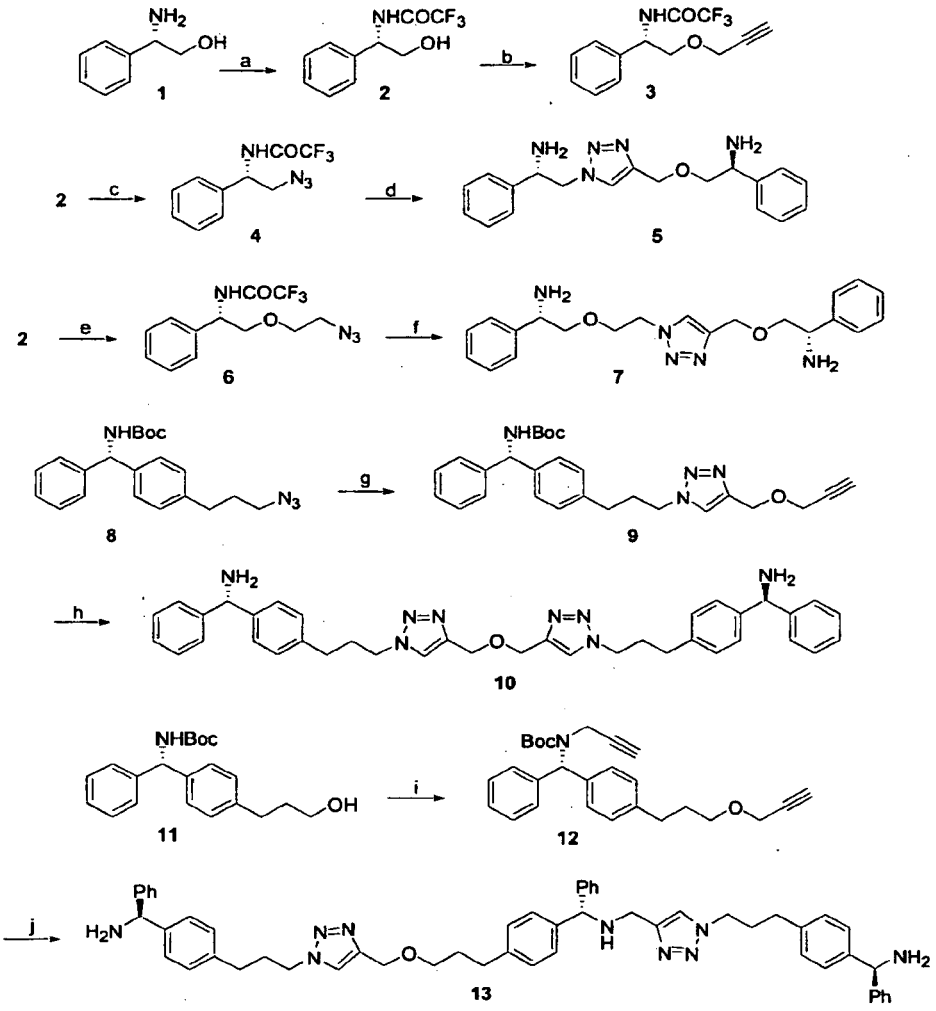
[0139] To a solution of the substrate in methanol (20 mg/mL) was added a solution of HCl in 1,4-dioxane (4 M, 10-20 eq per Boc). The solution was stirred at room temperature overnight and then condensed to give the product.

EXAMPLE 2

Synthesis of DQ-24, SH-143, SH-155 and SH-142

[0140] Compounds DQ-24, SH-143, SH-155 and SH-142 were synthesized according to Scheme I.

Scheme I:



Reagents and condititons: (a) i. trifluoroacetic anhydride, Et_3N, CH_2Cl_2, rt; ii. $NaHCO_3$, MeOH, 95%; (b) NaH, propargyl bromide, DMF, 92%; (c) i. MsCl, Et_3N; ii. NaN_3, DMF, 100 °C, 85% over two steps; (d) i. **3**, $CuSO_4$, (+)-sodium L-ascorbate, CH_3CN-H2O 3:1; ii. 2N LiOH, 1,4-dioxane-H_2O 1:1, 74% over two steps; (e) i. NaH, benzyl 2-bromoethyl ether; ii. 10% Pd-C, H_2, MeOH; iii. MsCl, Et_3N; iv. NaN_3, DMF, 65% over four steps; (f) i. **3**, $CuSO_4$, (+)-sodium L-ascorbate, CH_3CN-H_2O 3:1; ii. 2N LiOH, 1,4-dioxane-H_2O 1:1, 72% over two steps; (g) propargyl ether (5 eq), $CuSO_4$, (+)-sodium L-ascorbate, CH_3CN-H_2O 3:1, 69%; (h) i. **8**, $CuSO_4$, (+)-sodium L-ascorbate, CH_3CN-H_2O 3:1, ii. 4N HCl in 1,4-dioxane, MeOH, 95%; (i) NaH, propargyl bromide, DMF, 82%; (j) i. **8** (2.2 eq), $CuSO_4$, (+)-sodium L-ascorbate, CH_3CN-H_2O 3:1, ii. 4N HCl in 1,4-dioxane, MeOH, 62% over two steps.

[0141] Selective protection of the amino group in L-phenylglycinol **1** with trifluoroacetic anhydride gave an alcohol **2**. Alkylation of 2 with propargyl bromide yielded an alkyne **3**. Reaction of **2** with methanesulfonyl chloride followed by substitution of the resulted mesylate with NaN_3 furnished an azide **4**. Cycloaddition of **3** and **4** under the catalyzation of $CuSO_4$-(+)-sodium-L-ascorbate followed by removal of the trifluoro acetyl groups afforded a diamine 5.

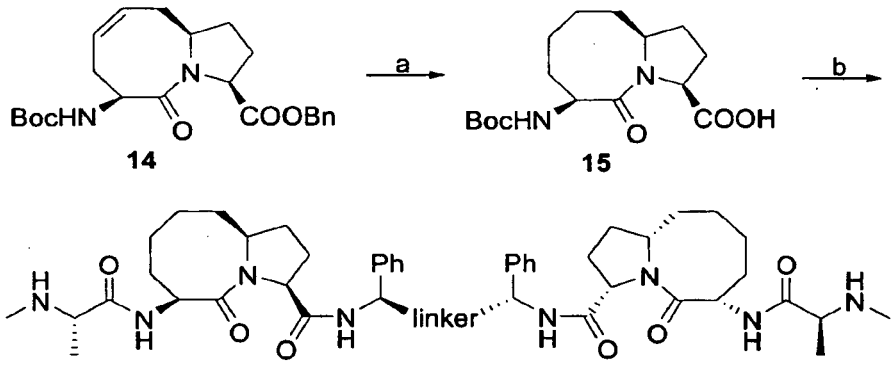
[0142] Alkylation of **2** with benzyl 2-bromoethyl ether followed by hydrolysis of the benzyl protecting group furnished an alcohol. Reaction of this alcohol with

methanesulfonyl chloride followed by substitution of the resulted mesylate with NaN_3 furnished azide **6**. Cycloaddition of **6** with **3** under the catalyzation of $CuSO_4$-(+)-sodium-L-ascorbate followed by removal of the trifluoro acetyl groups afforded a diamine **7**.

[0143] Compound **8** was synthesized according to our previously reported method (Sun *et al., Tetrahedron Letters, 46:7015* (2005)). Cycloaddition of compound **8** with excessive amount of propargyl ether (5-10 eq) yielded an alkyne **9**. Cycloaddition of **9** and **8** under the catalyzation of $CuSO_4$-(+)-sodium-L-ascorbate followed by removal of the Boc protecting groups afforded a diamine **10**.

[0144] Compound **11** was synthesized according to our previously reported method (Sun *et al., Tetrahedron Letters, 46:7015* (2005)). Alkylation of **11** with propargyl bromide yielded an alkyne **12**. Cycloaddition of 2.2 eq of **8** with 1 eq of **12** under the catalyzation of $CuSO_4$-(+)-sodium-L-ascorbate followed by removal of the Boc protecting groups afforded a diamine **13**.

Scheme II:



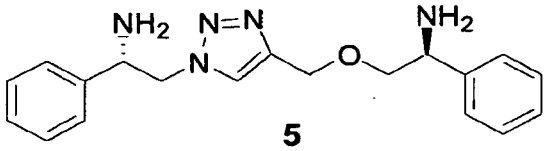
Reagents and conditions: (a) 10% Pd-C, MeOH, H_2, 100%; (b) i. diamine, EDC, HOBt, N,N-diisopropylethyl amine, CH_2Cl_2; ii. 4N HCl in 1,4-dioxane, MeOH; iii. L-N-Boc-N-methyl alanine, EDC, HOBt, N,N-diisopropylethyl amine, CH_2Cl_2; iv. 4N HCl in 1,4-dioxane.

[0145] Compound **14** can be synthesized according to literature reported methods (Duggan *et al., Org. Biomol. Chem., 3:2287* (2005)) (Scheme II). Reduction of the C-C double bond and hydrolysis of the benzyl ester in compound **14** gave an acid **15**. Condensation of 2.2 eq of **15** with the above diamines respectively followed by removal of the Boc protecting groups gave four ammonium salts. Condensation of these salts with L-N-Boc-N-methyl alanine respectively followed by deprotection of the Boc protecting groups afforded the bivalent Smac mimetics DQ-24, SH-143,

SH-142 and SH-155. The efficiency of the synthetic scheme for each compound is shown in Table 2.

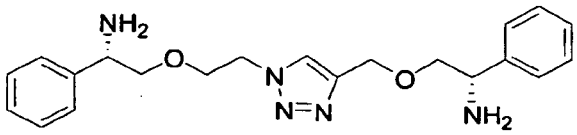
TABLE 2

Name	Yield (%, over four steps)
DQ-24	61
SH-143	62
SH-155	59
SH-142	55



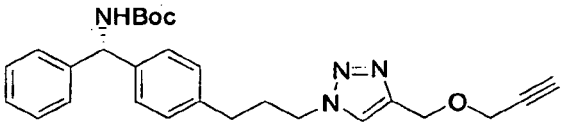
5

[0146] ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.50 (s, 1H), 7.38-7.20 (m, 3H), 7.28-7.20 (m, 2H), 7.26-7.05 (m, 5H), 4.98-4.75 (m, 2H), 4.23 (s, 2H), 4.36 (m, 2H), 3.50 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 143.78, 133.54, 132.53, 130.26, 129.97, 129.70, 129.62, 127.47, 127.10, 126.40, 69.89, 63.23, 54.67, 54.60, 52.40.



7

[0147] ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.59 (s, 1H), 7.32-7.22 (m, 3H), 7.22-7.13 (m, 5H), 7.12-7.05 (m, 2H), 4.55-4.29 (m, 6H), 3.85-3.75 (m, 1H), 3.75-3.56 (m, 5H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 143.51, 133.88, 133.63, 129.83, 129.61, 129.52, 129.38, 127.36, 127.32, 125.59, 70.89, 70.20, 69.25, 63.42, 54.62, 54.39, 50.49.

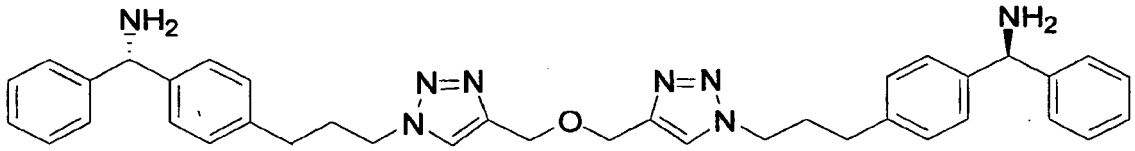


9

[0148] ^{1}H NMR (300 HMz, $CDCl_3$): δ 7.55 (s, 1H), 7.40-7.08 (m, 9H), 5.90 (brs, 1H), 5.24 (brs, 1H), 4.74 (s, 2H), 4.34 (t, J = 7.1 Hz, 2H), 4.23 (d, J = 2.4 Hz, 1H),

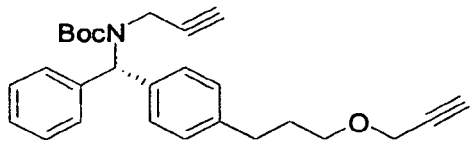
2.96 (t, J = 7.3 Hz, 2H), 2.49 (t, J = 2.4 Hz, 1H), 2.22 (m, 2H), 1.43 (brs, 9H); ^{13}C NMR (75 HMz, $CDCl_3$): δ 154.93, 144.26, 141.98, 140.15, 139.04, 128.54, 128.50, 127.36, 127.22, 127.07, 122.56, 79.67, 79.16, 74.89, 62.91, 58.06, 57.37, 49.37, 31.94, 31.44, 28.25.

[0149]



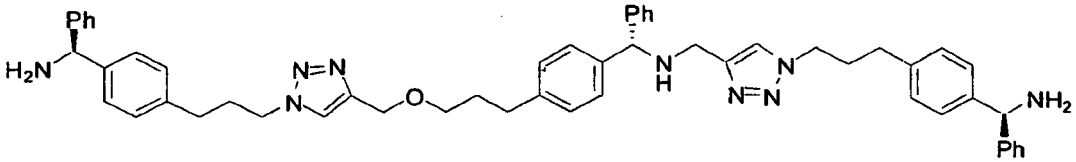
10

[0150] ^1H NMR (300 MHz, $CDCl_3$): δ 7.52 (s, 2H), 7.38-7.12 (m, 10H), 7.08-6.99 (m, 4H), 6.92-6.79 (m, 4H), 5.42 (s, 2H), 4.40 (s, 4H), 4.02 (m, 4H), 2.18 (m, 4H), 1.78 (m, 4H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 144.10, 139.59, 137.31, 132.04, 131.80, 131.72, 129.70, 129.64, 127.47, 65.29, 60.60, 52.51, 34.08, 33.18.



12

[0151] ^1H NMR (300 MHz, $CDCl_3$): δ 7.40-7.18 (m, 5H), 7.15 (brs, 4H), 6.45 (brs, 1H), 4.24 (d, J = 2.4 Hz, 2H), 3.90 (d, J = 1.9 Hz, 2H), 3.55 (t, J = 6.3 Hz, 2H), 2.72 (dd, J = 8.9, 7.4 Hz, 2H), 2.77 (t, J = 2.4 Hz, 1H), 2.04 (t, J = 1.9 Hz, 1H), 1.92 (m, 2H), 1.43 (brs, 9H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 155.17, 140.92, 139.85, 136.99, 128.76, 128.53, 128.40, 128.22, 127.22, 80.68, 80.58, 79.86, 74.19, 70.26, 69.16, 58.01, 34.75, 31.79, 30.99, 28.23.

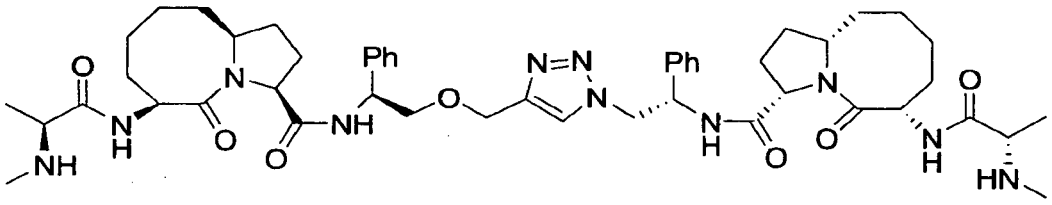


13

[0152] ^1H NMR (300 MHz, D_2O): δ 7.50 (s, 1H), 7.33 (s, 1H), 7.23-7.03 (m, 17H), 6.99-6.92 (m, 6H), 6.80-6.68 (m, 4H), 5.38 (s, 1H), 5.34 (s, 1H), 5.10 (s, 1H), 4.08 (s, 2H), 4.08 (t, J = 6.8 Hz, 1H), 3.99 (s, 2H), 3.92 (t, J = 6.8 Hz, 2H), 3.02 (t, J =

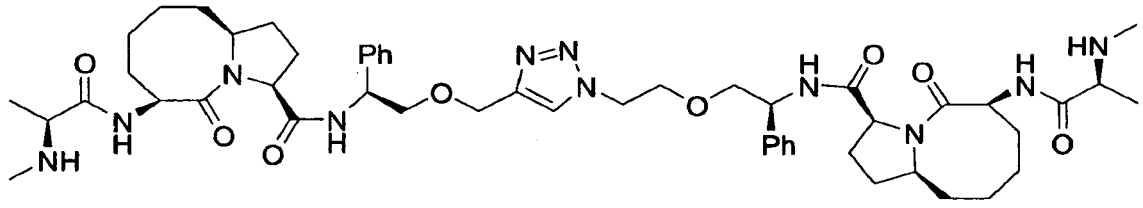
6.2 Hz, 2H), 2.30 (t, J = 7.3 Hz, 2H), 2.17 (t, J = 7.3 Hz, 2H), 2.11 (t, J = 7.3 Hz, 2H), 1.89-1.80 (m, 2H), 1.78-1.62 (m, 2H), 1.48-1.35 (m, 2H); ^{13}C NMR (75 MHz, D_2O): δ 163.46, 162.99, 144.04, 143.16, 141.81, 141.56, 137.61, 137.05, 134.70, 129.75, 129.64, 129.57, 129.54, 129.41, 129.28, 127.64, 127.45, 127.28, 127.16, 126.49, 125.00, 118.54, 114.67, 68.74, 65.33, 62.55, 58.06, 50.20, 49.98, 40.52, 31.70, 31.60, 30.98, 30.67, 30.42, 29.96.

DQ-24



[0153] ^{1}H NMR (300 MHz, D_2O): δ 7.77 (s, 1H), 7.78-7.21 (m, 10H), 5.32 (m, 1H), 4.91 (m, 1H), 4.75-4.56 (m, 4H), 4.50 (s, 2H), 4.33 (m, 1H), 4.17 (m, 3H), 3.79 (m, 2H), 3.60 (m, 2H), 2.55 (s, 3H), 2.53 (s, 3H), 2.25-1.80 (m, 4H), 1.79-1.61 (m, 7 H), 1.60-1.45 (m, 9H), 1.40-1.38 (m, 4H), 1.37 (d, J = 7.5 Hz, 3H), 1.33 (d, J = 7.2 Hz, 3H); ^{13}C NMR (75 MHz, D_2O): δ 173.82, 173.65, 172.34, 172.29, 144.94, 138.64, 137.46, 129.41, 129.25, 128.87, 128.23, 126.91, 126.88, 125.73, 72.14, 63.14, 62.15, 61.16, 60.96, 57.28, 54.14, 53.64, 53.34, 51.10, 35.94, 32.94, 32.33, 31.31, 27.95, 25.86, 21.99, 15.60.

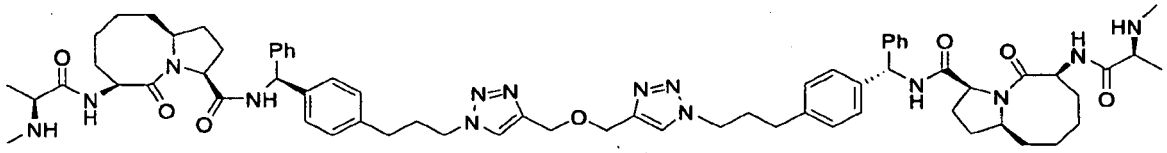
SH-143



[0154] ^{1}H NMR (300 MHz, D_2O): δ 7.50 (s, 1H), 7.30-7.08 (m, 10H), 4.95-4.80 (m, 3H), 4.75 (m, 1H), 4.47 (s, 2H), 4.39 (m, 2H), 4.32-4.10 (m, 4H), 4.35-4.08 (m, 4H), 3.66-3.50 (m, 4H), 2.55 (s, 6H), 2.22-1.43 (m, 24H), 1.39 (m, 6H); ^{13}C NMR (75 MHz, D_2O): δ 173.71, 172.30, 169.52, 143.92, 138.73, 129.07, 128.18, 126.96,

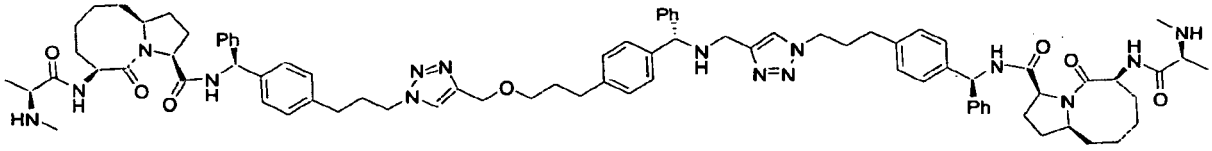
125.53, 72.87, 72.32, 68.99, 63.36, 62.21, 62.14, 61.05, 57.20, 53.40, 53.24, 51.14, 50.42, 35.96, 32.99, 32.32, 31.32, 27.89, 25.08, 21.94, 15.63.

SH-155



[0155] ^{1}H NMR (300 MHz, D_2O): δ 7.29 (s, 2H), 7.10-6.92 (m, 10H), 6.85 (d, J = 8.0 Hz, 4H), 6.58 (d, J = 8.0 Hz, 4H), 5.78 (s, 2H), 4.65 (m, 2H), 4.38 (s, 4H), 4.22 (m, 2H), 4.08 (m, 2H), 3.95-3.73 (m, 6H), 2.55 (s, 6H), 2.21-1.28 (m, 36H); ^{13}C NMR (75 MHz, D_2O): δ 179.33, 172.64, 172.07, 144.32, 141.56, 140.08, 139.74, 129.15, 127.99, 127.69, 127.53, 124.85, 63.13, 62.04, 61.01, 57.48, 57.30, 51.12, 49.98, 36.03, 33.27, 32.47, 31.77, 31.44, 31.22, 27.87, 25.25, 21.99, 15.78.

SH-142 (free amine)



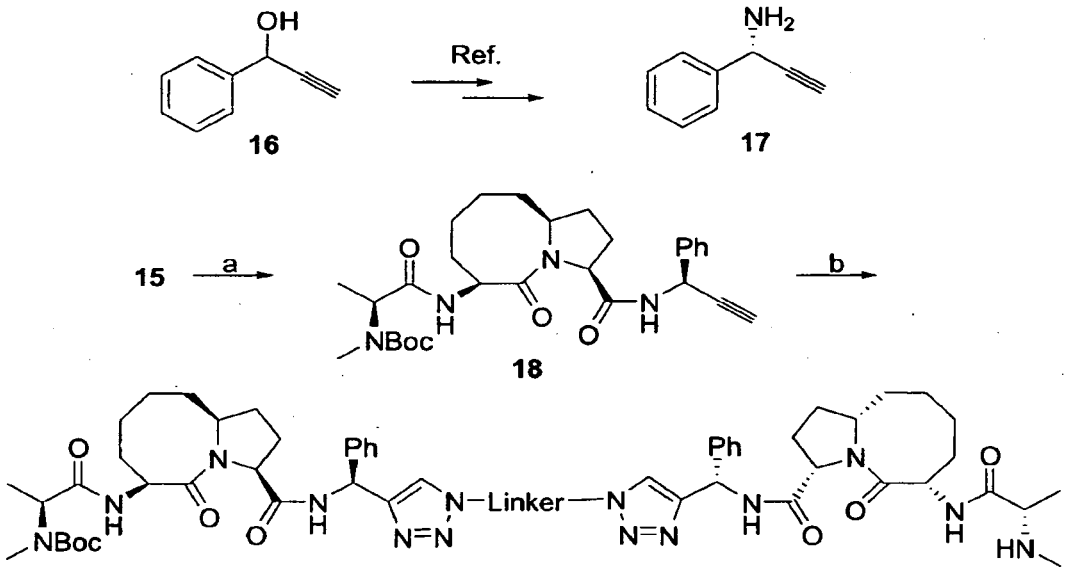
[0156] ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.92 (brd, J = 8.4 Hz, 2H), 7.82 (brd, J = 8.4 Hz, 2H), 7.49 (s, 1H), 7.45-7.06 (m, 28H), 6.21 (s, 1H), 6.19 (s, 1H), 4.90 (m, 2H), 4.85 (s, 1H), 4.75 (m, 2H), 4.62 (s, 2H), 4.33 (t, J = 7.1 Hz, 4H), 4.20 (m, 2H), 3.82 (s, 2H), 3.49 (t, J = 7.1 Hz, 2H), 3.06 (m, 2H), 2.70-2.55 (m, 8H), 2.38 (s, 6H), 2.30-1.35 (m, 28H), 1.30 (d, J = 6.9 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 174.16, 172.05, 169.69, 145.37, 141.64, 140.60, 139.70, 139.15, 139.11, 128.60, 128.56, 128.50, 127.59, 127.47, 127.32, 127.29, 127.27, 127.02, 122.22, 121.52, 69.87, 66.39, 64.35, 60.15, 59.75, 59.18, 56.78, 53.41, 49.41, 49.26, 42.65, 36.71, 35.97, 35.12, 32.03, 31.59, 31.55, 31.09, 24.91, 24.06, 23.20, 19.44.

