

SMALL MOLECULE INHIBITION OF A PDZ-DOMAIN INTERACTION

BACKGROUND AND FIELD OF THE INVENTION

5 [0001] This invention relates to the inhibition of interactions of PDZ domains of a protein or proteins with other proteins, and more particularly to novel compounds that have been found to be effective in inhibiting PDZ domains. In a very specific aspect, this invention relates to the inhibition of a PDZ domain of proteins that regulate the function of the oncosuppressive protein PTEN, or of the PDZ domain of the Dishevelled protein (Dvl), and
10 compounds that have been found to possess such inhibiting capability. Compounds of the invention have been shown to produce apoptosis in cancer cells overexpressing Dvl.

[0002] PDZ domains are regions of signaling proteins that function to modulate protein-protein interactions such as protein-protein recognition. PDZ domains were named for three proteins in which this domain was initially discovered: PSD-95 (a 95 kDa protein involved in
15 the signaling at the post-synaptic density), DLG [Drosophila lethal(1)discs large-1], and ZO-1 (the zonula occludens-1 protein involved in maintenance of epithelial polarity). These proteins play important roles in neuronal synaptic transmission, tumor suppression, and cell junction formation, respectively. They are understood as functioning in vivo by organizing multiprotein complexes that function in signaling, e.g. communication between cells. For
20 example, PDZ-organized signaling complexes are known to function in communication involving neurons or epithelial cells, e.g., by coupling activated receptors to downstream second messenger systems, and in transporting and targeting proteins to sites of cellular signaling. They are involved in the functioning of important cell signal mediators including ion channels, transmembrane receptors, and regulatory enzymes. PDZ-containing proteins
25 are believed to be involved in disorders associated with defective cell signaling, including ischemic nerve damage and tumorigenesis.

[0003] Structurally, PDZ domains are 80-90 amino acid modular protein interaction domains that comprise six beta-strands (betaA to betaF) and two alpha-helices, A and B, compactly arranged in a globular structure. Peptide binding of the ligand takes place in an
30 elongated surface groove as an anti-parallel beta-strand interacts with the betaB strand and the B helix. The structure of PDZ domains allows binding to a free carboxylate group at the end of a peptide through a carboxylate-binding loop between the betaA and betaB strands.

[0004] Among proteins with PDZ domains are the MAGIs (membrane associated guanylate kinase proteins with inverse orientation). Proteins in this class participate in the assembly of multiprotein complexes on the inner surface of the plasma membrane at regions of cell-cell contact. The MAGIs are a small family of adaptors, widely expressed in the human body, that have six PDZ domains. MAGI-3 binds to the tumor suppressor PTEN, a lipid/protein phosphatase, using its second PDZ domain (MAGI3-PDZ2). The interaction of MAGI-3 and PTEN decreases phosphatidylinositol 3-kinase and Akt/PKB signaling whereas release of PTEN from MAGI-3 increases Akt/PKB signaling. Normally, Akt/PKB signaling ensures cell survival during response to cellular insults by suppressing apoptosis. However, PTEN mutants that cause constitutive Akt/PKB signaling have been associated with human cancers. Chemical disruption of this interaction would be a unique way to investigate the role Akt/PKB signaling in transformation and cancer, and could affect the development of cancerous growths.

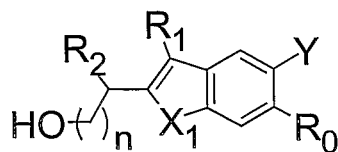
[0005] Also among proteins that have been found to possess a PDZ domain is the Dishevelled protein (Dvl). Its interactions with the Wnt and Frizzled proteins have been indicated as being involved in one or more types of cancers.

[0006] Small-molecule inhibitors of interactions of proteins having PDZ domains with other proteins would be desirable. Until recently, no small molecules having this capability were reported. In 2002 and 2003, we disclosed several compounds that had such a capability [Novak et al., Investigation of the PDZ Domain Ligand Binding Site Using Chemically Modified Peptides, *Bioorganic & Medicinal Chemistry Lett.* **2002** (2471); Fujii et al., Targeting PDZ-domain by Rationally Designed Non-peptide Small Molecules (poster) (American Society of Cell Biology, December 2002 meeting); Novak et al., Small molecule inhibition of a PDZ domain interaction (poster) (American Society of Biochemistry and Molecular Biology, April, 2003 meeting); Fujii et al., A selective irreversible inhibitor targeting a PDZ domain interaction protein, *JACS* **2003** 125:12074.

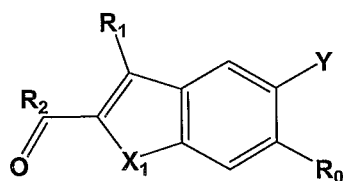
BRIEF SUMMARY OF THE INVENTION

[0007] This invention relates to novel compounds that have been found effective in inhibiting PDZ domain interactions, and particularly interactions of PDZ domains in MAGIs with the oncosuppressive (tumor suppressor) protein PTEN, and of a PDZ domain in the Dishevelled protein with Frizzled proteins, and to the inhibition of PDZ domain activity by the use of these compounds.

[0008] The novel compounds have the general formula

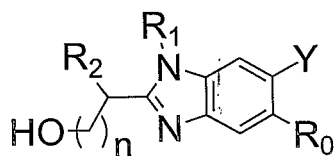


(I)



(II)

or



(III)

15 in which:

n is 0, 1 or 2;

X_1 is NH, N(CH₃), CH₂, CH(CH₃), C(CH₃)₂, O, S, S(O), or SO₂;

20 R_0 is selected from the group consisting of C₁-C₃ alkyl, cyclopropyl, halo, OR₅ and S(O) _{m} R₅ in which m is 0, 1 or 2;

R_1 and R_2 are independently selected from the group consisting of C₂-C₈ alkenyl, phenylcyclopropyl, phenylpropenyl, R₆-X₂-C(R₈)(R₈)-R₇-, R₆-X₂-N(R₈)-R₇-, and R₁₀X₃R₇-;

R_3 and R_4 are independently hydrogen, methyl or ethyl;

R₅ is methyl or ethyl;

R₆ is selected from the group consisting of hydrogen, C₁-C₁₀ alkyl, aryl, W, Y, NH₂, NHCONR₃R₄, NHCOOR₃ and NHSO₂R₉;

R₇ is selected from the group consisting of a direct bond, an alkyl group having
5 from 1 to 10 carbon atoms, aryl, -(NH)_p(CH₂CH₂O)_q(NH)_p- in which *p* is 0 or 1 and *q* is an integer from 1 to 4, and W;

R₈ is selected from the group consisting of H, Y, OH, -NHCONR₃R₄; -NHCOOR₃; -NHSO₂R₉, -(CH₂)_rCO₂R₃, and (CH₂)_rCONR₃R₄ in which *r* is an integer from 1 to 3;

R₉ is aryl or C₁-C₆ alkyl;

10 R₁₀ is selected from C₁-C₁₀ alkyl, aryl and W;

X₂ is selected from the group consisting of a direct bond, -NH-, -N(CH₃)-,
-NCONR₃R₄, -NCOOR₃, and -NSO₂R₉;

X₃ is selected from O, S, SO and SO₂;

W is a saturated carbocyclic or heterocyclic group;

15 Y is selected from the group consisting of COOH, COOR₃, CONR₃R₄, CONHSO₂R₅, hydroxymethyl, -CH₂COOH, CH₂CONR₃R₄, and 5-tetrazolyl;

and hydrates and salts thereof, and labeled derivatives thereof.

[0009] Preferred embodiments of compounds of Formula (I) include those in which X₁ is NH or S, those in which R₁ and R₂ are independently alkyl, optionally substituted by a
20 phenyl, cycloalkyl, carboxyl or hydroxyl group, those in which R₁ is a cycloalkyl group, and those in which R₁ is a phenyl group. In one embodiment, R₂ is an unsubstituted alkyl group having from 1 to 20, preferably from 1 to 10, and more preferably from 1 to 8, and most preferably from 3 to 8, carbon atoms and R₁ is an alkyl group with the same possibilities, optionally substituted by a phenyl, cycloalkyl, carboxyl or hydroxyl group. In other
25 embodiments, R₁ is phenyl or phenethyl and R₂ is an alkyl group, optionally substituted by a phenyl, cycloalkyl, carboxyl or hydroxyl group. In yet other embodiments, R₂ is a cycloalkyl group.

[0010] This invention also includes processes and intermediates for the preparation of these compounds. This invention also includes libraries of such compounds and methods for

preparing such libraries. The invention also includes labeled versions of the compounds and chemical probes prepared by linking the novel compounds to various labeling moieties.

5 [0011] In another aspect, this invention includes methods for inhibiting the interaction of a PDZ domain of a protein with other proteins, more particularly the interaction of a MAGI protein or of the Dishevelled protein (Dvl) with other proteins, by contacting the protein that contains the PDZ domain, or the PDZ domain, with an inhibitory effective amount of a compound as defined herein. In yet another aspect this invention relates to methods of studying protein interactions and/or PDZ domain functioning that involves contacting the protein or the domain with a compound or compounds as described herein. The invention
10 also includes arrays of such compounds for studying protein interactions or for screening proteins for PDZ domain activity.

[0012] In a more specific aspect of this, the invention comprises inhibiting interactions of PDZ domains in MAGIs with the oncogenic (tumor suppressor) protein PTEN or of inhibiting interactions between the PDZ domain in the Dishevelled protein and other proteins,
15 for example the Frizzled (Fz) protein, by contacting the MAGI protein, the Dishevelled protein, or a PDZ domain of such protein with an effective inhibitory amount of a compound as described herein.

