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(54) Title: METHOD FOR SCREENING FOR COMPOUNDS SELECTIVELY INTERACTING WITH RAD9

(57) Abstract: Natural and synthetic compounds of Formulae Ia-Ie having a lactone structure, in particular Securolide, have been determined to be effective antitumor compounds which target the hRad9 gene and/or protein encoded thereby or complex containing the protein and/or the p53 gene and/or protein. Securolide is cytoselctive for mutants of hRad9 based on studies conducted in Rad9 mutant yeast strains. Securolide appears to interact with mutant hRad9 in cancer cells to produce DNA lesions which result in apoptosis. Studies have demonstrated that Securolide is useful for treating proliferation disorders such as melanoma, leukemia, breast cancer, lung cancer, ovarian cancer, colon cancer, esophagus cancer, liver cancer, and lymphatic cancer, and to alleviate pain associated with the cancer. Other compounds effective for the treatment of cancer and optionally pain associated therewith may also be identified using the same assays, for example, by screening for efficacy in assays using Rad9 and/or p53 defective mutant yeasts.



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METHOD FOR SCREENING FOR COMPOUNDS SELECTIVELY INTERACTING WITH RAD9

Field of the Invention

5 The present invention is generally in the field of targets for anticancer compounds, and methods of screening therefore.

Cross Reference to Related Applications

10 This application claims priority to U.S.S.N. 61/108,224 "*Method for Screening for Compounds Selectively Interacting with RAD9*" by David Terrero, filed on October 24, 2008.

Background of the Invention

15 Many compounds are known for the treatment of cancer. Most act via inhibition of DNA replication or cell proliferation, in general, and are not specific for transformed cells. Although specificity has been imparted through the use of targeting ligands, and binding to specific receptors on the tumor cells, in general most anti-tumor compounds are effective by virtue of killing more of the more rapidly proliferating tumor cells as compared to the more slowly replicating normal cells.

20 It would be highly desirable to have more selective compounds, that are cytotoxic to tumor cells but not to normal cells.

It is therefore an object of this invention to provide a method for identifying compounds that exhibit selective anti-tumor activity.

25 It is still further an object of this invention to provide a new class of compounds which exhibit anti-tumor activity through the targeting of the hRad9 gene in humans.

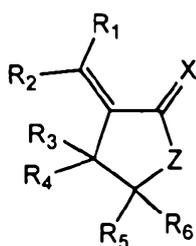
Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

30 Any discussion of documents, acts, materials, devices, articles or the like which has been included in the present specification is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present disclosure as it existed before the priority date of each claim of this application.

Summary of the Invention

In a first aspect, the present invention provides a method for screening for compounds having anti-cancer activity comprising

- (a) providing cells having one or more mutations in the cell cycle checkpoint protein complex that includes Rad9, wherein the cells have a mutation in the Rad9 gene, and wherein the cells are defective in the Rad9 protein-mediated cell cycle arrest;
- (b) adding a compound to be screened to the cells, wherein the compound has the structure of Formula Ia:



Formula Ia

- wherein R₁-R₆ independently are selected from a hydrogen atom, a halogen atom, a hydroxyl group, alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, phenyl, substituted phenyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, halo, hydroxyl, alkoxy, phenoxy, substituted phenoxy, aroxy, substituted aroxy, alkylthio, phenylthio, substituted phenylthio, arylthio, substituted arylthio, cyano, isocyano, substituted isocyano, carbonyl, carboxyl, substituted carboxyl, amino, substituted amino, amido, substituted amido, sulfonyl, sulfonic acid, phosphoryl, phosphonyl, polyaryl, substituted polyaryl, C₃-C₂₀ cyclic, substituted C₃-C₂₀ cyclic, heterocyclic, substituted heterocyclic, an amino acid, a peptide, or a polypeptide group; or R₃-R₆ taken together form a substituted or unsubstituted ring that optionally includes one or more heteroatoms selected from the group consisting of oxygen, sulfur, and nitrogen;

Z is a heteroatom selected from oxygen, sulfur, or nitrogen; and

X is a heteroatom selected from oxygen, sulfur, or nitrogen;

- (c) determining if the compound kills or induces apoptosis in some or all of the cells;
- (d) comparing the resultant determination of step (c) to the resultant determination induced by the compound in normal cells not having the one or more mutations in (a) to determine if the compound has anti-cancer activity.

Natural and synthetic compounds of Formulae Ia-Ie, or metabolites thereof, having a lactone structure, in particular Securolide, have been determined to be highly

effective anti-tumor compounds which target the hrad9 gene and/or protein encoded thereby or complex containing the protein and/or the p53 gene and/or protein encoded thereby. Securolide is cytoselective for mutants of hRad9 based on studies conducted in Rad9 mutant yeast strains. Securolide appears to interact with mutant hRad9 in
5 cancer cells to produce DNA lesions which result in apoptosis. Studies have

demonstrated that Securolide is useful for treating proliferation disorders such as melanoma, leukemia, breast cancer, lung cancer, ovarian cancer, colon cancer, esophagus cancer, liver cancer, and lymphatic cancer, and to alleviate pain associated with the cancer. Other compounds effective for the treatment of cancer and optionally pain associated therewith may also be identified using the same assays as were used to demonstrate the mechanism of action of Securolide, for example, by screening for efficacy in assays using Rad9 defective mutant yeasts.

Detailed Description of the Invention

10 Definitions

“Alkyl”, as used herein, refers to the radical of saturated or unsaturated aliphatic groups, including straight-chain alkyl, alkenyl, or alkynyl groups, branched-chain alkyl, alkenyl, or alkynyl groups, cycloalkyl, cycloalkenyl, or cycloalkynyl (alicyclic) groups, alkyl substituted cycloalkyl, cycloalkenyl, or cycloalkynyl groups, and cycloalkyl substituted alkyl, alkenyl, or alkynyl groups. Unless otherwise indicated, a straight chain or branched chain alkyl has 30 or fewer carbon atoms in its backbone (e.g., C1-C30 for straight chain, C3-C30 for branched chain), preferably 20 or fewer, preferably 10 or fewer, more preferably 6 or fewer, most preferably 5 or fewer: If the alkyl is unsaturated, the alkyl chain generally has from 2-30 carbons in the chain, preferably from 2-20 carbons in the chain, preferably from 2-10 carbons in the chain, more preferably from 2-6 carbons, most preferably from 2-5 carbons. Likewise, preferred cycloalkyls have from 3-20 carbon atoms in their ring structure, preferably from 3-10 carbons atoms in their ring structure, most preferably 5, 6 or 7 carbons in the ring structure. Examples of saturated hydrocarbon radicals include, but are not limited to, methyl, ethyl, n-propyl, isopropyl, n-butyl, t-butyl, isobutyl, sec-butyl, cyclohexyl, (cyclohexyl)methyl, cyclopropylmethyl, and homologs and isomers of, for example, n-pentyl, n-hexyl, n-heptyl, n-octyl. Examples of unsaturated alkyl groups include, but are not limited to, vinyl, 2-propenyl, crotyl, 2-isopentenyl, 2-(butadienyl), 2,4-pentadienyl, 3-(1,4-pentadienyl), ethynyl, 1- and 3-propynyl, and 3-butynyl.