EXAMPLE 3

Synthesis of SH-156, SH-158, SH-159, SH-164, SH-165, SH-166 and SH-167

[0157] Compounds SH-156, SH-158, SH-159, SH-164, SH-165, SH-166 and SH-167 were synthesized according to Scheme III.

Scheme III:

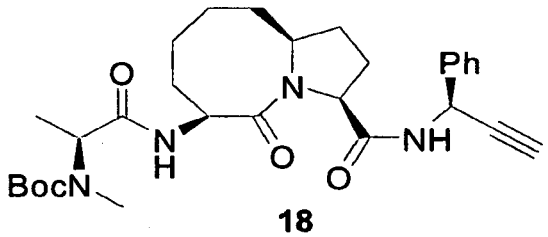


Reagents and conditions: (a) i. **17**, EDC, HOBt, N,N-diisopropylethyl amine, CH_2Cl_2; ii. 4 N HCl in 1,4-dioxane, MeOH; iii. *L*-N-Boc-N-methyl alanine, EDC, HOBt, CH_2Cl_2, 78 % over three steps; (b) i. diazide, $CuSO_4$, (+)-sodium L-ascorbate, *t*-BuOH--H_2O 3:1, ii. 4N HCl in 1,4-dioxane, MeOH.

[0158] The chiral amine **17** can be prepared according to literature reported methods from compound **16** [Messina, *et al., J. Org. Chem., 64:3767* **(1999)**]. Condensation of acid **15** with chiral amine **17** followed by deprotection of the Boc protecting group with HCl in methanol yielded an ammonium salt. Condensation of this salt with L-N-Boc-N-methyl alanine furnished intermediate **18**. Cycloaddition of **18** with corresponding diazide under the catalyzation of $CuSO_4$-(+)-sodium-L-ascorbate respectively followed by deprotection of the Boc protecting group gave designed bivalent Smac mimetics SH-156, SH-158, SH-159, SH-164, SH-165, SH-166 and SH-167. The efficiency of the synthetic scheme for each compound is shown in Table 3.

TABLE 3

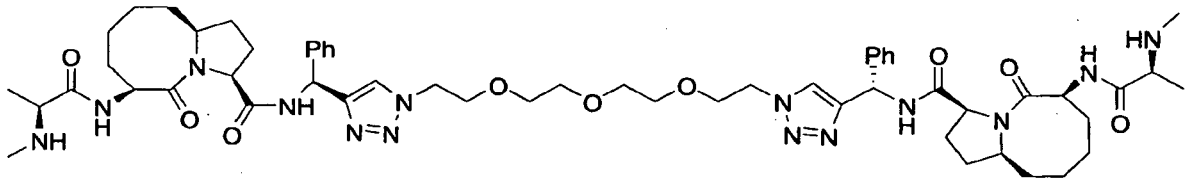
Name	Yield (%, over two steps)
SH-156	63
SH-158	65
SH-159	61
SH-164	62
SH-165	59
SH-166	58
SH-167	59



18

[0159] ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.75 (brd, J = 8.5 Hz, 1H), 7.50-7.44 (m, 2H), 7.38-7.23 (m, 3H), 6.90 (brs, 1H), 5.95 (dd, J = 8.5, 2.4 Hz, 1H), 4.80 (m, 1H), 4.64 (dd, J = 8.4, 6.2 Hz, 1H), 4.60 (brm, 1H), 4.15 (m, 1H), 2.88 (s, 3H), 2.62 (m, 1H), 2.53 (d, J = 2.4 Hz, 1H), 2.20-1.70 (m, 5H), 1.51 (brs, 9H), 1.56-1.05 (m, 9H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 171.99, 170.95, 169.73, 138.96, 129.03, 128.55, 127.53, 82.13, 73.25, 60.03, 59.47, 50.32, 45.21, 36.94, 36.30, 32.36, 30.48, 28.80, 25.29, 24.42, 23.45, 14.16.

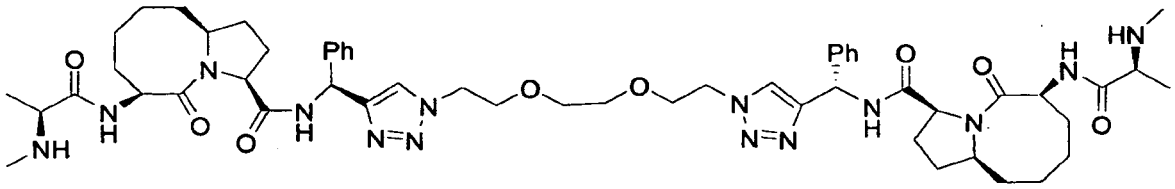
SH-156



[0160] ^{1}H NMR (300 MHz, D_2O): δ 7.58 (s, 2H), 7.29-7.13 (m, 10H), 6.08 (s, 2H), 4.70 (m, 2H), 4.38 (m, 4H), 4.27 (m, 2H), 4.22 (m, 2H), 3.85 (m, 2H), 3.73 (m, 4H), 3.32 (m, 4H), 3.25 (m, 4H), 2.58 (s, 6H), 2.25-1.48 (m, 22H), 1.40 (d, J = 7.0 Hz, 6H), 1.39 (m, 2H); ^{13}C NMR (75 MHz, D_2O): δ 173.36, 172.32, 169.56, 148.12,

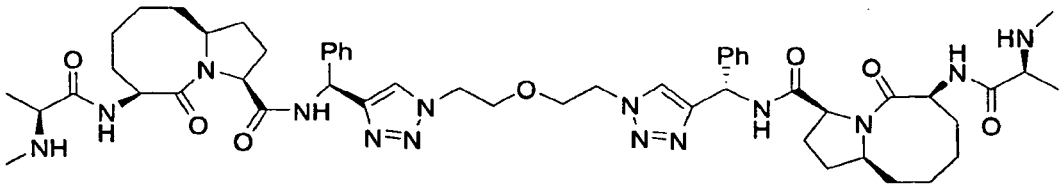
139.21, 129.32, 128.54, 127.40, 124.51, 69.98, 69.75, 68.97, 62.07, 61.07, 57.20, 51.13, 50.46, 50.41, 35.94, 33.01, 32.35, 31.31, 27.81, 25.07, 21.92, 15.63.

SH-158



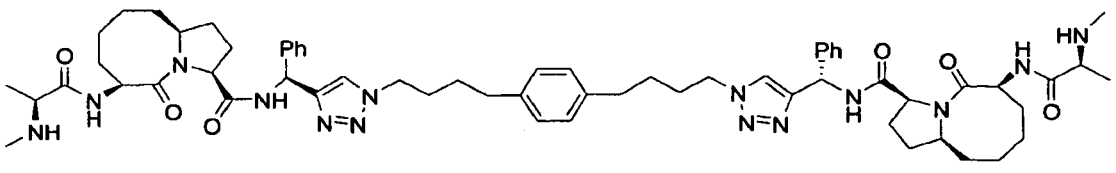
[0161] ^{1}H NMR (300 MHz, D_2O): δ 7.56 (s, 2H), 7.29-7.13 (m, 10H), 6.05 (s, 2H), 4.70 (m, 2H), 4.38-4.14 (m, 8H), 3.85 (m, 2H), 3.63 (m, 4H), 3.35 (s, 4H), 2.55 (s, 6H), 2.22-1.45 (m, 22H), 1.42 (d, J = 7.1 Hz, 6H), 1.40 (m, 2H); ^{13}C NMR (75 MHz, D_2O): δ 173.31, 172.28, 169.54, 148.15, 139.23, 129.30, 128.53, 127.38, 124.45, 69.85, 68.90, 62.05, 61.05, 57.20, 51.12, 50.39, 35.93, 33.03, 32.34, 31.32, 27.78, 25.07, 21.93, 15.63.

SH-159



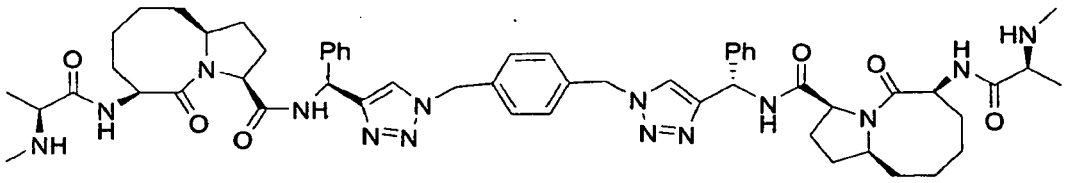
[0162] ^{1}H NMR (300 MHz, D_2O): δ 7.51 (s, 2H), 7.28-7.04 (m, 10H), 6.04 (s, 2H), 4.70 (m, 2H), 4.39-4.15 (m, 8H), 3.82 (m, 2H), 3.70 (m, 4H), 2.56 (s, 6H), 2.20-1.45 (m, 22H), 1.40 (d, J = 6.9 Hz, 6H), 1.38 (m, 2H); ^{13}C NMR (75 MHz, D_2O): δ 173.28, 172.22, 169.52, 148.14, 139.30, 129.31, 128.48, 127.33, 124.36, 68.99, 62.04, 61.06, 57.21, 51.10, 50.42, 50.35, 35.93, 33.06, 32.35, 31.32, 27.81, 25.09, 21.93, 15.64.

SH-164



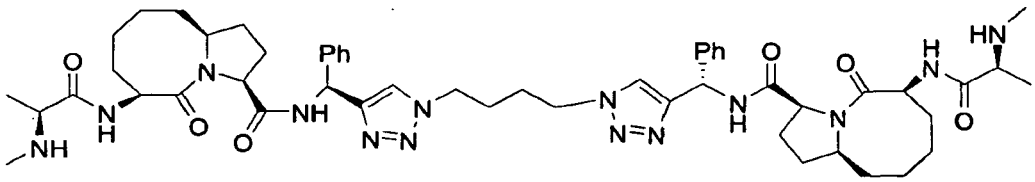
[0163] ^{1}H NMR (300 MHz, D_2O): δ 7.40 (s, 2H), 7.15-6.85 (m, 10H), 6.65 (s, 4H), 6.08 (s, 2H), 4.65 (m, 2H), 4.32 (m, 2H), 4.08 (m, 2H), 3.92-3.74 (m, 6H), 2.84 (m, 4H), 2.54 (s, 6H), 2.28-1.04 (m, 38H); ^{13}C NMR (75 MHz, D_2O): δ 172.24, 171.83, 169.34, 148.50, 139.56, 139.41, 129.07, 128.53, 127.43, 122.92, 61.70, 60.72, 57.20, 51.23, 50.86, 50.15, 36.08, 34.96, 34.64, 31.34, 29.61, 28.63, 28.57, 28.20, 27.60, 25.20, 15.71.

SH-165



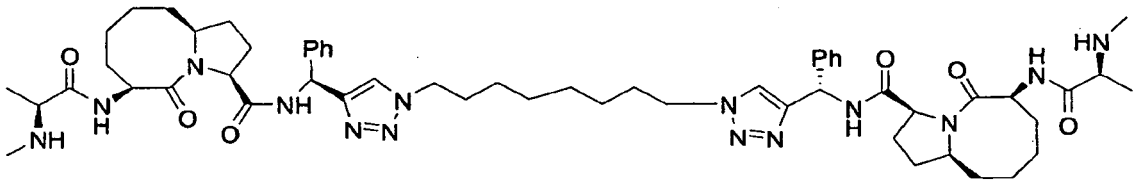
[0164] ^{1}H NMR (300 MHz, D_2O): δ 7.55 (s, 2H), 7.19-7.05 (m, 10H), 6.85 (s, 4H), 5.98 (s, 2H), 5.15 (s, 4H), 4.65 (m, 2H), 4.25 (t, J = 7.2 Hz, 2H), 4.10 (m, 2H), 3.82 (m, 2H), 2.54 (s, 6H), 2.12-1.20 (m, 30H); ^{13}C NMR (75 MHz, D_2O): δ 173.04, 172.16, 169.49, 148.55, 139.08, 135.38, 129.27, 128.82, 128.51, 127.40, 123.90, 62.92, 60.92, 57.19, 53.62, 51.05, 50.39, 35.88, 33.05, 32.28, 31.32, 27.66, 25.06, 21.91, 15.64.

SH-166



[0165] ^{1}H NMR (300 MHz, D_2O): δ 7.59 (s, 2H), 7.28-7.10 (m, 10H), 6.02 (s, 2H), 4.65 (m, 2H), 4.29 (m, 2H), 4.22-4.08 (m, 6H), 3.82 (m, 2H), 2.53 (s, 6H), 2.20-1.42 (m, 26H), 1.40 (d, J = 7.1 Hz, 6H), 1.35 (m, 2H); ^{13}C NMR (75 MHz, D_2O): δ 173.35, 172.29, 169.53, 148.20, 139.07, 129.31, 128.54, 127.36, 124.06, 62.05, 61.03, 57.19, 51.11, 50.32, 50.05, 35.92, 33.02, 32.33, 31.31, 27.76, 26.68, 25.06, 21.93, 15.63.

SH-167



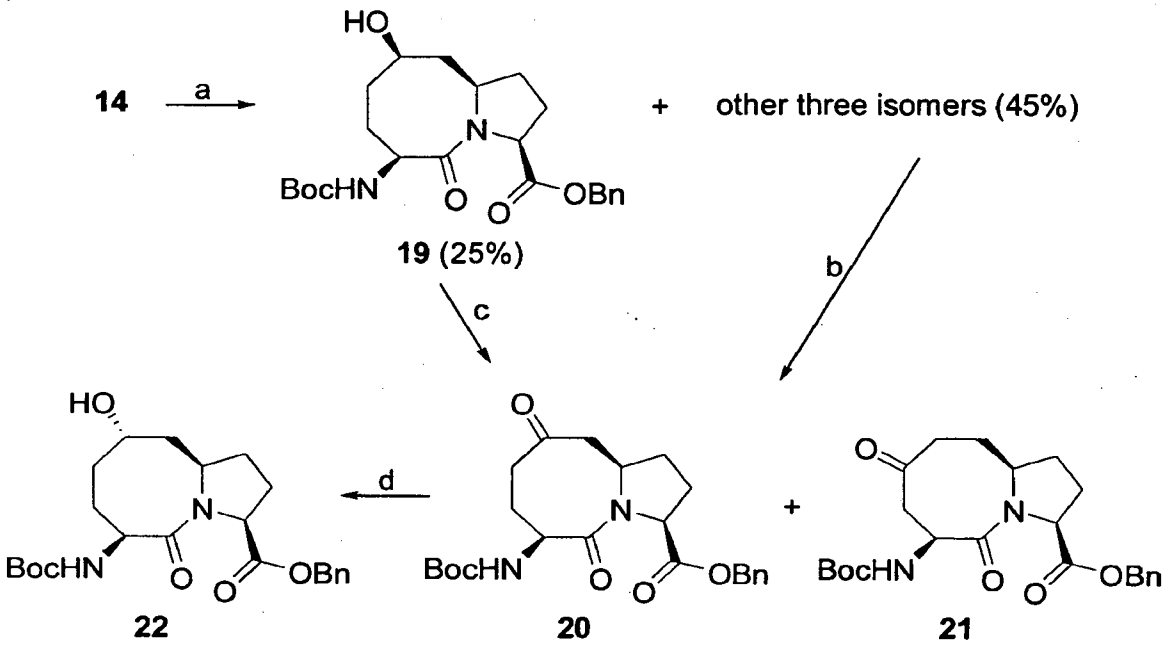
[0166] ^{1}H NMR (300 MHz, D_2O): δ 7.62 (s, 2H), 7.28-7.12 (m, 10H), 6.07 (s, 2H), 4.65 (m, 2H), 4.30 (t, J = 8.8 Hz, 2H), 4.25-4.10 (m, 6H), 3.84 (m, 2H), 2.55 (s, 6H), 2.23-1.95 (m, 4H), 1.95-1.45 (m, 22H), 1.40 (d, J = 7.0 Hz, 6H), 1.35 (m, 2H), 1.05-0.85 (m, 8H); ^{13}C NMR (75 MHz, D_2O): δ 173.33, 172.28, 169.55, 148.22, 139.18, 129.30, 128.54, 127.43, 123.96, 62.04, 61.02, 57.18, 51.10, 50.72, 50.44, 35.94, 33.03, 32.34, 31.32, 29.35, 27.86, 25.40, 25.09, 21.90, 15.64.

EXAMPLE 4

Synthesis of SH-153 and SH-172

[0167] Compounds SH-153 and SH-172 were synthesized according to Schemes IV and V.

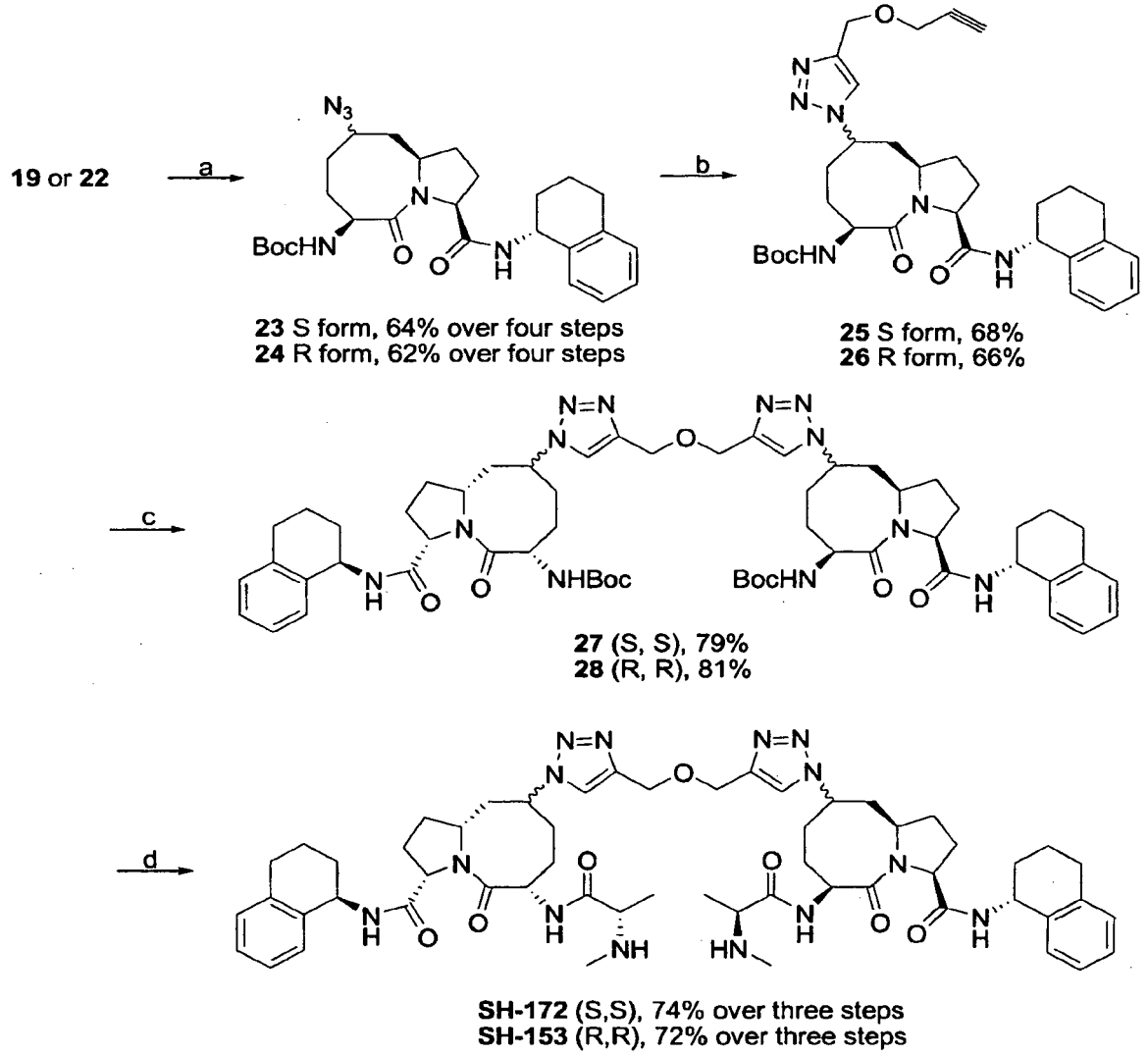
Scheme IV:



Reagents and coditions: (a) 9-BBN, THF, then H_2O_2 (35% in water), 3 N NaOH; (b) Dess-Martin periodinane, CH_2Cl_2, yield for **20** 33%, yield for **21** 62%; (c)Dess-Martin periodinane, CH_2Cl_2, 96%; (d) $NaBH_3CN$, MeOH, H_2SO_4 (cata.), 94%.

[0168] Borohydrogenation of the C-C double bond in compound **14** by treatment with 9-BBN followed by oxidation of the resulted borane by alkaline H_2O_2 gave a mixture of four alcohols. Alcohol **19** can be separated from the other three isomers by chromatography and its structure was confirmed by X-ray analysis. Oxidation of the mixture of the other three isomers by Dess-Martin periodinane yielded two ketones **20** and **21** which can be separated by chromatography. Reduction of ketone **20** by $NaBH_3CN$ in the presence of a catalytic amount of H_2SO_4 furnished alcohol **22** as a single isomer. Oxidation of alcohol **19** by Dess-Martin periodinane also gave ketone **20**, so the structure of alcohol **22** was also confirmed.

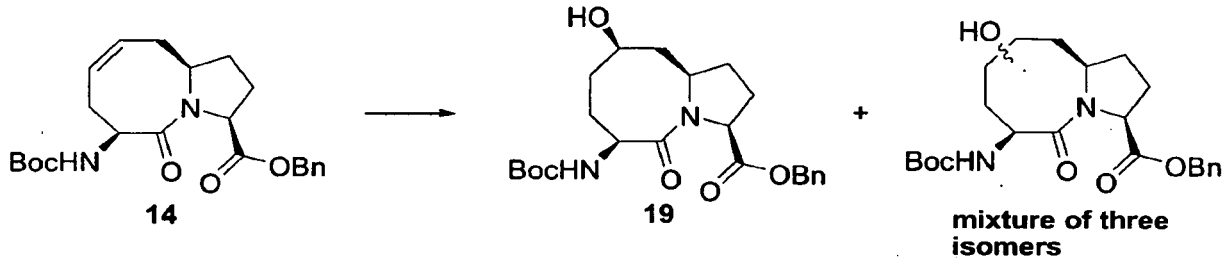
Scheme V:



Reagents and conditions: (a) i. 10% Pd-C, H_2, MeOH; ii. (R)-(-)-1,2,3,4-tetrahydro-1-naphthylamine, EDC, HOBt, N,N-diisopropylethyl amine, CH_2Cl_2; iii. MsCl, N,N-diisopropylethyl amine, CH_2Cl_2; iv. NaN_3, DMF; (b) propargyl ether (5 eq), $CuSO_4$, (+)-sodium L-ascorbate, AcCN:*t*-BuOH:H_2O 2:2:1, rt; (c) **23** or **24**, $CuSO_4$, (+)-sodium L-ascorbate, *t*-BuOH:H_2O 1:1, rt; (d) i. 4 N HCl in 1,4-dioxane, MeOH, ii. L-N-Boc-N-methyl alanine, EDC, HOBt, N,N-diisopropylethyl amine, CH_2Cl_2; iii. 4 N HCl in 1,4-dioxane, MeOH.

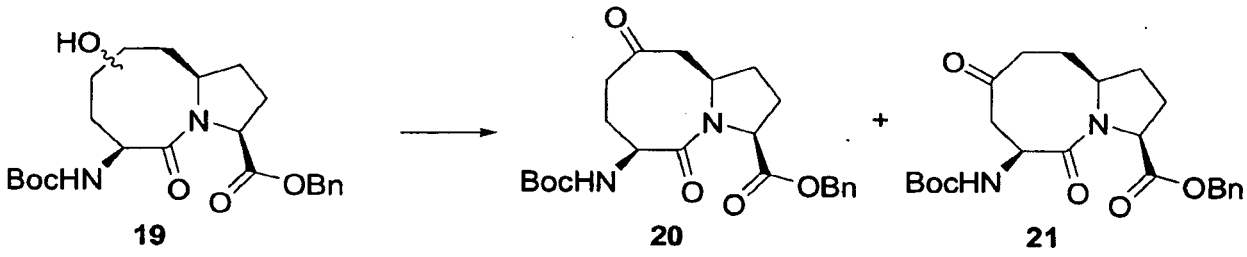
[0169] Hydrolysis of the benzyl esters in **19** and **22** followed by condensation of the resulted acid with (R)-(-)-1,2,3,4-tetrahydro-1-naphthylamine yielded two amides (Scheme V). Reaction of these two amides with methanesulfonyl chloride followed by substitution of the resulted two mesylates with NaN_3 furnished two azides **23** and **24**. Cycloaddition of these two azides with excessive amount propargyl ether under the catalyzation of $CuSO_4$-(+)-sodium-L-ascorbate gave two alkynes **25** and **26**. Cycloaddition of **23** and **24** with these two alkynes respectively furnished

compounds **27** and **28**. Removal of the Boc protecting groups in these two compounds followed by condensation with L-N-Boc-N-methyl alanine yielded two amides. Removal of the Boc protecting groups in these two amides gave SH-153 and SH-172, respectively.