[0013] In another embodiment this invention also provides therapeutic methods of treating cancer comprising contacting the cancer or cancerous cells with an effective PDZ domain -
20 inhibiting amount of a compound of the invention. In these embodiments, the cancer cell typically is in a patient and the step of contacting is carried out by administering a therapeutic agent, namely one or more compounds of the invention, or a composition containing the same, to the patient. The method may further comprise administering to the patient a second therapeutic agent, such as a chemotherapeutic agent or radiation therapy. The cancer cell
25 may be a breast cancer cell, colorectal cancer cell, a lung cancer cell, a sarcoma cell, or a mesothelioma cell, a prostate cancer cell, a pancreatic cancer cell, a cervical cancer cell, an ovary cancer cell, a gastric cancer cell, an esophageal cancer cell, a head and neck cancer cell, a hepatocellular carcinoma cell, a melanoma cell, a glioma cell, a squamous cancer cell, or a glioblastoma cell.

30 [0014] United States patent application 10/678,639 filed October 3, 2003, titled "Methods for Treating Cancer by Inhibiting WNT Signaling", of He et al., is hereby incorporated herein in its entirety. That application discloses inhibiting the growth of cancer cells that

overexpress a Wnt protein by contacting the cell with an agent that inhibits binding of the Wnt protein to a Frizzled receptor. PCT application WO 02/088081 discloses that overexpression of Wnt appears connected to the occurrence of head and neck squamous cancer. Wong et al, *J. Mol. Cell* 12:1251 (November, 2003) disclosed that binding of the Dvl protein to Fz occurs at the PDZ domain of Fz. Inhibition of the PDZ-domain/Dvl interaction can thus inhibit Wnt signaling and consequently inhibit the growth of cancer cells

[0015] The term "Frizzled protein" (Fz or Frz) refers to a family of mammalian proteins related to the *Drosophila frizzled* genes, which play a role in the development of tissue polarity. The Frizzled family comprises at least 10 mammalian genes. Exemplary human Frizzled receptors include Frizzled1, Frizzled2, Frizzled3, Frizzled4, Frizzled5, Frizzled6, Frizzled7, Frizzled8, Frizzled9 and Frizzled10. Frizzled protein receptors are involved in a dynamic model of transmembrane signal transduction analogous to G-protein-coupled receptors with amino-terminal ligand binding domains.

[0016] The term "Dishevelled" or "Dvl" refers to a member of a family of Dishevelled proteins, the full-length sequences of which typically possess three conserved domains, a DIX domain, present in the Wnt antagonizing protein Axin; a PDZ domain involved in protein-protein interactions, and a DEP domain found in proteins that regulate Rho GTPases. Dvl proteins include, for example, Dvl-1, Dvl-2, and Dvl-3. Nucleic acid and protein Dvl sequence are known from a variety of species, including mouse and human. Exemplary human Dvl-1, Dvl-2, and Dvl-3 protein sequences are available under reference sequences NP_004412, NP_004413, and NM_004414, respectively.

[0017] "Inhibitors of Wnt signaling" refers to compounds that, e.g., bind to Dishevelled proteins so as to interfere with Dishevelled/Frizzled interaction, and consequently partially or totally block Wnt signaling, as measured for example, in known assays for Wnt signaling (e.g., measurement of β -catenin levels, or oncogene expression controlled by Tcf and Lef transcription factors).

[0018] A "cancer cell that overexpresses a Wnt protein" is a cancer cell in which expression of a particular Wnt protein is at least about 2 times, usually at least about 5 times the level of expression in a normal cell from the same tissue. Methods for determining the level of expression of a particular gene are well known in the art. Such methods include RT-PCR, use of antibodies against the gene products, and the like.

[0019] In still another aspect this invention involves screening proteins for PDZ domain activity by contacting the proteins with a compound or compounds of the invention.

[0020] Studying the functioning of proteins having a PDZ domain or screening proteins for PDZ domain activity may involve the use of a single compound of the invention, or a

5 number, including a large number of compounds of the invention. The latter may be carried out with a number of tests using individual proteins, or with arrays or libraries of such compounds. The compounds may be in the above-shown form or preferably also include a labeling moiety. Additionally, the compounds may be conjugated or bonded to a solid support, for example a plate or a particulate material, and such combinations of solid support
10 and compounds are another aspect of this invention.

[0021] By "inhibitors" is meant compounds that, *e.g.*, bind to, partially or totally block stimulation, decrease, prevent, or delay activation, or inactivate, desensitize, or down-regulate signal transduction. Similarly, the term "inhibition" means a partial or total blocking, stimulation, decrease, prevention or delaying of activation, or inactivation, desensitizing or
15 down-regulation of signal transduction. An "effective inhibitory amount" of a compound or composition is an amount that produces inhibition in a particular assay or in a patient.

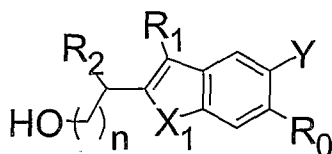
BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Figure 1 depicts binding of a compound of the invention to GST-fused MAGI3 PDZ2 domain protein GMP32.

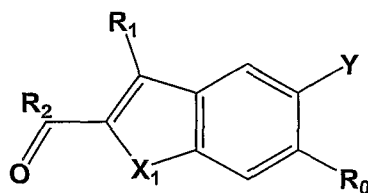
DETAILED DESCRIPTION OF THE INVENTION

[0023] This invention relates to novel compounds that have been found effective in inhibiting PDZ domain interactions, particularly interactions of a PDZ domain in MAGIs with the oncosuppressive (tumor suppressor) protein PTEN and interactions of a PDZ domain in the Dishevelled protein with a Frizzled protein or receptor, and to the inhibition of PDZ
25 domain activity by the use of these compounds. The invention also relates to antitumor effects produced by such compounds, and to the use of such compounds in treating cancer.

[0024] The novel compounds have the general formulas:

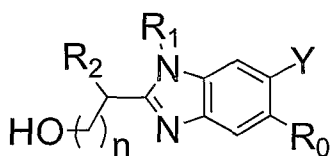


(I)



(II)

or



(III)

in which:

 n is 0, 1 or 2; X_1 is NH, N(CH₃), CH₂, CH(CH₃), C(CH₃)₂, O, S, S(O), or SO₂;

R_0 is selected from the group consisting of C₁-C₃ alkyl, cyclopropyl, halo, OR₅ and S(O) _{m} R₅ in which m is 0, 1 or 2;

R_1 and R_2 are independently selected from the group consisting of C₂-C₈ alkenyl, phenylcyclopropyl, phenylpropenyl, R₆-X₂-C(R₈)(R₈)-R₇-, R₆-X₂-N(R₈)-R₇-, and R₁₀X₃R₇-;

R_3 and R_4 are independently hydrogen, methyl or ethyl;

R_5 is methyl or ethyl;

R_6 is selected from the group consisting of hydrogen, C₁-C₁₀ alkyl, aryl, W, Y, NH₂, NHCONR₃R₄, NHCOOR₃ and NHSO₂R₉;

R_7 is selected from the group consisting of a direct bond, an alkyl group having from 1 to 10 carbon atoms, aryl, $-(NH)_p(CH_2CH_2O)_q(NH)_p-$ in which p is 0 or 1 and q is an integer from 1 to 4, and W;

R_8 is selected from the group consisting of H, Y, OH, $-NHCONR_3R_4$; $-NHCOOR_3$;
5 $-NHOSO_2R_9$, $-(CH_2)_rCO_2R_3$, and $(CH_2)_rCONR_3R_4$ in which r is an integer from 1 to 3;

R_9 is aryl or C_1 - C_6 alkyl;

R_{10} is selected from C_1 - C_{10} alkyl, aryl and W;

X_2 is selected from the group consisting of a direct bond, $-NH-$, $-N(CH_3)-$,
 $-NCONR_3R_4$, $-NCOOR_3$, and $-NSO_2R_9$;

10 X_3 is selected from O, S, SO and SO_2 ;

W is a saturated carbocyclic or heterocyclic group;

Y is selected from the group consisting of COOH, $COOR_3$, $CONR_3R_4$,
 $CONHSO_2R_5$, hydroxymethyl, $-CH_2COOH$, $CH_2CONR_3R_4$, and 5-tetrazolyl;

and hydrates and salts thereof, and labeled derivatives thereof.

15 **[0025]** Preferred embodiments of compounds of Formula (I) include those in which X_1 is NH or S, those in which R_1 and R_2 are independently alkyl, optionally substituted by a phenyl, cycloalkyl, carboxyl or hydroxyl group, and those in which R_1 is a phenyl group. In one embodiment, R_2 is an unsubstituted alkyl group having from 1 to 20, preferably from 1 to 10, and more preferably from 1 to 8, and most preferably from 3 to 8, carbon atoms and R_1 is
20 an alkyl group with the same possibilities, optionally substituted by a phenyl, cycloalkyl, carboxyl or hydroxyl group.

[0026] Some preferred embodiments for R_1 and R_2 include C_3 - C_8 alkyl; C_3 - C_6 cycloalkyl; C_1 - C_3 alkyl substituted by a C_3 - C_6 cycloalkyl group, C_3 - C_8 alkenyl; $-(CH_2)_mC_6H_5$ where m is 0 or an integer from 1-3; $-CH_2OC_6H_5$, $CH_2COC_6H_5$, phenyl(C_2 - C_4 alkenyl), or analogous
25 moieties having substituted phenyl groups; optionally substituted phenylcyclopropyl; $-(CH_2)_sOH$, $-(CH_2)_sCONH_2$ and $-(CH_2)_sCOOH$ where s is an integer from 1 to 3; phenyl; thienyl; and optionally substituted C_3 - C_6 cycloalkyl- $(C_1$ - C_3 alkyl). Particularly preferred embodiments are phenyl, phenethyl, phenylpropyl, hydroxyethyl, hydroxypropyl, and various propyl, butyl and pentyl groups. In one preferred embodiment R_1 is $-(CH_2)_mC_6H_5$ where m is

0 or an integer from 1-3, more preferably phenyl or phenethyl, and R₂ is an alkyl group having from 1-8, preferably 3-8, carbon atoms, optionally substituted by a phenyl, cycloalkyl, carboxyl or hydroxyl group. In another embodiment, R₁ is an alkyl group having from 1-8, preferably from 3-8 carbon atoms, optionally substituted by a phenyl, cycloalkyl, carboxyl or hydroxyl group, and R₂ is an alkyl group having from 1-8, preferably from 3-8, carbon atoms.