The term "alkyl" includes one or more substitutions at one or more carbon atoms of the hydrocarbon radical as well as heteroalkyls. Suitable substituents include, but are not limited to, halogens, such as fluorine, chlorine, bromine, or iodine; hydroxyl; $-NR_1R_2$, wherein R_1 and R_2 are independently hydrogen, alkyl, or aryl, and wherein the nitrogen atom is optionally quaternized; $-SR$, wherein R is hydrogen, alkyl, or aryl; $-CN$; $-NO_2$; $-COOH$; carboxylate; $-COR$, $-COOR$, or $-CONR_2$, wherein R is hydrogen, alkyl, or aryl; azide, aralkyl, alkoxy, imino, phosphonate, phosphinate, silyl, ether, sulfonyl, sulfonamido, heterocyclyl, aromatic or heteroaromatic moieties, $-CF_3$; $-CN$; $-NCOCOCH_2CH_2$; $-NCOCOCHCH$; $-NCS$; and combinations thereof.

"Aryl", as used herein, refers to C_5 - C_{10} -membered aromatic, heterocyclic, fused aromatic, fused heterocyclic, biaromatic, or biheterocyclic ring systems. Broadly defined, "aryl", as used herein, includes 5-, 6-, 7-, 8-, 9-, and 10-membered single-ring aromatic groups that may include from zero to four heteroatoms, for example, benzene, 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 can be substituted at one or more ring positions with one or more substituents including, but not limited to, halogen, azide, alkyl, aralkyl, alkenyl, alkynyl, cycloalkyl, hydroxyl, alkoxy, amino (or quaternized amino), nitro, sulfhydryl, imino, amido, phosphonate, phosphinate, carbonyl, carboxyl, silyl, ether, alkylthio, sulfonyl, sulfonamido, ketone, aldehyde, ester, heterocyclyl, aromatic or heteroaromatic moieties, $-CF_3$, $-CN$; and combinations thereof.

The term "aryl" also includes polycyclic ring systems having two or more cyclic rings in which two or more carbons are common to two adjoining rings (i.e., "fused rings") wherein at least one of the rings is aromatic, e.g., the other cyclic ring or rings can be cycloalkyls, cycloalkenyls, cycloalkynyls, aryls and/or heterocycles. Examples of heterocyclic rings include, but are not limited to, benzimidazolyl,

benzofuranyl, benzothiofuranyl, benzothiophenyl, benzoxazolyl,
benzoxazoliny, benzthiazolyl, benztriazolyl, benztetrazolyl, benzisoxazolyl,
benzisothiazolyl, benzimidazoliny, carbazolyl, 4aH carbazolyl, carboliny,
chromanyl, chromenyl, cinnoliny, decahydroquinoliny, 2*H*,6*H*-1,5,2-
5 dithiaziny, dihydrofuro[2,3 b]tetrahydrofuran, furanyl, furazany,
imidazolidiny, imidazoliny, imidazolyl, 1*H*-indazolyl, indolenyl, indoliny,
indoliziny, indolyl, 3*H*-indolyl, isatinoyl, isobenzofuranyl, isochromanyl,
isoindazolyl, isoindoliny, isoindolyl, isoquinoliny, isothiazolyl, isoxazolyl,
methylenedioxyphenyl, morpholiny, naphthyridiny,
10 octahydroisoquinoliny, oxadiazolyl, 1,2,3-oxadiazolyl, 1,2,4-oxadiazolyl,
1,2,5-oxadiazolyl, 1,3,4-oxadiazolyl, oxazolidiny, oxazolyl, oxindolyl,
pyrimidiny, phenanthridiny, phenanthroliny, phenaziny, phenothiaziny,
phenoxathiny, phenoxaziny, phthalaziny, piperaziny, piperidiny,
piperidony, 4-piperidony, piperony, pteridiny, puriny, pyranyl, pyraziny,
15 pyrazolidiny, pyrazoliny, pyrazolyl, pyridaziny, pyridooxazole,
pyridoimidazole, pyridothiazole, pyridiny, pyridyl, pyrimidiny,
pyrrolidiny, pyrroliny, 2*H*-pyrroly, pyrroly, quinazoliny, quinoliny, 4*H*-
quinoliziny, quinoxaliny, quinuclidiny, tetrahydrofuranyl,
tetrahydroisoquinoliny, tetrahydroquinoliny, tetrazolyl, 6*H*-1,2,5-
20 thiadiaziny, 1,2,3-thiadiazolyl, 1,2,4-thiadiazolyl, 1,2,5-thiadiazolyl, 1,3,4-
thiadiazolyl, thianthrenyl, thiazolyl, thienyl, thienothiazolyl, thienooxazolyl,
thienoimidazolyl, thiophenyl and xanthenyl. One or more of the rings can be
substituted as defined above for “aryl”.

The terms “alkenyl” and “alkynyl” refer to unsaturated aliphatic
25 groups analogous in length and possible substitution to the alkyls described
above, but that contain at least one double or triple bond respectively.

The term “heteroalkyl”, as used herein, refers to straight or branched
chain, or cyclic carbon-containing radicals, or combinations thereof,
containing at least one heteroatom. Suitable heteroatoms include, but are not
30 limited to, O, N, Si, P and S, wherein the nitrogen, phosphorous and sulfur
atoms are optionally oxidized, and the nitrogen heteroatom is optionally
quaternized. Heteroalkyls can be substituted as defined above for alkyl
groups.

“Alkoxy”, “alkylamino”, and “alkylthio” are used to refer to those alkyl groups attached to the remainder of the molecule via an oxygen atom, an amino group, or a sulfur atom, respectively.

5 “Alkylaryl”, as used herein, refers to an alkyl group substituted with an aryl group (e.g., an aromatic or hetero aromatic group).

