CYCLOPAMINE LACTAM ANALOGS AND METHODS OF USE THEREOF

Technical Field

The present invention generally relates to cyclopamine analogs, pharmaceutical compositions thereof, and methods for using such analogs and compositions. These compounds and compositions can be useful for the treatment of hedgehog mediated disorders, such as cancer and psoriasis.

Background Art

The Hedgehog polypeptide is a secreted protein that functions as a signaling ligand in the hedgehog pathway. Three different forms of the hedgehog protein are found in humans; Sonic hedgehog (Shh), Desert hedgehog (Dhh) and Indian hedgehog (Ihh). Sonic hedgehog is the most prevalent hedgehog member in mammals and also is the best characterized ligand of the hedgehog family. Prior to secretion, Shh undergoes an intramolecular cleavage and lipid modification reaction. The lipid modified peptide is responsible for signaling activities.

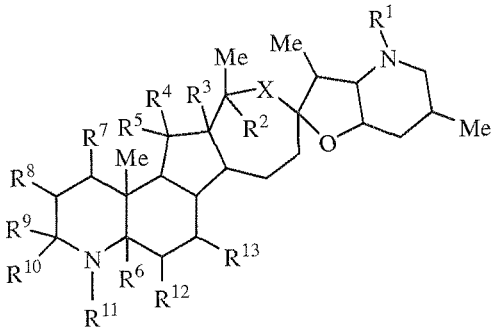
Inhibition of the hedgehog pathway in certain cancers has been shown to result in inhibition of tumor growth. For example, anti-hedgehog antibodies have been shown to antagonize the function of the hedgehog pathway and inhibit the growth of tumors. Small molecule inhibition of hedgehog pathway activity has also been shown to result in cell death in a number of cancer types.

Research in this area has focused primarily on the elucidation of hedgehog pathway biology and the discovery of new hedgehog pathway inhibitors. Although inhibitors of the hedgehog pathway have been identified, there still exists the need to identify more potent inhibitors of the hedgehog pathway.

Summary

The present invention relates to analogs of steroidal alkaloids, pharmaceutical compositions, and methods of using them.

The invention includes compounds of Formula 1, compositions comprising at least one such compound, and methods of using the compounds and compositions, where Formula 1 is:



1

or a pharmaceutically acceptable salt thereof;

wherein;

R^1 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, hydroxyl, aralkyl, heteroaryl, heteroaralkyl, haloalkyl, alkoxyl, $-SR^{20}$, $-OR^{20}$, $-N(R^{20})(R^{20})$, $-C(O)R^{20}$, $-CO_2R^{20}$, $-OC(O)R^{20}$, $-C(O)N(R^{20})(R^{20})$, $-N(R^{20})C(O)R^{20}$, $-N(R^{20})C(O)N(R^{20})(R^{20})$, $-S(O)R^{20}$, $-S(O)_2R^{20}$, $-S(O)_2N(R^{20})(R^{20})$, $-N(R^{20})S(O)_2R^{20}$, $-[(W)-C(O)]_pR^{20}$, $-[(W)-C(O)O]_pR^{20}$, $-[(W)-OC(O)]_pR^{20}$, $-[(W)-SO_2]_pR^{20}$, $-[(W)-N(R^{20})SO_2]_pR^{20}$, $-[(W)-C(O)N(R^{20})]_pR^{20}$, $-[(W)-O]_pR^{20}$, $-[(W)-N(R^{20})]_pR^{20}$, or $-[(W)-S]_pR^{20}$;

each of R^2, R^7 and R^{13} is independently H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, alkoxyl, aryloxy, acyloxy, halide, hydroxyl, amino, alkylamino, arylamino, acylamino, aralkylamino, alkylseleno, aralkylseleno, arylseleno, alkylthio, aralkylthio, arylthio, heteroaryl, or heteroaralkyl;

R^3 is H; or R^2 and R^3 taken together form a bond;

each of R^4 and R^5 independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, nitrile, aralkyl, alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, alkylamino, arylamino, acylamino, aralkylamino, heteroaryl, or heteroaralkyl;

or R^4 and R^5 taken together form =O, =S, $=N(R^{20})$, $=N\text{-}OR^{20}$ or $=N(N(R^{20})_2)$;

R^6 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, or aralkyl;

each of R^8 and R^{12} independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, or aralkyl; or R^7 and R^8 taken together form a bond; or R^{12} and R^{13} taken together form a bond

each of R^9 and R^{10} independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, nitrile, aralkyl, heteroaryl, or heteroaralkyl; or R^9 and R^{10} taken together form =O, $=N(R^{20})$, $=N\text{-}OR^{20}$, or =S;

R^{11} is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, $-C(O)R^{20}$, $-C(S)R^{20}$, $-CO_2R^{20}$, $-SO_2R^{20}$, $-C(O)N(R^{20})(R^{20})$, or $-C(S)N(R^{20})(R^{20})$; or has the formula $-[C(R^{20})_2]_q-R^{21}$;

R^{20} independently for each occurrence is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, or $-[C(R)_2]_q-R^{21}$, where each R is independently H or C1-C6 alkyl; or any two occurrences of R^{20} can be taken together to form a 4-8 membered optionally substituted ring which contains 0-3 heteroatoms selected from N, O, S, and P;

R^{21} independently for each occurrence is H, cycloalkyl, aryl, heteroaryl, heterocyclyl; alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, acylamino, amido, or a carbonyl-containing group;

R^{22} independently for each occurrence is H, halide, ester, amide, or nitrile;

p is 0, 1, 2, 3, 4, 5, or 6;

q is 0, 1, 2, 3, 4, 5, or 6;

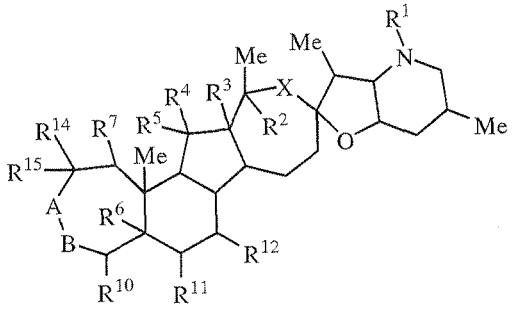
W is a diradical;

X is a bond or $-C(R^{22})_2-$

and each alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, whether alone or part of another group, is optionally substituted.

In other aspects, the invention includes a compound of formula 15, as well as compositions comprising at least one such compound and methods of using such compounds and compositions for treatment of conditions such as hyperproliferative disorders, including cancer, that are mediated by the hedgehog pathway. The compounds of formula 15 are represented by:

A compound of formula **15**:



15

or a pharmaceutically acceptable salt thereof;

wherein;

each of A and B independently is $-N(R^{13})-$, -(C=O)-, or -(C=S)-;

R^1 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, hydroxyl, aralkyl, heteroaryl, heteroaralkyl, haloalkyl, alkoxyl, $-SR^{20}$, $-OR^{20}$, $-N(R^{20})(R^{20})$, $-C(O)R^{20}$, $-CO_2R^{20}$, $-OC(O)R^{20}$, $-C(O)N(R^{20})(R^{20})$, $-N(R^{20})C(O)R^{20}$, $-N(R^{20})C(O)N(R^{20})(R^{20})$, $-S(O)R^{20}$, $-S(O)_2R^{20}$, $-S(O)_2N(R^{20})(R^{20})$, $-N(R^{20})S(O)_2R^{20}$, $-[(W)-C(O)]_pR^{20}$, $-[(W)-C(O)O]_pR^{20}$, $-[(W)-OC(O)]_pR^{20}$, $-[(W)-SO_2]_pR^{20}$, $-[(W)-N(R^{20})SO_2]_pR^{20}$, $-[(W)-C(O)N(R^{20})]_pR^{20}$, $-[(W)-O]_pR^{20}$, $-[(W)-N(R^{20})]_pR^{20}$, or $-[(W)-S]_pR^{20}$;

each of R^2, R^7 and R^{10} is independently H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, alkoxyl, aryloxy, acyloxy, halide, hydroxyl, amino, alkylamino, arylamino, acylamino, aralkylamino, alkylseleno, aralkylseleno, arylseleno, alkylthio, aralkylthio, arylthio, heteroaryl, or heteroaralkyl;

R^3 is H; or R^2 and R^3 taken together form a bond;

each of R^4 and R^5 independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, nitrile, aralkyl, alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, alkylamino, arylamino, acylamino, aralkylamino, heteroaryl, or heteroaralkyl; or R^4 and R^5 taken together form =O, =S, $=N(R^{20})$, $=N\text{-}OR^{20}$ or $=N(N(R^{20})_2)$;

R^6 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, or aralkyl; or R^6 and R^{10} taken together form a bond;

each of R^{11}, R^{12}, R^{14} and R^{15} independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, or aralkyl; or R^{11} and R^{12} taken together form a bond; or R^7 and R^{14} taken together form a bond;

R^{13} is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, $-C(O)R^{20}$, $-C(S)R^{20}$, $-CO_2R^{20}$, $-SO_2R^{20}$, $-C(O)N(R^{20})(R^{20})$, or $-C(S)N(R^{20})(R^{20})$; or has the formula $-[C(R^{20})_2]_q\text{-}R^{21}$;

R^{20} independently for each occurrence is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, or $-[C(R)_2]_q\text{-}R^{21}$, where each R is independently H or C1-C6 alkyl; or any two occurrences of R^{20} can be taken together to form a 4-8 membered optionally substituted ring which contains 0-3 heteroatoms selected from N, O, S, and P;

R^{21} independently for each occurrence is H, cycloalkyl, aryl, heteroaryl, heterocyclyl; alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, acylamino, amido, or a carbonyl-containing group;

R^{22} independently for each occurrence is H, halide, ester, amide, or nitrile;

p is 0, 1, 2, 3, 4, 5, or 6;

q is 0, 1, 2, 3, 4, 5, or 6;

W is a diradical;

X is a bond or -C(R^{22})$_2$-;

and each alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, whether alone or part of another group, is optionally substituted;

provided that when A is –N(R^{13})-; B must be -(C=O)-, or -(C=S)-; and

provided that when A is -(C=O)-, or -(C=S)-; B must be –N(R^{13})-.

Brief Description of the Drawings

Figure 1 depicts the carboskeleton of a steroidal alkaloid with the rings labeled A-F.

Modes of Carrying Out the Invention

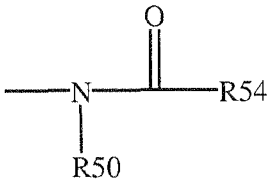
Definitions

The definitions of terms used herein are meant to incorporate the present state-of-the-art definitions recognized for each term in the chemical and pharmaceutical fields. Where appropriate, exemplification is provided. The definitions apply to the terms as they are used throughout this specification, unless otherwise limited in specific instances, either individually or as part of a larger group.

As used herein, the definition of each expression, *e.g.*, alkyl, m, n, etc., when it occurs more than once in any structure, is intended to be independent of its definition elsewhere in the same structure.

The term "acyl" as used herein refers to a group of the general formula R-C(=O)-, where R can be H, alkyl, aryl, or aralkyl. In typical acyl groups, R is H or C1-C6 alkyl, which is optionally substituted, or R can be aralkyl, wherein the aryl portion of the aralkyl is a 5-7 membered aromatic or heteroaromatic ring, and the alkyl portion is a C1-C4 alkylene group; and both the alkyl and aryl portions are optionally substituted as described herein for such groups. Benzyl, p-methoxybenzyl, and phenylethyl are examples of a typical aralkyl.

The term "acylamino" refers to a moiety that may be represented by the general formula:



wherein R50 is as defined below, and R54 represents a hydrogen, an alkyl, an alkenyl or -(CH_2)$_m$-R61, where m and R61 are as defined below.

The terms "alkenyl" and "alkynyl" refer to unsaturated aliphatic groups analogous in length and possible substitution to the alkyls described below, but that contain at least one

double or triple bond respectively. Alkenyl and alkynyl groups may be substituted with the same groups that are suitable as substituents on alkyl groups, to the extent permitted by the available valences. Typical alkenyl and alkynyl groups contain 2-10 carbons in the backbone structure.

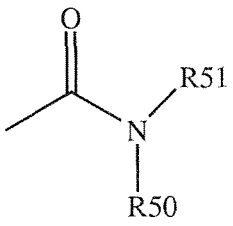
The terms "alkoxyl" or "alkoxy" refers to an alkyl group, as defined below, having an oxygen radical attached thereto. Representative alkoxyl groups include methoxy, ethoxy, propyloxy, tert-butoxy and the like. The alkyl portion of an alkoxy group is sized like the alkyl groups, and can be substituted by the same groups that are suitable as substituents on alkyl groups, to the extent permitted by the available valences.

The term "alkyl" refers to the radical of saturated aliphatic groups, including straight-chain alkyl groups, branched-chain alkyl groups, cycloalkyl (alicyclic) groups, alkyl substituted cycloalkyl groups, and cycloalkyl substituted alkyl groups. In certain embodiments, a straight chain or branched chain alkyl has 30 or fewer carbon atoms in its backbone (*e.g.*, C_1-C_{30} for straight chain, C_3-C_{30} for branched chain), 20 or fewer. Typically, an alkyl group contains 1-10 carbon atoms as its backbone, and may be substituted or unsubstituted. Likewise, certain cycloalkyls have from 3-10 carbon atoms in their ring structure, and others have 5, 6 or 7 carbons in the ring structure. Unless otherwise indicated, alkyl and cycloalkyl groups, whether alone or as part of another group such as an aralkyl group, can be substituted by suitable substituents such as, but not limited to, halogen, azide, oxo, acyl, cycloalkyl, hydroxyl, alkoxyl, amino, nitro, sulfhydryl, imino, oximino, amido, acylamino, phosphonate, phosphinate, carbonyl, carboxylic acids or their esters or amides, silyl, alkoxy, alkylthio, alkylsulfonyl, alkylsulfonamido, ketone, aldehyde, ester, heterocyclyl, aromatic or heteroaromatic moieties, $-CF_3$, -CN, and the like.

Where alkyl, alkenyl, or alkynyl is part of another group, such as in alkoxy, alkylthio, etc., or it is a substituent on another group, it is frequently an optionally substituted lower alkyl group or lower alkenyl group, or lower alkynyl group having up to six carbon atoms. For such purposes, the typical substituents include halo, -OR', -SR', $-SO_2R'$, $-SO_2NR'_2$, COOR', $CONR'_2$, oxo, $-NR'_2$, NR'C(O)R', NR'C(O)OR', $NR'SO_2R'$, OC(O)R', where each R' is independently H or unsubstituted C1-C6 alkyl, C2-C6 alkenyl, or C2-C6 alkynyl.

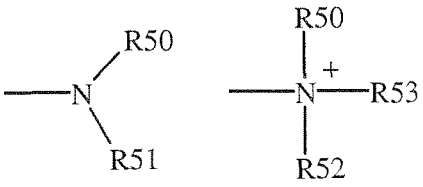
The term "alkylthio" refers to an alkyl group, as defined above, having a sulfur radical attached thereto. In certain embodiments, the "alkylthio" moiety is represented by one of -S-alkyl, -S-alkenyl, -S-alkynyl, and $-S-(CH_2)_m$-R61, wherein m and R61 are defined below. Representative alkylthio groups include methylthio, ethyl thio, and the like.

The term "amido" is art recognized as an amino-substituted carbonyl and includes a moiety that may be represented by the general formula:



wherein R50 and R51 are as defined below. Certain embodiments of the amide in the present invention will not include imides which may be unstable.

The terms "amine" and "amino" are art-recognized and refer to both unsubstituted and substituted amines, *e.g.*, a moiety that may be represented by the general formulas:



wherein R50, R51 and R52 and R53 each independently represent a hydrogen, an alkyl, an alkenyl, $-(CH_2)_m-R61$, or R50 and R51 (or R50 and R52 in the ammonium species), taken together with the N atom to which they are attached complete a heterocycle having from 4 to 8 atoms in the ring structure; R61 represents an aryl, a cycloalkyl, a cycloalkenyl, a heterocycle or a polycycle; and m is zero or an integer in the range of 1 to 8. In other embodiments, R50 and R51 (and optionally R52) each independently represent a hydrogen, an alkyl, an alkenyl, or $-(CH_2)_m-R61$. Thus, the term "alkylamine" includes an amine group, as defined above, having a substituted or unsubstituted alkyl attached thereto, *i.e.*, at least one of R50 and R51 is an alkyl group.

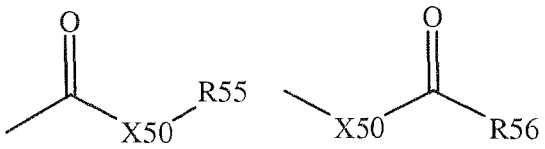
The term "aralkyl", as used herein, whether alone or as part of a group name such as, for example, aralkyloxy, refers to an alkyl group as described herein substituted with an aryl group as described herein (*e.g.*, an aromatic or heteroaromatic group). Both the alkyl and the aryl portion of each aralkyl group are typically optionally substituted. Typical aralkyl groups include, for example, groups of general formula $Ar-(CH_2)_t-$, where Ar represents an aryl ring and t is an integer from 1-6.

The term "aryl" as used herein, whether alone or as part of another name such as 'aryloxy', includes 5-, 6- and 7-membered single-ring aromatic groups that may include from zero to four heteroatoms selected from N, O and S as ring members, as well as fused bicyclic an tricyclic systems consisting of such rings, for example, benzene, anthracene, naphthalene, pyrene, pyrrole, furan, thiophene, imidazole, oxazole, thiazole, triazole,

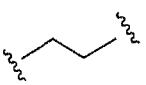
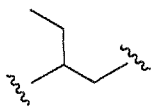
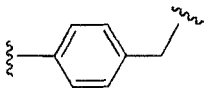
pyrazole, pyridine, pyrazine, pyridazine and pyrimidine, and the like. Those aryl groups having heteroatoms in the ring structure may also be referred to as "aryl heterocycles" or "heteroaromatics." The aromatic ring may be substituted as available valences permit at one or more ring positions with such substituents as described above, for example, halogen, azide, alkyl, aralkyl, alkenyl, alkynyl, cycloalkyl, hydroxyl, alkoxyl, amino, nitro, sulfhydryl, imino, amido, phosphonate, phosphinate, carbonyl, carbonyl-containing group, silyl, ether, alkylthio, sulfonyl, sulfonamido, ketone, aldehyde, ester, heterocyclyl, aromatic or heteroaromatic moieties, $-CF_3$, -CN, or the like. The term "aryl" also includes polycyclic ring systems having two or more cyclic rings, often two or three rings, in which two or more carbons are common to two adjoining rings (the rings are "fused rings") wherein at least one of the rings is aromatic, *e.g.*, the other cyclic rings may be cycloalkyls, cycloalkenyls, cycloalkynyls, aryls and/or heterocyclyls. In some embodiments, each aryl is selected from phenyl, thiophene, furan, pyrrole, pyridine, pyrimidine, pyrazole, imidazole, oxazole, thiazole, isoxazole and isothiazole. Phenyl is sometimes preferred.

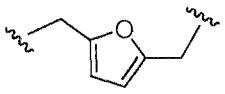
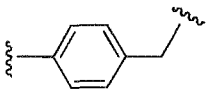
The term "Brønsted acid" refers to any substance that can act as a hydrogen ion (proton) donor.

The term "carbonyl-containing group" includes such moieties as may be represented by the general formulas:



wherein X50 is a bond or represents an oxygen or a sulfur, and each of R55 and R56 represents independently a hydrogen, an alkyl, an alkenyl, $-(CH_2)_m$-R61 or a cation representing a pharmaceutically acceptable salt, where m and R61 are defined above. In some embodiments where a carbonyl-containing group is present, it is a carboxylic acid or ester, or an acyloxy group; X50 is O in such embodiments, and R55 or R56, whichever is present, is often H or an optionally substituted alkyl group.