[0170] To a solution of compound **14** (1.25 g, 3 mmol) in 50 mL of dry THF was added 9 mL of 9-BBN solution (0.5 M in THF, 4.5 mmol). After the solution was refluxed for 12 h, 1.5 mL of 3 M NaOH solution and 2 mL of H_2O_2 solution (35% in water) was added dropwise at 0 °C. After warming to room temperature and stirring for 2 h, the mixture was extracted with ethyl acetate by three times. The combined organic layer was dried over Na_2SO_4 and then condensed. The residue was purified by chromatography to give compound **19** (330 mg, 25%) and a mixture of three other isomers (580 mg, 45%).

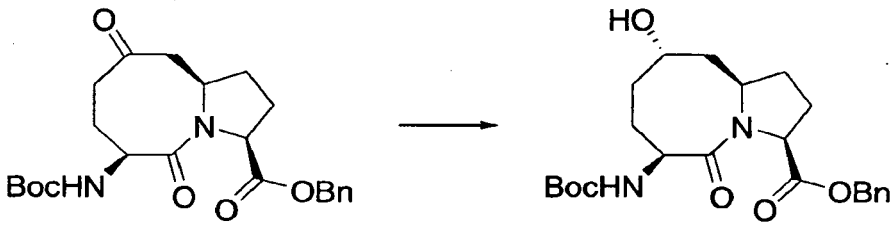
[0171] Chemical data for compound **19**: ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.40-7.28 (m, 5H), 5.43 (brd, J = 7.8 Hz, 1H), 5.28, 5.18 (ABq, J = Hz, 2H), 4.67 (t, J = 8.4 Hz, 1H), 4.65 (m, 1H), 4.20 (m, 1H), 3.96 (m, 1H), 2.45-1.60 (m, 10H), 1.38 (brs, 9H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 172.38, 170.83, 155.13, 135.39, 128.58, 128.40, 128.34, 79.70, 70.63, 67.14, 60.13, 56.16, 50.70, 45.22, 32.67, 31.70, 28.35, 27.34.



[0172] To a solution of the mixture of three isomers obtained above (570 mg, 1.3 mmol) in 15 mL of CH_2Cl_2 was added Dess-Martin periodinane (660 mmol, 1.56 mmol) at room temperature. The mixture was stirred at the same temperature for 2 h and then condensed. The residue was purified by chromatography to give compound **20** (160 mg, 28%) and **21** (330 mg, 58%). Compound **19** can be oxidized to compound **20** in the same method.

[0173] Chemical data for compound **20**: ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.40-7.28 (m, 5H), 5.42 (brd, J = 8.2 Hz, 1H), 5.28, 5.18 (ABq, J = 12.2 Hz, 2H), 4.62 (t, J = 8.4 Hz, 1H), 4.37 (m, 1H), 3.13 (m, 1H), 3.02 (t, 1H), 2.50-1.98 (m, 8H), 1.83 (m, 1H), 1.60 (m, 1H), 1.38 (brs, 9H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 211.37, 172.20, 170.94, 154.92, 135.23, 128.56, 128.41, 128.22, 79.81, 67.17, 60.53, 56.06, 53.39, 52.88, 36.79, 32.36, 30.18, 28.22, 27.00.

[0174] Chemical data for compound **21**: ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.40-7.20 (m, 5H), 5.49 (brd, J = 7.7 Hz, 1H), 5.17 (s, 2H), 5.09 (m, 1H), 4.52 (t, J = 8.5 Hz, 1H), 4.22 (m, 1H), 3.08 (dd, J = 12.7, 4.5 Hz, 1H), 2.92 (m, 1H), 2.60 (m, 2H), 2.36-1.72 (m, 6H), 1.43 (brs, 9H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 207.72, 170.93, 170.15, 154.74, 135.58, 128.37, 128.30, 128.14, 80.00, 66.67, 60.10, 59.74, 52.13, 48.52, 39.65, 34.18, 32.36, 28.21, 26.90.

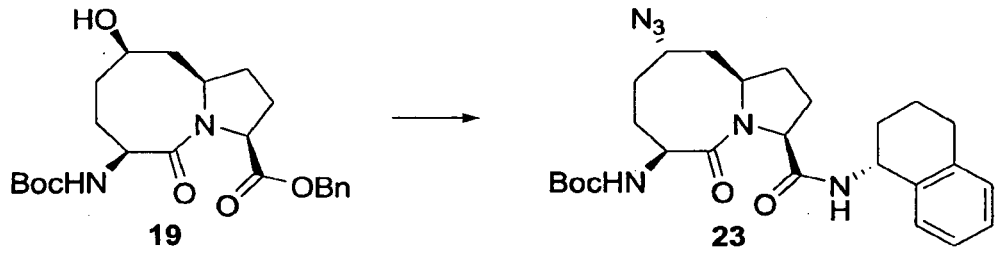


20 **22**

[0175] To a solution of compound **20** (160 mg, 0.37 mmol) in 15 mL of methanol was added $NaBH_3CN$ (120 mg, 1.9 mmol) and 3 drop of H_2SO_4 (98%) at -15 °C. After stirring at the same temperature for 4 h, 10 mL of water was added and the mixture was extracted with ethyl acetate (30 mL × 4). The combined organic layers were dried over Na_2SO_4 and then condensed. The residue was purified by chromatography to give compound **22** (147 mg, 92%).

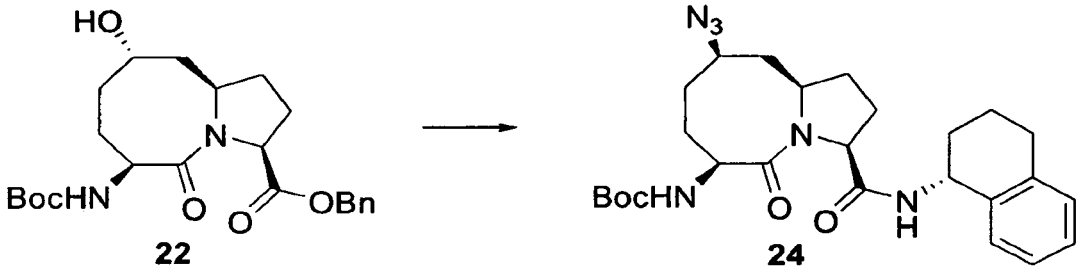
[0176] ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.30 (brs, 5H), 5.45 (brd, J = 8.4 Hz, 1H), 5.20, 5.10 (ABq, J = 14.1 Hz, 2H), 4.85 (m, 1H), 4.48 (m, 2H), 4.13 (m, 1H), 3.16

(brs, 1H), 2.42-1.45 (m, 10H), 1.38 (brs, 9H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 172.30, 171.03, 155.06, 135.43, 128.49, 128.27, 128.15, 79.36, 67.70, 66.87, 59.74, 54.00, 51.65, 43.62, 32.12, 31.82, 29.30, 28.29, 27.11.



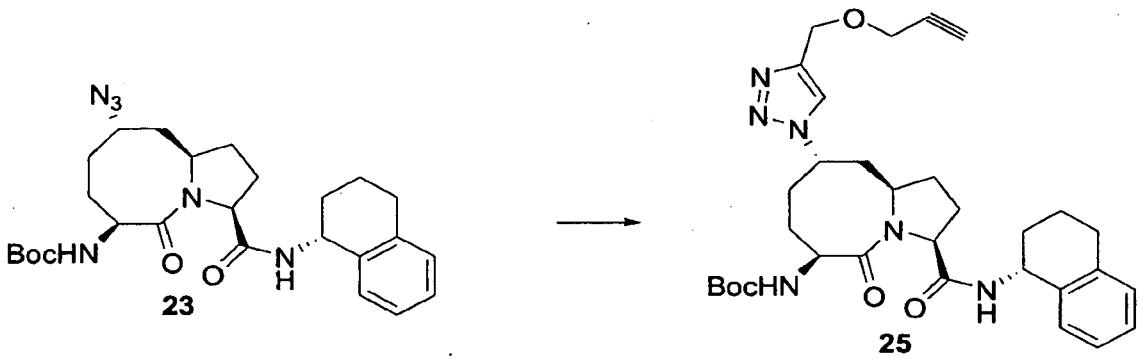
[0177] To a solution of compound **19** (170 mg, 0.39 mmol) in 10 mL of CH_2Cl_2 was added methanesulfonyl chloride (0.05 mL, 0.6 mmol). The solution was cooled to 0 °C and then 0.2 mL of N,N-diisopropylethylamine was added dropwise. The mixture was stirred at room temperature for 4 h and then condensed. The residue was purified by chromatography to give a mesylate. To a solution of this mesylate in 10 mL of methanol was added 50 mg of 10% Pd-C. After the mixture was stirred at room temperature under H_2 for 3 h, the catalyst was filtered off and the filtration was condensed to yield an acid. The acid was dissolved in 10 mL of CH_2Cl_2. To this solution was added (R)-(-)-1,2,3,4-tetrahydro-1-naphthylamine (60 mg, 0.4 mmol), EDC (77 mg, 0.4 mmol), HOBt (55 mg, 0.4 mmol) and 0.3 mL of N,N-diisopropylethylamine subsequently. The solution was stirred at room temperature overnight and then condensed. The residue was purified by chromatography to furnish an amide. To a solution of this amide in 5 mL of DMF was added 0.2 g of NaN_3. The mixture was stirred at 110 °C for 6 h and then partitioned between 60 mL of ethyl acetate and 15 mL of brine. The organic layer was dried over Na_2SO_4 and then condensed. The residue was purified by chromatography to give compound **23** (132 mg, 68% over four steps).

[0178] ^1H NMR (300 MHz, $CDCl_3$): δ 7.30 (m, 1H), 7.20-7.03 (m, 3H), 6.81 (brd, J = 8.2 Hz, 1H), 5.50 (brd, J = 8.4 Hz, 1H), 5.18 (m, 1H), 4.65 (m, 1H), 4.48 (m, 1H), 4.35 (m, 1H), 3.84 (m, 1H), 2.80 (m, 2H), 2.45 (m, 1H), 2.30-1.78 (m, 13H), 1.45 (brs, 9H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 171.19, 170.26, 154.87, 137.18, 136.41, 129.07, 128.73, 127.28, 126.16, 79.56, 60.47, 59.30, 54.47, 50.79, 47.57, 40.40, 33.19, 32.56, 29.83, 29.02, 28.32, 27.82, 25.43, 19.74.



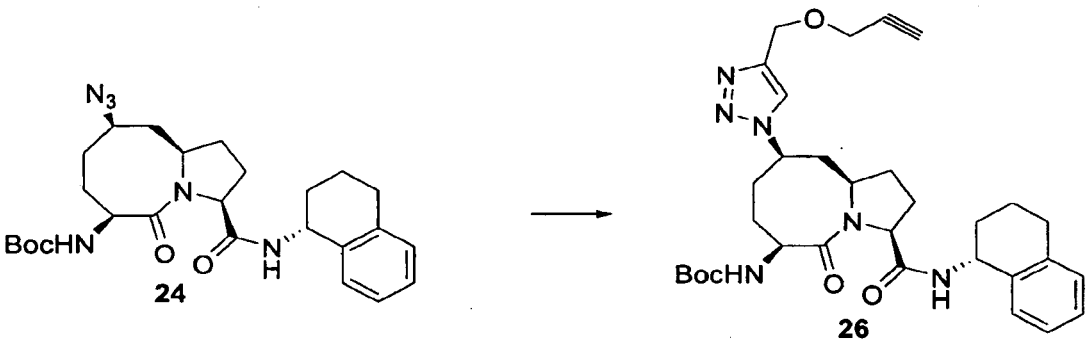
[0179] Compound **24** was synthesized in the same sequence as that for compound **6** from compound **22** (63% over four steps).

[0180] ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.32 (m, 1H), 7.15 (m, 2H), 7.06 (m, 1H), 6.77 (brd, J = 8.3 Hz, 1H), 5.43 (brd, J = 8.2 Hz, 1H), 5.16 (m, 1H), 4.54 (m, 1H), 4.48 (t, J = 7.5 Hz, 1H), 4.25 (m, 1H), 3.52 (m, 1H), 2.80 (m, 2H), 2.48-1.50 (m, 14H), 1.42 (brs, 9H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 171.02, 170.07, 154.94, 137.11, 136.33, 128.98, 128.76, 127.20, 126.23, 79.76, 61.17, 60.35, 56.99, 49.85, 47.47, 42.20, 32.74, 29.84, 29.14, 29.01, 28.25, 26.08, 19.76.



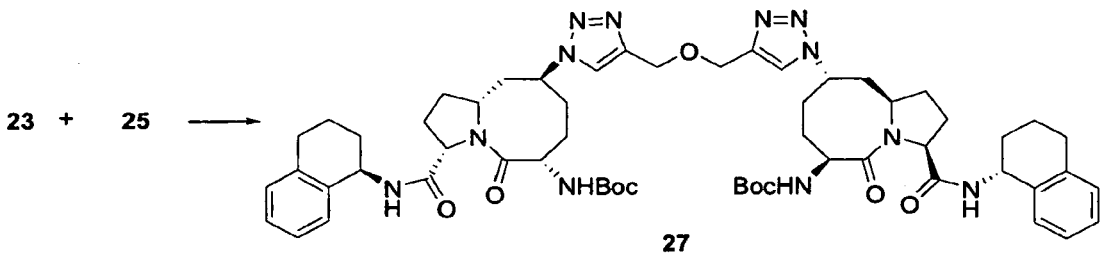
[0181] To a solution of 20 mg of $CuSO_4$ in 2 mL of water was added 40 mg of (+)-sodium L-ascorbate. The mixture was shaken until the color turned to bright yellow. This mixture was added dropwise to a solution of compound **23** (120 mg, 0.24 mmol) and 0.2 mL of propargyl ether in 3 mL of acetonitrile and 3 mL of *t*-BuOH at room temperature. The mixture was stirred at the same temperature overnight and then partitioned between 60 mL of CH_2Cl_2 and 15 mL of brine. The organic layer was dried over Na_2SO_4 and then condensed. The residue was purified by chromatography to give compound **25** (105 mg, 74%).

[0182] ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.64 (s, 1H), 7.39 (m, 1H), 7.18 (m, 2H), 7.07 (m, 1H), 6.50 (brd, J = 8.3 Hz, 1H), 5.83 (brd, J = 7.1 Hz, 1H), 5.19 (m, 1H), 4.76 (m, 1H), 4.70 (s, 2H), 4.55-4.32 (m, 3H), 4.23 (d, J = 2.4 Hz, 2H), 2.80 (m, 2H), 2.50 (t, J = 2.4 Hz, 1H), 2.46-1.63 (m, 14H), 1.48 (brs, 9H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 170.63, 170.48, 154.79, 143.58, 137.35, 136.30, 129.11, 128.59, 127.36, 126.41, 122.65, 79.71, 79.31, 74.87, 62.96, 60.83, 59.13, 57.49, 54.65, 53.29, 47.84, 41.98, 34.53, 32.49, 31.26, 30.15, 29.10, 28.34, 25.81, 20.06.



[0183] Compound **26** was synthesized in the same method as that for compound **25** from compound **24** (yield 73%).

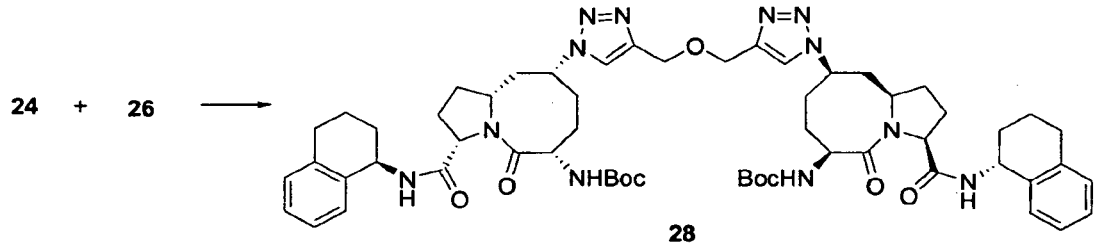
[0184] ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.59 (s, 1H), 7.36 (m, 1H), 7.13 (m, 2H), 7.04 (m, 1H), 6.68 (brd, J = 8.2 Hz, 1H), 5.48 (brd, J = 8.3 Hz, 1H), 5.15 (m, 1H), 4.89 (m, 1H), 4.72 (m, 1H), 4.70 (s, 2H), 4.56-4.35 (m, 2H), 4.14 (d, J = 2.3 Hz, 1H), 2.80 (m, 2H), 2.58-1.55 (m, 15H), 1.43 (brs, 9H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 170.83, 170.60, 155.02, 144.76, 137.22, 136.29, 129.03, 128.79, 127.31, 126.32, 120.18, 79.86, 79.18, 74.97, 62.97, 61.36, 60.02, 57.52, 57.22, 49.65, 47.76, 43.81, 32.84, 32.72, 30.50, 29.92, 29.01, 28.29, 26.56, 19.86.



[0185] To a solution of compound **23** and **25** in 3 mL of acetonitrile and 3 mL of t-BuOH was added a mixture of 20 mg of $CuSO_4$ and 40 mg of (+)-sodium L-

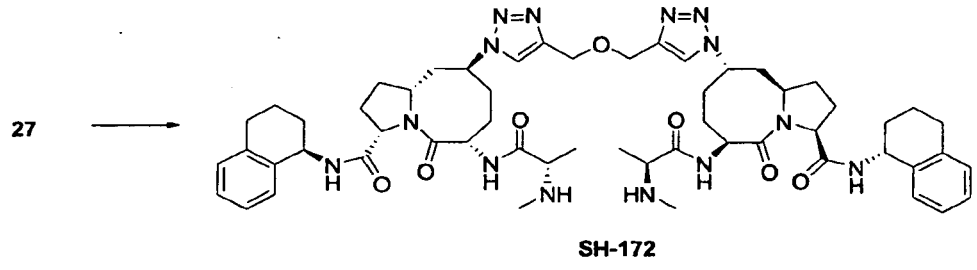
ascorbate in 2 mL of water. The mixture was stirred at room temperature overnight and then partitioned between 60 mL of CH_2Cl_2 and 15 mL of brine. The organic layer was dried over Na_2SO_4 and then condensed. The residue was purified by chromatography to give compound **27** (79%).

[0186] ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.70 (s, 2H), 7.40 (m, 2H), 7.19 (m, 4H), 7.11 (m, 2H), 6.54 (brd, J = 8.3 Hz, 2H), 5.79 (brd, J = 7.1 Hz, 2H), 5.19 (m, 2H), 4.75 (m, 2H), 4.67 (s, 4H), 4.47 (m, 4H), 4.35 (t, J = 8.5 Hz, 2H), 2.79 (m, 4H), 2.45-1.60 (m, 28H), 1.43 (brs, 18H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 170.57, 170.48, 154.78, 143.89, 137.31, 136.32, 129.06, 128.62, 127.31, 126.39, 122.60, 79.66, 63.66, 60.80, 59.06, 54.65, 53.27, 47.80, 41.93, 34.49, 32.49, 30.13, 29.21, 29.09, 28.32, 25.78, 20.03.



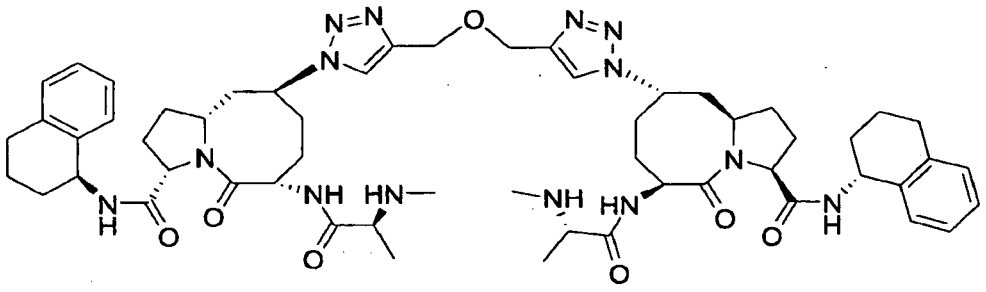
[0187] Compound **28** was synthesized in the same method as that for compound **27** from compound **24** and **26**.

[0188] ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.61 (s, 2H), 7.38 (m, 1H), 7.20-6.99 (m, 6H), 6.60 (brd, J = 8.0 Hz, 2H), 5.48 (brd, J = 8.1 Hz, 2H), 5.16 (m, 2H), 4.89 (m, 2H), 4.73 (m, 2H), 4.70 (s, 4H), 4.52-4.33 (m, 4H), 2.78 (m, 4H), 2.56-1.58 (m, 28H), 1.43 (brs, 18H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 170.89, 170.51, 155.01, 137.22, 136.25, 129.03, 128.81, 127.33, 126.35, 120.21, 79.87, 63.85, 61.38, 60.03, 57.27, 49.65, 47.75, 43.86, 32.85, 32.73, 30.51, 29.21, 29.03, 28.30, 26.54, 19.84.



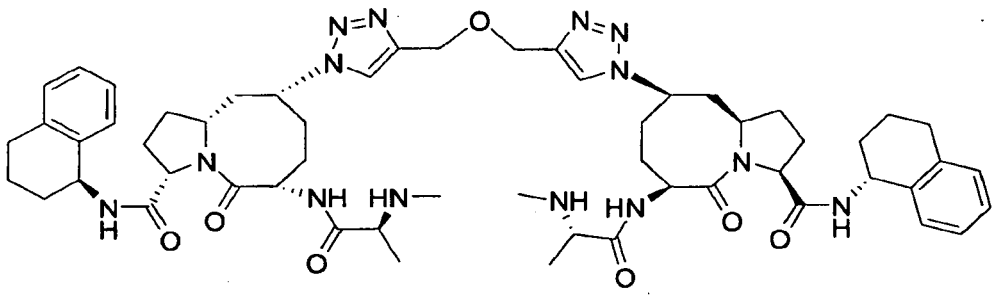
[0189] To a solution of compound **27** in 5 mL of methanol was added 1 mL of HCl solution (4 N in 1,4-dioxane). The solution was stirred at room temperature overnight and then condensed. The residue was suspended in 5 mL of CH_2Cl_2. To this mixture was added L-N-methyl-N-Boc-alanine, EDC, HOBt and N,N-diisopropylethylamine. The mixture was stirred at room temperature overnight and then condensed. The residue was purified by chromatography to give an amide. To a solution of this amide in 5 mL of methanol was added 1 mL of HCl solution (4 N in 1,4-dioxane). The solution was stirred at room temperature overnight and then condensed to give crude **SH-172** as a salt with HCl. This compound was purified by HPLC to give pure product. The gradient ran from 75% of solvent A (water contained 0.1% of TFA) and 25% of solvent B (acetonitrile contained 0.1% of TFA) to 55% of solvent A and 45% of solvent in 25 min. Analytical HPLC showed the purity is over 95%.

SH-172



[0190] ^{1}H NMR (300 MHz, D_2O): δ 7.85 (s, 2H), 7.22-7.02 (m, 8H), 4.98-4.79 (m, 4H), 4.80-4.60 (m, 4H), 4.52 (s, 4H), 4.28 (t, J = 8.7 Hz, 2H), 3.82 (m, 2H), 2.72-2.50 (m, 10H), 2.48-1.55 (m, 28H), 1.45 (d, J = 7.0 Hz, 6H); ^{13}C NMR (75 MHz, D_2O): δ 173.57, 171.59, 169.27, 138.30, 136.14, 129.54, 128.56, 127.82, 126.61, 124.46, 62.79, 61.98, 59.66, 57.28, 55.45, 53.24, 48.38, 41.25, 31.93, 31.32, 31.11, 29.86, 28.81, 27.24, 20.27, 15.64.

SH-153



[0191] SH-153 was synthesized in the same sequence as that for SH-172 from compound **28**.