[0027] The term "alkyl" as used herein means a straight or branched chain, or non-aromatic cyclical, hydrocarbon radical, or combination thereof, that is fully saturated and has the number of carbon atoms designated (i.e. C₁-C₁₀ means one to ten carbon atoms). Examples of acyclic alkyl groups include, but are not limited to, groups such as methyl, ethyl, n-propyl, isopropyl, n-butyl, t-butyl, isobutyl, sec-butyl, homologs and isomers of, for example, n-pentyl, n-hexyl, n-heptyl, n-octyl, and the like. Examples of cyclical alkyl groups include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, and the like. The term "lower alkyl" means a group of the type mentioned, having up to ten, preferably up to six, carbon atoms. For use in the invention, alkyl groups generally may be of any desirable size. Preferably they will contain up to 20, more preferably, up to 10, and most preferably up to 8, carbon atoms. Cycloalkyl groups contain from 3 to 8 carbon atoms.

[0028] The term "alkenyl" as used herein means a straight or branched chain, or non-aromatic cyclical, hydrocarbon radical, or combination thereof, that contains one or more olefinic bonds and has the number of carbon atoms designated (i.e. C₁-C₁₀ means one to ten carbon atoms). Examples of acyclic alkenyl groups include, but are not limited to, groups such as vinyl, allyl, propenyl, butenyl, crotyl, butadienyl, and the like. Examples of cyclical alkenyl groups include cyclopentenyl, cyclohexenyl, cyclohexadienyl, and the like. For use in the invention, alkenyl groups generally may be of any desirable size. Preferably they will contain up to 20, more preferably, up to 10, and most preferably up to 8, carbon atoms.

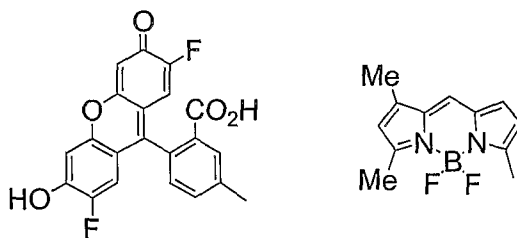
[0029] The alkyl and alkenyl groups used in this invention may be unsubstituted or may be mono- or polysubstituted, as indicated above.

[0030] Substituted alkyl, alkenyl, or cycloalkyl groups also include arylalkyl groups, namely alkyl (including cycloalkyl) groups substituted by one or more aryl groups; for instance, benzyl, phenethyl, 1-phenylpropyl, triphenylmethyl, phenylpropenyl, cyclohexylmethyl, cyclopropylmethyl, and the like. They also may include cycloalkyl groups having an aryl group as a substituent such as phenylcyclopropyl. The aromatic ring or rings in the arylalkyl groups may be further substituted similarly to other aliphatic groups, e.g.

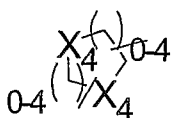
chlorobenzyl, methylbenzyl, etc. Substituted alkyl groups also include alkyl groups substituted by one or more saturated or unsaturated heterocyclic groups, i.e. the substituted alkyl groups are pyridylmethyl, pyridylethyl, piperidinylmethyl, pyrrolidinylmethyl, morpholinylmethyl, quinolylmethyl, etc. Such groups may be substituted by one or more
 5 halogens, hydroxyl groups, lower alkyl groups, or lower alkoxy groups (including combinations of such groups).

[0031] As used herein, "aryl" refers to the typical substituted or unsubstituted non-aliphatic hydrocarbyl groups of this class, i.e., a polyunsaturated, typically aromatic, hydrocarbon substituent, which can be a single ring or multiple rings (up to three rings) which are fused
 10 together or linked covalently, such as phenyl, naphthyl, and the like. This class of moieties also includes fused-ring moieties such as indanyl, etc. Substituents for the aromatic moieties are similar to those for the aliphatic groups. "Aryl", as used herein, also includes analogous heterocyclic groups (sometimes termed "heteroaromatic" groups), namely polyunsaturated cyclical moieties containing carbon atoms in the ring and additionally one or more hetero
 15 atoms, which are typically oxygen, nitrogen, sulfur and or phosphorus, such as pyridinyl, pyrazinyl, pyrazolyl, thienyl, furyl, thiazolyl, imidazolyl, pyrrolyl, etc., and fused-ring moieties such as benzoxazolyl, benzthiazolyl, etc. These may be optionally substituted with one or more substituents such as halogen, hydroxy, amino, optionally substituted lower alkyl, optionally substituted lower alkoxy, NCONR₃R₄ and NCOOR₃, and other substituents
 20 included above within the definition of group R₆.

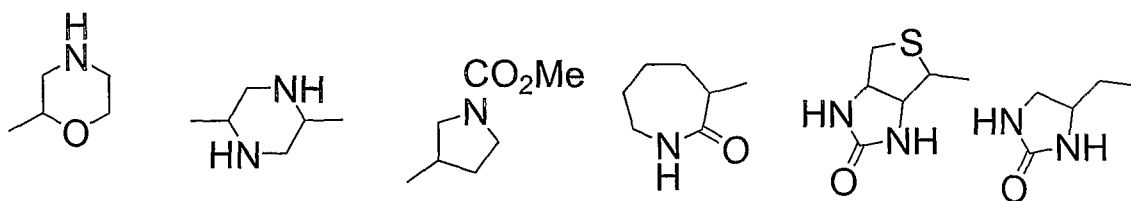
[0032] Aryl compounds also include fluorescent aromatic moieties such as



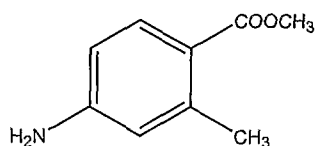
[0033] Carbocyclic or heterocyclic moieties for W generally have the formula



25 wherein X₄ is a direct bond, NH, N(CH₃), CH₂, CH(CH₃), C(CH₃)₂, O, S, S(O), SO₂, C(O), NCONR₃R₄ or NCO₂R₈, where R₃, R₄ and R₈ are as defined above, and are, for example:



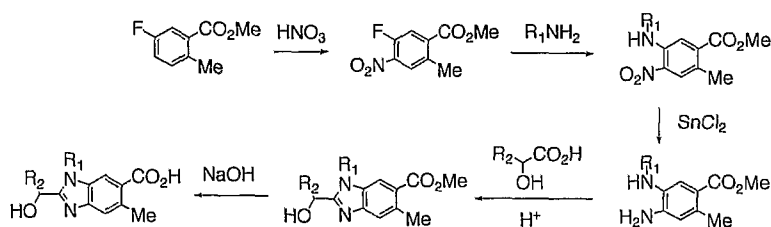
[0034] In general, compounds of Formula (I) may be synthesized from a starting aminobenzene, for instance



or analogous compounds with various moieties as indicated above for groups Y and R₀, followed by iodination of the 5-position and reaction with a compound such as R₁CH≡TMS or R₁CH≡TES (where TMS and TES stand for a trimethylsilyl and triethylsilyl group, respectively) to form a substituted indole, and alkylation or the like to add the group -CHR₂(CH₂)_nOH. An illustration of such a method is shown in the "Examples" section below.

[0035] Derivatives can be made by appropriate substitution of groups of the compounds made as just described.

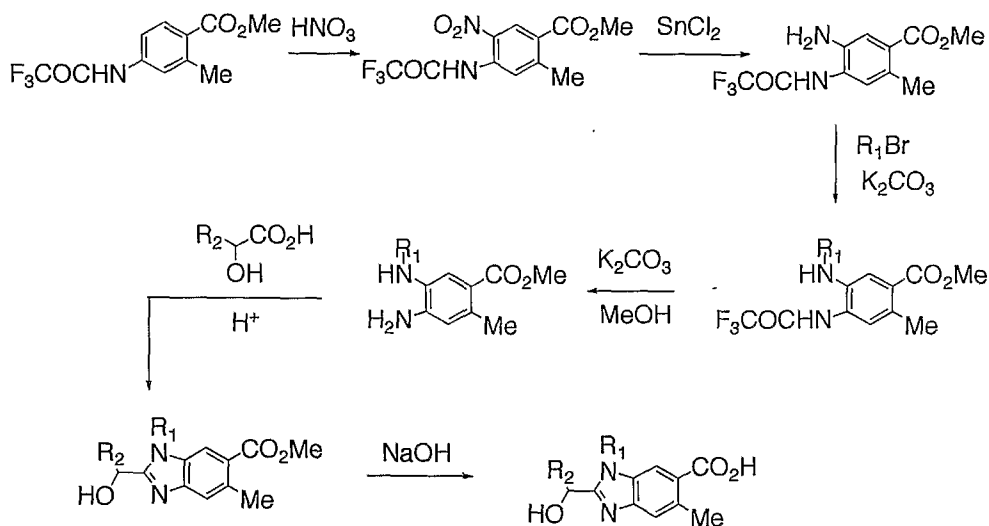
[0036] Compounds of Formula (III) can generally be synthesized as follows. 3-Fluoro-4-nitro-6-methylbenzoate ester is treated with primary amines followed by tin(2) chloride to afford 3-alkylamino-4-amino-6-methylbenzoic acid esters. This compounds are reacted with 2-hydroxycarboxylic acids under acidic conditions followed by alkaline hydrolysis (Scheme A):



scheme A

[0037] Compounds of Formula (III) can also be synthesized as follows. A trifluoroacetylated compound of the aniline shown in paragraph [0034] above is nitrated

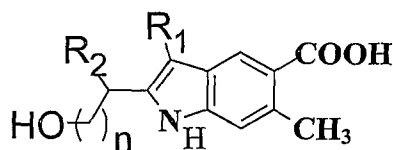
followed by tin(2) chloride treatment, giving a mono-trifluoroacetylated diaminobenzene. Alkylation and deprotection of the trifluoroacetyl group affords a monoalkylated diaminobenzene, which then can be converted to the compounds of Formula (III) as shown in Scheme A. This process is shown in Scheme B below.



scheme B

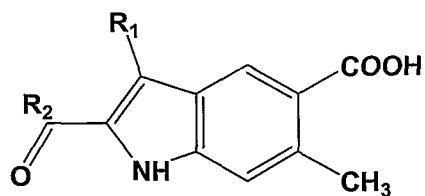
[0038] The following Tables IA and IB show representative compounds of Formulas (I) and (II) of the invention that were made either individually or as libraries by a process as shown above.

