

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
10 May 2007 (10.05.2007)

PCT

(10) International Publication Number
WO 2007/053725 A2

(51) International Patent Classification:
A61K 31/5513 (2006.01)

(21) International Application Number:
PCT/US2006/042753

(22) International Filing Date:
1 November 2006 (01.11.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/732,045 1 November 2005 (01.11.2005) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: NOVEL 1,4-BENZODIAZEPINE-2,5-DIONES WITH THERAPEUTIC PROPERTIES

(57) Abstract: The present invention relates to novel chemical compounds, methods for their discovery, and their therapeutic use. In particular, the present invention provides novel 1,4- benzodiazepine-2,5-dione compounds, and methods of using novel 1,4-benzodiazepine-2,5-dione compounds as therapeutic agents to treat a number of conditions associated with the faulty regulation of the processes of programmed cell death, autoimmunity, inflammation, hyperproliferation, and the like.



WO 2007/053725 A2

NOVEL 1,4-BENZODIAZEPINE-2,5-DIONES WITH THERAPEUTIC PROPERTIES

The present application claims priority to U.S. Provisional Patent Application Serial
5 No. 60/732,045, filed 11/01/2005, which is herein incorporated by reference in its entirety.

This invention was made with government support under AI 47450 awarded by the National Institutes of Health. The government has certain rights in the invention.

FIELD OF THE INVENTION

10 The present invention relates to novel chemical compounds, methods for their discovery, and their therapeutic use. In particular, the present invention provides novel 1,4-benzodiazepine-2,5-dione compounds, and methods of using novel 1,4-benzodiazepine-2,5-dione compounds as therapeutic agents to treat a number of conditions associated with the faulty regulation of the processes of programmed cell death, autoimmunity, inflammation,
15 hyperproliferation, vascular abnormalities, cancer, anti-angiogenesis, and the like.

BACKGROUND OF THE INVENTION

Multicellular organisms exert precise control over cell number. A balance between cell proliferation and cell death achieves this homeostasis. Cell death occurs in nearly every
20 type of vertebrate cell via necrosis or through a suicidal form of cell death, known as apoptosis. Apoptosis is triggered by a variety of extracellular and intracellular signals that engage a common, genetically programmed death mechanism.

Multicellular organisms use apoptosis to instruct damaged or unnecessary cells to destroy themselves for the good of the organism. Control of the apoptotic process therefore
25 is very important to normal development, for example, fetal development of fingers and toes requires the controlled removal, by apoptosis, of excess interconnecting tissues, as does the formation of neural synapses within the brain. Similarly, controlled apoptosis is responsible for the sloughing off of the inner lining of the uterus (the endometrium) at the start of menstruation. While apoptosis plays an important role in tissue sculpting and normal
30 cellular maintenance, it is also the primary defense against cells and invaders (*e.g.*, viruses) which threaten the well being of the organism.

Not surprisingly many diseases are associated with dysregulation of the process of cell death. Experimental models have established a cause-effect relationship between

aberrant apoptotic regulation and the pathenogenicity of various neoplastic, autoimmune and viral diseases. For instance, in the cell mediated immune response, effector cells (*e.g.*, cytotoxic T lymphocytes “CTLs”) destroy virus-infected cells by inducing the infected cells to undergo apoptosis. The organism subsequently relies on the apoptotic process to destroy
5 the effector cells when they are no longer needed. Autoimmunity is normally prevented by the CTLs inducing apoptosis in each other and even in themselves. Defects in this process are associated with a variety of autoimmune diseases such as lupus erythematosus and rheumatoid arthritis.

Multicellular organisms also use apoptosis to instruct cells with damaged nucleic
10 acids (*e.g.*, DNA) to destroy themselves prior to becoming cancerous. Some cancer-causing viruses overcome this safeguard by reprogramming infected (transformed) cells to abort the normal apoptotic process. For example, several human papilloma viruses (HPVs) have been implicated in causing cervical cancer by suppressing the apoptotic removal of transformed cells by producing a protein (E6) which inactivates the p53 apoptosis promoter.
15 Similarly, the Epstein-Barr virus (EBV), the causative agent of mononucleosis and Burkitt's lymphoma, reprograms infected cells to produce proteins that prevent normal apoptotic removal of the aberrant cells thus allowing the cancerous cells to proliferate and to spread throughout the organism.

Still other viruses destructively manipulate a cell's apoptotic machinery without
20 directly resulting in the development of a cancer. For example, the destruction of the immune system in individuals infected with the human immunodeficiency virus (HIV) is thought to progress through infected CD4⁺ T cells (about 1 in 100,000) instructing uninfected sister cells to undergo apoptosis.

Some cancers that arise by non-viral means have also developed mechanisms to
25 escape destruction by apoptosis. Melanoma cells, for instance, avoid apoptosis by inhibiting the expression of the gene encoding Apaf-1. Other cancer cells, especially lung and colon cancer cells, secrete high levels of soluble decoy molecules that inhibit the initiation of CTL mediated clearance of aberrant cells. Faulty regulation of the apoptotic machinery has also been implicated in various degenerative conditions and vascular
30 diseases.

It is apparent that the controlled regulation of the apoptotic process and its cellular machinery is vital to the survival of multicellular organisms. Typically, the biochemical changes that occur in a cell instructed to undergo apoptosis occur in an orderly procession.

However, as shown above, flawed regulation of apoptosis can cause serious deleterious effects in the organism.

There have been various attempts to control and restore regulation of the apoptotic machinery in aberrant cells (*e.g.*, cancer cells). For example, much work has been done to
5 develop cytotoxic agents to destroy aberrant cells before they proliferate. As such, cytotoxic agents have widespread utility in both human and animal health and represent the first line of treatment for nearly all forms of cancer and hyperproliferative autoimmune disorders like lupus erythematosus and rheumatoid arthritis.

Many cytotoxic agents in clinical use exert their effect by damaging DNA (*e.g.*, cis-
10 diaminodichroplatanim(II) cross-links DNA, whereas bleomycin induces strand cleavage). The result of this nuclear damage, if recognized by cellular factors like the p53 system, is to initiate an apoptotic cascade leading to the death of the damaged cell.

However, existing cytotoxic chemotherapeutic agents have serious drawbacks. For example, many known cytotoxic agents show little discrimination between healthy and
15 diseased cells. This lack of specificity often results in severe side effects that can limit efficacy and/or result in early mortality. Moreover, prolonged administration of many existing cytotoxic agents results in the expression of resistance genes (*e.g.*, *bcl-2* family or multi-drug resistance (MDR) proteins) that render further dosing either less effective or useless. Some cytotoxic agents induce mutations into p53 and related proteins. Based on
20 these considerations, ideal cytotoxic drugs should only kill diseased cells and not be susceptible to chemo-resistance.

Many autoimmune diseases and haematologic malignancies result from the aberrant survival and expansion of B and T cells in central and peripheral lymphoid organs. Current therapies for these for these disorders generally employ cytotoxic drugs whose mechanisms
25 of action frequently involves DNA damage. Hence, the selectivity of these drugs is limited and often relies on the differential ability of diseased and healthy cells to tolerate and repair drug-induced cellular damage.

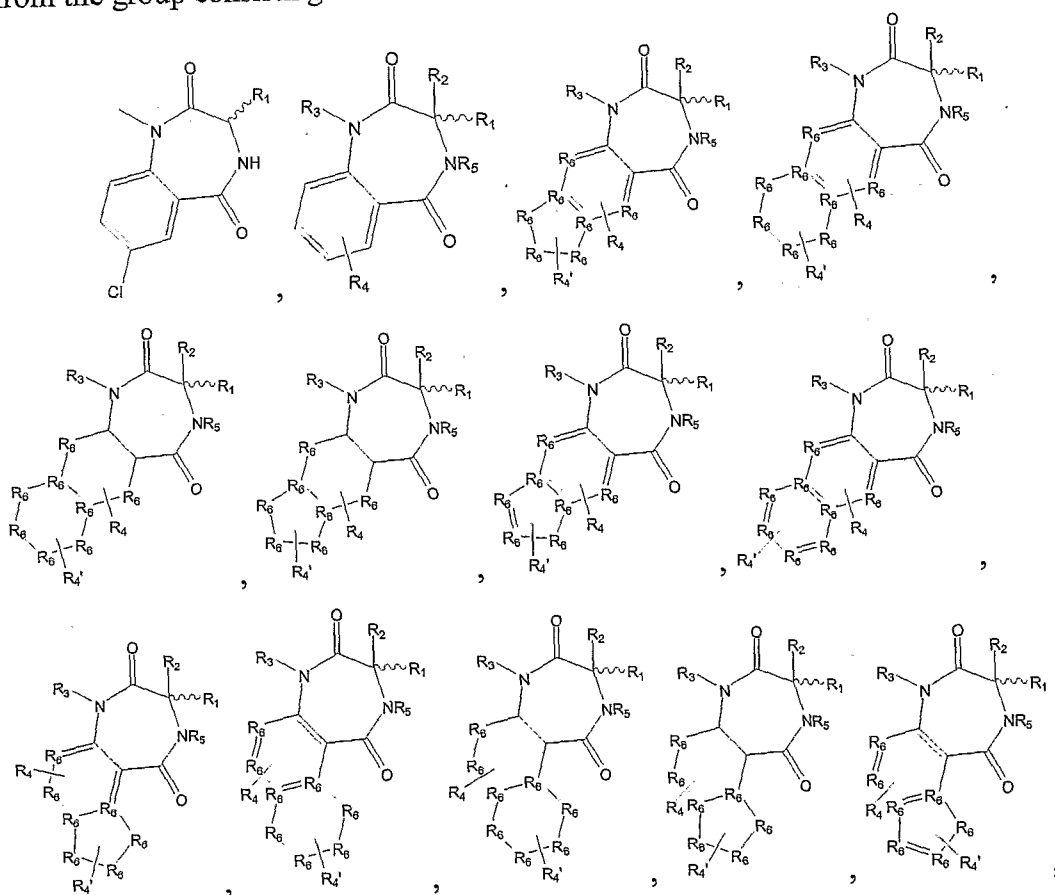
What are needed are improved compositions and methods for regulating the apoptotic processes in subjects afflicted with diseases and conditions characterized by faulty
30 regulation of these processes (*e.g.*, viral infections, hyperproliferative autoimmune disorders, chronic inflammatory conditions, and cancers).

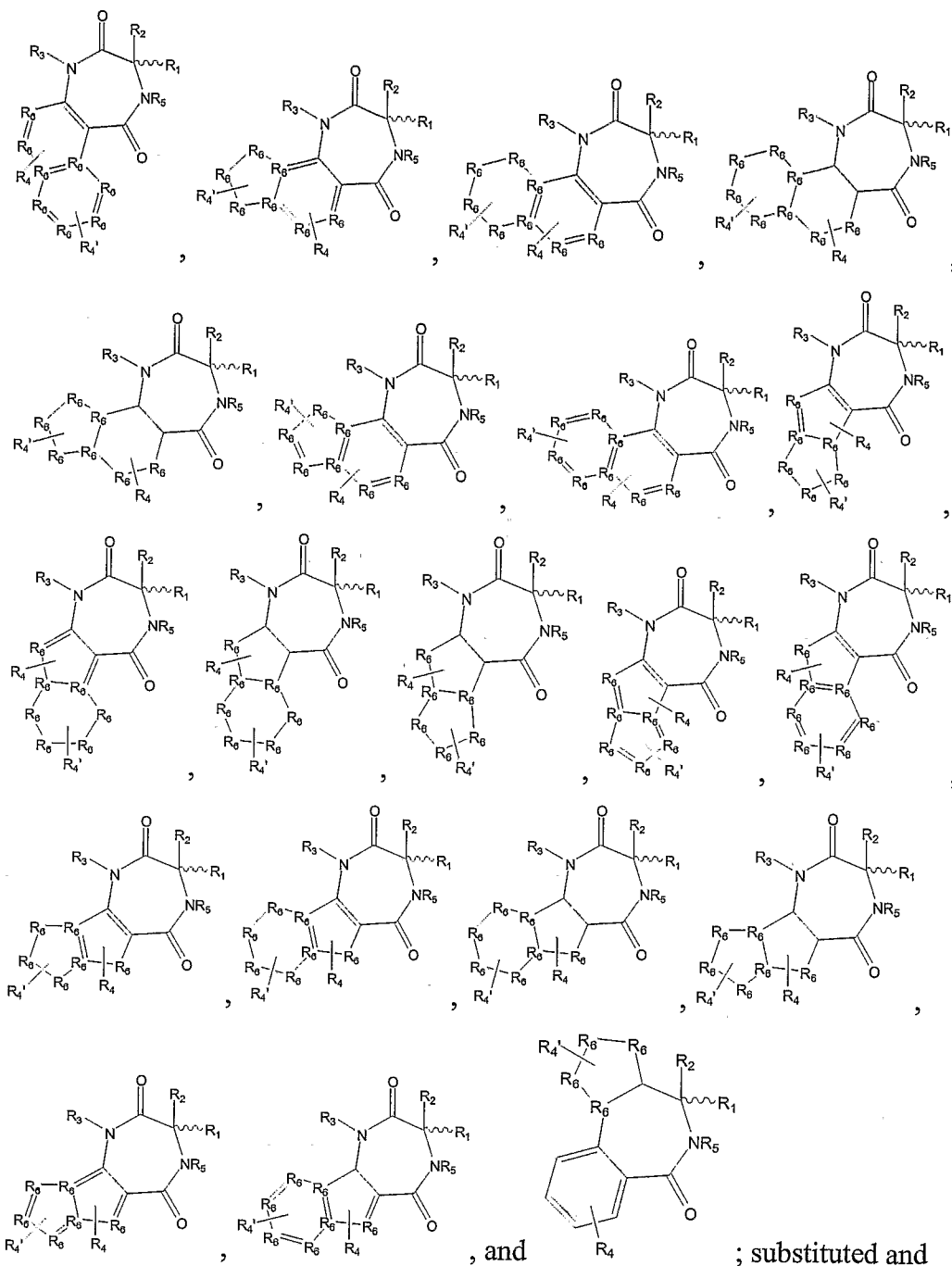
SUMMARY

The present invention relates to novel chemical compounds, methods for their discovery, and their therapeutic use. In particular, the present invention provides novel 1,4-benzodiazepine-2,5-dione compounds, and methods of using novel 1,4-benzodiazepine-2,5-dione compounds as therapeutic agents to treat a number of conditions associated with the faulty regulation of the processes of programmed cell death, cancer, anti-angiogenesis, autoimmunity, inflammation, hyperproliferation, vascular abnormalities, and the like. Such compounds and uses are described throughout the present application and represent a diverse collection of compositions and applications.

Certain preferred compositions and uses are described below. The present invention is not limited to these particular compositions and uses. The present invention provides a number of useful compositions as described throughout the present application.

In certain embodiments, the present invention provides a composition comprising novel 1,4-benzodiazepine-2,5-dione compounds. In certain embodiments, the present invention provide a composition comprising a compound described by a formula selected from the group consisting of:

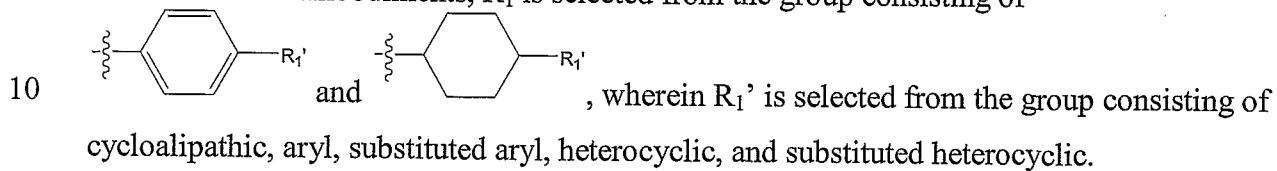




unsubstituted, including both R and S enantiomeric forms and racemic mixtures.

In some embodiments, R₁ is an electron rich heterocycle. In some embodiments, the electron rich heterocycle contains 5 or more heterocyclic atoms.

In some embodiments, R₁ is selected from the group consisting of



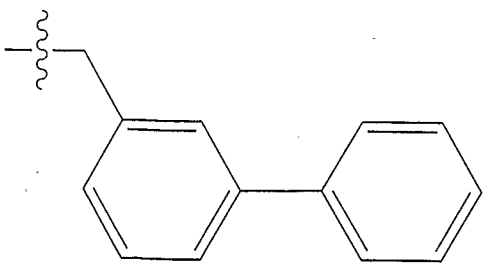
In some embodiments, R_2 is selected from the group consisting of H, alkyl, substituted alkyl, and R_1 .

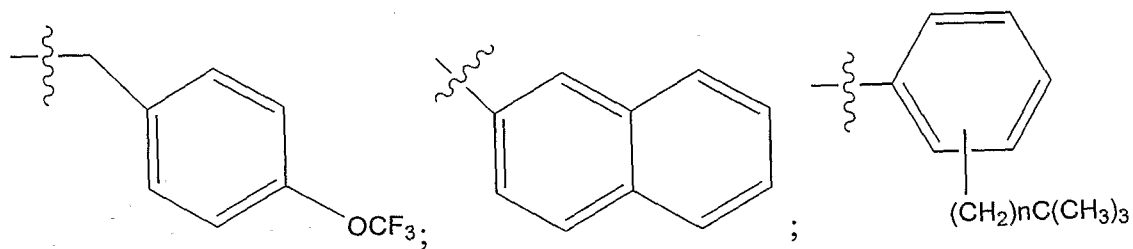
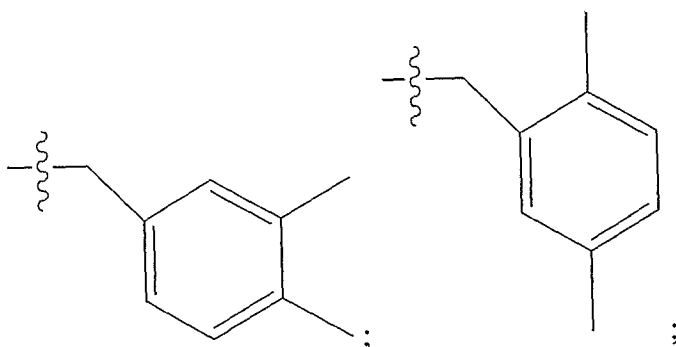
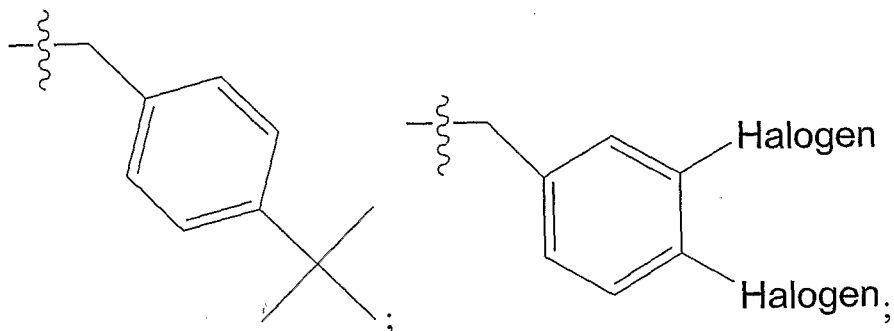
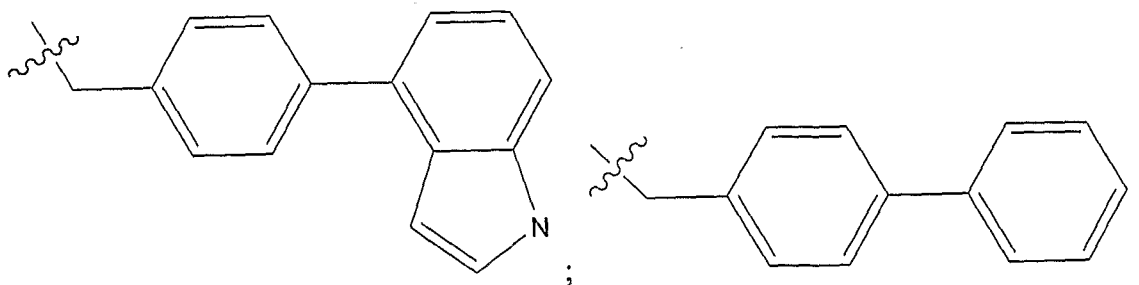
In some embodiments, R_3 is selected from the group consisting of H, alkyl, and substituted alkyl.

- 5 In some embodiments, R_3 is selected from the group consisting of hydrogen; halogen; OH; a chemical moiety comprising an aryl subgroup; a chemical moiety comprising a substituted aryl subgroup; a chemical moiety comprising a cycloaliphatic subgroup; a chemical moiety comprising a substituted cycloaliphatic subgroup; a chemical moiety comprising a heterocyclic subgroup; a chemical moiety comprising a substituted
- 10 heterocyclic subgroup; a chemical moiety comprising at least one ester subgroup; a chemical moiety comprising at least one ether subgroup; a linear or branched, saturated or unsaturated, substituted or non-substituted, aliphatic chain having at least 2 carbons; a chemical moiety comprising Sulfur; a chemical moiety comprising Nitrogen; $-OR-$, wherein R is selected from the group consisting of a chemical moiety comprising an aryl
- 15 subgroup; a chemical moiety comprising a substituted aryl subgroup; a chemical moiety comprising a cycloaliphatic subgroup; a chemical moiety comprising a substituted cycloaliphatic subgroup; a chemical moiety comprising a heterocyclic subgroup; a chemical moiety comprising a substituted heterocyclic subgroup; a linear or branched, saturated or unsaturated, substituted or non-substituted, aliphatic chain having at least 2 carbons; a
- 20 chemical moiety comprising at least one ester subgroup; a chemical moiety comprising at least one ether subgroup; a chemical moiety comprising Sulfur; a chemical moiety comprising Nitrogen.

