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(71) Demandeur/Applicant:
SIRTRIS PHARMACEUTICALS, INC., US

(72) Inventeurs/Inventors:
MILBURN, MICHAEL, US;
MILNE, JILL, US;
BEMIS, JEAN, US;

(54) Titre : MODULATEURS DE LA SIRTUINE A BASE D'ACRIDINE ET DE QUINEOLINE
(54) Title: ACRIDINE AND QUINOLINE DERVATIVES AS SIRTUIN MODULATORS

(57) Abrégé/Abstract:
Provided herein are sirtuin-modulating compounds which are derivatives of guioline or acridine and methods of use thereof . The sirtuin-modulating compounds may be used for increasing the lifespan of a cell, and treating and/or preventing a wide variety of diseases and disorders including, for example, diseases or disorders related to aging or stress, diabetes, obesity, neurodegenerative diseases, chemo therapeutic induced neuropathy, neuropathy associated with an ischemic event, polyglutamine diseases, ocular diseases and/or disorders, cardiovascular disease, blood clotting disorders, inflammation, cancer, and/or flushing. Also provided are compositions comprising a sirtuin-modulating compound in combination with another therapeutic agent.

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(72) Inventeurs(suite)/Inventors(continued): NUNES, JOSEPH J., US; XIE, ROGER, US; NORMINGTON, KARL D., US

(74) Agent: BORDEN LADNER GERVAIS LLP

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(71) Applicant *(for all designated States except US)*: **SIRTRIS PHARMACEUTICALS, INC.** [US/US]; 790 Memorial Drive, Suite 104, Cmabridge, Massachusetts 02139 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **MILBURN, Michael** [US/US]; 508 Hollowridge Court, Cary, North Carolina 27519-9725 (US). **MILNE, Jill** [US/US]; 169 Mason Terrace, Brookline, Massachusetts 02446-2768 (US). **BEMIS, Jean** [US/US]; 256 Appleton Street, Arington, Massachusetts 02476 (US). **NUNES, Joseph, J.** [US/US]; 70 Elm Street, Andover, Massachusetts 01810 (US). **XIE, Roger** [CN/US]; 9 Johnson Road, Southborough, Massachusetts 01772 (US). **NORMINGTON, Karl, D.** [US/US]; 204 Parker Street, Acton, Massachusetts 01720 (US).

(74) Agent: **VINCENT, Matthew, P.**; Fish & Neave IP Group, Ropes & Gray LLP, One International Place, Boston, Massachusetts 02110-2624 (US).

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(54) Title: ACRIDINE AND QUINOLINE DERVATIVES AS SIRTUIN MODULATORS

(57) Abstract: Provided herein are sirtuin-modulating compounds which are derivatives of guioline or acridine and methods of use thereof . The sirtuin-modulating compounds may be used for increasing the lifespan of a cell, and treating and/or preventing a wide variety of diseases and disorders including, for example, diseases or disorders related to aging or stress, diabetes, obesity, neurodegenerative diseases, chemo therapeutic induced neuropathy, neuropathy associated with an ischemic event, polyglutamine diseases, ocular diseases and/or disorders, cardiovascular disease, blood clotting disorders, inflammation, cancer, and/or flushing. Also provided are compositions comprising a sirtuin-modulating compound in combination with another therapeutic agent.

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ACRIDINE AND QUINOLINE SIRTUIN MODULATORS

RELATED APPLICATION

This application claims the benefit of priority to U.S. Provisional Application Nos. 60/658,711, filed March 3, 2005, and 60/705,609, filed August 4, 2005, which applications are hereby incorporated by reference in their entireties.

BACKGROUND

The Silent Information Regulator (SIR) family of genes represents a highly conserved group of genes present in the genomes of organisms ranging from archaebacteria to a variety of eukaryotes (Frye, 2000). The encoded SIR proteins are involved in diverse processes from regulation of gene silencing to DNA repair. The proteins encoded by members of the SIR gene family show high sequence conservation in a 250 amino acid core domain. A well-characterized gene in this family is S. cerevisiae SIR2, which is involved in silencing HM loci that contain information specifying yeast mating type, telomere position effects and cell aging (Guarente, 1999; Kaeberlein et al., 1999; Shore, 2000). The yeast Sir2 protein belongs to a family of histone deacetylases (reviewed in Guarente, 2000; Shore, 2000). The Sir2 homolog, CobB, in Salmonella typhimurium, functions as an NAD (nicotinamide adenine dinucleotide)-dependent ADP-ribosyl transferase (Tsang and Escalante-Semerena, 1998).

The Sir2 protein is a class III deacetylase which uses NAD as a cosubstrate (Imai et al., 2000; Moazed, 2001; Smith et al., 2000; Tanner et al., 2000; Tanny and Moazed, 2001). Unlike other deacetylases, many of which are involved in gene silencing, Sir2 is insensitive to class I and II histone deacetylase inhibitors like trichostatin A (TSA) (Imai et al., 2000; Landry et al., 2000a; Smith et al., 2000).

Deacetylation of acetyl-lysine by Sir2 is tightly coupled to NAD hydrolysis, producing nicotinamide and a novel acetyl-ADP ribose compound (Tanner et al., 2000; Landry et al., 2000b; Tanny and Moazed, 2001). The NAD-dependent deacetylase activity of Sir2 is essential for its functions which can connect its biological role with cellular metabolism in yeast (Guarente, 2000; Imai et al., 2000; Lin et al., 2000; Smith et al., 2000). Mammalian Sir2 homologs have NAD-dependent histone deacetylase activity (Imai et al., 2000; Smith et al., 2000). Most information

about Sir2 mediated functions comes from the studies in yeast (Gartenberg, 2000; Gottschling, 2000).