The term "diradical" refers to any of a series of divalent groups from alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, and heteroaralkyl groups, each of which can be optionally substituted. For example,  is an alkyl diradical;  is also an alkyl diradical;  is an aralkyl diradical; and

 is an (alkyl)heteroaralkyl diradical. Typical examples include alkylenes of general structure $(CH_2)_x$ where x is 1-6, and corresponding alkenylene and alkynylene linkers having 2-6 carbon atoms and containing one or more double or triple bonds; cycloalkylene groups having 3-8 ring members; groups such as $(CH_2)_aC(=O)(CH_2)_b$, where a and b are each integers from 0-4; and aralkyl groups wherein one open valence is on the aryl ring and one is on the alkyl portion such as  and its isomers. The alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, and heteroaralkyl portions of a diradical are optionally substituted as described above.

The term "haloalkyl", as used herein, refers to an alkyl group where anywhere from 1 to all hydrogens have been replaced with a halide. A "perhaloalkyl" is where all of the hydrogens have been replaced with a halide.

The term "heteroatom" as used herein means an atom of any element other than carbon or hydrogen. Examples of heteroatoms include boron, nitrogen, oxygen, phosphorus, sulfur and selenium. Typically, the heteroatoms are selected from N, O and S.

The term 'heteroalkyl' and 'heterocycloalkyl' refer to alkyl and cycloalkyl groups as described herein, wherein at least one carbon atom of the alkyl or cycloalkyl portion is replaced by a heteroatom selected from N, O and S. Typical examples include methoxymethyl, allylthioethyl, dimethylaminoethyl, and tetrahydrofuranyl.

The terms "heterocyclyl" or "heterocyclic group" refer to 3- to 10-membered ring structures, in some instances from 3- to 7-membered rings, whose ring structures include at least one carbon atom and one to four heteroatoms. Heterocycles can also be polycycles. Heterocyclyl groups include, for example, thiophene, thianthrene, furan, pyran, isobenzofuran, chromene, xanthene, phenoxathiin, pyrrole, imidazole, pyrazole, isothiazole, isoxazole, pyridine, pyrazine, pyrimidine, pyridazine, indolizine, isoindole, indole, indazole, purine, quinolizine, isoquinoline, quinoline, phthalazine, naphthyridine, quinoxaline, quinazoline, cinnoline, pteridine, carbazole, carboline, phenanthridine, acridine, pyrimidine, phenanthroline, phenazine, phenarsazine, phenothiazine, furazan, phenoxazine, pyrrolidine, oxolane, thiolane, oxazole, piperidine, piperazine, morpholine, lactones, lactams such as azetidinones and pyrrolidinones, sultams, sultones, and the like. The heterocyclic ring may be substituted at one or more positions with such substituents as described above, as for example, halogen, alkyl, aralkyl, alkenyl, alkynyl, cycloalkyl, hydroxyl, amino, nitro, sulfhydryl, imino, amido, phosphonate, phosphinate, carbonyl, carbonyl-containing group,

silyl, ether, alkylthio, sulfonyl, ketone, aldehyde, ester, a heterocyclyl, an aromatic or heteroaromatic moiety, $-CF_3$, -CN, or the like.

The term "Lewis acid" refers to any substance that can act as an electron pair acceptor.

Unless the number of carbons is otherwise specified, "lower alkyl" as used herein means an alkyl group, as defined above, but having from one to ten carbons, in some embodiments from one to six carbon atoms in its backbone structure. Likewise, "lower alkenyl" and "lower alkynyl" have similar chain lengths. Certain alkyl groups are lower alkyls. In some embodiments, a substituent designated herein as alkyl is a lower alkyl.

As used herein, the term "nitro" means $-NO_2$; the term "halogen" designates -F, -Cl, -Br or -I; the term "sulfhydryl" means -SH; the term "hydroxyl" means -OH; and the term "sulfonyl" means $-SO_2-$.

The term "optionally substituted" as used herein indicates that a specified group may be unsubstituted or it may be substituted with one or more substituents to the extent consistent with the number of available valences on the specified group. In some embodiments, each optionally substituted group is substituted with up to four substituents or with 0-3 substituents.

The term "oxo" refers to a carbonyl oxygen (=O).

The terms "polycyclyl" or "polycyclic group" refer to two or more rings (*e.g.*, cycloalkyls, cycloalkenyls, cycloalkynyls, aryls and/or heterocyclyls) in which two or more carbons are common to two adjoining rings, *e.g.*, the rings are "fused rings". Rings that are joined through non-adjacent atoms are termed "bridged" rings. Each of the rings of the polycycle may be substituted with such substituents as described above, as for example, halogen, alkyl, aralkyl, alkenyl, alkynyl, cycloalkyl, hydroxyl, amino, nitro, sulfhydryl, imino, amido, phosphonate, phosphinate, carbonyl, carbonyl-containing group, silyl, ether, alkylthio, sulfonyl, ketone, aldehyde, ester, a heterocyclyl, an aromatic or heteroaromatic moiety, $-CF_3$, -CN, or the like.

The phrase "protecting group" as used herein means temporary substituents which protect a potentially reactive functional group from undesired chemical transformations. Examples of such protecting groups include esters of carboxylic acids, silyl ethers of alcohols, and acetals and ketals of aldehydes and ketones, respectively. The field of protecting group chemistry has been reviewed (Greene, T. W.; Wuts, P. G. M., Protective Groups in Organic Synthesis, 2nd ed.; Wiley: New York, 1991).

The term "sugar" as used herein refers to a natural or an unnatural monosaccharide, disaccharide or oligosaccharide comprising one or more pyranose and/or furanose rings. The sugar may be covalently bonded to the steroidal alkaloid of the present invention through an ether linkage or through an alkyl linkage. In certain embodiments the saccharide moiety may be covalently bonded to a steroidal alkaloid of the present invention at an anomeric center of a saccharide ring. Sugars may include, but are not limited to ribose, arabinose, xylose, lyxose, allose, altrose, glucose, mannose, gulose, idose, galactose, talose, glucose, and trehalose.

The terms "triflyl", "tosyl", "mesyl", and "nonaflyl" refer to trifluoromethanesulfonyl, *p*-toluenesulfonyl, methanesulfonyl, and nonafluorobutanesulfonyl groups, respectively. The terms "triflate", "tosylate", "mesylate", and "nonaflate" refer to trifluoromethanesulfonate ester, *p*-toluenesulfonate ester, methanesulfonate ester, and nonafluorobutanesulfonate ester functional groups and molecules that contain said groups, respectively.

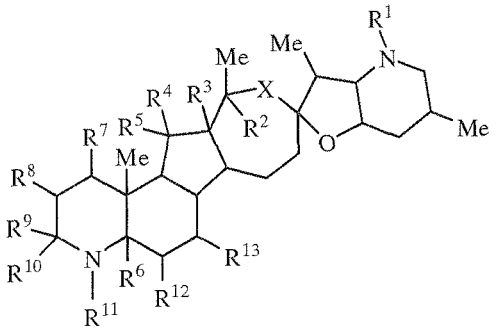
The term "thioxo" refers to a carbonyl sulfur (=S).

The abbreviations Me, Et, Ph, Tf, Nf, Ts, Ms represent methyl, ethyl, phenyl, trifluoromethanesulfonyl, nonafluorobutanesulfonyl, *p*-toluenesulfonyl and methanesulfonyl, respectively. A more comprehensive list of the abbreviations utilized by organic chemists of ordinary skill in the art appears in the first issue of each volume of the *Journal of Organic Chemistry*; this list is typically presented in a table entitled Standard List of Abbreviations.

It will be understood that "substitution" or "substituted with" includes the implicit proviso that such substitution is in accordance with permitted valence of the substituted atom and the substituent, and that the substitution results in a stable compound, *e.g.*, which does not spontaneously undergo transformation such as by rearrangement, cyclization, elimination, etc.

Where two groups are "taken together form a bond," if the groups are attached to atoms that are not otherwise directly bonded to each other, they represent a bond between the atoms to which they are attached. If the groups are on atoms that are directly bonded to each other, they represent an additional bond between those two atoms. Thus, for example, when R^2 and R^3 taken together form a bond, the structure -C(A)R^2-C(B)R^3- represents –C(A)=C(B)-.

The invention, in one aspect, includes compounds of Formula **1**:



1

and the pharmaceutically acceptable salt thereof, wherein:

R^1 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, hydroxyl, aralkyl, heteroaryl, heteroaralkyl, haloalkyl, alkoxyl, $-SR^{20}$, $-OR^{20}$, $-N(R^{20})(R^{20})$, $-C(O)R^{20}$, $-CO_2R^{20}$, $-OC(O)R^{20}$, $-C(O)N(R^{20})(R^{20})$, $-N(R^{20})C(O)R^{20}$, $-N(R^{20})C(O)N(R^{20})(R^{20})$, $-S(O)R^{20}$, $-S(O)_2R^{20}$, $-S(O)_2N(R^{20})(R^{20})$, $-N(R^{20})S(O)_2R^{20}$, $-[(W)-C(O)]_pR^{20}$, $-[(W)-C(O)O]_pR^{20}$, $-[(W)-OC(O)]_pR^{20}$, $-[(W)-SO_2]_pR^{20}$, $-[(W)-N(R^{20})SO_2]_pR^{20}$, $-[(W)-C(O)N(R^{20})]_pR^{20}$, $-[(W)-O]_pR^{20}$, $-[(W)-N(R^{20})]_pR^{20}$, or $-[(W)-S]_pR^{20}$;

each of R^2, R^7 and R^{13} is independently H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, alkoxyl, aryloxy, acyloxy, halide, hydroxyl, amino, alkylamino, arylamino, acylamino, aralkylamino, alkylseleno, aralkylseleno, arylseleno, alkylthio, aralkylthio, arylthio, heteroaryl, or heteroaralkyl;

R^3 is H; or R^2 and R^3 taken together form a bond;

each of R^4 and R^5 independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, nitrile, aralkyl, alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, alkylamino, arylamino, acylamino, aralkylamino, heteroaryl, or heteroaralkyl; or R^4 and R^5 taken together form =O, =S, $=N(R^{20})$, $=N\text{-}OR^{20}$ or $=N(N(R^{20})_2)$;

R^6 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, or aralkyl;

each of R^8 and R^{12} independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, or aralkyl; or R^7 and R^8 taken together form a bond; or R^{12} and R^{13} taken together form a bond

each of R^9 and R^{10} independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, nitrile, aralkyl, heteroaryl, or heteroaralkyl; or R^9 and R^{10} taken together form =O, $=N(R^{20})$, $=N\text{-}OR^{20}$, or =S;

R^{11} is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, $-C(O)R^{20}$, $-C(S)R^{20}$, $-CO_2R^{20}$, $-SO_2R^{20}$, $-C(O)N(R^{20})(R^{20})$, or $-C(S)N(R^{20})(R^{20})$; or has the formula $-[C(R^{20})_2]_q\text{-}R^{21}$;

R^{20} independently for each occurrence is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, or $-[C(R)_2]_q-R^{21}$, where each R is independently H or C1-C6 alkyl; or any two occurrences of R^{20} can be taken together to form a 4-8 membered optionally substituted ring which contains 0-3 heteroatoms selected from N, O, S, and P;

R^{21} independently for each occurrence is H, cycloalkyl, aryl, heteroaryl, heterocyclyl; alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, acylamino, amido, or carbonyl-containing group;

R^{22} independently for each occurrence is H, halide, ester, amide, or nitrile;

p is 0, 1, 2, 3, 4, 5, or 6;

q is 0, 1, 2, 3, 4, 5, or 6;

W is a diradical; and

X is a bond or $-C(R^{22})_2-$;

and each alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, whether alone or part of another group, is optionally substituted.

Certain compounds of the present invention may exist in particular geometric or stereoisomeric forms. The present invention contemplates all such compounds, including *cis*- and *trans*-isomers, *R*- and *S*-enantiomers, diastereomers, (D)-isomers, (L)-isomers, the racemic mixtures thereof, and other mixtures thereof, as falling within the scope of the invention. Additional asymmetric carbon atoms may be present in a substituent such as an alkyl group. All such isomers, as well as mixtures thereof, are intended to be included in this invention. Where tautomers are possible in a compound of the invention, the invention includes each tautomeric form. Where stereochemistry of a chiral center is not expressly depicted or described, the structure includes each isomer at that center. Where the absolute stereochemistry of a compound is depicted in a drawing of a structure, the depicted isomer is a preferred embodiment; a racemic mixture of each specifically depicted compound is also an embodiment of the invention.

In some embodiments, the invention provides a compound of formula 1, wherein each of R^7, R^8, R^{12} and R^{13} represents H. In some embodiments, R^{11} is H or optionally substituted C1-C6 alkyl.

In some of the foregoing embodiments of the compounds of formula 1, R^4 and R^5 are both H; or R^4 and R^5 taken together form =O.

In some of the foregoing embodiments, R^2 and R^3 taken together form a bond, so the D-ring contains a double bond. In such embodiments, X is sometimes a bond and it is sometimes CH_2. In some embodiments, R^2 and R^3 are each H.

In some of the foregoing embodiments, R^9 and R^{10} are each H; in others, R^9 and R^{10} taken together form =O or =S, so that the A-ring is a lactam or thiolactam. In some embodiments, R^6 is H or Me.

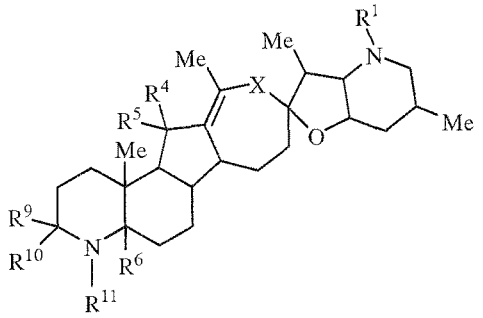
In some of the foregoing embodiments, R^1 is preferably H or an optionally substituted C1-C6 alkyl or aryl-(C1-C6)-alkyl. In other of the foregoing embodiments, R^1 is preferably of the form $C(O)R^{20}$, SO_2R^{20} or CO_2R^{20}, where R^{20} is an optionally substituted C1-C6 alkyl or aryl-(C1-C6)-alkyl. In certain embodiments, when R^1 is $COOR^{20}$, R^{20} is benzyl, methyl, ethyl, or tert-butyl.

In some of the foregoing embodiments, R^{11} is preferably H or an optionally substituted C1-C6 alkyl or aryl-(C1-C6)-alkyl. In other of the foregoing embodiments, R^{11} is preferably of the form $C(O)R^{20}$, SO_2R^{20} or CO_2R^{20}, where R^{20} is an optionally substituted C1-C6 alkyl or aryl-(C1-C6)-alkyl. In certain embodiments, when R^{11} is $COOR^{20}$, R^{20} is benzyl, methyl, ethyl, or tert-butyl.

In some of the foregoing embodiments, R^7 and R^8 are both H; in other embodiments, when R^7 and R^8 are not H, R^7 and R^8 taken together form a bond, so the A-ring contains a double bond.

In some of the foregoing embodiments, p is 0 or 1 independently at each occurrence. In some such embodiments, p is 1.

In some embodiments, the compound of Formula 1 is a compound of formula **9**:



9

or a pharmaceutically acceptable salt thereof;

wherein;

R^1, R^4, R^5, and R^6 are as defined above for formula 1,

each of R^9 and R^{10} independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, nitrile, aralkyl, heteroaryl, or heteroaralkyl; or R^9 and R^{10} taken together form =O, $=N(R^{20})$, $=N\text{-}OR^{20}$, or =S;

R^{11} is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, $-C(O)R^{20}$, $-C(S)R^{20}$, $-CO_2R^{20}$, $-SO_2R^{20}$, $-C(O)N(R^{20})(R^{20})$, or $-C(S)N(R^{20})(R^{20})$; or has the formula $-[C(R^{20})_2]_q-R^{21}$;

R^{20} independently for each occurrence is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, or $-[C(R)_2]_q-R^{21}$, where each R is independently H or C1-C6 alkyl; or any two occurrences of R^{20} can be taken together to form a 4-8 membered optionally substituted ring which contains 0-3 heteroatoms selected from N, O, S, and P;

R^{21} independently for each occurrence is H, cycloalkyl, aryl, heteroaryl, heterocyclyl; alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, acylamino, amido, or carbonyl-containing group; and

p is 0, 1, 2, 3, 4, 5, or 6;

q is 0, 1, 2, 3, 4, 5, or 6;

W is a diradical;

X is a bond or $-CH_2-$;

and each alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, whether alone or part of another group, is optionally substituted.

In some embodiments of the compound of formula 9, X is $-CH_2-$. In other embodiments, X is a bond.

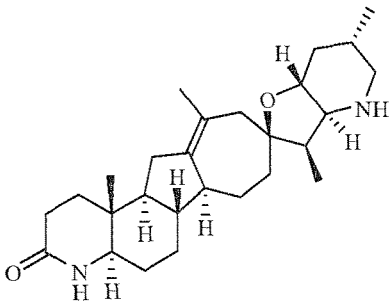
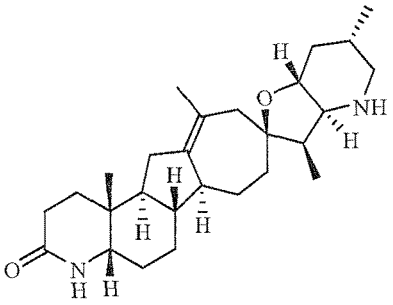
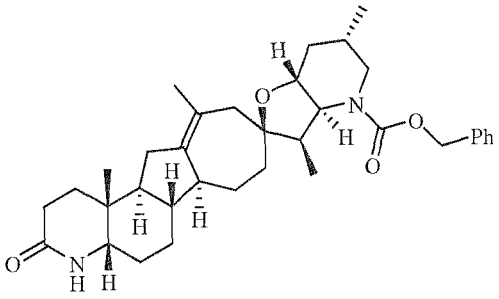
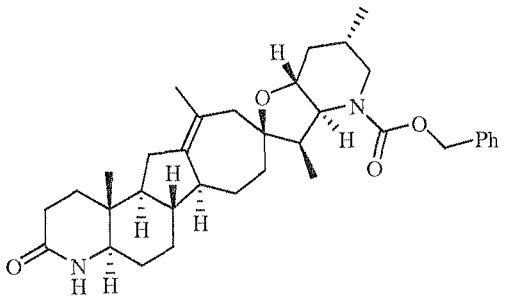
In some of the foregoing embodiments of compounds of formula 9, R^6 is H or optionally substituted C1-C6 alkyl. Sometimes R^6 is Me.

In some embodiments of the compounds of formula 9, R^1 is H. In other embodiments, R^1 is alkyl, alkenyl, alkynyl, aryl, cycloalkyl, hydroxyl, aralkyl, heteroaryl, heteroaralkyl, haloalkyl, alkoxyl, $-C(O)N(R^{20})(R^{20})$, $COOR^{20}$, $-[C(R^{20})_2]_p-R^{20}$, $-[(W)-N(R^{20})C(O)]_pR^{20}$, $-[(W)-C(O)]_pR^{20}$, $-[(W)-C(O)O]_pR^{20}$, $-[(W)-OC(O)]_pR^{20}$, $-[(W)-SO_2]_pR^{20}$, $-[(W)-N(R^{20})SO_2]_pR^{20}$, $-[(W)-C(O)N(R^{20})]_pR^{20}$, $-[(W)-O]_pR^{20}$, $-[(W)-N(R^{20})]_pR^{20}$, or $-[(W)-S]_pR^{20}$. Often R^1 is H, optionally substituted C1-C6 alkyl, $C(O)R^{20}$, SO_2R^{20}, or it is $COOR^{20}$. In certain embodiments, R^1 is H or $C(O)R^{20}$ or $COOR^{20}$, where R^{20} is benzyl, methyl, ethyl, or tert-butyl. In some of the foregoing embodiments, p is 0 or 1 independently at each occurrence. In some such embodiments, p is 1.

In some embodiments of the compounds of formula 9, R^4 and R^5 are both H. In other such embodiments, R^4 and R^5 taken together form a bond.