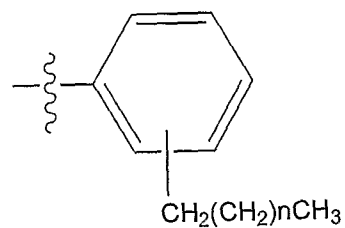
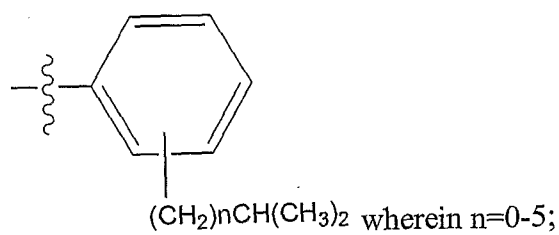
In some embodiments, R_3 is selected from group consisting of: naphthalene; phenol;

1-Napthalenol; 2-Napthalenol;

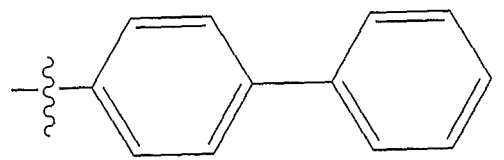
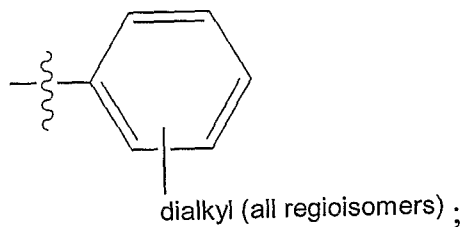


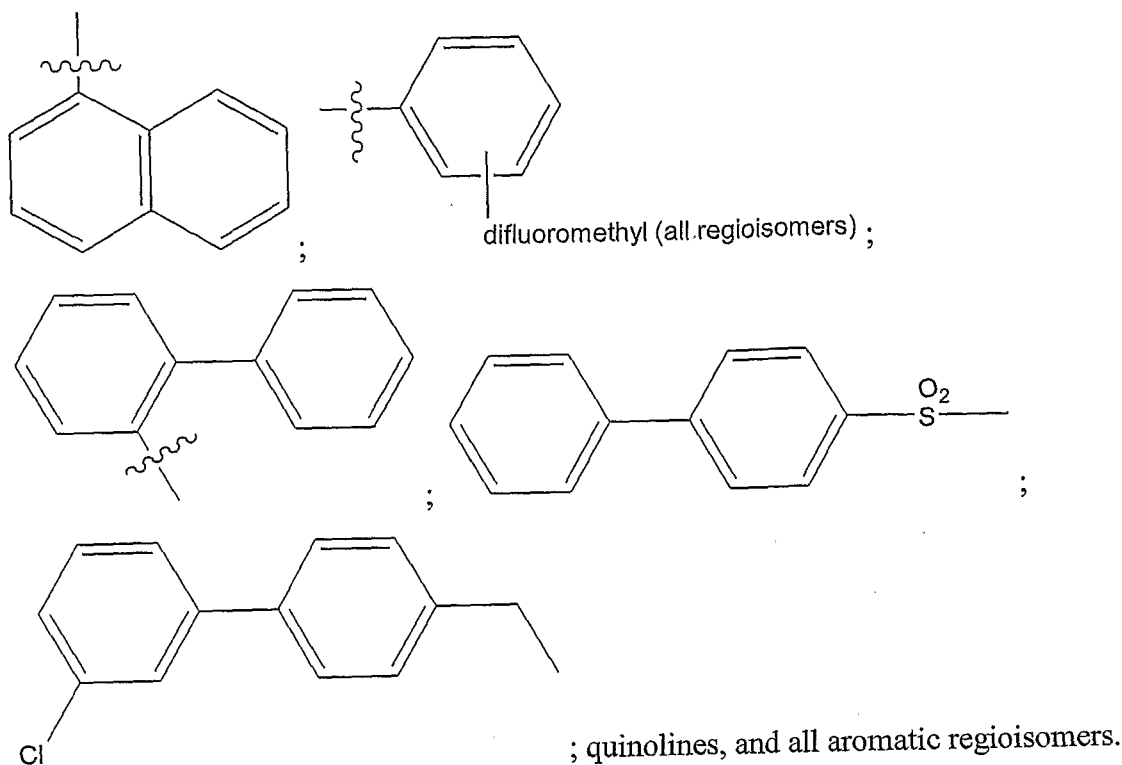


5 wherein n=0-5;



wherein n=0-5;





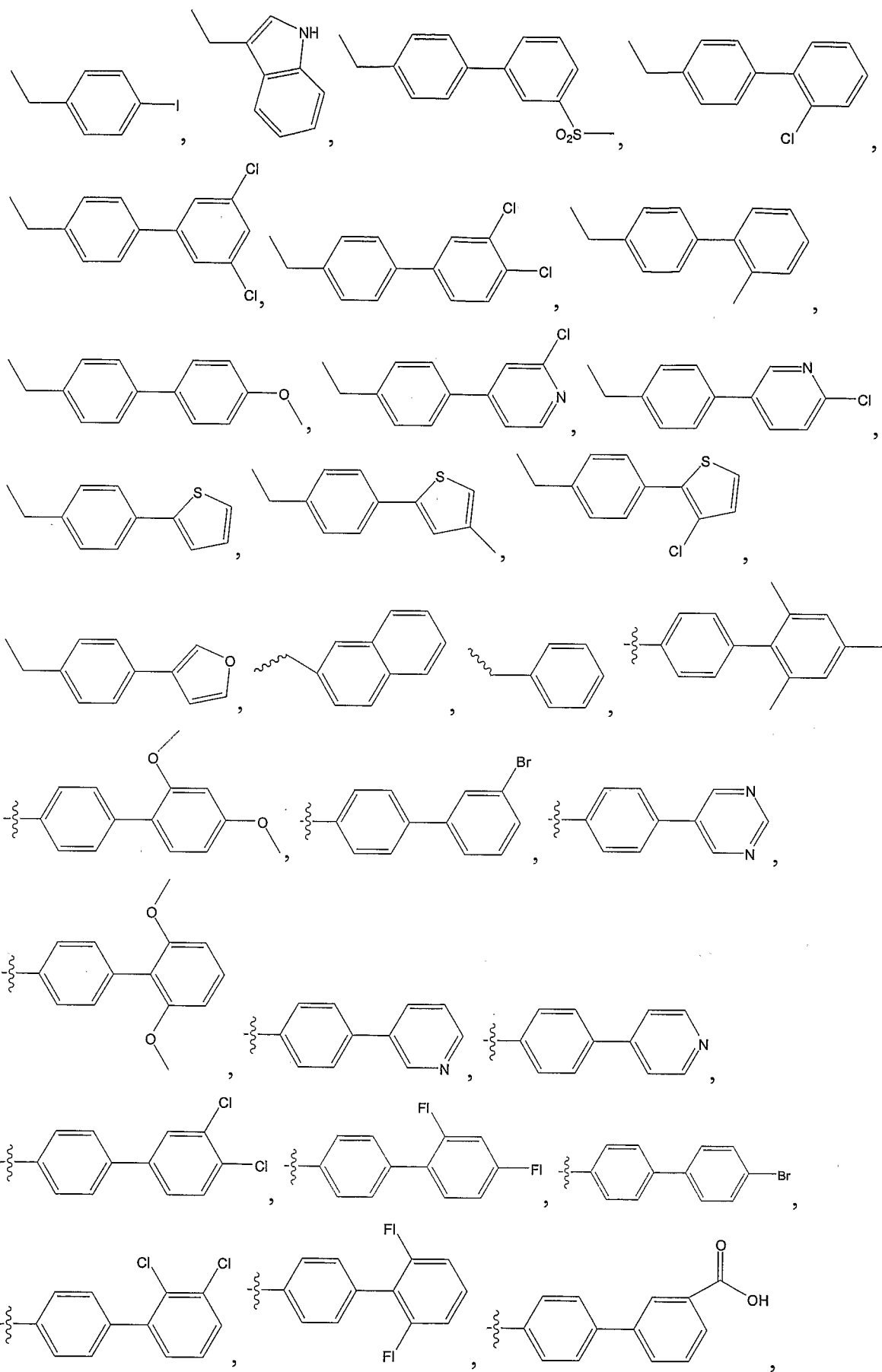
In some embodiments, the R1 and R3 groups may be interchanged (e.g., in some
 5 embodiments, the R1 group is positioned at the first position of the benzodiazepine ring and
 the R3 group is positioned at the third position of the benzodiazepine ring; in some
 embodiments, the R1 group is positioned at the third position of the benzodiazepine ring
 and the R3 group is positioned at the first position of the benzodiazepine ring).

In some embodiments, R₄ and R₄' is independently selected from the group
 10 consisting of CH₃, halogen, SO₂R₄'', SO₂N(R₄'')₂, OR₄'', N(R₄'')₂, CON(R₄'')₂,
 NHCOR₄'', NHSO₂R₄', alkyl, mono-substituted alkyl, di-substituted alkyl, tri-substituted
 alkyl; wherein R₄'' is selected from the group consisting of halogen, H, alkyl, mono-
 substituted alkyl, di-substituted alkyl, tri-substituted alkyl, aryl, mono-substituted aryl, di-
 substituted aryl, tri-substituted aryl, cycloaliphatic, mono-substituted cycloaliphatic, di-
 15 substituted cycloaliphatic, tri-substituted cycloaliphatic.

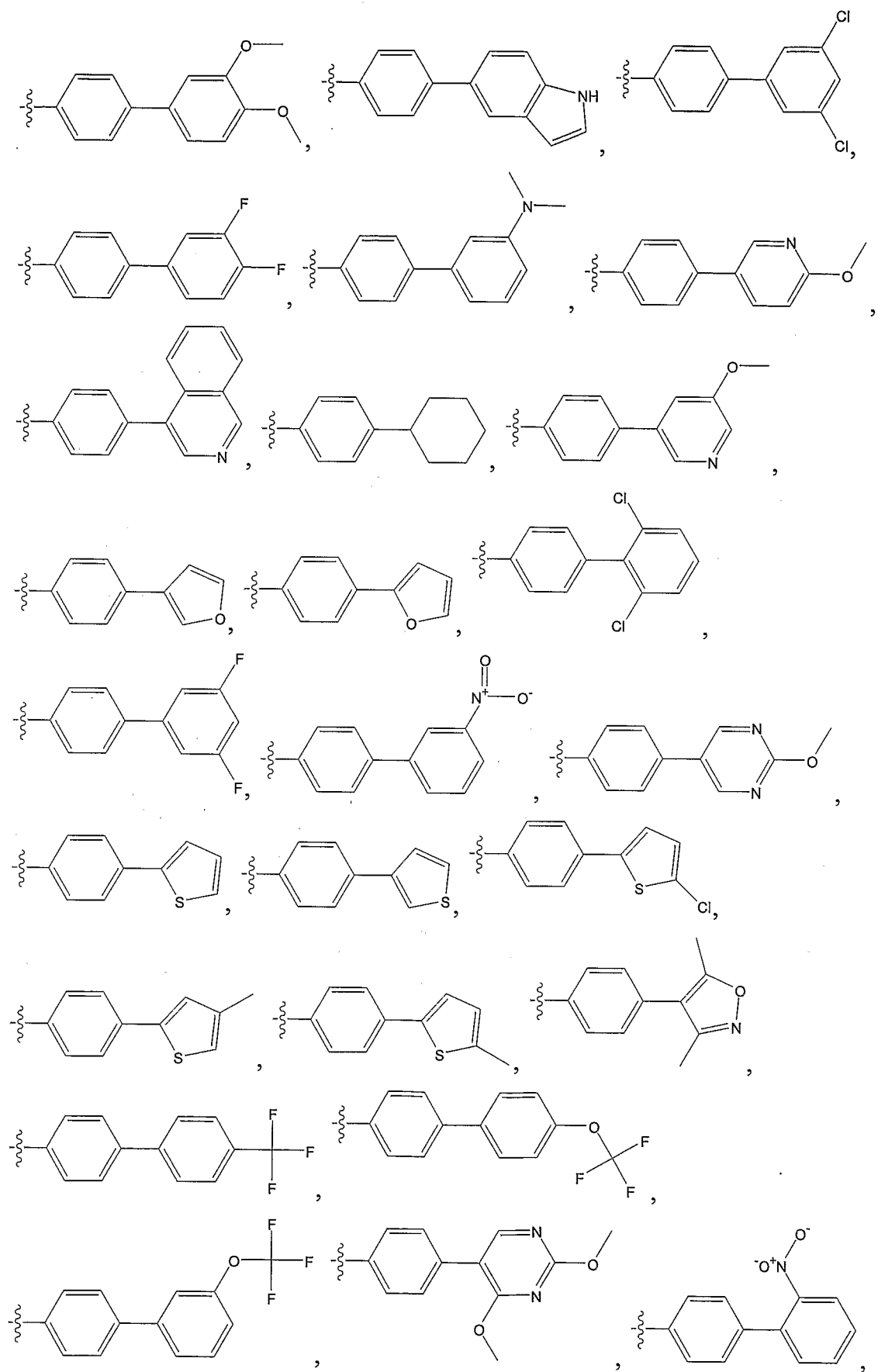
In some embodiments, R₅ is selected from the group consisting of H, alkyl, mono-
 substituted aryl, di-substituted aryl, and tri-substituted aryl.

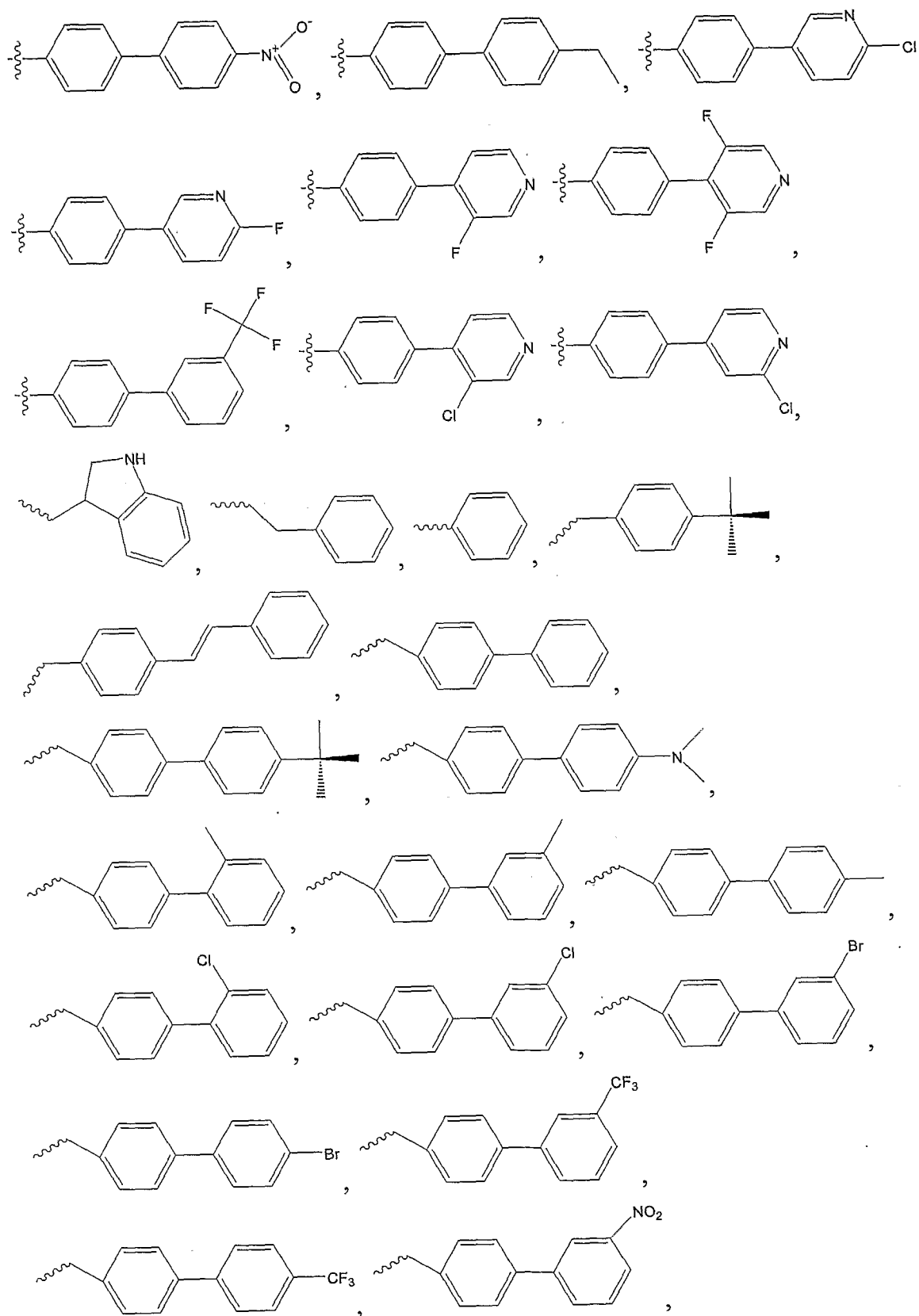
In some embodiments, R₆ is selected from the group consisting of C, N or S.

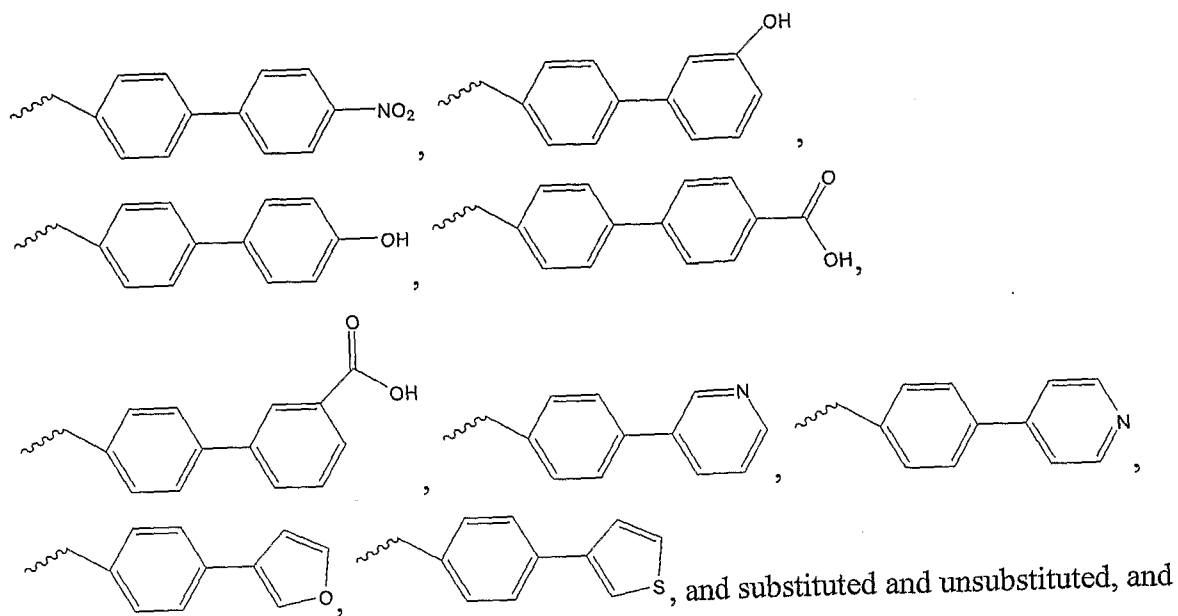
In some embodiments, R₁ is selected from the group consisting of:



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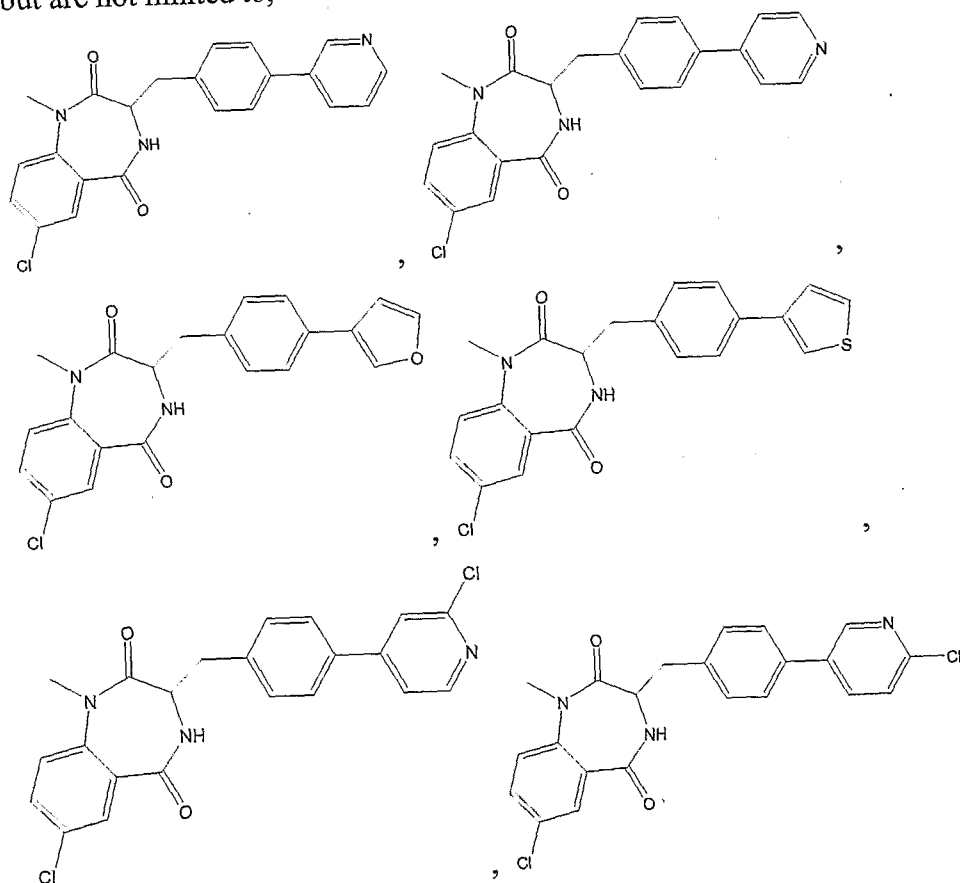




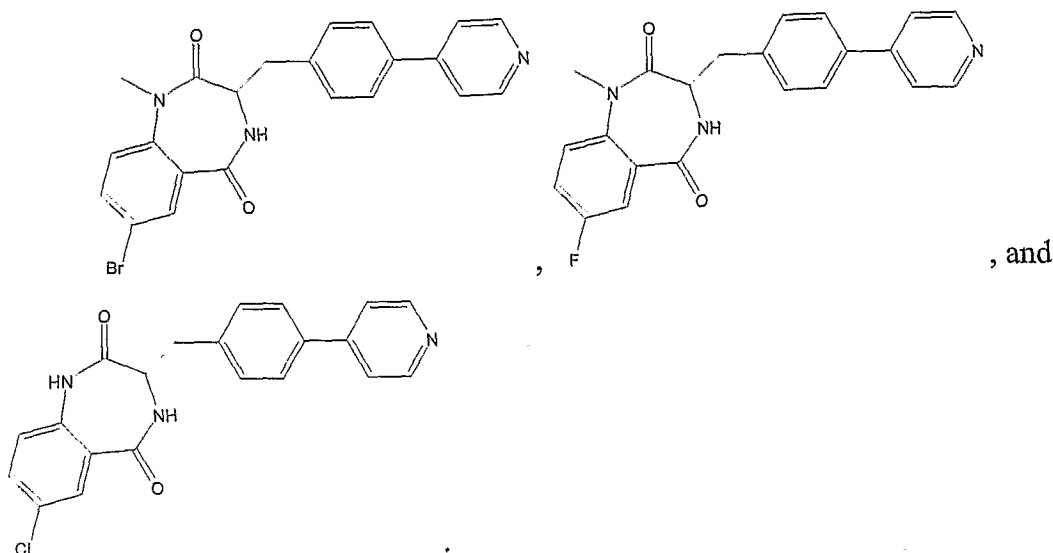


5 derivatives thereof.

Certain 1,4-benzodiazepine-2,5-dione compounds of the present invention include, but are not limited to,



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In certain embodiments, the present invention provides a method of treating cells, comprising a) providing i) target cells; and ii) a composition comprising a 1,4-benzodiazepine-2,5-dione compound having an electron rich heterocycle at the third carbon position of the benzodiazepine structure; and b) exposing the target cells to the composition under conditions such that said composition interacts with the target cell so as to induce cellular apoptosis. Such methods find use in research, drug screening, and therapeutic applications.

In some embodiments, the target cells are in a subject having, for example, an autoimmune disorder, a haematologic malignancy, or a hyperproliferative disorder. In some embodiments, the target cells are selected from the group consisting of *in vitro* cells, *in vivo* cells, and *ex vivo* cells. In other embodiments, the target cells are cancer cells. In still other embodiments, the target cells are selected from the group consisting of B cells, T cells, and granulocytes.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the structure of Bz-423 and an exemplary 1,4-benzodiazepine-2,5-dione.

Figure 2 shows exemplary compounds of the present invention and their biological activities.

Figure 3 shows ATP Synthesis and Hydrolysis Inhibition Graph for 1,4-benzodiazepine-2,5-diones.

Figure 4 shows exemplary compounds of the present invention and their biological activities.

Figure 5 presents additional selectivity data for additional 1,4-benzodiazepine-2,5-dione compounds of the present invention.

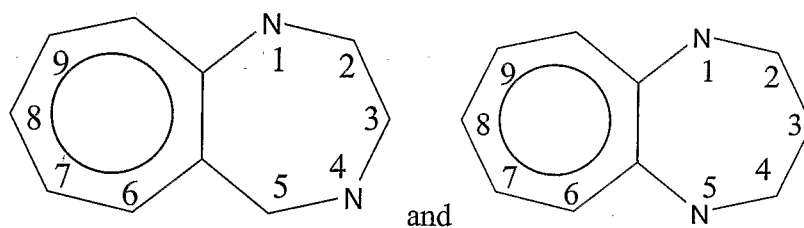
Figure 6 shows cellular ATP synthesis in the presence of the compounds of the present invention.

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DEFINITIONS

To facilitate an understanding of the present invention, a number of terms and phrases are defined below.

10 As used herein, the term "benzodiazepine" refers to a seven membered non-aromatic heterocyclic ring fused to a phenyl ring wherein the seven-membered ring has two nitrogen atoms, as part of the heterocyclic ring. In some aspects, the two nitrogen atoms are in the 1 and 4 positions or the 1 and 5 positions, as shown in the general structures below:



15 The term "larger than benzene" refers to any chemical group containing 7 or more non-hydrogen atoms.

The term "chemical moiety" refers to any chemical compound containing at least one carbon atom. Examples of chemical moieties include, but are not limited to, aromatic chemical moieties, chemical moieties comprising Sulfur, chemical moieties comprising
20 Nitrogen, hydrophilic chemical moieties, and hydrophobic chemical moieties.

As used herein, the term "aliphatic" represents the groups including, but not limited to, alkyl, alkenyl, alkynyl, and acyclic.

As used herein, the term "aryl" represents a single aromatic ring such as a phenyl ring, or two or more aromatic rings (*e.g.*, biphenyl, naphthalene, anthracene), or an aromatic
25 ring and one or more non-aromatic rings. The aryl group can be optionally substituted with a lower aliphatic group (*e.g.*, alkyl, alkenyl, alkynyl, or acyclic). Additionally, the aliphatic and aryl groups can be further substituted by one or more functional groups including, but not limited to, chemical moieties comprising N, S, O, -NH₂, -NHCOCH₃, -OH, lower alkoxy (C₁-C₄), and halo (-F, -Cl, -Br, or -I).