Biochemical studies have shown that Sir2 can readily deacetylate the amino-terminal tails of histones H3 and H4, resulting in the formation of 1-O-acetyl-ADP-ribose and nicotinamide. Strains with additional copies of SIR2 display increased rDNA silencing and a 30% longer life span. It has recently been shown that additional copies of the C. elegans SIR2 homolog, sir-2.1, and the D. melanogaster dSir2 gene greatly extend life span in those organisms. This implies that the SIR2-dependent regulatory pathway for aging arose early in evolution and has been well conserved. Today, Sir2 genes are believed to have evolved to enhance an organism's health and stress resistance to increase its chance of surviving adversity.

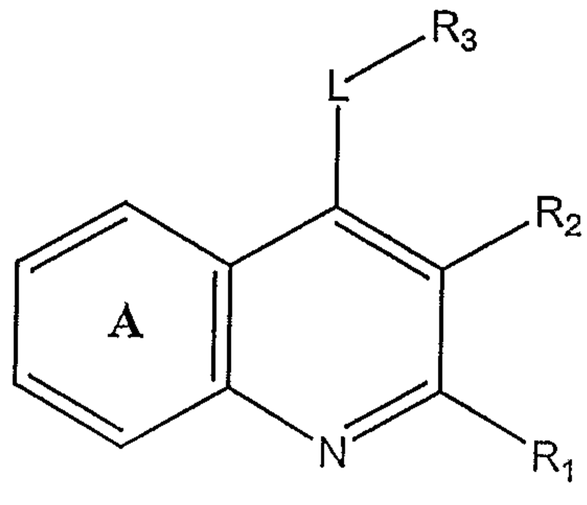
SIRT3 is a homolog of SIRT1 that is conserved in prokaryotes and eukaryotes (P. Onyango et al., Proc. Natl. Acad. Sci. USA 99: 13653-13658 (2002)). The SIRT3 protein is targeted to the mitochondrial cristae by a unique domain located at the N-terminus. SIRT3 has NAD+-dependent protein deacetylase activity and is upbiquitously expressed, particularly in metabolically active tissues. Upon transfer to the mitochondria, SIRT3 is believed to be cleaved into a smaller, active form by a mitochondrial matrix processing peptidase (MPP) (B. Schwer et al., J. Cell Biol. 158: 647-657 (2002)).

Caloric restriction has been known for over 70 years to improve the health and extend the lifespan of mammals (Masoro, 2000). Yeast life span, like that of metazoans, is also extended by interventions that resemble caloric restriction, such as low glucose. The discovery that both yeast and flies lacking the SIR2 gene do not live longer when calorically restricted provides evidence that SIR2 genes mediate the beneficial health effects of this diet (Anderson et al., 2003; Helfand and Rogina, 2004). Moreover, mutations that reduce the activity of the yeast glucose-responsive cAMP (adenosine 3'5'-monophosphate)-dependent (PKA) pathway extend life span in wild type cells but not in mutant sir2 strains, demonstrating that SIR2 is likely to be a key downstream component of the caloric restriction pathway (Lin et al., 2001).

SUMMARY

Provided herein are novel sirtuin-modulating compounds and methods of use thereof.

In one aspect, the invention provides novel sirtuin-modulating compounds of Formula (I):



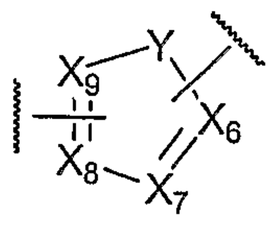
(I),

or a salt thereof, where, as valence permits:

Ring A is optionally substituted;

R_1 and R_2 are independently selected from –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted non-aromatic heterocyclic group, halogen, $-OR_4$, -CN, $-CO_2R_4$, $-OCOR_4$, $-OCO_2R_4$, $-C(O)NR_4R_5$, $-OC(O)NR_4R_5$, $-C(O)R_4$, $-COR_4$, $-SR_4$, $-OSO_3H$, $-S(O)_nR_4$, $-S(O)_nOR_4$, $-S(O)_nNR_4R_5$, $-NR_4R_5$, $-NR_4C(O)OR_5$, $-NR_4C(O)R_5$ and $-NO_2$, or R_1 and R_2 taken together with the atoms to which they are attached form an optionally substituted ring;

L is selected from $-CH=CH-C(O)-$, $-CH_2-N(R_4)-C(O)-$, $-C(O)-CH_2-$, $-C(O)NR_4-$, $-C(O)-N(R_4)-C(O)-$, $-C(O)-N(R_4)-N(R_5)-$, $-C(O)-N(R_4)-N(R_5)-C(O)-$, $-CH_2-N(R_4)-N(R_5)-$, $-N(R_4)-S(O)_2-$, $-S(O)_2-N(R_4)-$, $-N(R_4)-N(R_5)-C(O)-$,



$-N(R_4)-N(R_5)-CH_2$, $-N(R_4)-N(R_5)-$ or ;

R_3, R_4 and R_5 are, independently for each occurrence, –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group or a substituted or unsubstituted non-aromatic heterocyclic group;