Table 1A (Formula I)



Cmpd. No.	R ₁	R ₂	n
1	C ₂ H ₄ C ₆ H ₅ (phenethyl)	<i>n</i> -C ₄ H ₉	0
2	C ₂ H ₄ C ₆ H ₅	<i>i</i> -C ₄ H ₉	0
3	C ₂ H ₄ C ₆ H ₅	<i>s</i> -C ₄ H ₉	0

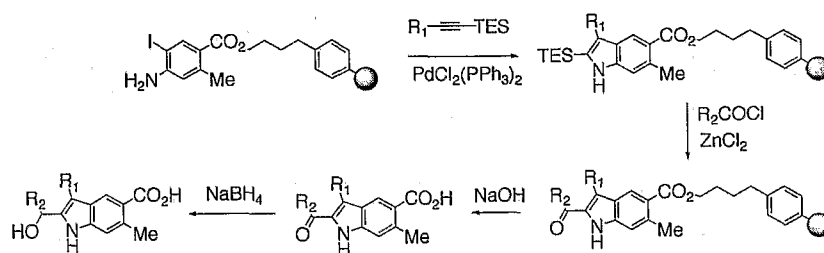
4	$C_2H_4C_6H_5$	cyclopentylmethyl	0
5	$C_2H_4C_6H_5$	cyclohexyl	0
6	$C_2H_4C_6H_5$	$HOOC(CH_2)_3-$	0
7	$C_2H_4C_6H_5$	C_6H_5	0
8	$C_2H_4C_6H_5$	$C_6H_5CH_2-$	0
9	$C_2H_4C_6H_5$	$C_6H_5C_2H_4-$	0
10	$n-C_5H_{11}$	$n-C_4H_9$	0
11	$i-C_4H_9$	$n-C_4H_9$	0
12	cyclohexyl	$n-C_4H_9$	0
13	C_6H_5	$n-C_4H_9$	0
14	$C_6H_5CH_2$	$n-C_4H_9$	0
15	$C_6H_5(CH_2)_3$	$n-C_4H_9$	0
16	$-(CH_2)_3OH$	$n-C_4H_9$	0
17	$(CH_2)_3COOH$	$n-C_4H_9$	0
18	C_6H_5	<i>i</i> -butyl	0
19	C_6H_5	<i>s</i> - C_4H_9	0
20	C_6H_5	<i>i</i> - C_3H_7	0
21	C_6H_5	cyclopentylmethyl	0
22	C_6H_5	cyclohexyl	0
23	C_6H_5	2,2- dimethylpropyl	0
24	C_6H_5	$C_6H_5C_2H_4$	0
25	C_6H_5	$C_6H_5(CH_3)_3$	0

Table 1B (Formula II)

Cmpd. No.	R ₁	R ₂
26	C ₂ H ₄ C ₆ H ₅ (phenethyl)	<i>n</i> -C ₄ H ₉
27	C ₂ H ₄ C ₆ H ₅	<i>i</i> -C ₄ H ₉
28	C ₂ H ₄ C ₆ H ₅	<i>s</i> -C ₄ H ₉
29	C ₂ H ₄ C ₆ H ₅	cyclopentyl- methyl
30	C ₂ H ₄ C ₆ H ₅	cyclohexyl
31	C ₂ H ₄ C ₆ H ₅	HOOC(CH ₂) ₃ -
32	C ₂ H ₄ C ₆ H ₅	C ₆ H ₅
33	C ₂ H ₄ C ₆ H ₅	C ₆ H ₅ CH ₂
34	C ₆ H ₅ C ₂ H ₄	C ₂ H ₄ C ₆ H ₅
35	<i>n</i> -C ₅ H ₁₁	<i>n</i> -C ₄ H ₉
36	<i>i</i> -C ₄ H ₉	<i>n</i> -C ₄ H ₉
37	cyclohexyl	<i>n</i> -C ₄ H ₉
38	C ₆ H ₅	<i>n</i> -C ₄ H ₉
39	C ₆ H ₅ CH ₂	<i>n</i> -C ₄ H ₉
40	C ₆ H ₅ (CH ₂) ₃	<i>n</i> -C ₄ H ₉
41	-(CH ₂) ₃ OH	<i>n</i> -C ₄ H ₉
42	(CH ₂) ₃ COOH	<i>n</i> -C ₄ H ₉
43	C ₆ H ₅	<i>i</i> -C ₄ H ₉
44	C ₆ H ₅	<i>s</i> -C ₄ H ₉
45	C ₆ H ₅	<i>i</i> -C ₃ H ₇
46	C ₆ H ₅	cyclopentyl- methyl

47	C ₆ H ₅	cyclohexyl
48	C ₆ H ₅	2,2-dimethyl-propyl
49	C ₆ H ₅	C ₆ H ₅ C ₂ H ₄
50	C ₆ H ₅	C ₆ H ₅ (CH ₂) ₃

[0039] A procedure that may be used to prepare libraries of the compounds of Formulas (I) and (II) is shown below (scheme C).



scheme C

This process includes the production of compounds of Formula (II) as penultimate compounds in the synthesis of Formula (I) compounds. However, as will be seen from the test data that follow, Formula (II) compounds are not merely intermediates but many demonstrate activity, as well.

Formulation and administration.

[0040] Compounds of the invention that inhibit interactions between the PDZ domain of a protein and other proteins can be administered to a patient or subject at doses effective to provide the desired inhibition, or at therapeutically effective doses to prevent, treat, or control conditions, for example to act as neuroprotecting drugs and anti-tumor agents. Compositions containing the substances are administered to a patient or subject in an amount sufficient to elicit an effective therapeutic response in the patient. An amount adequate to accomplish this is defined as an "effective inhibitory amount," a "therapeutically effective dose" or a "therapeutically effective amount". The dose or amount will be determined by the efficacy of the particular active substance employed and the condition of the subject. The size of the dose also will be determined by the existence, nature, and extent of any adverse effects that accompany the administration of a particular compound in a particular subject. Typically, the patient or subject is human. However, the patient or subject may be a non-human mammal

(e.g., a primate, a mouse, a pig, a cow, a cat, a goat, a rabbit, a rat, a guinea pig, a hamster, a horse, a sheep, a dog, a cat and the like), and may be male or female.

[0041] Toxicity and therapeutic efficacy of the compounds can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, for example, by

5 determining the LD₅₀ (the dose lethal to 50% of the population) and the ED₅₀ (the dose therapeutically effective in 50% of the population). The dose ratio between toxic and therapeutic effects is the therapeutic index and can be expressed as the ratio, LD₅₀/ED₅₀. Compounds that exhibit large therapeutic indices are preferred. While compounds that exhibit toxic side effects can be used, care should be taken to design a delivery system that
10 targets such compounds to the site of affected tissue to minimize potential damage to normal cells and thereby reduce side effects.

[0042] The data obtained from cell culture assays and animal studies can be used to formulate a dosage range for use in humans. The dosage of such compounds lies preferably within a range of circulating concentrations that include the ED₅₀ with little or no toxicity.

15 The dosage can vary within this range depending upon the dosage form employed and the route of administration. For any compound used in the methods of the invention, the therapeutically effective dose can be estimated initially from cell culture assays. A dose can be formulated in animal models to achieve a circulating plasma concentration range that includes the IC₅₀ (the concentration of the test compound that achieves a half-maximal
20 inhibition of symptoms) as determined in cell culture. Such information can be used to more accurately determine useful doses in humans. Levels in plasma can be measured, for example, by high performance liquid chromatography (HPLC).

[0043] Pharmaceutical compositions for use in the present invention can be formulated by standard techniques using one or more physiologically acceptable carriers or excipients. The
25 compounds and their physiologically acceptable salts and solvates can be formulated for administration by any suitable route, including via inhalation, topically, sublingually, intranasally, orally, parenterally (e.g., intravenously, intraperitoneally, intramuscularly, subcutaneously, intravesically or intrathecally), or mucosally (including intranasally, orally and rectally).

30 [0044] For oral or sublingual administration, pharmaceutical compositions of compositions of the invention can take the form of, for example, lozenges, tablets or capsules prepared by conventional means with pharmaceutically acceptable excipients, including binding agents,

for example, pregelatinized cornstarch, polyvinylpyrrolidone, or hydroxypropyl methylcellulose; fillers, for example, lactose, microcrystalline cellulose, or calcium hydrogen phosphate; lubricants, for example, magnesium stearate, talc, or silica; disintegrants, for example, potato starch or sodium starch glycolate; or wetting agents, for example, sodium lauryl sulfate. Tablets can be coated by methods well known in the art. Liquid preparations for oral administration can take the form of, for example, solutions, syrups, or suspensions, or they can be presented as a dry product for constitution with water or other suitable vehicle before use. Such liquid preparations can be prepared by conventional means with pharmaceutically acceptable additives, for example, suspending agents, for example, sorbitol syrup, cellulose derivatives, or hydrogenated edible fats; emulsifying agents, for example, lecithin or acacia; non-aqueous vehicles, for example, almond oil, oily esters, ethyl alcohol, or fractionated vegetable oils; and preservatives, for example, methyl or propyl-p-hydroxybenzoates or sorbic acid. The preparations can also contain buffer salts, flavoring, coloring, and/or sweetening agents as appropriate. If desired, preparations for oral administration can be suitably formulated to give controlled release of the active compound.

[0045] For administration by inhalation, the compounds may be conveniently delivered in the form of an aerosol spray presentation from pressurized packs or a nebulizer, with the use of a suitable propellant, for example, dichlorodifluoromethane, trichlorofluoromethane, dichlorotetrafluoroethane, carbon dioxide, or other suitable gas. In the case of a pressurized aerosol, the dosage unit can be determined by providing a valve to deliver a metered amount. Capsules and cartridges of, for example, gelatin for use in an inhaler or insufflator can be formulated containing a powder mix of the compound and a suitable powder base, for example, lactose or starch.