As used herein, the term "substituted aliphatic" refers to an alkane, alkene, alkyne, or alicyclic moiety where at least one of the aliphatic hydrogen atoms has been replaced by, for example, a halogen, an amino, a hydroxy, an ether, a nitro, a thio, a ketone, a sulfone, a sulfonamide, an aldehyde, an ester, an amide, a lower aliphatic, a substituted lower
5 aliphatic, or a ring (aryl, substituted aryl, cycloaliphatic, or substituted cycloaliphatic, *etc.*). Examples of such include, but are not limited to, 1-chloroethyl and the like.

As used herein, the term "substituted aryl" refers to an aromatic ring or fused aromatic ring system consisting of at least one aromatic ring, and where at least one of the hydrogen atoms on a ring carbon has been replaced by, for example, a halogen, an amino, a
10 hydroxy, a nitro, a thio, a ketone, an aldehyde, an ether, an ester, an amide, a sulfone, a sulfonamide, a lower aliphatic, a substituted lower aliphatic, or a ring (aryl, substituted aryl, cycloaliphatic, or substituted cycloaliphatic). Examples of such include, but are not limited to, hydroxyphenyl and the like.

As used herein, the term "cycloaliphatic" refers to an aliphatic structure containing a
15 fused ring system. Examples of such include, but are not limited to, decalin and the like.

As used herein, the term "substituted cycloaliphatic" refers to a cycloaliphatic structure where at least one of the aliphatic hydrogen atoms has been replaced by a halogen, a heteroatom, a nitro, a thio, an amino, a hydroxy, a ketone, an aldehyde, an ester, an amide, a lower aliphatic, a substituted lower aliphatic, or a ring (aryl, substituted aryl,
20 cycloaliphatic, or substituted cycloaliphatic). Examples of such include, but are not limited to, 1-chlorodecalyl, bicyclo-heptanes, octanes, and nonanes (*e.g.*, nonbornyl) and the like.

As used herein, the term "heterocyclic" represents, for example, an aromatic or nonaromatic ring containing one or more heteroatoms. The heteroatoms can be the same or different from each other. Examples of heteroatoms include, but are not limited to nitrogen,
25 oxygen and sulfur. Aromatic and nonaromatic heterocyclic rings are well-known in the art. Some nonlimiting examples of aromatic heterocyclic rings include pyridine, pyrimidine, indole, purine, quinoline and isoquinoline. Nonlimiting examples of nonaromatic heterocyclic compounds include piperidine, piperazine, morpholine, pyrrolidine and pyrazolidine. Examples of oxygen containing heterocyclic rings include, but not limited to
30 furan, oxirane, 2H-pyran, 4H-pyran, 2H-chromene, and benzofuran. Examples of sulfur-containing heterocyclic rings include, but are not limited to, thiophene, benzothiophene, and parathiazine. Examples of nitrogen containing rings include, but not limited to, pyrrole, pyrrolidine, pyrazole, pyrazolidine, imidazole, imidazoline, imidazolidine, pyridine,

piperidine, pyrazine, piperazine, pyrimidine, indole, purine, benzimidazole, quinoline, isoquinoline, triazole, and triazine. Nonlimiting examples of heterocyclic rings containing two different heteroatoms include, but are not limited to, phenothiazine, morpholine, parathiazine, oxazine, oxazole, thiazine, and thiazole. The heterocyclic ring is optionally further substituted with one or more groups selected from aliphatic, nitro, acetyl (*i.e.*, -C(=O)-CH₃), or aryl groups.

As used herein, the term “substituted heterocyclic” refers to a heterocyclic structure where at least one of the ring hydrogen atoms is replaced by oxygen, nitrogen or sulfur, and where at least one of the aliphatic hydrogen atoms has been replaced by a halogen, hydroxy, a thio, nitro, an amino, an ether, a sulfone, a sulphonamide, a ketone, an aldehyde, an ester, an amide, a lower aliphatic, a substituted lower aliphatic, or a ring (aryl, substituted aryl, cycloaliphatic, or substituted cycloaliphatic). Examples of such include, but are not limited to 2-chloropyranyl.

As used herein, the term “electron-rich heterocycle,” means cyclic compounds in which one or more ring atoms is a heteroatom (e.g., oxygen, nitrogen or sulfur), and the heteroatom has unpaired electrons which contribute to a 6- π electronic system. Exemplary electron-rich heterocycles include, but are not limited to, pyrrole, indole, furan, benzofuran, thiophene, benzothiophene and other similar structures.

As used herein, the term “linker” refers to a chain containing up to and including eight contiguous atoms connecting two different structural moieties where such atoms are, for example, carbon, nitrogen, oxygen, or sulfur. Ethylene glycol is one non-limiting example.

As used herein, the term “lower-alkyl-substituted-amino” refers to any alkyl unit containing up to and including eight carbon atoms where one of the aliphatic hydrogen atoms is replaced by an amino group. Examples of such include, but are not limited to, ethylamino and the like.

As used herein, the term “lower-alkyl-substituted-halogen” refers to any alkyl chain containing up to and including eight carbon atoms where one of the aliphatic hydrogen atoms is replaced by a halogen. Examples of such include, but are not limited to, chlorethyl and the like.

As used herein, the term “acetylamino” shall mean any primary or secondary amino that is acetylated. Examples of such include, but are not limited to, acetamide and the like.

As used herein, the term "a moiety that participates in hydrogen bonding" as used herein represents a group that can accept or donate a proton to form a hydrogen bond thereby. Some specific non-limiting examples of moieties that participate in hydrogen bonding include a fluoro, oxygen-containing and nitrogen-containing groups that are well-known in the art. Some examples of oxygen-containing groups that participate in hydrogen bonding include: hydroxy, lower alkoxy, lower carbonyl, lower carboxyl, lower ethers and phenolic groups. The qualifier "lower" as used herein refers to lower aliphatic groups (C₁-C₄) to which the respective oxygen-containing functional group is attached. Thus, for example, the term "lower carbonyl" refers to *inter alia*, formaldehyde, acetaldehyde. Some nonlimiting examples of nitrogen-containing groups that participate in hydrogen bond formation include amino and amido groups. Additionally, groups containing both an oxygen and a nitrogen atom can also participate in hydrogen bond formation. Examples of such groups include nitro, N-hydroxy and nitrous groups. It is also possible that the hydrogen-bond acceptor in the present invention can be the π electrons of an aromatic ring.

The term "derivative" of a compound, as used herein, refers to a chemically modified compound wherein the chemical modification takes place either at a functional group of the compound (e.g., aromatic ring) or benzodiazepine backbone. Such derivatives include, but are not limited to, esters of alcohol-containing compounds, esters of carboxy-containing compounds, amides of amine-containing compounds, amides of carboxy-containing compounds, imines of amino-containing compounds, acetals of aldehyde-containing compounds, ketals of carbonyl-containing compounds, and the like.

As used herein, the term "subject" refers to organisms to be treated by the methods of the present invention. Such organisms preferably include, but are not limited to, mammals (e.g., murines, simians, equines, bovines, porcines, canines, felines, and the like), and most preferably includes humans. In the context of the invention, the term "subject" generally refers to an individual who will receive or who has received treatment (e.g., administration of a compound of the present invention and optionally one or more other agents) for a condition characterized by the dysregulation of apoptotic processes.

The term "diagnosed," as used herein, refers to the recognition of a disease by its signs and symptoms (e.g., resistance to conventional therapies), or genetic analysis, pathological analysis, histological analysis, and the like.

As used herein, the terms “anticancer agent,” or “conventional anticancer agent” refer to any chemotherapeutic compounds, radiation therapies, or surgical interventions, used in the treatment of cancer.

As used herein the term, “*in vitro*” refers to an artificial environment and to
5 processes or reactions that occur within an artificial environment. *In vitro* environments include, but are not limited to, test tubes and cell cultures. The term “*in vivo*” refers to the natural environment (*e.g.*, an animal or a cell) and to processes or reaction that occur within a natural environment.

As used herein, the term “host cell” refers to any eukaryotic or prokaryotic cell (*e.g.*,
10 mammalian cells, avian cells, amphibian cells, plant cells, fish cells, and insect cells), whether located *in vitro* or *in vivo*.

As used herein, the term “cell culture” refers to any *in vitro* culture of cells. Included within this term are continuous cell lines (*e.g.*, with an immortal phenotype), primary cell cultures, finite cell lines (*e.g.*, non-transformed cells), and any other cell population
15 maintained *in vitro*, including oocytes and embryos.

In preferred embodiments, the “target cells” of the compositions and methods of the present invention include, refer to, but are not limited to, lymphoid cells or cancer cells. Lymphoid cells include B cells, T cells, granulocytes, dendritic cells, and antigen presenting cells. Granulocytes include eosinophils and macrophages. In some embodiments, target cells
20 are continuously cultured cells or uncultured cells obtained from patient biopsies.

Cancer cells include tumor cells, neoplastic cells, malignant cells, metastatic cells, and hyperplastic cells. Neoplastic cells can be benign or malignant. Neoplastic cells are benign if they do not invade or metastasize. A malignant cell is one that is able to invade and/or metastasize. Hyperplasia is a pathologic accumulation of cells in a tissue or organ, without
25 significant alteration in structure or function.

In one specific embodiment, the target cells exhibit pathological growth or proliferation. As used herein, the term “pathologically proliferating or growing cells” refers to a localized population of proliferating cells in an animal that is not governed by the usual limitations of normal growth.

30 As used herein, the term “un-activated target cell” refers to a cell that is either in the G₀ phase or one in which a stimulus has not been applied.

As used herein, the term “activated target lymphoid cell” refers to a lymphoid cell that has been primed with an appropriate stimulus to cause a signal transduction cascade, or

alternatively, a lymphoid cell that is not in G₀ phase. Activated lymphoid cells may proliferate, undergo activation induced cell death, or produce one or more of cytotoxins, cytokines, and other related membrane-associated proteins characteristic of the cell type (*e.g.*, CD8⁺ or CD4⁺). They are also capable of recognizing and binding any target cell that displays a particular antigen on its surface, and subsequently releasing its effector molecules.

As used herein, the term "activated cancer cell" refers to a cancer cell that has been primed with an appropriate stimulus to cause a signal transduction. An activated cancer cell may or may not be in the G₀ phase.

An activating agent is a stimulus that upon interaction with a target cell results in a signal transduction cascade. Examples of activating stimuli include, but are not limited to, small molecules, radiant energy, and molecules that bind to cell activation cell surface receptors. Responses induced by activation stimuli can be characterized by changes in, among others, intracellular Ca²⁺, hydroxyl radical levels; the activity of enzymes like kinases or phosphatases; or the energy state of the cell. For cancer cells, activating agents also include transforming oncogenes.

As used herein, the term "effective amount" refers to the amount of a compound (*e.g.*, a compound of the present invention) sufficient to effect beneficial or desired results. An effective amount can be administered in one or more administrations, applications or dosages and is not limited intended to be limited to a particular formulation or administration route.

As used herein, the term "dysregulation of the process of cell death" refers to any aberration in the ability of (*e.g.*, predisposition) a cell to undergo cell death via either necrosis or apoptosis. Dysregulation of cell death is associated with or induced by a variety of conditions, including for example, autoimmune disorders (*e.g.*, systemic lupus erythematosus, rheumatoid arthritis, myasthenia gravis, Sjögren's syndrome, *etc.*), chronic inflammatory conditions (*e.g.*, graft-versus-host disease, psoriasis, asthma and Crohn's disease), hyperproliferative disorders (*e.g.*, tumors, B cell lymphomas, T cell lymphomas, *etc.*), viral infections (*e.g.*, herpes, papilloma, HIV), and other conditions such as osteoarthritis and atherosclerosis.

It should be noted that when the dysregulation is induced by or associated with a viral infection, the viral infection may or may not be detectable at the time dysregulation

occurs or is observed. That is, viral-induced dysregulation can occur even after the disappearance of symptoms of viral infection.

A "hyperproliferative disorder," as used herein refers to any condition in which a localized population of proliferating cells in an animal is not governed by the usual limitations of normal growth. Examples of hyperproliferative disorders include tumors, neoplasms, lymphomas and the like. A neoplasm is said to be benign if it does not undergo, invasion or metastasis and malignant if it does either of these. A metastatic cell or tissue means that the cell can invade and destroy neighboring body structures. Hyperplasia is a form of cell proliferation involving an increase in cell number in a tissue or organ, without significant alteration in structure or function. Metaplasia is a form of controlled cell growth in which one type of fully differentiated cell substitutes for another type of differentiated cell. Metaplasia can occur in epithelial or connective tissue cells. A typical metaplasia involves a somewhat disorderly metaplastic epithelium.

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

As used herein, the term "chronic inflammatory condition" refers to a condition wherein the organism's immune cells are activated. Such a condition is characterized by a persistent inflammatory response with pathologic sequelae. This state is characterized by infiltration of mononuclear cells, proliferation of fibroblasts and small blood vessels, increased connective tissue, and tissue destruction. Examples of chronic inflammatory diseases include, but are not limited to, Crohn's disease, psoriasis, chronic obstructive pulmonary disease, inflammatory bowel disease, multiple sclerosis, and asthma. Autoimmune diseases such as rheumatoid arthritis and systemic lupus erythematosus can also result in a chronic inflammatory state.

As used herein, the term "co-administration" refers to the administration of at least two agent(s) (*e.g.*, a compound of the present invention) or therapies to a subject. In some embodiments, the co-administration of two or more agents/therapies is concurrent. In other embodiments, a first agent/therapy is administered prior to a second agent/therapy. Those of skill in the art understand that the formulations and/or routes of administration of the various agents/therapies used may vary. The appropriate dosage for co-administration can be readily determined by one skilled in the art. In some embodiments, when agents/therapies are co-administered, the respective agents/therapies are administered at lower dosages than appropriate for their administration alone. Thus, co-administration is especially desirable in embodiments where the co-administration of the agents/therapies lowers the requisite dosage of a known potentially harmful (*e.g.*, toxic) agent(s).

As used herein, the term "toxic" refers to any detrimental or harmful effects on a cell or tissue as compared to the same cell or tissue prior to the administration of the toxicant.

As used herein, the term "pharmaceutical composition" refers to the combination of an active agent with a carrier, inert or active, making the composition especially suitable for diagnostic or therapeutic use *in vivo*, *in vivo* or *ex vivo*.

As used herein, the term "pharmaceutically acceptable carrier" refers to any of the standard pharmaceutical carriers, such as a phosphate buffered saline solution, water, emulsions (*e.g.*, such as an oil/water or water/oil emulsions), and various types of wetting agents. The compositions also can include stabilizers and preservatives. For examples of carriers, stabilizers and adjuvants. (*See e.g.*, Martin, Remington's Pharmaceutical Sciences, 15th Ed., Mack Publ. Co., Easton, PA [1975]).

As used herein, the term "pharmaceutically acceptable salt" refers to any pharmaceutically acceptable salt (*e.g.*, acid or base) of a compound of the present invention which, upon administration to a subject, is capable of providing a compound of this invention or an active metabolite or residue thereof. As is known to those of skill in the art, "salts" of the compounds of the present invention may be derived from inorganic or organic acids and bases. Examples of acids include, but are not limited to, hydrochloric, hydrobromic, sulfuric, nitric, perchloric, fumaric, maleic, phosphoric, glycolic, lactic, salicylic, succinic, toluene-p-sulfonic, tartaric, acetic, citric, methanesulfonic, ethanesulfonic, formic, benzoic, malonic, naphthalene-2-sulfonic, benzenesulfonic acid, and the like. Other acids, such as oxalic, while not in themselves pharmaceutically acceptable,

may be employed in the preparation of salts useful as intermediates in obtaining the compounds of the invention and their pharmaceutically acceptable acid addition salts.

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

Examples of salts include, but are not limited to: acetate, adipate, alginate, aspartate, benzoate, benzenesulfonate, bisulfate, butyrate, citrate, camphorate, camphorsulfonate, cyclopentanepropionate, digluconate, dodecylsulfate, ethanesulfonate, fumarate, flucoheptanoate, glycerophosphate, hemisulfate, heptanoate, hexanoate, hydrochloride, hydrobromide, hydroiodide, 2-hydroxyethanesulfonate, lactate, maleate, methanesulfonate, 2-naphthalenesulfonate, nicotinate, oxalate, palmoate, pectinate, persulfate, phenylpropionate, picrate, pivalate, propionate, succinate, tartrate, thiocyanate, tosylate, undecanoate, and the like. Other examples of salts include anions of the compounds of the present invention compounded with a suitable cation such as Na^+ , NH_4^+ , and NW_4^+ (wherein W is a C_{1-4} alkyl group), and the like.

For therapeutic use, salts of the compounds of the present invention are contemplated as being pharmaceutically acceptable. However, salts of acids and bases that are non-pharmaceutically acceptable may also find use, for example, in the preparation or purification of a pharmaceutically acceptable compound.

As used herein, the term "pathogen" refers a biological agent that causes a disease state (*e.g.*, infection, cancer, *etc.*) in a host. "Pathogens" include, but are not limited to, viruses, bacteria, archaea, fungi, protozoans, mycoplasma, prions, and parasitic organisms.

The terms "bacteria" and "bacterium" refer to all prokaryotic organisms, including those within all of the phyla in the Kingdom Procaryotae. It is intended that the term encompass all microorganisms considered to be bacteria including Mycoplasma, Chlamydia, Actinomyces, Streptomyces, and Rickettsia. All forms of bacteria are included within this definition including cocci, bacilli, spirochetes, spheroplasts, protoplasts, *etc.* Also included within this term are prokaryotic organisms which are gram negative or gram positive. "Gram negative" and "gram positive" refer to staining patterns with the Gram-staining process which is well known in the art. (*See e.g.*, Finegold and Martin, Diagnostic Microbiology, 6th Ed., CV Mosby St. Louis, *pp.* 13-15 [1982]). "Gram positive bacteria" are bacteria which retain the primary dye used in the Gram stain, causing the stained cells to appear dark blue to purple under the microscope. "Gram negative bacteria"

do not retain the primary dye used in the Gram stain, but are stained by the counterstain. Thus, gram negative bacteria appear red.

As used herein, the term "microorganism" refers to any species or type of microorganism, including but not limited to, bacteria, archaea, fungi, protozoans, mycoplasma, and parasitic organisms. The present invention contemplates that a number of microorganisms encompassed therein will also be pathogenic to a subject.

As used herein, the term "fungi" is used in reference to eukaryotic organisms such as the molds and yeasts, including dimorphic fungi.

As used herein, the term "virus" refers to minute infectious agents, which with certain exceptions, are not observable by light microscopy, lack independent metabolism, and are able to replicate only within a living host cell. The individual particles (*i.e.*, virions) typically consist of nucleic acid and a protein shell or coat; some virions also have a lipid containing membrane. The term "virus" encompasses all types of viruses, including animal, plant, phage, and other viruses.

The term "sample" as used herein is used in its broadest sense. A sample suspected of indicating a condition characterized by the dysregulation of apoptotic function may comprise a cell, tissue, or fluids, chromosomes isolated from a cell (*e.g.*, a spread of metaphase chromosomes), genomic DNA (in solution or bound to a solid support such as for Southern blot analysis), RNA (in solution or bound to a solid support such as for Northern blot analysis), cDNA (in solution or bound to a solid support) and the like. A sample suspected of containing a protein may comprise a cell, a portion of a tissue, an extract containing one or more proteins and the like.

As used herein, the terms "purified" or "to purify" refer, to the removal of undesired components from a sample. As used herein, the term "substantially purified" refers to molecules that are at least 60% free, preferably 75% free, and most preferably 90%, or more, free from other components with which they usually associated.

As used herein, the term "antigen binding protein" refers to proteins which bind to a specific antigen. "Antigen binding proteins" include, but are not limited to, immunoglobulins, including polyclonal, monoclonal, chimeric, single chain, and humanized antibodies, Fab fragments, F(ab')₂ fragments, and Fab expression libraries. Various procedures known in the art are used for the production of polyclonal antibodies. For the production of antibody, various host animals can be immunized by injection with the peptide corresponding to the desired epitope including but not limited to rabbits, mice, rats,

sheep, goats, *etc.* In a preferred embodiment, the peptide is conjugated to an immunogenic carrier (*e.g.*, diphtheria toxoid, bovine serum albumin (BSA), or keyhole limpet hemocyanin [KLH]). Various adjuvants are used to increase the immunological response, depending on the host species, including but not limited to Freund's (complete and incomplete), mineral
5 gels such as aluminum hydroxide, surface active substances such as lysolecithin, pluronic polyols, polyanions, peptides, oil emulsions, keyhole limpet hemocyanins, dinitrophenol, and potentially useful human adjuvants such as BCG (Bacille Calmette-Guerin) and *Corynebacterium parvum*.

For preparation of monoclonal antibodies, any technique that provides for the
10 production of antibody molecules by continuous cell lines in culture may be used (*See e.g.*, Harlow and Lane, *Antibodies: A Laboratory Manual*, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY). These include, but are not limited to, the hybridoma technique originally developed by Köhler and Milstein (Köhler and Milstein, *Nature*, 256:495-497 [1975]), as well as the trioma technique, the human B-cell hybridoma technique (*See e.g.*,
15 Kozbor *et al.*, *Immunol. Today*, 4:72 [1983]), and the EBV-hybridoma technique to produce human monoclonal antibodies (Cole *et al.*, in *Monoclonal Antibodies and Cancer Therapy*, Alan R. Liss, Inc., *pp.* 77-96 [1985]).

According to the invention, techniques described for the production of single chain antibodies (U.S. 4,946,778; herein incorporated by reference) can be adapted to produce
20 specific single chain antibodies as desired. An additional embodiment of the invention utilizes the techniques known in the art for the construction of Fab expression libraries (Huse *et al.*, *Science*, 246:1275-1281 [1989]) to allow rapid and easy identification of monoclonal Fab fragments with the desired specificity.

Antibody fragments that contain the idiotype (antigen binding region) of the
25 antibody molecule can be generated by known techniques. For example, such fragments include but are not limited to: the F(ab')₂ fragment that can be produced by pepsin digestion of an antibody molecule; the Fab' fragments that can be generated by reducing the disulfide bridges of an F(ab')₂ fragment, and the Fab fragments that can be generated by treating an antibody molecule with papain and a reducing agent.

30 Genes encoding antigen binding proteins can be isolated by methods known in the art. In the production of antibodies, screening for the desired antibody can be accomplished by techniques known in the art (*e.g.*, radioimmunoassay, ELISA (enzyme-linked immunosorbant assay), "sandwich" immunoassays, immunoradiometric assays, gel

diffusion precipitin reactions, immunodiffusion assays, *in situ* immunoassays (using colloidal gold, enzyme or radioisotope labels, for example), Western Blots, precipitation reactions, agglutination assays (*e.g.*, gel agglutination assays, hemagglutination assays, *etc.*), complement fixation assays, immunofluorescence assays, protein A assays, and
5 immunoelectrophoresis assays, *etc.*) *etc.*

As used herein, the term "immunoglobulin" or "antibody" refer to proteins that bind a specific antigen. Immunoglobulins include, but are not limited to, polyclonal, monoclonal, chimeric, and humanized antibodies, Fab fragments, F(ab')₂ fragments, and includes immunoglobulins of the following classes: IgG, IgA, IgM, IgD, IgE, and secreted
10 immunoglobulins (sIg). Immunoglobulins generally comprise two identical heavy chains and two light chains. However, the terms "antibody" and "immunoglobulin" also encompass single chain antibodies and two chain antibodies.

The term "epitope" as used herein refers to that portion of an antigen that makes contact with a particular immunoglobulin. When a protein or fragment of a protein is used
15 to immunize a host animal, numerous regions of the protein may induce the production of antibodies which bind specifically to a given region or three-dimensional structure on the protein; these regions or structures are referred to as "antigenic determinants". An antigenic determinant may compete with the intact antigen (*i.e.*, the "immunogen" used to elicit the immune response) for binding to an antibody.

The terms "specific binding" or "specifically binding" when used in reference to the interaction of an antibody and a protein or peptide means that the interaction is dependent upon the presence of a particular structure (*i.e.*, the antigenic determinant or epitope) on the protein; in other words the antibody is recognizing and binding to a specific protein
20 structure rather than to proteins in general. For example, if an antibody is specific for epitope "A," the presence of a protein containing epitope A (or free, unlabelled A) in a reaction containing labeled "A" and the antibody will reduce the amount of labeled A bound to the antibody.

As used herein, the terms "non-specific binding" and "background binding" when used in reference to the interaction of an antibody and a protein or peptide refer to an
30 interaction that is not dependent on the presence of a particular structure (*i.e.*, the antibody is binding to proteins in general rather than a particular structure such as an epitope).

As used herein, the term “modulate” refers to the activity of a compound (*e.g.*, a compound of the present invention) to affect (*e.g.*, to promote or retard) an aspect of cellular function, including, but not limited to, cell growth, proliferation, apoptosis, and the like.