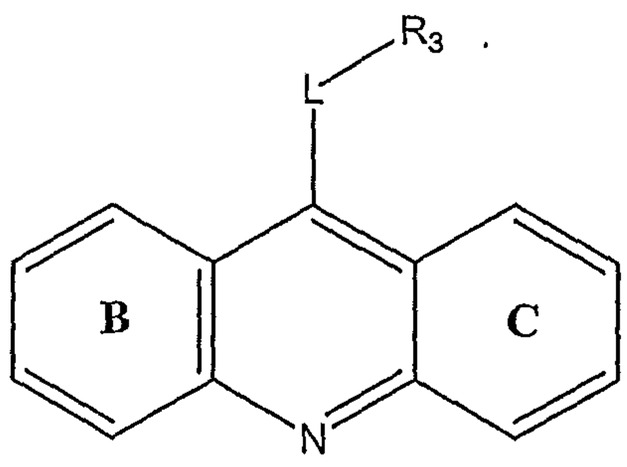
Y is selected from O, S, or NR_4;

each of X_6, X_7, X_8 and X_9 is independently selected from CR_7, C, or N, wherein at least two of X_6, X_7, X_8 or X_9 are not N;

each R_7 is independently selected from H or (C_1-C_3)-straight or branched alkyl; and

n is 1 or 2.

In another aspect, the invention provides novel sirtuin-modulating compounds of Formula (II):



(II),

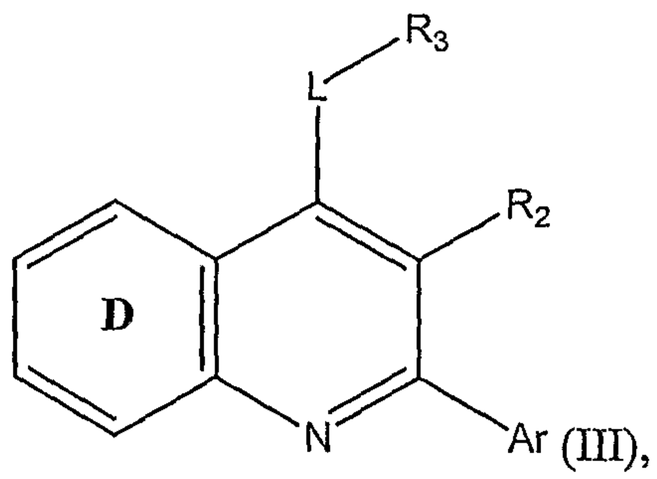
or a salt thereof, where:

Rings B and C are independently optionally substituted;

L is $-NR_4R_5$-, -C(O)O-, $-C(O)NR_4$-, $-NR_4C(O)$-, $-NR_4$-NR_5-C(O)-, -C(O)-NR_4-NR_5- or $-CHR_4=CHR_5$-; and

R_3, R_4 and R_5 are independently –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group or a substituted or unsubstituted non-aromatic heterocyclic group.

In yet another aspect, the the invention provides novel sirtuin-modulating compounds of Formula (III):



(III),

or a salt thereof, wherein, as valence permits:

Ring D is optionally substituted;

Ar is a substituted or unsubstituted aryl group;

R_2 is selected from –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted non-aromatic heterocyclic group, halogen, $-OR_4$, -CN, $-CO_2R_4$, $-OCOR_4$, $-OCO_2R_4$, $-C(O)NR_4R_5$, $-OC(O)NR_4R_5$, $-C(O)R_4$, $-COR_4$, $-SR_4$, $-OSO_3H$, $-S(O)_nR_4$, $-S(O)_nOR_4$, $-S(O)_nNR_4R_5$, $-NR_4R_5$, $-NR_4C(O)OR_5$, $-NR_4C(O)R_5$ and $-NO_2$;

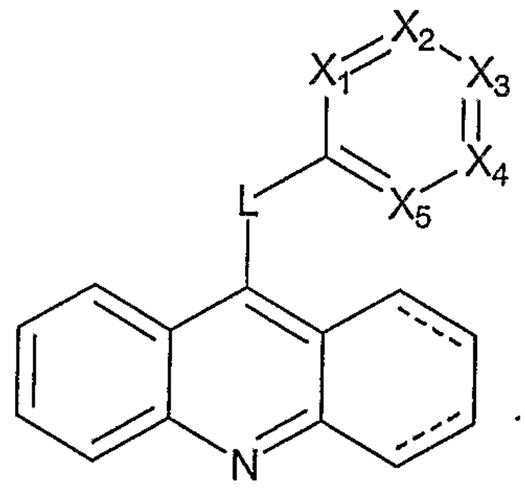
L is $-C(O)NR_4$-, $-NR_4C(O)$-, $-NR_4$-NR_5-C(O)-, -C(O)-NR_4-NR_5- or $-CHR_4=CHR_5$-;

R_3, R_4 and R_5 are independently –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group or a substituted or unsubstituted non-aromatic heterocyclic group; and

n is 1 or 2.

Prodrugs and metabolites of the preceding compounds are also included in the invention.

In a further aspect, the invention provides sirtuin-modulating compounds represented by Structural Formula (V):



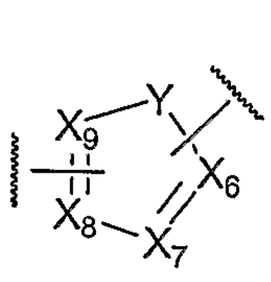
(V),

wherein, as valence permits:

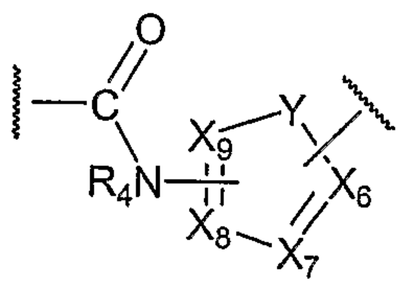
each of X_1, X_2, X_3, X_4 and X_5 is independently selected from N or CR_6, wherein no more than two of X_1, X_2, X_3, X_4 or X_5 are N;

each R_6 is independently selected from H, -OCH_3, -CH_3, or -CF_3;