“Heterocycle” or “heterocyclic”, as used herein, refers to a cyclic radical attached via a ring carbon or nitrogen of a monocyclic or bicyclic ring containing 3-10 ring atoms, and preferably from 5-6 ring atoms, consisting of carbon and one to four heteroatoms each selected from the group consisting of non-peroxide oxygen, sulfur, and N(Y) wherein Y is absent or is H, O, (C₁₋₁₀)alkyl, phenyl or benzyl, and optionally containing 1-3 double bonds and optionally substituted with one or more substituents. Examples of heterocyclic ring include, but are not limited to, benzimidazolyl, benzofuranyl, benzothiofuranyl, benzothiophenyl, benzoxazolyl, benzoxazoliny, benzthiazolyl, benztriazolyl, benztetrazolyl, benzisoxazolyl, benzisothiazolyl, benzimidazoliny, carbazolyl, 4*aH*-carbazolyl, carboliny, chromanyl, chromenyl, cinnoliny, decahydroquinoliny, 2*H*,6*H*-1,5,2-dithiaziny, dihydrofuro[2,3-*b*]tetrahydrofuran, furanyl, furazanyl, imidazolidiny, imidazoliny, imidazolyl, 1*H*-indazolyl, indolenyl, indoliny, indoliziny, indolyl, 3*H*-indolyl, isatinoyl, isobenzofuranyl, isochromanyl, isoindazolyl, isoindoliny, isoindolyl, isoquinoliny, isothiazolyl, isoxazolyl, methylenedioxyphenyl, morpholiny, naphthyridiny, octahydroisoquinoliny, oxadiazolyl, 1,2,3-oxadiazolyl, 1,2,4-oxadiazolyl, 1,2,5-oxadiazolyl, 1,3,4-oxadiazolyl, oxazolidiny, oxazolyl, oxepanyl, oxetanyl, oxindolyl, pyrimidiny, phenanthridiny, phenanthroliny, phenaziny, phenothiaziny, phenoxathiny, phenoxaziny, phthalaziny, piperaziny, piperidiny, piperidonyl, 4-piperidonyl, piperonyl, pteridiny, puriny, pyranly, pyraziny, pyrazolidiny, pyrazoliny, pyrazolyl, pyridaziny, pyridooxazole, pyridoimidazole, pyridothiazole, pyridiny, pyridyl, pyrimidiny, pyrrolidiny, pyrroliny, 2*H*-pyrrolyl, pyrrolyl, quinazoliny, quinoliny, 4*H*-quinoliziny, quinoxaliny, quinuclidiny, tetrahydrofuranyl, tetrahydroisoquinoliny, tetrahydropyranyl, tetrahydroquinoliny, tetrazolyl, 6*H*-1,2,5-thiadiaziny, 1,2,3-thiadiazolyl,

1,2,4-thiadiazolyl, 1,2,5-thiadiazolyl, 1,3,4-thiadiazolyl, thianthrenyl, thiazolyl, thienyl, thienothiazolyl, thienooxazolyl, thienoimidazolyl, thiophenyl and xanthenyl. Heterocyclic groups can optionally be substituted with one or more substituents as defined above for alkyl and aryl.

5 “Halogen”, as used herein, refers to fluorine, chlorine, bromine, or iodine.

Mechanism of Action

Cell cycle checkpoints regulate the precise order of cell cycle events, thus ensuring the distribution of complete copies of the genome to daughter
10 cells (Hartwell, L. & Weinert, T., *Science* 246, 629–634, 1989). Defects in checkpoints lead to genomic instability, a major contributory factor in the development of cancer, because cells with faulty checkpoints proceed into mitosis with damaged or incompletely replicated DNA (Hartwell, L.H. & Kastan, M.B., *Science* 266, 1821–1828, 1995; Nojima, H. *Hum. Cell* 10,
15 221–230, 1997).

Molecular and genetic studies in the yeasts *Saccharomyces cerevisiae* and *Schizosaccharomyces pombe* have identified an intricate network of genes required for the S-G2/M checkpoint, which ensures cell cycle arrest in response to DNA damage and/or incomplete DNA replication (Weinert, T.,
20 *Curr. Opin. Genet. Dev.* 8, 185–193, 1998). In fission yeast, a group of six nonessential checkpoint rad proteins, Hus1, Rad1, Rad3, Rad9, Rad17, and Rad26, constitute the sensory machinery of fission yeast checkpoint cascade (Humphrey, T., *Mutat. Res.* 451, 211–226, 2000). These proteins are required for cell cycle arrest in response to the inhibition of DNA synthesis
25 by compounds such hydroxyurea or DNA damages caused by UV and gamma radiation (Humphrey, T., *Mutat. Res.* 451, 211–226, 2000). These proteins have been highly conserved during evolution, and related proteins have been found in many other eukaryotes, including humans (Venclovas, C. & Thelen, M.P. *Nucleic Acids Res.* 28, 2481–2493, 2000). The human
30 analogs of these checkpoint rad proteins are referred to as hHus1, hRad1, hRad3, hRad9, and hRad17. Rad26 does not have a homolog in humans.

hRad9 interacts with hRad1 and hHus1 in a stable complex that has been dubbed the 9-1-1- complex (Burtelow et al., *J. Biol. Chem.*, 276, 25903-

25909, 2001). Structural homology between each member of the 9-1-1 complex and the replication processivity factor proliferating cell nuclear antigen (PCNA) has led to the hypothesis that the 9-1-1 complex replaces replication associated PCNA-dependent functions during DNA repair
5 (Caspari et al., *Mol. Cell. Biol.*, 20, 1254-1262, 2000). During DNA replication, the PCNA homotrimer forms a ring-like sliding clamp over DNA and acts to increase the processivity of DNA polymerase. The 9-1-1/PCNA model is supported by the observation that hRad9, hRad1, and hHus1 each interact with hRad17, which shares extensive homology to subunits of
10 replication factor C, a protein required for loading PCNA¹ onto DNA (Mossi, R, and Hubscher, U., *Eur. J. Biochem.*, 254, 209-216, 1998). Further studies have shown that DNA damage induces not only hyperphosphorylation of hRad9 and hRad1 but also the association of the 9-1-1 complex with chromatin. From this, a model has emerged in which
15 hRad17-dependent loading of 9-1-1 onto DNA at sites of damage could coordinate a multi-faceted checkpoint response (St.Onge et al., *J. Biol. Chem.*, 276, 41898-41905, 2001).