The term “test compound” refers to any chemical entity, pharmaceutical, drug, and the like, that can be used to treat or prevent a disease, illness, sickness, or disorder of bodily function, or otherwise alter the physiological or cellular status of a sample (*e.g.*, the level of dysregulation of apoptosis in a cell or tissue). Test compounds comprise both known and potential therapeutic compounds. A test compound can be determined to be therapeutic by using the screening methods of the present invention. A “known therapeutic compound” refers to a therapeutic compound that has been shown (*e.g.*, through animal trials or prior experience with administration to humans) to be effective in such treatment or prevention. In preferred embodiments, “test compounds” are agents that modulate apoptosis in cells.

GENERAL DESCRIPTION OF THE INVENTION

As a class of drugs, benzodiazepine compounds have been widely studied and reported to be effective medicaments for treating a number of disease. For example, U.S. 4,076,823, 4,110,337, 4,495,101, 4,751,223 and 5,776,946, each incorporated herein by reference in its entirety, report that certain benzodiazepine compounds are effective as analgesic and anti-inflammatory agents. Similarly, U.S. 5,324,726 and U.S. 5,597,915, each incorporated by reference in its entirety, report that certain benzodiazepine compounds are antagonists of cholecystokinin and gastrin and thus might be useful to treat certain gastrointestinal disorders.

Other benzodiazepine compounds have been studied as inhibitors of human neutrophil elastase in the treating of human neutrophil elastase-mediated conditions such as myocardial ischemia, septic shock syndrome, among others (*See e.g.*, U.S. 5,861,380 incorporated herein by reference in its entirety). U.S. 5,041,438, incorporated herein by reference in its entirety, reports that certain benzodiazepine compounds are useful as anti-retroviral agents.

Despite the attention benzodiazepine compounds have drawn, it will become apparent from the description below, that the present invention provides novel compounds (*e.g.*, 1,4-benzodiazepine-2,5-dione compounds) and related compounds and methods of using the novel compounds, as well as known compounds, for treating a variety of diseases.

Benzodiazepine compounds are known to bind to benzodiazepine receptors in the central nervous system (CNS) and thus have been used to treat various CNS disorders including anxiety and epilepsy. Peripheral benzodiazepine receptors have also been identified, which receptors may incidentally also be present in the CNS. The present invention demonstrates that 1,4-benzodiazepine-2,5-dione compounds with, for example, an electron rich heterocycle moiety at the C3 position of the benzodiazepine ring have pro-apoptotic properties consistent with a mechanism that does not result from interaction with the mitochondrial F_1F_0 -ATPase. The present invention also provides 1,4-benzodiazepine-2,5-dione compounds that demonstrate selective cytotoxicity against T cells as compared to B cells.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides novel chemical compounds, methods for their discovery, and their therapeutic, research, and diagnostic use. In particular, the present invention provides 1,4-benzodiazepine-2,5-dione compounds, and methods of using 1,4-benzodiazepine-2,5-dione compounds as therapeutic agents to treat a number of conditions associated with the faulty regulation of the processes of programmed cell death, autoimmunity, inflammation, and hyperproliferation, and the like.

Exemplary compositions and methods of the present invention are described in more detail in the following sections: I. Modulators of Cell Death; II. Exemplary Compounds; III. Pharmaceutical compositions, formulations, and exemplary administration routes and dosing considerations; IV. Drug screens; and V. Therapeutic Applications.

The present invention herein incorporates by reference known uses of benzodiazepine compounds, including, but not limited to the uses described in Otto, M.W., et al., (2005) *J. Clin. Psychiatry* 66 Suppl. 2:34-38; Yoshii, M., et al., (2005) *Nippon Yakurigaku Zasshi* 125(1):33-36; Yasuda, K. (2004) *Nippon Rinsho*. 62 Suppl. 12:360-363; Decaudin, D. (2004) 15(8):737-745; Bonnot, O., et al. (2003) *Encephale*. 29(6):553-559; Sugiyama, T. (2003) *Ryoikibetsu Shokogun Shirizu*. 40:489-492; Lacapere, J.J., et al., (2003) *Steroids*. 68(7-8):569-585; Galiege, S., et al., (2003) *Curr. Med. Chem.* 10(16):1563-1572; Papadopoulou, V. (2003) *Ann. Pharm. Fr.* 61(1):30-50; Goethals, I., et al., (2002) *Eur. J. Nucl. Med. Mol. Imaging* 30(2):325-328; Castedo, M., et al., (2002) *J. Exp. Med.* 196(9):1121-1125; Buffett-Jerrott, S.E., et al., (2002) *Curr. Pharm. Des.* 8(1):45-58; Beurdeley-Thomas, A., et al., (2000) *J. Neurooncol.* 46(1):45-56; Smyth, W.F., et al.,

(1998) Electrophoresis 19(16-17):2870-2882; Yoshii, M., et al., (1998) Nihon Shinkei Seishin Yakurigaku Zasshi. 18(2):49-54; Trimble, M. and Hindmarch, I. (2000) Benzodiazepines, published by Wrighton Biomedical Publishing; and Salamone, S.J. (2001) Benzodiazepines and GHB – Detection and Pharmacology, published by Humana Press.

5 The practice of the present invention employs, unless otherwise indicated, conventional techniques of organic chemistry, pharmacology, molecular biology (including recombinant techniques), cell biology, biochemistry, and immunology, which are within the skill of the art. Such techniques are explained fully in the literature, such as, “Molecular cloning: a laboratory manual” Second Edition (Sambrook *et al.*, 1989); “Oligonucleotide
10 synthesis” (M.J. Gait, ed., 1984); “Animal cell culture” (R.I. Freshney, ed., 1987); the series “Methods in enzymology” (Academic Press, Inc.); “Handbook of experimental immunology” (D.M. Weir & C.C. Blackwell, eds.); “Gene transfer vectors for mammalian cells” (J.M. Miller & M.P. Calos, eds., 1987); “Current protocols in molecular biology” (F.M. Ausubel *et al.*, eds., 1987, and periodic updates); “PCR: the polymerase chain
15 reaction” (Mullis *et al.*, eds., 1994); and “Current protocols in immunology” (J.E. Coligan *et al.*, eds., 1991), each of which is herein incorporated by reference in its entirety.

I. Modulators of Cell Death

In preferred embodiments, the present invention regulates apoptosis through the
20 exposure of cells to the compounds of the present invention (e.g., 1,4-benzodiazepine-2,5-diones). In particular, the present invention demonstrates that 1,4-benzodiazepine-2,5-diones with, for example, certain heterocycles at the C3 position of the benzodiazepine ring have pro-apoptotic properties consistent with a mechanism that does not result from interaction with the mitochondrial F_1F_0 -ATPase. The present invention also demonstrates
25 that 1,4-benzodiazepine-2,5-diones with an electron rich heterocycle moiety at the C3 position of the benzodiazepine ring can have pro-apoptotic selectivity for T cells over B cells.

The effect of compounds can be measured by detecting any number of cellular changes. Cell death may be assayed as described herein and in the art. In preferred
30 embodiments, cell lines are maintained under appropriate cell culturing conditions (e.g., gas (CO_2), temperature and media) for an appropriate period of time to attain exponential proliferation without density dependent constraints. Cell number and or viability are measured using standard techniques, such as trypan blue exclusion/hemo-cytometry, or

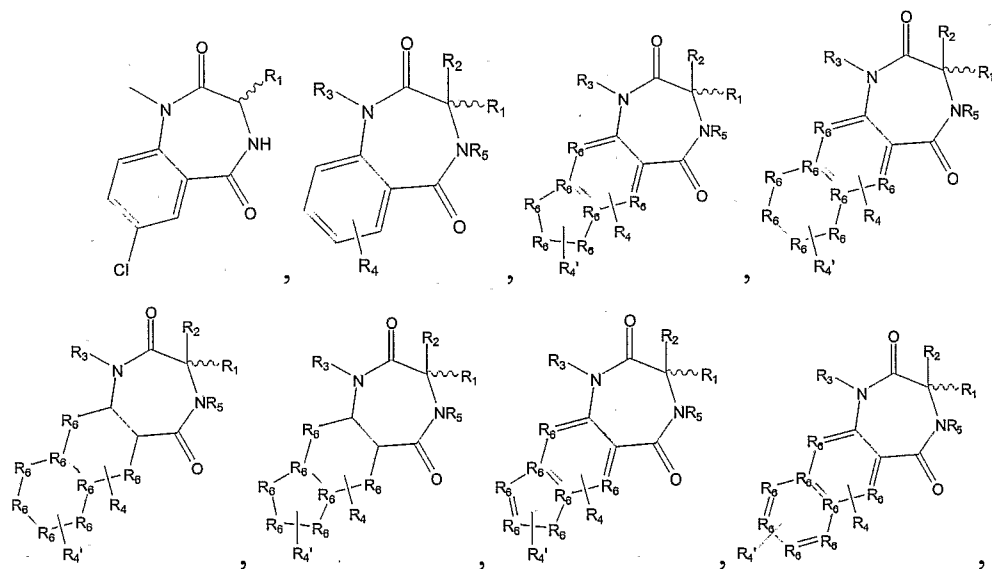
MTT dye conversion assay. Alternatively, the cell may be analyzed for the expression of genes or gene products associated with aberrations in apoptosis or necrosis.

II. Exemplary Compounds

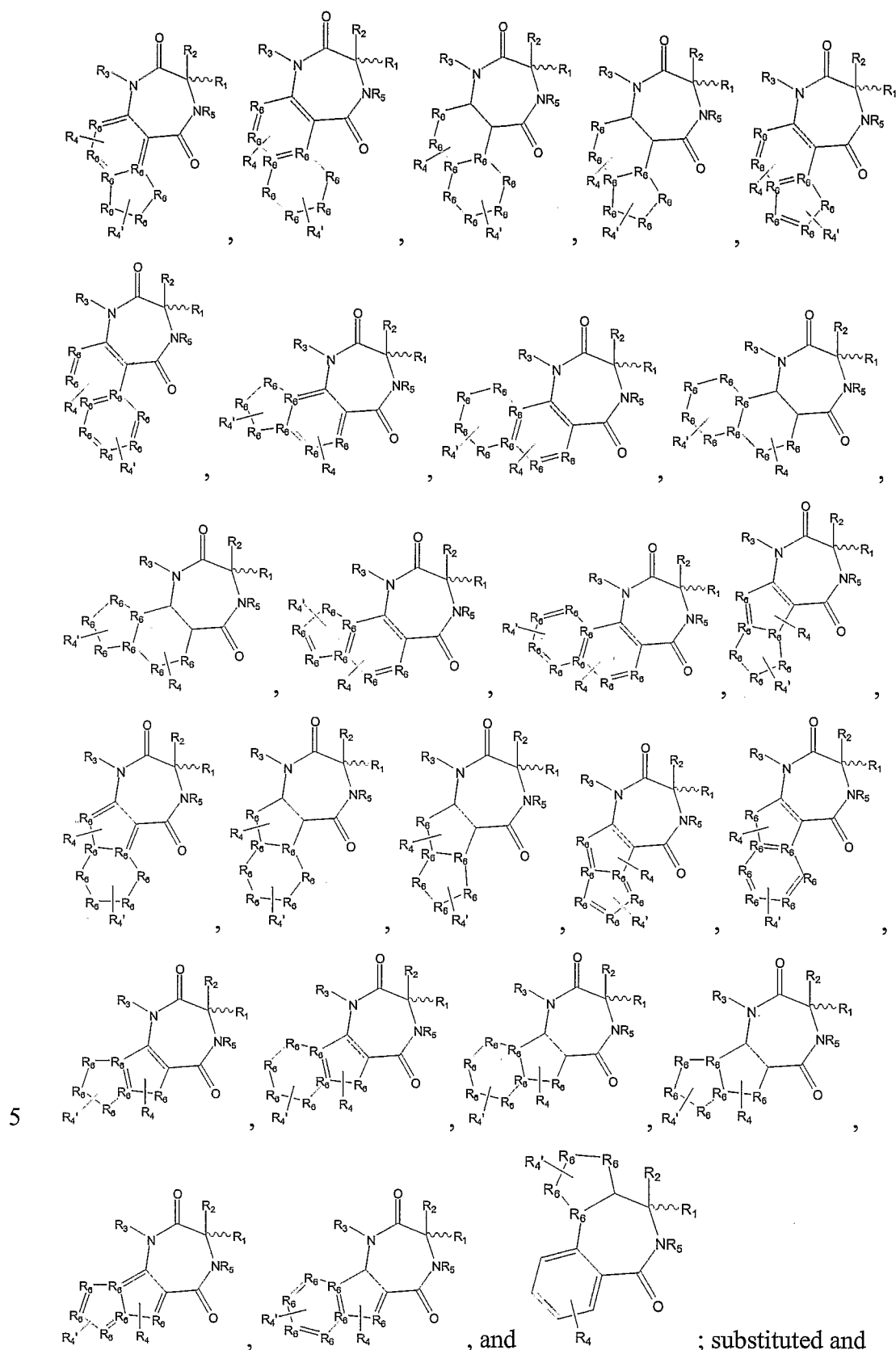
5 Exemplary compounds of the present invention are provided below. Certain 1,4-benzodiazepine-2,5-dione derivatives have been described (see, e.g., U.S. Patent Application No. 09/700,101; U.S. Patent No. 6,506,744; Kamal, et al., 2004 Synlett 14:2533-2535; Hulme, et al., 1998 J. Org. Chem. 63:8021-8022; Raboisson et al., 2005 Bioorg. Med. Chem. Lett. 15:1857-1861; Raboisson et al., 2005 Bioorg. Med. Chem. Lett. 15:765-770; Raboisson et al., 2005 J. Med. Chem. 48:909-912; each herein incorporated by
10 reference in their entireties). The present invention provides novel 1,4-benzodiazepine-2,5-dione compounds, and uses for 1,4-benzodiazepine-2,5-dione compounds.

Certain embodiments provide a composition comprising a compound described by a formula selected from the group consisting of:

15 In certain embodiments, the present invention provides a composition comprising novel 1,4-benzodiazepine-2,5-dione compounds. In certain embodiments, the present invention provide a composition comprising a compound described by a formula selected from the group consisting of:

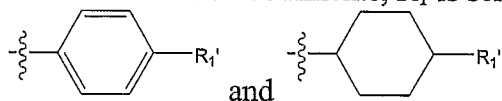


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In some embodiments, R₁ is an electron rich heterocycle. In some embodiments, the electron rich heterocycle contains 5 or more heterocyclic atoms.

In some embodiments, R₁ is selected from the group consisting of



5 , wherein R₁' is selected from the group consisting of cycloaliphatic, aryl, substituted aryl, heterocyclic, and substituted heterocyclic.

In some embodiments, R₂ is selected from the group consisting of H, alkyl, substituted alkyl, and R₁.

In some embodiments, R₃ is selected from the group consisting of H, alkyl, and substituted alkyl.

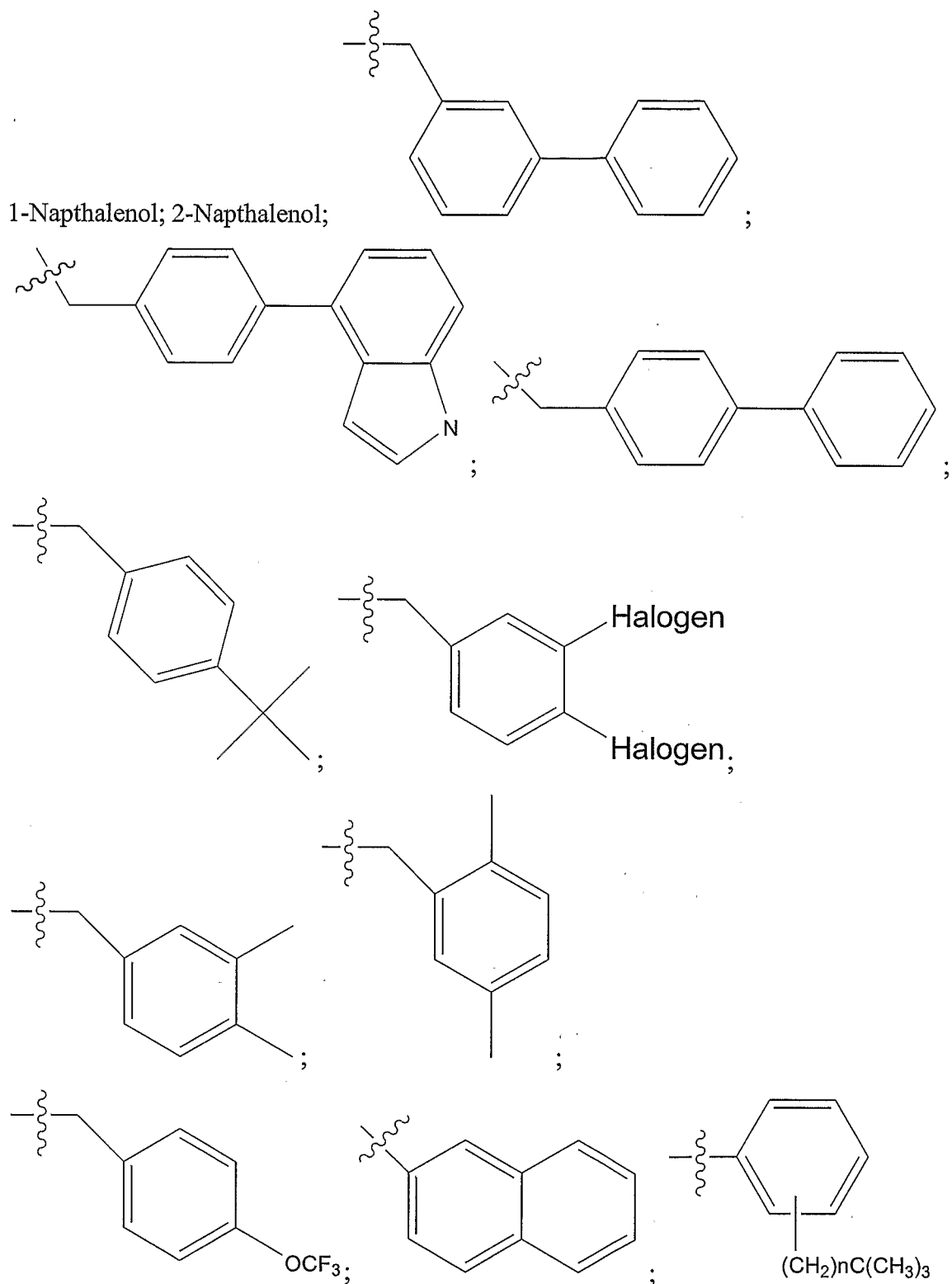
10 In some embodiments, R₃ is selected from the group consisting of hydrogen; halogen; OH; a chemical moiety comprising an aryl subgroup; a chemical moiety comprising a substituted aryl subgroup; a chemical moiety comprising a cycloaliphatic subgroup; a chemical moiety comprising a substituted cycloaliphatic subgroup; a chemical moiety comprising a heterocyclic subgroup; a chemical moiety comprising a substituted heterocyclic subgroup; a chemical moiety comprising at least one ester subgroup; a chemical moiety comprising at least one ether subgroup; a linear or branched, saturated or unsaturated, substituted or non-substituted, aliphatic chain having at least 2 carbons; a chemical moiety comprising Sulfur; a chemical moiety comprising Nitrogen; -OR-, wherein R is selected from the group consisting of a chemical moiety comprising an aryl subgroup; a chemical moiety comprising a substituted aryl subgroup; a chemical moiety comprising a cycloaliphatic subgroup; a chemical moiety comprising a substituted cycloaliphatic subgroup; a chemical moiety comprising a heterocyclic subgroup; a chemical moiety comprising a substituted heterocyclic subgroup; a linear or branched, saturated or unsaturated, substituted or non-substituted, aliphatic chain having at least 2 carbons; a chemical moiety comprising at least one ester subgroup; a chemical moiety comprising at least one ether subgroup; a chemical moiety comprising Sulfur; a chemical moiety comprising Nitrogen.

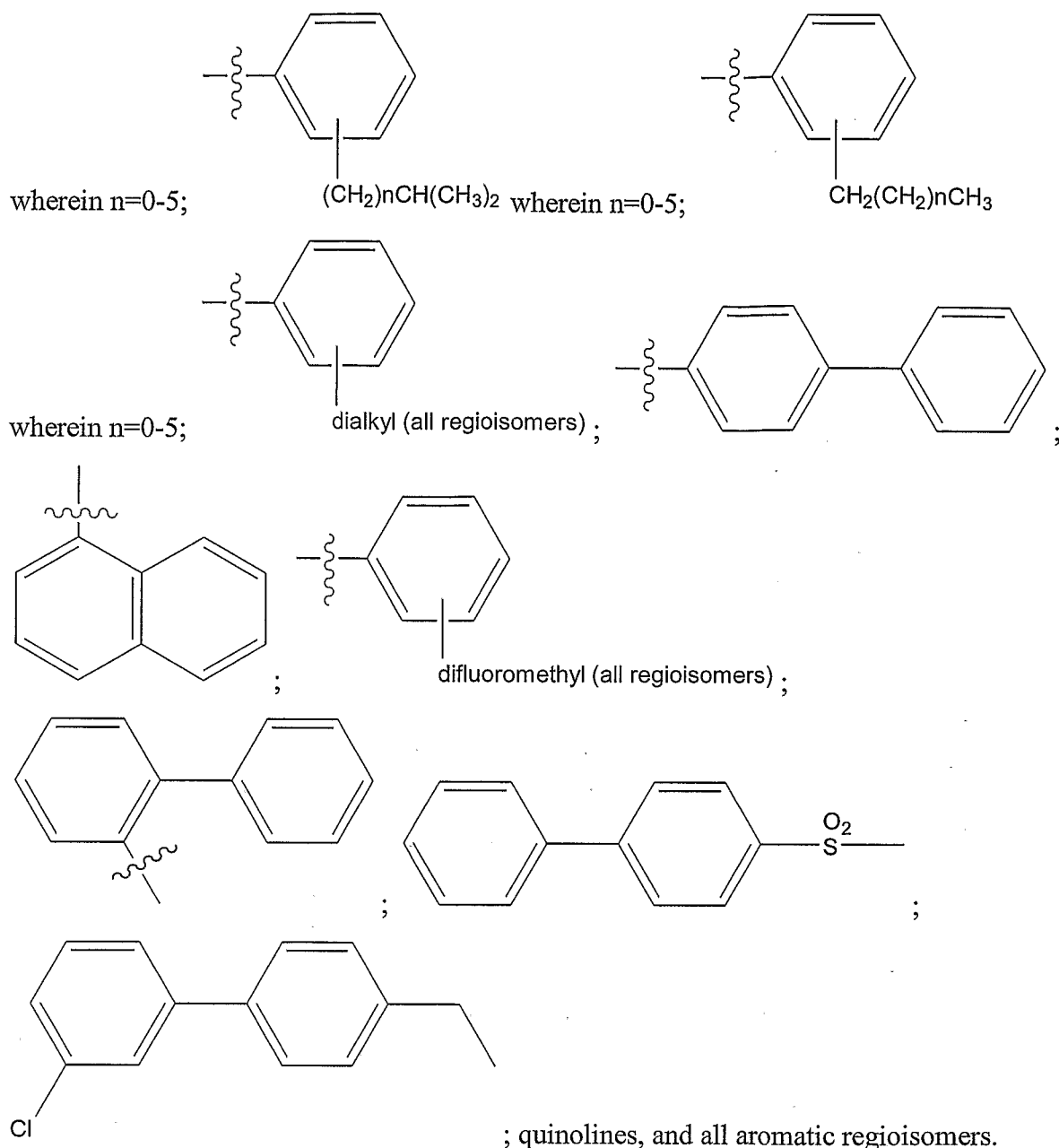
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In some embodiments, R3 is selected from group consisting of: naphthalene; phenol;





In some embodiments, the R1 and R3 groups may be interchanged (e.g., in some embodiments, the R1 group is positioned at the first position of the benzodiazepine ring and the R3 group is positioned at the third position of the benzodiazepine ring; in some embodiments, the R1 group is positioned at the third position of the benzodiazepine ring and the R3 group is positioned at the first position of the benzodiazepine ring).