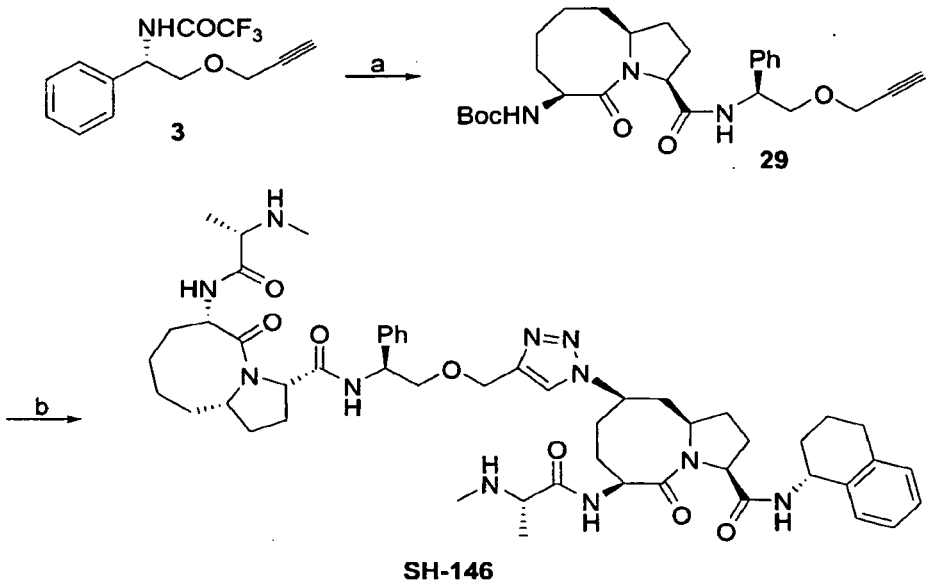
[0192] ^{1}H NMR (300 MHz, D_2O): δ 7.95 (s, 2H), 7.20-6.95 (m, 8H), 4.92-4.74 (m, 6H), 4.59 (s, 4H), 4.55 (m, 2H), 4.27 (m, 2H), 3.86 (m, 2H), 2.78-2.52 (m, 12H), 2.42-2.08 (m, 8H), 1.99-1.55 (m, 18H), 1.45 (d, J = 7.0 Hz, 6H); ^{13}C NMR (75 MHz, D_2O): δ 172.99, 171.58, 169.78, 138.23, 136.07, 129.46, 128.57, 127.78, 126.57, 123.39, 62.82, 62.56, 60.59, 58.14, 57.13, 50.49, 48.38, 42.62, 32.49, 31.30, 29.84, 29.53, 28.78, 27.86, 20.20, 15.61.

EXAMPLE 5

Synthesis of SH-146

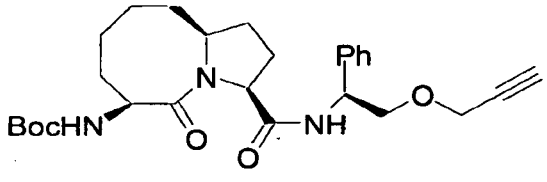
[0193] Compound SH-146 was synthesized according to Scheme VI.

Scheme VI:



Reagents and conditions: (a) i. 2 N LiOH, 1,4-dioxane:H2O 1:1; ii. **15**, EDC, HOBt, N,N-diisopropylethyl amine, CH2Cl2, 88% over two steps; (b) i. **24**, $CuSO_4$, (+)-sodium L-ascorbate, *t*-BuOH–H_2O 1:1, ii. 4N HCl in 1,4-dioxane, MeOH; iii. *L*-N-Boc-N-methyl alanine, EDC, HOBt, N,N-diisopropylethyl amine, CH_2Cl_2; iv. 4N HCl in 1,4-dioxane, MeOH, 55% over four steps.

[0194] Removal of the trifluoroacetyl protecting group in compound **3** followed by condensation of the resulted amine with acid **15** gave an amide **29**. Cycloaddition of azide **24** with alkyne **29** under the catalyzation of $CuSO_4$-(+)-sodium-L-ascorbate followed by removal of the Boc protecting groups afforded an ammonium salt. After condensation of this salt with L-N-Boc-N-methyl alanine, the Boc protecting groups were cleaved by treating with HCl in methanol to afford the bivalent Smac mimetic SH-146.

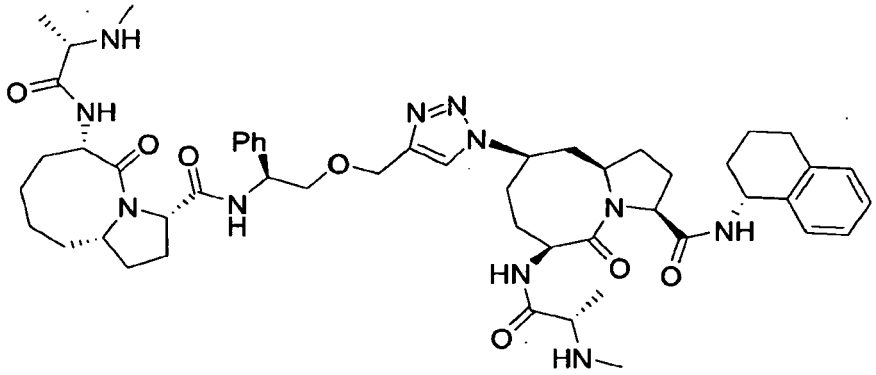


29

[0195] ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.75 (brs, J = 7.4Hz, 1H), 7.32-7.15 (m, 5H), 5.53 (brd, J = 7.1Hz, 1H), 5.08 (m, 1H), 4.73 (t, J = 6.6 Hz, 1H), 4.60 (m, 1H), 4.19 (brs, 2H), 4.12 (m, 1H), 3.80 (m, 2H), 2.62 (m, 1H), 2.45 (t, J = 2.3 Hz, 1H), 2.23-1.65 (m, 4H), 1.55-1.10 (m, 16H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 172.20, 169.94,

155.03, 139.45, 128.37, 127.46, 127.05, 79.59, 79.23, 74.91, 72.23, 59.76, 59.27, 58.34, 52.96, 51.08, 36.44, 32.00, 28.37, 24.93, 24.12, 23.08.

SH-146

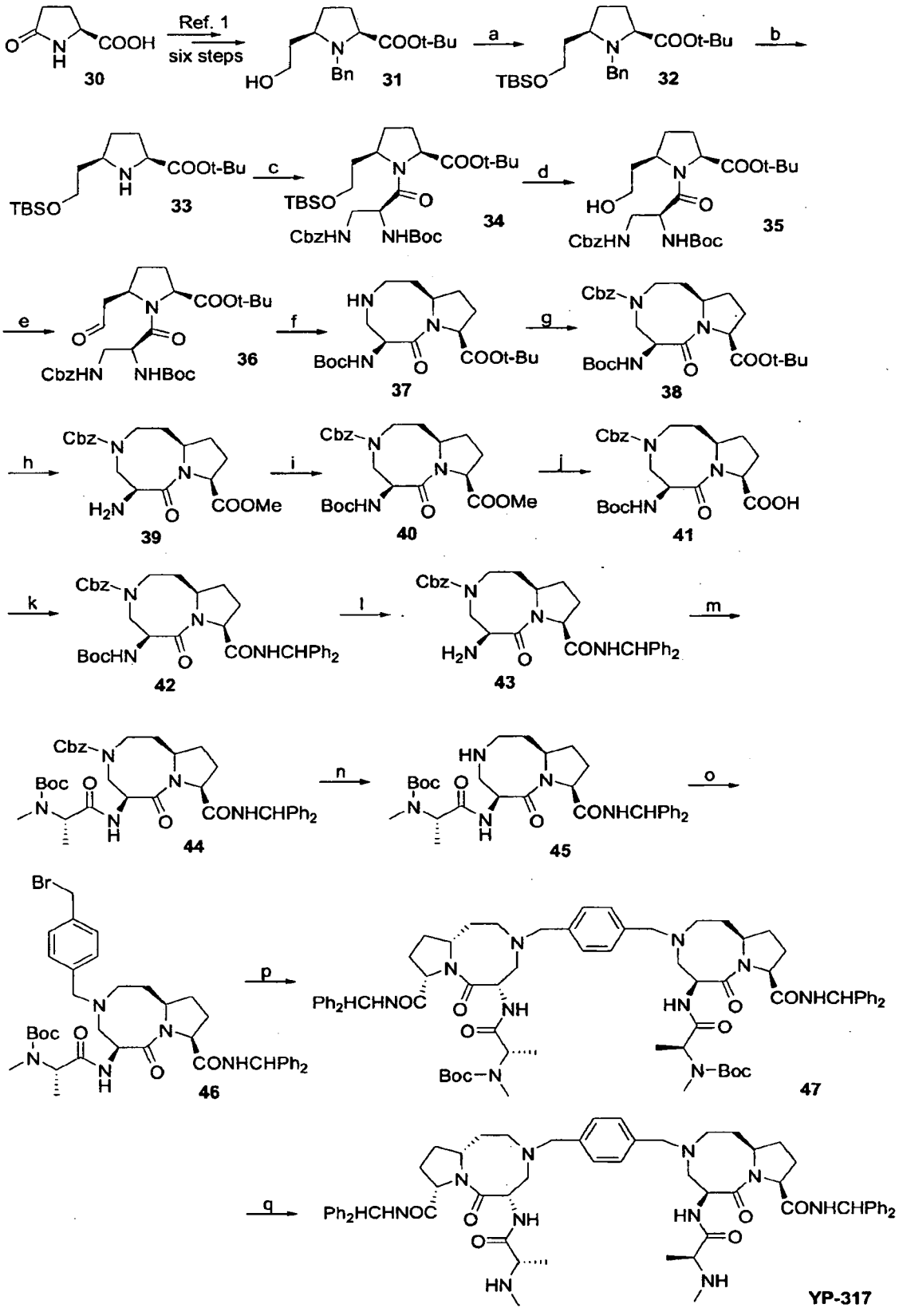


[0196] ^{1}H NMR (300 MHz, D_2O): δ 7.84 (s. 1H), 7.40-7.25 (m, 6H), 7.24-7.02 (m, 3H), 4.98-4.85 (m, 4H), 4.74 (m, 2H), 4.53 (s, 2H), 4.30 (m, 2H), 4.27 (m, 1H), 3.97-3.80 (m, 2H), 3.78-3.65 (m, 2H), 2.92 (m, 2H), 2.56 (s, 3H), 2.55 (s, 3H), 2.35-1.45 (m, 26H), 1.43 (d, J = 7.0 Hz, 3H), 1.38 (d, J = 7.0 Hz, 3H); ^{13}C NMR (75 MHz, D_2O): δ 173.88, 173.59, 172.24, 171.57, 169.52, 169.26, 143.92, 138.65, 138.31, 136.20, 129.51, 129.12, 128.48, 128.17, 127.80, 126.95, 126.60, 124.24, 72.30, 63.35, 62.21, 61.98, 61.05, 59.61, 57.27, 57.19, 55.46, 53.35, 53.20, 51.12, 48.41, 41.21, 35.95, 33.00, 32.34, 31.30, 29.83, 28.80, 27.94, 25.08, 21.91, 20.30, 15.62.

EXAMPLE 6

Synthesis of YP-317, YP-381, YP-383 and YP-385

[0197] Compound YP-317 was synthesized according to Scheme VII.


Ref. 1
six steps
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YP-317

Reagents and conditions: (a) *tert*-Butyldimethylsilyl chloride, N,N-diisopropylethyl amine, Methylene chloride; (b) 10% Pd-C, Methanol, H_2, 88% over two steps; (c) Boc-Dap(Z)-OH, EDC, HOBt, N,N-diisopropylethyl amine, Methylene chloride; (d) 1 M Tetrabutylammonium fluoride in tetrahydrofuran, Tetrahydrofuran, 87% over two steps; (e) Dess-Martin periodinane, Methylene chloride, 96%; (f) 10% Pd-C, Methanol, H_2, 64%; (g) Benzyl chloroformate, Sodium bicarbonate, 1,4-dioxane, 95%; (h) Thionyl chloride, Methanol; (i) Boc anhydride, Sodium bicarbonate, 1,4-dioxane, 71% over two steps; (j) 2 M Lithium hydroxide in H_2O, 1,4-dioxane-H_2O; (k) Aminodiphenylmethane, EDC, HOBt, N,N-diisopropylethyl amine, Methylene chloride, 74% over two steps; (l) 4 M Hydrogen chloride in 1,4-dioxane, Methanol; (m) L-N-Boc-N-methyl alanine, EDC, HOBt, N,N-diisopropylethyl amine, Methylene chloride, 78% over two steps; (n) 10% Pd-C, Methanol, H_2, 90%; (o) α,α'-dibromo-*p*-xylene, Sodium bicarbonate, 1,4-dioxane; (p) compound 21, Sodium bicarbonate, 1,4-dioxane; (q) 4M Hydrogen chloride in 1,4-dioxane, Methanol, 34% over three steps.

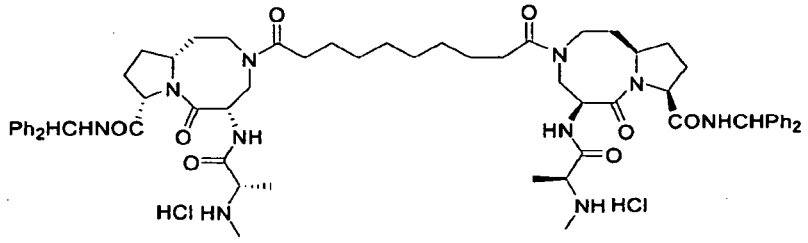
[0198] Compound 31 was prepared in six steps from pyroglutamic acid (compound 30) by the published methods (Zhang *et al.*, *Org. Lett.*, *4*:4029-4032 (2002); (b) Polyak *et al.*, *J. Org, Chem.* *63*:5937-5949 (1998)). The hydroxyl group in compound 31 was protected with TBS to yield compound 32. The benzyl protective group was removed by catalytic hydrogenation to yield amine 33, which was coupled with Boc-Dap(Z)-OH to give amide 34. The TBS protective group in compound 34 was removed by 1 M tetrabutylammonium fluoride in tetrahydrofuran to yield alcohol 35, which was then oxidized to aldehyde 36 by Dess-Martin Periodinane. Removal of the Cbz protective group in compound 36 by catalytic hydrogenation, intramolecular condensation of the desired amine with the aldehyde and subsequent reduction of the resulted enamine were carried out in one pot to give bicyclic compound 37. Amine 37 was protected with Cbz protective group to yield compound 38. The Boc protective group in compound 38 was removed and *tert*-butyl ester was converted to methyl ester by treating with thionyl chloride in methanol to give compound 39. The amine group was protected with Boc protective group to yield compound 40. Methyl ester 40 was transformed to carboxylic acid 41, which was condensed with aminodiphenylmethane to form amide 42. The Boc protective group in compound 42 was removed to give free amine 43, which was coupled with L-N-Boc-N-methyl alanine to yield amide 44. The Cbz protective group in compound 44 was removed by catalytic hydrogenation to give amine 45, which was treated with α,α'-dibromo-*p*-xylene to yield compound 46. Compound

46 was treated with compound 45 and sodium bicarbonate to give the protected dimer 47, whose Boc protective groups were removed to form the desired dimer YP-317.

[0199] ^{1}H NMR (D_2O) δ 9.23-9.26 (m, 1H), 7.18-7.22 (m, 8H), 7.06-7.08 (m, 4H), 6.02-6.05 (m, 1H), 5.30-5.36 (m, 1H), 4.59 (m, 1H), 4.52 (m, 1H), 4.27 (s, 2H), 3.78-3.86 (m, 2H), 3.53-3.58 (m, 2H), 2.99 (t, J = 2 Hz, 1H), 2.56 (s, 3H), 2.32 (m, 1H), 1.84-1.92 (m, 1H), 1.67-1.75 (m, 4H), 1.35-1.37 (d, J = 7Hz, 3H); ^{13}C NMR (D_2O) δ 173.93, 170.13, 167.90, 163.54, 163.07, 140.74, 140.62, 132.39, 130.59, 129.39, 129.26, 128.40, 128.13, 127.85, 127.58, 118.58, 114.72, 62.98, 61.07, 59.03, 58.25, 57.10, 56.42, 55.26, 54.18, 47.98, 31.65, 31.24, 30.98, 27.01, 15.42; HRMS Found: $[M+H]^+$ 1057.6057 (calcd 1057.6028).

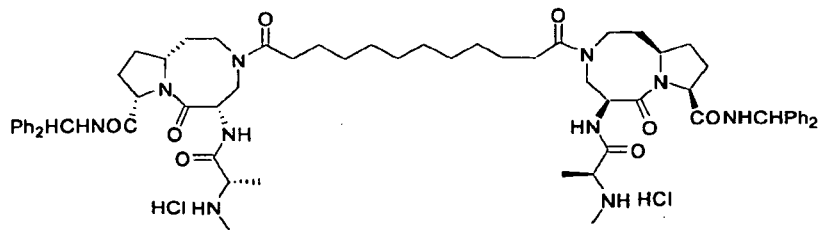
[0200] YP-381, YP-383 and YP-385 were synthesized in a similar fashion via acylation of compound **45**.

YP-381



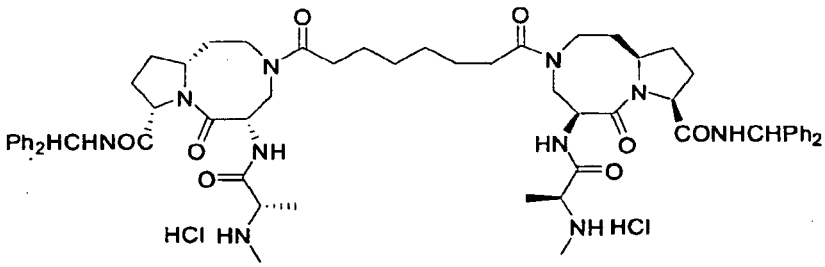
[0201] ^{1}H NMR (300 MHz, CD_3OD, TMS) δ 8.94-8.91 (d, *J* = 7.9 Hz, 1H), 7.37-7.24 (m, 10H), 6.17-6.14 (d, *J* = 8.2 Hz, 1H), 4.58-4.55 (m, 1H), 4.24 (br, 1H), 3.99-3.90 (m, 2H), 3.50-3.38 (m, 1H), 2.70 (s, 3H), 2.65-2.40 (m, 2H), 2.31 (m, 1H), 2.09-1.78 (m, 6H), 1.61 (m, 2H), 1.56-1.53 (d, *J* = 7.0 Hz, 3H), 1.32 (s, 4H). ^{13}CNMR (75 MHz, CD_3OD) δ 176.5, 175.9, 173.2, 169.6, 143.0, 129.6, 128.8, 128.2, 62.7, 58.2, 53.7, 34.4, 33.4, 32.3, 31.8, 30.3, 28.3, 26.1, 16.2. HRMS: calcd. m/z for $[M+Na]^+$ 1143.6371; found 1143.6387.

YP-383



[0202] ^{1}H NMR (300 MHz, CD_3OD, TMS) δ 7.35-7.27 (m, 10H), 6.16 (s, 1H), 4.59-4.52 (m, 1H), 4.24 (br, 1H), 4.02-3.99 (m, 1H), 3.97-3.92 (m, 1H), 3.90-3.87 (m, 1H), 3.58-3.48 (m, 2H), 2.70 (s, 3H), 2.56-2.34 (m, 2H), 2.34-2.32 (m, 1H), 2.06-1.19 (m, 6H), 1.56-1.53 (d, J = 7.0 Hz, 3H), 1.30 (s, 6H). ^{13}CNMR (75 MHz, CD_3OD) δ 176.5, 175.9, 173.2, 169.6, 143.0, 129.6, 128.8, 128.2, 62.7, 58.2, 53.7, 34.4, 33.4, 31.7, 30.6, 30.4, 28.3, 26.3, 16.1. HRMS: calcd. m/z for $[M+Na]^+$ 1171.6684; found 1171.6680.

YP-385

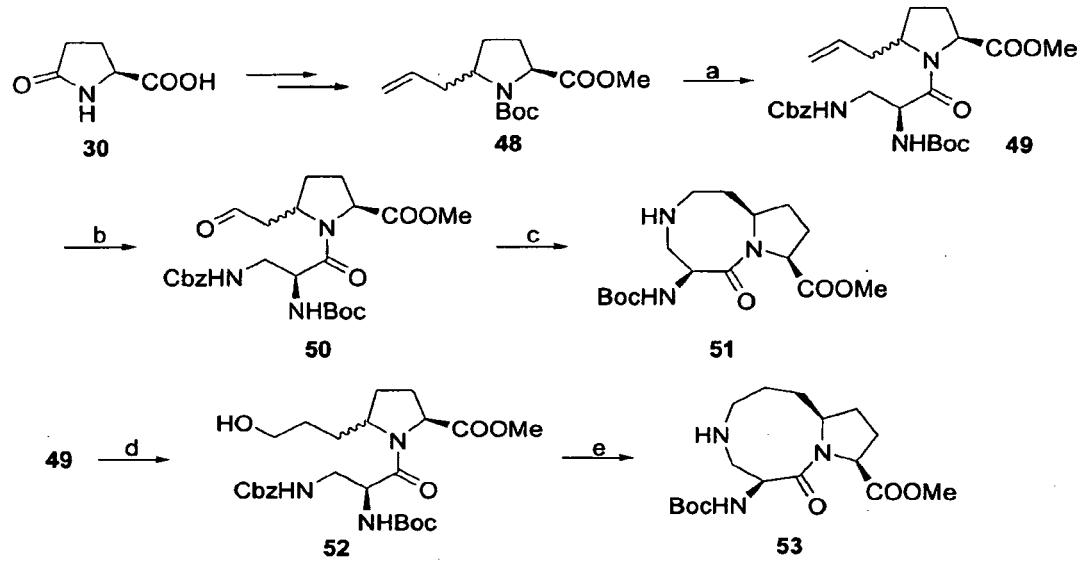


[0203] ^{1}H NMR (300 MHz, CD_3OD, TMS) δ 8.95-8.93 (d, J = 8.1 Hz, 1H), 7.37-7.24 (m, 10H), 6.17-6.14 (d, J = 8.0 Hz, 1H), 4.58-4.56 (m, 1H), 4.24 (br, 1H), 3.99-3.92 (m, 2H), 3.82-3.70 (m, 1H), 2.70 (s, 3H), 2.62-2.40 (m, 2H), 2:33 (m, 1H), 2.04-1.75 (m, 6H), 1.60-1.56 (m, 2H), 1.55-1.52 (d, J = 7.0 Hz, 3H), 1.34-1.30 (m, 2H). ^{13}CNMR (75 MHz, CD_3OD) δ 176.5, 175.8, 173.3, 169.7, 143.0, 129.6, 128.8, 128.2, 62.7, 58.2, 53.7, 34.5, 33.4, 31.7, 30.2, 28.3, 26.2, 16.1. HRMS: calcd. m/z for $[M+Na]^+$ 1115.6058; found 1115.6055.

EXAMPLE 7

Synthesis of Smac Mimetic Intermediates

Scheme VIII



Reagents and conditions: (a) i. 4 N HCl in 1,4-dioxane, methanol; ii. Boc-Dap(Z)-OH, EDC, HOBt, *N,N*-diisopropylethylamine, CH_2Cl_2, 52% over two steps; (b) O_3, then PPh_3, CH_2Cl_2, 90%; (c) H_2, 10% Pd-C, *i*-PrOH, 41%; (d) 9-BBN (2 eq), THF, reflux, 12h, then 3 N NaOH (2 eq), 35% H_2O_2 (2.5 eq), 0 °C - rt, 85%; (e) i. Dess-Martin periodinane, CH_2Cl_2; ii. H_2, 10% Pd-C, *i*-PrOH, 50% over two steps.

[0204] The synthesis of intermediates **51** and **53** is shown in Scheme VIII. Compound **48** may be prepared in five steps from pyroglutamic acid **30** according to reported methods (see: (1) Zhang, J.; Xiong, C.; Wang, W.; Ying, J.; Hruby, V., J. *Org. Lett.*, **2002**, *4* (23), 4029-4032 and (2) Polyak, F. and Lubell, W. D. *J. Org. Chem.* **1998**, *63*, 5937-5949) as a mixture of two diastereoisomers with the *R* form isomer as the major product (ratio is about 4:1). Removal of the Boc group in **48** followed by condensation with *N*-α-(*tert*-butoxylcarbonyl)-*N*-β-(benzoxylcarbonyl)-*L*-diamino-propionic acid (Boc-Dap(Z)-OH) gave amide **49**. Ozone oxidation of the C-C double bond in **49** yielded aldehyde **50**. Cleavage of the Cbz group in **4**, intra-molecular condensation of the resulting amine with the aldehyde group and subsequent reduction of the enamine were realized in one pot to give compound **51**. In this transformation only compound **51** was obtained and there was no detectable formation of its isomer, suggesting that the amino aldehyde from the minor isomer does not cyclize under these conditions.

[0205] Hydroboration of the C-C double bond in **49** with 9-BBN followed by alkaline oxidation of the resulted borane afforded alcohols **52**. Oxidation of **52** with Dess-Martin periodinane furnished a mixture of two aldehydes, which was cyclized in the same procedure as that for compound **51** to give compound **53**. Similar to **51**, during this transformation only one isomer was obtained.