Biomolecular studies *in vitro* and experimental models suggest that 4,5-dihydro-3-methylene-2-[3H]furanone, "Securolide" binds to intracellular
20 structures to trigger intrinsic immune regulators that prevent the growth of aberrant cells. Securolide results in cell death of Rad9 mutant yeast strains. Based on this data, it is believed that Securolide interacts with mutant hRad9 in cancer cells to produce DNA lesions which lead to apoptosis. Bioassays involving mutant strains of *Saccharomyces cerevisiae* showed cytotoxicity
25 only on the mutant strains and more specifically to the rad9 gene. This suggests that Securolide has selective cytotoxicity on unstable genomes. Human clinical trials have demonstrated that the *in vitro* assays are predictive of efficacy in the treatment of cancer and other disease, including patients with breast and prostate cancer who had failed conventional
30 chemotherapy and radiation therapy.

Damaged DNA in *S. cerevisiae* activates the gene rad9, which is known as a cell cycle repair checkpoint protein, to arrest the cell cycle after damage has occurred. Rad9 may also promote pro-apoptosis (cell suicide)

and suppress cell division. Bioassays show that Securoside causes injuries to damaged DNA through rad9. Hrad9 is the homolog of rad9 in human tumor cells. Since Securoside is cytotoxic to rad9 mutants in other types of yeasts, it is expected that Securoside targets hrad9 in humans to destabilize the
5 genomes of malignant cells.

The p53 gene is a tumor suppressor gene, i.e., its activity stops the formation of tumors. If a person inherits only one functional copy of the p53 gene from their parents, they are predisposed to cancer and usually develop several independent tumors in a variety of tissues in early adulthood. This
10 condition is rare, and is known as Li-Fraumeni syndrome. However, mutations in p53 are found in most tumor types, and so contribute to the complex network of molecular events leading to tumor formation.

The p53 gene has been mapped to chromosome 17. In the cell, p53 protein binds DNA, which in turn stimulates another gene to produce a
15 protein called p21 that interacts with a cell division-stimulating protein (cdk2). When p21 is complexed with cdk2 the cell cannot pass through to the next stage of cell division. Mutant p53 can no longer bind DNA in an effective way, and as a consequence the p21 protein is not made available to act as the 'stop signal' for cell division. Thus cells divide uncontrollably, and
20 form tumors.

p53 becomes activated in response to myriad stress types, which include but is not limited to DNA damage (induced by either UV, IR, or chemical agents such as hydrogen peroxide), oxidative stress, osmotic shock, ribonucleotide depletion and deregulated oncogene expression. This
25 activation is marked by two major events. Firstly, the half-life of the p53 protein is increased drastically, leading to a quick accumulation of p53 in stressed cells. Secondly, a conformational change forces p53 to take on an active role as a transcription regulator in these cells. The critical event leading to the activation of p53 is the phosphorylation of its N-terminal
30 domain. The N-terminal transcriptional activation domain contains a large number of phosphorylation sites and can be considered as the primary target for protein kinases transducing stress signals.

The protein kinases that are known to target this transcriptional activation domain of p53 can be roughly divided into two groups. A first group of protein kinases belongs to the MAPK family (JNK1-3, ERK1-2, p38 MAPK), which is known to respond to several types of stress, such as membrane damage, oxidative stress, osmotic shock, heat shock, etc. A second group of protein kinases (ATR, ATM, CHK1 and CHK2, DNA-PK, CAK) is implicated in the genome integrity checkpoint, a molecular cascade that detects and responds to several forms of DNA damage caused by genotoxic stress. Oncogenes also stimulate p53 activation, mediated by the protein p14ARF.

In unstressed cells, p53 levels are kept low through a continuous degradation of p53. A protein called Mdm2 (also called HDM2 in humans) binds to p53, preventing its action and transports it from the nucleus to the cytosol. Also Mdm2 acts as ubiquitin ligase and covalently attaches ubiquitin to p53 and thus marks p53 for degradation by the proteasome. However, ubiquitylation of p53 is reversible. A ubiquitin specific protease, USP7 (or HAUSP), can cleave ubiquitin off p53, thereby protecting it from proteasome-dependent degradation. This is one means by which p53 is stabilized in response to oncogenic insults.

Phosphorylation of the N-terminal end of p53 by the above-mentioned protein kinases disrupts Mdm2-binding. Other proteins, such as Pin1, are then recruited to p53 and induce a conformational change in p53 which prevents Mdm2-binding even more. Phosphorylation also allows for binding of transcriptional coactivators, like p300 or PCAF, which then acetylate the carboxy-terminal end of p53, exposing the DNA binding domain of p53, allowing it to activate or repress specific genes. Deacetylase enzymes, such as Sirt1 and Sirt7, can deacetylate p53, leading to an inhibition of apoptosis. Some oncogenes can also stimulate the transcription of proteins which bind to MDM2 and inhibit its activity.

Assay Systems

The studies of the efficacy of Securotide in inducing selective cell death in Rad9 and/or p53 mutant yeast cell lines demonstrates the feasibility

of using the cell lines to screen for other compounds that selectively induce cell death in Rad9 and/or p53 mutant lines as compared to the wild-type lines, or animal models. Suitable cell lines and animal models are commercially available or can be prepared with routine effort. For example, 5 the American Type Culture Collection, Manassas, VA 20108, lists several Rad9 mutant strains of yeast (catalog numbers 90731; 90730; 74154, 4003576, 4023576, and 4033576. A zebrafish containing a homologous cloned RAD9 is available from ATCC as catalog number 10169289. There are also numerous scientific publications on yeast strains that have various 10 defects involving not just RAD9 and/or p53 but other aspects of the complex involving RAD9 and/or p53, which may also be used to screen for compounds that induce cell death as compared to normal cells. Normal cells, especially mammalian cells, can also be engineered to induce mutations into the hRAD9 and/or p53 gene, for use in assays. The human homolog is listed 15 in the NCBI data base, along with the genes for mice and rats. (LocusID 5883).