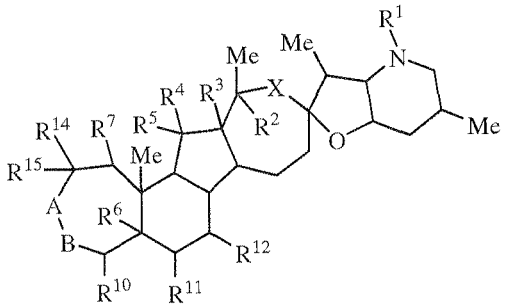
In some embodiments of the compounds of formula 9, R^9 and R^{10} taken together form =O or =S. In many such embodiments, they are taken together to form =O.

In some embodiments, the compounds of formula 9 is selected from:


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, and

,

and the pharmaceutically acceptable salts of these compounds.

In another aspect, the invention provides a compound of formula **15**:



15

or a pharmaceutically acceptable salt thereof, wherein;

each of A and B independently is $-N(R^{13})-$, -(C=O)-, or -(C=S)-;

R^1 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, hydroxyl, aralkyl, heteroaryl, heteroaralkyl, haloalkyl, alkoxyl, $-SR^{20}$, $-OR^{20}$, $-N(R^{20})(R^{20})$, $-C(O)R^{20}$, $-CO_2R^{20}$, $-OC(O)R^{20}$, $-C(O)N(R^{20})(R^{20})$, $-N(R^{20})C(O)R^{20}$, $-N(R^{20})C(O)N(R^{20})(R^{20})$, $-S(O)R^{20}$, $-S(O)_2R^{20}$, $-S(O)_2N(R^{20})(R^{20})$, $-N(R^{20})S(O)_2R^{20}$, $-[(W)-C(O)]_pR^{20}$, $-[(W)-C(O)O]_pR^{20}$, $-[(W)-OC(O)]_pR^{20}$, $-[(W)-SO_2]_pR^{20}$, $-[(W)-N(R^{20})SO_2]_pR^{20}$, $-[(W)-C(O)N(R^{20})]_pR^{20}$, $-[(W)-O]_pR^{20}$, $-[(W)-N(R^{20})]_pR^{20}$, or $-[(W)-S]_pR^{20}$;

each of R^2, R^7 and R^{10} is independently H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, alkoxyl, aryloxy, acyloxy, halide, hydroxyl, amino, alkylamino, arylamino, acylamino, aralkylamino, alkylseleno, aralkylseleno, arylseleno, alkylthio, aralkylthio, arylthio, heteroaryl, or heteroaralkyl;

R^3 is H; or R^2 and R^3 taken together form a bond;

each of R^4 and R^5 independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, nitrile, aralkyl, alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, alkylamino, arylamino, acylamino, aralkylamino, heteroaryl, or heteroaralkyl; or R^4 and R^5 taken together form =O, =S, =N(R^{20}), =N-OR^{20} or =N(N(R^{20})$_2$);

R^6 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, or aralkyl; or R^6 and R^{10} taken together form a bond;

each of R^{11}, R^{12}, R^{14} and R^{15} independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, or aralkyl; or R^{11} and R^{12} taken together form a bond; or R^7 and R^{14} taken together form a bond;

R^{13} is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, -C(O)R^{20}, -C(S)R^{20}, -CO_2R^{20}, -SO_2R^{20}, -C(O)N(R^{20})(R^{20}), or -C(S)N(R^{20})(R^{20}); or has the formula -[C(R^{20})$_2$]$_q$-R^{21};

R^{20} independently for each occurrence is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, or –[C(R)$_2$]$_q$-R^{21}, where each R is independently H or C1-C6 alkyl; or any two occurrences of R^{20} can be taken together to form a 4-8 membered optionally substituted ring which contains 0-3 heteroatoms selected from N, O, S, and P;

R^{21} independently for each occurrence is H, cycloalkyl, aryl, heteroaryl, heterocyclyl; alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, acylamino, amido, or carbonyl-containing group;

R^{22} independently for each occurrence is H, halide, ester, amide, or nitrile;

p is 0, 1, 2, 3, 4, 5, or 6;

q is 0, 1, 2, 3, 4, 5, or 6;

W is a diradical;

X is a bond or -C(R^{22})$_2$-;

and each alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, whether alone or part of another group, is optionally substituted;

provided that when A is –N(R^{13})-; B must be -(C=O)-, or -(C=S)-; and

provided that when A is -(C=O)-, or -(C=S)-; B must be –N(R^{13})-.

In some embodiments of the compounds of formula 15, A is –N(R^{13})- and B is C=O. In other embodiments of the compounds of formula 15, B is –N(R^{13})- and A is C=O.

In some of the foregoing embodiments of the compounds of formula 15, R^{13} is H. In other such embodiments, R^{13} is COOR^{20} or SO_2R^{20}, wherein R^{20} is C1-C6 alkyl or

aryl-(C1-C6)-alkyl, and each alkyl and aryl is optionally substituted. In certain embodiments, when R^{13} is $COOR^{20}$, R^{20} is benzyl, methyl, ethyl, or tert-butyl.

In some of the foregoing embodiments of the compounds of formula 15, R^{11} and R^{12} are each H. In others, R^{11} and R^{12} are taken together to form a bond.

In some of the foregoing embodiments of the compounds of formula 15, R^2 and R^3 taken together form a bond. In other embodiments, R^2 and R^3 are both H.

In some of the foregoing embodiments of the compounds of formula 15, R^4 and R^5 are each H; in other such embodiments, R^4 and R^5 taken together form =O.

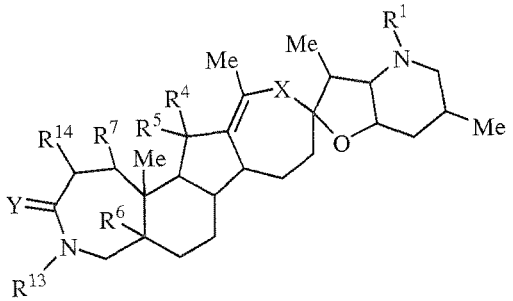
In some of the foregoing embodiments of the compounds of formula 15, R^7 and R^{10} are each H. In some of the foregoing embodiments of the compounds of formula 15, when R^7 is not H, R^7 and R^{14} are taken together to form a bond. In other embodiments, when R^{10} is not H, R^{10} and R^6 are sometimes taken together to form a bond.

In some of the foregoing embodiments of the compounds of formula 15, R^1 is H. In other such embodiments, R^1 is $COOR^{20}$ or SO_2R^{20}, wherein R^{20} is C1-C6 alkyl or aryl-(C1-C6)-alkyl, and each alkyl and aryl is optionally substituted. In certain embodiments, when R^1 is $COOR^{20}$, R^{20} is benzyl, methyl, ethyl, or tert-butyl.

In some of the foregoing embodiments, the compound of formula 15, X is CH_2. In other such embodiments, X is a bond.

In some of the foregoing embodiments, p is 0 or 1 independently at each occurrence. In some such embodiments, p is 1.

In some embodiments, the compound of formula 15 is a compound of formula **21**:



21

where R^1, R^4, R^5, R^7, R^{14}, R^{13}, R^6, R^{20}, and X are as defined above for formula 15, and Y is O or S; or a pharmaceutically acceptable salt thereof.

In some embodiments of the compound of formula 21, X is $-CH_2-$. In other embodiments, X is a bond.

In some of the foregoing embodiments of the compound of formula 21, Y is O. In some such embodiments, R^6 is H.

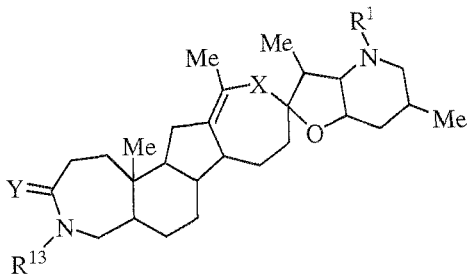
In some of the foregoing embodiments of the compounds of formula 21, R^1 is H. In other such embodiments, R^1 is $COOR^{20}$ or SO_2R^{20}, wherein R^{20} is C1-C6 alkyl or aryl-(C1-C6)-alkyl, and each alkyl and aryl is optionally substituted. In certain embodiments, when R^1 is $COOR^{20}$, R^{20} is benzyl, methyl, ethyl, or tert-butyl.

In some of the foregoing embodiments of the compounds of formula 21, R^7 and R^{14} are both H. In other such embodiments, R^7 and R^{14} are taken together to form a bond.

In some of the foregoing embodiments of the compound of formula 21, R^4 and R^5 are both H. In other such embodiments, R^4 and R^5 are taken together to form =O.

In some of the foregoing embodiments of the compound of formula 21, R^{13} is H or C1-C6 alkyl, such as methyl. In other such embodiments, R^{13} is $COOR^{20}$ or SO_2R^{20}, wherein R^{20} is C1-C6 alkyl or aryl-(C1-C6)-alkyl, and each alkyl and aryl is optionally substituted. In certain embodiments, when R^{13} is $COOR^{20}$, R^{20} is benzyl, methyl, ethyl, or tert-butyl. In some of the foregoing embodiments, p is 0 or 1 independently at each occurrence. In some such embodiments, p is 1.

In some of the foregoing embodiments, the compound of formula 21 has formula **23**:



23

wherein R^1, R^{13} and X are as defined for formula 15, and Y is O or S; or a pharmaceutically acceptable salt thereof.

In some embodiments of the compounds of formula 23, R^1 is H. In other such embodiments, R^1 is $COOR^{20}$ or SO_2R^{20}, wherein R^{20} is C1-C6 alkyl or aryl-(C1-C6)-alkyl, and each alkyl and aryl is optionally substituted. In certain embodiments, when R^1 is $COOR^{20}$, R^{20} is benzyl, methyl, ethyl, or tert-butyl.

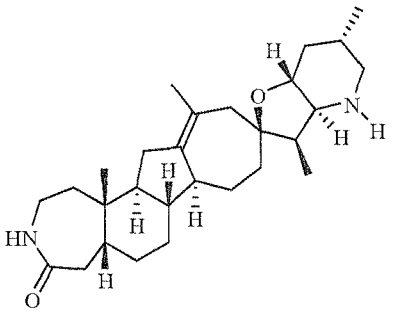
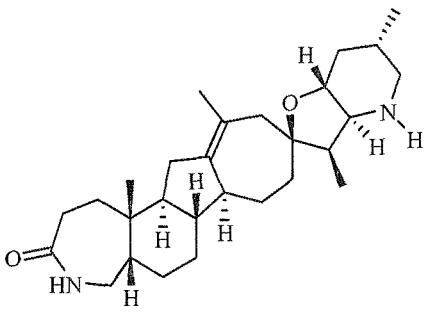
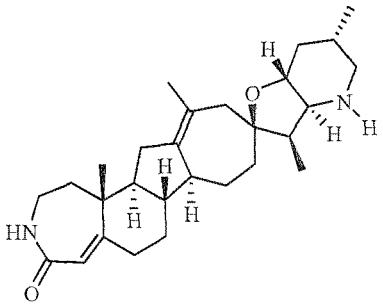
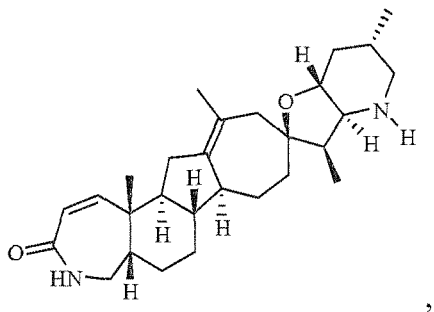
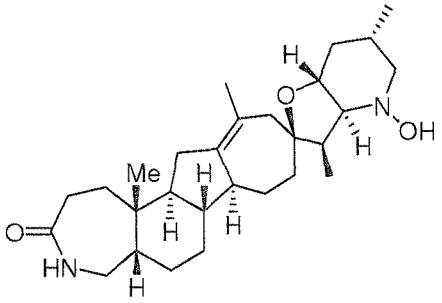
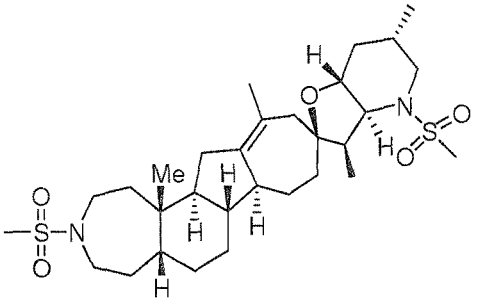
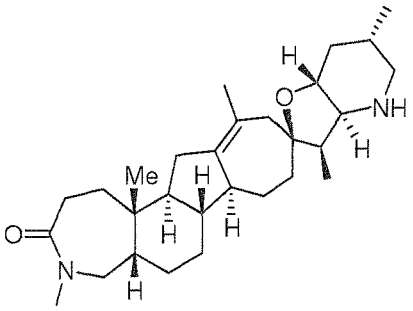
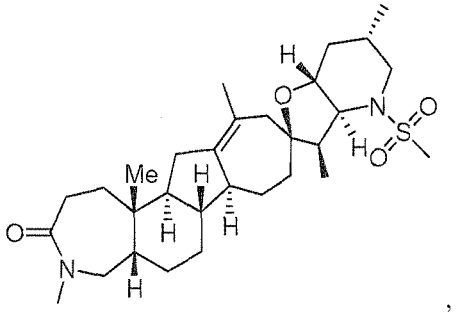
In some of the foregoing embodiments of the compounds of formula 23, R^{13} is H. In other such embodiments, R^{13} is $COOR^{20}$ or SO_2R^{20}, wherein R^{20} is C1-C6 alkyl or aryl-(C1-C6)-alkyl, and each alkyl and aryl is optionally substituted. In certain embodiments, when R^{13} is $COOR^{20}$, R^{20} is benzyl, methyl, ethyl, or tert-butyl.

In some of the foregoing embodiments of the compounds of formula 23, X is CH_2. In other such embodiments, X is a bond.

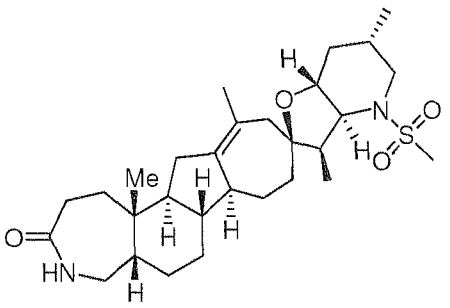
In some of the foregoing embodiments of the compounds of formula 23, Y is O.

In some of the foregoing embodiments, p is 0 or 1 independently at each occurrence. In some such embodiments, p is 1.

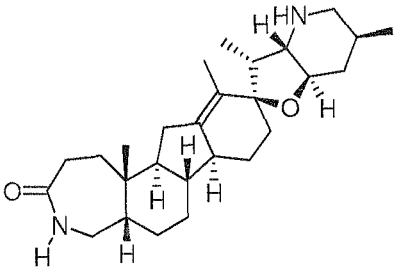
In some embodiments, the compound of formula 15 is selected from:


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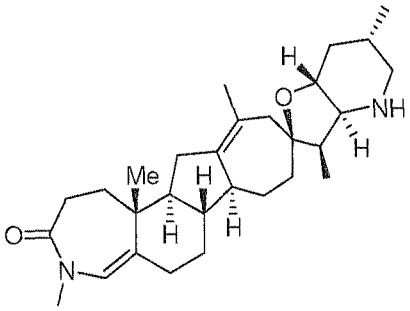
5



,



and



;

and their pharmaceutically acceptable salts.

The pharmaceutically acceptable salts of the compounds of the present invention include the conventional nontoxic salts or quaternary ammonium salts of the compounds, *e.g.*, from non-toxic organic or inorganic acids. For example, such conventional nontoxic salts include those derived from inorganic acids such as hydrochloride, hydrobromic, sulfuric, sulfamic, phosphoric, nitric, and the like; and the salts prepared from organic acids such as acetic, propionic, succinic, glycolic, stearic, lactic, malic, tartaric, citric, ascorbic, palmitic, maleic, hydroxymaleic, phenylacetic, glutamic, benzoic, salicyclic, sulfanilic, 2-acetoxybenzoic, fumaric, toluenesulfonic, methanesulfonic, ethane disulfonic, oxalic, isothionic, and the like.

In other cases, the compounds of the present invention may contain one or more acidic functional groups and, thus, are capable of forming pharmaceutically-acceptable salts with pharmaceutically-acceptable bases. The term "pharmaceutically-acceptable salts" in these instances refers to the relatively non-toxic, inorganic and organic base addition salts of compounds of the present invention. These salts can likewise be prepared *in situ* in the administration vehicle or the dosage form manufacturing process, or by separately reacting the purified compound in its free acid form with a suitable base, such as the hydroxide, carbonate or bicarbonate of a pharmaceutically-acceptable metal cation, with ammonia, or with a pharmaceutically-acceptable organic primary, secondary or tertiary amine. Representative alkali or alkaline earth salts include the lithium, sodium, potassium, calcium, magnesium, and aluminum salts and the like. Representative organic amines useful for the

formation of base addition salts include ethylamine, diethylamine, ethylenediamine, ethanolamine, diethanolamine, piperazine and the like. (See, for example, Berge, *et al.*, *supra*).

In another aspect, the invention provides a pharmaceutical composition comprising at least one compound described in the above embodiments, admixed with at least one pharmaceutically acceptable excipient.

In another aspect, the invention provides a method of treating a condition mediated by the hedgehog pathway, including administering to a subject an effective amount of a compound described herein. The invention also provides a method of antagonizing the hedgehog pathway in a subject, including administering to the subject an effective amount of a compound described herein. The invention also provides a method of treating cancer in a subject, including administering to a subject a therapeutically effective amount of a compound described herein. Such cancers include cancers of the central nervous system and cancers of the gastrointestinal tract. The invention further provides a method of inhibiting activation of a hedgehog pathway in a patient diagnosed with a hyperproliferative disorder, including administering to the patient a compound described herein in an amount sufficient to reduce the activation of the hedgehog pathway in a cell of the patient.

In another aspect, the invention provides a method to treat a subject afflicted by excessive activity of a hedgehog pathway, which comprises administering to the subject at least one compound described in any of the above embodiments, or a pharmaceutically acceptable salt thereof, or a pharmaceutical composition thereof. In some embodiments, the subject is a subject diagnosed with a hyperproliferative disorder, and in some embodiments, the hyperproliferative disorder is cancer.

Synthesis of Steroidal Alkaloid Compounds

The steroidal alkaloid derivatives described above can be prepared directly from naturally occurring steroidal alkaloids or synthetic analogs thereof. In certain instances, the steroidal alkaloid starting materials can be cyclopamine or jervine. These steroidal alkaloids can be purchased commercially or extracted from *Veratrum californicum.*

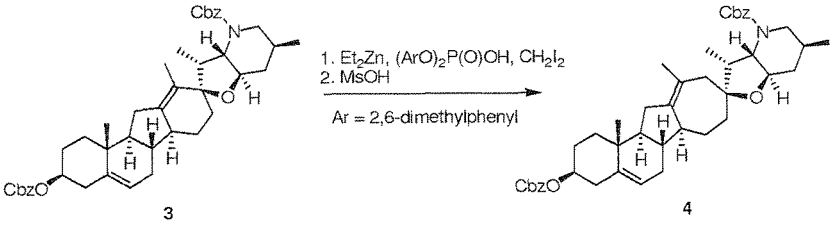
In certain instances, the compounds of the present invention may contain a six membered nitrogen containing A-ring (see Figure 1). These compounds may be accessed, as described below, by oxidative cleavage of the A-ring of a steroidal alkaloid with a double bond in the A-ring. Depending on the position of the double bond in the A-ring the site of cleavage and nitrogen incorporation into the ring may be changed. In the examples below, the double bond is conjugated to a ketone and upon exposure to sodium periodate and

potassium permanganate the double is oxidatively cleaved and one carbon is removed from the ring. The resulting keto-ester may be treated with an amine and a reducing agent to form the 6-membered lactam. In the example, below ammonium acetate is used to form the 6-membered lactam. The resulting lactam may be further alkylated or in the alternative, a primary amine may be used to access tertiary lactams. The resulting lactams may be reduced to yield steroidal alkaloids with an amine in the A-ring.

In certain instances, the compounds of the present invention may contain a 7-membered nitrogen containing A-ring. These compounds may be formed directly from A-ring oxime-derivatives via the Beckman rearrangement. The rearranged product may be further derivatized by alkylation of the nitrogen of the amide, reduction of the amide to an amine, and the like. In the examples below an A-ring oxime is treated with MsCl and base to affect the Beckman rearrangement to afford secondary and tertiary A-ring expanded lactams.