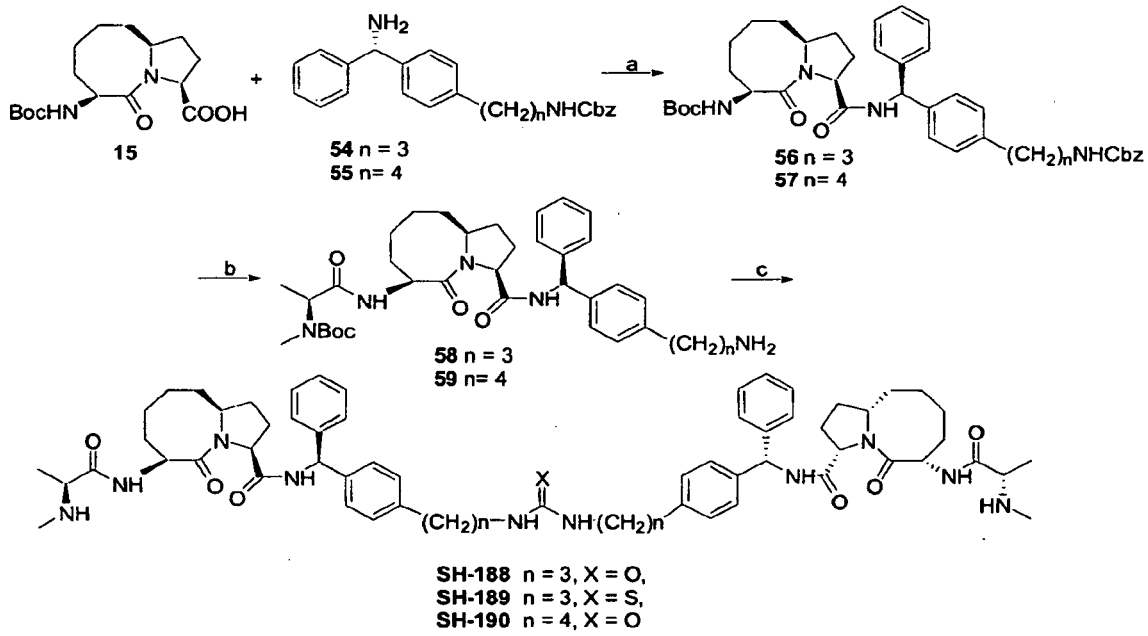
[0206] Analytical data for compound **51**: $[\alpha]^{20}_{D}$ – 30.2 (c = 1.7, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$, TMS) δ 5.45 (brd, J = 8.0 Hz, 1H), 4.67 (m, 1H), 4.52 (t, J = 9.0 Hz, 1H), 4.23 (m, 1H), 3.74 (s, 3H), 3.20 (m, 2H), 2.94 (m, 1H), 2.74 (dd, J = 13.6, 10.9 Hz, 1), 2.35 (m, 1H), 2.14 (m, 1H), 1.99 (m, 1H), 1.86-1.74 (m, 3H), 1.66 (m, 1H), 1.43 (brs, 9H); ^{13}C NMR (75 MHz, $CDCl_3$, TMS) δ 173.42, 170.60, 155.16, 79.68, 59.46, 58.39, 54.92, 52.44, 46.72, 37.45, 32.15, 29.64, 28.29, 26.98.

[0207] Analytical data for compound **53**: $[\alpha]^{20}_{D}$ – 23.2 (c = 1.0, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$, TMS) δ 5.23 (brd, J = 8.0 Hz, 1H), 4.79 (m, 1H), 4.65 (dd, J = 9.7, 8.2 Hz), 4.22 (m, 1H), 3.74 (s, 3H), 3.02-2.80 (m, 4H), 2.38-1.70 (m, 9H), 1.43 (brs, 9H); ^{13}C NMR (75 MHz, $CDCl_3$, TMS) δ 173.38, 171.59, 155.09, 79.68, 62.03, 59.82, 53.72, 53.15, 52.48, 50.09, 34.66, 34.55, 29.47, 28.31, 27.33.

EXAMPLE 8

Synthesis of SH-188, 189 and 190

Scheme IX



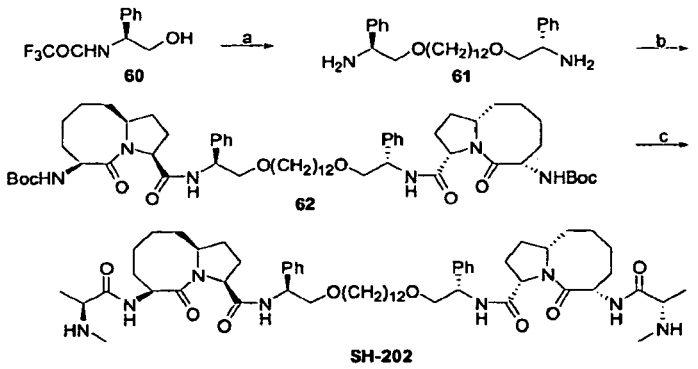
Reagents and conditions: (a) EDC, HOBt, N,N-diisopropylethylamine, CH_2Cl_2; (b) i. 4 N HCl in 1,4-dioxane, MeOH; ii. (*S*)-N-Boc-N-methylalanine, EDC, HOBt, N,N-diisopropylethylamine, CH_2Cl_2; iii. 10% Pd-C, H_2, MeOH; (c) thiophosgene or triphosgene, CH_2Cl_2; ii. 4 N HCl in 1,4-dioxane, MeOH.

[0208] Condensation of acid **15** with amine **54** or 55 gave amides **56** and **57** respectively (Scheme IX). Removal of the Boc protecting group in **56** or **57** followed by condensation of the resulted ammoniums with (*S*)-*N*-Boc-N-methyl alanine yielded two amides. Removal of the Cbz protecting groups in these two amides furnished amines **58** and **59**. Condensation of **58** or **59** with 0.5 eq of triphosgene afforded two ureas. Removal of the Boc protecting groups in these two ureas provided SH-188 and SH-190, respectively. Condensation of 58 with 0.5 eq of thiophosgene gave a thiourea. Removal of the Boc protecting group in this thiourea yielded SH-189.

EXAMPLE 9

Synthesis of SH-202

Scheme X



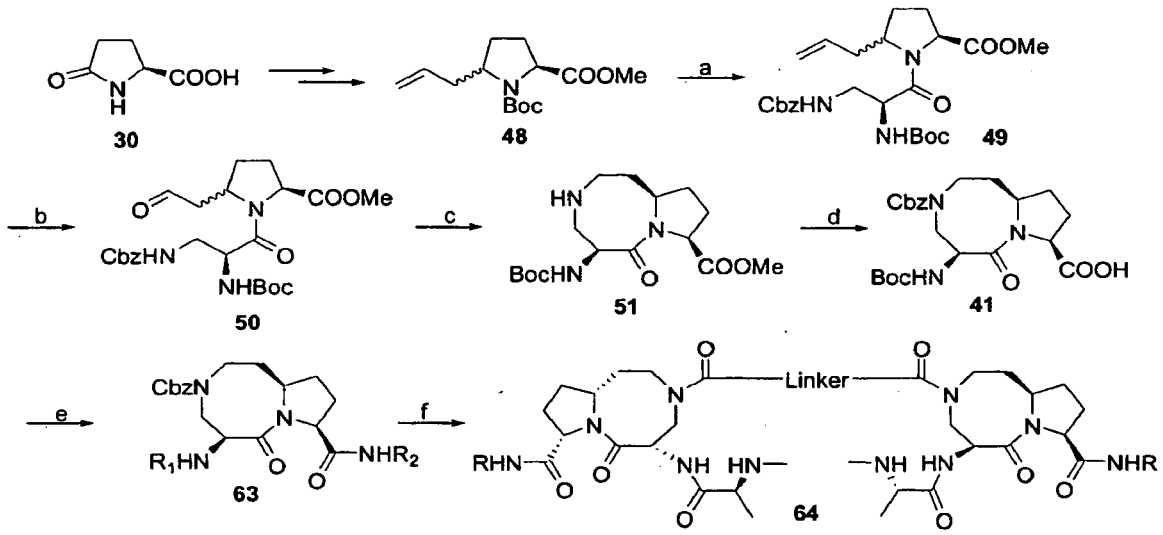
Reagents and conditions: (a). i. NaH (2.5 eq), 1,12-dibromododecane, DMF; ii. 3 N LiOH, 1,4-dioxane; (b) **acid 15** (2.2 eq), EDC, HOBt, N,N-diisopropylethylamine, CH_2Cl_2; (c) i. 4 N HCl, 1,4-dioxane, MeOH, ii. (S)-N-Boc-N-methyl alanine, EDC, HOBt, N,N-diisopropylethylamine, CH_2Cl_2; iii. 4 N HCl, 1,4-dioxane, MeOH.

[0209] Substitution of sodium alcoholate derived from compound **60** with 1,12-dibromododecane followed by removal of the trifluoroacetyl group gave diamine **61**. Condensation of **61** with 2 eq of acid **15** yielded an amide **62**. Removal of the Boc protecting groups in **62** followed by condensation with (*S*)-*N*-Boc-N-methyl alanine furnished an amide. Removal of the Boc protecting group in this amide provided SH-202.

EXAMPLE 10

Synthesis of Smac Mimetic Intermediates

Scheme XI



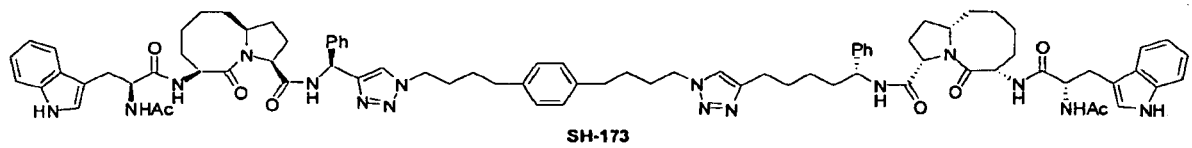
Reagents and conditions: (a) i. 4 N HCl in 1,4-dioxane, methanol; ii. Boc-Dap(Z)-OH, EDC, HOBt, *N,N*-diisopropylethylamine, CH_2Cl_2; (b) O_3, then PPh_3, CH_2Cl_2; (c) H_2, 10% Pd-C, *i*-PrOH; (d) i. CbzCl, $NaHCO_3$, 1,4-dioxane; ii. 3 N LiOH, 1,4-dioxane then 1 N HCl; (e) i. amine, EDC, HOBt, N,N-diisopropylethylamine, CH_2Cl_2; ii. 4 N HCl in 1,4-dioxane, methanol; iii. (S)-N-protected amino acid, EDC, HOBt, *N,N*-diisopropylethylamine, CH_2Cl_2; (f) i. diacid (0.5 eq), EDC, HOBt, N,N-diisopropylethylamine, CH_2Cl_2; ii. 4 N HCl in 1,4-dioxane, methanol.

[0210] A novel and efficient method for the synthesis of key intermediate **41** is presented in Scheme XI. Compound **48** may be prepared in five steps from pyroglutamic acid **30** according to reported methods (see: (1) Zhang, J.; Xiong, C.; Wang, W.; Ying, J. and Hruby, V., *J. Org. Lett.*, **2002**, *4* (23), 4029-4032 and (2) Polyak, F. and Lubell, W. D. *J. Org, Chem.* **1998**, *63*, 5937-5949) as a mixture of two diostereoisomers with the *R* form isomer as the major product (ratio is about 4:1). Removal of the Boc group in **48** followed by condensation with *N*-α-(*tert*-butoxylcarbonyl)-*N*-β-(benzoxylcarbonyl)-*L*-diamino-propionic acid (Boc-Dap(Z)-OH) gave amides **49**. Ozone oxidation of the C-C double bond in **49** followed by reduction with PPh_3 yielded aldehyde **50**. Cleavage of the Cbz group in **50**, intra-molecular condensation of the resulted amine with the aldehyde group and subsequent reduction of the enamine were realized in one pot to give the desired compound **51**. Protection of the amino group followed by hydrolysis of the methyl ester in **51** furnished acid **41**.

[0211] Condensation of **41** with different diamines gave a series of amides. Removal of the Boc protecting groups in these amides followed by condensation of the resulted ammonium salts with (S)-N-protected amino acids yielded a series of amides **63**. Removal of the protecting groups in these amides afforded our designed bivalent Smac mimetics **64**.

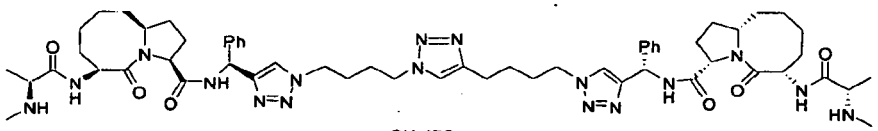
EXAMPLE 11

BIVALENT SMAC MIMETICS



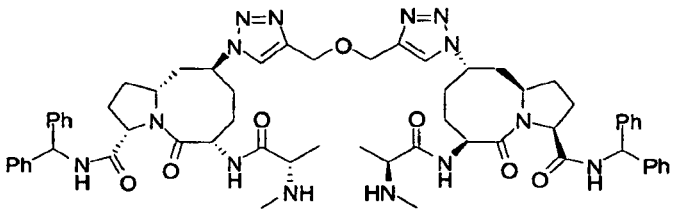
SH-173

[0212] **SH-173**: ^{1}H NMR (300 HMz, $CDCl_3$): δ 8.70 (s, 2H), 8.32 (d, J = 8.0 Hz, 2H), 7.60 (d, J = 7.4 Hz, 2H), 7.40-6.80 (m, 26 H), 6.47 (d, J = 7.9 Hz, 2H), 6.25 (d, J = 8.0 Hz, 2H), 4.81 (m, 2H), 4.70 (m, 2H), 4.50 (m, 2H), 4.27 (t, J = 7.1 Hz, 4H), 3.95 (m, 2H), 3.30-3.08 (m, 4H), 2.60 (t, J = 2.61 Hz, 4H), 2.45-2.25 (m, 2H), 2.12-1.20 (m, 36H); ^{13}C NMR (75 HMz, $CDCl_3$): δ 170.78, 170.41, 170.14, 169.88, 148.00, 140.45, 138.98, 136.19, 128.53, 128.44, 127.68, 127.56, 127.28, 123.70, 121.67, 121.55, 119.13, 118.57, 111.29, 110.25, 59.98, 59.06, 54.01, 50.40, 50.20, 50.01, 47.76, 35.93, 34.61, 31.74, 29.53, 29.09, 28.08, 24.83, 23.30, 22.95, 20.82;



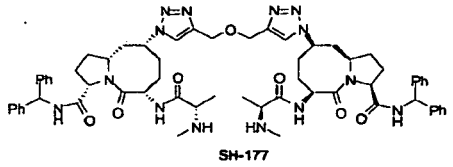
SH-175

[0213] **SH-175**: ^{1}H NMR (300 HMz, D_2O): δ 7.87 (s, 1H), 7.71 (s, 2H), 7.30-7.11 (m, 10H), 6.05 (s, 2H), 4.64 (m, 2H), 4.35-4.16 (m, 10H), 3.81 (m, 2H), 2.60 (t, J = 6.2 Hz, 2H), 2.54 (s, 6H), 2.10 (m, 2H), 1.98 (m, 2H), 1.75-1.42 (m, 34H); ^{13}C NMR (75 HMz, D_2O): δ 175.85, 174.79, 172.08, 150.63, 147.37, 141.60, 131.85, 131.09, 129.93, 128.50, 126.79, 64.57, 63.53, 59.73, 54.54, 53.66, 52.90, 52.59, 38.49, 35.57, 34.90, 33.93, 31.29, 30.32, 28.96, 28.65, 27.63, 27.38, 25.24, 24.49, 18.22.



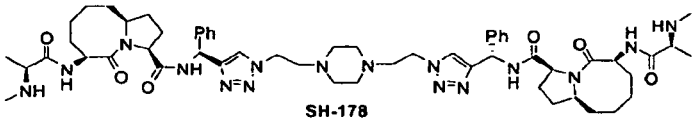
SH-176

[0214] **SH-176**: ^{1}H NMR (300 MHz, D_2O): δ 7.48 (s, 2H), 7.10-6.67 (20H), 5.84 (s, 2H), 4.65 (m, 2H), 4.55 (m, 2H), 4.42-4.16 (m, 8H), 3.80 (m, 2H), 2.53 (s, 6H), 2.25-1.30 (m, 26H); ^{13}C NMR (75 MHz, D_2O): δ 172.72, 171.00, 169.10, 143.67, 141.49, 141.30, 129.07, 127.96, 127.58, 127.39, 124.10, 62.76, 61.24, 59.43, 57.67, 57.27, 55.00, 53.20, 41.26, 32.12, 31.31, 26.98, 24.69, 15.62.



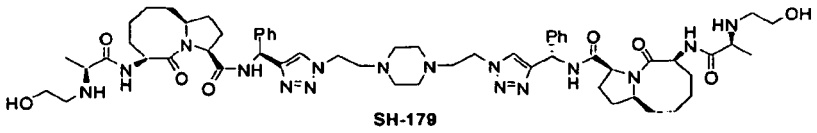
SH-177

[0215] **SH-177**: ^{1}H NMR (300 MHz, D_2O): δ 7.62 (s, 2H), 7.15-6.90 (20H), 5.90 (s, 2H), 4.75 (m, 4H), 4.43 (s, 4H), 4.39 (m, 4H), 3.83 (m, 2H), 2.80 (s, 6H), 2.46 (m, 2H), 2.22-1.90 (m, 8H), 1.75-1.43 (m, 10H), 1.36 (d, J = 8.4 Hz, 6H); ^{13}C NMR (75 MHz, D_2O): δ 175.14, 173.74, 172.25, 146.86, 144.06, 143.66, 131.72, 131.66, 130.55, 130.21, 129.97, 125.60, 65.46, 64.63, 62.98, 60.36, 59.70, 52.87, 45.02, 34.98, 33.87, 32.30, 30.26, 18.17.



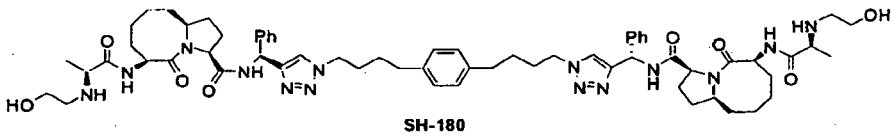
SH-178

[0216] **SH-178**: ^{1}H NMR (300 MHz, D_2O): δ 7.88 (s, 2H), 7.46-7.30 (m, 10H), 6.19 (s, 2H), 4.78 (m, 6H), 4.42 (m, 2H), 4.30 (m, 2H), 3.90 (m, 2H), 3.74 (m, 4H), 3.60 (m, 4H), 3.52 (m, 2H), 3.28 (m, 2H), 2.64 (s, 6H), 2.40-1.56 (m, 24H), 1.49 (d, J = 7.0 Hz, 6H); ^{13}C NMR (75 MHz, D_2O): δ 176.14, 174.90, 172.10, 151.28, 141.51, 131.90, 131.19, 130.01, 127.32, 64.64, 63.61, 59.73, 58.06, 53.68, 52.96, 52.05, 47.49, 38.50, 35.53, 34.90, 33.89, 30.35, 27.61, 24.48, 18.18.



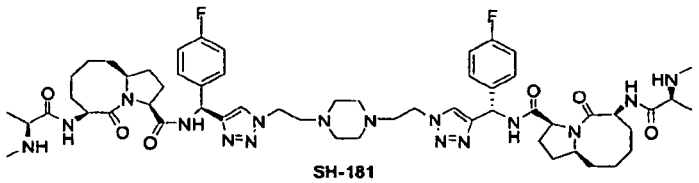
SH-179

[0217] **SH-179**: ^{1}H NMR (300 MHz, D_2O): δ 7.87 (s, 2H), 7.40-7.22 (m, 10H), 6.19 (s, 2H), 4.74 (m, 6H), 4.42 (m, 2H), 4.30 (m, 2H), 4.05 (m, 2H), 3.79 (t, J = 5.1 Hz, 4H), 3.71 (t, J = 5.1 Hz, 4H), 3.53 (brs, 8H), 3.10 (m, 4H), 2.40-1.60 (m, 24H), 1.50 (d, J = 7.0 Hz, 6H); ^{13}C NMR (75 MHz, D_2O): δ 176.15, 174.92, 172.00, 151.25, 141.51, 131.90, 131.19, 130.07, 127.28, 64.64, 63.60, 59.57, 58.60, 58.06, 53.69, 52.95, 52.14, 50.67, 47.56, 38.49, 35.53, 34.89, 30.34, 27.60, 24.47, 18.46.



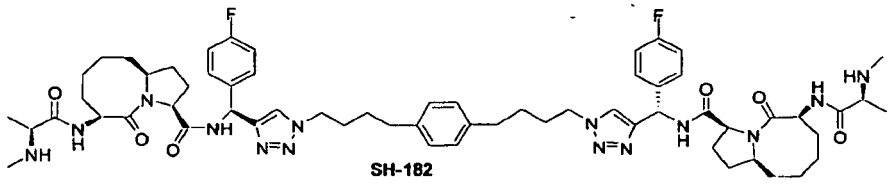
SH-180

[0218] **SH-180**: ^{1}H NMR (300 MHz, D_2O): δ 7.60 (s, 2H), 7.30-7.10 (m, 10H), 6.68 (s, 4H), 6.15 (s, 2H), 4.74 (m, 2H), 4.52-4.30 (m, 4H), 4.20 (m, 2H), 4.19-4.02 (m, 8H), 3.80 (m, 2H), 3.13 (m, 2H), 2.40-1.12 (m, 42H); ^{13}C NMR (75 MHz, D_2O): δ 172.79, 170.36, 169.39, 148.33, 139.54, 129.24, 128.55, 127.41, 123.46, 61.91, 60.88, 60.28, 57.02, 56.06, 50.99, 50.38, 49.08, 48.13, 35.98, 34.26, 33.10, 32.32, 29.20, 27.85, 25.11, 21.95, 16.84.



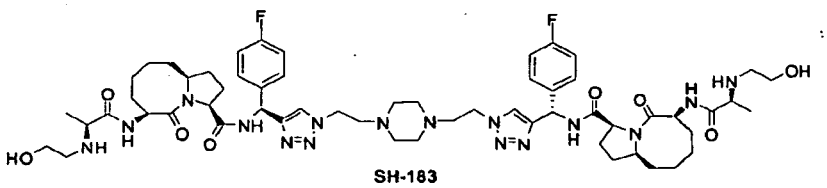
SH-181

[0219] **SH-181**: ^{1}H NMR (300 MHz, D_2O): δ 7.87 (s, 2H), 7.31 (m, 4H), 7.08 (m, 4H), 6.16 (s, 2H), 4.82-4.72 (m, 6H), 4.50 (m, 2H), 4.26 (m, 2H), 3,88 (m, 2H), 3.78 (m, 4H), 3.68 (brs, 8H), 2.61 (s, 6H), 2.36-1.53 (m, 24H), 1.50 (t, J = 7.0 Hz, 6H); ^{13}C NMR (75 MHz, D_2O): δ 176.03, 174.85, 172.05, 163.45, 151.16, 137.40, 131.90, 127.33, 118.51, 64.59, 63.58, 59.73, 58.02, 53.64, 52.30, 51.87, 47.26, 38.48, 35.53, 34.86, 33.85, 30.27, 27.60, 24.47, 18.16.



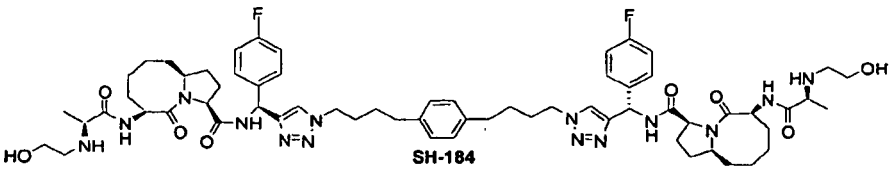
SH-182

[0220] **SH-182**: ^{1}H NMR (300 MHz, D_2O): δ 7.61 (s, 2H), 7.23 (m, 4H), 6.78 (m, 4H), 6.53 (m, 4H), 6.12 (s, 2H), 4.70 (m, 2H), 4.32 (m, 2H), 4.18 (m, 2H), 4.10-3.83 (m, 6H), 2.61 (s, 6H), 2.22-1.03 (m, 42H); ^{13}C NMR (75 MHz, D_2O): δ 172.53, 171.92, 169.39, 160.60, 148.31, 139.38, 134.84, 129.40, 128.42, 115.60, 61.76, 60.78, 57.20, 50.94, 50.27, 49.59, 35.99, 34.42, 33.22, 32.32, 31.33, 29.41, 27.95, 25.14, 21.99, 15.66.



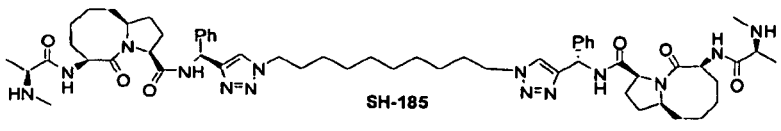
SH-183

[0221] **SH-183**: ^{1}H NMR (300 HMz, D_2O): δ 7.87 (s, 2H), 7.38-7.22 (m, 4H), 7.12-6.99 (m, 4H), 6.17 (s, 2H), 4.85-4.74 (m, 6H), 4.34 (m, 2H), 4.27 (m, 2H), 3.98 (m, 2H), 3.80-3.65 (m, 8H), 3.55 (s, 8H), 3.10 (m, 2H), 2.37-1.40 (m, 30H).



SH-184

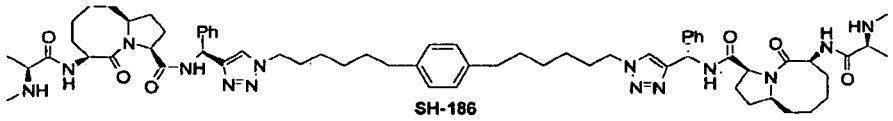
[0222] **SH-184**: ^{1}H NMR (300 MHz, D_2O): δ 7.62 (s, 2H), 7.20 (m, 4H), 6.90-6.70 (m, 4H), 6.69-6.50 (brs, 4H), 6.19 (s, 2H), 4.72 (m, 2H), 4.50-4.28 (m, 4H), 4.20-3.80 (m, 6H), 3.12 (m, 4H), 2.22-0.98 (m, 42H).