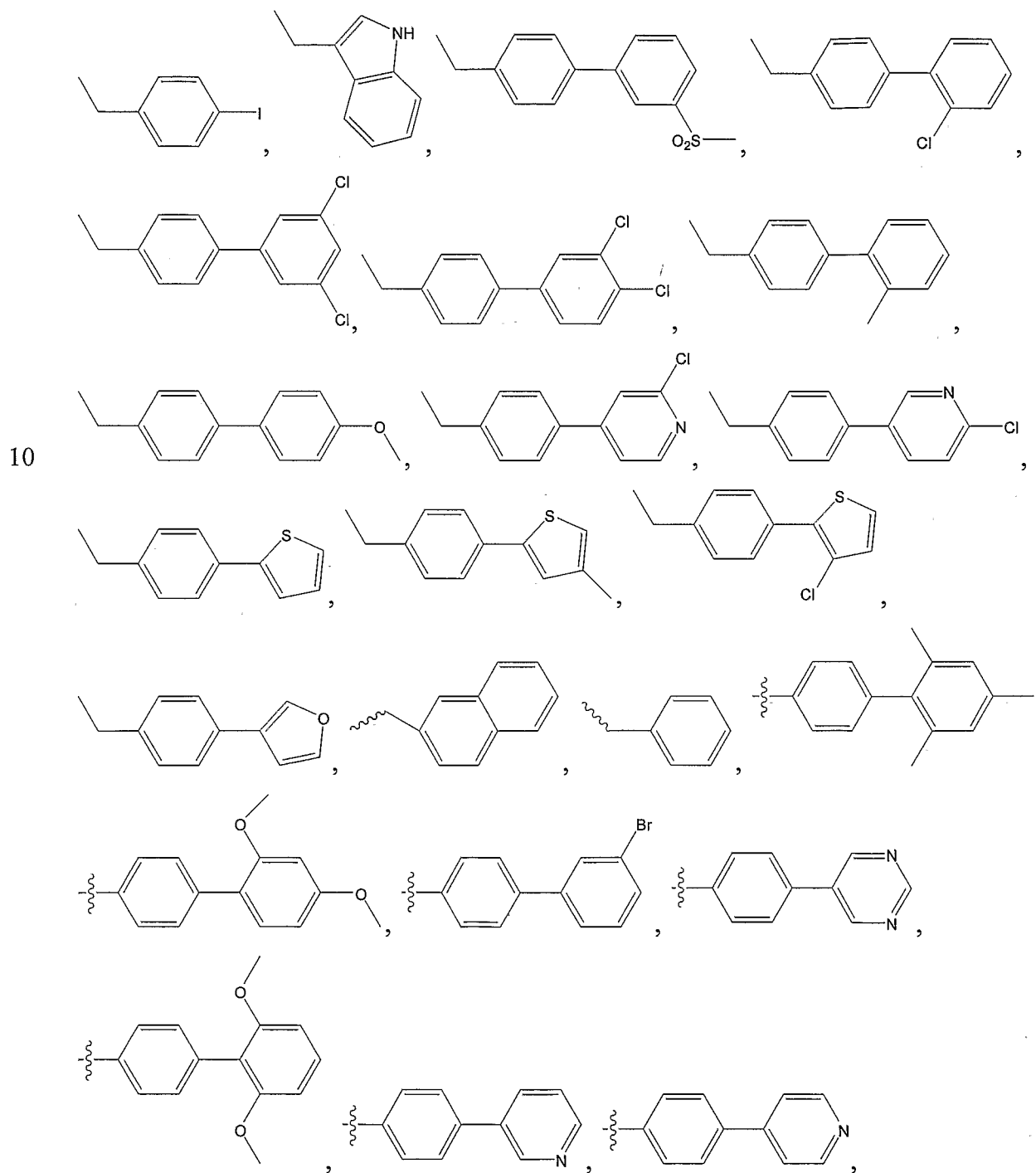
In some embodiments, R_4 and R_4' is independently selected from the group consisting of CH_3 , halogen, SO_2R_4'' , $SO_2N(R_4'')$, OR_4'' , $N(R_4'')$, $CON(R_4'')$, $NHCOR_4''$, $NHSO_2R_4'$, alkyl, mono-substituted alkyl, di-substituted alkyl, tri-substituted alkyl; wherein R_4'' is selected from the group consisting of halogen, H, alkyl, mono-

substituted alkyl, di-substituted alkyl, tri-substituted alkyl, aryl, mono-substituted aryl, di-substituted aryl, tri-substituted aryl, cycloaliphatic, mono-substituted cycloaliphatic, di-substituted cycloaliphatic, tri-substituted cycloaliphatic.

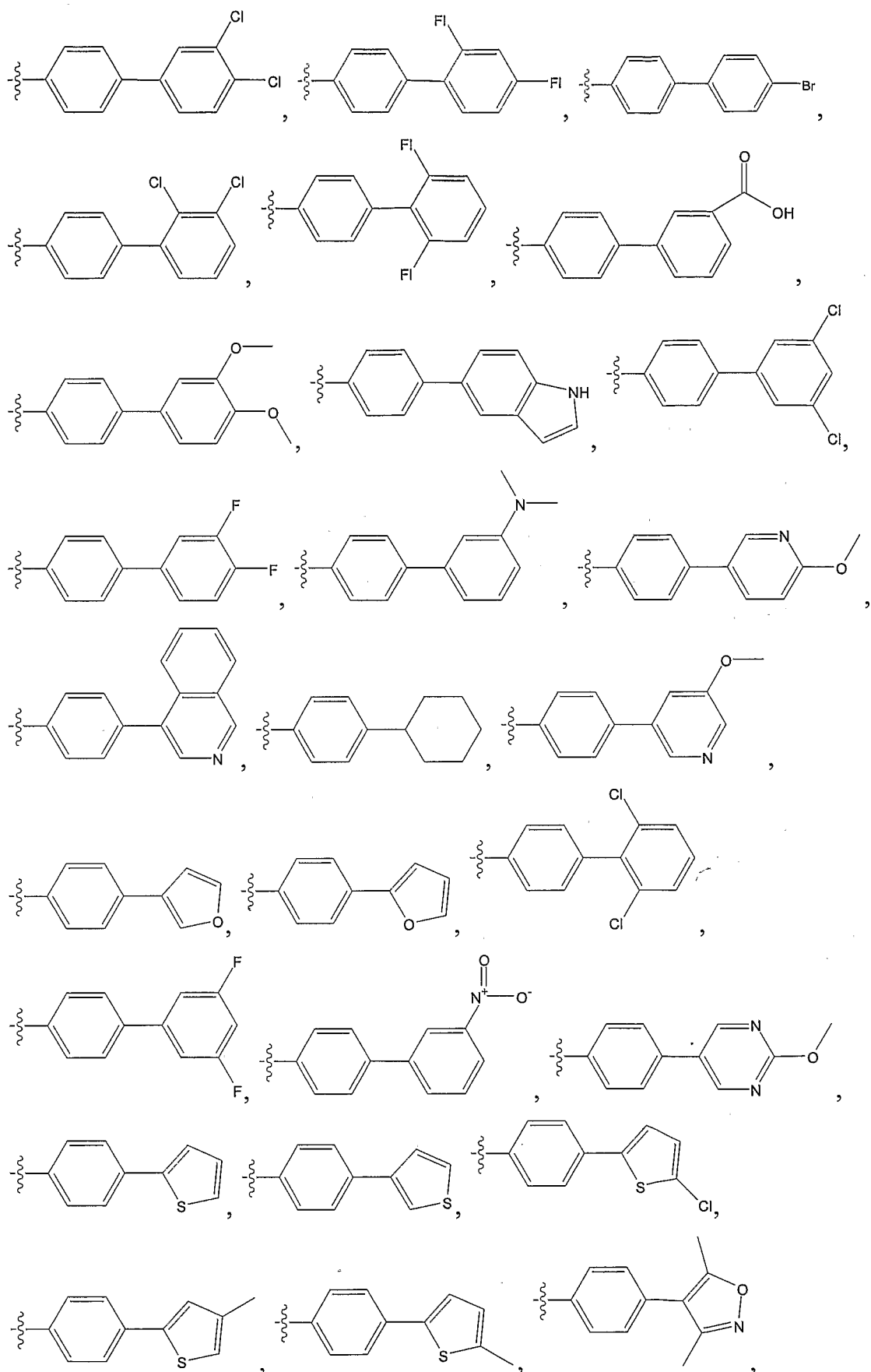
In some embodiments, R₅ is selected from the group consisting of H, alkyl, mono-substituted aryl, di-substituted aryl, and tri-substituted aryl.

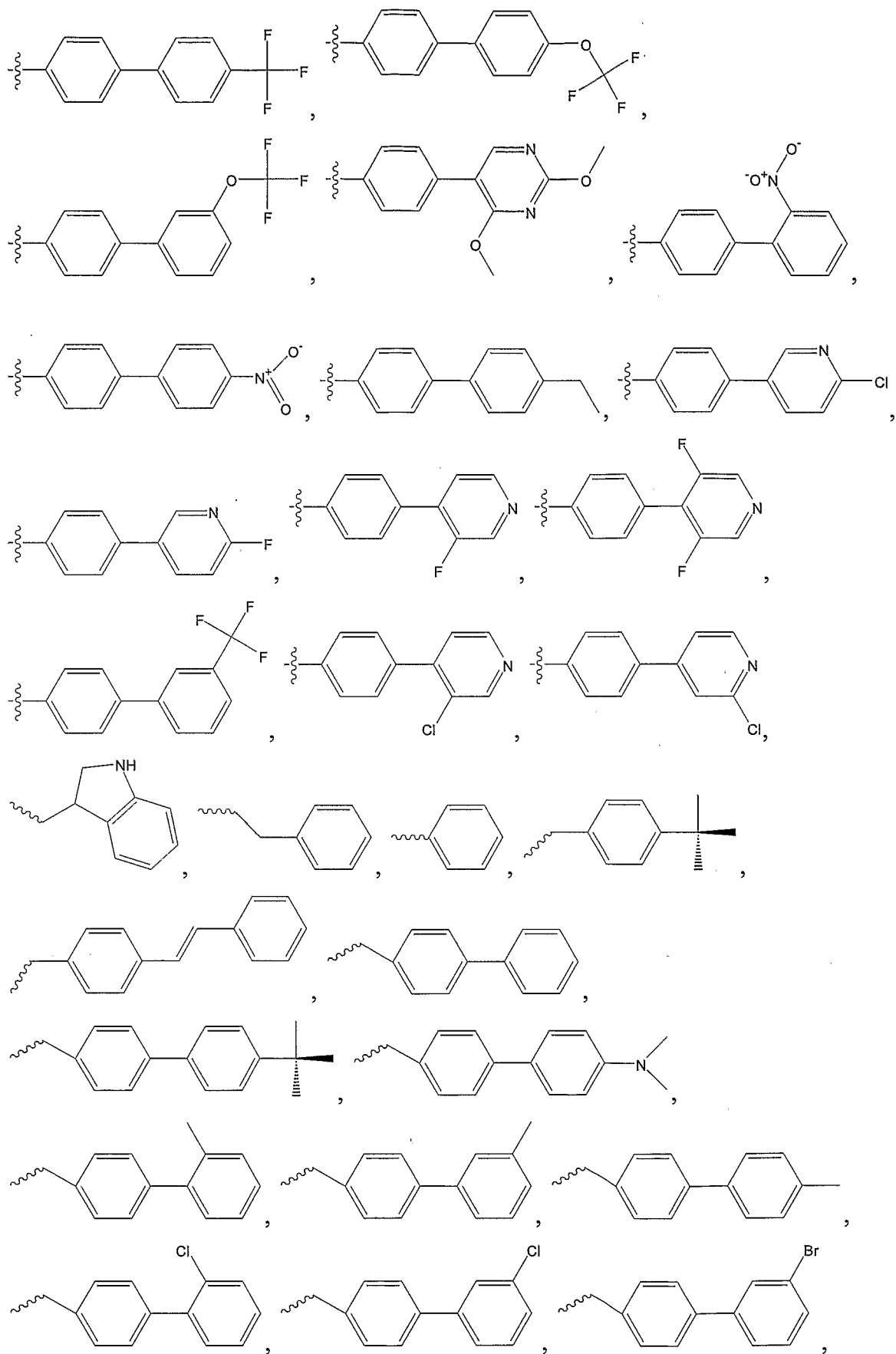
In some embodiments, R₆ is selected from the group consisting of C, N or S.

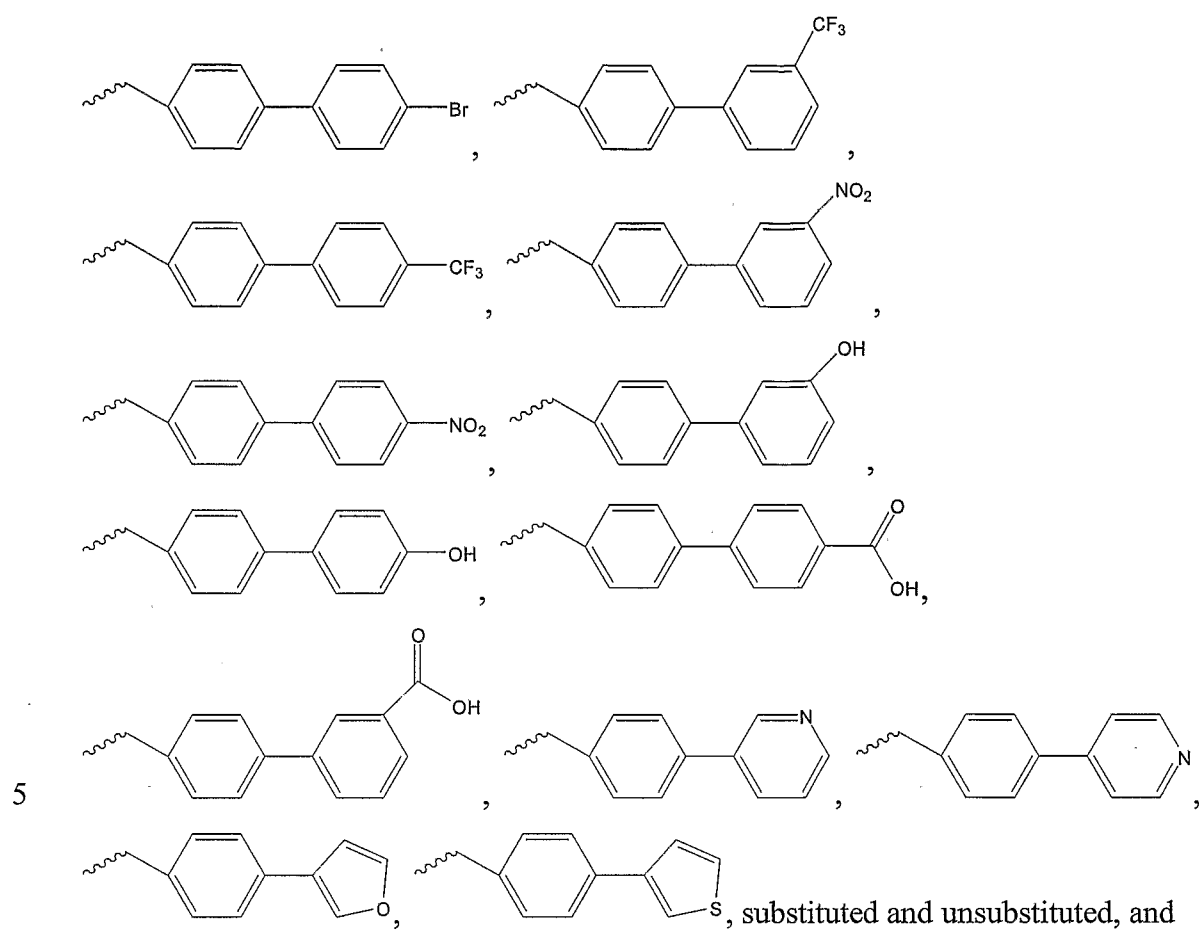
In some embodiments, R₁ is selected from the group consisting of:



5

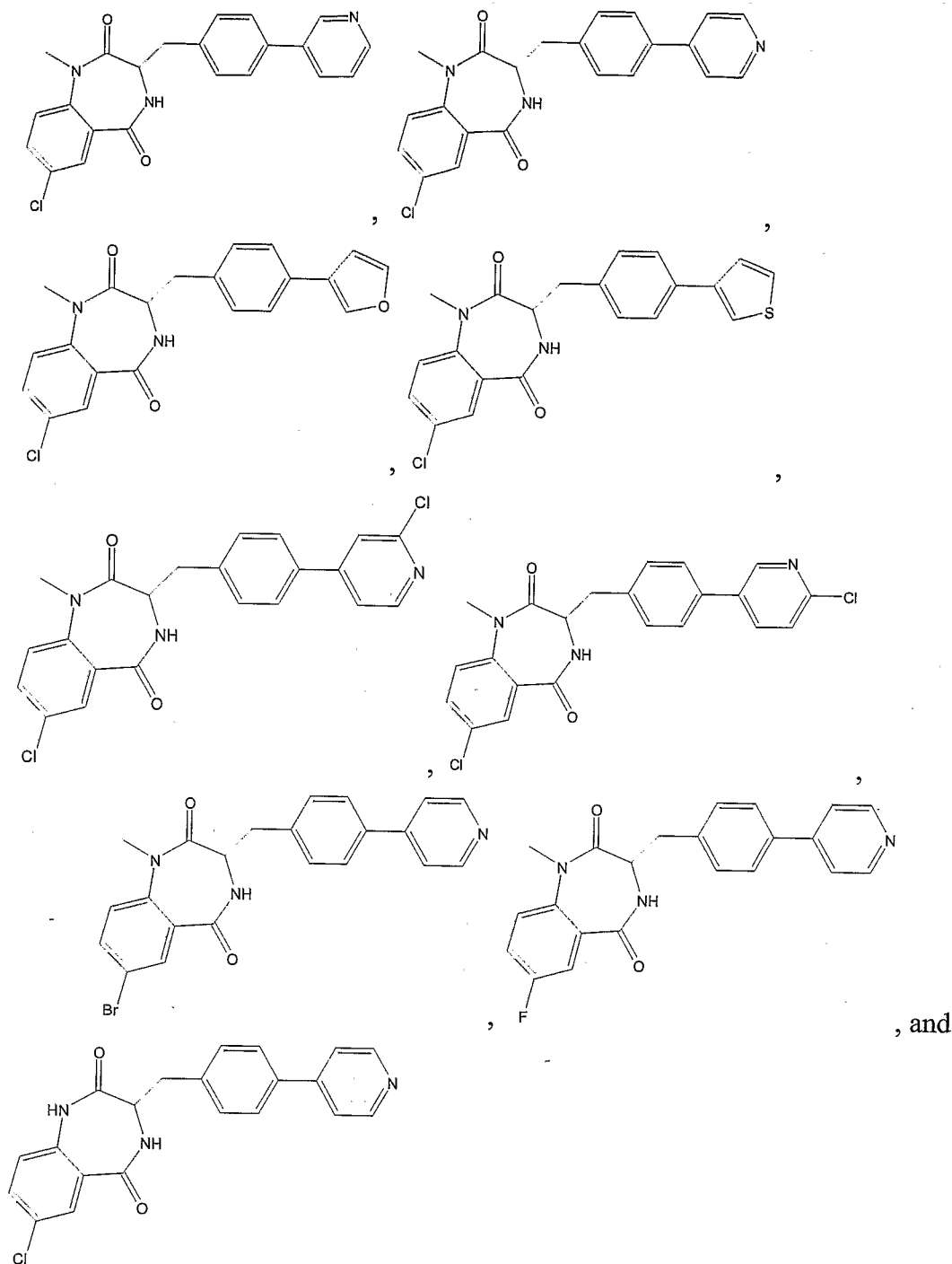






derivatives thereof.

Certain 1,4-benzodiazepine-2,5-dione compounds of the present invention include, but are not limited to,



From the above description, it is apparent that many specific examples are represented by the generic formulas presented above. A wide variety of sub combinations arising from selecting a particular group at each substituent position are possible and all such combinations are within the scope of this invention. The experimental examples, provided below, describe biological activities of these compounds and provide assays for assessing activities of derivatives or other related compounds.

In summary, a large number of compounds are presented herein. Any one or more of these compounds can be used to treat a variety of dysregulatory disorders related to cellular death as described elsewhere herein. Additionally, any one or more of these compounds can be used in combination with at least one other therapeutic agent (e.g., potassium channel openers, calcium channel blockers, sodium hydrogen exchanger inhibitors, antiarrhythmic agents, antiatherosclerotic agents, anticoagulants, antithrombotic agents, prothrombolytic agents, fibrinogen antagonists, diuretics, antihypertensive agents, ATPase inhibitors, mineralocorticoid receptor antagonists, phosphodiesterase inhibitors, antidiabetic agents, anti-inflammatory agents, antioxidants, angiogenesis modulators, antiosteoporosis agents, hormone replacement therapies, hormone receptor modulators, oral contraceptives, antiobesity agents, antidepressants, antianxiety agents, antipsychotic agents, antiproliferative agents, antitumor agents, antiulcer and gastroesophageal reflux disease agents, growth hormone agents and/or growth hormone secretagogues, thyroid mimetics, anti-infective agents, antiviral agents, antibacterial agents, antifungal agents, cholesterol/lipid lowering agents and lipid profile therapies, and agents that mimic ischemic preconditioning and/or myocardial stunning, antiatherosclerotic agents, anticoagulants, antithrombotic agents, antihypertensive agents, antidiabetic agents, and antihypertensive agents selected from ACE inhibitors, AT-1 receptor antagonists, ET receptor antagonists, dual ET/AII receptor antagonists, and vasopepsidase inhibitors, or an antiplatelet agent selected from GPIIb/IIIa blockers, P2Y₁ and P2Y₁₂ antagonists, thromboxane receptor antagonists, and aspirin) cellular activating agents in along with a pharmaceutically-acceptable carrier or diluent in a pharmaceutical composition. The above-described compounds can also be used in drug screening assays and other diagnostic and research methods.

III. Pharmaceutical compositions, formulations, and exemplary administration routes and dosing considerations

Exemplary embodiments of various contemplated medicaments and pharmaceutical compositions are provided below.

A. Preparing Medicaments

The compounds of the present invention are useful in the preparation of medicaments to treat a variety of conditions associated with dysregulation of cell death, aberrant cell growth and hyperproliferation.

5 In addition, the compounds are also useful for preparing medicaments for treating other disorders wherein the effectiveness of the compounds are known or predicted. Such disorders include, but are not limited to, autoimmune disorders disorders. The methods and techniques for preparing medicaments of a compound of the present invention are well-known in the art. Exemplary pharmaceutical formulations and routes of delivery are
10 described below.

One of skill in the art will appreciate that any one or more of the compounds described herein, including the many specific embodiments, are prepared by applying standard pharmaceutical manufacturing procedures. Such medicaments can be delivered to the subject by using delivery methods that are well-known in the pharmaceutical arts.

B. Exemplary pharmaceutical compositions and formulation

In some embodiments of the present invention, the compositions are administered alone, while in some other embodiments, the compositions are preferably present in a pharmaceutical formulation comprising at least one active ingredient/agent, as defined
20 above, together with a solid support or alternatively, together with one or more pharmaceutically acceptable carriers and optionally other therapeutic agents (*e.g.*, a benzodiazepine compound as described in 60/812,270, 60/802,394, 60/607,599, and 60/641,040, and U.S. Patent Application Nos. 11/445,010, 11/324,419, 11/176,719, 11/110,228, 10/935,333, 10/886,450, 10/795,535, 10/634,114, 10/427,211, 10/427,212,
25 10/217,878, 09/767,283, 09/700,101, and related applications; each herein incorporated by reference in their entireties). Each carrier should be "acceptable" in the sense that it is compatible with the other ingredients of the formulation and not injurious to the subject.

Contemplated formulations include those suitable oral, rectal, nasal, topical (including transdermal, buccal and sublingual), vaginal, parenteral (including subcutaneous,
30 intramuscular, intravenous and intradermal) and pulmonary administration. In some embodiments, formulations are conveniently presented in unit dosage form and are prepared by any method known in the art of pharmacy. Such methods include the step of bringing into association the active ingredient with the carrier which constitutes one or more

accessory ingredients. In general, the formulations are prepared by uniformly and intimately bringing into association (*e.g.*, mixing) the active ingredient with liquid carriers or finely divided solid carriers or both, and then if necessary shaping the product.

Formulations of the present invention suitable for oral administration may be presented as discrete units such as capsules, cachets or tablets, wherein each preferably contains a predetermined amount of the active ingredient; as a powder or granules; as a solution or suspension in an aqueous or non-aqueous liquid; or as an oil-in-water liquid emulsion or a water-in-oil liquid emulsion. In other embodiments, the active ingredient is presented as a bolus, electuary, or paste, *etc.*

In some embodiments, tablets comprise at least one active ingredient and optionally one or more accessory agents/carriers are made by compressing or molding the respective agents. In preferred embodiments, compressed tablets are prepared by compressing in a suitable machine the active ingredient in a free-flowing form such as a powder or granules, optionally mixed with a binder (*e.g.*, povidone, gelatin, hydroxypropylmethyl cellulose), lubricant, inert diluent, preservative, disintegrant (*e.g.*, sodium starch glycolate, cross-linked povidone, cross-linked sodium carboxymethyl cellulose) surface-active or dispersing agent. Molded tablets are made by molding in a suitable machine a mixture of the powdered compound (*e.g.*, active ingredient) moistened with an inert liquid diluent. Tablets may optionally be coated or scored and may be formulated so as to provide slow or controlled release of the active ingredient therein using, for example, hydroxypropylmethyl cellulose in varying proportions to provide the desired release profile. Tablets may optionally be provided with an enteric coating, to provide release in parts of the gut other than the stomach.