Mutations are preferably introduced by site-directed mutagenesis. Site-directed mutagenesis is a molecular biology technique in which a mutation is created at a defined site in a DNA molecule. In general, site- 20 directed mutagenesis requires that the wild-type gene sequence be known. An oligonucleotide with its sequence containing a desired mutation is chemically synthesized. The oligonucleotide is attached by base pair hydrogen bonding to the complementary wild-type gene sequence. The synthetic oligonucleotide is used as a primer for the in vitro synthesis of a 25 new DNA strand that is complementary to the original (template) strand. The DNA synthesis is performed by adding the enzyme DNA polymerase to the DNA template. The newly synthesized strand of DNA has the primer and the desired mutation incorporated into it. By using a pair of primers and the polymerase chain reaction it is possible to amplify the newly created DNA 30 molecule and produce enough copies to make further manipulation of the new DNA possible. Typically, the mutated DNA is then inserted into an expression vector by means of restriction enzymes and DNA ligase. The expression vector is then typically inserted into a cell where it can be used as

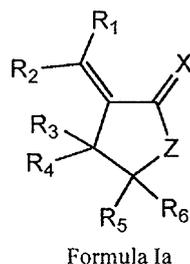
a genetic template for the synthesis of a mutated protein. The biological activity of the mutated protein can then be compared to that of the wild-type protein.

Assays

5 In a preferred embodiment, the compound to be screened for activity is added to both normal (i.e., not having a deficiency in a checkpoint protein complex including Rad9 and/or a mutation in the p53 gene) and abnormal cells (i.e., having a mutation or inactivation in one or more of the proteins, or genes encoding the proteins, in the checkpoint protein complex including
10 Rad9 and/or in p53). Those compounds which cause cell death in the abnormal cells as compared to the normal cells are then screened in further assays to assess general cytotoxicity and activity against specific cell types, such as tumor cells, bacterial cells, and virally infected cells.

Compounds

15 Suitable compounds which may exhibit anti-tumor activity through the selective targeting of the hRad9 and/or p53 gene in humans include:



Formula Ia

wherein

20 R₁-R₆ taken independently or R₃-R₆ taken together are a hydrogen atom, a halogen atom, a hydroxyl group, or any other organic groupings containing any number of carbon atoms, preferably 1 – 8 carbon atoms, and optionally include a heteroatom such as oxygen, sulfur, or nitrogen grouping in linear, branched, or cyclic structural formats. R₁-R₆ may be substituted or unsubstituted.

25 R₁-R₆ are selected from alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, phenyl, substituted phenyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, halo, hydroxyl, alkoxy,

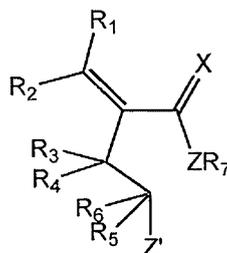
substituted alkoxy, phenoxy, substituted phenoxy, aroxy, substituted aroxy, alkylthio, substituted alkylthio, phenylthio, substituted phenylthio, arylthio, substituted arylthio, cyano, isocyano, substituted isocyano, carbonyl, substituted carbonyl, carboxyl, substituted carboxyl, amino, substituted

5 amino, amido, substituted amido, sulfonyl, substituted sulfonyl, sulfonic acid, phosphoryl, substituted phosphoryl, phosphonyl, substituted phosphonyl, polyaryl, substituted polyaryl, C1-C20 cyclic, substituted C1-C20 cyclic, heterocyclic, substituted heterocyclic, aminoacid, peptide, or polypeptide group;

10 Z is a heteratom such as oxygen, sulfur, or nitrogen grouping in linear, branched, or cyclic structural formats; and

X is a heteratom such as oxygen, sulfur, or nitrogen grouping in linear, branched, or cyclic structural formats.

15 In another embodiment, the compound has the following chemical structure:



Formula Ib

wherein

R₁-R₇ taken independently or R₃-R₆ taken together may be a hydrogen atom, a halogen atom, a hydroxyl group, or any other organic

20 groupings containing any number of carbon atoms, preferably 1 – 8 carbon atoms, and optionally include a heteroatom such as oxygen, sulfur, or nitrogen grouping in linear, branched, or cyclic structural formats, representative R₁-R₆ groupings being alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, phenyl, substituted phenyl,

25 aryl, substituted aryl, heteroaryl, substituted heteroaryl, halo, hydroxyl, alkoxy, substituted alkoxy, phenoxy, substituted phenoxy, aroxy, substituted

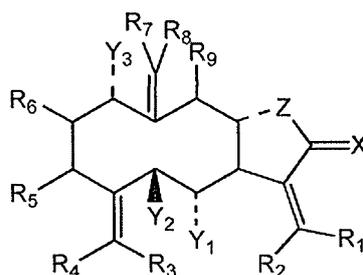
aroxy, alkylthio, substituted alkylthio, phenylthio, substituted phenylthio, arylthio, substituted arylthio, cyano, isocyano, substituted isocyano, carbonyl, substituted carbonyl, carboxyl, substituted carboxyl, amino, substituted amino, amido, substituted amido, sulfonyl, substituted sulfonyl, sulfonic acid, phosphoryl, substituted phosphoryl, phosphonyl, substituted phosphonyl, polyaryl, substituted polyaryl, C1-C20 cyclic, substituted C1-C20 cyclic, heterocyclic, substituted heterocyclic, aminoacid, peptide, or polypeptide group;

X is a heteroatom such as oxygen, sulfur, or nitrogen grouping in linear, branched, or cyclic structural formats;

Z is a heteroatom such as oxygen, sulfur, or nitrogen grouping in linear, branched, or cyclic structural formats; and

Z' may a hydrogen atom, a halogen atom, a hydroxyl group, or any other organic composition containing from 1 – 8 carbon atoms and optionally include a heteroatom such as oxygen, sulfur, or nitrogen grouping in linear, branched, or cyclic structural formats.

In still another embodiment, the lactones having an alpha-methylene group can have the structure as show below:



Formula Ic

20 wherein

R1-R9 taken independently or R5 and R6 taken together may be a hydrogen atom, a halogen atom, a hydroxyl group, or any other organic groupings containing any number of carbon atoms, preferably 1 – 8 carbon atoms, and optionally include a heteroatom such as oxygen, sulfur, or nitrogen grouping in linear, branched, or cyclic structural formats, representative R1-R6 groupings being alkyl, substituted alkyl, alkenyl,