In certain instances, the compounds of the present invention may contain a six or seven membered D-ring. Compounds with a 6-membered D-ring are accessible from certain natural products such as jervine or cyclopamine. Briefly, as illustrated by the example in Scheme A, the seven membered D-ring analogs may be accessed by cyclopropanating the D-ring of a suitable steroidal alkaloid followed by treating the resulting cyclopropanated product with a Lewis or Brønsted acid to catalyze a ring expansion rearrangement to yield the seven membered D-ring analogs.

Scheme A. Exemplary formation of a 7-membered D-ring.



3 4

This ring expansion can be performed either before or after modifications of the A-ring are accomplished. These ring expanded analogs may be further functionalized using a variety of functionalization reactions known in the art. Representative examples include palladium coupling reactions to alkenylhalides or aryl halides, oxidations, reductions, reactions with nucleophiles, reactions with electrophiles, pericyclic reactions, installation of protecting groups, removal of protecting groups, and the like.

Pharmaceutical Compositions

The compounds disclosed herein or salts thereof may be formulated into composition suitable for administration, using one or more pharmaceutically acceptable carriers (additives) and/or diluents. The pharmaceutical compositions may be specially formulated for administration in solid or liquid form, including those adapted for the following: (1) oral administration, for example, drenches (aqueous or non-aqueous solutions or suspensions), tablets, *e.g.*, those targeted for buccal, sublingual, and systemic absorption, capsules, boluses, powders, granules, pastes for application to the tongue; (2) parenteral administration, for example, by subcutaneous, intramuscular, intravenous or epidural injection as, for example, a sterile solution or suspension, or sustained-release formulation; (3) topical application, for example, as a cream, ointment, or a controlled-release patch or spray applied to the skin; (4) intravaginally or intrarectally, for example, as a pessary, cream or foam; (5) sublingually; (6) ocularly; (7) transdermally; (8) pulmonarily, or (9) nasally.

Examples of suitable aqueous and nonaqueous carriers which may be employed in the pharmaceutical compositions include water, ethanol, polyols (such as glycerol, propylene glycol, polyethylene glycol, and the like), and suitable mixtures thereof, vegetable oils, such as olive oil, and injectable organic esters, such as ethyl oleate. Proper fluidity can be maintained, for example, by the use of coating materials, such as lecithin, by the maintenance of the required particle size in the case of dispersions, and by the use of surfactants.

These compositions may also contain adjuvants such as preservatives, wetting agents, emulsifying agents, dispersing agents, lubricants, and/or antioxidants. Prevention of the action of microorganisms upon the compounds disclosed herein may be ensured by the inclusion of various antibacterial and antifungal agents, for example, paraben, chlorobutanol, phenol sorbic acid, and the like. It may also be desirable to include isotonic agents, such as sugars, sodium chloride, and the like into the compositions. In addition, prolonged absorption of the injectable pharmaceutical form may be brought about by the inclusion of agents which delay absorption such as aluminum monostearate and gelatin.

Methods of preparing these formulations or compositions include the step of bringing into association a compound with the carrier and, optionally, one or more accessory ingredients. In general, the formulations are prepared by uniformly and intimately bringing into association a compound with liquid carriers, or finely divided solid carriers, or both, and then, if necessary, shaping the product.

When the compounds disclosed herein are administered as pharmaceuticals, to humans and animals, they can be given per se or as a pharmaceutical composition containing, for example, about 0.1 to 99%, or about 10 to 50%, or about 10 to 40%, or about 10 to 30, or about 10 to 20%, or about 10 to 15% of active ingredient in combination with a pharmaceutically acceptable carrier.

Actual dosage levels of the active ingredients in the pharmaceutical compositions may be varied so as to obtain an amount of the active ingredient which is effective to achieve the desired therapeutic response for a particular patient, composition, and mode of administration, without being toxic to the patient.

The selected dosage level will depend upon a variety of factors including the activity of the particular compound employed, or the ester, salt or amide thereof, the route of administration, the time of administration, the rate of excretion or metabolism of the particular compound being employed, the rate and extent of absorption, the duration of the treatment, other drugs, compounds and/or materials used in combination with the particular compound employed, the age, sex, weight, condition, general health and prior medical history of the patient being treated, and like factors well known in the medical arts.

In general, a suitable daily dose of a compound disclosed herein will be that amount of the compound which is the lowest dose effective to produce a therapeutic effect. Such an effective dose will generally depend upon the factors described above. Generally, oral, intravenous and subcutaneous doses of the compounds for a patient, when used for the indicated effects, will range from about 0.0001 to about 200 mg, or about 0.001 to about 100 mg, or about 0.01 to about 100 mg, or about 0.1 to about 100 mg per, or about 1 to about 50 mg per kilogram of body weight per day.

The compounds can be administered daily, every other day, three times a week, twice a week, weekly, or bi-weekly. The dosing schedule can include a "drug holiday," *i.e.*, the drug can be administered for two weeks on, one week off, or three weeks on, one week off, or four weeks on, one week off, etc., or continuously, without a drug holiday. The compounds can be administered orally, intravenously, intraperitoneally, topically, transdermally, intramuscularly, subcutaneously, intranasally, sublingually, or by any other route.

The subject receiving this treatment is any animal in need, including primates, in particular humans, and other mammals such as equines, cattle, swine and sheep; and poultry and pets in general.

Methods of Treatment

Hedgehog signaling is essential in many stages of development, especially in formation of left-right symmetry. Loss or reduction of hedgehog signaling leads to multiple developmental deficits and malformations, one of the most striking of which is cyclopia.

Many tumors and proliferative conditions have been shown to depend on the hedgehog pathway. The growth of such cells and survival can be affected by treatment with the compounds disclosed herein. Recently, it has been reported that activating hedgehog pathway mutations occur in sporadic basal cell carcinoma (Xie *et al.* (1998) Nature 391: 90-2) and primitive neuroectodermal tumors of the central nervous system (Reifenberger *et al.* (1998) Cancer Res 58: 1798-803). Uncontrolled activation of the hedgehog pathway has also been shown in numerous cancer types such as GI tract cancers including pancreatic, esophageal, gastric cancer (Berman *et al.* (2003) Nature 425: 846-51, Thayer *et al.* (2003) Nature 425: 851-56) lung cancer (Watkins *et al.* (2003) Nature 422: 313-317, prostate cancer (Karhadkar *et al* (2004) Nature 431: 707-12, Sheng *et al.* (2004) Molecular Cancer 3: 29-42, Fan *et al.* (2004) Endocrinology 145: 3961-70), breast cancer (Kubo *et al.* (2004) Cancer Research 64: 6071-74, Lewis *et al.* (2004) Journal of Mammary Gland Biology and Neoplasia 2: 165-181) and hepatocellular cancer (Sicklick *et al.* (2005) ASCO conference, Mohini *et al.* (2005) AACR conference).

For example, small molecule inhibition of the hedgehog pathway has been shown to inhibit the growth of basal cell carcinoma (Williams, *et al.*, 2003 PNAS 100: 4616-21), medulloblastoma (Berman *et al.*, 2002 Science 297: 1559-61), pancreatic cancer (Berman *et al.*, 2003 Nature 425: 846-51), gastrointestinal cancers (Berman *et al.*, 2003 Nature 425: 846-51, published PCT application WO 05/013800), esophageal cancer (Berman *et al.*, 2003 Nature 425: 846-51), lung cancer (Watkins *et al.*, 2003. Nature 422: 313-7), and prostate cancer (Karhadkar *et al.*, 2004. Nature 431: 707-12).

In addition, it has been shown that many cancer types have uncontrolled activation of the hedgehog pathway, for example, breast cancer (Kubo *et al.*, 2004. Cancer Research 64: 6071-4), heptacellular cancer (Patil *et al.*, 2005. 96th Annual AACR conference, abstract #2942 Sicklick *et al.*, 2005. ASCO annual meeting, abstract #9610), hematological malignancies (Watkins and Matsui, unpublished results), basal carcinoma (Bale & Yu, 2001. Human Molec. Genet. 10:757-762 Xie *et al.*, 1998 Nature 391: 90-92), medulloblastoma (Pietsch *et al.*, 1997. Cancer Res. 57: 2085-88), and gastric cancer (Ma *et al.*, 2005 Carcinogenesis May 19, 2005 (Epub)). In addition, investigators have found that small molecule inhibition of the hedgehog pathway has been shown to ameliorate the symptoms of

psoriasis (Tas, *et al.*, 2004 Dermatology 209: 126-131). As shown in the Examples, the compounds disclosed herein have been shown to modulate the hedgehog pathway, and selected compounds have been shown to inhibit tumor growth. It is therefore believed that these compounds can be useful to treat a variety of hyperproliferative disorders, such as various cancers.

Proliferative disorders that can be treated using the methods disclosed herein include: lung cancer (including small cell lung cancer and non small cell lung cancer), other cancers of the pulmonary system, medulloblastoma and other brain cancers, pancreatic cancer, basal cell carcinoma, breast cancer, prostate cancer and other genitourinary cancers, gastrointestinal stromal tumor (GIST) and other cancers of the gastrointestinal tract, colon cancer, colorectal cancer, ovarian cancer, cancers of the hematopoietic system (including multiple myeloma, acute lymphocytic leukemia, acute myelocytic leukemia, chronic myelocytic leukemia, chronic lymphocytic leukemia, Hodgkin lymphoma, and non-Hodgkin lymphoma, and myelodysplastic syndrome), polycythemia Vera, Waldenstrom's macroglobulinemia, heavy chain disease, soft-tissue sarcomas, such as fibrosarcoma, myxosarcoma, liposarcoma, chondrosarcoma, osteogenic sarcoma, chordoma, angiosarcoma, endotheliosarcoma, lymphangiosarcoma, lymphangioendotheliosarcoma, synovioma, mesothelioma, Ewing's tumor, leiomyosarcoma, rhabdomyosarcoma, squamous cell carcinoma, basal cell carcinoma, melanoma, and other skin cancers, adenocarcinoma, sweat gland carcinoma, sebaceous gland carcinoma, papillary carcinoma, papillary adenocarcinomas, stadenocarcinoma, medullary carcinoma, bronchogenic carcinoma, renal cell carcinoma, hepatoma, bile duct carcinoma, choriocarcinoma, seminoma, embryonal carcinoma, Wilms' tumor, cervical cancer, uterine cancer, testicular cancer, bladder carcinoma, and other genitourinary cances, epithelial carcinoma, glioma, astrocytoma, medulloblastoma, craniopharyngioma, ependymoma, pinealoma, hemangioblastoma, acoustic neuroma, oligodendroglioma, meningioma, neuroblastoma, retinoblastoma, endometrial cancer, follicular lymphoma, diffuse large B-cell lymphoma, mantle cell lymphoma, hepatocellular carcinoma, thyroid cancer, gastric cancer, esophageal cancer, head and neck cancer, small cell cancers, essential thrombocythemia, agnogenic myeloid metaplasia, hypereosinophilic syndrome, systemic mastocytosis, familiar hypereosinophilia, chronic eosinophilic leukemia, thyroid cancer, neuroendocrine cancers, and carcinoid tumors. Additional disorders include Gorlin's syndrome and psoriasis

The subject receiving this treatment is any animal in need, including primates, in particular humans, and other mammals such as equines, cattle, swine and sheep; and poultry and pets in general.

The hedgehog inhibitors disclosed herein can be combined with other cancer treatments. For example, they can be combined with surgical treatments; radiation; biotherapeutics (such as interferons, cytokines -- *e.g.*, Interferon α, Interferon γ, and tumor necrosis factor, hematopoietic growth factors, monoclonal serotherapy, vaccines and immunostimulants); antibodies (*e.g.*, Avastin, Erbitux, Rituxan, and Bexxar); endocrine therapy (including peptide hormones, corticosteroids, estrogens, androgens and aromatase inhibitors); anti-estrogens (*e.g.*, Tamoxifen, Raloxifene, and Megestrol); LHRH agonists (*e.g.*, goscrclin and Leuprolide acetate); anti-androgens (*e.g.*, flutamide and Bicalutamide); gene therapy; bone marrow transplantation; photodynamic therapies (*e.g.*, vertoporfin (BPD-MA), Phthalocyanine, photosensitizer Pc4, and Demethoxy-hypocrellin A (2BA-2-DMHA)); and chemotherapeutics.

Examples of chemotherapeutics include gemcitabine, methotrexate, taxol, mercaptopurine, thioguanine, hydroxyurea, cytarabine, cyclophosphamide, ifosfamide, nitrosoureas, cisplatin, carboplatin, mitomycin, dacarbazine, procarbizine, etoposides, prednisolone, dexamethasone, cytarbine, campathecins, bleomycin, doxorubicin, idarubicin, daunorubicin, dactinomycin, plicamycin, mitoxantrone, asparaginase, vinblastine, vincristine, and vinorelbine. Additional agents include nitrogen mustards (*e.g.*, cyclophosphamide, ifosfamide, trofosfamide, chlorambucil, estramustine, and melphalan), nitrosoureas (*e.g.*, carmustine (BCNU) and lomustine (CCNU)), alkylsulphonates (*e.g.*, busulfan and treosulfan), triazenes (*e.g.*, dacarbazine and temozolomide), platinum containing compounds (*e.g.*, cisplatin, carboplatin, and oxaliplatin), vinca alkaloids (*e.g.*, vincristine, Vinblastine, Vindesine, and Vinorelbine), taxoids (*e.g.*, paclitaxel and Docetaxol), epipodophyllins (*e.g.*, etoposide, teniposide, topotecan, 9-aminocamptothecin, camptoirinotecan, crisnatol, and mytomycin C), anti-metabolites, DHFR inhibitors (*e.g.*, methotrexate and trimetrexate), IMP dehydrogenase Inhibitors (*e.g.*, mycophenolic acid, tiazofurin, ribavirin, and EICAR), ribonuclotide reductase Inhibitors (*e.g.*, hydroxyurea and deferoxamine), uracil analogs (*e.g.*, fluorouracil, floxuridine, doxifluridine, ratitrexed, and capecitabine), cytosine analogs (*e.g.*, cytarabine (ara C), cytosine arabinoside, and fludarabine), purine analogs (*e.g.*, mercaptopurine and thioguanine), vitamin D3 analogs (*e.g.*, EB 1089, CB 1093, and KH 1060), isoprenylation inhibitors (*e.g.*, Lovastatin), dopaminergic neurotoxins (*e.g.*, 1-methyl-4-phenylpyridinium ion), cell cycle inhibitors

(*e.g.*, staurosporine), actinomycins (*e.g.*, actinomycin D and dactinomycin), bleomycins (*e.g.*, bleomycin A2, bleomycin B2, and peplomycin), anthracyclines (*e.g.*, daunorubicin, doxorubicin (Adriamycin®), idarubicin, epirubicin, pirarubicin, zorubicin, and mitoxantrone), MDR inhibitors (*e.g.*, verapamil), Ca^{2+} ATPase inhibitors (*e.g.*, thapsigargin), imatinib, thalidomide, lenalidomide, erlotinib, gefitinib, sorafenib, and sunitinib, and proteasome inhibitors, including bortezomib.

When the hedgehog inhibitors disclosed herein are administered in combination with other treatments, such as additional therapeutics or with radiation or surgery, the doses of each agent or therapy will in most instances be lower than the corresponding dose for single-agent therapy. Also, in general, the hedgehog inhibitors described herein and the second therapeutic agent do not have to be administered in the same pharmaceutical composition, and may, because of different physical and chemical characteristics, be administered by different routes. For example, one compound can be administered orally, while the second therapeutic is administered intravenously. The determination of the mode of administration and the advisability of administration, where possible, in the same pharmaceutical composition, is well within the knowledge of the skilled clinician. The initial administration can be made according to established protocols known in the art, and then, based upon the observed effects, the dosage, modes of administration and times of administration can be modified by the skilled clinician.

The hedgehog inhibitor and the second therapeutic agent and/or radiation may be administered concurrently (*e.g.*, simultaneously, essentially simultaneously or within the same treatment protocol) or sequentially (*i.e.*, one followed by the other, with an optional time interval in between), depending upon the nature of the proliferative disease, the condition of the patient, and the actual choice of second therapeutic agent and/or radiation to be administered.

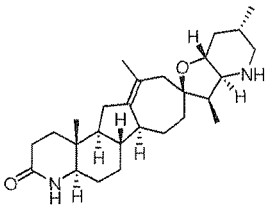
If the hedgehog inhibitor, and the second therapeutic agent and/or radiation are not administered simultaneously or essentially simultaneously, then the optimum order of administration may be different for different conditions. Thus, in certain situations the hedgehog inhibitor may be administered first followed by the administration of the second therapeutic agent and/or radiation; and in other situations the second therapeutic agent and/or radiation may be administered first followed by the administration of a hedgehog inhibitor. This alternate administration may be repeated during a single treatment protocol. The determination of the order of administration, and the number of repetitions of administration of each therapeutic agent during a treatment protocol, is well within the

knowledge of the skilled physician after evaluation of the disease being treated and the condition of the patient. For example, the second therapeutic agent and/or radiation may be administered first, especially if it is a cytotoxic agent, and then the treatment continued with the administration of a hedgehog inhibitor followed, where determined advantageous, by the administration of the second therapeutic agent and/or radiation, and so on until the treatment protocol is complete.

Exemplification

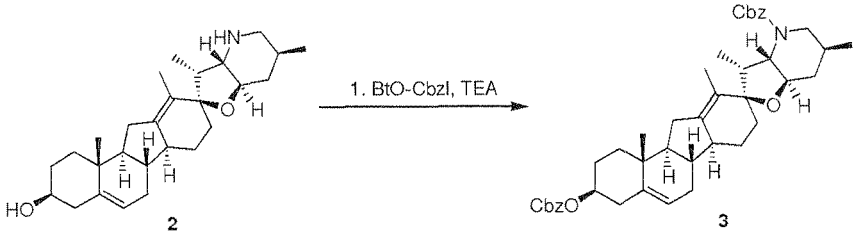
The invention now being generally described, it will be more readily understood by reference to the following examples, which are included merely for purposes of illustration of certain aspects and embodiments of the present invention, and are not intended to limit the invention.

Example 1



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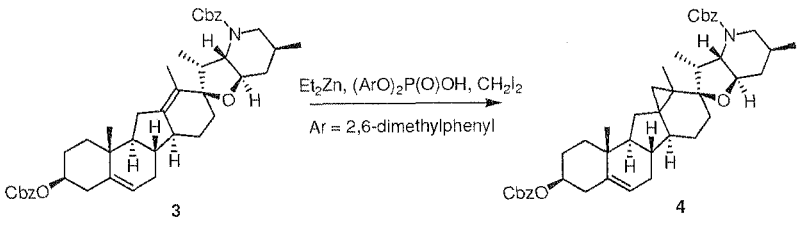
Step A



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Cyclopamine **2** (5.02 g, 12.2 mmol, 1.0 eq) was dissolved in anhydrous pyridine (25 mL). DMAP (300 mg, 2.44 mmol, 0.2 eq.) and triethyl amine (5.5 mL, 39.1 mmol, 3.2 eq) were added, followed by BtO-Cbz (10.5 g, 39.1 mmol, 3.2 eq) and the mixture was heated at 40°C for 2h. The mixture was cooled to rt, treated with 30 mL water, heated to get a homogeneous solution and allowed to cool to rt. The white precipitate that formed was collected by filtration, the filter cake was washed with portions of water (3 X 50 mL), and dried in air to afford 9.53 g of crude material which crystallized from toluene/heptanes (1:9, 70 mL) to give 6.75 g of the desired product.