Formulations suitable for topical administration in the mouth include lozenges comprising the active ingredient in a flavored basis, usually sucrose and acacia or tragacanth; pastilles comprising the active ingredient in an inert basis such as gelatin and glycerin, or sucrose and acacia; and mouthwashes comprising the active ingredient in a suitable liquid carrier.

Pharmaceutical compositions for topical administration according to the present invention are optionally formulated as ointments, creams, suspensions, lotions, powders, solutions, pastes, gels, sprays, aerosols or oils. In alternative embodiments, topical formulations comprise patches or dressings such as a bandage or adhesive plasters impregnated with active ingredient(s), and optionally one or more excipients or diluents. In

preferred embodiments, the topical formulations include a compound(s) that enhances absorption or penetration of the active agent(s) through the skin or other affected areas. Examples of such dermal penetration enhancers include dimethylsulfoxide (DMSO) and related analogues.

5 If desired, the aqueous phase of a cream base includes, for example, at least about 30% w/w of a polyhydric alcohol, *i.e.*, an alcohol having two or more hydroxyl groups such as propylene glycol, butane-1,3-diol, mannitol, sorbitol, glycerol and polyethylene glycol and mixtures thereof.

10 In some embodiments, oily phase emulsions of this invention are constituted from known ingredients in a known manner. This phase typically comprises a lone emulsifier (otherwise known as an emulgent), it is also desirable in some embodiments for this phase to further comprises a mixture of at least one emulsifier with a fat or an oil or with both a fat and an oil.

15 Preferably, a hydrophilic emulsifier is included together with a lipophilic emulsifier so as to act as a stabilizer. In some embodiments it is also preferable to include both an oil and a fat. Together, the emulsifier(s) with or without stabilizer(s) make up the so-called emulsifying wax, and the wax together with the oil and/or fat make up the so-called emulsifying ointment base which forms the oily dispersed phase of the cream formulations.

20 Emulgents and emulsion stabilizers suitable for use in the formulation of the present invention include Tween 60, Span 80, cetostearyl alcohol, myristyl alcohol, glyceryl monostearate and sodium lauryl sulfate.

25 The choice of suitable oils or fats for the formulation is based on achieving the desired properties (*e.g.*, cosmetic properties), since the solubility of the active compound/agent in most oils likely to be used in pharmaceutical emulsion formulations is very low. Thus creams should preferably be a non-greasy, non-staining and washable products with suitable consistency to avoid leakage from tubes or other containers. Straight or branched chain, mono- or dibasic alkyl esters such as di-isoadipate, isocetyl stearate, propylene glycol diester of coconut fatty acids, isopropyl myristate, decyl oleate, isopropyl palmitate, butyl stearate, 2-ethylhexyl palmitate or a blend of branched chain esters known
30 as Crodamol CAP may be used, the last three being preferred esters. These may be used alone or in combination depending on the properties required. Alternatively, high melting point lipids such as white soft paraffin and/or liquid paraffin or other mineral oils can be used.

Formulations suitable for topical administration to the eye also include eye drops wherein the active ingredient is dissolved or suspended in a suitable carrier, especially an aqueous solvent for the agent.

5 Formulations for rectal administration may be presented as a suppository with suitable base comprising, for example, cocoa butter or a salicylate.

Formulations suitable for vaginal administration may be presented as pessaries, creams, gels, pastes, foams or spray formulations containing in addition to the agent, such carriers as are known in the art to be appropriate.

10 Formulations suitable for nasal administration, wherein the carrier is a solid, include coarse powders having a particle size, for example, in the range of about 20 to about 500 microns which are administered in the manner in which snuff is taken, *i.e.*, by rapid inhalation (*e.g.*, forced) through the nasal passage from a container of the powder held close up to the nose. Other suitable formulations wherein the carrier is a liquid for administration include, but are not limited to, nasal sprays, drops, or aerosols by nebulizer, and include
15 aqueous or oily solutions of the agents.

Formulations suitable for parenteral administration include aqueous and non-aqueous isotonic sterile injection solutions which may contain antioxidants, buffers, bacteriostats and solutes which render the formulation isotonic with the blood of the intended recipient; and aqueous and non-aqueous sterile suspensions which may include
20 suspending agents and thickening agents, and liposomes or other microparticulate systems which are designed to target the compound to blood components or one or more organs. In some embodiments, the formulations are presented/formulated in unit-dose or multi-dose sealed containers, for example, ampoules and vials, and may be stored in a freeze-dried (lyophilized) condition requiring only the addition of the sterile liquid carrier, for example
25 water for injections, immediately prior to use. Extemporaneous injection solutions and suspensions may be prepared from sterile powders, granules and tablets of the kind previously described.

Preferred unit dosage formulations are those containing a daily dose or unit, daily subdose, as herein above-recited, or an appropriate fraction thereof, of an agent.

30 It should be understood that in addition to the ingredients particularly mentioned above, the formulations of this invention may include other agents conventional in the art having regard to the type of formulation in question, for example, those suitable for oral administration may include such further agents as sweeteners, thickeners and flavoring

agents. It also is intended that the agents, compositions and methods of this invention be combined with other suitable compositions and therapies. Still other formulations optionally include food additives (suitable sweeteners, flavorings, colorings, *etc.*), phytonutrients (*e.g.*, flax seed oil), minerals (*e.g.*, Ca, Fe, K, *etc.*), vitamins, and other acceptable compositions (*e.g.*, conjugated linoelic acid), extenders, and stabilizers, *etc.*

C. Exemplary administration routes and dosing considerations

Various delivery systems are known and can be used to administer therapeutic agents (*e.g.*, exemplary compounds as described in Section II above) of the present invention, *e.g.*, encapsulation in liposomes, microparticles, microcapsules, receptor-mediated endocytosis, and the like. Methods of delivery include, but are not limited to, intra-arterial, intra-muscular, intravenous, intranasal, and oral routes. In specific embodiments, it may be desirable to administer the pharmaceutical compositions of the invention locally to the area in need of treatment; this may be achieved by, for example, and not by way of limitation, local infusion during surgery, injection, or by means of a catheter.

The agents identified can be administered to subjects or individuals susceptible to or at risk of developing pathological growth of target cells and correlated conditions. When the agent is administered to a subject such as a mouse, a rat or a human patient, the agent can be added to a pharmaceutically acceptable carrier and systemically or topically administered to the subject. To identify patients that can be beneficially treated, a tissue sample is removed from the patient and the cells are assayed for sensitivity to the agent. Therapeutic amounts are empirically determined and vary with the pathology being treated, the subject being treated and the efficacy and toxicity of the agent.

In some embodiments, *in vivo* administration is effected in one dose, continuously or intermittently throughout the course of treatment. Methods of determining the most effective means and dosage of administration are well known to those of skill in the art and vary with the composition used for therapy, the purpose of the therapy, the target cell being treated, and the subject being treated. Single or multiple administrations are carried out with the dose level and pattern being selected by the treating physician.

Suitable dosage formulations and methods of administering the agents are readily determined by those of skill in the art. Preferably, the compounds are administered at about 0.01 mg/kg to about 200 mg/kg, more preferably at about 0.1 mg/kg to about 100 mg/kg, even more preferably at about 0.5 mg/kg to about 50 mg/kg. When the compounds

described herein are co-administered with another agent (*e.g.*, as sensitizing agents), the effective amount may be less than when the agent is used alone.

The pharmaceutical compositions can be administered orally, intranasally, parenterally or by inhalation therapy, and may take the form of tablets, lozenges, granules, capsules, pills, ampoules, suppositories or aerosol form. They may also take the form of suspensions, solutions and emulsions of the active ingredient in aqueous or nonaqueous diluents, syrups, granulates or powders. In addition to an agent of the present invention, the pharmaceutical compositions can also contain other pharmaceutically active compounds or a plurality of compounds of the invention.

More particularly, an agent of the present invention also referred to herein as the active ingredient, may be administered for therapy by any suitable route including, but not limited to, oral, rectal, nasal, topical (including, but not limited to, transdermal, aerosol, buccal and sublingual), vaginal, parental (including, but not limited to, subcutaneous, intramuscular, intravenous and intradermal) and pulmonary. It is also appreciated that the preferred route varies with the condition and age of the recipient, and the disease being treated.

Ideally, the agent should be administered to achieve peak concentrations of the active compound at sites of disease. This may be achieved, for example, by the intravenous injection of the agent, optionally in saline, or orally administered, for example, as a tablet, capsule or syrup containing the active ingredient.

Desirable blood levels of the agent may be maintained by a continuous infusion to provide a therapeutic amount of the active ingredient within disease tissue. The use of operative combinations is contemplated to provide therapeutic combinations requiring a lower total dosage of each component antiviral agent than may be required when each individual therapeutic compound or drug is used alone, thereby reducing adverse effects.

D. Exemplary co-administration routes and dosing considerations

The present invention also includes methods involving co-administration of the compounds described herein with one or more additional active agents. Indeed, it is a further aspect of this invention to provide methods for enhancing prior art therapies and/or pharmaceutical compositions by co-administering a compound of this invention. In co-administration procedures, the agents may be administered concurrently or sequentially. In one embodiment, the compounds described herein are administered prior to the other active

agent(s). The pharmaceutical formulations and modes of administration may be any of those described above. In addition, the two or more co-administered chemical agents, biological agents or radiation may each be administered using different modes or different formulations.

5 The agent or agents to be co-administered depends on the type of condition being treated. For example, when the condition being treated is cancer, the additional agent can be a chemotherapeutic agent or radiation. When the condition being treated is an autoimmune disorder, the additional agent can be an immunosuppressant or an anti-inflammatory agent. When the condition being treated is chronic inflammation, the additional agent can be an anti-inflammatory agent. The additional agents to be co-administered, such as anticancer, immunosuppressant, anti-inflammatory, and can be any of the well-known agents in the art, including, but not limited to, those that are currently in clinical use. The determination of appropriate type and dosage of radiation treatment is also within the skill in the art or can be determined with relative ease.

15 Treatment of the various conditions associated with abnormal apoptosis is generally limited by the following two major factors: (1) the development of drug resistance and (2) the toxicity of known therapeutic agents. In certain cancers, for example, resistance to chemicals and radiation therapy has been shown to be associated with inhibition of apoptosis. Some therapeutic agents have deleterious side effects, including non-specific lymphotoxicity, renal and bone marrow toxicity.

20 The methods described herein address both these problems. Drug resistance, where increasing dosages are required to achieve therapeutic benefit, is overcome by co-administering the compounds described herein with the known agent. The compounds described herein sensitize target cells to known agents (and vice versa) and, accordingly, less of these agents are needed to achieve a therapeutic benefit.

25 The sensitizing function of the claimed compounds also addresses the problems associated with toxic effects of known therapeutics. In instances where the known agent is toxic, it is desirable to limit the dosages administered in all cases, and particularly in those cases where drug resistance has increased the requisite dosage. When the claimed compounds are co-administered with the known agent, they reduce the dosage required which, in turn, reduces the deleterious effects. Further, because the claimed compounds are themselves both effective and non-toxic in large doses, co-administration of proportionally

more of these compounds than known toxic therapeutics will achieve the desired effects while minimizing toxic effects.

IV. Drug screens

5 In some embodiments of the present invention, the compounds of the present invention, and other potentially useful compounds, are screened for pro-apoptotic properties consistent with a mechanism that does not entail interaction with the mitochondrial F_1F_0 -ATPase. In preferred embodiments of the present invention, the compounds of the present invention, and other potentially useful compounds, are screened for pro-apoptotic selectivity
10 for T cells over B cells.

A number of suitable screens for measuring the binding affinity of drugs and other small molecules to receptors are known in the art. In some embodiments, binding affinity screens are conducted in *in vitro* systems. In other embodiments, these screens are conducted in *in vivo* or *ex vivo* systems.

V. Therapeutic Application

In particularly preferred embodiments, the compositions of the present invention are contemplated to provide therapeutic benefits to patients suffering from any one or more of a number of conditions (*e.g.*, diseases characterized by dysregulation of necrosis and/or
20 apoptosis processes in a cell or tissue, disease characterized by aberrant cell growth and/or hyperproliferation, autoimmune diseases, haematologic malignancies resulting from aberrant survival and expansion of B and T cells in central and peripheral lymphoid organs, *etc.*) by modulating (*e.g.*, inhibiting or promoting) apoptosis in affected cells or tissues. In further preferred embodiments, the compositions of the present invention are used to treat
25 autoimmune/chronic inflammatory conditions.

In particularly preferred embodiments, the compositions of the present invention regulate apoptosis through the exposure of cells to the compounds of the present invention (*e.g.*, 1,4-benzodiazepine-2,5-diones). In particular, the present invention demonstrates that 1,4-benzodiazepine-2,5-diones with, for example, an electron rich heterocycle moiety at the
30 C3 position of the benzodiazepine ring have pro-apoptotic properties consistent with a mechanism that does not result from interaction with the mitochondrial F_1F_0 -ATPase. The present invention also demonstrates that 1,4-benzodiazepine-2,5-diones with an electron

rich heterocycle moiety at the C3 position of the benzodiazepine ring have pro-apoptotic selectivity for T cells over B cells.

Accordingly, preferred methods embodied in the present invention provide therapeutic benefits to patients by providing compounds of the present invention that modulate (*e.g.*, inhibiting or promoting) cellular apoptosis in affected cells or tissues without interacting with the mitochondrial F_1F_0 -ATPase.

In some embodiments, compounds potentially useful in methods of the present invention are screened against the National Cancer Institute's (NCI-60) cancer cell lines for efficacy. (*See e.g.*, A. Monks *et al.*, J. Natl. Cancer Inst., 83:757-766 [1991]; and K.D. Paull *et al.*, J. Natl. Cancer Inst., 81:1088-1092 [1989]). Additional screens suitable screens (*e.g.*, autoimmunity disease models, *etc.*) are within the skill in the art.

In one aspect, derivatives (*e.g.*, pharmaceutically acceptable salts, analogs, stereoisomers, and the like) of the exemplary compounds or other suitable compounds are also contemplated as being useful in the methods of the present invention.

Those skilled in the art of preparing pharmaceutical compounds and formulations will appreciate that when selecting optional compounds for use in the methods disclosed herein, that suitability considerations include, but are not limited to, the toxicity, safety, efficacy, availability, and cost of the particular compounds.

20 EXAMPLES

The following examples are provided to demonstrate and further illustrate certain preferred embodiments of the present invention and are not to be construed as limiting the scope thereof.

25 Example 1.

This example describes the formulation of exemplary 1,4-benzodiazepine-2,5-diones. As shown in Figure 1, Bz-423 is a pro-apoptotic 1,4 benzodiazepine with potent activity in animal models of lupus (*see, e.g.*, Blatt, N.B., *et al.*, J. Clin. Invest. 2002, 10, 1123; Bednarski, J. J., *et al.*, Arthritis Rheum. 2003, 48, 757; each herein incorporated by reference in their entirety). Bz-423 binds to the oligomycin sensitivity conferring protein (OSCP) component of the mitochondrial F_1F_0 -ATPase (*see, e.g.*, Johnson, K.M., *et al.*, Chemistry and Biology. 2005, 12, 485; herein incorporated by reference in its entirety). Bz-423 inhibits the enzyme, which produces a state 3 to state 4 transition within the

mitochondrial respiratory chain (MRC), ultimately resulting in the production of O_2^- from MRC complex III. This reactive oxygen species functions as a signal- initiating a tightly-regulated apoptotic process (see, e.g., Johnson, K.M., et al., Chemistry and Biology. 2005, 12, 485; herein incorporated by reference in its entirety).

Previous studies revealed that a hydrophobic aromatic substituent at C3 along with the phenolic hydroxyl group is required for the cytotoxic activity of Bz-423. As part of efforts to further define the elements of Bz-423 required for inhibiting the F_1F_0 -ATPase, a series of 1,4-benzodiazepine-2,5-diones were synthesized as intermediates for other chemistry. Most of these compounds were cytotoxic and unlike Bz-423, many were more selective for T cells compared to B cells (Figure 2). Replacing the naphthyl moiety with other hydrophobic groups of comparable size (2, 3), but which occupy different space, had relatively small effects on activity compared with 1, and in some cases altered the selectivity. By contrast, reducing the size of the C3 group (4, 5) was not tolerated. Given the similarity between the structures in Figure 2 and the pro-apoptotic 1,4-benzodiazepines previously reported (see, e.g., Johnson, K.M., et al., Chemistry and Biology. 2005, 12, 485; herein incorporated by reference in its entirety), experiments were conducted to determine if the 1,4-benzodiazepine-2,5-dione compounds inhibit the F_1F_0 -ATPase and generate O_2^- in the same manner as Bz-423. Compounds listed in Figure 2 neither blocked the F_1F_0 -ATPase nor inhibited by agents that specifically scavenge superoxide. These results indicated that the 1,4-benzodiazepine-2,5-dione compounds shown in Figure 2 have a different molecular target and apoptotic mechanism than Bz-423. By contrast, the *m*-biphenyl analog inhibited ATP hydrolysis while not blocking synthesis, similar to previously reported 1,4-benzodiazepine (see, e.g., Hamann, L.G., et al., Bio. Med. Chem. Lett. 2004, 14, 1031; herein incorporated by reference in its entirety).

Example 2.

This example describes the optimization of the novel 1,4-benzodiazepine-2,5-dione compounds of the present invention. The data in Figure 2 show that the size of the C3 is important for the activity of the 1,4-benzodiazepine-2,5-dione compounds. Moreover, these data suggest that it is possible to optimize potency and selectivity based on the biphenyl or 2-naphthylene C3 side chains. A range of substituted biphenyls can be prepared readily by Suzuki couplings of aryl halides with commercially available boronic acids (see, e.g., Suzuki, A. Acc.Chem. Res. 1982, 15, 178; herein incorporated by reference in its entirety).

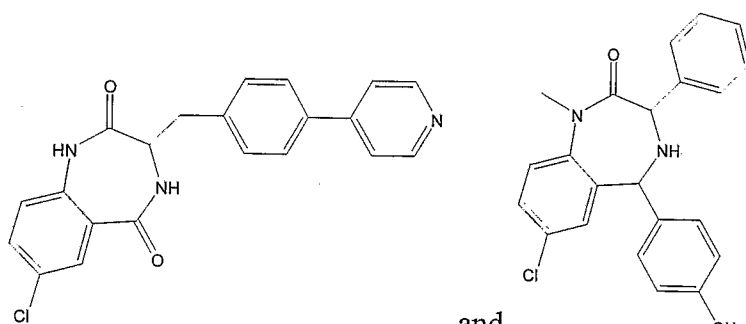
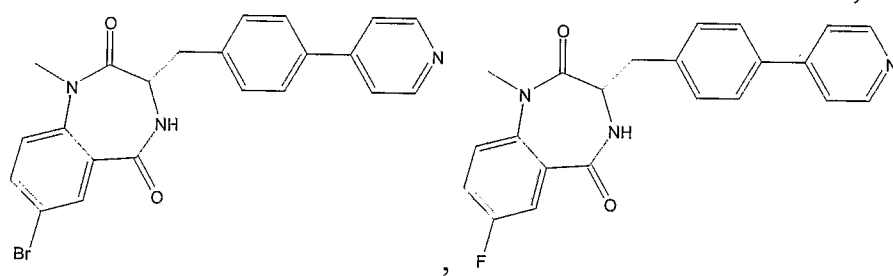
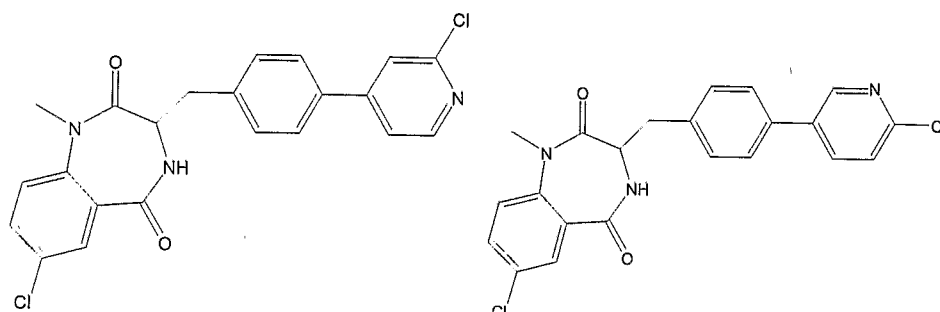
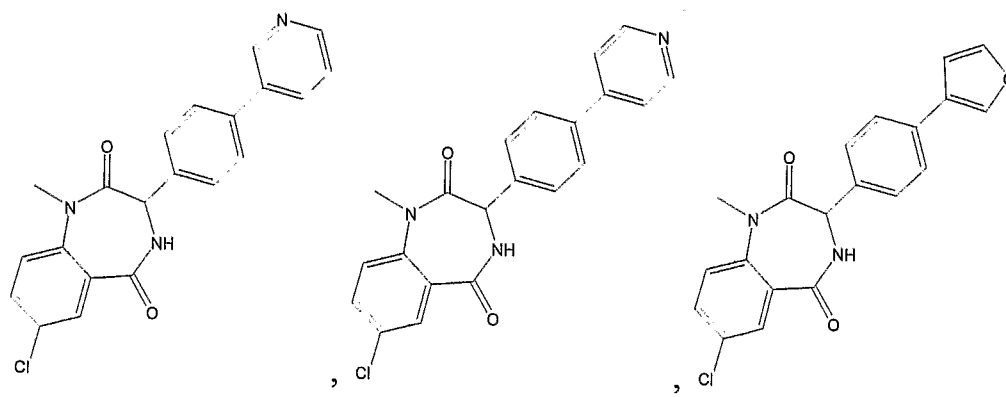
Therefore, the relationship between the stereoelectronics of the C3 side chain and cytotoxicity of the 1,4-benzodiazepine-2,5-dione compounds, was further evaluated by synthesizing substituted analogs of **10** (Figure 3).

In the first group of derivatives a methyl group or chlorine atom was substituted at each of the 2', 3', or 4'-positions. Analysis of these compounds revealed that substitution had little effect of killing T cells but improved the potency against B cells. Since substitution at either the 3' or 4' position led to the greatest improvement in potency, substitutions at those positions was further explored. The addition of electron rich substituents to the *meta* and *para* positions (**26**, **27**) increased potency, whereas the carboxylic acid **28** had the reverse effect. In addition, electron rich, heterocyclic aromatic rings (**30-33**) provided selectively potent compounds, namely (**30**, **31**). Collectively, this data indicate that electron rich aromatic heterocycles at R₁ of Figure 4 provide optimal activity and selectivity, although the present invention is not limited to such compounds.

Figure 5 presents additional selectivity data for additional 1,4-benzodiazepine-2,5-dione compounds of the present invention. Ramos EC₅₀ refers to the concentration of drug required to 50% of Ramos B cells and Jurkat EC₅₀ refers to the concentration of drug required to 50% of Jurkat T cells. Selectivity was calculated by dividing the B cell EC₅₀ data by the that for the T cells. All measurements were conducted as described previously (see, e.g., T. Francis, et al., Bioorg. Med. Chem. Lett. 2006 16, 2423-2427; herein incorporated by reference in its entirety).

Example 3.

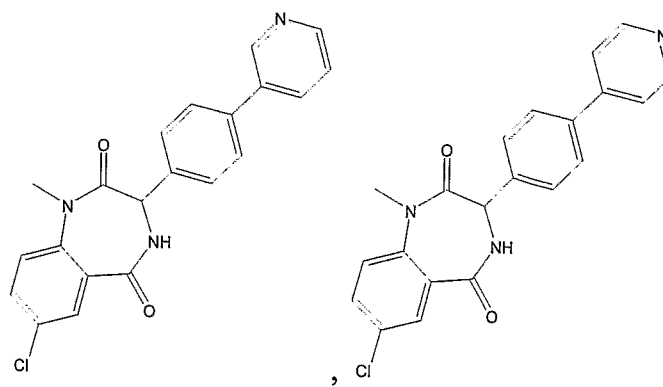
This example demonstrates that 1,4-benzodiazepine-2,5-dione compounds of the present invention do not inhibit ATP synthesis. The following four compounds were exposed to cells, and ATP synthesis measured:

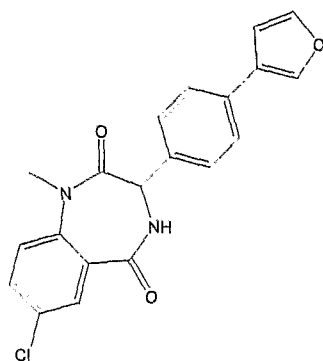


, and

. As shown in Figure 6, the

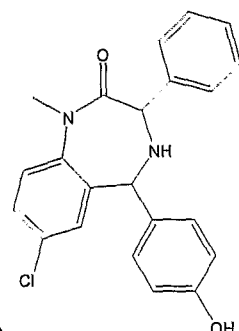
5 following compounds,





inhibit ATP synthesis.