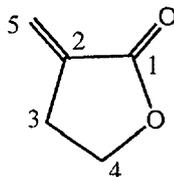
substituted alkenyl, alkynyl, substituted alkynyl, phenyl, substituted phenyl,
aryl, substituted aryl, heteroaryl, substituted heteroaryl, halo, hydroxyl,
alkoxy, substituted alkoxy, phenoxy, substituted phenoxy, aroxy, substituted
aroxy, alkylthio, substituted alkylthio, phenylthio, substituted phenylthio,
5 arylthio, substituted arylthio, cyano, isocyano, substituted isocyano,
carbonyl, substituted carbonyl, carboxyl, substituted carboxyl, amino,
substituted amino, amido, substituted amido, sulfonyl, substituted sulfonyl,
sulfonic acid, phosphoryl, substituted phosphoryl, phosphonyl, substituted
phosphonyl, polyaryl, substituted polyaryl, C1-C20 cyclic, substituted C1-
10 C20 cyclic, heterocyclic, substituted heterocyclic, aminoacid, peptide, or
polypeptide group;

Y₁, Y₂, and Y₃ taken independently or Y₁ and Y₂ taken together may
be a hydrogen atom, a halogen atom, a hydroxyl group, or any other organic
groupings containing any number of carbon atoms, preferably 1 – 8 carbon
15 atoms, and optionally include a heteroatom such as oxygen, sulfur, or
nitrogen grouping in linear, branched, or cyclic structural formats,
representative R₁-R₆ groupings being alkyl, substituted alkyl, alkenyl,
substituted alkenyl, alkynyl, substituted alkynyl, phenyl, substituted phenyl,
aryl, substituted aryl, heteroaryl, substituted heteroaryl, halo, hydroxyl,
20 alkoxy, substituted alkoxy, phenoxy, substituted phenoxy, aroxy, substituted
aroxy, alkylthio, substituted alkylthio, phenylthio, substituted phenylthio,
arylthio, substituted arylthio, cyano, isocyano, substituted isocyano,
carbonyl, substituted carbonyl, carboxyl, substituted carboxyl, amino,
substituted amino, amido, substituted amido, sulfonyl, substituted sulfonyl,
25 sulfonic acid, phosphoryl, substituted phosphoryl, phosphonyl, substituted
phosphonyl, polyaryl, substituted polyaryl, C1-C20 cyclic, substituted C1-
C20 cyclic, heterocyclic, substituted heterocyclic, aminoacid, peptide, or
polypeptide group;

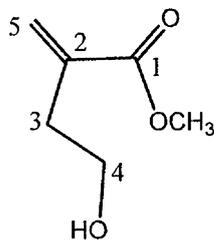
Z is a heteroatom such as oxygen, sulfur, or nitrogen grouping in
30 linear, branched, or cyclic structural formats; and

X is a heteroatom such as oxygen, sulfur, or nitrogen grouping in
linear, branched, or cyclic structural formats.

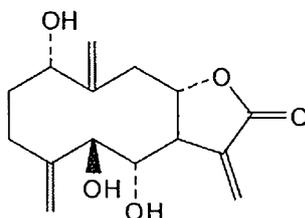
In one embodiment, the lactone is a securoside, which is an α -methylene-lactone (1) having the structure:



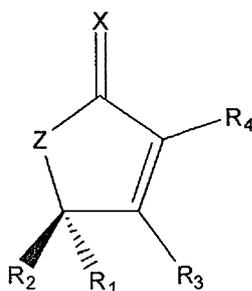
5 In another embodiment, the ester is methyl α -methylene- γ -hydroxybutanoate (2) as shown in the following structure:



10 In still another embodiment, the lactone is a bicyclic compound having the following structure:



Other suitable compounds may include:



Formula Id

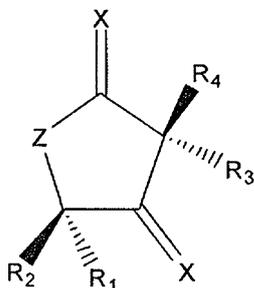
wherein

R₁-R₄ taken independently may be a hydrogen atom, a halogen atom,
 5 a hydroxyl group, or any other organic groupings containing any number of
 carbon atoms, preferably 1 – 8 carbon atoms, and optionally include a
 heteroatom such as oxygen, sulfur, or nitrogen grouping in linear, branched,
 or cyclic structural formats, representative R₁-R₄ groupings being H, alkyl,
 substituted alkyl, allyl, substituted allyl, alkenyl, substituted alkenyl, alkynyl,
 10 substituted alkynyl, phenyl, substituted phenyl, aryl, substituted aryl,
 heteroaryl, substituted heteroaryl, halo, hydroxyl, alkoxy, substituted alkoxy,
 alloxy, phenoxy, substituted phenoxy, aroxy, substituted aroxy, alkylthio,
 substituted alkylthio, phenylthio, substituted phenylthio, arylthio, substituted
 arylthio, cyano, isocyano, substituted isocyano, carbonyl, substituted
 15 carbonyl, carboxyl, substituted carboxyl, amino, substituted amino, amido,
 substituted amido, sulfonyl, substituted sulfonyl, sulfonic acid, phosphoryl,
 substituted phosphoryl, phosphonyl, substituted phosphonyl, polyaryl,
 substituted polyaryl, C1-C20 cyclic, substituted C1-C20 cyclic, heterocyclic,
 substituted heterocyclic, aminoacid, peptide, or polypeptide group;

20 X is a heteroatom such as oxygen, sulfur, or nitrogen grouping in
 linear, branched, or cyclic structural formats; and

Z is a heteroatom such as oxygen, sulfur, or nitrogen grouping in
 linear, branched, or cyclic structural formats.

In still another embodiment, the lactones having an alpha-methylene group can have the structure as show below:



Formula Ie

wherein

- 5 R₁-R₄ taken independently may be a hydrogen atom, a halogen atom, a hydroxyl group, or any other organic groupings containing any number of carbon atoms, preferably 1 – 8 carbon atoms, and optionally include a heteroatom such as oxygen, sulfur, or nitrogen grouping in linear, branched, or cyclic structural formats, representative R₁-R₄ groupings being alkyl, allyl, substituted alkyl, alkenyl, allyl, substituted allyl, substituted alkenyl, alkynyl, substituted alkynyl, phenyl, substituted phenyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, halo, hydroxyl, alkoxy, substituted alkoxy, alloxy, phenoxy, substituted phenoxy, aroxy, substituted aroxy, alkylthio, substituted alkylthio, phenylthio, substituted phenylthio, arylthio, substituted arylthio, cyano, isocyano, substituted isocyano, carbonyl, substituted carbonyl, carboxyl, substituted carboxyl, amino, substituted amino, amido, substituted amido, sulfonyl, substituted sulfonyl, sulfonic acid, phosphoryl, substituted phosphoryl, phosphonyl, substituted phosphonyl, polyaryl, substituted polyaryl, C1-C20 cyclic, substituted C1-C20 cyclic, heterocyclic, substituted heterocyclic, aminoacid, peptide, or polypeptide group;