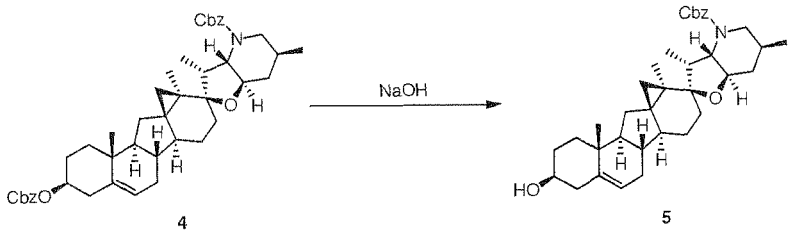
Step B



3 4

Bis(2,6-dimethylphenyl)phosphate (6.76 g, 22.1 mmol, 3 eq) was dissolved at rt with anhydrous DCM (50 mL) and azeotroped (2X). The resulting solid was placed under high vacuum for 12 h. The solid was suspended in DCM (50 mL) to yield a clear solution (Flask A). Bis-Cbz protected cyclopamine (5 g, 7.35 mmol, 1 eq) was dissolved in anhydrous DCM (50 mL) and azetroped (2X). The resulting white foam was placed under high vacuum for 12 h. The dried Bis-Cbz protected cyclopamine was dissolved in anhydrous DCM (15 mL) (Flask B). In a glove box, a flame dried 500 mL flask was charged with diethylzinc (2.63 g, 21.3 mmol, 2.9 eq). The flask was sealed with a septum and taken out of the dry box. The flask was placed under a balloon of Ar and charged with anhydrous DCM (50 mL) (Flask C). Flask B was added via cannula to flask C over 15 min. The reaction was allowed to stir at rt for 20 min. A clear solution was obtained. Flask A was transferred to the reaction flask C via cannula over 10 min. The reaction was stirred for an additional 5 min resulting in a slightly hazy yellow solution. Diiodomethane (1.78 mL, 22.1 mmol, 3 eq) was added at rt over 1 min. The reaction was allowed to stir for 24 h. The reaction was quenched by the addition of a saturated aqueous NH_4Cl solution. The layers were separated and the aqueous layers were back extracted with DCM. The combined organic layers were washed with saturated aqueous NH_4Cl solution (1x), 5% $NaHCO_3$ (2x), 10% Na_2SO_3 (1x). The organic solvent was dried over Na_2SO_4, filtered, and evaporated to dryness to give a foamy solid. Purification by flash silica gel chromatography (hexanes/EtOAc 95:5 to 8:2) yielded 3.8 g of the desired material.

Step C

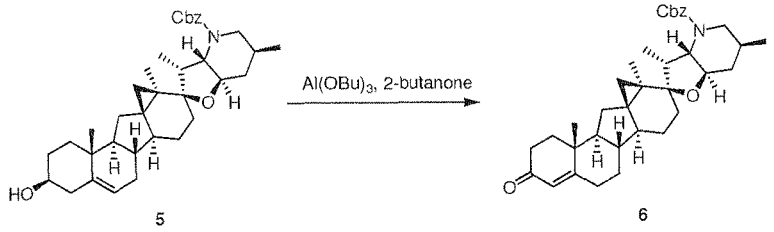


4 5

A round-bottom flask was charged with Bis-Cbz-protected cyclopropylcyclopamine (2 g, 2.88 mmol, 1 eq), MeOH (15 mL), and THF (5 mL) and vigorously stirred with 2N NaOH (2 mL) at 55°C for 3h. The THF and MeOH were removed under reduced pressure

and the residue was extracted with EtOAc (3X). The combined organic layers were washed with brine, dried over Na_2SO_4, filtered, and evaporated to dryness to give a foamy solid. Purification by flash silica gel chromatography (hexanes/EtOAc 9:1 to 8:2) to afford 1.1 g of the desired material.

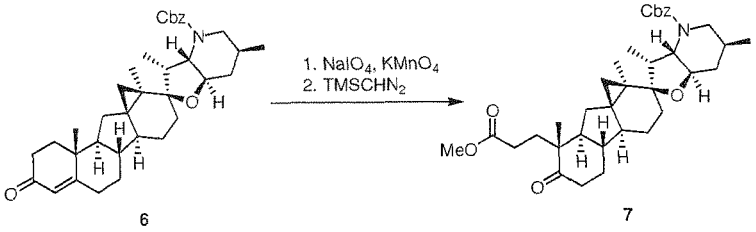
Step D



5 6

A round-bottom flask was charged with *N*-Cbz-cyclopropylcyclopamine (2.3 g, 4.1 mmol, 1 eq), $Al(OBu)_3$ (1.4 g, 5.76 mmol, 1.4 eq), toluene (30 mL), and 2-butanone (30 mL). The mixture was heated at 75 °C under Ar for 10h. The reaction was quenched by the addition of an aqueous 20% Rochelle's salt solution. The biphasic mixture was stirred at 40°C for 20 min. The layers were separated and the aqueous layer was extracted three times with EtOAc/toluene (1:1). The combined organic layers were washed with 20% Rochelle's salt, dried over Na_2SO_4, filtered, and concentrated to dryness by two successive azeotropic distillations with heptanes. The crude material was purified using silica gel flash chromatography (hexanes/EtOAc 4:1) to afford 859 mg of the desired product.

Step E

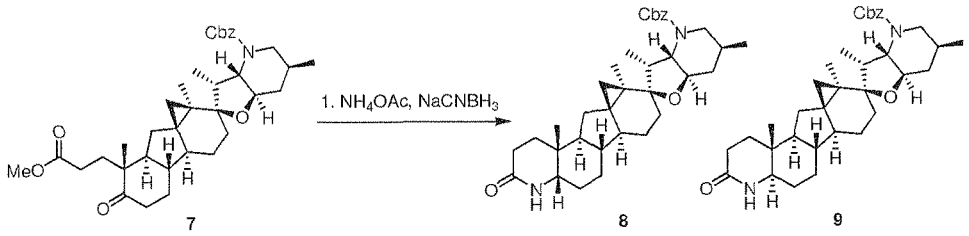


6 7

The enone derivative (350 mg, 0.63 mmol, 1 eq) was dissolved in *t*-BuOH (5 mL) then a solution of Na_2CO_3 (100 mg, 0.94 mmol, 1.5 eq) in water (5 mL) was added. The mixture was heated to 80°C and charged with a solution of $NaIO_4$ (0.94 g, 4.4 mmol, 7 eq) and $KMnO_4$ (7 mg, 0.043 mmol, 0.07 eq) in water (5 mL). After 60 min, the mixture was cooled to rt. The basic mixture was acidified with 2N HCl, and extracted with EtOAc (3X). The combined organic layers were washed with saturated aqueous NH_4Cl, dried over Na_2SO_4, filtered and concentrated to dryness. The material was chased a couple times with MTBE. The material (373 mg) was dissolved in toluene/MeOH (10 mL; 4:1, HPLC grade) and treated with of 2M $TMSCHN_2$ in hexanes (630 µL, 1.2 mmol, 2 eq). Bubbling was observed and the bright yellow color persisted. Nitrogen was bubbled through the solution

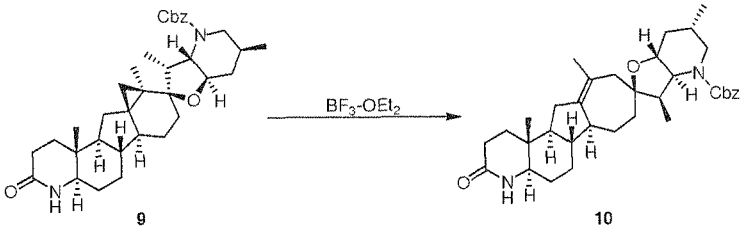
then the solution was concentrated to dryness. The crude material (366 mg) was purified using silica gel flash chromatography (hexanes/EtOAc 95:5 to 4:1) to afford the desired material as a white foam (245 mg).

Step F



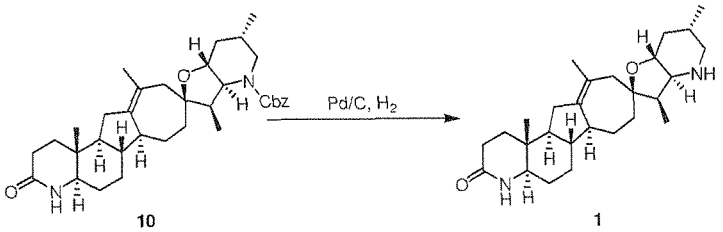
The compound **7** (237 mg, 0.4 mmol, 1 eq) was dissolved in MeOH (5 mL) and treated with NH_4OAc (1.2 g, 16 mmol, 40 eq) and sodium cyanoborohydride (251 mg, 4 mmol, 10 eq) at rt for 3h. Then, NH_4OAc (600 mg, 8 mmol, 20 eq) was added to the reaction mixture, which was warmed to 50°C and stirred for 4h. Saturated aqueous $NaHCO_3$ was added and MeOH was distilled under reduced pressure. The residue was extracted with EtOAc (3X). The combined organic layers were washed with 1N NaOH (1X), then saturated NH_4Cl (1X), then the layers clearly separated. The organic layer was dried over Na_2SO_4, filtered, and concentrated to dryness. The crude material (257 mg) was purified using flash silica gel flash chromatography (hexanes/EtOAc 1:9 to 100% EtOAc) to give 5β-reduced lactam (82 mg compound **8**) followed by 5α-reduced lactam (89 mg, compound **9**).

Step G



A cooled (-78°C) solution of compound **9** (82 mg, 0.15 mmol, 1 eq) in anhydrous DCM (3 mL) was treated with BF_3-OEt_2 (55 µL, 0.45 mmol, 3 eq). The mixture was stirred at -78°C for 15 min then warmed up to 0°C and stirred for 30 min. The reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The residue was extracted with DCM (3X). The combined DCM layers were washed with saturated aqueous $NaHCO_3$, water, dried over Na_2SO_4, filtered, and evaporated to dryness. The crude material (71 mg) was purified by silica gel flash chromatography (hexanes/EtOAc 1:9 to 100% EtOAc) to afford the desired 5α-reduced lactam product as solidifying oil (48 mg).

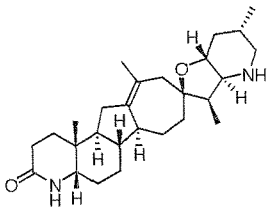
Step H



10 1

Compound **10** (42 mg, 0.075 mmol, 1 equiv.) was dissolved in EtOAc (3 mL) and treated with Pd/C 10% (8 mg , wet, Aldrich Degussa type E101 lot 08331KC). The flask was sealed and purged with hydrogen (3X) and stirred for 10 h under 1 atm of hydrogen. The mixture was filtered through a 0.2 micron AcrosDisc filter to give 46 mg of crude material. Purification by silica gel flash chromatography (DCM to DCM/MeOH 92:8) afforded 20 mg of pure material ([M+H] = 427.4 m/z).

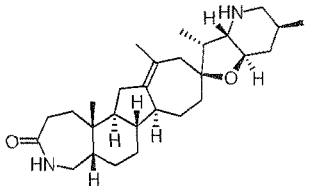
Example 2



11

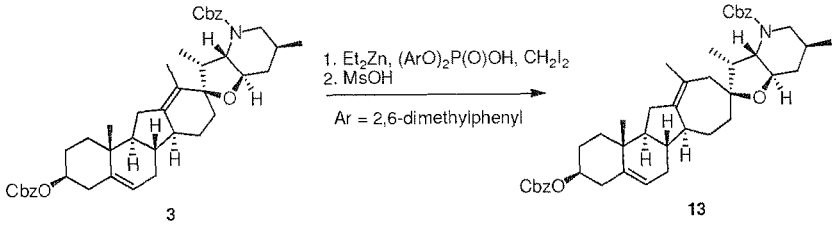
Compound 11 was synthesized according to the procedure described in example 1, using compound **8** in place of compound **9** in steps G and H.

Example 3



12

Step A

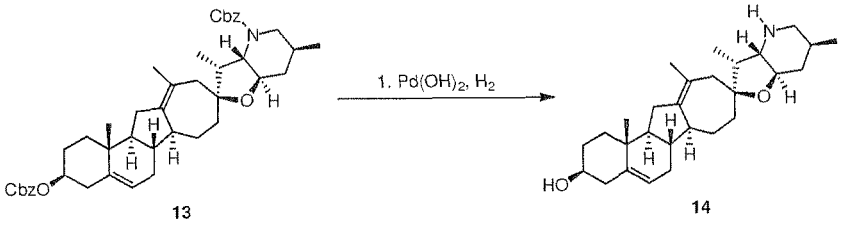


3 13

To a solution of diethyl zinc (572 mg, 482 µL, 4.63 mmol, 3 eq) in DCM (5.0 mL) at -20°C was added a solution of bis-(2,6-Dimethylphenyl)phosphoric acid (1.42 g, 4.63 mmol, 3 eq) in DCM (15 mL) while maintaining the reaction temperature below -8°C. The solution was aged for 15 min. at 0°C, neat diiodomethane (1.24 g, 374 µL, 3 eq) was added, and the

mixture was aged for 15 min. at 0°C before adding a solution of (Bis-CBz-cyclopamine, 1.05 g, 1.54 mmol, 1.0 eq), in DCM (10 mL). The cooling bath was replaced by a water bath at rt and maintained at rt for 4.5 h. The mixture was cooled to -76°C with a dry ice-acetone bath and treated drop wise with methanesulfonic acid DCM solution (0.6 mL 50% v/v solution 4.63 mmol, 3.0 eq) while maintaining the reaction temperature below -74°C. The mixture was aged for 15-20 min. and quenched drop wise with morpholine (2.69 g, 2.70 mL, 20 eq) maintaining the reaction temperature below -65°C. The cooling bath was removed, the reaction mixture was stirred for 16-18 h., the white precipitate was filtered off, and the filtrate was successively washed with 2.0 m HCl (2 x 20 mL), satd. sodium bicarbonate (2 x 20 mL), water (2 x 20 mL) and brine (20 mL). It was then dried over magnesium sulfate, concentrated *in vacuo* to dryness and the crude was purified by silica gel flash chromatography (hexanes/EtOAc 17:3→4:1) to afford 924 mg (1.33 mmol, 86%) of the desired product.

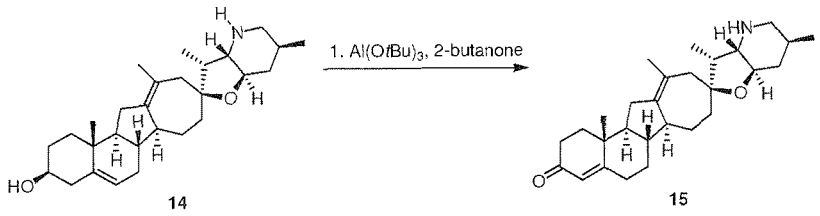
Step B



13 14

To a solution of compound **13** (4.05 g, 5.83 mmol, 1 eq) in a solution of EtOAc:toluene (2:1, 60 mL) was added 20% palladium hydroxide on carbon (823 mg, 0.583 mmol, 0.1 eq). The flask was evacuated and filled with hydrogen three times. The mixture was stirred under an atmosphere of hydrogen for 1h. Neat ethylene diamine (0.38 mL) was added, and the mixture was stirred for 1h., before the catalyst was filtered off. The filter cake was washed twice with EtOAc:toluene (2:1, 12 mL). The combined filtrates were washed with a 2% aqueous solution of ethylene diamine (3 X 20 mL), dried over sodium sulfate and concentrated *in vacuo* to give 2.46 g as a white crystalline solid.

Step C

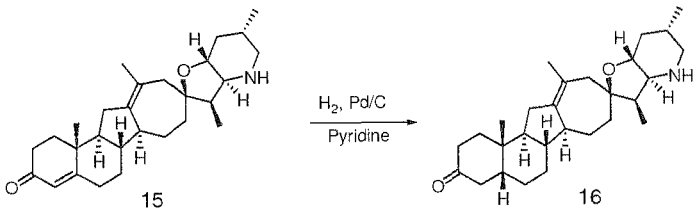


14 15

A round bottom flask was sequentially charged with the homo-allylic alcohol **14** (7.50 g, 17.6 mmol, 1 eq), aluminum *tert*-butoxide (6.10 g, 24.8 mmol, 1.4 eq), anhydrous

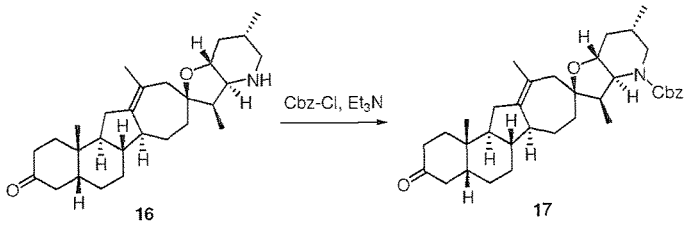
toluene (115 mL), and 2-butanone (90 g, 1.24 mol, 7 eq). The suspension was heated under a nitrogen atmosphere to 75°C for 16 h. The reaction temperature was then allowed to cool to 49°C. Aqueous 20% (w/w) potassium sodium tartrate solution (226 g) was added to the stirred suspension. The suspension was stirred at rt for 3.5 h. The layers were separated. The organic layer was washed with aqueous 20% Rochelle's salt (2 x 250 mL) and water (225 mL), then dried over sodium sulfate and filtered. The residue was rinsed with toluene (30 mL) and discarded. The combined organics were concentrated to dryness. Residual reaction solvents were removed from the material by concentrating from 2-propanol (250 mL added portion-wise) to a final solution mass of 44 g. Solvent exchange from 2-propanol to *n*-heptane (275 mL added portion-wise) to a final solution mass of 41 g fully precipitated the desired product. The suspension was diluted with additional *n*-heptane (40 mL), stirred at rt for 1 h, and filtered. The product was washed with *n*-heptane (17 mL) and dried to afford 5.4 g of the desired product.

Step D



A round-bottom flask was charged with starting material (110 mg, 0.26 mmol, 1 eq) and 10% palladium on carbon (106 mg). The solids were suspended in pyridine (4 mL). The suspension was placed under hydrogen atmosphere (1 atm) and the mixture was stirred overnight at rt. The reaction mixture was filtered through celite and the filtrate concentrated *in vacuo*. The crude material was purified using silica gel flash chromatography (MeOH/DCM 5:95) to afford 93 mg of the desired compound.

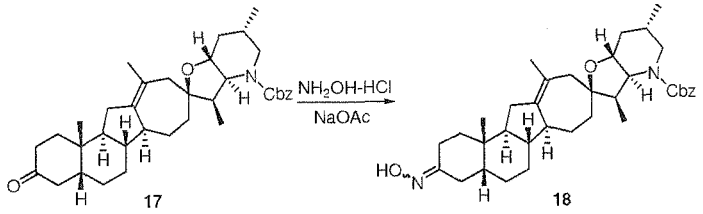
Step E



A round-bottom flask was charged with compound **16** (4.23 g, 9.94 mmol, 1 eq) and THF (60 mL). Triethylamine (6.92 mL, 49.7 mmol, 5.0 eq) and benzyl chloroformate (1.54 mL, 10.93 mmol, 1.1 eq) were added and the mixture was stirred for 1 h at rt. The reaction mixture was partitioned between saturated aqueous bicarbonate (100 mL) and

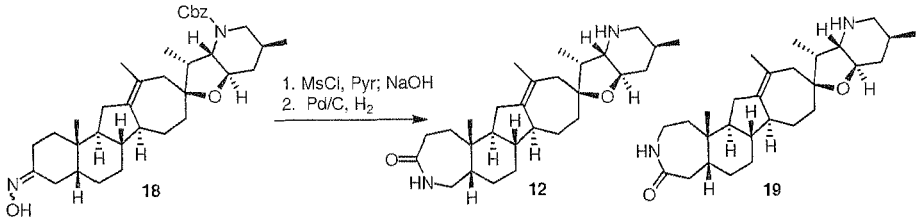
EtOAc (100 mL). The phases were separated and the organics were dried (Na_2SO_4) and concentrated to dryness. The crude material was purified using silica gel flash chromatography (EtOAc/Hexanes 2:98→14:86) to give 3.75g of material.

Step F



An ethanol solution (5 ml) of compound **17** (185 mg, 0.3 mmol, 1 eq) was treated with hydroxylamine hydrochloride (140 mg, 2 mmol, 6 eq), sodium acetate (160 mg, 2 mmol, 6 eq), and water (0.5 ml), and the mixture was stirred at rt for 1 hr. The mixture was split between EtOAc and water (50 ml each). The organic layer was washed with brine (30 ml), dried over sodium sulfate, and concentrated to a white residue. The crude product was purified by silica gel chromatography (ether/hexanes 2:3→1:1) to give 193 mg of oxime **18**.