L is selected from -CH=CH-C(O)-, -CH_2-N(R_4)-C(O)-, -C(O)-CH_2-, -C(O)-N(R_4)-, -C(O)-N(R_4)-CH_2-, -C(O)-N(R_4)-CH_2-CH_2-, -C(O)-N(R_4)-C(O)-, -C(O)-N(R_4)-N(R_5)-, -CH_2-N(R_4)-N(R_5)-, -N(R_4)-S(O)$_2$-, -S(O)$_2$-N(R_4)-, -N(R_4)-N(R_5)-C(O)-, -C(O)-N(R_4)-N(R_5)-C(O)-, -N(R_4)-N(R_5)-CH_2, -N(R_4)-N(R_5)-,



, or



;

each of R_4 and R_5 is independently selected from H or CH_3;

Y is selected from O, S, or NR_4;

each of X_6, X_7, X_8 and X_9 is independently selected from CR_7, C, or N, wherein at least two of X_6, X_7, X_8 or X_9 are not N;

each R_7 is independently selected from H or (C_1-C_3)-straight or branched alkyl; and

the hashed bonds are either simultaneously present or simultaneously absent.

In another aspect, the invention provides novel sirtuin-modulating compounds of Formulas (I)-(V), including salts, prodrugs and metabolites thereof.

Also provided are pharmaceutical compositions comprising one or more compounds of Formulas (I)-(V), or a salt, prodrug or metabolite thereof.

In another aspect, the invention provides methods for using sirtuin-modulating compounds, or compostions comprising sirtuin-modulating compounds. In certain embodiments, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used for a variety of therapeutic applications including, for example, increasing the lifespan of a cell, and treating and/or preventing a wide variety of diseases and disorders including, for example, diseases or disorders related to aging or stress, diabetes, obesity, neurodegenerative diseases, chemotherapeutic induced neuropathy, neuropathy associated with an ischemic event, ocular diseases and/or disorders, cardiovascular disease, blood clotting disorders, inflammation, and/or flushing, etc. Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may also be used for treating a disease or disorder in a subject that would benefit from increased mitochondrial activity, for enhancing muscle performance, for increasing muscle ATP levels, or for treating or preventing muscle tissue damage associated with hypoxia or ischemia. In other embodiments, sirtuin-modulating compounds that decrease the level and/or activity of a sirtuin protein may be used for a variety of therapeutic applications including, for example, increasing cellular sensitivity to stress, increasing apoptosis, treatment of cancer, stimulation of appetite, and/or stimulation of weight gain, etc. As described further below, the methods comprise administering to a subject in need thereof a pharmaceutically effective amount of a sirtuin-modulating compound.

In certain aspects, the sirtuin-modulating compounds may be administered alone or in combination with other compounds, including other sirtuin-modulating compounds, or other therapeutic agents.

DETAILED DESCRIPTION

1. Definitions

As used herein, the following terms and phrases shall have the meanings set forth below. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art.

The singular forms "a," "an," and "the" include plural reference unless the context clearly dictates otherwise.

The term "agent" is used herein to denote a chemical compound, a mixture of chemical compounds, a biological macromolecule (such as a nucleic acid, an antibody, a protein or portion thereof, e.g., a peptide), or an extract made from biological materials such as bacteria, plants, fungi, or animal (particularly mammalian) cells or tissues. The activity of such agents may render it suitable as a "therapeutic agent" which is a biologically, physiologically, or pharmacologically active substance (or substances) that acts locally or systemically in a subject.

The term "bioavailable" when referring to a compound is art-recognized and refers to a form of a compound that allows for it, or a portion of the amount of compound administered, to be absorbed by, incorporated to, or otherwise physiologically available to a subject or patient to whom it is administered.

"Biologically active portion of a sirtuin" refers to a portion of a sirtuin protein having a biological activity, such as the ability to deacetylate. Biologically active portions of a sirtuin may comprise the core domain of sirtuins. Biologically active portions of SIRT1 having GenBank Accession No. NP_036370 that encompass the NAD+ binding domain and the substrate binding domain, for example, may include without limitation, amino acids 62-293 of GenBank Accession No. NP_036370, which are encoded by nucleotides 237 to 932 of GenBank Accession No. NM_012238. Therefore, this region is sometimes referred to as the core domain. Other biologically active portions of SIRT1, also sometimes referred to as core domains, include about amino acids 261 to 447 of GenBank Accession No. NP_036370, which are encoded by nucleotides 834 to 1394 of GenBank Accession No. NM_012238; about amino acids 242 to 493 of GenBank Accession No. NP_036370, which are encoded by nucleotides 777 to 1532 of GenBank Accession No. NM_012238; or about amino acids 254 to 495 of GenBank Accession No. NP_036370, which are encoded by nucleotides 813 to 1538 of GenBank Accession No. NM_012238.

The term "companion animals" refers to cats and dogs. As used herein, the term "dog(s)" denotes any member of the species Canis familiaris, of which there are a large number of different breeds. The term "cat(s)" refers to a feline animal including domestic cats and other members of the family Felidae, genus Felis.

The terms "comprise" and "comprising" are used in the inclusive, open sense, meaning that additional elements may be included.