Z is a heteroatom such as oxygen, sulfur, or nitrogen grouping in linear, branched, or cyclic structural formats; and

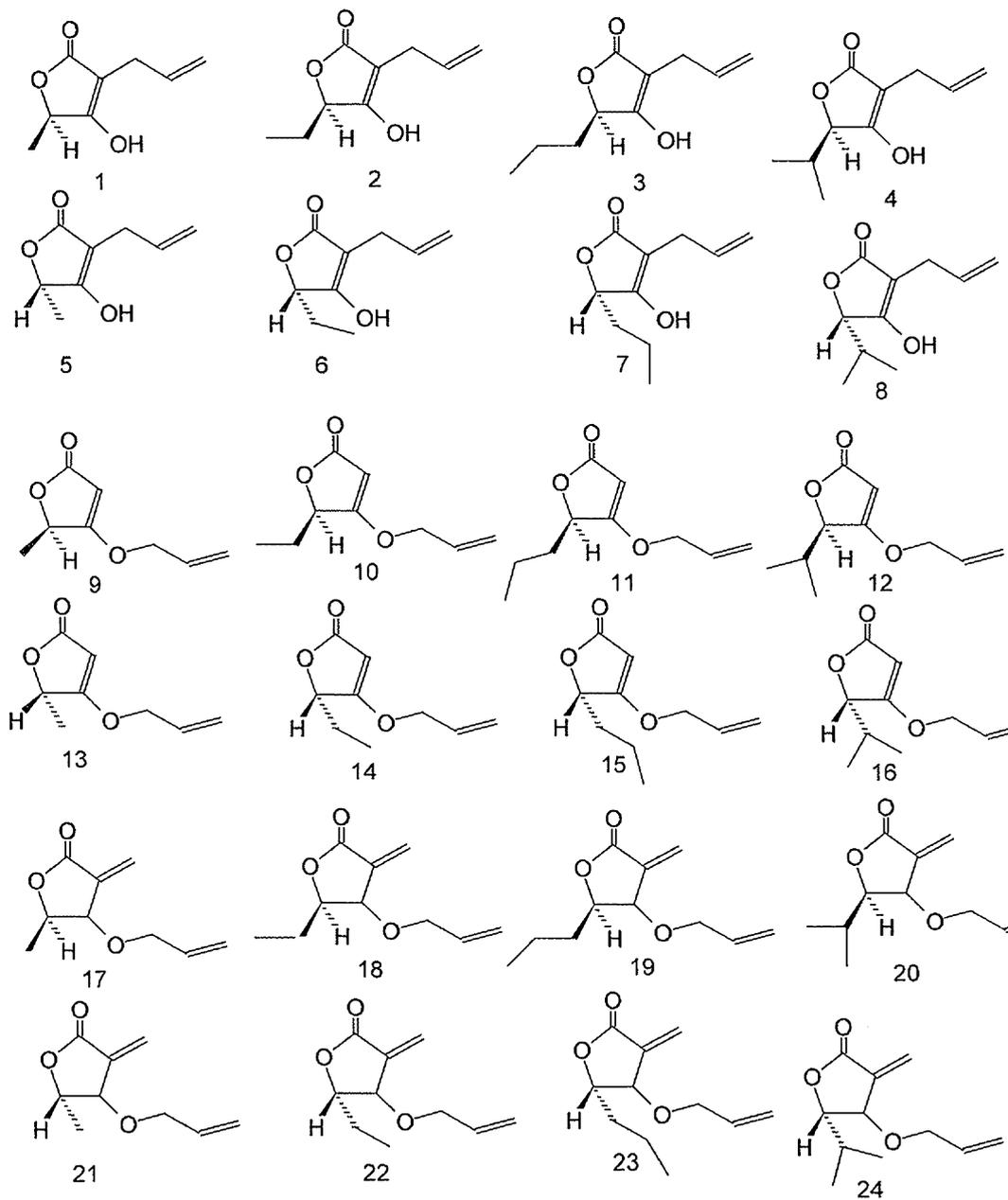
X is a heteroatom such as oxygen, sulfur, or nitrogen grouping in linear, branched, or cyclic structural formats.

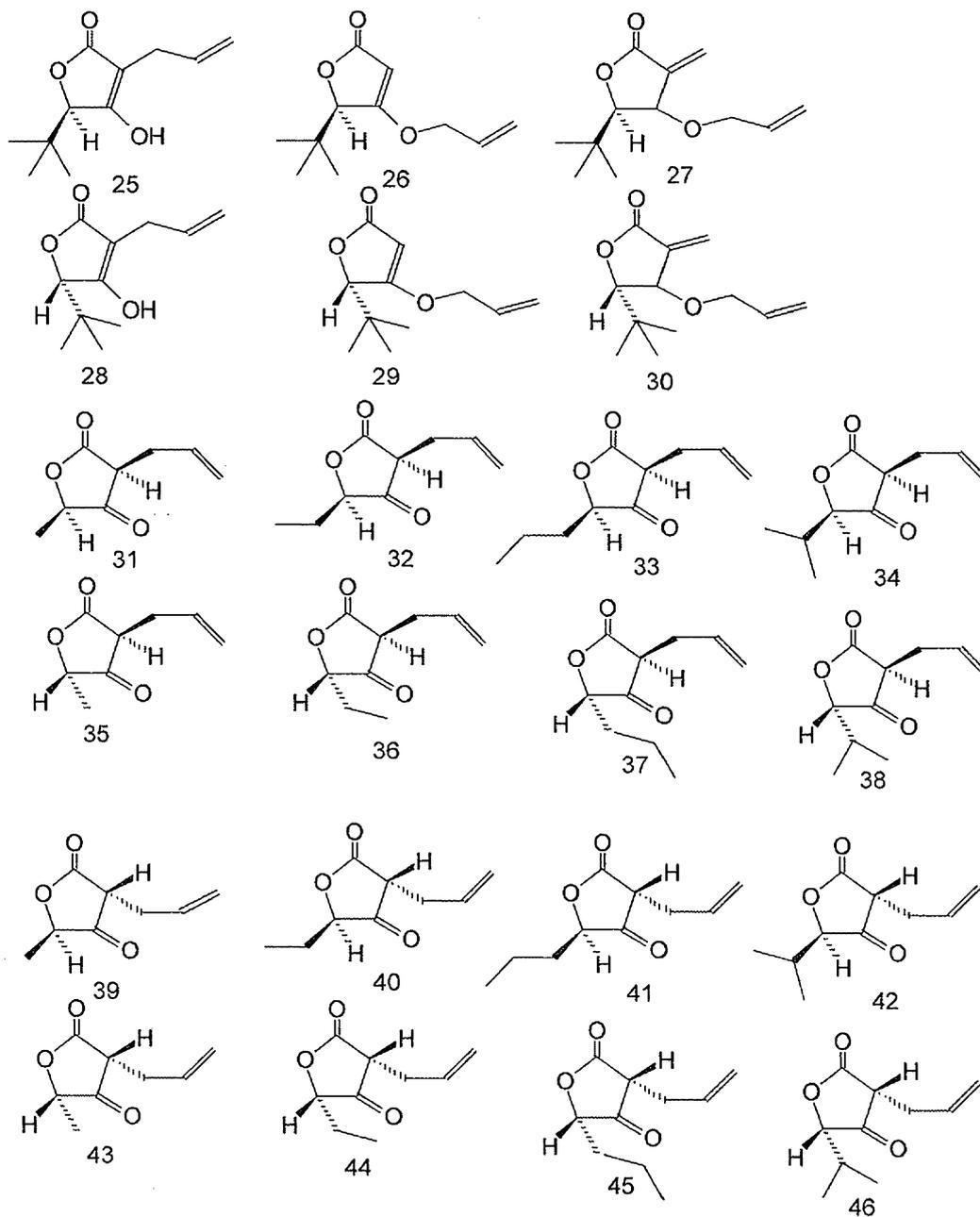
- 25 Suitable compounds also include metabolites of the compounds described above, stereoisomers of the compounds described above,