, failed to inhibit ATP synthesis, while



did

All publications and patents mentioned in the above specification are herein
5 incorporated by reference. Although the invention has been described in connection with
specific preferred embodiments, it should be understood that the invention as claimed
should not be unduly limited to such specific embodiments. Indeed, various modifications
of the described modes for carrying out the invention that are obvious to those skilled in the
relevant fields are intended to be within the scope of the following claims.

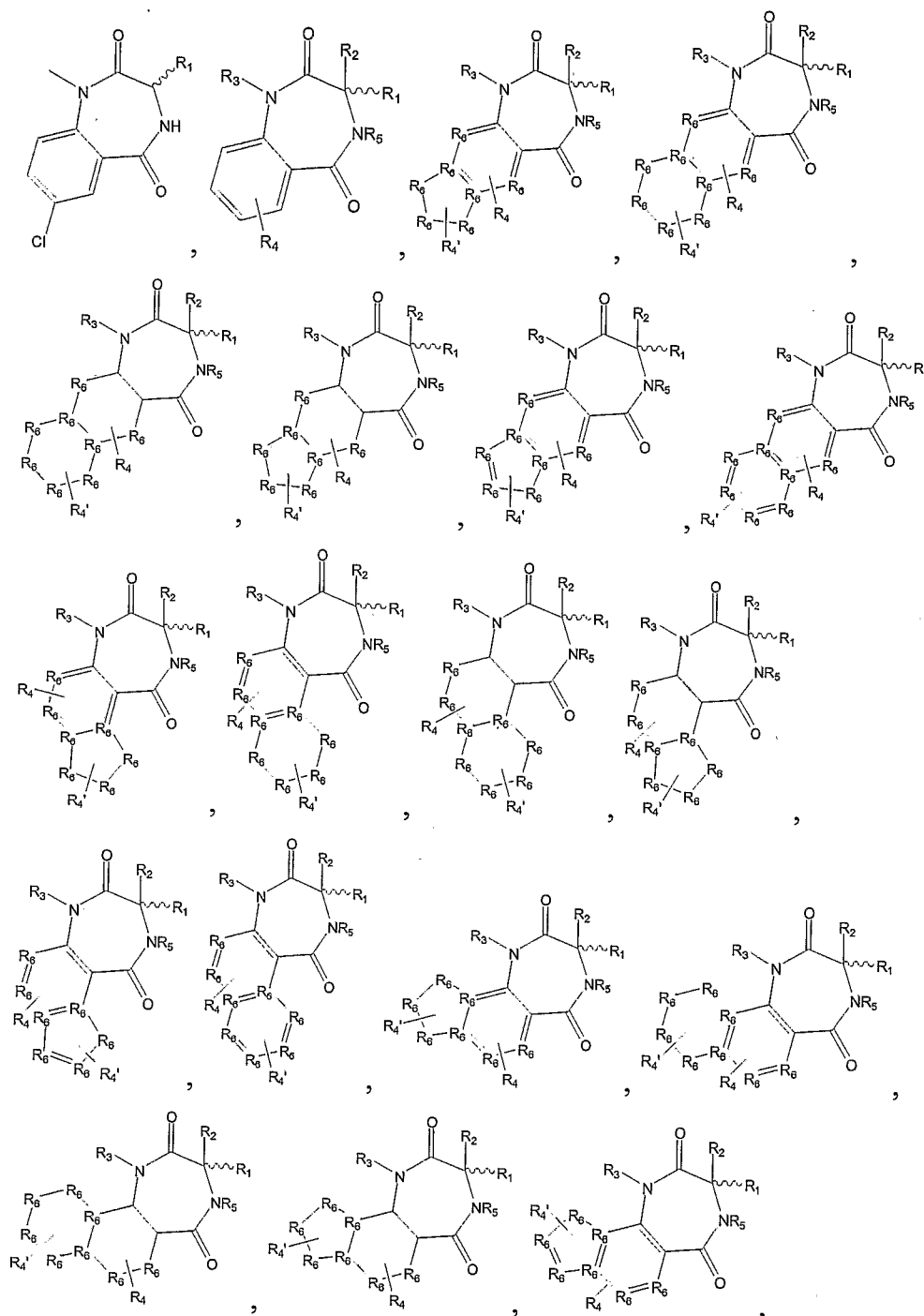
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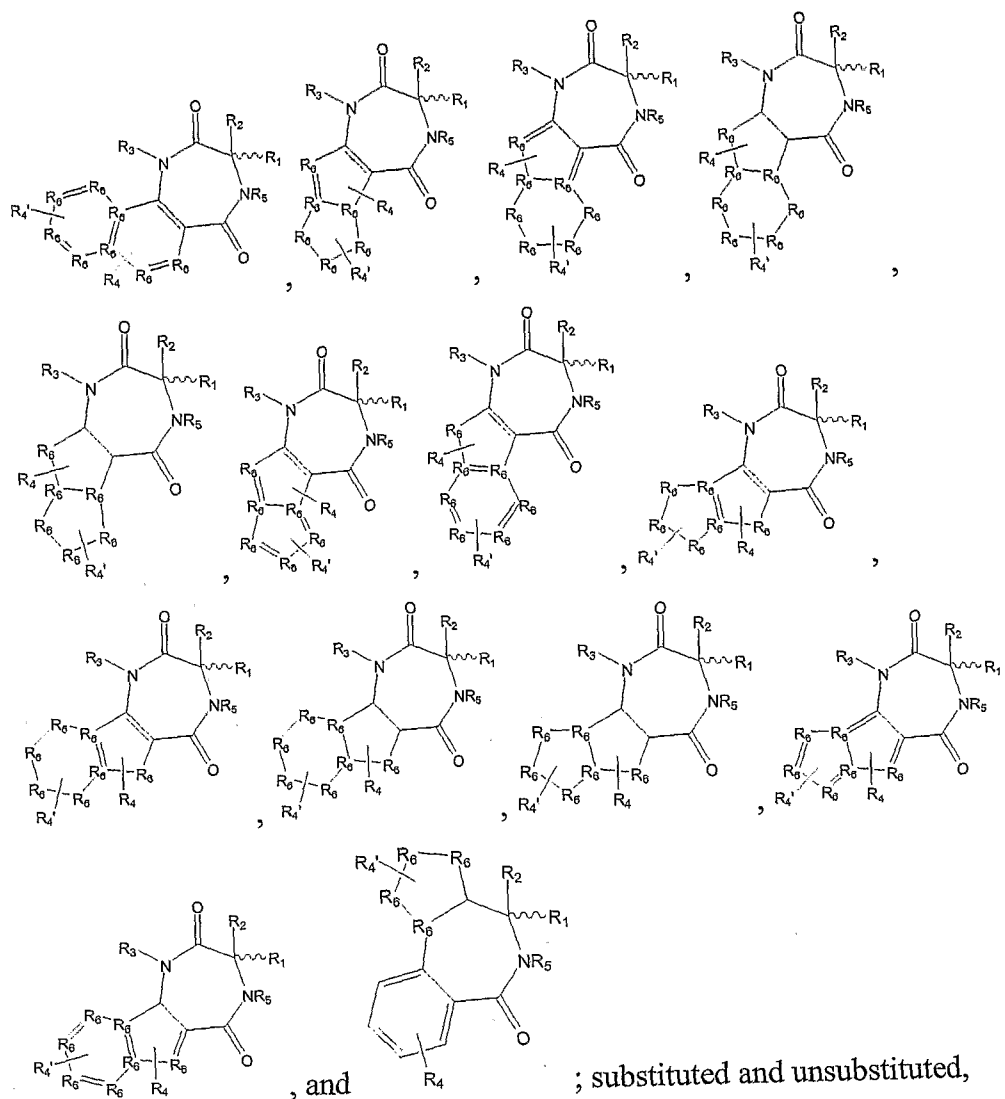
CLAIMS

We claim:

Claim 1.

A composition configured to induce apoptosis in a cell, said composition comprising a compound described by a formula selected from the group consisting of:





, and ; substituted and unsubstituted,
including both R and S enantiomeric forms and racemic mixtures;

wherein R1 is an electron rich heterocycle;

wherein R2 is selected from the group consisting of H, alkyl,
substituted alkyl, and R1;

wherein R3 is selected from the group consisting of H, alkyl, and
substituted alkyl;

wherein R4 and R4' is independently selected from the group
consisting of CH₃, halogen, SO₂R₄'', SO₂N(R₄'')₂, OR₄'', N(R₄'')₂,
CON(R₄'')₂, NHCOR₄'', NHSO₂R₄', alkyl, mono-substituted alkyl, di-
substituted alkyl, tri-substituted alkyl; wherein R₄'' is selected from the
group consisting of halogen, H, alkyl, mono-substituted alkyl, di-substituted
alkyl, tri-substituted alkyl, aryl, mono-substituted aryl, di-substituted aryl,

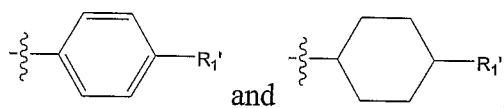
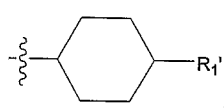
tri-substituted aryl, cycloaliphatic, mono-substituted cycloaliphatic, di-substituted cycloaliphatic, tri-substituted cycloaliphatic.;

wherein R₅ is selected from the group consisting of H, alkyl, mono-substituted aryl, di-substituted aryl, and tri-substituted aryl; and

5 wherein R₆ is selected from the group consisting of C, N or S.

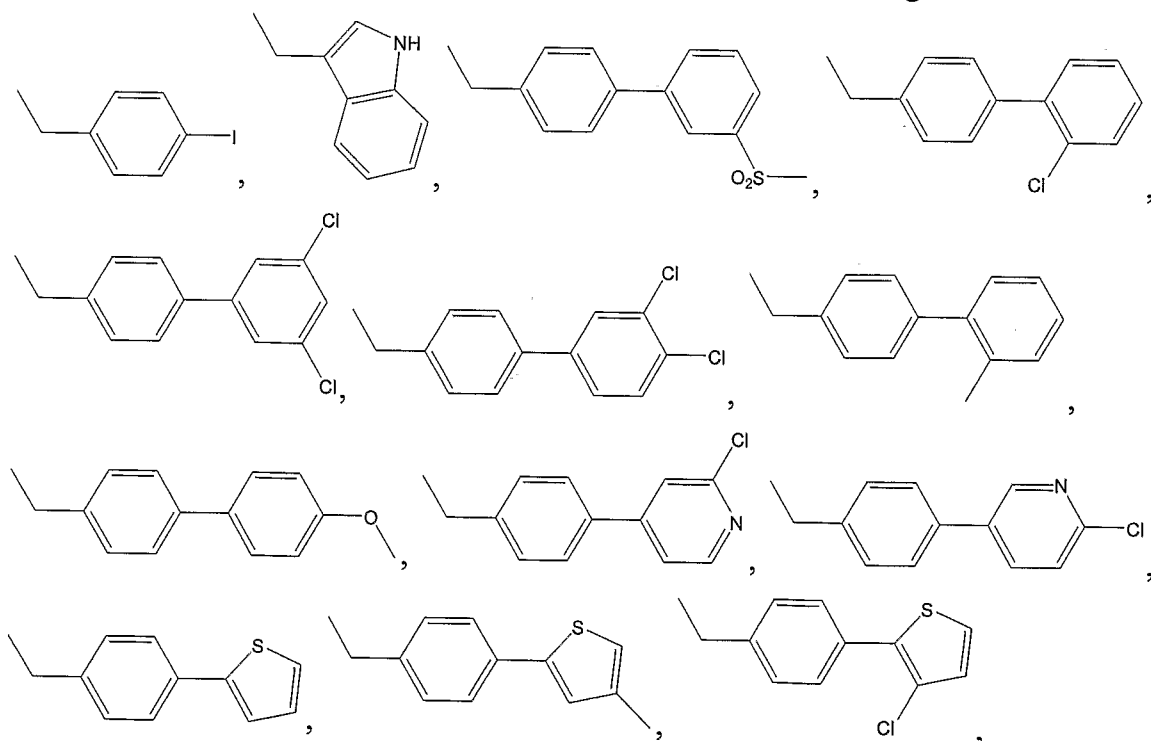
Claim 2. The composition of Claim 1, wherein said electron rich heterocycle contains 5 or more heterocyclic atoms.

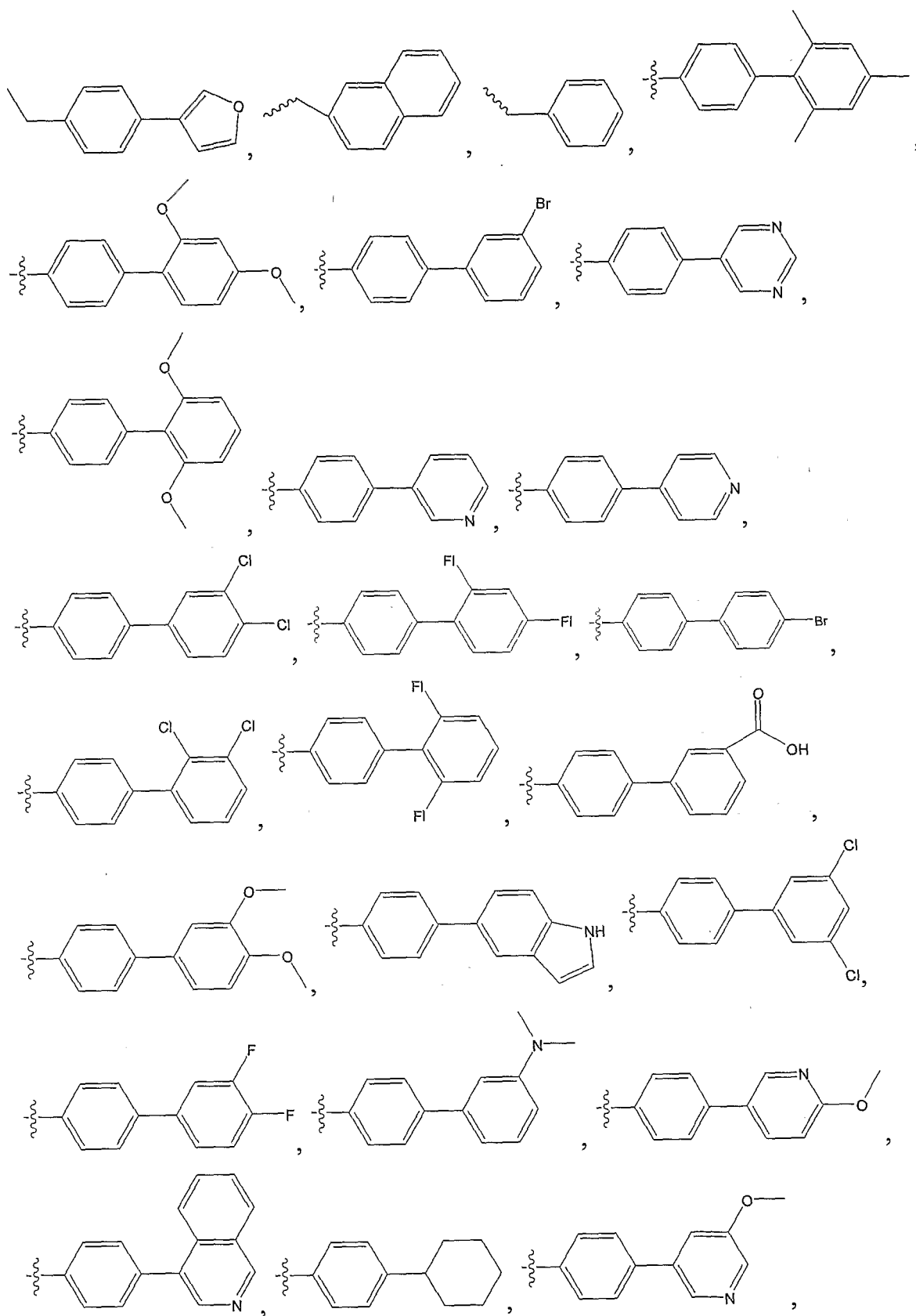
10 Claim 3. The composition of Claim 1, wherein R₁ is selected from the group consisting of

 and , wherein R₁' is selected from the group consisting of cycloaliphatic, aryl, substituted aryl, heterocyclic, and substituted heterocyclic.

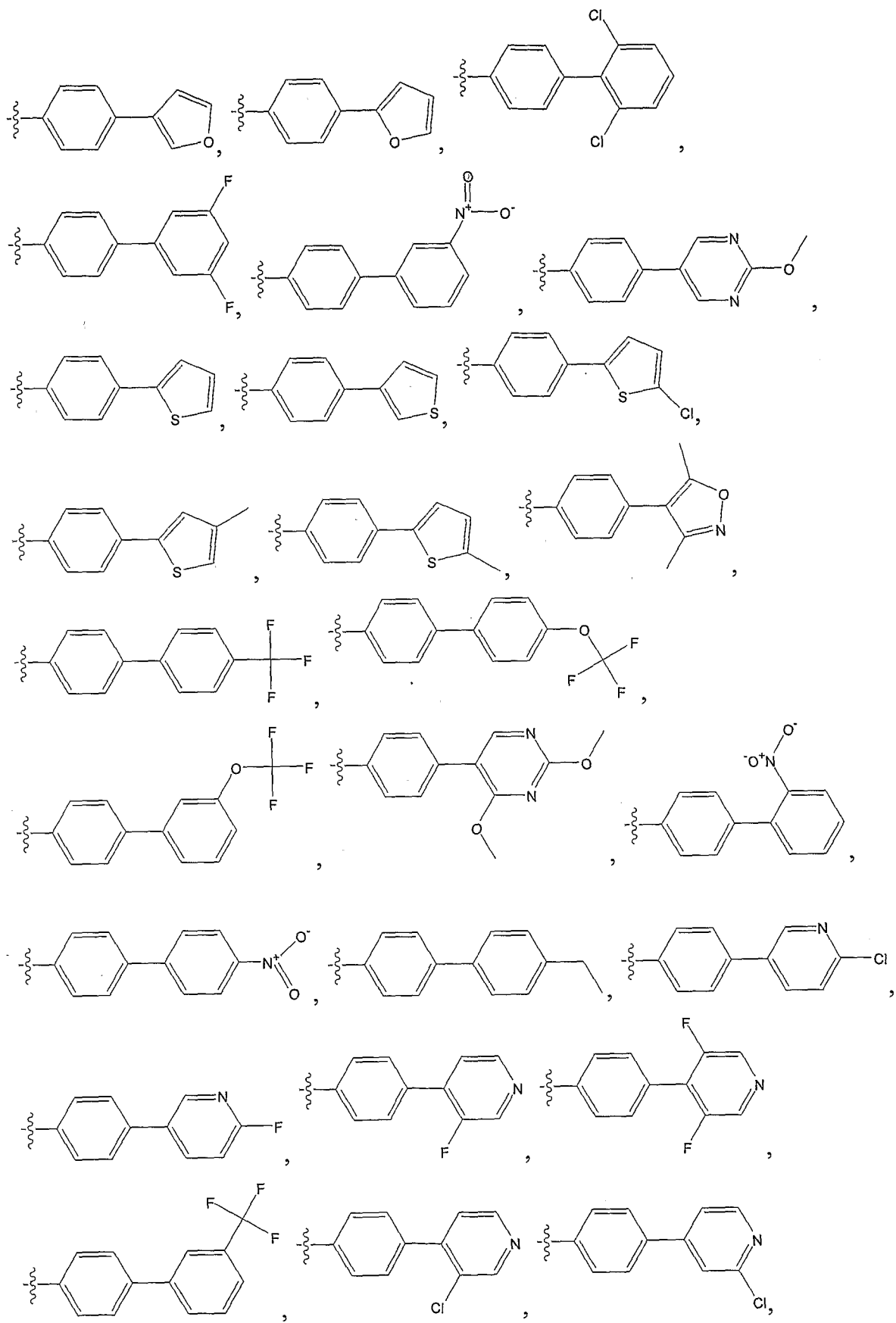
15 Claim 4. The composition of Claim 1, wherein R₁ is selected from the group consisting of:

In some embodiments, R₁ is selected from the group consisting of:



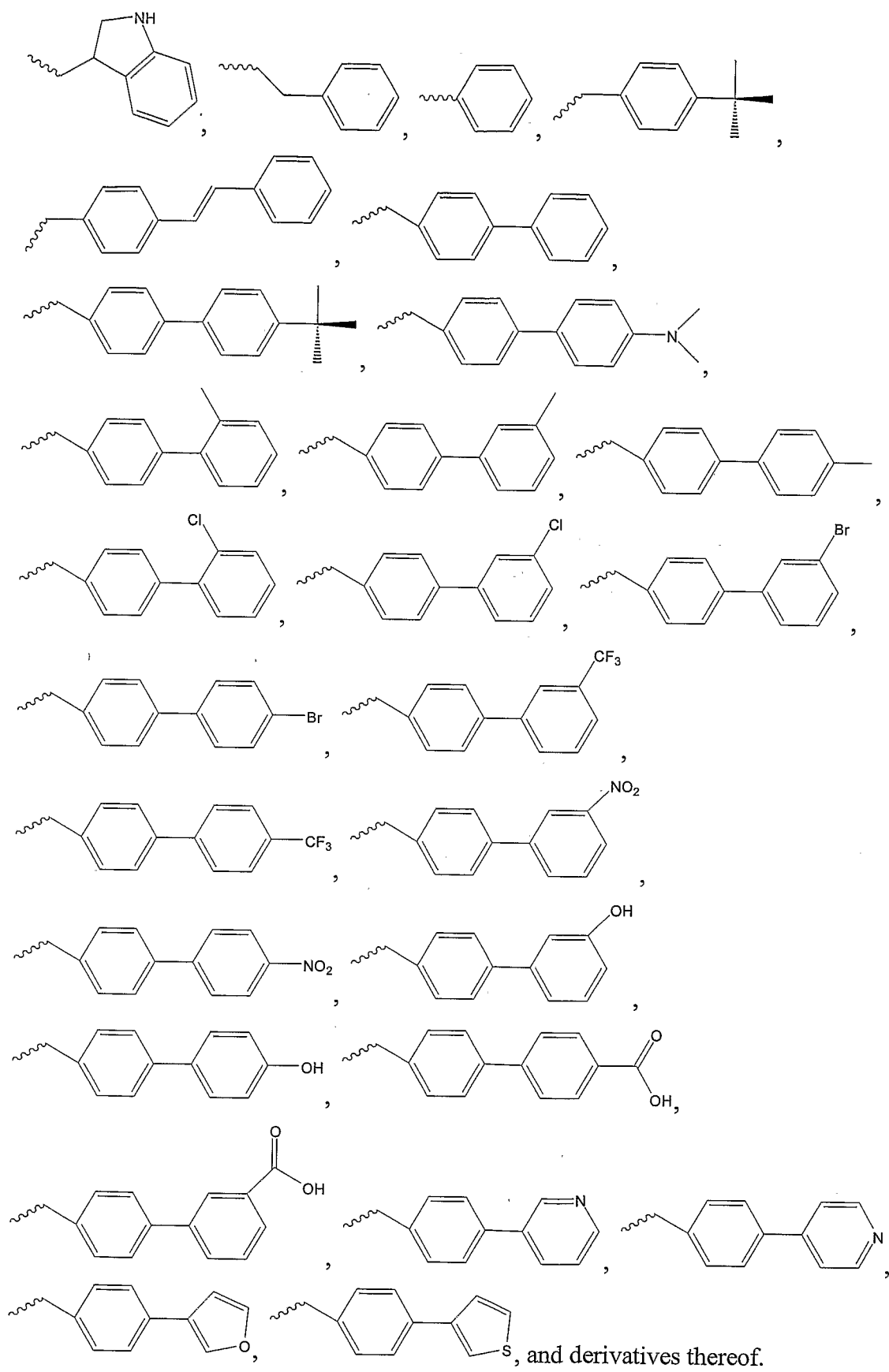


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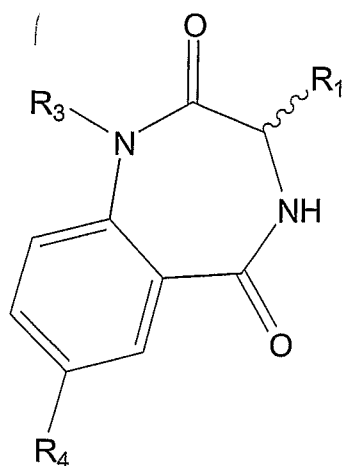
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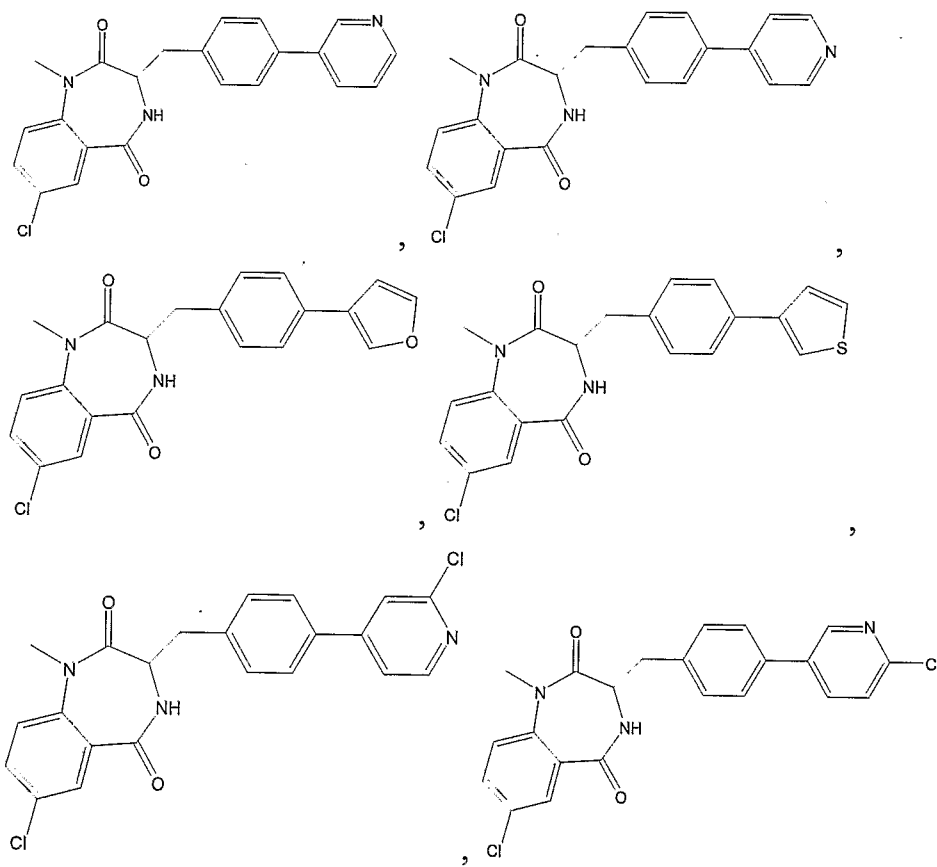