The term "conserved residue" refers to an amino acid that is a member of a group of amino acids having certain common properties. The term "conservative amino acid substitution" refers to the substitution (conceptually or otherwise) of an amino acid from one such group with a different amino acid from the same group. A functional way to define common properties between individual amino acids is to analyze the normalized frequencies of amino acid changes between corresponding proteins of homologous organisms (Schulz, G. E. and R. H. Schirmer., Principles of Protein Structure, Springer-Verlag). According to such analyses, groups of amino acids may be defined where amino acids within a group exchange preferentially with each other, and therefore resemble each other most in their impact on the overall protein structure (Schulz, G. E. and R. H. Schirmer, Principles of Protein Structure, Springer-Verlag). One example of a set of amino acid groups defined in this manner include: (i) a charged group, consisting of Glu and Asp, Lys, Arg and His, (ii) a positively-charged group, consisting of Lys, Arg and His, (iii) a negatively-charged group, consisting of Glu and Asp, (iv) an aromatic group, consisting of Phe, Tyr and Trp, (v) a nitrogen ring group, consisting of His and Trp, (vi) a large aliphatic nonpolar group, consisting of Val, Leu and Ile, (vii) a slightly-polar group, consisting of Met and Cys, (viii) a small-residue group, consisting of Ser, Thr, Asp, Asn, Gly, Ala, Glu, Gln and Pro, (ix) an aliphatic group consisting of Val, Leu, Ile, Met and Cys, and (x) a small hydroxyl group consisting of Ser and Thr.

"Diabetes" refers to high blood sugar or ketoacidosis, as well as chronic, general metabolic abnormalities arising from a prolonged high blood sugar status or a decrease in glucose tolerance. "Diabetes" encompasses both the type I and type II (Non Insulin Dependent Diabetes Mellitus or NIDDM) forms of the disease. The risk factors for diabetes include the following factors: waistline of more than 40 inches for men or 35 inches for women, blood pressure of 130/85 mmHg or higher, triglycerides above 150 mg/dl, fasting blood glucose greater than 100 mg/dl or high-density lipoprotein of less than 40 mg/dl in men or 50 mg/dl in women.

A "direct activator" of a sirtuin is a molecule that activates a sirtuin by binding to it. A "direct inhibitor" of a sirtuin is a molecule inhibits a sirtuin by binding to it.

The term "ED_{50}" is art-recognized. In certain embodiments, ED_{50} means the dose of a drug which produces 50% of its maximum response or effect, or alternatively, the dose which produces a pre-determined response in 50% of test subjects or preparations. The term "LD_{50}" is art-recognized. In certain embodiments, LD_{50} means the dose of a drug which is lethal in 50% of test subjects. The term "therapeutic index" is an art-recognized term which refers to the therapeutic index of a drug, defined as LD_{50}/ED_{50}.

The term "hyperinsulinemia" refers to a state in an individual in which the level of insulin in the blood is higher than normal.

The term "including" is used to mean "including but not limited to". "Including" and "including but not limited to" are used interchangeably.

The term "insulin resistance" refers to a state in which a normal amount of insulin produces a subnormal biologic response relative to the biological response in a subject that does not have insulin resistance.

An "insulin resistance disorder," as discussed herein, refers to any disease or condition that is caused by or contributed to by insulin resistance. Examples include: diabetes, obesity, metabolic syndrome, insulin-resistance syndromes, syndrome X, insulin resistance, high blood pressure, hypertension, high blood cholesterol, dyslipidemia, hyperlipidemia, dyslipidemia, atherosclerotic disease including stroke, coronary artery disease or myocardial infarction, hyperglycemia, hyperinsulinemia and/or hyperproinsulinemia, impaired glucose tolerance, delayed insulin release, diabetic complications, including coronary heart disease, angina pectoris, congestive heart failure, stroke, cognitive functions in dementia, retinopathy, peripheral neuropathy, nephropathy, glomerulonephritis, glomerulosclerosis, nephrotic syndrome, hypertensive nephrosclerosis some types of cancer (such as endometrial, breast, prostate, and colon), complications of pregnancy, poor female reproductive health (such as menstrual irregularities, infertility, irregular ovulation, polycystic ovarian syndrome (PCOS)), lipodystrophy, cholesterol related disorders, such as gallstones, cholescystitis and cholelithiasis, gout, obstructive sleep apnea and respiratory problems, osteoarthritis, and prevention and treatment of bone loss, e.g. osteoporosis.

The term "livestock animals" refers to domesticated quadrupeds, which includes those being raised for meat and various byproducts, e.g., a bovine animal including cattle and other members of the genus Bos, a porcine animal including

domestic swine and other members of the genus Sus, an ovine animal including sheep and other members of the genus Ovis, domestic goats and other members of the genus Capra; domesticated quadrupeds being raised for specialized tasks such as use as a beast of burden, e.g., an equine animal including domestic horses and other members of the family Equidae, genus Equus.

The term "mammal" is known in the art, and exemplary mammals include humans, primates, livestock animals (including bovines, porcines, etc.), companion animals (e.g., canines, felines, etc.) and rodents (e.g., mice and rats).

The term "naturally occurring form" when referring to a compound means a compound that is in a form, e.g., a composition, in which it can be found naturally. For example, since resveratrol can be found in red wine, it is present in red wine in a form that is naturally occurring. A compound is not in a form that is naturally occurring if, e.g., the compound has been purified and separated from at least some of the other molecules that are found with the compound in nature. A "naturally occurring compound" refers to a compound that can be found in nature, i.e., a compound that has not been designed by man. A naturally occurring compound may have been made by man or by nature.

A "naturally occurring compound" refers to a compound that can be found in nature, i.e., a compound that has not been designed by man. A naturally occurring compound may have been made by man or by nature. For example, resveratrol is a naturally-occurring compound. A "non-naturally occurring compound" is a compound that is not known to exist in nature or that does not occur in nature.