SH-185

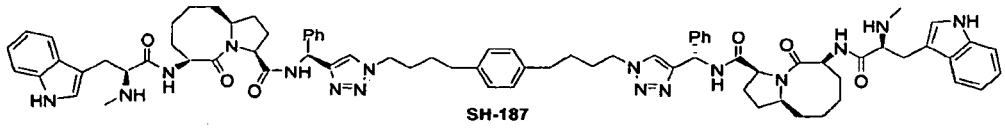
[0223] **SH-185**: ^{1}H NMR (300 HMz, D_2O): δ 7.67 (s, 2H), 7.26-7.10 (m, 10H), 6.07 (s, 2H), 4.73 (m, 2H), 4.28 (m, 2H), 4.25-4.10 (m, 6H), 3.83 (m, 2H), 2.54 (s, 6H), 2.20-1.92 (m, 4H), 1.86-1.30 (m, 34H), 0.98-0.80 (m, 12H); ^{13}C NMR (75 HMz, D_2O): δ 177.43, 173.05, 172.22, 148.26, 139.29, 129.28, 128.50, 127.43, 123.81, 62.00, 60.99, 57.20, 51.08, 50.76, 50.40, 36.00, 33.06, 32.36, 31.32, 29.52, 28.62, 28.26, 27.77, 25.76, 25.10, 21.93, 15.65.

[0224]



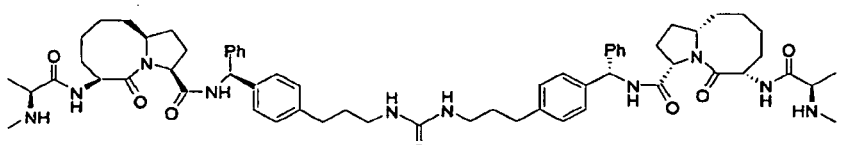
SH-186

[0225] **SH-186**: ^{1}H NMR (300 HMz, D_2O): δ 7.58 (s, 2H), 7.20-6.90 (m, 10H), 6.61 (s, 4H), 6.08 (s, 2H), 4.72 (m, 2H), 4.30 (m, 2H), 4.10 (m, 2H), 3.95 (m, 4H), 3.80 (m, 2H), 2.52 (s, 6H), 2.25-1.05 (m, 36H), 1.02-0.75 (m, 14H); ^{13}C NMR (75 HMz, D_2O): δ 174.88, 174.40, 171.91, 151.04, 142.52, 142.31, 131.63, 130.92, 130.00, 125.57, 125.09, 64.30, 63.24, 59.74, 53.42, 52.90, 38.63, 38.20, 35.90, 34.85, 34.28, 33.87, 32.69, 32.05, 31.73, 30.20, 29.07, 27.76, 24.49, 18.23.



SH-187

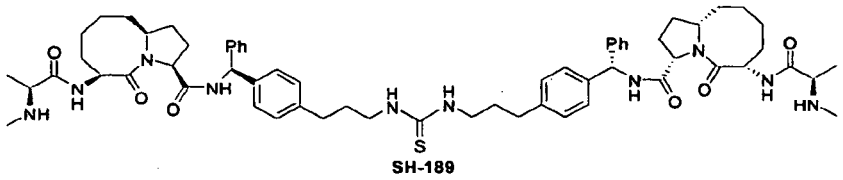
[0226] **SH-187**: ^{1}H NMR (300 HMz, D_2O): δ 7.56 (s, 2H), 7.40-7.05 (m, 16H), 7.02 (m, 2H), 6.90 (m, 2H), 6.78 (m, 4H), 6.11 (s, 2H), 4.75 (m, 2H), 4.49 (m, 2H), 4.25 (m, 4H), 4.20 (m, 2H), 3.98 (m, 2H), 3.84 (m, 2H), 2.49 (s, 6H), 2.38 (m, 4H), 2.24-1.22 (m, 36H).



SH-188

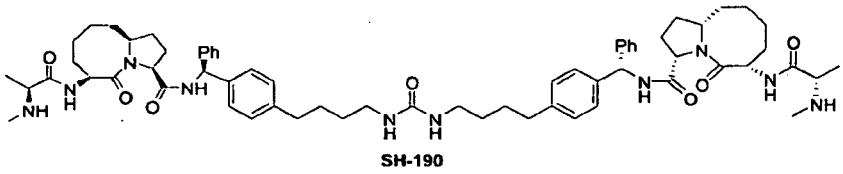
[0227] **SH-188**: ^{1}H NMR (300 HMz, D_2O): δ 7.10-6.92 (m, 10H), 6.85 (m, 4H), 6.70 (m, 4H), 5.85 (s, 2H), 4.65 (m, 2H), 4.32 (m, 2H), 4.06 (m, 2H), 3.82 (m,

2H), 2.74 (m, 4H), 2.54 (s, 6H), 2.15 (m, 4H), 2.02-1.20 (m, 34H); ^{13}C NMR (75 HMz, D_2O): δ 172.36, 171.92, 169.41, 160.17, 141.40, 141.15, 139.27, 129.01, 127.66, 127.46, 61.88, 60.87, 57.18, 50.94, 39.72, 35.99, 33.20, 32.49, 31.60, 31.33, 27.79, 25.19, 21.91, 15.69.



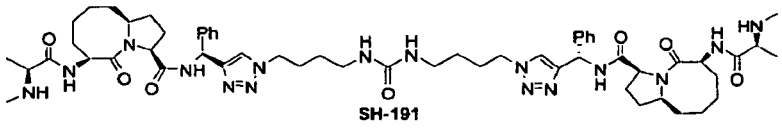
SH-189

[0228] **SH-189**: ^{1}H NMR (300 HMz, D_2O): δ 7.18-6.99 (m, 10H), 6.95 (m, 4H), 6.80 (m, 4H), 5.90 (s, 2H), 4.72 (m, 2H), 4.36 (m, 2H), 4.13 (m, 2H), 3.89 (m, 2H), 3.30 (brm, 4H), 2.63 (s, 6H), 2.30 (m, 4H), 2.12-1.18 (m, 34H).



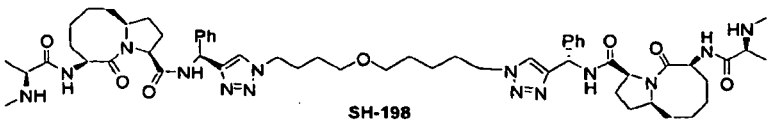
SH-190

[0229] **SH-190**: ^{1}H NMR (300 HMz, D_2O): δ ^{13}C NMR (75 HMz, D_2O): δ 7.15-6.93 (m, 10H), 6.95 (m, 4H), 6.79 (m, 4H), 6.85 (s, 2H), 4.74 (m, 2H), 4.36 (m, 2H), 4.13 (m, 2H), 3.88 (m, 2H), 2.80 (m, 4H), 2.58 (s, 6H), 2.36-1.08 (m, 42H).



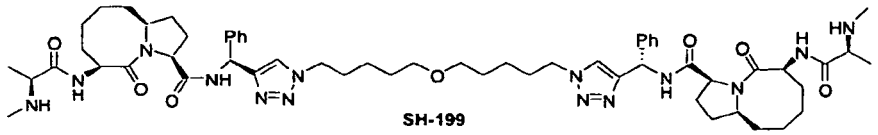
SH-191

[0230] **SH-191**: ^{1}H NMR (300 HMz, D_2O): δ 7.75 (s, 2H), 7.40-7.20 (m, 10H), 6.16 (s, 2H), 4.74 (m, 2H), 4.36 (m, 2H), 4.32-4.20 (m, 6H), 3.89 (m, 2H), 2.95 (t, J = 6.6 Hz, 4H), 2.64 (s, 6H), 2.32-1.20 (m, 38H).



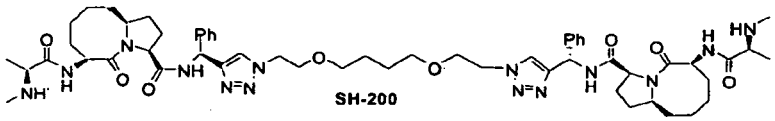
SH-198

[0231] **SH-198**: ^{1}H NMR (300 HMz, D_2O): δ 7.70 (s, 2H), 7.30-7.12 (m, 10H), 6.07 (s, 2H), 4.65 (m, 2H), 4.32 (m, 2H), 4.25-4.10 (m, 6H), 3.84 (m, 2H), 3.10 (m, 4H), 2.55 (s, 6H), 2.20-1.20 (m, 38H), 0.98 (m, 2H); ^{13}C NMR (75 HMz, D_2O): δ 173.17, 172.22, 169.53, 148.15, 139.16, 129.32, 128.54, 127.40, 124.04, 70.20, 69.63, 62.01, 60.98, 57.19, 51.10, 50.82, 50.63, 50.35, 35.97, 33.06, 32.36, 31.37, 29.29, 28.17, 27.77, 26.48, 25.80, 25.10, 22.58, 21.95, 15.67.



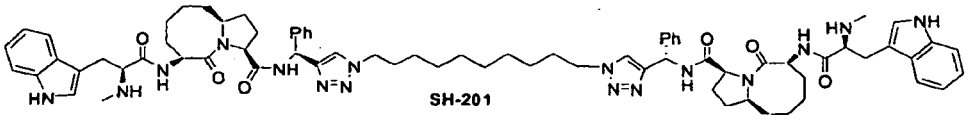
SH-199

[0232] **SH-199**: ^{1}H NMR (300 HMz, D_2O): δ 7.73 (s, 2H), 7.20-7.02 (m, 10H), 6.05 (s, 2H), 4.65 (m, 2H), 4.30 (m, 2H), 4.22-4.08 (m, 6H), 3.84 (m, 2H), 3.08 (m, 4H), 2.52 (s, 6H), 2.25-0.90 (m, 42H); ^{13}C NMR (75 HMz, D_2O): δ 173.02, 172.13, 169.49, 147.91, 139.07, 129.31, 128.55, 127.41, 124.14, 70.25, 66.87, 61.93, 60.90, 57.18, 50.97, 50.22, 36.01, 33.08, 32.37, 31.40, 29.33, 28.23, 27.74, 25.11, 22.62, 21.97, 15.70.



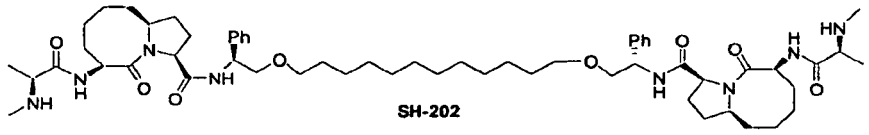
SH-200

[0233] **SH-200**: ^{1}H NMR (300 HMz, D_2O): δ 7.77 (s, 2H), 7.22-7.08 (m, 10H), 6.05 (s, 2H), 4.65 (m, 2H), 4.37-4.22 (m, 6H), 4.16 (m, 2H), 3.82 (m, 2H), 3.48 (m, 4H), 3.08 (m, 4H), 2.52 (s, 6H), 2.16-1.42 (m, 30H), 1.01 (m, 4H); ^{13}C NMR (75 HMz, D_2O): δ 173.11, 172.16, 169.49, 148.01, 139.10, 129.32, 128.56, 127.38, 124.62, 70.59, 68.39, 66.87, 61.96, 60.95, 57.19, 50.73, 50.24, 35.98, 33.09, 32.36, 31.40, 27.77, 25.43, 25.12, 21.96, 15.69.



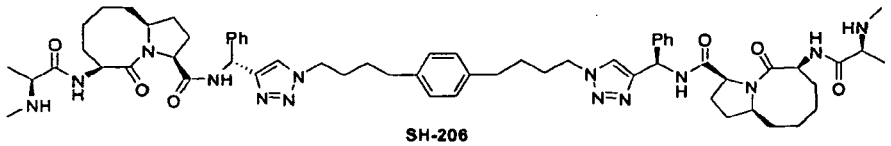
SH-201

[0234] **SH-201:** ^{1}H NMR (300 HMz, D_2O): δ 7.60 (s, 2H), 7.40-6.70 (m, 20), 6.16 (s, 2H), 4.75 (m, 2H), 4.49 (m, 2H), 4.25 (m, 4H), 4.20 (m, 2H), 3.98 (m, 2H), 3.84 (m, 2H), 2.49 (s, 6H), 2.40-1.20 (m, 48H).



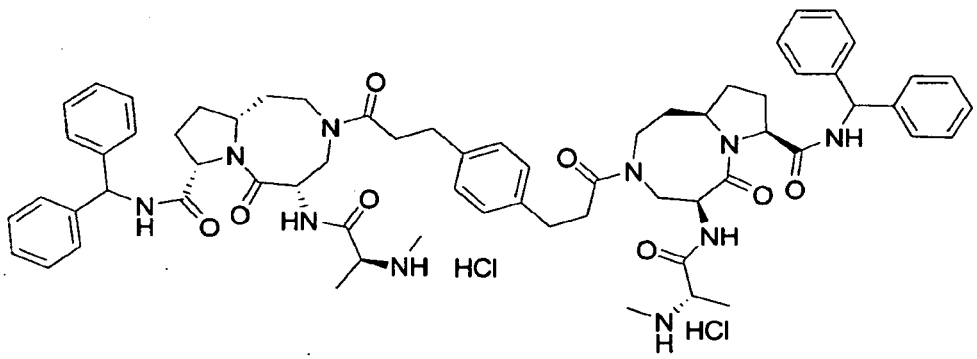
SH-202

[0235] **SH-202:** ^{1}H NMR (300 HMz, D_2O): δ 7.35-7.16 (m, 10H), 5.02 (m, 2H), 4.74 (m, 2H), 4.39 (m, 2H), 4.27 (m, 2H), 3.92 (m, 2H), 3.55 (m, 4H), 3.34 (m, 4H), 2.64 (s, 6H), 2.28-1.20 (m, 54H); ^{13}C NMR (75 HMz, D_2O): δ 175.35, 174.62, 172.04, 141.98, 131.60, 130.66, 129.70, 75.84, 73.59, 64.68, 63.33, 59.74, 55.57, 53.55, 38.93, 35.65, 35.05, 33.93, 32.55, 32.31, 30.64, 28.86, 27.85, 24.68, 18.29.



SH-206

[0236] **SH-206:** ^{1}H NMR (300 HMz, D_2O): δ 7.44 (s, 2H), 7.30-6.80 (m, 10H), 6.49 (s, 4H), 5.99 (s, 2H), 4.63 (m, 2H), 4.28 (m, 2H), 4.06 (m, 2H), 3.92 (m, 2H), 3.80 (m, 4H), 2.55 (s, 6H), 2.28-0.95 (m, 42H); ^{13}C NMR (75 HMz, D_2O): δ 175.04, 174.33, 171.97, 150.65, 143.08, 141.97, 131.63, 131.00, 130.59, 129.60, 126.25, 64.31, 63.33, 59.74, 53.47, 52.92, 38.47, 36.87, 35.85, 34.86, 33.87, 31.85, 30.42, 27.65, 24.52, 18.26.



SM-410

[0237] **SM-410**: ^{1}H NMR (MeOH-d_4, 300 M Hz) δ 8.91 (m, 2H), 7.37-7.13 (m, 24H), 6.16 (m, 2H), 4.73 (m, 2H), 4.53 (m, 2H), 4.06-3.73 (m, 8H), 3.37-3.27 (m, 6H), 2.92 (m, 6H), 2.68 (m, 6H), 2.30 (m, 2H), 2.05-1.81 (m, 10H), 1.55 (m, 6H); ^{13}C NMR (MeOH-d_4, 300 M Hz) δ 174.4, 172.3, 169.3, 168.6, 142.2, 142.0, 139.3, 129.1, 128.7, 128.5, 127.8, 127.5, 127.3, 61.8, 57.3, 52.6, 51.8, 46.6, 34.9, 32.4, 31.4, 30.9, 27.3, 15.3.

EXAMPLE 12

Binding of Inhibitors to XIAP BIR3

[0238] In order to test the binding ability of the bivalent Smac mimetics to IAP proteins, a sensitive and quantitative *in vitro* binding assay using the fluorescence polarization (FP) based method was developed and used to determine the binding affinity of Smac mimetics to XIAP protein (Nikolovska-Coleska *et al.*, *Anal Biochem. 332*:261-73 (2004)). For this assay, 5-carboxyfluorescein (5-Fam) was coupled to the lysine side chain of the mutated Smac peptide, AbuRPF-K-(5-Fam)-NH_2 (termed SM5F). The K_d value of the binding of SM5F peptide to XIAP BIR3 protein was determined to be 17.92 nM, showing that this peptide binds to the surface pocket of the XIAP protein with high affinity. The recombinant XIAP BIR3 protein of human XIAP (residues 241-356) fused to His-tag was stable and soluble, and was used for the FP based binding assay.

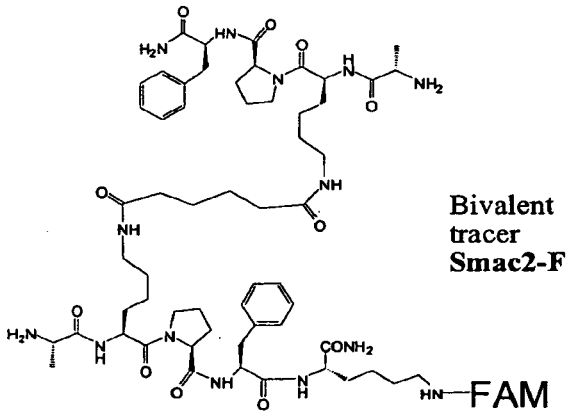
[0239] The dose-dependent binding experiments were carried out with serial dilutions of the tested compounds in DMSO. A 5 μl sample of the tested samples and preincubated XIAP BIR3 protein (30 nM) and SM5F peptide (5 nM) in the assay buffer (100 mM potassium phosphate, pH 7.5; 100 μg/ml bovine gamma globulin; 0.02% sodium azide, purchased from Invitrogen™ Life Technology), were added in Dynex 96-well, black, round-bottom plates (Fisher Scientific) to produce a final volume of 125 μl. For each assay, the bound peptide control containing recombinant XIAP BIR3 protein and SM5F (equivalent to 0% inhibition) and free peptide control containing only free SM5F (equivalent to 100% inhibition) were included. The polarization values were measured after 3 hrs of incubation when the

binding reached equilibrium using an ULTRA READER (Tecan U.S. Inc., Research Triangle Park, NC). IC_{50} values, the inhibitor concentration at which 50% of bound peptide is displaced, were determined from a plot using nonlinear least-squares analysis. Curve fitting was performed using GRAPHPAD PRISM software (GraphPad Software, Inc., San Diego, CA).

EXAMPLE 13

Fluorescence-polarization-based binding assay to XIAP protein

[0240] A Smac mimetic was incubated with human XIAP protein (residues 120-356) (10 nM) and a fluorescently tagged, Smac-based bivalent peptide, called Smac2-F (0.5 nM) as the tracer in the assay buffer (100 mM potassium phosphate, pH 7.5; 100 ug/ml bovine gamma globulin; 0.02% sodium azide) in Dynex 96-well, black, round-bottom plates (Fisher Scientific). Smac2-F was determined to bind XIAP with a K_d value of 1.2 nM. For each assay, the controls included XIAP and Smac2-F peptide (equivalent to 0% inhibition), and Smac-2F only (equal to 100% of inhibition). The polarization values were measured after 2 hours incubation, using the Ultra plate reader. The IC_{50} value, the inhibitor concentration at which 50% of bound tracer is displaced, is determined from the plot using nonlinear least-squares analysis. Curve fitting is performed using GraphPad Prism® software.



[0241] When tested in the binding assay, bivalent Smac mimetic SH-164 had an IC_{50} of 1.9 ± 0.5 nM (FIG. 1). This was more than 500-fold better than the binding affinity of the monovalent Smac mimetic SH-122 and >5000 times more potent

than the natural Smac peptide AVPI (SEQ ID NO: 1). These data suggest that bivalent Smac mimetics will act as potent inhibitors of IAP activity. The binding affinities of additional bivalent Smac mimetics are presented in Table 4.

Table 4

Name	Binding Affinities to XIAP BIR3 (IC_{50} [uM])
YP-245P3	1-10
YP-246P	0.1-1
YP-330	<0.1
YP-337	<0.1
YP-350	<0.1
YP-356	<0.1
YP-376	<0.1
YP-377	<0.1
SM-401	<0.1
SM-402	<0.1
SM-403	<0.1
SM-404	<0.1
SM-405	<0.1
SM-406	<0.1
SM-407	<0.1
SM-408	<0.1
SM-409	<0.1
SH-207	<1

EXAMPLE 14

Cell Growth Inhibition by Bivalent Smac Mimetics

[0242] The effect of SH-164 on the growth of various cancer cell lines was tested. Cells were seeded in 96-well flat bottom cell culture plates at a density of 3000 cells/well with a tested compound and incubated at 37 °C in an atmosphere of 95% air and 5% CO_2 for 4 days. The rate of cell growth inhibition after treatment with different concentrations of the compound was determined using a WST-8 kit (2-(2-methoxy-4-nitrophenyl)-3-(4-nitrophenyl)-5-(2, 4 disulfophenyl)-2H-tetrazolium monosodium salt; Dojindo Molecular Technologies, Inc., Gaithersburg, Maryland).

WST-8 was added at a final concentration of 10% to each well, and then the plates were incubated at 37 °C for 2-3 hrs. The absorbance of the samples was measured at 450 nm using a ULTRA Tecan Reader (Molecular Device). The concentration of the tested compound that inhibited cell growth by 50% (IC_{50}) was calculated by comparing absorbance in untreated cells and the cells treated with the tested compound.

[0243] When tested against the MDA-MB-231 human breast cancer cell line and the MAMEL-3M melanoma cell line, SH-164 exhibited an IC_{50} of 1.4 nM (FIG. 2). In addition, SH-164 is also a potent inhibitor in several other cancer cell lines (FIG. 2).

EXAMPLE 15

Induction of Cell Death by Bivalent Smac Mimetics

[0244] The ability of SH-164 to induce cell death in various cancer cell lines was tested using a Trypan blue cell viability assay. 0.3 x 10^6 cells were seeded in 6 well plates and incubated at 37 °C in an atmosphere of 95% air and 5% CO_2 without or with tested compound for 2 days. A 1:1 dilution of 0.4% Trypan blue (Invitrogen Corporation) was used to determine cell viability. SH-164 was shown to be an effective inducer of cell death when incubated with MDA-MB-231, MAMLE-3M, and OVCAR-4 cells (FIG. 3). In each case, SH-164 induced at least 70% cell death at a concentration of 100 nM.

EXAMPLE 16

Effect of Combinations of Bivalent Smac Mimetics and Other Agents on Cell Growth Inhibition

[0245] To test the ability of bivalent Smac mimetics to sensitize cancer cells to the growth inhibiting effects of other agents, cell growth inhibition assays were carried out with various agents alone or in combination with increasing doses of bivalent Smac mimetics. Exposure of MDA-MB-231 (2LMP) breast cancer cells to TRAIL alone resulted in an IC_{50} of 2.2 ng/ml (FIG. 4A). Combination of TRAIL and SH-164 lowered the IC_{50} for TRAIL significantly, with TRAIL in the presence of 100

nM SH-164 having an IC_{50} of 0.008 ng/ml. A similar result was seen with MDA-MB-453 breast cancer cells, where TRAIL alone had an IC_{50} of >1000 ng/ml and the combination of TRAIL and 100 nM SH-164 had an IC_{50} of 16 ng/ml (FIG. 4B). When PC-3 human prostate cancer cells were used, TRAIL alone had an IC_{50} of >300 ng/ml while TRAIL in the presence of 100 nM SH-164 had an IC_{50} of 2 ng/ml (FIG. 4C). SH-122 had a similar although less potent effect, with the combination of TRAIL and 1000 nM SH-122 having an IC_{50} of 30 ng/ml. In contrast 500 nM SH-149 did not lower the IC_{50} of TRAIL.

[0246] SH-164 was also tested for its ability to enhance the growth inhibitory effects of the chemotherapeutic agents cisplatin and mitoxantrone. When tested on MDA-MB-231 (2LMP) human breast cancer cells, SH-164 at a concentration of 100 nM sensitized the cells to growth inhibition by both agents (FIG. 5). These data indicate that bivalent Smac mimetics are capable of sensitizing cells to the growth inhibitory effects of a variety of cancer-treating agents.