Step G

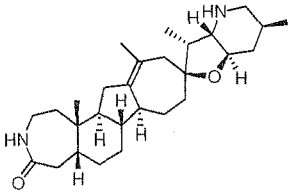


Compound **18** (50 mg, 0.087 mmol, 1.0 eq) was dissolved in dry pyridine (1.0 mL) and at 0°C treated with methanesulfonyl chloride (20.0 mg, 0.174 mmol, 2.0 eq). After stirring for 2 h, the solution was warmed to rt and treated with 5N sodium hydroxide (0.3 ml, 1.5 mmol, 18 eq) and stirred for 1 h. The mixture was split between EtOAc (30 mL) and 1M aqueous hydrogen chloride (15 mL). The organic layer was washed with water, washed with brine, dried over sodium sulfate, and concentrated to a clear oil. The mixture of lactams was purified by silica gel chromatography (80-100% ethyl acetate/hexanes, then 1% methanol in ethyl acetate) to afford a mixture of the lactam regioisomers as a clear oil (34 mg, 68% yield).

The product carbamate lactams were dissolved in EtOAc (7 ml) in a flask with stir bar and rubber septum. The solution was sparged with nitrogen, and 10% Pd/C (wet, Degussa type E101, Aldrich, 25 mg) was added. This mixture was sparged with nitrogen and then hydrogen gas and stirred at rt for 3 h. The mixture was then sparged with nitrogen,

filtered through a 0.45 μm polyethylene membrane and concentrated to a clear oil. The oil was purified by silica gel flash chromatography (0.5% ammonium hydroxide/2-20% MeOH/DCM), and the pure fractions were concentrated to give an oil that was lyophilized from 7 % water/*t*butanol, to afford a 1:1 mixture of unseparated lactams, as a white powder (19 mg: [M+H] = 441.6 m/z).

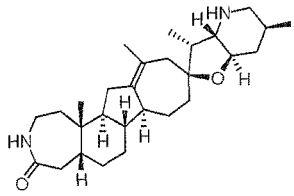
Example 4



19

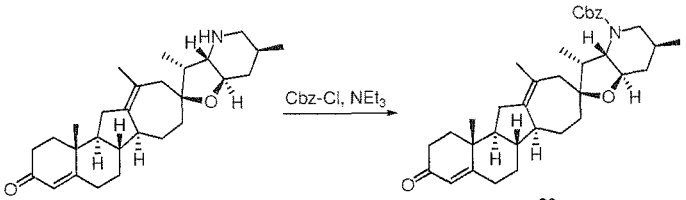
Compound **19** was made using procedures similar to those described in Example 3.

Example 5



19

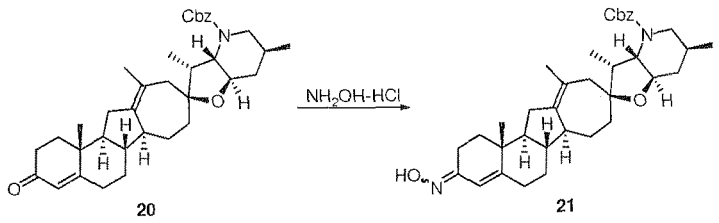
Step A



15 20

Compound **15** (2.0 g, 4.7 mmol, 1.0 eq) was dissolved in DCM (20.0 mL) and THF (20.0 mL) and at rt treated with triethylamine (3.3 ml, 23.6 mmol, 5.0 eq) and Cbz-Cl (0.73 ml, 5.2 mmol, 1.1 eq). 4-Dimethylaminopyridine (50 mg) was added, and the mixture was stirred for 60 min at rt. The mixture was split between EtOAc (200 mL) and 5% aqueous sodium bicarbonate (150 mL). The organic layer was washed with brine (50 mL), dried over sodium sulfate, and concentrated. Purification of the residue by silica gel flash chromatography (5 → 40% EtOAc/hexanes) afforded the desired carbamate as a white foam. (2.4 g).

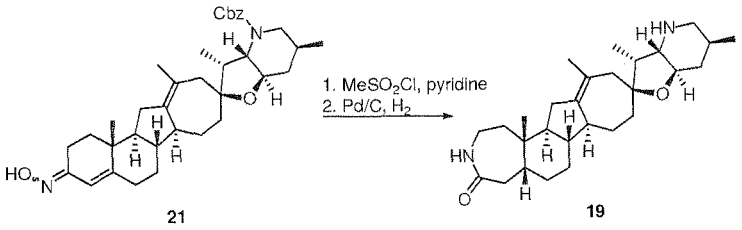
Step B



20 21

Compound **20** (200.0 mg, 0.36 mmol, 1.0 eq) was dissolved in EtOH (3.0 mL) and water (0.3 mL) and at rt treated with hydroxylamine hydrochloride (150 mg, 2.1 mmol, 6.0 eq) and sodium acetate (176 mg, 2.1 mmol, 6 eq). The mixture was heated at 70°C for 10 min. The mixture was split between EtOAc (30 mL) and water (15 mL). The organic layer was washed with brine (15 mL), dried over sodium sulfate, and concentrated to give the oxime **21** as a white foam. (202 mg).

Step C



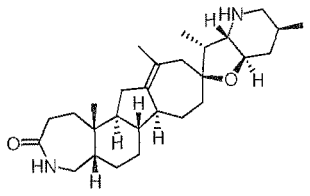
21 19

Compound **21** (200.0 mg, 0.34 mmol, 1.0 eq) was dissolved in dry pyridine (1.0 mL) and at 0°C treated with methanesulfonyl chloride (120.0 mg, 1.05 mmol, 3.0 eq). After stirring for 2 h, the solution was warmed to rt and treated with 5 N sodium hydroxide (0.75 ml, 4.25 mmol, 12 eq) and stirred for 12 h. The mixture was split between EtOAc (30 mL) and 1 m aqueous HCl (15 mL). The organic layer was washed with water and then brine (15 mL each), dried over sodium sulfate, and concentrated to give the oxime O-methanesulfonate as a clear oil. This oil was suspended in MeOH (5 mL), treated with concentrated aqueous HCl (0.75 mL), and heated at 60°C for 2 h. This dark brown mixture was concentrated *in vacuo* and purified by silica gel flash chromatography (50 → 100% EtOAc/hexanes followed by 1 → 5% MeOH in EtOAc) to give the unsaturated lactam as an isomerically pure white solid (45 mg).

The product carbamate lactam was dissolved in pyridine (7 mL) in a flask with stir bar and rubber septum. The solution was sparged with nitrogen, and 10% Pd/C (wet, Degussa type E101, Aldrich, 25 mg) was added. This mixture was sparged with nitrogen and then hydrogen gas and stirred at rt for 48 h. The mixture was then sparged with nitrogen, filtered through a 0.45 μm polyethylene membrane and concentrated to a clear oil. The oil was purified by silica gel chromatography (0.5% ammonium hydroxide/2 → 20%

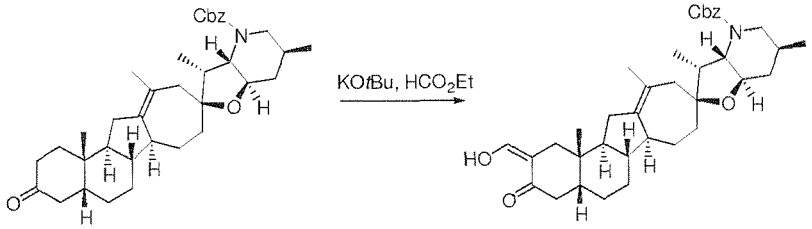
MeOH/DCM), and the pure fractions were concentrated to give an oil that was lyophilized from 7% water/*t*-butanol, affording the product as a white powder (14 mg: [M+H] = 441.7 m/z).

Example 6



12

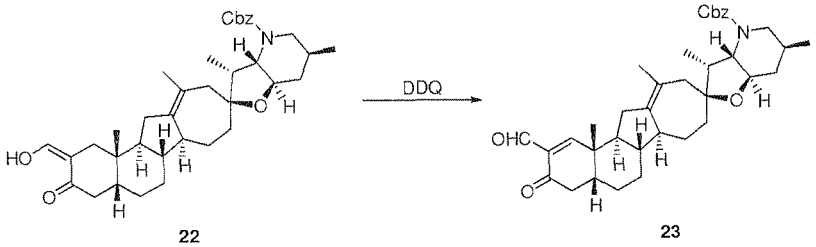
Step A



17 22

A dry round-bottom flask was charged with KO*t*Bu (0.57 g, 5.1 mmol, 7 eq) and *t*BuOH (6 mL) and the solution was stirred at rt for 10 min. Compound **17** (0.3 g, 0.73 mmol, 1 eq) was added and stirred for 5 min. The white suspension became a yellow clear solution. Ethyl formate (0.35 mL, 4.4 mmol, 6 eq) was added dropwise, and the solution became slightly opaque and produced bubbles. The slurry was stirred at rt for 48 h. The mixture was then portioned between MTBE/1% NaOH (2 x 20 mL). The aqueous layer was acidified with 2 N HCl until the pH reached 5, then extracted with chloroform (2X). The combined organic layers were washed with water, dried over Na_2SO_4, and concentrated to dryness to give 200 mg pale yellow foam. This material was used without further purification in the next step.

Step B

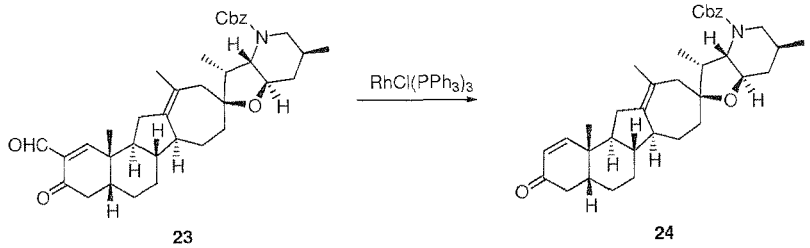


22 23

A round-bottom flask was charged with compound **22** (2.0 g, 3.40 mmol, 1 eq) and was dissolved in toluene (25 mL). The reaction was charged with DDQ (0.849 g, 3.74 mmol, 1.1 eq). The mixture was stirred for 0.5 hr at rt. The reaction mixture was then

concentrated *in vacuo* to 10% the original volume. The residue was purified using silica gel flash chromatography (EtOAc/hexanes 10% → 20%) to afford the desired material.

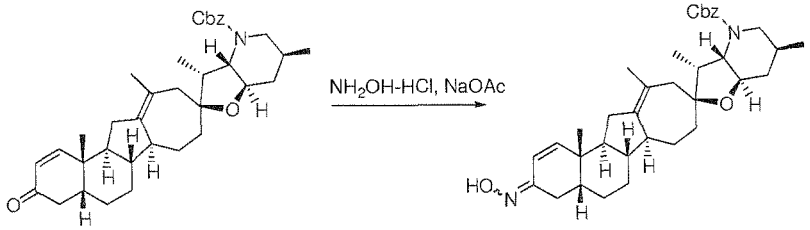
Step C



23 24

A round-bottom flask was charged with compound **23** (1.10 g, 1.88 mmol, 1 eq) and was dissolved in toluene (25 mL). The reaction was charged with Wilkinson's catalyst (1.77 g, 1.92 mmol, 1.02 eq). The mixture was heated to 80°C stirred for 0.5 h. The reaction mixture was cooled and concentrated *in vacuo* to 10% the original volume. The residue was purified using silica gel flash chromatography (EtOAc/hexanes 10% → 15%) to afford the desired material.

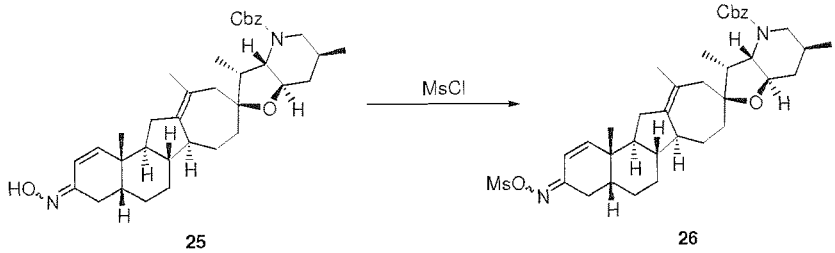
Step D



24 25

A round-bottom flask was charged with compound **24** (750 mg, 1.34 mmol, 1 eq) and was dissolved in EtOH (10 mL) and water (1 mL). The reaction was charged with hydroxylamine hydrochloride (662 mg, 8.07 mmol, 6.0 eq) and sodium acetate (561 mg, 8.07 mmol, 6 eq). The mixture was stirred for 0.5 h at rt. The reaction mixture was partitioned between water and EtOAc. The organic was separated, dried and concentrated to dryness. The residue was purified using silica gel flash chromatography (EtOAc/hexanes 10% → 25%) to afford the desired material.

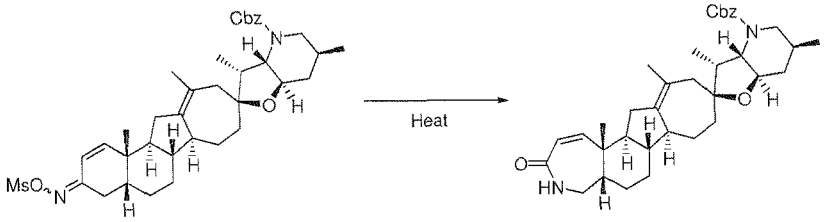
Step E



25 26

A round-bottom flask was charged with compound **25** (770 mg, 1.34 mmol, 1 eq) and was dissolved in pyridine (10 mL). The reaction was charged with methanesulfonylchloride (462 mg, 4.03 mmol, 3.0 eq). The mixture was stirred for 0.5 h at rt. The reaction mixture was partitioned between an aqueous solution of 1 N HCl and EtOAc. The organic was separated, dried and concentrated to dryness. The residue was purified using silica gel flash chromatography (EtOAc/hexanes 15% → 20%) to afford the desired material.

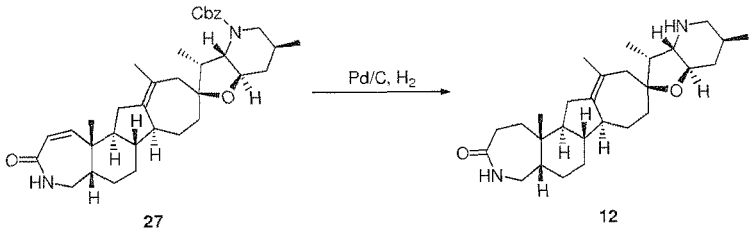
Step F



26 27

A round-bottom flask was charged with compound **26** (765 mg, 1.18 mmol, 1 eq) and was dissolved in MeOH (30 mL). The reaction was charged with concentrated HCl (300 mg, 3.54 mmol, 7.0 eq). The mixture was heated to 60°C and stirred for 17 h. The reaction mixture was partitioned between a saturated aqueous solution of sodium bicarbonate and EtOAc. The organic was separated, dried and concentrated to dryness. The residue was purified using silica gel flash chromatography (EtOAc/hexanes 50% → 90%) to afford the desired material.

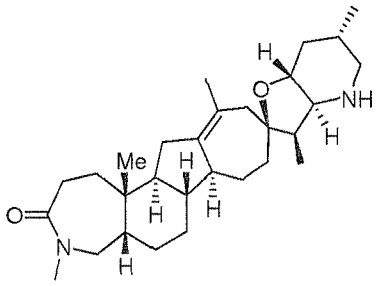
Step G



27 12

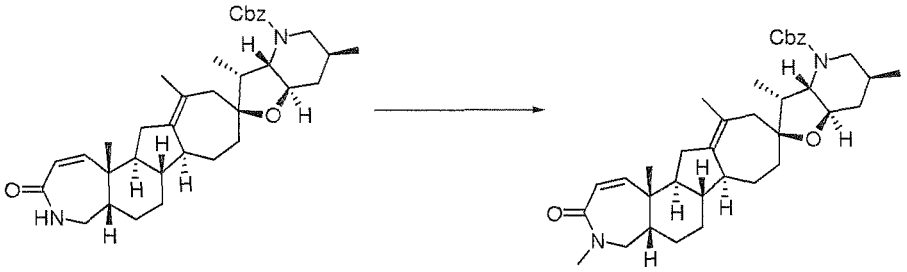
A round-bottom flask was charged with compound **27** (142 mg, 0.248 mmol, 1 eq) and 10% palladium on carbon (30 mg). The solids were suspended in EtOH (3 mL). The suspension was placed under hydrogen atmosphere and the mixture was stirred for 2 h at rt. The reaction mixture was filtered on celite and the filtrate concentrated to dryness. The residue was purified using silica gel flash chromatography (MeOH/DCM 0 % → 5 %) to afford the desired material. ([M+H] = 441.5 m/z).

Example 7



31

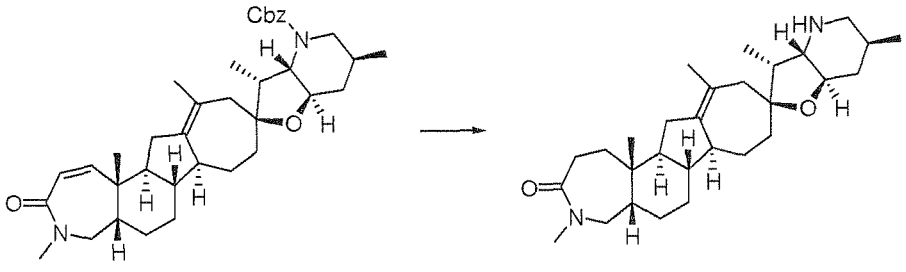
Step A



27 32

A round-bottom flask was charged with starting material (51 mg, 0.09 mmol, 1 eq). The solid was dissolved in 5 mL of tetrahydrofuran. The solution was cooled to -78°C. A 0.5M solution of potassium bis(trimethylsilyl)amide in toluene (0.207 mL, 0.104 mmol, 1.2 eq.) was charged and the solution was stirred for 0.5 hr at -78°C. The reaction was then charged with methyliodide (11 uL, 0.179 mmol, 2 eq.) and the reaction was warmed to 25°C. The reaction was stirred o/n then charged with water and ethyl acetate. The organic was separated, dried and concentrated to dryness. The residue was dissolved in DCM and was loaded onto a SiO_2. Elution with 50 to 90% EtOAc/hexanes gave Compound 32 ([M+H] = 587.8 m/z).