[0046] The compounds can be formulated for parenteral administration by injection, for example, by bolus injection or continuous infusion. Formulations for injection can be presented in unit dosage form, for example, in ampoules or in multi-dose containers, with an added preservative. The compositions can take such forms as suspensions, solutions, or emulsions in oily or aqueous vehicles, and can contain formulatory agents, for example, suspending, stabilizing, and/or dispersing agents. Alternatively, the active ingredient can be in powder form for constitution with a suitable vehicle, for example, sterile pyrogen-free water, before use.

[0047] The compositions of the invention may also be formulated in rectal compositions such as suppositories or retention enemas, *e.g.*, containing conventional suppository bases such as cocoa butter or other glycerides.

[0048] The compositions of the invention may also be formulated for transdermal administration. For transdermal administration, the active compounds are formulated into ointments, salves, gels, or creams as generally known in the art. Pharmaceutical compositions adapted for transdermal administration can be provided as discrete patches intended to remain in intimate contact with the epidermis for a prolonged period of time. If the compositions of the invention are to be administered topically, the compositions can be formulated in the form of, *e.g.*, an ointment, cream, transdermal patch, lotion, gel, spray, aerosol, solution, emulsion, or other form well-known to one of skill in the art. For non-sprayable topical dosage forms, viscous to semi-solid or solid forms comprising a carrier or one or more excipients compatible with topical application and having a dynamic viscosity preferably greater than water are typically employed. Suitable formulations include, without limitation, solutions, suspensions, emulsions, creams, ointments, powders, liniments, salves, and the like, which are, if desired, sterilized or mixed with auxiliary agents (*e.g.*, preservatives, stabilizers, wetting agents, buffers, or salts) for influencing various properties, such as, for example, osmotic pressure. Other suitable topical dosage forms include sprayable aerosol preparations wherein the active ingredient, preferably in combination with a solid or liquid inert carrier, is packaged in a mixture with a pressurized volatile (*e.g.*, a gaseous propellant, such as Freon), or in a squeeze bottle. Moisturizers or humectants can also be added to pharmaceutical compositions and dosage forms if desired. Examples of such additional ingredients are well-known in the art. Compositions may also be included in a device for transdermal delivery such as a skin patch or a more complex device.

[0049] The compounds also may be formulated as a depot preparation. Such long-acting formulations can be administered by implantation (for example, subcutaneously or intramuscularly) or by intramuscular injection. Thus, for example, the compounds can be formulated with suitable polymeric or hydrophobic materials (for example as an emulsion in an acceptable oil) or ion exchange resins, or as sparingly soluble derivatives, for example, as a sparingly soluble salt.

[0050] The compositions may also be in the form of controlled release or sustained release compositions as known in the art, for instance, in matrices of biodegradable or non-

biodegradable injectable polymeric microspheres or microcapsules, in liposomes, in emulsions, and the like.

[0051] The compositions can, if desired, be presented in a pack or dispenser device that can contain one or more unit dosage forms containing the active ingredient. The pack can, for example, comprise metal or plastic foil, for example, a blister pack. The pack or dispenser
5 device can be accompanied by instructions for administration.

[0052] Depending on their chemical and physical nature, compounds of the invention may be included in the compositions and administered to the patient per se, or in another form such as a salt, solvate, complex, chelate or other derivative as appropriate or as needed for
10 good formulation or administration of the substance. Likewise, a prodrug of the substance may be included in the compositions, that is, a substance that releases the active substance either on preparation of the composition or on administration of the composition to the patient or subject.

[0053] As mentioned above, this invention also provides therapeutic methods of treating
15 cancer comprising administering one or more compounds of the invention, or a composition containing the same, to the patient. The method may further comprise administering to the patient a second therapeutic agent, such as a chemotherapeutic agent or radiation therapy. The cancer being treated may be a breast cancer, a colorectal cancer, a lung cancer, a sarcoma, a mesothelioma, a prostate cancer, a pancreatic cancer, a cervical cancer, an ovary
20 cancer, a gastric cancer, an esophageal cancer, a head and neck cancer, a hepatocellular carcinoma, a melanoma, a glioma, a squamous cancer, or a glioblastoma.

[0054] In carrying out the invention, a single inhibitory compound, or a combination of compounds according to this invention may be administered to a patient. The effective compounds may be administered alone or in combination with (or in time proximity to) other
25 therapeutic agents administered for similar or other therapeutic purposes, for example administration of a compound according to this invention together with an adjuvant or other anti-inflammatory agent. Similarly, compositions containing one or more of the compounds of this invention may also contain other pharmaceutical or therapeutic agents.

[0055] The present invention also includes arrays for testing substances for interaction with
30 or inhibition of PDZ domains. Typically such arrays will be used for testing combinatorial or other libraries. The arrays will comprise standard equipment such as a plate, which will contain compounds arranged on the surface of the plate, for example in wells or bound to

certain locations on the surface. A plate or array may contain compounds of a single type or it may contain different compounds, located in prearranged fashion.

[0056] In one aspect therefore the invention provides *in vitro*, *ex vivo*, and *in vivo* assays for inhibitors of proteins having PDZ domains or for studying inhibition of the activity of a given PDZ domain or a protein containing one. In particular, the assays can be used to test for compounds that possess this activity for testing for binding to, or inhibition of the activity of, PDZ domains. Typically in such assays, the compound or compounds to be tested are contacted with the protein having a PDZ domain and suitable tests are carried out to ascertain whether the normal activity of that domain has been inhibited. For example, the results of the assay may be compared to a control assay that comprises the protein alone, without the test compound(s), using any known activity of the protein as the comparison standard.

[0057] Alternatively screening of a compound for inhibition of PDZ domain activity of a protein may comprise contacting such a protein or a cell containing or expressing it with a compound of the invention and detecting specific binding of the compound to the domain. The detecting may be carried out via a method such as capillary electrophoresis, Western blot, mass spectroscopy, ELISA, immunochromatography, or immunohistochemistry.

[0058] Binding of test compounds to PDZ domains of proteins can be performed in solution, in a bilayer membrane, attached to a solid phase, in a lipid monolayer, or in vesicles. Binding of test compounds can be tested by measuring or observing changes in activity or by, *e.g.*, changes in spectroscopic characteristics or in chromatographic or solubility properties. Binding of test compounds can also be ascertained in competitive binding assays, for example, by ascertaining whether unlabeled test compounds prevent the interaction between the protein and a biotinylated or fluorescent derivative of a reference compound.

[0059] The assays that form an aspect of this invention may be designed to screen large chemical libraries for inhibition of one or more of the proteins using automated assay steps, which are typically run in parallel (*e.g.*, in microtiter formats on microtiter plates in robotic assays). In one preferred embodiment, high throughput screening methods are used that involve providing a combinatorial chemical or other library containing a large number of potential inhibitory compounds. Such libraries are then screened in one or more assays, as described herein, to identify those library members (either particular chemical species or subclasses) that display the desired activity. When screening for modulators, a positive assay result need not indicate that particular test agent is a good pharmaceutical. Rather, a positive

test result can simply indicate that the test agent can be used to inhibit activity of a PDZ domain of a protein. The compounds thus identified may serve as conventional "lead compounds" for PDZ domain inhibitor discovery or may themselves be used as potential or actual therapeutics.

5 [0060] Thus, another aspect of this invention lies in libraries, such as combinatorial libraries, of compounds that are produced for testing based on activity, i.e., inhibition of a PDZ domain as described herein, within the general definitions of compounds herein, such as formulas (I) and (II). A combinatorial chemical library is a collection of such chemical compounds generated by either chemical synthesis or biological synthesis, by combining a
10 number of chemical "building blocks" such as reagents. For example, a linear combinatorial chemical library is formed by combining a set of chemical building blocks in every possible way for a given compound type.

[0061] Devices for the preparation of combinatorial libraries are commercially available (*see, e.g.*, 357 MPS, 390 MPS, Advanced Chem Tech, Louisville KY, Symphony, Rainin,
15 Woburn, MA, 433A Applied Biosystems, Foster City, CA, 9050 Plus, Millipore, Bedford, MA).

[0062] Chemical libraries containing a multiplicity of compounds of Formulas (I) or (II), respectively, are an aspect of this invention and may be synthesized by conducting parallel syntheses as described above for individual compounds.

20 [0063] The compounds used in screening or testing for inhibition of PDZ domain functioning are typically supported on a solid inert support, which may be particulate or non-particulate. Typically the immobilization is achieved by covalently or otherwise bonding the compounds to the solid support material. The bond may be made via a moiety that is part of the chemical composition of the support or that is attached to it, for example to provide an
25 activated surface (for instance, in the case of glass). Numerous types of solid supports suitable for immobilizing compounds are known in the art. These include nylon, nitrocellulose, activated agarose, diazotized cellulose, latex particles, plastic, polystyrene, glass and polymer coated surfaces. These solid supports are used in many formats such as membranes, microtiter plates, beads, probes, dipsticks etc. A wide variety of chemical
30 procedures are known to covalently link various compounds directly or through a linker to these solid supports.