"Obese" individuals or individuals suffering from obesity are generally individuals having a body mass index (BMI) of at least 25 or greater. Obesity may or may not be associated with insulin resistance.

The terms "parenteral administration" and "administered parenterally" are art-recognized and refer to modes of administration other than enteral and topical administration, usually by injection, and includes, without limitation, intravenous, intramuscular, intraarterial, intrathecal, intracapsular, intraorbital, intracardiac, intradermal, intraperitoneal, transtracheal, subcutaneous, subcuticular, intra-articulare, subcapsular, subarachnoid, intraspinal, and intrasternal injection and infusion.

A "patient", "subject", "individual" or "host" refers to either a human or a non-human animal.

The term "percent identical" refers to sequence identity between two amino acid sequences or between two nucleotide sequences. Identity can each be determined by comparing a position in each sequence which may be aligned for purposes of comparison. When an equivalent position in the compared sequences is occupied by the same base or amino acid, then the molecules are identical at that position; when the equivalent site occupied by the same or a similar amino acid residue (e.g., similar in steric and/or electronic nature), then the molecules can be referred to as homologous (similar) at that position. Expression as a percentage of homology, similarity, or identity refers to a function of the number of identical or similar amino acids at positions shared by the compared sequences. Expression as a percentage of homology, similarity, or identity refers to a function of the number of identical or similar amino acids at positions shared by the compared sequences. Various alignment algorithms and/or programs may be used, including FASTA, BLAST, or ENTREZ. FASTA and BLAST are available as a part of the GCG sequence analysis package (University of Wisconsin, Madison, Wis.), and can be used with, e.g., default settings. ENTREZ is available through the National Center for Biotechnology Information, National Library of Medicine, National Institutes of Health, Bethesda, MD. In one embodiment, the percent identity of two sequences can be determined by the GCG program with a gap weight of 1, e.g., each amino acid gap is weighted as if it were a single amino acid or nucleotide mismatch between the two sequences.

Other techniques for alignment are described in Methods in Enzymology, vol. 266: Computer Methods for Macromolecular Sequence Analysis (1996), ed. Doolittle, Academic Press, Inc., a division of Harcourt Brace & Co., San Diego, California, USA. Preferably, an alignment program that permits gaps in the sequence is utilized to align the sequences. The Smith-Waterman is one type of algorithm that permits gaps in sequence alignments. See Meth. Mol. Biol. 70: 173-187 (1997). Also, the GAP program using the Needleman and Wunsch alignment method can be utilized to align sequences. An alternative search strategy uses MPSRCH software, which runs on a MASPAR computer. MPSRCH uses a Smith-Waterman algorithm to score sequences on a massively parallel computer. This approach improves ability to pick up distantly related matches, and is especially tolerant of small gaps and nucleotide sequence errors. Nucleic acid-encoded amino acid sequences can be used to search both protein and DNA databases.

The term "pharmaceutically acceptable carrier" is art-recognized and refers to a pharmaceutically-acceptable material, composition or vehicle, such as a liquid or solid filler, diluent, excipient, solvent or encapsulating material, involved in carrying or transporting any subject composition or component thereof. Each carrier must be "acceptable" in the sense of being compatible with the subject composition and its components and not injurious to the patient. Some examples of materials which may serve as pharmaceutically acceptable carriers include: (1) sugars, such as lactose, glucose and sucrose; (2) starches, such as corn starch and potato starch; (3) cellulose, and its derivatives, such as sodium carboxymethyl cellulose, ethyl cellulose and cellulose acetate; (4) powdered tragacanth; (5) malt; (6) gelatin; (7) talc; (8) excipients, such as cocoa butter and suppository waxes; (9) oils, such as peanut oil, cottonseed oil, safflower oil, sesame oil, olive oil, corn oil and soybean oil; (10) glycols, such as propylene glycol; (11) polyols, such as glycerin, sorbitol, mannitol and polyethylene glycol; (12) esters, such as ethyl oleate and ethyl laurate; (13) agar; (14) buffering agents, such as magnesium hydroxide and aluminum hydroxide; (15) alginic acid; (16) pyrogen-free water; (17) isotonic saline; (18) Ringer's solution; (19) ethyl alcohol; (20) phosphate buffer solutions; and (21) other non-toxic compatible substances employed in pharmaceutical formulations.

The terms "polynucleotide", and "nucleic acid" are used interchangeably. They refer to a polymeric form of nucleotides of any length, either deoxyribonucleotides or ribonucleotides, or analogs thereof. Polynucleotides may have any three-dimensional structure, and may perform any function, known or unknown. The following are non-limiting examples of polynucleotides: coding or non-coding regions of a gene or gene fragment, loci (locus) defined from linkage analysis, exons, introns, messenger RNA (mRNA), transfer RNA, ribosomal RNA, ribozymes, cDNA, recombinant polynucleotides, branched polynucleotides, plasmids, vectors, isolated DNA of any sequence, isolated RNA of any sequence, nucleic acid probes, and primers. A polynucleotide may comprise modified nucleotides, such as methylated nucleotides and nucleotide analogs. If present, modifications to the nucleotide structure may be imparted before or after assembly of the polymer. The sequence of nucleotides may be interrupted by non-nucleotide components. A polynucleotide may be further modified, such as by conjugation with a labeling component. The term "recombinant" polynucleotide means a polynucleotide of

genomic, cDNA, semisynthetic, or synthetic origin which either does not occur in nature or is linked to another polynucleotide in a nonnatural arrangement.