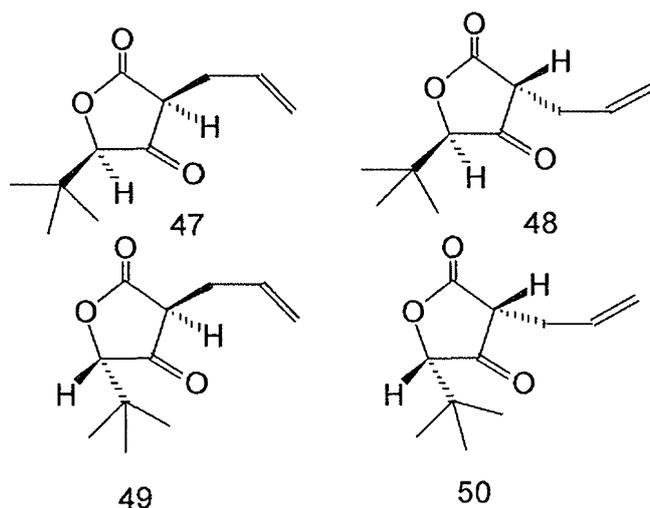
pharmaceutically acceptable salts thereof, and combinations thereof.

Representative lactones are listed in Table

I:







Pharmaceutically acceptable acid addition salts of compounds of formula Ia-Ie may be prepared in a conventional manner by treating a solution or suspension of the free base with about one chemical equivalent of a pharmaceutically acceptable acid. Conventional concentration and recrystallization techniques can be employed to isolate the salt.

The pharmaceutically acceptable base addition salts of compounds containing an acid group may be prepared in a conventional manner from the acid, e.g. by reaction with about one chemical equivalent of a base.

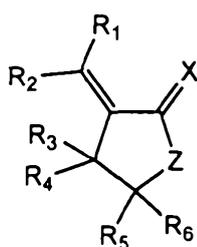
The present invention will be further understood by reference to following non-limiting examples.

Example 1: Bioassay with Securolide on *Saccharomyces Cerevisiae*

Bioassays on solid mediums were performed with Securolide (LMSV-6) in a concentration between ten and one hundred micrograms/milliliter on a set of mutant strains of *Saccharomyces cerevisiae* with DNA similar to that in tumor/cancer cells. Securolide showed marked cytotoxic activity only on the mutant strains, specifically the gene rad9. This indicates that Securolide has selective cytotoxicity to cells having unstable genomes.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method for screening for compounds having anti-cancer activity comprising
 (a) providing cells having one or more mutations in the cell cycle checkpoint
 5 protein complex that includes Rad9, wherein the cells have a mutation in the Rad9
 gene, and wherein the cells are defective in the Rad9 protein-mediated cell cycle arrest;
 (b) adding a compound to be screened to the cells, wherein the compound has
 the structure of Formula Ia:



Formula Ia

- 10 wherein R₁-R₆ independently are selected from a hydrogen atom, a halogen
 atom, a hydroxyl group, alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl,
 substituted alkynyl, phenyl, substituted phenyl, aryl, substituted aryl, heteroaryl,
 substituted heteroaryl, halo, hydroxyl, alkoxy, phenoxy, substituted phenoxy, aroxy,
 substituted aroxy, alkylthio, phenylthio, substituted phenylthio, arylthio, substituted
 15 arylthio, cyano, isocyano, substituted isocyano, carbonyl, carboxyl, substituted
 carboxyl, amino, substituted amino, amido, substituted amido, sulfonyl, sulfonic acid,
 phosphoryl, phosphonyl, polyaryl, substituted polyaryl, C₃-C₂₀ cyclic, substituted C₃-
 C₂₀ cyclic, heterocyclic, substituted heterocyclic, an amino acid, a peptide, or a
 polypeptide group; or R₃-R₆ taken together form a substituted or unsubstituted ring that
 20 optionally includes one or more heteroatoms selected from the group consisting of
 oxygen, sulfur, and nitrogen;
 Z is a heteroatom selected from oxygen, sulfur, or nitrogen; and
 X is a heteroatom selected from oxygen, sulfur, or nitrogen;
 (c) determining if the compound kills or induces apoptosis in some or all of
 25 the cells;
 (d) comparing the resultant determination of step (c) to the resultant
 determination induced by the compound in normal cells not having the one or more
 mutations in (a) to determine if the compound has anti-cancer activity.
- 30 2. The method of claim 1, wherein the cells are yeast cells.

3. The method of claim 1, wherein the cells are mammalian cells.
4. The method of claim 1, wherein the cells are tumor cells.
- 5 5. The method of any preceding claim, wherein the cells have an inactive or less active Rad9 protein.
6. The method of claim 3, wherein the method is an *in vitro* assay.
- 10 7. The method of any preceding claim, substantially as described herein.