[0064] Typically the use of any solid support requires the presence of a nucleophilic group

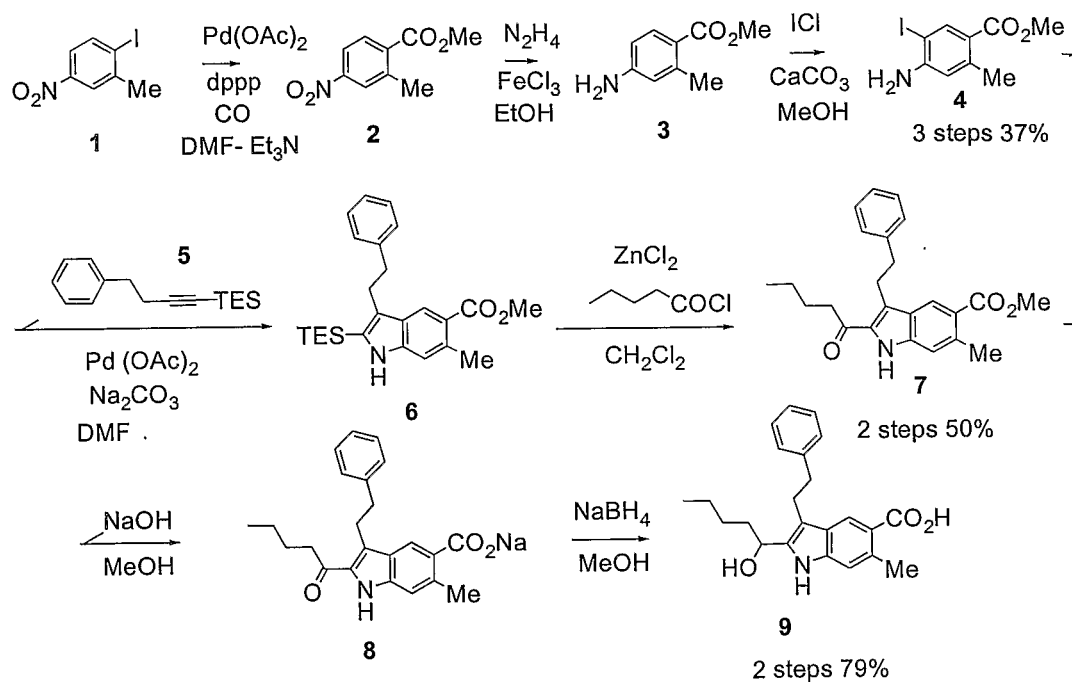
to react with a compound that must contain a "reactive group" capable of reacting with the nucleophilic group. Alternatively, a "reactive group" is present or is introduced into the solid support to react with a nucleophile present in or attached to the oligonucleotide. Suitable nucleophilic groups or moieties include hydroxyl, sulfhydryl, amino and activated carboxyl groups, while the groups capable of reacting with these and other nucleophiles (reactive groups) include dichlorotriazinyl, alkylepoxy, maleimido, bromoacetyl groups and others. Chemical procedures to introduce the nucleophilic or the reactive groups onto solid support are known in the art, and include procedures to activate nylon (U.S. Pat. No. 5,514,785), glass (Rodgers et al., Anal. Biochem., 23-30 (1999)), agarose (Highsmith et al., J., Biotechniques 12: 418-23 (1992) and polystyrene (Gosh et al., Nuc. Acid Res., 15: 5353-5372 (1987)). Dependent on the presence of either a reactive or nucleophilic groups on the solid support and in the test compound, coupling can either be performed directly or with bifunctional reagents. Bifunctional and coupling reagents are well known in the art and many are available from commercial sources.

[0065] Typically, glass surfaces are activated by the introduction of amino-, sulfhydryl-, carboxyl- or epoxy-groups to the glass using the appropriate siloxane reagent. Specifically, immobilization of oligonucleotide arrays on glass supports has been described: by Guo et al., Nuc. Acid Res., 22: 5456-5465 (1994) using 1,4-phenylene diisothiocyanate; by Joos et al., Anal. Biochem., 247: 96-101 (1997) using succinic anhydride and carbodiimide coupling; and by Beatti, et al., Mol. Biotech., 4: 213-225 (1995) using 3-glycidoxypropyltrimethoxysilane.

[0066] The following are examples of the preparation of compounds according to this invention.

Example 1: Synthesis of PDZ domain inhibitor (2-(1-Hydroxypentyl)-3-(2-phenylethyl)-6-methylindole-5-carboxylic acid [Formula (I); Table 1A, compound 1]

[0067] The general scheme for this synthesis was (Scheme D):



scheme D

- [0068] Methyl (4-amino-5-iodo-2-methyl)benzoate (4)** A mixture of 2-iodo-5-nitrotoluene (**1**, 10 g), triethylamine (16 mL), palladium acetate (68 mg), methanol (20 mL) and DMF (10 mL) was stirred at 90°C overnight under carbon monoxide atmosphere (1 atm). The reaction mixture was diluted with ethyl acetate (200 mL), washed with water twice (100 mL each) followed by brine (100 mL), dried (Na₂SO₄), and evaporated. The residue was filtered through a short pad of silica gel and evaporated to give **2** as a crude oil. A mixture of **2**, ethanol (140 mL), water (2 mL), hydrazine monohydrate (3.8 mL), ferric trichloride (0.17 g) and charcoal (0.1 g) was stirred under reflux for 3 hours. The reaction mixture was filtrated, diluted with ethyl acetate (200 mL), washed with water twice (100 mL each) followed by brine (100 mL), dried (Na₂SO₄), and evaporated. The residue was filtered through a short pad of silica gel and evaporated to give **3** as a crude oil. To a mixture of **3**, methanol (33 mL), calcium carbonate (10 g), iodine monochloride solution (33 mL, 1M in dichloromethane) was added slowly at 4°C and stirred overnight at the ambient temperature. The reaction mixture was filtrated, diluted with ethyl acetate (200 mL), washed with aqueous sodium sulfite solution (100 mL), followed by brine (100 mL), dried (Na₂SO₄), and evaporated. The residue was purified by column chromatography (silica gel 0.2 L, eluent: 10% ethyl acetate in hexanes) and evaporated to give **4** (4.30 g) as pale brown crystals. ¹H NMR (CDCl₃, 400 MHz) δ 8.28 (s, 1H), 6.54 (s, 1H), 4.39 (broad s, 2H), 3.84 (s, 3H), 2.50 (s, 3H).

- [0069] **Methyl (2-(1-oxopentyl)-3-(2-phenylethyl)-6-methyl)indole-5-carboxylate (7)** A mixture of **4** (250 mg), 1-triethylsilyl-4-phenylbutyne (**5**, 320 mg), palladium acetate (30 mg), sodium carbonate (450 mg), and degassed DMF (2 mL) was stirred at 100°C under argon atmosphere for 5 hours. The reaction mixture was filtered through fluorisil, eluted with 20% ethyl acetate/hexanes and evaporated to afford indole **6** as an amorphous. To a mixture of **6**, dichloromethane (3 mL) and valeryl chloride (0.52 mL), zinc chloride (1M in diethyl ether solution, 0.77 mL) was added slowly at 4°C, and stirred at 4°C for 3 hours. The reaction mixture was treated with methanol (3 mL), diluted with ethyl acetate (30 mL), washed with water twice (10 mL each), aqueous sodium carbonate (10 mL) followed by brine (10 mL), dried (Na₂SO₄), and evaporated. The crude residue was washed with hexanes to give **7** (165 mg) as a brown solid. Mp 145-147°C; ¹H NMR (CDCl₃, 400 MHz) δ 8.87 (s, 1H), 8.32 (s, 1H), 7.30-7.20 (m, 3H), 7.19 (s, 1H), 7.14 (d, *J* = 7.6 Hz, 2H), 3.93 (s, 3H), 3.39 (t, *J* = 8.4 Hz, 2H), 3.01 (t, *J* = 7.2 Hz, 2H), 2.74 (t, *J* = 7.6 Hz, 2H), 2.71 (s, 3H), 1.68 (quintet, *J* = 7.6 Hz, 2H), 1.68 (dt, *J* = 7.6 Hz, 15.2 Hz, 2H), 0.95 (t, *J* = 7.2 Hz, 3H).
- [0070] **(2-(1-Hydroxypentyl)-3-(2-phenylethyl)-6-methyl)indole-5-carboxylic acid (9)** A mixture of **7** (210 mg), methanol (2 mL), 1,4-dioxane (2 mL) and 10% aqueous sodium hydroxide solution (0.90 mL) was heated at 90°C for 3 hours to give a solution of **8**. Sodium borohydride (210 mg) was added to the solution at the room temperature. The reaction mixture was stirred at the ambient temperature overnight, diluted with ethyl acetate (30 mL), washed with brine (10 mL), dried (Na₂SO₄), and evaporated. The crude residue was filtered through fluorisil, eluted with 40% ethyl acetate/hexanes and evaporated. The residue was washed with hexanes to give **9** (161 mg) as pale brown crystals. Mp 161-163°C; ¹H NMR (CDCl₃, 400 MHz) δ 10 (broad, 1H), 8.45 (s, 1H), 8.10 (s, 1H), 7.3-7.1 (m, 3H), 7.18 (s, 1H), 6.98 (d, *J* = 6.8 Hz, 2H), 4.39 (t, *J* = 7.2 Hz, 1H), 3.19-2.87 (m, 4H), 2.77 (s, 3H), 1.78-1.05 (m, 6H), 0.84 (t, *J* = 6.8 Hz).

PROTEIN EXPRESSION

- [0071] A plasmid consisting of a GST fusion construct of the second PDZ domain of MAGI-3 was obtained from Genentech. The plasmid was transformed into BL21 DE3 cells, grown at 37°C to an O.D.₆₀₀ of 0.8, and induced with 1 mM of IPTG. After three hours the cells were harvested, lysed, and the protein was purified through a slurry of glutathione sepharose beads (Pharmacia). The protein was dialyzed into the assay buffer (35 mM HEPES at pH 7.4, 0.01% triton X-100, 10% glycerol) and concentrated with 10,000 MW cutoff Centricon filters (Waters). Protein purity was verified by SDS-PAGE with Coomassie

and silver staining. Quantification of the protein was done with the BCA protocol by Pierce. The protein was stored in the assay buffer at -80°C . GST alone was expressed, purified and stored in the same manner.