The term "prophylactic" or "therapeutic" treatment is art-recognized and refers to administration of a drug to a host. If it is administered prior to clinical manifestation of the unwanted condition (e.g., disease or other unwanted state of the host animal) then the treatment is prophylactic, i.e., it protects the host against developing the unwanted condition, whereas if administered after manifestation of the unwanted condition, the treatment is therapeutic (i.e., it is intended to diminish, ameliorate or maintain the existing unwanted condition or side effects therefrom).

The term "protecting group" is art-recognized and refers to temporary substituents that protect a potentially reactive functional group from undesired chemical transformations. Examples of such protecting groups include esters of carboxylic acids, silyl ethers of alcohols, and acetals and ketals of aldehydes and ketones, respectively. The field of protecting group chemistry has been reviewed by Greene and Wuts in Protective Groups in Organic Synthesis (2^{nd} ed., Wiley: New York, 1991).

The term "pyrogen-free", with reference to a composition, refers to a composition that does not contain a pyrogen in an amount that would lead to an adverse effect (e.g., irritation, fever, inflammation, diarrhea, respiratory distress, endotoxic shock, etc.) in a subject to which the composition has been administered. For example, the term is meant to encompass compositions that are free of, or substantially free of, an endotoxin such as, for example, a lipopolysaccharide (LPS).

"Replicative lifespan" of a cell refers to the number of daughter cells produced by an individual "mother cell." "Chronological aging" or "chronological lifespan," on the other hand, refers to the length of time a population of non-dividing cells remains viable when deprived of nutrients. "Increasing the lifespan of a cell" or "extending the lifespan of a cell," as applied to cells or organisms, refers to increasing the number of daughter cells produced by one cell; increasing the ability of cells or organisms to cope with stresses and combat damage, e.g., to DNA, proteins; and/or increasing the ability of cells or organisms to survive and exist in a living state for longer under a particular condition, e.g., stress (for example, heatshock, osmotic stress, high energy radiation, chemically-induced stress, DNA damage, inadequate salt level, inadequate nitrogen level, or inadequate nutrient

level). Lifespan can be increased by at least about 20%, 30%, 40%, 50%, 60% or between 20% and 70%, 30% and 60%, 40% and 60% or more using methods described herein.

"Sirtuin-activating compound" refers to a compound that increases the level of a sirtuin protein and/or increases at least one activity of a sirtuin protein. In an exemplary embodiment, a sirtuin-activating compound may increase at least one biological activity of a sirtuin protein by at least about 10%, 25%, 50%, 75%, 100%, or more. Exemplary biological activities of sirtuin proteins include deacetylation, e.g., of histones and p53; extending lifespan; increasing genomic stability; silencing transcription; and controlling the segregation of oxidized proteins between mother and daughter cells.

"Sirtuin-inhibiting compound" refers to a compound that decreases the level of a sirtuin protein and/or decreases at least one activity of a sirtuin protein. In an exemplary embodiment, a sirtuin-inhibiting compound may decrease at least one biological activity of a sirtuin protein by at least about 10%, 25%, 50%, 75%, 100%, or more. Exemplary biological activities of sirtuin proteins include deacetylation, e.g., of histones and p53; extending lifespan; increasing genomic stability; silencing transcription; and controlling the segregation of oxidized proteins between mother and daughter cells.

"Sirtuin-modulating compound" refers to a compound of Formulas (I)-(V) as described herein. In exemplary embodiments, a sirtuin-modulating compound may either up regulate (e.g., activate or stimulate), down regulate (e.g., inhibit or suppress) or otherwise change a functional property or biological activity of a sirtuin protein. Sirtuin-modulating compounds may act to modulate a sirtuin protein either directly or indirectly. In certain embodiments, a sirtuin-modulating compound may be a sirtuin-activating compound or a sirtuin-inhibiting compound.

"Sirtuin protein" refers to a member of the sirtuin deacetylase protein family, or preferably to the sir2 family, which include yeast Sir2 (GenBank Accession No. P53685), *C. elegans* Sir-2.1 (GenBank Accession No. NP_501912), and human SIRT1 (GenBank Accession No. NM_012238 and NP_036370 (or AF083106)) and SIRT2 (GenBank Accession No. NM_012237, NM_030593, NP_036369, NP_085096, and AF083107) proteins. Other family members include the four additional yeast Sir2-like genes termed "*HST* genes" (homologues of Sir two) HST1,

HST2, HST3 and HST4, and the five other human homologues hSIRT3, hSIRT4, hSIRT5, hSIRT6 and hSIRT7 (Brachmann et al. (1995) Genes Dev. 9:2888 and Frye et al. (1999) BBRC 260:273). Preferred sirtuins are those that share more similarities with SIRT1, i.e., hSIRT1, and/or Sir2 than with SIRT2, such as those members having at least part of the N-terminal sequence present in SIRT1 and absent in SIRT2 such as SIRT3 has.