Step B

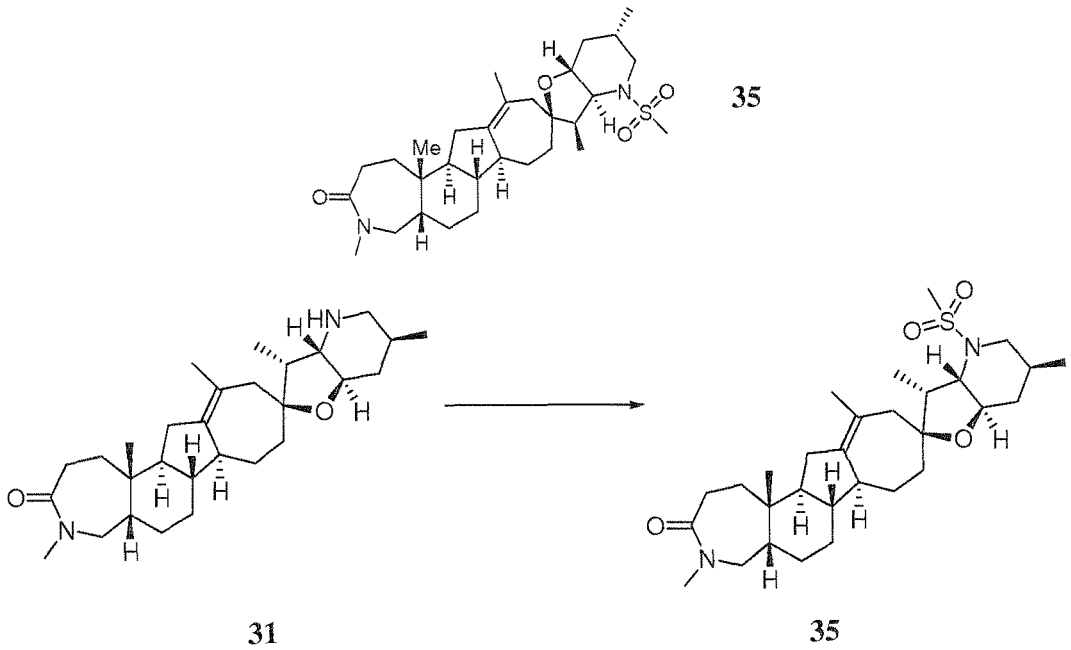


31

A round-bottom flask was charged with starting material (50 mg, 0.085 mmol, 1 eq) and 10% palladium on carbon (10 mg). The solids were suspended in 3 mL of ethanol. The

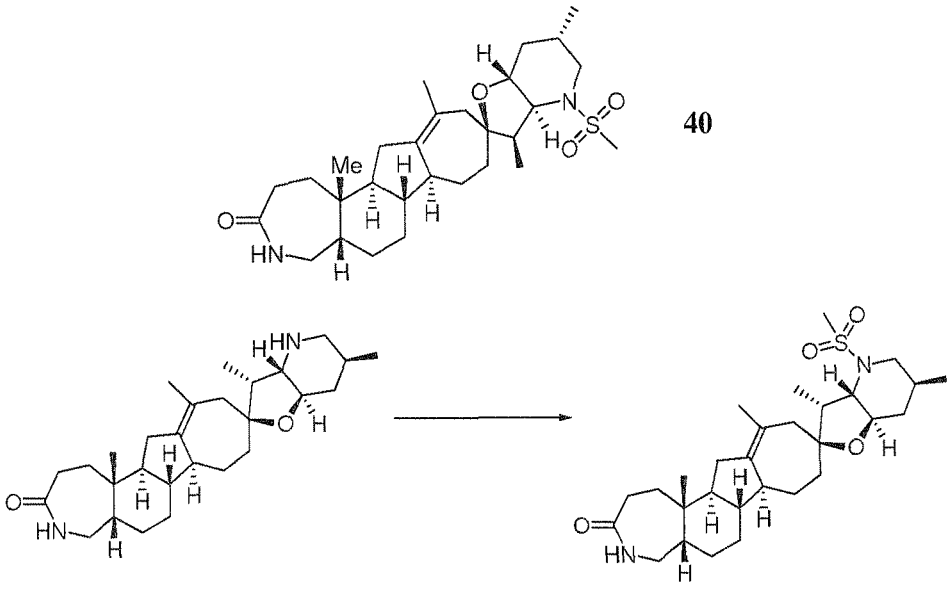
suspension was placed under hydrogen atmosphere and the mixture was stirred for 4 hrs at 25°C. LCMS show complete disappearance of starting material. The reaction mixture was filtered on celite and the filtrate concentrated to dryness. The residue was dissolved in DCM and was loaded onto a SiO_2. Elution with 0 to 8% MeOH/DCM gave the desired product Compound 31 ([M+H] = 455.5 m/z).

Example 8



A round-bottom flask was charged with Compound 31 (10 mg, 0.022 mmol, 1 eq) and dichloromethane (1 mL). The solution was charged with triethylamine (3.2 uL, 0.066 mmol, 3 eq.) and methane sulfonylchloride (14 uL, 0.088 mmol, 4 eq.) were charged and the solution was stirred for 0.5 hr. The reaction mixture was partitioned between a solution a saturated aqueous solution of sodium bicarbonate and ethyl acetate. The organic was separated, dried and concentrated to dryness. The residue was dissolved in DCM and was loaded onto a SiO_2. Elution with 75 to 90% EtOAc/hexanes gave the desired material Compound 35 ([M+H] = 533.8 m/z).

Example 9

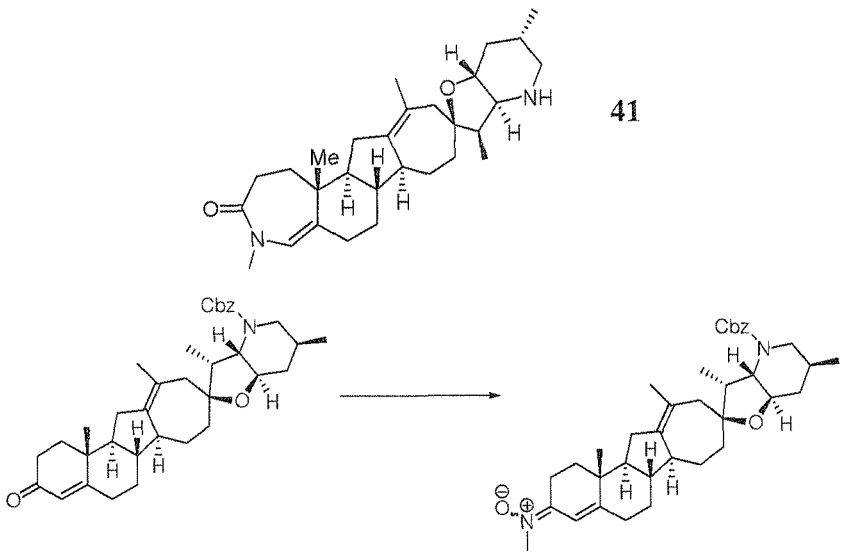


40

12 40

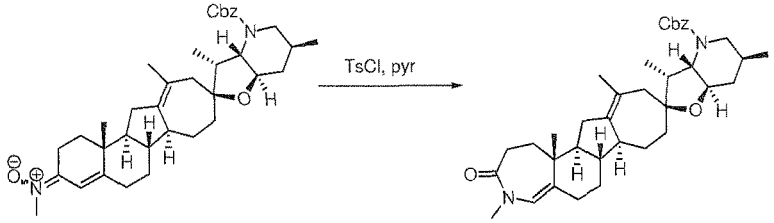
A round-bottom flask was charged with Compound 12 (16 mg, 0.036 mmol, 1 eq) and dichloromethane (1 mL). The solution was charged with triethylamine (8.0 uL, 0.109 mmol, 3 eq.) and methane sulfonylchloride (20 uL, 0.149 mmol, 4 eq.) were charged and the solution was stirred for 0.5 hr. The reaction mixture was partitioned between a solution a saturated aqueous solution of sodium bicarbonate and ethyl acetate. The organic was separated, dried and concentrated to dryness. The residue was dissolved in DCM and was loaded onto a SiO_2. Elution with 75 to 90% EtOAc/hexanes gave the desired material Compound 40 ([M+H] = 519.8 m/z).

Example 10

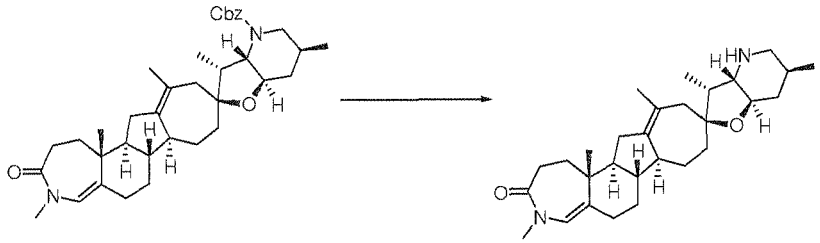


41

A round-bottom flask was charged with starting material (1.15 g, 2.06 mmol, 1 eq) and ethanol (15 mL). The solution was charged with sodium acetate (1.015g, 12.37 mmol, 6 eq.) and N-methylhydroxylamine HCl (0.189 g, 2.27 mmol, 1.1 eq.) were charged and the solution was heated to 70°C and stirred for 6 hrs. The reaction mixture was cooled to rt and concentrated. The residue was partitioned between water and ethyl acetate. The organic was separated, dried and concentrated to dryness. The residue was dissolved in DCM and was loaded onto a SiO_2. Elution with 0 to 10% MeOH/DCM gave the desired material ([M+H] = 587.9 m/z).

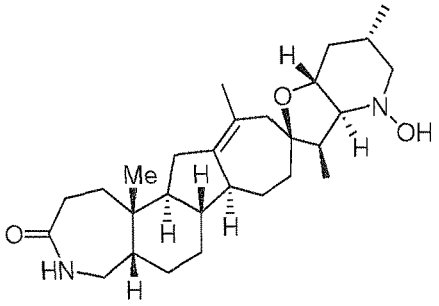


A round-bottom flask was charged with starting material (1.10 g, 1.875 mmol, 1 eq) and dissolved in pyridine (15 mL) and water (0.7mL). The solution was charged with tosyl chloride (0.430 g, 2.249 mmol, 1.2 eq.) was charged and the solution the solution was stirred at rt for 0.5 hr. The reaction mixture was cooled to rt and concentrated. The residue was partitioned between water and MTBE. The organic was separated, dried and concentrated to dryness. The residue was dissolved in DCM and was loaded onto a SiO_2. Elution with 10 to 80% EtOAc/Hex gave the desired material ([M+H] = 587.9 m/z).



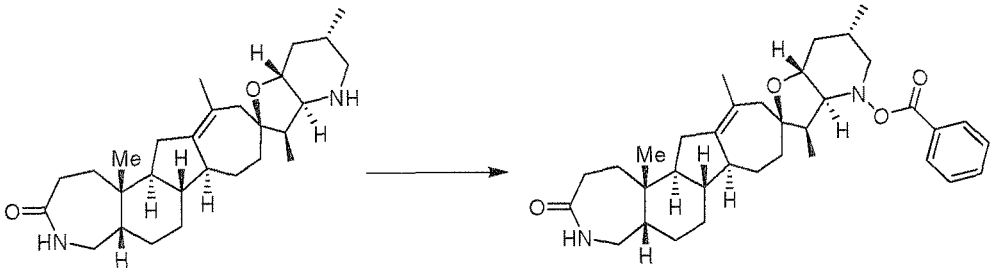
A round-bottom flask was charged with starting material (100 mg, 0.170 mmol, 1 eq) and 10% palladium on carbon (50 mg). The solids were suspended in 3 mL of ethyl acetate. The suspension was placed under hydrogen atmosphere and the mixture was stirred for 4 hrs at 25°C. The reaction mixture was filtered on celite and the filtrate concentrated to dryness. The residue was dissolved in DCM and was loaded onto a SiO_2. Elution with 0 to 10% MeOH/DCM gave the desired Compound 41 ([M+H] = 453.5 m/z).

Example 11



45

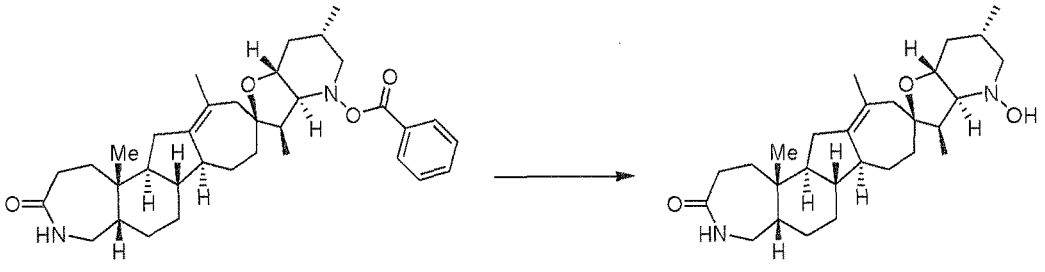
Step A



46 47

A dried flask was charged with **46** (355 mg, 0.806 mmol, 1 equiv.) and dry THF (5 mL) and pyridine (326 uL, 4.03 mmol, 5 equiv.). The cooled (0°C) solution was treated with benzoyl peroxide (585 mg, 2.42 mmol, 3 equiv.). The mixture was stirred for 1 h at 0°C , then the solution was gradually warmed to 25°C. After 2 h, the mixture was diluted with EtOAc and washed with aqueous saturated $NaHCO_3$ solution. The aqueous layer was extracted once more with EtOAc. The combined organic layer were dried over Na_2SO_4, filtered, and evaporated to dryness. The oil was dissolved in CH_2Cl_2 and purified by SiO_2 column eluting with hexane/EtOAc (40 to 100%) to give 238 mg of desired compound **47**.

Step B

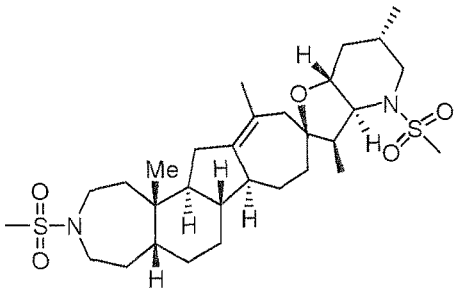


47 45

A round-bottom flask was charged with **47** (229 mg, 0.41 mmol, 1 equiv.) and MeOH (5 mL). The solution was treated at 25°C in presence of 2 N KOH (1 mL, 2 mmol, 5 equiv.). The mixture was stirred for 3h. The solvent was removed by nitrogen stream and

the solution was neutralized with 500 uL of 1N HCl. The aqueous layer was extracted with three portions of CH_2Cl_2. Combined organic layers were dried over Na_2SO_4, filtered, and concentrated to dryness. The crude material (220 mg) was dissolved with CH_2Cl_2, loaded onto a SiO_2 column (12 g) and eluted with CH_2Cl_2/MeOH (0% to 100%) to give the hydroxylamine **45**. The material recrystallized from heptane/2-propanol to give desired material **3** ([M+H] = 547.5 m/z).

Compound 50 was prepared using techniques similar to those described above.



50

Example 12

Inhibition of the Hedgehog Pathway in Cell Culture Using Analogs of Cyclopamine

Hedgehog pathway specific cancer cell killing effects may be ascertained using the following assay. C3H10T1/2 cells differentiate into osteoblasts when contacted with the sonic hedgehog peptide (Shh-N). Upon differentiation; these osteoblasts produce high levels of alkaline phosphatase (AP) which can be measured in an enzymatic assay (Nakamura, *et al.*, *BBRC* (1997) 237:465). Compounds that block the differentiation of C3H10T1/2 into osteoblasts (a Shh dependent event) can therefore be identified by a reduction in AP production (van der Horst, *et al.*, *Bone* (2003) 33:899). The assay details are described below. The results (EC_{50} for inhibition) of the differentiation assay are shown below in Table 1.

Assay Protocol

Cell Culture

Mouse embryonic mesoderm fibroblasts C3H10T1/2 cells (obtained from ATCC) were cultured in Basal MEM Media (Gibco/Invitrogen) supplemented with 10% heat inactivated FBS (Hyclone), 50 units/ml penicillin and 50ug/ml streptomycin (Gibco/Invitrogen) at 37°C with 5% CO_2 in air atmosphere.

Alkaline Phosphatase Assay

C3H10T1/2 cells were plated in 96 wells with a density of $8x10^3$ cells/well. Cells were grown to confluence (72 hrs). After sonic Hedgehog (250 ng/ml), and/or compound

treatment, the cells were lysed in 110 µL of lysis buffer (50 mM Tris pH 7.4, 0.1% Triton X 100), plates were sonicated and lysates spun through 0.2 µm PVDF plates (Corning). 40 µL of lysates was assayed for AP activity in alkaline buffer solution (Sigma) containing 1 mg/ml p-Nitrophenyl Phosphate. After incubating for 30 min at 37°C, the plates were read on an Envision plate reader at 405 nm. Total protein was quantified with a BCA protein assay kit from Pierce according to manufacturer's instructions. AP activity was normalized against total protein. Note that "A" indicates that the IC_{50} is less than 20 nM, "B" indicates that the IC_{50} is 20-100 nM, "C" indicates that the IC_{50} is > 100 nM.

Table 1 Approximate EC_{50} for Inhibition

Compound	Differentiation Assay EC_{50}
1	A
11	C
12	B
19	C
31	B
35	C
40	A
41	C
50	C

Example 13

Pancreatic Cancer Model

The activity of Compound 12 was further tested in a human pancreatic model: BXPC-3 cells were implanted subcutaneously into the flanks of the right legs of mice. On day 42 post-tumor implant, the mice were randomized into two groups to receive either Vehicle (30%HPBCD) or Compound 12. Compound 12 was administered orally at 30mg/kg/day. After receiving 25 daily doses, Compound 12 reduced tumor volume growth by 16% when compared to the vehicle control. At the end of the study, the tumors were harvested 4 hours post the last dose to evaluate an on target response by q-RT-PCR analysis of the HH pathway genes. Analysis of human Gli-1 resulted in no modulation. Analysis of murine Gli-1 mRNA levels resulted in a robust down-regulation in the Compound treated group, when compared to the Vehicle treated group. Inhibition of the hedgehog pathway in mouse cells, but not human tumor cells, indicates that one effect of the hedghog inhibitor is to affect a tumor-stroma interaction.

Example 14

Medulloblastoma Model

The activity of Compound 12 was also evaluated in a transgenic mouse model of medulloblastoma. Mice that are heterozygous for loss of function mutations in the tumor suppressors Patched1 (Ptch1) and Hypermethylated in Cancer (Hic1) develop spontaneous medulloblastoma. Similar to human medulloblastoma, these tumors demonstrate complete promoter hypermethylation of the remaining Hic1 allele, as well as loss of expression of the wild type Ptch1 allele. When passaged as subcutaneous allografts, these tumors grow aggressively and are Hedgehog pathway-dependent. This model was employed to evaluate the efficacy of orally administered Compound, and to correlate activity with drug exposure in plasma and tumors. Oral administration (PO) of a single dose of Compound 12 led to dose-dependent down-regulation of the HH pathway in subcutaneously implanted tumors, as measured by decreased Gli-1 mRNA expression 8 hours post dose administration.

Daily (QD) administration of the Compound PO led to a dose dependent inhibition of tumor growth, with frank tumor regression seen at higher doses. The approximate effective daily oral dose for 50% inhibition of tumor growth (ED50) is between 3 and 7.5mg/kg. This demonstrates that the hedgehog inhibitor Compound 12 inhibits both the hedgehog pathway and tumor growth in a tumor dependent on the hedgehog pathway due to a genetic mutation.

Example 15

Multiple Myeloma

The ability of Compound 12 to inhibit the growth of multiple myeloma cells (MM) in vitro was tested, using human multiple myeloma cells lines (NCI-H929 and KMS12) and primary clinical bone marrow specimens derived from patients with MM. The cells were treated for 96 hours with Compound, washed, then plated in methylcellulose. Tumor colonies were quantified 10-21 days later as an indicator of cell growth potential following treatment. Treatment of cell lines or primary patient specimens resulted in decreased cell growth compared to an untreated control. Where the untreated control showed 100% growth of cells, each of the treated cell lines, as well as the clinical samples, showed less than about 25% growth.

Example 16

Acute myeloid leukemia and myelodysplastic syndrome

The ability of Compound 12 to inhibit the in vitro growth of human cell lines derived from patients with acute myeloid leukemia (AML, cell line U937) and myelodysplastic syndrome (MDS, cell line KG1 and KG1a) was studied. Each of the cell lines was treated for 72 hours with Compound 12 (1.0 uM) followed by plating in methylcellulose. Growth of these cell lines was inhibited by Compound 12, as summarized in the table below.

Table 2 Inhibition of cell growth in AML and MDS

Disease	AML	MDS	
Cell line	U937	KG1	KG1a
% colony formation with Compound 12 (relative to vehicle control)	43.4	25.1	34.6

Example 17

Non-Hodgkin's lymphoma (NHL) and Hodgkin's disease (HD)

The ability of Compound 12 to inhibit the in vitro growth of human cell lines derived from patients with non-Hodgkin's lymphoma (cell lines RL and Jeko-1) and Hodgkin's disease (cell line L428) was studied. Each of the cell lines was treated for 72 hours with Compound 12 (1.0 uM) followed by plating in methylcellulose. Growth of these cell lines was inhibited by Compound 12, as summarized in the table below.