Binding Assay

5 [0072] A fluorescence polarization competition assay was used to detect binding of the compounds to MAGI-3 PDZ2. A fluorescein labeled carboxy terminal sequence of PTEN, OregonGreenTM-PFDEDQHTQITKV-COOH, was used as a probe. For a positive control, we chose PFDEDQHTQITWV-COOH, the highest affinity peptide sequence for MAGI-3 PDZ2 known. To synthesize the labeled peptide we used standard Fmoc conditions on Wang
10 resin to build a 13 residue peptide. A typical coupling cycle includes deprotecting the terminal amino acid with 20% piperidine in dry DMF, washing the resin 2-3 times with DMF then methylene chloride and both again, and determining the existence of free amine by ninhydrin kaiser test. A slurry containing coupling reagent 2.4 equivalents of HBTU, the next N terminal amino acid to be added to the growing peptide 2.5 equivalents of Fmoc
15 protected amino acid, 5 equivalents of DIEA in dry DMF. The amino acid was coupled over 2-3 hours and the kaiser test was used to determine completeness. Coupling steps were repeated if a positive kaiser test resulted. This method was used for each residue of the peptide. The finished peptide was cleaved from the resin with 95% TFA with a cocktail of scavengers including thioanisole and phenol. The peptide was precipitated with ether and
20 lyophilized. Peptides were purified using HPLC and identified with MALDI mass spectrometry.

Results are shown in Figure 1.

[0073] To detect binding of compounds to the PDZ2 domain of the MAGI-3 protein, a competition polarization assay was employed. The buffer included 35 mM HEPES at pH 7.4,
25 triton X-100 0.01%, and 10% glycerol. The protein was added to a final concentration of 300 nM and the probe, 10 nM. The competitor was then added to final concentration range of 10pM to 300μM. Triplicates of the samples in a total volume of 20μL were transferred to 384 well Corning opaque plate for analysis. Fluorescence polarization was measured at equilibrium by LJI Biosystems plate reader. Competition data was fit to a one-site
30 competition expression and the IC_{50} values of the nonpeptide compounds were compared.

Apoptotic effects of compounds in cancer cells overexpressing Dvl

[0074] Compound 1 of Table 1A was tested for apoptotic effects to represent the inhibitory effects of compounds on interaction between the PDZ domain of the Dishevelled (Dvl) protein and the Fz protein (Wnt receptor). Cell lines H513 and H1703 were utilized, with the test compound being applied at 0 (control), 10 μ M and 100 μ M. The results are shown in Table 2.

Table 2

Compound no.	Conc., μ M	Cell line	days	apoptosis, %
1	10	H1703	1	8.3
1	100	H1703	1	14.7
1	10	H513	1	15.8
1	100	H513	1	18.1

Inhibition of human cancer cell growth in vivo

[0075] Compound 1 (Example 1) was tested for antitumor efficiency using in vivo studies with immune deficiency nude mice bearing with human cancer cell xenografts.

Human melanoma cell line LOX was injected at 8×10^5 cells/animal and human lung carcinoma cell line H460 was injected at 10^6 cells/animal. Human cancer cell lines were adjusted in 100 μ L volume with normal cell culture medium and were injected s.c. into nude mice on the dorsal area. After injection, cancer cell xenografts were allowed to grow for 7 days. After that, mice were randomly grouped with each group consisting of 8 animals (n=8). Animals were individually tagged with ear tags.

[0076] Compound 1 was dissolved in water and stored in aliquots and stored at -80 °C prior to use. The dose used for injection was calculated as 50 mg/kg body weight. The average mouse body weight was 20g $\pm$ 0.5g. The amount of test compound (1 mg) was adjusted to 80 μ L with PBS, and was injected (i.p.) daily for 14 days. Controls were PBS alone. Tumor size and mouse body weight were measured one week after first injection.

[0077] The results showed that by the end of two weeks with injection of Compound 1 (see Table 2), tumor size from the injection was reduced by 66% in LOX xenografts and 20% in H460 xenografts as compared with PBS controls. The average mouse body weights were 24.5g for PBS controls and 22.2g for Compound 1-injected animals.

[0078] The results are shown in Table 3.

Table 3

	PBS controls	PBS controls	Compound 1 injection	Compound 1 injection
Cell lines	LOX	H460	LOX	H460
Tumor volume	361 mm ²	415 mm ²	68 mm ²	341 mm ²
Mouse weight	24.5 g		23.3g	

[0079] In a subsequent similar test, Compound 1 was tested for antitumor efficiency using
 5 in vivo studies with immune deficiency nude mice bearing with human cancer cell
 xenografts.

[0080] Human melanoma cell line LOX was injected at 8000 cells/animal and human lung
 carcinoma cell line H460 was injected at 1000000 cells/animal. Human cancer cell lines were
 adjusted in 100 µL volume with normal cell culture medium and were injected s.c. into nude
 10 mice on the dorsal area. After injection, cancer cell xenografts were allowed to grow for 7
 days. After that, mice were randomly grouped with each group consisting of 8 animals (n=8).
 Animals were individually tagged with ear tags.

[0081] Compound 1 was dissolved in water as sodium salt. The dose used for injection
 was calculated as 50 mg/kg body weight. The average mouse body weight was 24.2 g +/- 3.2
 15 g. The 1 mg of Compound 1 was adjusted to 80 µL with PBS, and was injected (i.p.) daily
 for 14 days. Controls were PBS alone. Tumor size and mouse body weight were measured
 one week after first injection.

[0082] The results showed that by the end of two weeks with injection of Compound 1
 (Table 1A), tumor size from the injection was reduced by 82% in LOX xenografts and 34%
 20 in H460 xenografts as compared with PBS controls. The average mouse body weights were
 25.0 g for PBS controls and 22.2g for FJ-9 -injected animals. The results are summarized in
 Table 4.

Table 4

	PBS controls	PBS controls	Compound 1 injection	FJ-9 injection

Cell lines	LOX	H460	LOX	H460
Tumor volume	379 mm ²	498 mm ²	69 mm ²	328 mm ²
Mouse weight	24.5 g		23.3g	

[0083] Compound 1 and other compounds of Tables 1A and 1B were similarly tested for apoptotic effects to represent the inhibitory effects of compounds on interaction between the PDZ domain of the Dishevelled (Dvl) protein and the Fz protein (Wnt receptor). Cell lines

5 H460 and LOX were utilized, with the test compound being applied at 10 μ M for 3 days.

Cultured cells treated with the test compounds in the culture media were harvested by trypsinization and stained using an Annexin V FITC Apoptosis Detection kit (Oncogene Science, Cambridge, MA), according to the manufacturer's protocol. Stained cells were immediately analyzed by flow cytometry (FACScan; Becton-Dickinson, Franklin Lake, NJ).

10 The results are shown in Table 5.

Table 5

Assay 1			Assay 2			Assay 3		
library 1	apopto sis, %		library 2	apopto sis, %		library 3	apopto sis, %	
Compound	H460	LOX	Compound	H460	LOX	Compound	H460	LOX
control	9.22	10.85	control	10.24	9.67	control	7.59	8.81
1	24.62	18.53	1	28.31	13.37	1	14.59	14.27
26	16.13	16.86	35	34.73	23.23	43	34.22	20.24
27	16.91	18.5	36	41.48	13.51	44	37.38	54.13
28	58.76	38.53	37	45.05	7.49	45	96.96	86.71
29	64.1	74.11	38	51.61	13.58	46	39.06	38.6
30	78.07	55.76	39	42.9	29.35	47	49.77	73.02
31	9.07	12.06	40	23.93	16.5	48	24.48	15.14
32	21.13	15.36	41	19.96	12.69	49	82.53	96.34
33	12.66	15.03	42	49.41	15.22	50	41.75	72.47
34	76.59	44.73	10	39.64	19.08	18	21.11	9.53
2	34.21	36.32	11	24.48	14.83	19	44.15	47.62
3	79.9	56.29	12	28.8	15.83	20	28.9	11.77
4	36.41	32.52	13	35.51	17.84	21	31.22	19.99
5	24.39	27.15	14	24.26	11.88	22	16.22	15.47
6	8.62	9.22	15	37.4	17.57	23	12.09	11.34
7	13.92	17.96	16	15.7	14.5	24	26.58	26.56
9	36.74	34.71	17	18.93	15.62	25	37.04	65.26

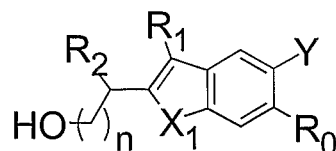
[0084] Other proteins that are targets of the compounds of this invention, particularly for anti-tumor activity, include EPB50, ZO-1, nNOS, ERBIN and MUPP1.

[0085] It is understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to persons skilled in the art and are to be included within the spirit and purview of this application and scope of the appended claims.

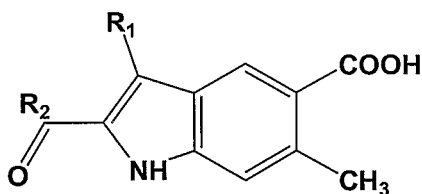
[0086] All publications, patents, and patent applications cited herein are hereby incorporated by reference in their entirety for all purposes.

WHAT IS CLAIMED IS

1. A compound having the formula

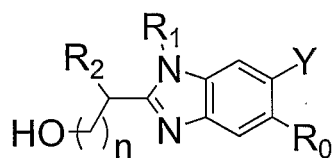


(I)



(II)

or



(III)

in which:

n is 0, 1 or 2;

X_1 is NH, N(CH₃), CH₂, CH(CH₃), C(CH₃)₂, O, S, S(O), or SO₂;

R_0 is selected from the group consisting of C₁-C₃ alkyl, cyclopropyl, halo, OR₅ and S(O) _{m} R₅ in which m is 0, 1 or 2;

R_1 and R_2 are independently selected from the group consisting of C₂-C₈ alkenyl, phenylcyclopropyl, phenylpropenyl, R₆-X₂-C(R₈)(R₈)-R₇-, R₆-X₂-N(R₈)-R₇-, and R₁₀X₃R₇-;

R_3 and R_4 are independently hydrogen, methyl or ethyl;

R_5 is methyl or ethyl;

R_6 is selected from the group consisting of hydrogen, C_1 - C_{10} alkyl, aryl, W, Y, NH_2 , $NHCONR_3R_4$, $NHCOOR_3$ and $NHSO_2R_9$;

5 R_7 is selected from the group consisting of a direct bond, an alkyl group having from 1 to 10 carbon atoms, aryl, $-(NH)_p(CH_2CH_2O)_q(NH)_p-$ in which p is 0 or 1 and q is an integer from 1 to 4, and W;

R_8 is selected from the group consisting of H, Y, OH, $-NHCONR_3R_4$, $-NHCOOR_3$, $-NHSO_2R_9$, $-(CH_2)_rCO_2R_3$, and $(CH_2)_rCONR_3R_4$ in which r is an integer from
10 1 to 3;

R_9 is aryl or C_1 - C_6 alkyl;

R_{10} is selected from C_1 - C_{10} alkyl, aryl and W;

X_2 is selected from the group consisting of a direct bond, $-NH-$, $-N(CH_3)-$, $-NCONR_3R_4$, $-NCOOR_3$, and $-NSO_2R_9$;

15 X_3 is selected from O, S, SO and SO_2 ;

W is a saturated carbocyclic or heterocyclic group;

Y is selected from the group consisting of COOH, $COOR_3$, $CONR_3R_4$, $CONHSO_2R_5$, hydroxymethyl, $-CH_2COOH$, $CH_2CONR_3R_4$, and 5-tetrazolyl;

and hydrates and salts thereof, and labeled derivatives thereof.