EXAMPLE 17

Apoptosis Assay

[0247] Analysis of apoptosis was performed using an apoptosis detection kit (BioVision Research Products, Mountain View, CA) according to the manufacturer's protocol. Briefly, cells were treated with Smac mimetics for 12 hours, harvested and washed with ice-cold PBS. Cells were stained with Annexin V-FITC and Propidium iodide (P.I.) for 15 minutes at room temperature in the dark and immediately analyzed by FACS calibur flow cytometer (Becton Dickinson, Erembodegem, Belgium). Cells that were stained Annexin V (+) and P.I. (−) were considered early-stage apoptotic cells. Cells that were stained annexin V (+) and P.I. (+) were considered late-stage apoptotic cells and cells that were stained annexin V (-) and P.I. (+) were considered necrotic cells (FIG. 6).

EXAMPLE 18

Binding affinities to XIAP and activities in cell growth inhibition

[0248] The binding affinities to XIAP and activities in cell growth inhibition of Smac mimetics are presented in Table 5.

Table 5

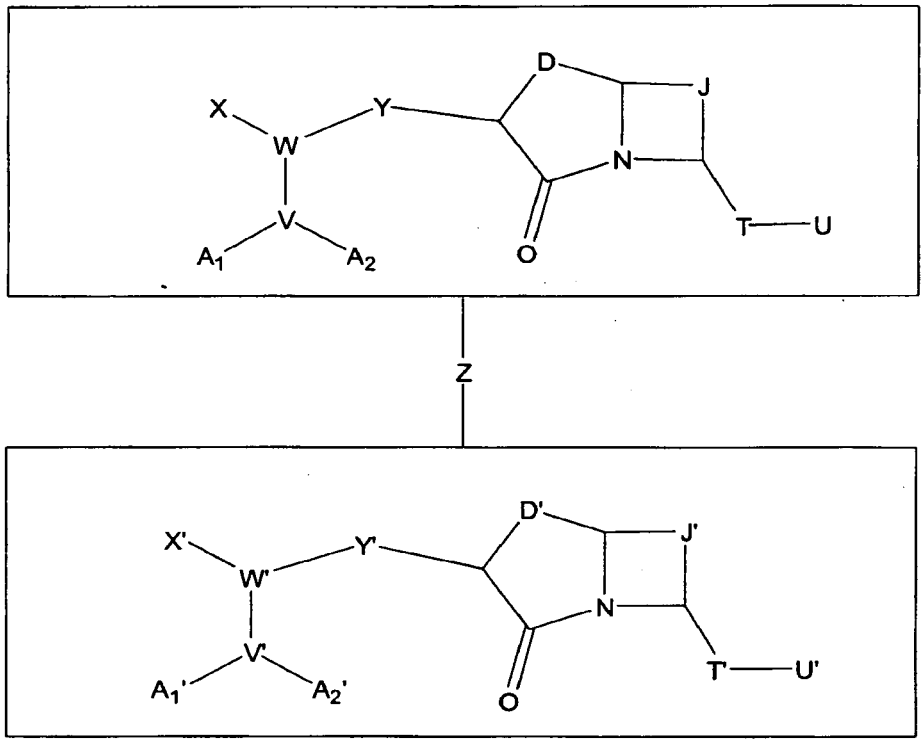
Compound	Binding to XIAP IC_{50} values [nM]	IC50 values (nM) In WST-assay (MDA-MB-231)	IC50 values (nM) In WST-assay SK-OV-3
SH-142	<50	<100	
SH-143	<50		
SH-146	<50		
SH-153	<10	<1000	
SH-155	<10	<100	<100
SH-156	<10	<1000	<1000
SH-158	<10	<1000	<1000
SH-159	<10	<1000	<1000
SH-164	<10	<10	<10
SH-165	<10	<1000	<1000
SH-166	<10	<1000	<1000
SH-167	<10	<10	<10
SH-172	<10	<1000	
SH-173	>10,000	>10000	>10000
SH-175	<50	<100	<100
SH-176	<10	<100	
SH-177	<10	<100	
SH-178	<100	<10,000	
SH-179	<100	<10000	
SH-180	<100	<1000	<1000
SH-181	<100	<10000	

SH-182	<100	<10	<10
SH-183	<100	<10,000	
SH-184	<100	<10	<100
SH-185	<50	<10	<10
SH-186	<50	<10	<10
SH-187	>10000	>10000	>10000
SH-188	<100	<100	<100
SH-189	<100	<100	<100
SH-190	<100	<10	<10
SH-191	<100	<100	<100
SH-198	<100	<10	<10
SH-199	<10	<10	<10
SH200	<10	<100	<100
SH-201	>10,000	>1000	>1000
SH-202	<100	<10	<10
SH-206	<1000	<1000	<1000
YP-317	<100	<100	
YP-343	<100	<100	
YP-381	<10	<10	<10
YP-383	<10	<10	<10
YP-385	<10	<10	<10
SM-410	<100	<500	<500

[0249] Having now fully described the invention, it will be understood by those of skill in the art that the same can be performed within a wide and equivalent range of conditions, formulations, and other parameters without affecting the scope of the invention or any embodiment thereof. All patents, patent applications and publications cited herein are fully incorporated by reference herein in their entirety.

WHAT IS CLAIMED IS:

1. The compound having Formula II:



II

wherein:

A_1 and A_1' are independently selected from the group consisting of hydrogen, optionally substituted alkyl and Z;

A_2 and A_2' are independently selected from the group consisting of hydrogen, optionally substituted alkyl and COR^1, wherein A_2 is absent when V is O and A_2' is absent when V' is O;

V and V' are independently selected from the group consisting of N, CH and O;

W and W' are independently selected from the group consisting of CH and N;

X and X' are independently optionally substituted C_{1-3} alkyl;

Y and Y' are independently selected from the group consisting of $CONR^1$, C(O)O, $(CR^1R^2)_{1-3}$, wherein one or more CH_2 groups can be replaced by O, S or NR^1, optionally substituted aryl and optionally substituted heteroaryl;

D and D' are independently selected from the group consisting of optionally substituted alkylenyl and $(CR^1R^2)_n$-R^{5a}-$(CR^3R^4)_m$;

J and J' are independently selected from the group consisting of optionally substituted alkylenyl and $(CR^1R^2)_p$-R^{5b}-$(CR^3R^4)_q$;

T and T' are independently selected from the group consisting of C=O, C=S, C=NR^1, S, O, NR^1, CR^1R^2, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

U and U' are independently selected from the group consisting of hydrogen, NR^1R^2, OR^1, SR^1, optionally substituted alkyl and optionally substituted aryl;

n, m, p and q are independently 0-5;

each R^1 is selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl, optionally substituted heteroaryl and Z;

each R^2, R^3 and R^4 are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

R^{5a} and R^{5b} are independently selected from the group consisting of C=O, C=S, C=NR^1, S, O, NR^1 and CR^1R^2; and

Z is a linker covalently linking one of A_1, Y, D, J, T and U with one of A_1', Y', D', J', T' and U';

or pharmaceutically acceptable salts or prodrugs thereof.

2. The compound of claim 1, wherein Z links D with U'.

3. The compound of claim 1, wherein Z links D with D'.

4. The compound of claim 1, wherein Z links U with U'

5. The compound of claim 1, wherein n and m are independently selected from 0-4 such that n + m is 3 or 4.

6. The compound of claim 1, wherein p and q are independently selected from 0 and 1 such that p + q is 1.

7. The compound of claim 1, wherein n and m are independently selected from 0-4 such that n + m is 3 or 4 and p and q are independently selected from 0 and 1 such that p + q is 1.

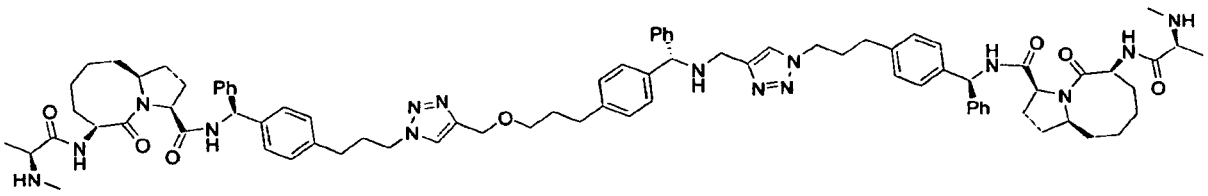
8. The compound of claim 7, wherein T is C=O.

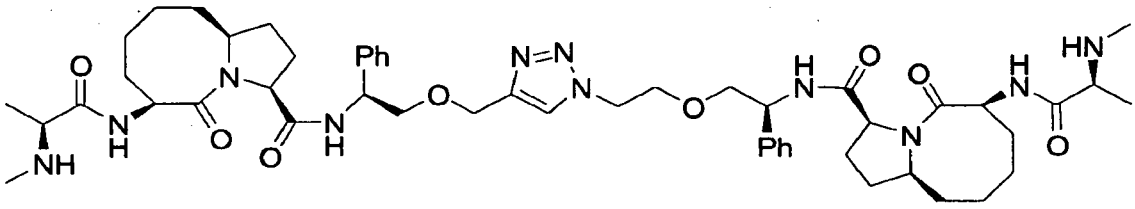
9. The compound of claim 8, wherein U is NR^1R^2.

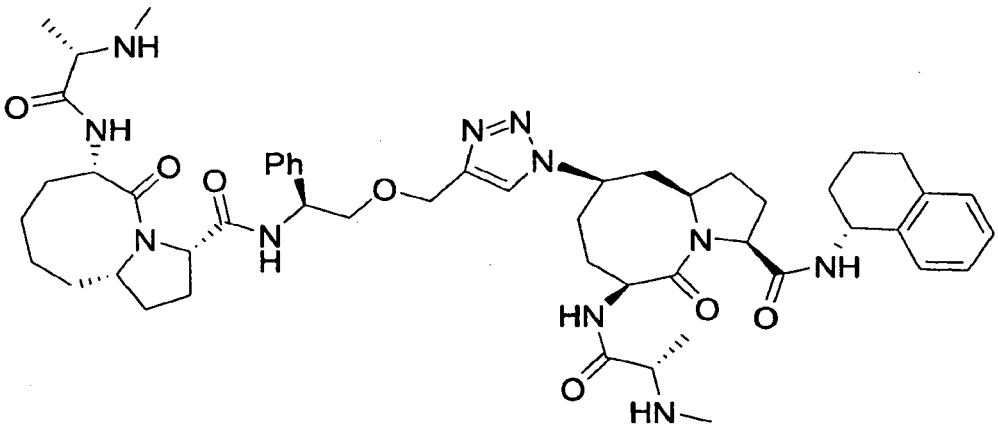
10. The compound of claim 9, wherein R^{5b} is CH_2.

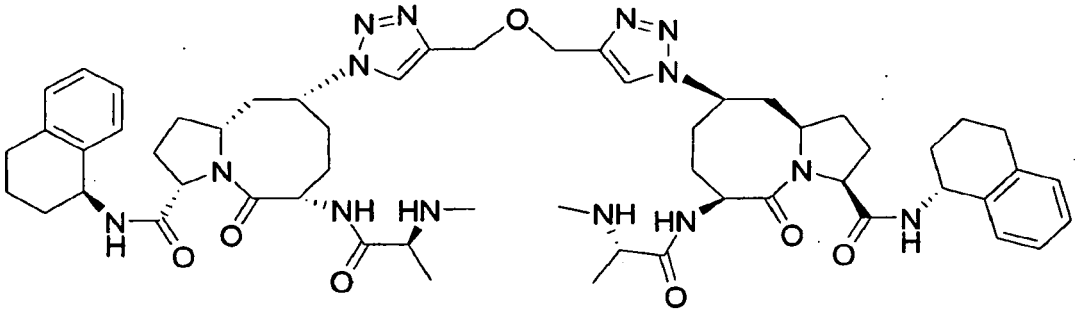
11. The compound of claim 1, wherein Y is CONH, W is CH and V is N.

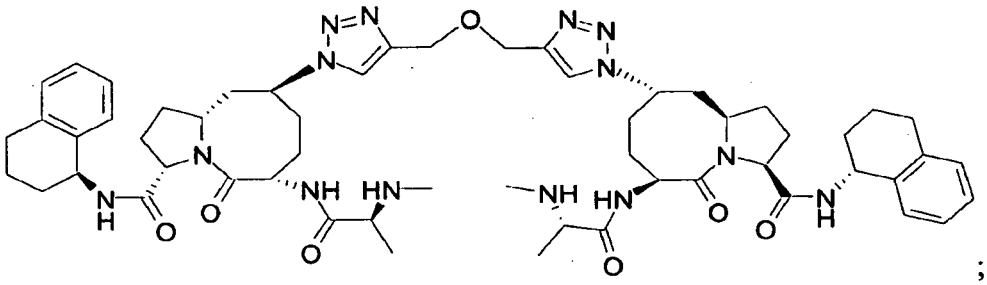
12. The compound of claim 1, selected from the group consisting of:

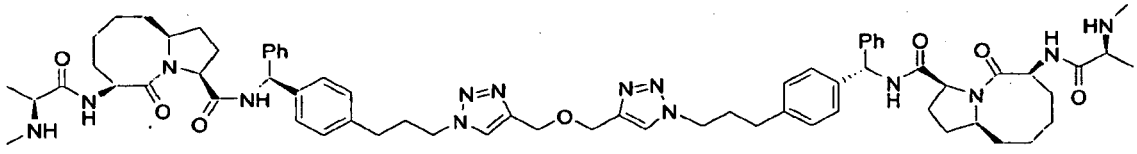

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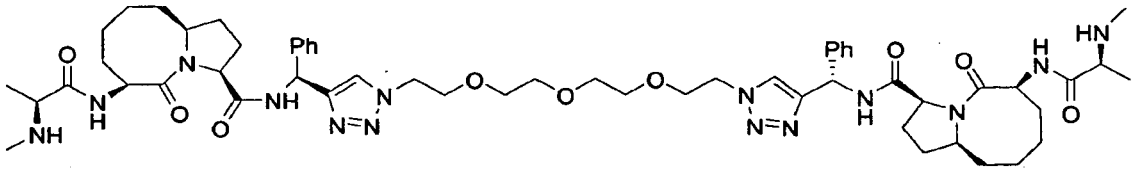

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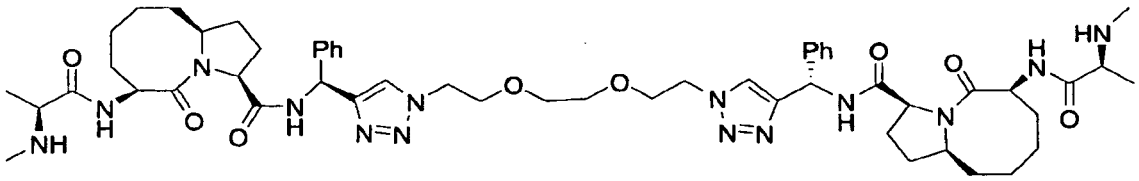

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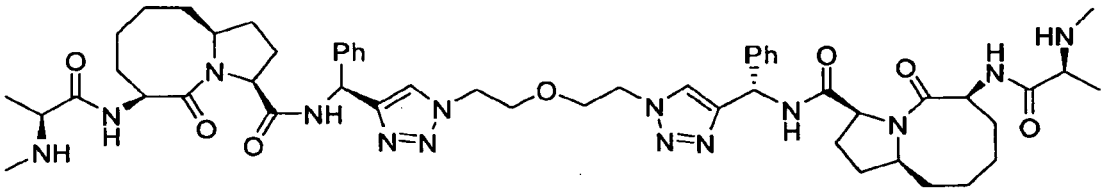

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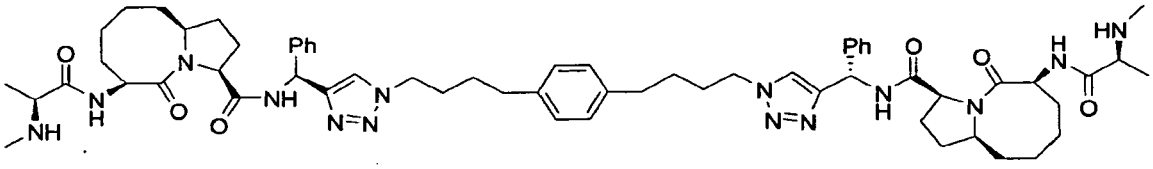

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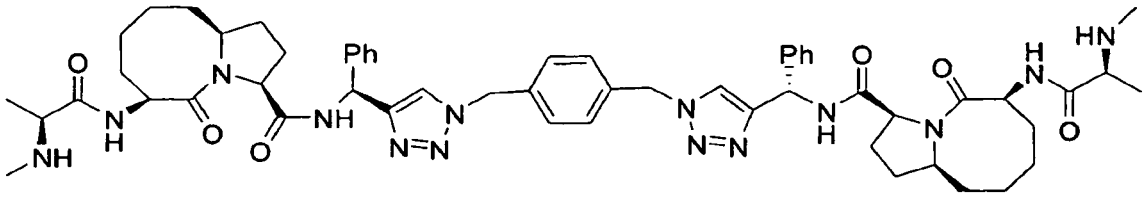

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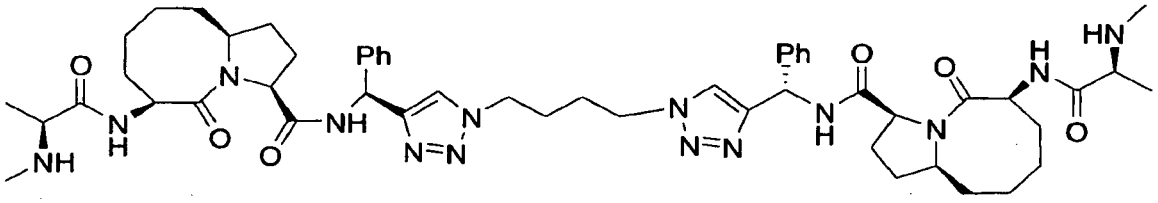

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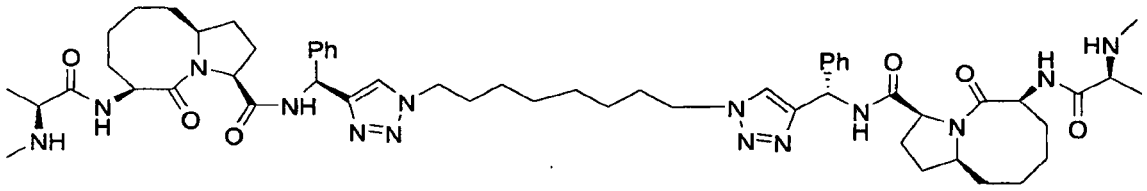

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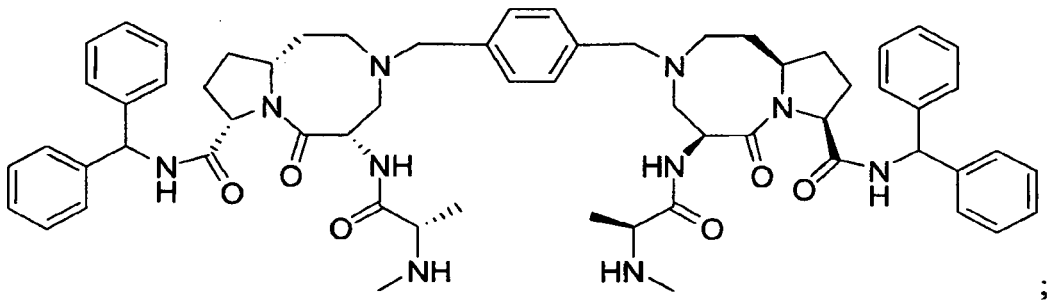

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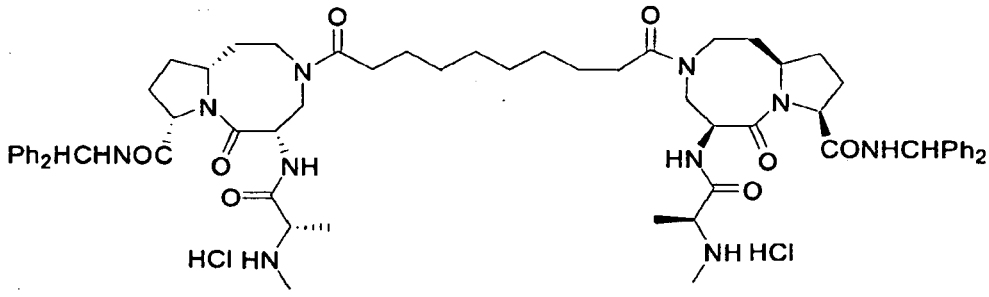

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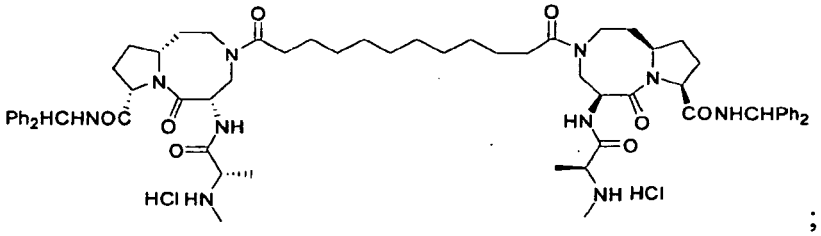

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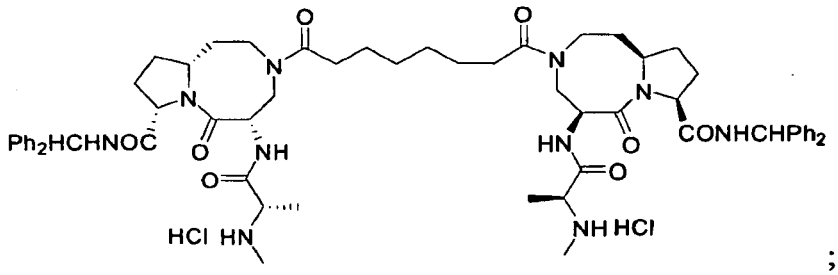

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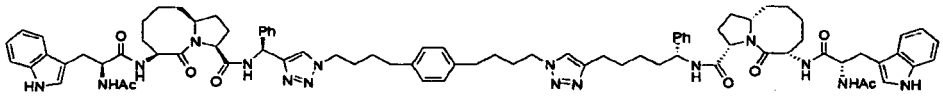

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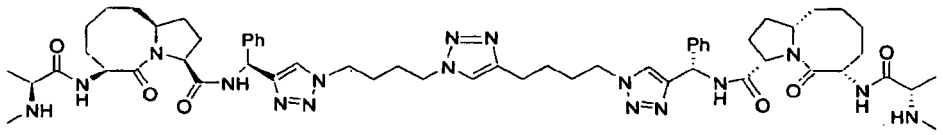