Table 3 Inhibition of cell growth in HD and NHL

Disease	HD	NHL	
Cell line	L428	RL	Jeko-1
% colony formation with Compound 12 (relative to vehicle control)	21.4	14.3	27.4

Example 18

Pre-B cell acute lymphocytic leukemia

The activity of Compound 12 (1 uM) against three pre-B cell acute lymphocytic leukemia cell lines (REH, RS4-11, and Nalm-6) was studied, using a transient transfection assay in which a Gli-reponsive luciferase reporter was transiently transfected into cells. Treatment with Compound 12 repressed luciferase activity compared to a vehicle treated control (Table 4). This demonstrates that Compound 12 is an effective antagonist of the hedgehog pathway.

Table 4 Repression of luciferase activity

Cell line	REH	RS4-11	Nalm-6
Relative luc activity (vehicle alone)	6.73	12.97	8.42
Relative luc activity (+ Compound)	1.12	1.31	1.44

The effect of Compound 12 on the growth of two of these cell lines, treated *in vitro* for 72 hours, was also studied. Following treatment, cells were washed and plated in methylcellulose. There was little inhibition of colony formation, but subsequent replating of colonies demonstrated a significant inhibition of cell growth (Table 5).

Table 5 Inhibition of cell growth in ALL

Cell line	REH	RS4-11
% colony formation with Compound (relative to vehicle control) – 1° plating	63	71
% colony formation with Compound (relative to vehicle control) – 2° plating	9	11

Incorporation by Reference

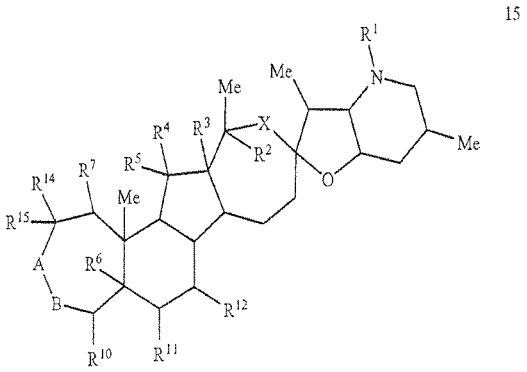
All of the U.S. patents and U.S. published patent applications cited herein are hereby incorporated by reference.

Equivalents

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

Claims

1. A compound of formula 15:



15

or a pharmaceutically acceptable salt thereof;

wherein;

each of A and B independently is —N(R^{13})—, —(C=O)—, or —(C=S)—;

R^1 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, hydroxyl, aralkyl, heteroaryl, heteroaralkyl, haloalkyl, alkoxyl, —SR^{20}, —OR^{20}, —N(R^{20})(R^{20}), —C(O)R^{20}, —CO_2R^{20}, —OC(O)R^{20}, —C(O)N(R^{20})(R^{20}), —N(R^{20})C(O)R^{20}, —N(R^{20})C(O)N(R^{20})(R^{20}), —S(O)R^{20}, —$S(O)_2R^{20}$, —$S(O)_2$N(R^{20})(R^{20}), —N(R^{20})$S(O)_2R^{20}$, —[(W)—C(O)]$_p R^{20}$, —[(W)—C(O)O]$_p R^{20}$, —[(W)—OC(O)]$_p R^{20}$, —[(W)—SO_2]$_p R^{20}$, —[(W)—N(R^{20})SO_2]$_p R_{20}$, —[(W)—C(O)N(R^{20})]$_p R^{20}$, —[(W)—O]$_p R^{20}$, —[(W)—N(R^{20})]$_p R^{20}$, or [(W)—S]$_p R^{20}$;

each of R^2, R^7 and R^{10} is independently H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, alkoxyl, aryloxy, acyloxy, halide, hydroxyl, amino, alkylamino, arylamino, acylamino, aralkylamino, alkylseleno, aralkylseleno, arylseleno, alkylthio, aralkylthio, arylthio, heteroaryl, or heteroaralkyl;

R^3 is H; or R^2 and R^3 taken together form a bond;

each of R^4 and R^5 independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, nitrile, aralkyl, alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio,

aralkylthio, hydroxyl, amino, alkylamino, arylamino, acylamino, aralkylamino, heteroaryl, or heteroaralkyl; or R^4 and R^5 taken together form =O, =S, =N(R^{20}), =N—OR^{20} or =N(N(R^{20})$_2$);

R^6 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, or aralkyl; or R^6 and R^{10} taken together form a bond;

each of R^{11}, R^{12}, R^{14} and R^{15} independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, or aralkyl; or R^{11} and R^{12} taken together form a bond; or R^7 and R^{14} taken together form a bond;

R^{13} is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, —C(O)R^{20}, —C(S)R^{20}, —CO_2R^{20}, —SO_2R^{20}, —C(O)N(R^{20})(R^{20}), or —C(S)N(R^{20})(R^{20}); or has the formula —[C(R^{20})$_2$]$_q$—R^{21};

R^{20} independently for each occurrence is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, or —[C(R)^2]$_q$—R^{21}, where each R is independently H or C1-C6 alkyl; or any two occurrences of R^{20} can be taken together to form a 4-8 membered optionally substituted ring which contains 0-3 heteroatoms selected from N, O, S, and P;

R^{21} independently for each occurrence is H, cycloalkyl, aryl, heteroaryl, heterocyclyl; alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, acylamino, amido, or carbonyl-containing group;

R^{22} independently for each occurrence is H, halide, ester, amide, or nitrile;

p is 0, 1, 2, 3, 4, 5, or 6;

q is 0, 1, 2, 3, 4, 5, or 6;

W is a diradical;

X is a bond or —C(R^{22})$_2$—;

and each alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, whether alone or part of another group, is optionally substituted;

provided that when A is —N(R^{13})—; B must be —(C=O)—, or —(C=S)—; and

provided that when A is —(C=O)—, or —(C=S)—; B must be —N(R^{13})—.

2. The compound of claim 1, wherein A is —N(R^{13})— and B is C=O.

3. The compound of claim 1, wherein R^{11} and R^{12} are each H.

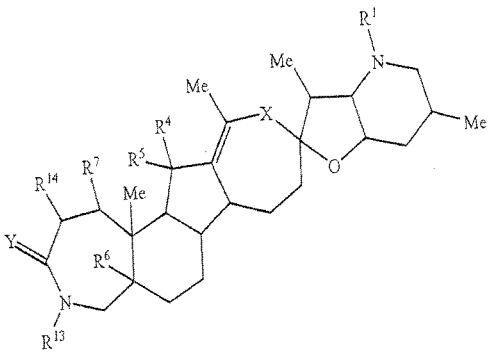
4. The compound of claim 1, wherein R^2 and R^3 taken together form a bond.

5. The compound of claim 1, wherein R^7 and R^{10} are each H.

6. The compound of claim 1, wherein B is —N(R^{13})— and A is C=O.

7. A compound of formula 21:

21



or a pharmaceutically acceptable salt thereof, wherein:

R^1 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, hydroxyl, aralkyl, heteroaryl, heteroaralkyl, haloalkyl, alkoxyl, —SR^{20}, —OR^{20}, —N(R^{20})(R^{20}), —C(O)R^{20}, —

CO_2R^{20}, —$OC(O)R^{20}$, —$C(O)N(R^{20})(R^{20})$, —$N(R^{20})C(O)R^{20}$, —$N(R^{20})C(O)N(R^{20})(R^{20})$, —$S(O)R^{20}$, —$S(O)_2R^{20}$, —$S(O)_2N(R^{20})(R^{20})$, —$N(R^{20})S(O)_2R^{20}$, —$[(W)—C(O)]_pR^{20}$, —$[(W)—C(O)O]_pR^{20}$, —$[(W)—OC(O)]_pR^{20}$, —$[(W)—SO_2]_pR^{20}$, —$[(W)—N(R^{20})SO_2]_pR^{20}$, —$[(W)—C(O)N(R^{20})]_pR^{20}$, —$[(W)—O]_pR^{20}$, —$[(W)—N(R^{20})]_pR^{20}$, or $[(W)—S]_pR^{20}$;

each of R^4 and R^5 independently is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, nitrile, aralkyl, alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, alkylamino, arylamino, acylamino, aralkylamino, heteroaryl, or heteroaralkyl; or R^4 and R^5 taken together form =O, =S, $=N(R^{20})$, $=N—OR^{20}$, or $=N(N(R^{20})_2)$;

R^6 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, or aralkyl;

R^7 is independently H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, alkylseleno, aralkylseleno, arylseleno, alkylthio, aralkylthio, arylthio, heteroaryl, heteroaralkyl, or nitrile;

R^{13} is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, —$C(O)R^{20}$, —$C(S)R^{20}$, —CO_2R^{20}, —SO_2R^{20}, —$C(O)N(R^{20})(R^{20})$, or —$C(S)N(R^{20})(R^{20})$; or has the formula —$[C(R^{20})_2]_q—R^{21}$;

R^{14} is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, or aralkyl; or R^7 and R^{14} taken together form a bond;

R^{20} independently for each occurrence is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, or —$[C(R^{20})_2]_q—R^{21}$; or any two occurrences of R^{20} can be taken together to form a 4-8 membered optionally substituted ring which contains 0-3 heteroatoms selected from N, O, S, and P;

R^{21} independently for each occurrence is H, cycloalkyl, aryl, heteroaryl, heterocyclyl; alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, acylamino, amido, or carbonyl-containing group;

R^{22} independently for each occurrence is H, halide, ester, amide, or nitrile;

p is 0, 1, 2, 3, 4, 5, or 6;

q is 0, 1, 2, 3, 4, 5, or 6;

W is a diradical;

X is a bond or $—C(R^{22})_2—$; and

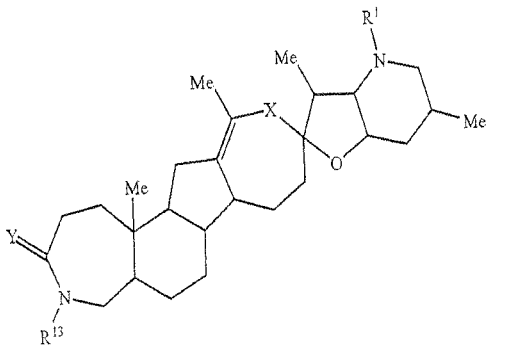
Y is O or S;

and each alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, whether alone or part of another group, is optionally substituted.

8. The compound of claim 7, wherein X is $—CH_2—$.

9. The compound of claim 7, wherein said compound has formula 23:

23



or a pharmaceutically acceptable salt thereof, wherein

R^1 is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, hydroxyl, aralkyl, heteroaryl, heteroaralkyl, haloalkyl, alkoxyl, $—SR^{20}$, $—OR^{20}$, $—N(R^{20})(R^{20})$, $—C(O)R^{20}$, $—CO_2R^{20}$, $—OC(O)R^{20}$, $—C(O)N(R^{20})(R^{20})$, $—N(R^{20})C(O)R^{20}$, $—N(R^{20})C(O)N(R^{20})(R^{20})$, $—S(O)R^{20}$, $—S(O)_2R^{20}$, $—S(O)_2N(R^{20})(R^{20})$, $—N(R^{20})S(O)_2R^{20}$, $—[(W)—C(O)]_pR^{20}$, $—[(W)—C(O)O]_pR^{20}$, $—[(W)—OC(O)]_p R^{20}$, —

$[(W)—SO_2]_pR^{20}$, $—[(W)—N(R^{20})SO_2]_pR^{20}$, $—[(W)—C(O)N(R^{20})]_pR^{20}$, $—[(W)—O]_pR^{20}$, $—[(W)—N(R^{20})]_pR^{20}$, or $—[(W)—S]_pR^{20}$;

R^{13} is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, $—C(O)R^{20}$, $—C(S)R^{20}$, $—CO_2R^{20}$, $—SO_2R^{20}$, $—C(O)N(R^{20})(R^{20})$, or $—C(S)N(R^{20})(R^{20})$; or has the formula $—[C(R^{20})_2]_q—R^{21}$;

R^{20} independently for each occurrence is H, alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, or $—[C(R^{20})_2]_q—R^{20}$; or any two occurrences of R^{20} can be taken together to form a 4-8 membered optionally substituted ring which contains 0-3 heteroatoms selected from N, O, S, and P;

R^{21} independently for each occurrence is H, cycloalkyl, aryl, heteroaryl, heterocyclyl; alkoxyl, aryloxy, acyloxy, halide, sulfhydryl, alkylthio, arylthio, aralkylthio, hydroxyl, amino, acylamino, amido, or carbonyl-containing group;

p is 0, 1, 2, 3, 4, 5, or 6;

q is 0, 1, 2, 3, 4, 5, or 6;

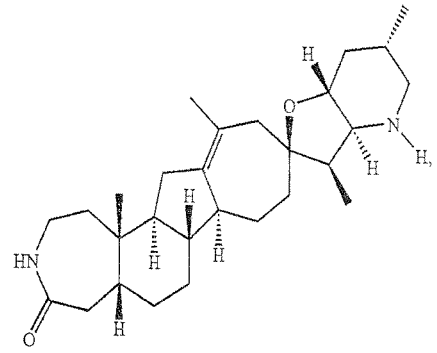
W is a diradical;

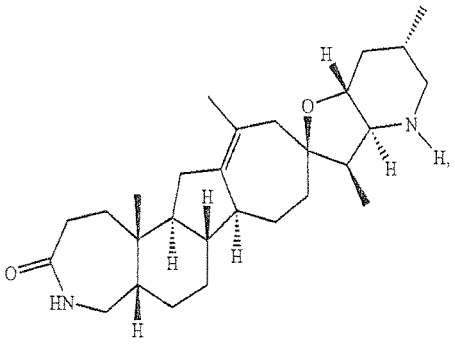
X is a bond or $—CH_2—$; and

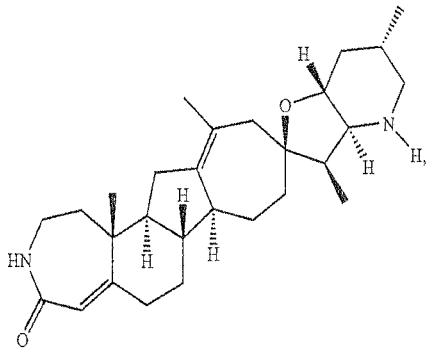
Y is O or S;

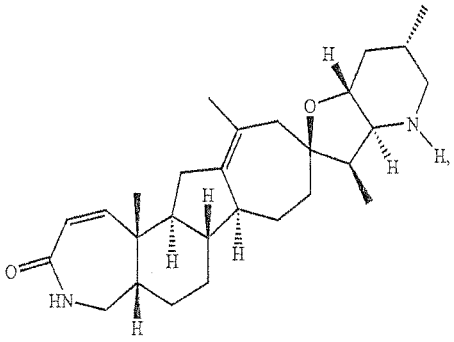
and each alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocycloalkyl, aralkyl, heteroaryl, heteroaralkyl, whether alone or part of another group, is optionally substituted.

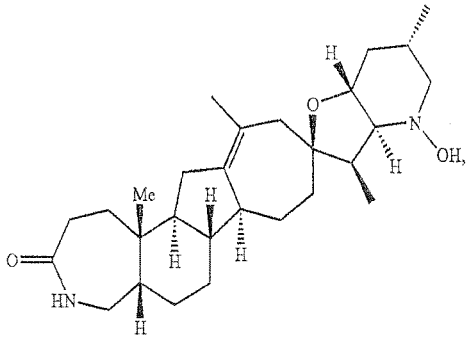
10. A compound selected from the group consisting of:

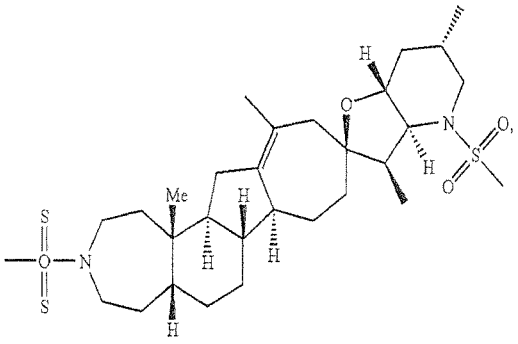


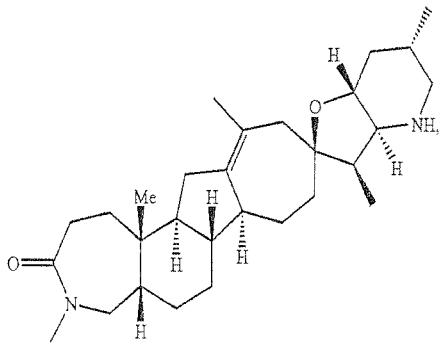


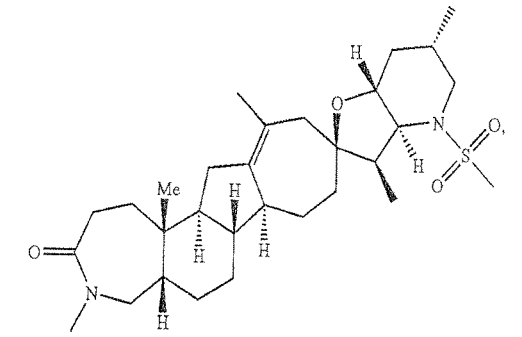


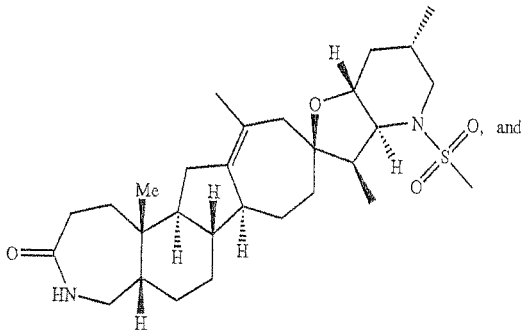




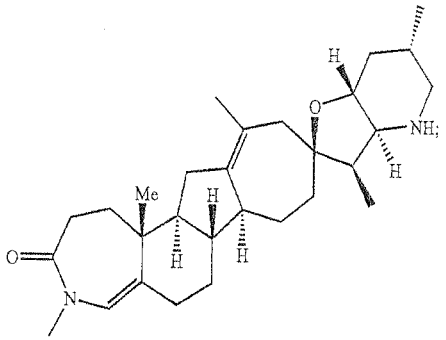








and



and the pharmaceutically acceptable salts thereof.

11. A pharmaceutical composition comprising Compound or salt as claimed in claim 1, and at least one pharmaceutically acceptable excipient.

12. Use of the compound or salt as claimed in claim 1 in an amount sufficient to reduce the activation of the hedgehog pathway in a cell of a patient in the manufacture of a medicament for inhibiting activation of a hedgehog pathway in a patient diagnosed with a hyperproliferative disorder.

13. The use of claim 12, wherein said hyperproliferative disorder is cancer.

14. Use of an effective amount of the compound or salt as claimed in claim 1 in the manufacture of a medicament for antagonizing the hedgehog pathway in a subject.

15. Use of a therapeutically effective amount of the compound or salt as claimed in claim 1 in the manufacture of a medicament for treating a hematological cancer, wherein the hematological cancer is selected from multiple myeloma, acute lymphocytic leukemia, acute myelocytic leukemia, chronic myelocytic leukemia, chronic lymphocytic leukemia, Hodgkin lymphoma, non-Hodgkin lymphoma, and myelodysplastic syndrome.

16. Use of a therapeutically effective amount of the compound or salt as claimed in claim 1 in the manufacture of a medicament for treating leukemia, wherein the leukemia is selected from acute lymphocytic leukemia, acute myelocytic leukemia, chronic myelocytic leukemia, and chronic lymphocytic leukemia.

17. Use of a therapeutically effective amount of the compound or salt as claimed in claim 1 in the manufacture of a medicament for treating cancer, wherein the cancer is selected from pancreatic cancer, medulloblastoma, multiple myeloma, myeloid leukemia, myelodysplastic syndrome, non-Hodgkins lymphoma, Hodgkin's disease, and acute lymphocytic leukemia.

18. Use of a therapeutically effective amount of the compound or salt as claimed in claim 1 in the manufacture of a medicament for treating pancreatic cancer.

19. Use of a therapeutically effective amount of the compound or salt as claimed in claim 1 in the manufacture of a medicament for treating chondrosarcoma.