20 2. A compound of Formula (I) according to claim 1.

3. A compound of Formula (II) according to claim 1.

4. A compound of Formula (III) according to claim 1.

5. A compound according to claim 2 in which n is 0.

6. A compound according to claim 2 in which X_1 is NH.

25 7. A compound according to claim 2 in which X_1 is O.

8. A compound according to claim 2 in which X_1 is S.

9. A compound according to claim 2 in which X_1 is NCH_3 or $N(C_2H_5)$.

10. A compound according to claim 1 in which Y is COOH or COOR₃.
11. A compound according to claim 1 in which R₀ is a C₁-C₃ alkyl group.
12. A compound according to claim 9 in which R₀ is methyl.
13. A compound according to claim 1 in which R₁ and R₂ are
5 independently selected from C₃-C₆ cycloalkyl and C₁-C₂₀ alkyl optionally substituted by a phenyl, cycloalkyl, carboxyl or hydroxyl group.
14. A compound according to claim 1 in which R₁ and R₂ are independently selected from C₃-C₆ cycloalkyl and C₁-C₁₀ alkyl optionally substituted by a phenyl, cycloalkyl, carboxyl or hydroxyl group.
- 10 15. A compound according to claim 1 in which R₁ and R₂ are independently selected from C₃-C₆ cycloalkyl and C₁-C₈ alkyl optionally substituted by a phenyl, cycloalkyl, carboxyl or hydroxyl group.
- 15 16. A compound according to claim 1 in which R₁ and R₂ are independently selected from C₃-C₆ cycloalkyl and C₃-C₈ alkyl optionally substituted by a phenyl, cycloalkyl, carboxyl or hydroxyl group.
17. A compound according to claim 1 in which R₁ and R₂ are independently selected from C₃-C₈ alkyl, C₃-C₆ cycloalkyl, -(CH₂)_mC₆H₅ where *m* is 0 or an integer from 1 to 3, and a C₁-C₃ alkyl group substituted with a C₃-C₆ cycloalkyl group.
- 20 18. A compound according to claim 1 in which R₁ is optionally substituted phenethyl.
19. A compound according to claim 1 in which R₁ is 2-hydroxyethyl.
20. A compound according to claim 1 in which R₁ is phenyl.
21. A compound according to claim 1 in which R₁ is a butyl group.
22. A compound according to claim 1 in which R₂ is a butyl group

23. A compound according to claim 20 in which R_2 is selected from C_3 - C_6 cycloalkyl, C_1 - C_3 alkyl substituted by a C_3 - C_6 cycloalkyl group, $-(CH_2)_mC_6H_5$ where m is 0 or an integer from 1 to 3, and C_3 - C_8 alkyl optionally substituted by a phenyl, cycloalkyl, carboxyl or hydroxyl group.

5 24. A compound according to claim 1 in which R_2 is n-butyl or phenethyl.

25. A compound according to claim 1 in which R_2 is $R_6-X_2-C(R_8)(R_8)-R_7$ - or $R_6-X_2-N(R_8)-R_7$ -, and the group $R_6-X_2-C(R_8)(R_8)-R_7$ - or $R_6-X_2-N(R_8)-R_7$ - is selected from C_3 - C_8 alkyl; C_3 - C_6 cycloalkyl; C_3 - C_8 alkenyl; $-(CH_2)_mC_6H_5$ where m is 0 or an integer from 1-3; $-CH_2OC_6H_5$, $CH_2COC_6H_5$, phenyl(C_2 - C_4 alkenyl), or analogous moieties having
10 substituted phenyl groups; optionally substituted phenylcyclopropyl; $-(CH_2)_sOH$, -
 $(CH_2)_sCONH_2$ and $-(CH_2)_sCOOH$ where s is an integer from 1 to 3; phenyl; thienyl; and optionally substituted C_3 - C_6 cycloalkyl-(C_1 - C_3 alkyl).

26. A compound according to claim 2 in which R_0 is methyl, R_1 is phenethyl, R_2 is n-butyl, X_1 is -NH, Y is COOH and n is 0.

15 27. A compound according to claim 2 in which R_0 is methyl, R_1 is phenethyl, R_2 is phenethyl, X_1 is -NH, Y is COOH and n is 0.

28 A probe comprising a compound according to claim 1 and a detectable label.

29. A method for inhibiting the functioning of a PDZ domain of a protein
20 comprising contacting the protein with an inhibitory effective amount of a compound according to claim 1.

30. A method for inhibiting the functioning of a PDZ domain of a protein comprising contacting the protein with an inhibitory effective amount of a compound according to claim 2.

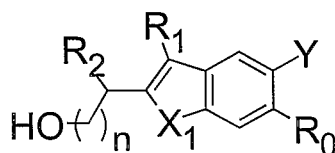
25 31. A method for inhibiting the functioning of a PDZ domain of a protein comprising contacting the protein with an inhibitory effective amount of a compound according to claim 3.

32. A method for inhibiting the functioning of a PDZ domain of a protein comprising contacting the protein with an inhibitory effective amount of a compound according to claim 4.

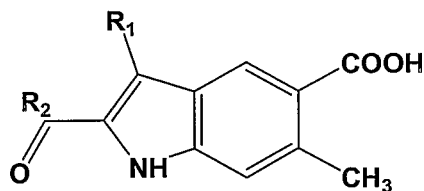
33. A method for inhibiting the functioning of a PDZ domain of a protein comprising contacting the protein with an inhibitory effective amount of a compound according to claim 25.

34. A method according to claim 29 in which the protein is a MAGI protein.

35. A combinatorial library of two or more compounds having the formula

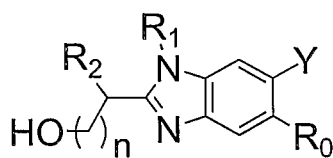


(I)



(II)

or



(III)

in which:

n is 0, 1 or 2;

X₁ is NH, N(CH₃), CH₂, CH(CH₃), C(CH₃)₂, O, S, S(O), or SO₂;

5 R₀ is selected from the group consisting of C₁- C₃ alkyl, cyclopropyl, halo,
OR₅ and S(O)_{*m*}R₅ in which *m* is 0, 1 or 2;

R₁ and R₂ are independently selected from the group consisting of C₂-C₈ alkenyl, phenylcyclopropyl, phenylpropenyl, R₆-X₂-C(R₈)(R₈)-R₇-, R₆-X₂-N(R₈)-R₇-, and R₁₀-X₃-R₇-;

R₃ and R₄ are independently hydrogen, methyl or ethyl;

R₅ is methyl or ethyl;

15 R₆ is selected from the group consisting of hydrogen, C₁-C₁₀ alkyl, aryl, W, Y, NH₂, NHCONR₃R₄, NHCOOR₃ and NHSO₂R₉;

R₇ is selected from the group consisting of a direct bond, an alkyl group having from 1 to 10 carbon atoms, aryl, -(NH)_p(CH₂CH₂O)_q(NH)_p- in which *p* is 0 or 1 and *q* is an integer from 1 to 4, and W;

R₈ is selected from the group consisting of H, Y, OH, -NHCONR₃R₄; -NHCOOR₃; -NHSO₂R₉, -(CH₂)_rCO₂R₃, and (CH₂)_rCONR₃R₄ in which *r* is an integer from 1 to 3;

R₉ is aryl or C₁-C₆ alkyl;

25 R₁₀ is selected from C₁-C₁₀ alkyl, aryl and W;

X₂ is selected from the group consisting of a direct bond, -NH-, -N(CH₃)-, -NCONR₃R₄, -NCOOR₃, and -NSO₂R₉;

30 X_3 is selected from O, S, SO and SO_2 ;

W is a saturated carbocyclic or heterocyclic group;

Y is selected from the group consisting of COOH, COOR₃, CONR₃R₄, CONHSO₂R₅, hydroxymethyl, -CH₂COOH, CH₂CONR₃R₄, and 5-tetrazolyl;

and hydrates and salts thereof, and labeled derivatives thereof.

5 36. A combinatorial library according to claim 35 in which the compounds are of Formula (I).

 37. A combinatorial library according to claim 35 in which the compounds are of Formula (II).

 38. A combinatorial library according to claim 35 in which the compounds are of Formula (III).

10 39. A method for screening one or more proteins for PDZ domain activity comprising contacting the one or more proteins with a compound according to claim 1.

 40. An array for screening for PDZ domain activity or inhibition of the same, or for studying protein-protein interactions comprising two or more compounds according to claim 1.

15 41. A method for treating a cancer in cancerous cells or in a patient comprising contacting the cancerous cells with, or administering to the patient, a therapeutically effective amount of a compound according to claim 1.

 42. A method for treating a cancer in a patient comprising administering to the patient a therapeutically effective amount of a compound according to claim 2.

20 43. A method for treating a cancer in a patient comprising administering to the patient a therapeutically effective amount of a compound according to claim 3.

 44. A method for treating a cancer in a patient comprising administering to the patient a therapeutically effective amount of a compound according to claim 4.