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CONHCHPh2
HCl HN
NH HCl

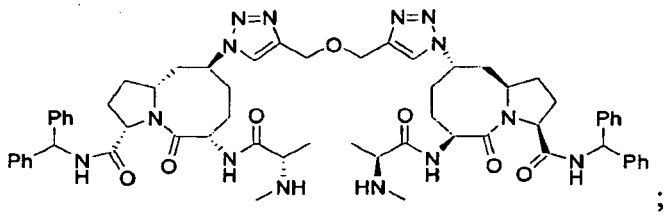
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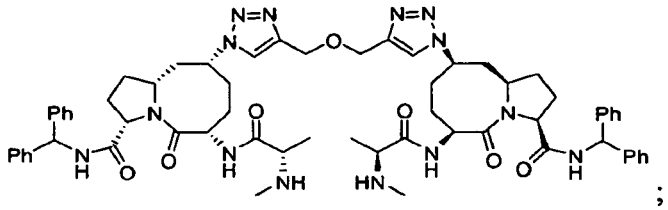
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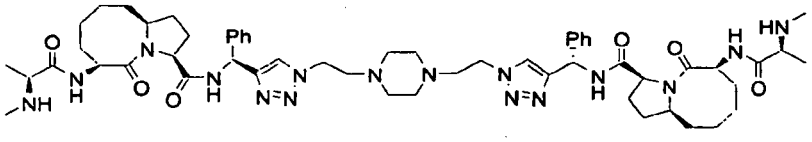
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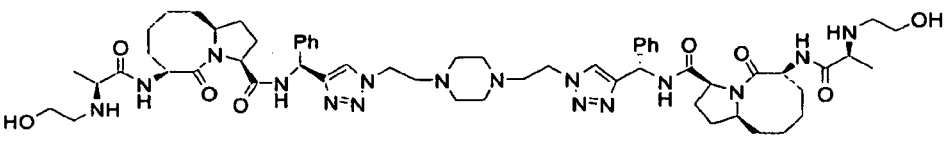
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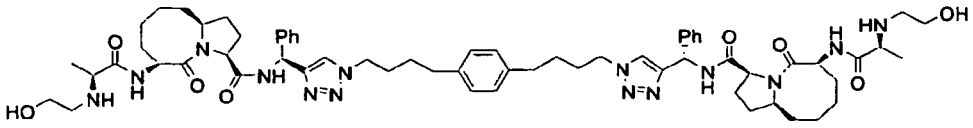
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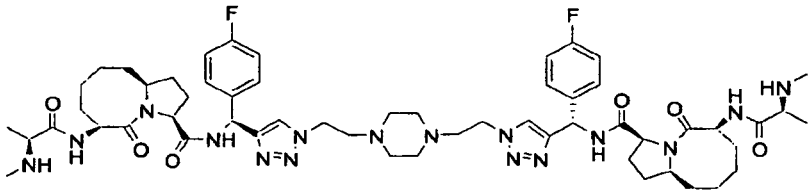
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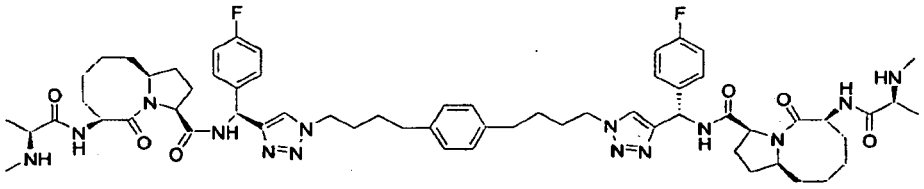
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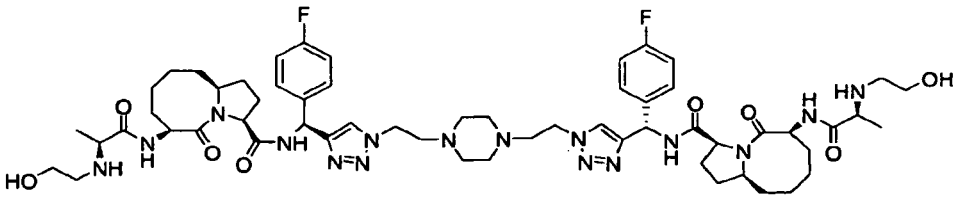
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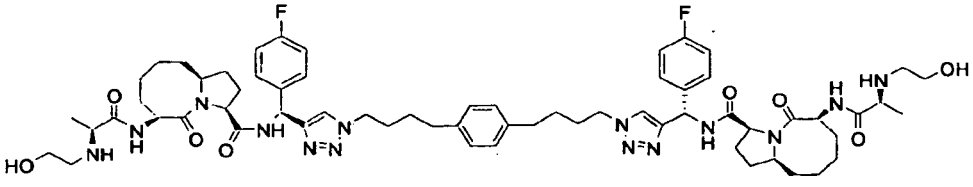
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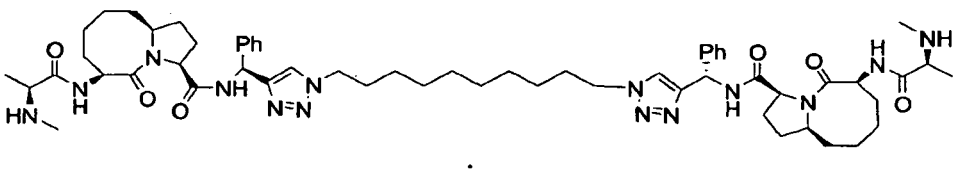
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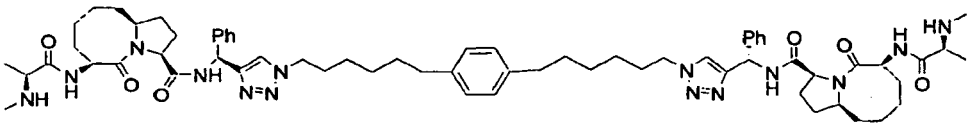
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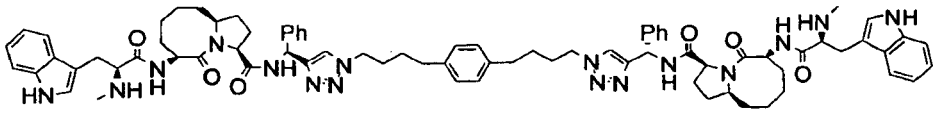
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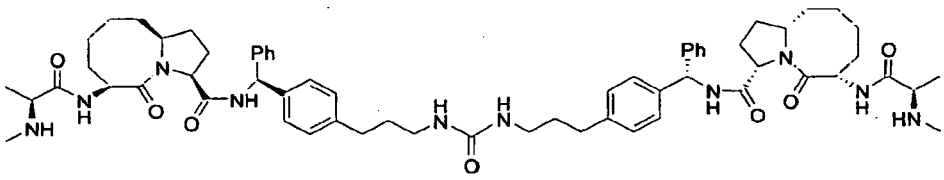
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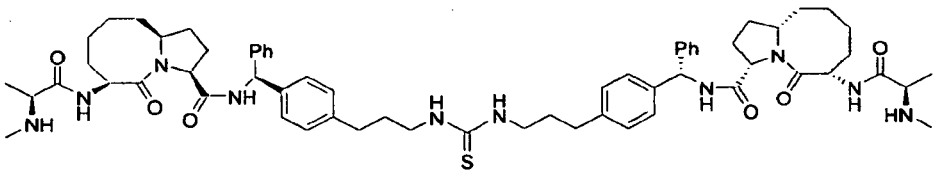
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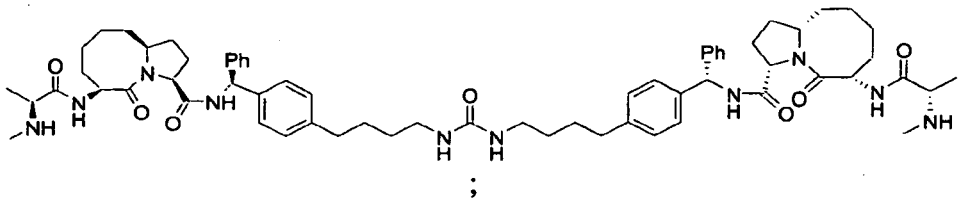
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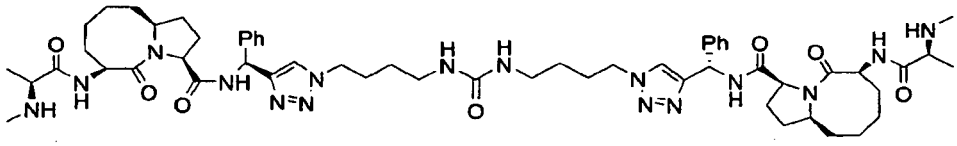
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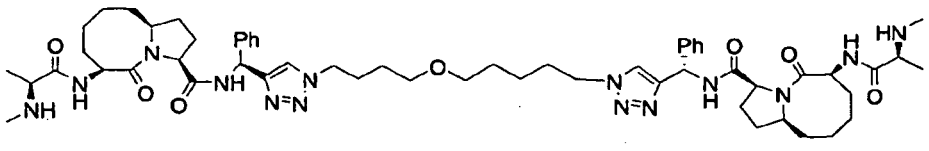
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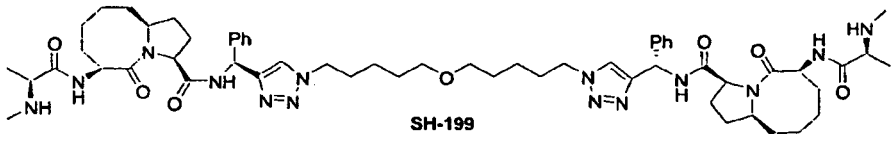
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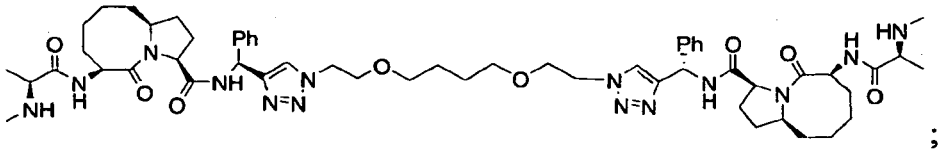


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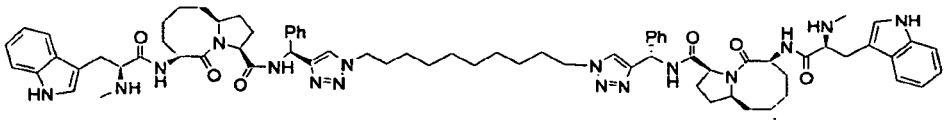


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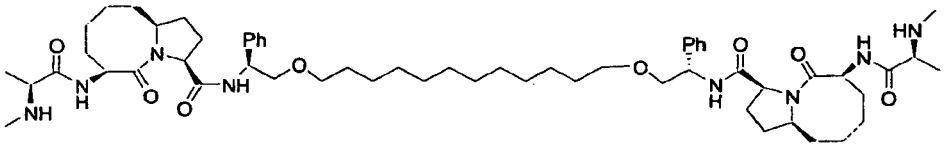
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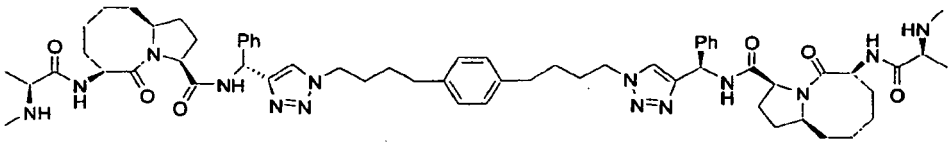
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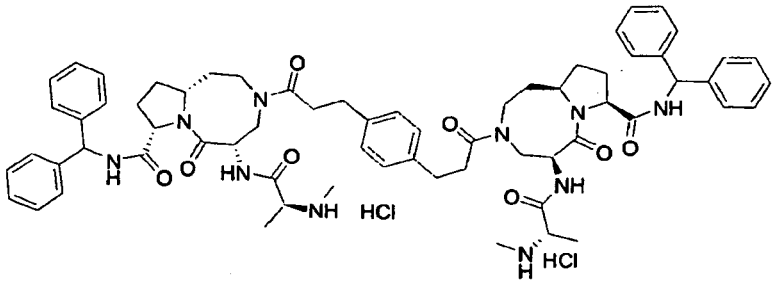


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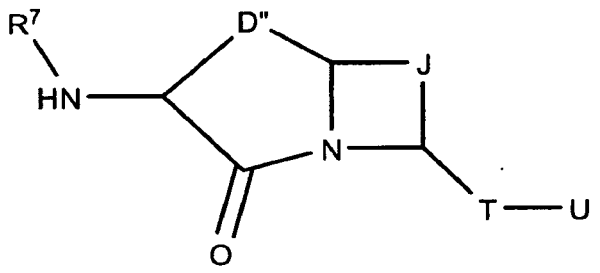
and



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or the free base thereof or another pharmaceutically acceptable salt thereof.

13. The compound having formula XIII:



XIII

wherein:

D" is $(CR^1R^2)_n$-R^{5c}-$(CR^3R^4)_m$;

J is selected from the group consisting of optionally substituted alkylenyl and $(CR^1R^2)_p$-R^{5b}-$(CR^3R^4)_q$;

T is selected from the group consisting of C=O, C=S, C=NR^1, S, O, NR^1, CR^1R^2, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

U is selected from the group consisting of hydrogen, NR^1R^2, OR^1, SR^1, optionally substituted alkyl and optionally substituted aryl;

n, m, p and q are independently selected from 0-5;

each R^1, R^2, R^3 and R^4 are independently selected from the group consisting of hydrogen, optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

R^{5c} is selected from the group consisting of C=O, C=S, C=NR^1, S, O, NR^1, $CR^{1a}R^{2a}$, $NCOR^8$ and NCO_2R^8;

R^{1a} and R^{2a} are independently selected from the group consisting of hydrogen, hydroxy, azido, optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

R^{5b} is selected from the group consisting of O, S, NR^1, CR^1R^2, C=O, C=S and C=NR^1;

R^7 is selected from the group consisting of hydrogen, CO_2R^{7a} and $COCH(R^{7b})N(R^{7c})CO_2R^{7a}$;

R^{7a} is selected from the group consisting of optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl;

R^{7b} is optionally substituted C_{1-3} alkyl;

R^{7c} is selected from the group consisting of hydrogen and optionally substituted alkyl;

and,

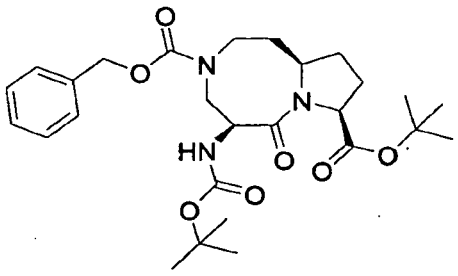
R^{8} is selected from the group consisting of optionally substituted alkyl, optionally substituted carbocyclic, optionally substituted heterocyclic, optionally substituted aryl and optionally substituted heteroaryl.

14. The compound of claim 13, wherein R^{7a} is t-butyl.

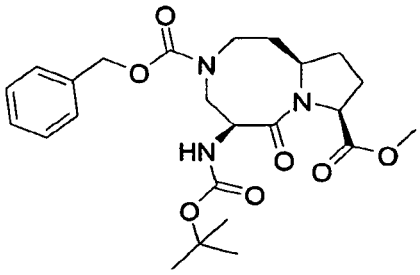
15. The compound of claim 13, wherein n is 1, m is 2, R^{5c} is NCO_2R^8 and R^8 is benzyl.

16. The compound of claim 13, wherein R^{5c} is $CR^{1a}R^{2a}$, R^{1a} is selected from the group consisting of hydroxy, azido and optionally substituted heteroaryl and R^{2a} is hydrogen.

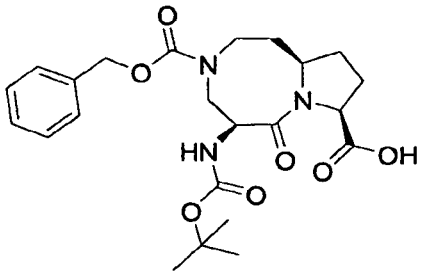
17. The compound of claim 13, selected from the group consisting of:



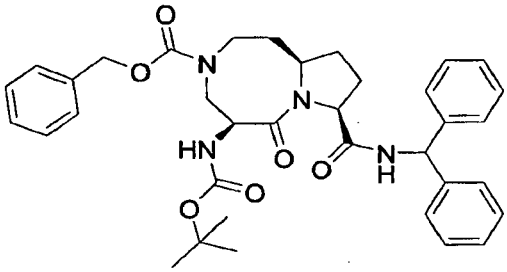
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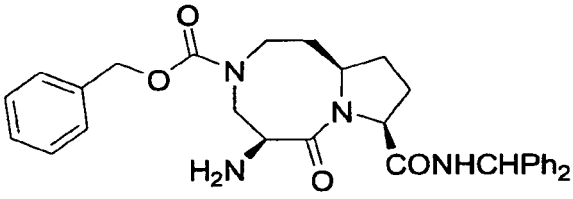
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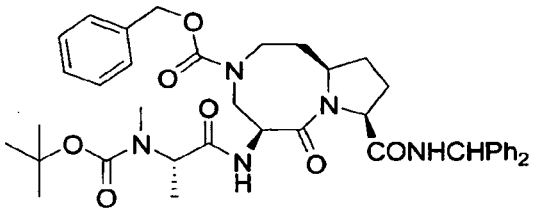
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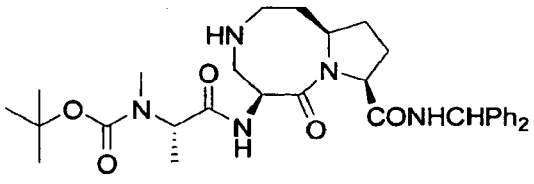
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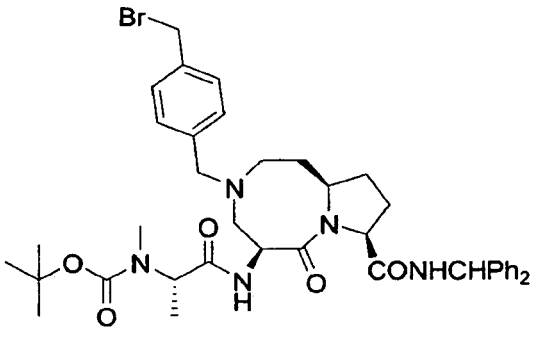
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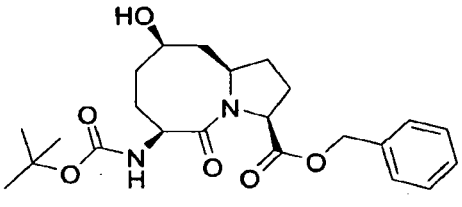

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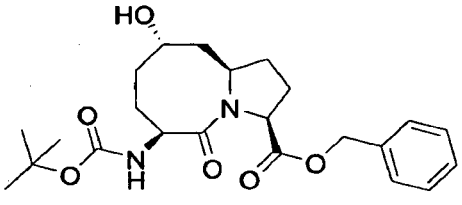
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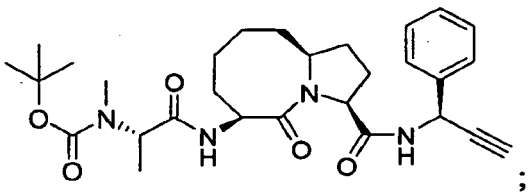

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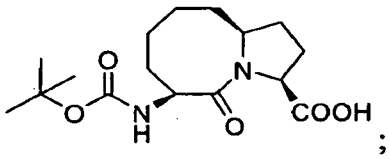
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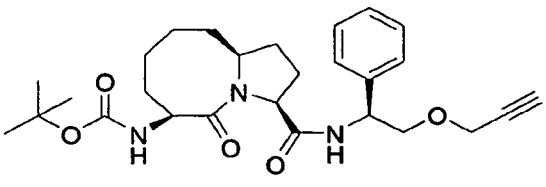

Br
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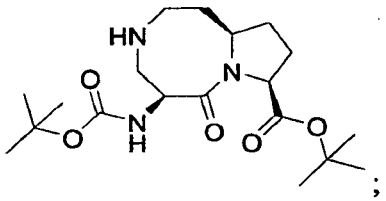

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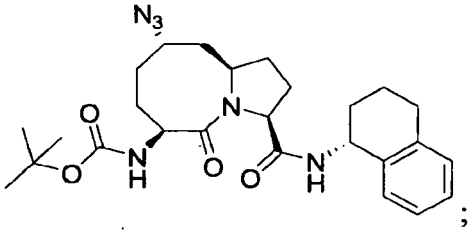

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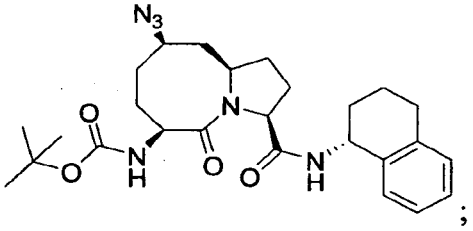

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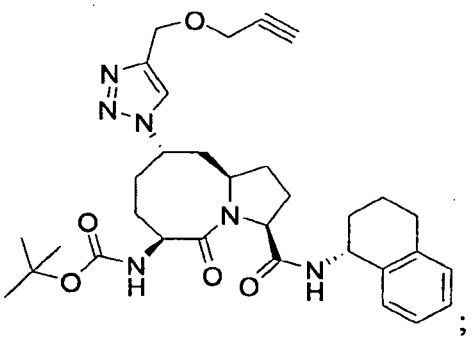

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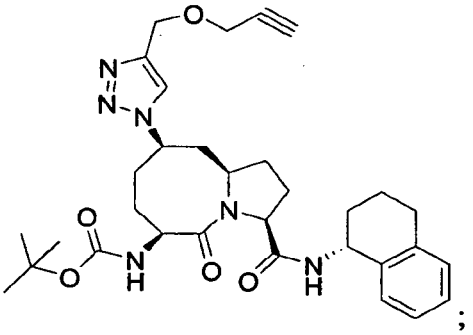

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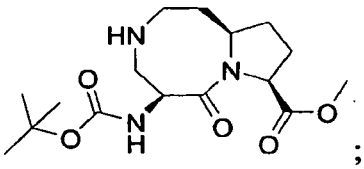




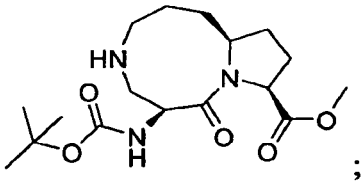




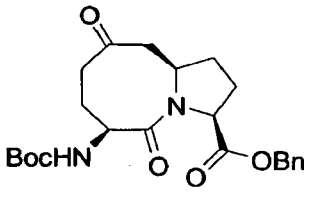




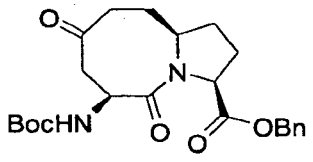
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18. A pharmaceutical composition comprising a compound of claim 1 and a pharmaceutically acceptable carrier.

19. A method of inducing apoptosis in a cell comprising contacting the cell with a compound of claim 1.

20. A method of rendering a cell sensitive to an inducer of apoptosis comprising contacting the cell with a compound of claim 1.

21. The method of claim 20, further comprising contacting the cell with an inducer of apoptosis.

22. The method of claim 21, wherein said inducer of apoptosis is a chemotherapeutic agent.

23. The method of claim 21, wherein said inducer of apoptosis is radiation.

24. The method of claim 21, wherein said inducer of apoptosis is a tumor necrosis factor (TNF), a TNF-related ligand, or an agonist of TRAIL-R1 or TRAIL-R2.

25. The method of claim 24, wherein said TNF-related ligand is selected from the group consisting of a TRAMP ligand, a Fas/CD95 ligand, a TNFR-1 ligand, and TRAIL.

26. The method of claim 25, wherein said TNF-related ligand is TRAIL.

27. The method of claim 25, wherein said agonist of TRIAL-R1 or TRAIL-R2 is an antibody.

28. A method of treating, ameliorating, or preventing a disorder responsive to the induction of apoptosis in an animal, comprising administering to said animal a therapeutically effective amount of a compound of claim 1.

29. The method of claim 28, further comprising administering an inducer of apoptosis.

30. The method of claim 28, wherein said inducer of apoptosis is a chemotherapeutic agent.

31. The method of claim 29, wherein said inducer of apoptosis is radiation.

32. The method of claim 29, wherein said inducer of apoptosis is a TNF, a TNF-related ligand, or an agonist of TRAIL-R1 or TRAIL-R2.

33. The method of claim 32, wherein said TNF-related ligand is selected from the group consisting of a TRAMP ligand, a Fas/CD95 ligand, a TNFR-1 ligand, and TRAIL.

34. The method of claim 33, wherein said TNF-related ligand is TRAIL.

35. The method of claim 32, wherein said agonist of TRAIL-R1 or TRAIL-R2 is an antibody.

36. The method of claim 28, wherein said disorder responsive to the induction of apoptosis is a hyperproliferative disease.

37. The method of claim 36, wherein said hyperproliferative disease is cancer.

38. The method of claim 28, wherein said compound of claim 1 is administered prior to said inducer of apoptosis.

39. The method of claim 28, wherein said compound of claim 1 is administered after said inducer of apoptosis.

40. The method of claim 28, wherein said compound of claim 1 is administered concurrently with said inducer of apoptosis.

41. A method of treating, ameliorating, or preventing a hyperproliferative disease in an animal, comprising administering to said animal a therapeutically effective amount of a compound of claim 1.

42. The method of claim 41, further comprising administering an inducer of apoptosis.

43. The method of claim 42, wherein said inducer of apoptosis is a chemotherapeutic agent.

44. The method of claim 42, wherein said inducer of apoptosis is radiation.

45. The method of claim 42, wherein said inducer of apoptosis is a TNF, a TNF-related ligand, or an agonist of TRAIL-R1 or TRAIL-R2.

46. The method of claim 45, wherein said TNF-related ligand is selected from the group consisting of a TRAMP ligand, a Fas/CD95 ligand, a TNFR-1 ligand, and TRAIL.

47. The method of claim 46, wherein said TNF-related ligand is TRAIL.

48. The method of claim 45, wherein said agonist of TRAIL-R1 or TRAIL-R2 is an antibody.

49. The method of claim 41, wherein said hyperproliferative disease is cancer.

50. The method of claim 49, wherein said compound of claim 1 is administered prior to said inducer of apoptosis.

51. The method of claim 49, wherein said compound of claim 1 is administered after said inducer of apoptosis.

52. The method of claim 49, wherein said compound of claim 1 is administered concurrently with said inducer of apoptosis.

53. A kit comprising a compound of claim 1 and instructions for administering said compound to an animal.

54. The kit of claim 53, further comprising an inducer of apoptosis.

55. The kit of claim 54 wherein said inducer of apoptosis is a chemotherapeutic agent.

56. The kit of claim 55, wherein said inducer of apoptosis is a TNF, a TNF-related ligand, or an agonist of TRAIL-R1 or TRAIL-R2.

57. The kit of claim 56 wherein the TNF-related ligand is selected from the group consisting of a TRAMP ligand, a Fas/CD95 ligand, a TNFR-1 ligand, and TRAIL.

58. The kit of claim 57, wherein said TNF-related ligand is TRAIL.

59. The kit of claim 56, wherein said agonist of TRAIL-R1 or TRAIL-R2 is an antibody.

60. The kit of claim 53, wherein said instructions are for administering said compound to an animal having a hyperproliferative disease.

61. The kit of claim 60, wherein said hyperproliferative disease is cancer.