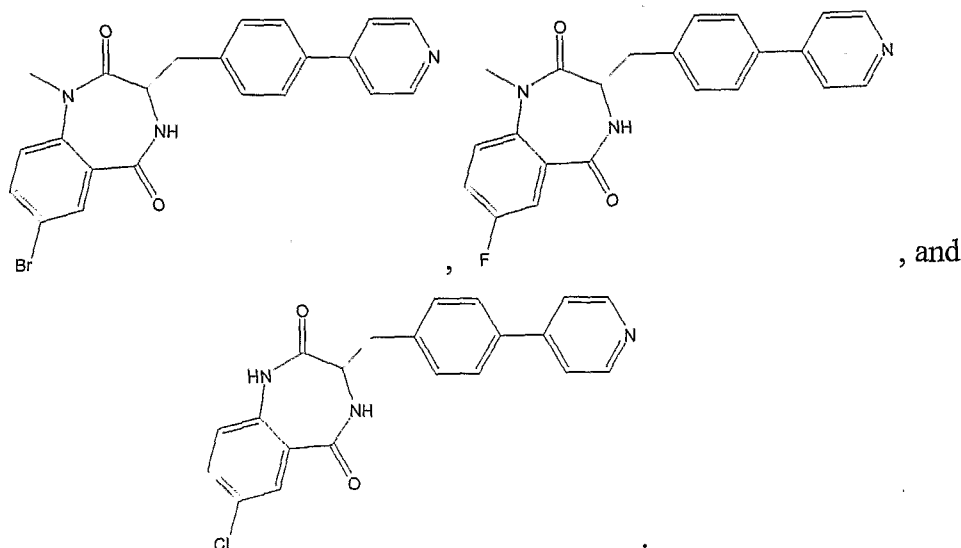
10

Claim 5. The composition of Claim 1, wherein said compound is described by the following formula:



5 Claim 6. The composition of Claim 1, wherein said compound is selected from the group consisting of:





Claim 7. The composition of Claim 1, wherein said cells are selected from the group consisting of B cells, T cells, granulocytes, and proliferating cells.

Claim 8. A method for regulating cell death, comprising

a. providing:

i. target cells;

the composition described in Claim 1; and

b. exposing said target cells to said composition under conditions such that said composition binds to said target cells so as to induce cellular apoptosis.

Claim 9. The method of Claim 8, wherein said target cells are *in vitro* cells.

Claim 10. The method of Claim 8, wherein said target cells are *in vivo* cells.

Claim 11. The method of Claim 8, wherein said target cells are *ex vivo* cells.

Claim 12. The method of Claim 8, wherein said target cells are cancer cells.

Claim 13. The method of Claim 8, wherein said target cells are selected from the group consisting of B cells, T cells, and granulocytes.

Claim 14. The method of Claim 8, wherein said target cells are proliferating cells.

Claim 15. A method of treating autoimmune disorders, comprising:

- 5 a) providing a subject and the composition described in Claim 1,
wherein said composition is capable of inducing cellular apoptosis, and
wherein said composition demonstrates selective cytotoxicity against T cells
as compared to B cells; and
- b) administering said composition to said subject.
- 10

Figure 1.

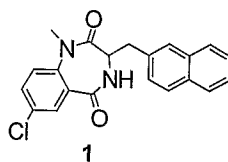
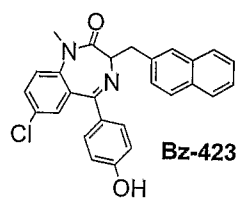


Figure 2.

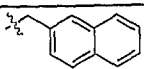
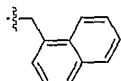
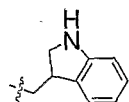
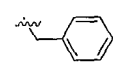
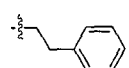

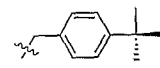
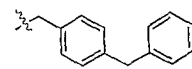
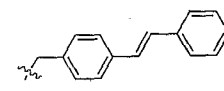
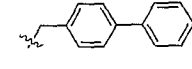
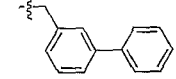
Comps	R	Ramos Cytotoxicity EC ₅₀ , μM^a	Jurkat Cytotoxicity EC ₅₀ , μM^a
1		10.7	3.0
2		12.6	20.5
3		9.2	26.2
4		>100	>80
5		>100	>80
6		6.2	2.3
7		16.2	8.2
8		18.6	17.6
9		50.3	7.5
10		6.2	2.3
11		19.1	5.4

Figure 3.

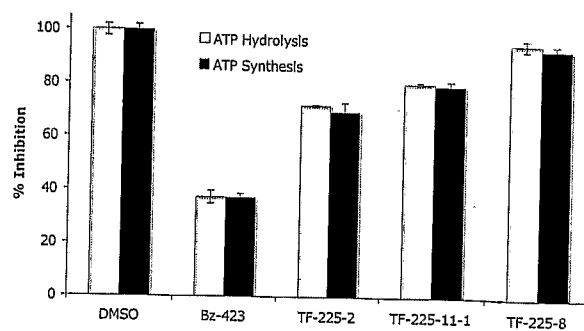
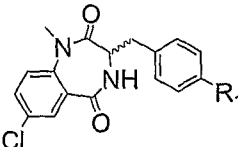
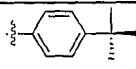
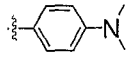


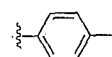


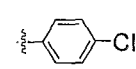

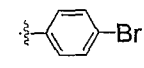
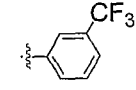
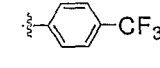
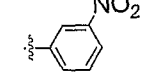
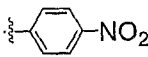
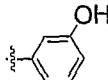
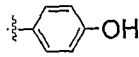
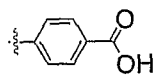
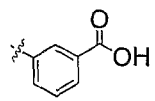






Figure 4.

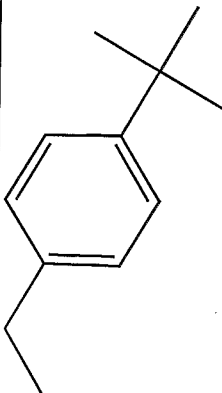
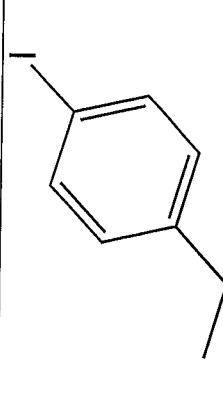
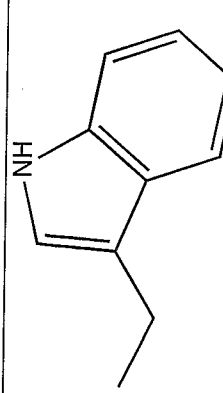


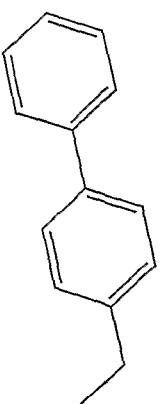
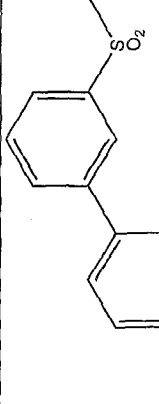
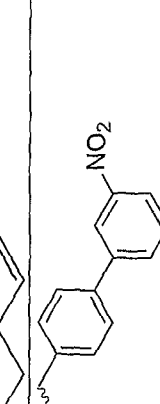
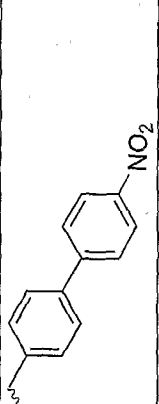
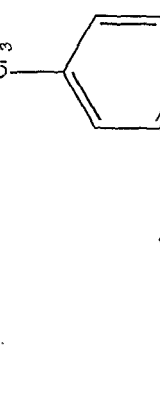
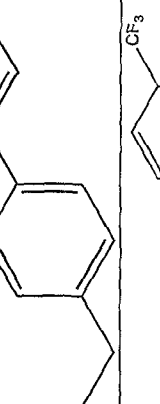
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13		20.0	13.1	1.5
14		6.7	5.4	1.2
15		2.8	3.1	0.9
16		6.9	3.6	1.9
17		10.3	8.3	1.2
18		1.5	2.0	0.8
19		6.5	6.5	1.0
20		9.2	4.8	1.9
21		>20	9.8	>2
22		4.0	4.5	0.9
23		4.8	5.2	0.9
24		4.2	1.5	2.8

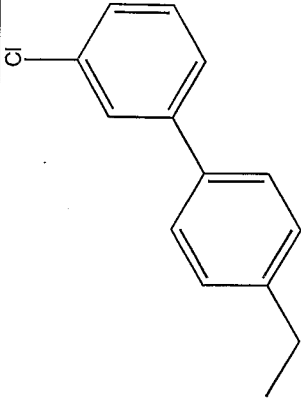
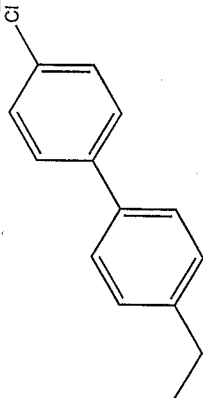
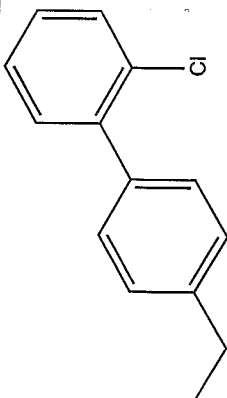
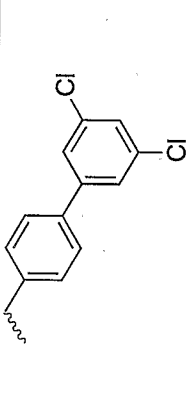
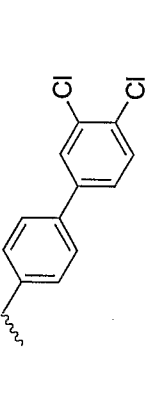
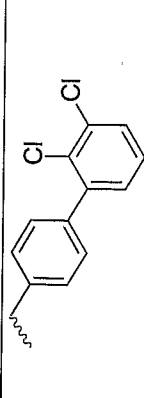
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26		4.0	1.5	2.7
27		6.0	1.5	4.0
28		31.8	15.1	2.1
29		>20	>20	n/a
30		4.0	0.5	8.0
31		3.0	0.5	6.0
32		2.0	0.5	4.0
33		4.1	1.5	2.7

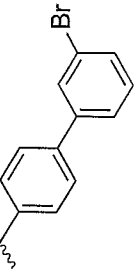
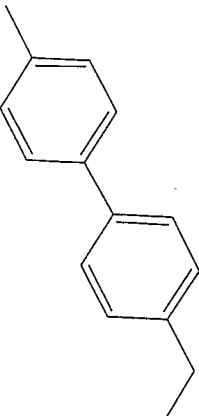
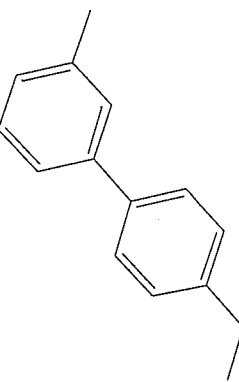
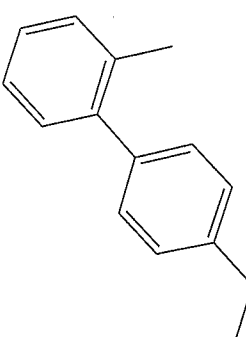
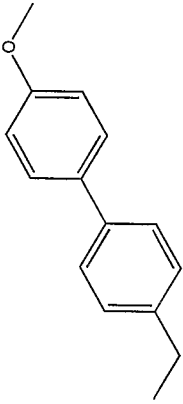
^aValues are means of three experiments, standard deviation is $\pm 3\%$.

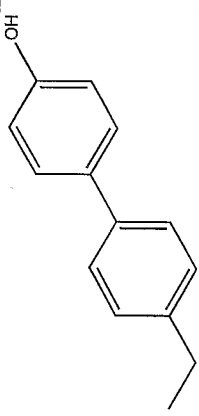
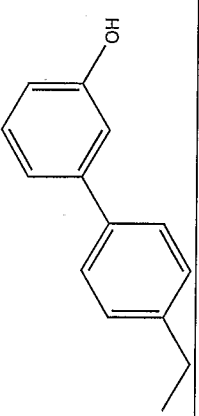
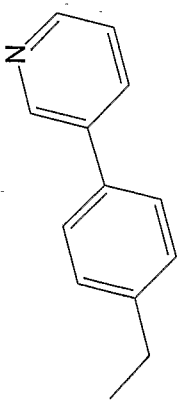
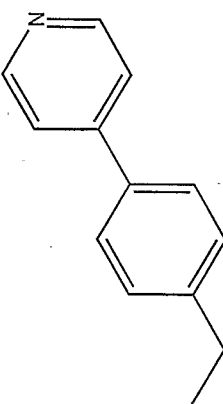
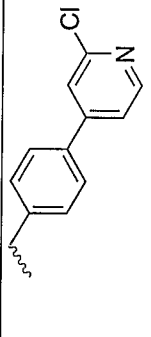
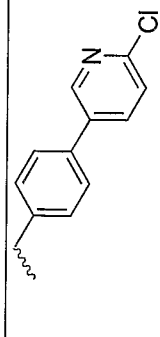
Fig. 5.

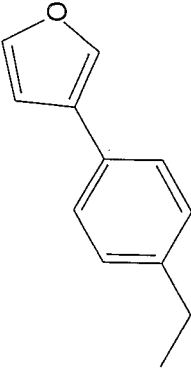
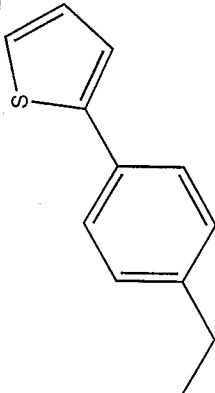
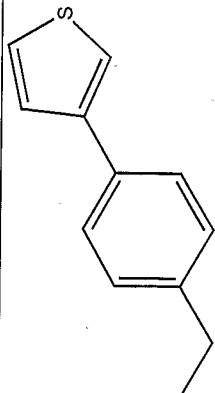
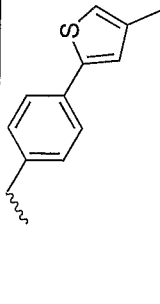
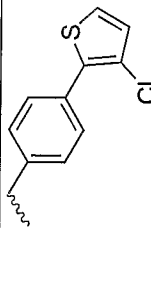
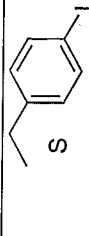
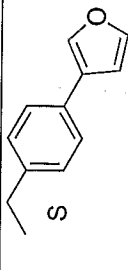
Cmpd	R1	R2	R3	R4	Ramos EC ₅₀ (fold change) highest[drug] % dead	Jurkat EC ₅₀ (fold change) highest[drug] % dead	Selectivity
TMG-19		Me	7-Cl	H	16.2 (3.2x) [25μM] = 100%	8.2 (1.1x) [40μM] = 100%	2.0
TMG-36		Me	7-Cl	H	8.9 (1.8x) [40μM] = 95%	3.6 (0.5x) [40μM] = 97%	2.5
TMG-50		Me	7-Cl	H	9 (1.8x) [100μM] = 50%	26.2 (3.6x) [80μM] = 73%	NA

TMG-39 Tmf-ii-45 TMFI-225-20		Me	7-Cl	H	6.2 (1.2x) [18μM] = 92%	2.3 (0.3x) [9μM] = 95%	2.7
TMFI-225-20		Me	7-Cl	H	8.5 (1.4) Bz = 6.0 [20μM] = 63%	3.0 (0.5x) Bz = 6.0 [20μM] = 90%	2.8
Tmf-294-8		Me	7-Cl	H	4.2 (0.8x) Bz = 5.5 [20μM] = 83%	1.5 (0.3x) Bz = 5.0 [20μM] = 90%	2.8
Tmf-294-10		Me	7-Cl	H	10.0 (1.8x) Bz = 5.5 [20μM] = 83%	3.8 (0.8x) Bz = 5.0 [20μM] = 95%	2.6
TMFI-225-16		Me	7-Cl	H	4.0 (0.6x) Bz = 6.5 [30μM] = 100%	4.5 (0.56x) Bz = 8.0 [30μM] = 98%	NA
TMFI-225-17		Me	7-Cl	H	4.8 (0.8x) Bz = 6.0 [20μM] = 100%	5.2 (0.9x) Bz = 6.0 [20μM] = 95%	NA

TMFI-225-2		Me	7-Cl	H	1.5 (0.2x) Bz = 6.5 [30μM] = 100%	2.0 (0.3x) Bz = 8.0 [20μM] = 100%	NA
TMFI-225-3		Me	7-Cl	H	6.5 (1.0x) Bz = 6.5 [30μM] = 100%	6.5 (0.8x) Bz = 8.0 [20μM] = 100%	1.0
TMFI-225-1		Me	7-Cl	H	10 (1.7x) Bz = 6.0 [20μM] = 53%	8 (1.3) Bz = 6.0 [20μM] = 88%	1.3
Tmfi-294-19		Me	7-Cl	H	5.8 (0.7x) Bz = 8.0 [20μM] = 89%	3.8 (0.6x) Bz = 6.0 [20μM] = 73%	1.5
Tmfi-294-20		Me	7-Cl	H	6.5 (0.8x) Bz = 8.0 [20μM] = 90%	7.5 (1.3x) Bz = 6.0 [20μM] = 89%	na
Tmfi-294-21		Me	7-Cl	H	9.0 (1.1x) Bz = 8.0 [20μM] = 68%	7.2 (1.2x) Bz = 6.0 [20μM] = 80%	na

Tmfi-294-11		Me	7-Cl	H	9.2 (1.2x) Bz = 8.0 [20μM] = 68%	4.8 (0.8x) Bz = 6.0 [20μM] = 83%	1.9
TMG-84		Me	7-Cl	H	6.9 (1.4x) [18μM] = 96%	3.6 (0.5x) [8μM] = 96%	1.9
TMG-85		Me	7-Cl	H	2.8 (0.6x) [12μM] = 96%	3.1 (0.4x) [8μM] = 96%	NA
TMG-86		Me	7-Cl	H	6.7 (1.3x) [15μM] = 96%	5 (0.7x) [12μM] = 95%	1.3
TMFI-225-15		Me	7-Cl	H	4.5 (0.7x) Bz = 6.5 [30μM] = 100%	3.0 (0.3x) Bz = 8.0 [20μM] = 98%	1.5

TMFI-225-14		Me	7-Cl	H	6.0 (0.9x) Bz = 6.5 [30μM] = 100%	1.5μm (0.2x) Bz = 8.0 [20μM] = 98%	4.0
TMFI-225-13		Me	7-Cl	H	4.0 (0.6x) Bz = 6.5 [30μM] = 100%	1.5 (0.2x) Bz = 8.0 [20μM] = 93%	2.7
TMG-76		Me	7-Cl	H	4.7 (0.9x) [21μM] = 81%	0.7 (0.1x) [20μM] = 95%	6.7
TMFI-225-8					4.0 (0.6x) Bz = 6.5 [30μM] = 100%	0.5 (0.1x) Bz = 8.0 [20μM] = 99%	8
TMFI-225-9		Me	7-Cl	H	3.0 (0.5x) Bz = 6.0 [20μM] = 80%	0.5 (0.08x) Bz = 6.0 [20μM] = 90%	6
294-16		Me	7-Cl	H	7.0 (1.0x) Bz = 7.0 [20μM] = 85%	1.5 (0.2x) Bz = 7.0 [20μM] = 90%	4.6
294-14		Me	7-Cl	H	9.0 (1.3x) Bz = 7.0 [20μM] = 85%	2.0 (0.3x) Bz = 7.0 [20μM] = 90%	4.5

TMG-78		Me	7-Cl	H	4.5 (0.9x) [21μM] = 89%	1.7 (0.2x)	2.6
TMFI-225-7 Tmf-ii-46					2.0 (0.3x) Bz = 6.5 [20μM] = 95%	0.5 (0.08x) Bz = 6.5 [20μM] = 100%	4.0
Tmf-294-4		Me	7-Cl	H	6.2 (0.9x) Bz = 6.8 [20μM] = 95%	1.5 (0.2x) Bz = 7.5 [20μM] = 98%	4.1
TMFI-225-11		Me	7-Cl	H	4.1 (0.6x) Bz = 6.5 [30μM] = 100%	1.5 (0.2x) Bz = 8.0 [20μM] = 96%	2.7
Tmf-294-22		Me	7-Cl	H	6.4 (0.8x) Bz = 8.0 [20μM] = 87%	3.7 (0.6x) Bz = 6.0 [20μM] = 92%	
Tmf-294-24		Me	7-Cl	H	7.0 (1.03x) Bz = 6.8 [20μM] = 96%	3.1 (0.4x) Bz = 7.5 [20μM] = 98%	2.25
Tmf-ii-49		Me	7-Cl	H	9.0	2.0	4.5
Tmf-ii-53		Me	7-Cl	H	5.6	0.85	6.6

Tmf-ii-56		Me	7-Cl	H	8.5	3.5	2.4
Tmf-ii-54		Me	7-Cl	H	5.7	0.7	8.0
Tmf-ii-57		Me	7-Cl	H	9.0	0.9	10.0
Tmf-ii-55		Me	7-Cl	H	3.5	0.5	7.0
Tmf-ii-58		Me	7-Cl	H	8.2	1.0	8.2
Tmf-ii-80		H	7-Cl	H	9.2	1.5	6.1
Tmf-ii-128		H	7-Cl	H	2.7	0.5	5.4
Tmf-ii-176		H	7-Me	H	2.6	0.75	3.5
Tmf-ii-189		Me	7-Me	H	2.6	1.0	2.6

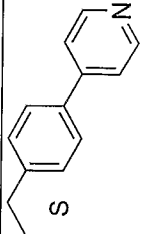
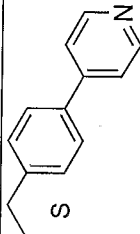
Tmf-ii-95		Me	7-Br	H	7.0	1.5	4.7
Tmf-ii-218		Me	7-F	H	1.2	0.3	4.0

Figure 6.