"SIRT1 protein" refers to a member of the sir2 family of sirtuin deacetylases. In one embodiment, a SIRT1 protein includes yeast Sir2 (GenBank Accession No. P53685), C. elegans Sir-2.1 (GenBank Accession No. NP_501912), human SIRT1 (GenBank Accession No. NM_012238 or NP_036370 (or AF083106)), and human SIRT2 (GenBank Accession No. NM_012237, NM_030593, NP_036369, NP_085096, or AF083107) proteins, and equivalents and fragments thereof. In another embodiment, a SIRT1 protein includes a polypeptide comprising a sequence consisting of, or consisting essentially of, the amino acid sequence set forth in GenBank Accession Nos. NP_036370, NP_501912, NP_085096, NP_036369, or P53685. SIRT1 proteins include polypeptides comprising all or a portion of the amino acid sequence set forth in GenBank Accession Nos. NP_036370, NP_501912, NP_085096, NP_036369, or P53685; the amino acid sequence set forth in GenBank Accession Nos. NP_036370, NP_501912, NP_085096, NP_036369, or P53685 with 1 to about 2, 3, 5, 7, 10, 15, 20, 30, 50, 75 or more conservative amino acid substitutions; an amino acid sequence that is at least 60%, 70%, 80%, 90%, 95%, 96%, 97%, 98%, or 99% identical to GenBank Accession Nos. NP_036370, NP_501912, NP_085096, NP_036369, or P53685, and functional fragments thereof. Polypeptides of the invention also include homologs (e.g., orthologs and paralogs), variants, or fragments, of GenBank Accession Nos. NP_036370, NP_501912, NP_085096, NP_036369, or P53685.

"SIRT3 protein" refers to a member of the sirtuin deacetylase protein family and/or to a homolog of a SIRT1 protein. In one embodiment, a SIRT3 protein includes human SIRT3 (GenBank Accession No. AAH01042, NP_036371, or NP_001017524) and mouse SIRT3 (GenBank Accession No. NP_071878) proteins, and equivalents and fragments thereof. In another embodiment, a SIRT3 protein includes a polypeptide comprising a sequence consisting of, or consisting essentially of, the amino acid sequence set forth in GenBank Accession Nos. AAH01042, NP_036371, NP_001017524, or NP_071878. SIRT3 proteins include polypeptides

comprising all or a portion of the amino acid sequence set forth in GenBank Accession AAH01042, NP_036371, NP_001017524, or NP_071878; the amino acid sequence set forth in GenBank Accession Nos. AAH01042, NP_036371, NP_001017524, or NP_071878 with 1 to about 2, 3, 5, 7, 10, 15, 20, 30, 50, 75 or more conservative amino acid substitutions; an amino acid sequence that is at least 60%, 70%, 80%, 90%, 95%, 96%, 97%, 98%, or 99% identical to GenBank Accession Nos. AAH01042, NP_036371, NP_001017524, or NP_071878, and functional fragments thereof. Polypeptides of the invention also include homologs (e.g., orthologs and paralogs), variants, or fragments, of GenBank Accession Nos. AAH01042, NP_036371, NP_001017524, or NP_071878. In one embodiment, a SIRT3 protein includes a fragment of SIRT3 protein that is produced by cleavage with a mitochondrial matrix processing peptidase (MPP) and/or a mitochondrial intermediate peptidase (MIP).

The term "substantially homologous" when used in connection with amino acid sequences, refers to sequences which are substantially identical to or similar in sequence with each other, giving rise to a homology of conformation and thus to retention, to a useful degree, of one or more biological (including immunological) activities. The term is not intended to imply a common evolution of the sequences.

The term "synthetic" is art-recognized and refers to production by *in vitro* chemical or enzymatic synthesis.

The terms "systemic administration," "administered systemically," "peripheral administration" and "administered peripherally" are art-recognized and refer to the administration of a subject composition, therapeutic or other material other than directly into the central nervous system, such that it enters the patient's system and, thus, is subject to metabolism and other like processes.

The term "therapeutic agent" is art-recognized and refers to any chemical moiety that is a biologically, physiologically, or pharmacologically active substance that acts locally or systemically in a subject. The term also means any substance intended for use in the diagnosis, cure, mitigation, treatment or prevention of disease or in the enhancement of desirable physical or mental development and/or conditions in an animal or human.

The term "therapeutic effect" is art-recognized and refers to a local or systemic effect in animals, particularly mammals, and more particularly humans caused by a pharmacologically active substance. The phrase "therapeutically-

effective amount" means that amount of such a substance that produces some desired local or systemic effect at a reasonable benefit/risk ratio applicable to any treatment. The therapeutically effective amount of such substance will vary depending upon the subject and disease condition being treated, the weight and age of the subject, the severity of the disease condition, the manner of administration and the like, which can readily be determined by one of ordinary skill in the art. For example, certain compositions described herein may be administered in a sufficient amount to produce a desired effect at a reasonable benefit/risk ratio applicable to such treatment.

"Transcriptional regulatory sequence" is a generic term used throughout the specification to refer to DNA sequences, such as initiation signals, enhancers, and promoters, which induce or control transcription of protein coding sequences with which they are operable linked. In preferred embodiments, transcription of one of the recombinant genes is under the control of a promoter sequence (or other transcriptional regulatory sequence) which controls the expression of the recombinant gene in a cell-type which expression is intended. It will also be understood that the recombinant gene can be under the control of transcriptional regulatory sequences which are the same or which are different from those sequences which control transcription of the naturally-occurring forms of genes as described herein.

"Treating" a condition or disease refers to curing as well as ameliorating at least one symptom of the condition or disease.

A "vector" is a self-replicating nucleic acid molecule that transfers an inserted nucleic acid molecule into and/or between host cells. The term includes vectors that function primarily for insertion of a nucleic acid molecule into a cell, replication of vectors that function primarily for the replication of nucleic acid, and expression vectors that function for transcription and/or translation of the DNA or RNA. Also included are vectors that provide more than one of the above functions. As used herein, "expression vectors" are defined as polynucleotides which, when introduced into an appropriate host cell, can be transcribed and translated into a polypeptide(s). An "expression system" usually connotes a suitable host cell comprised of an expression vector that can function to yield a desired expression product.

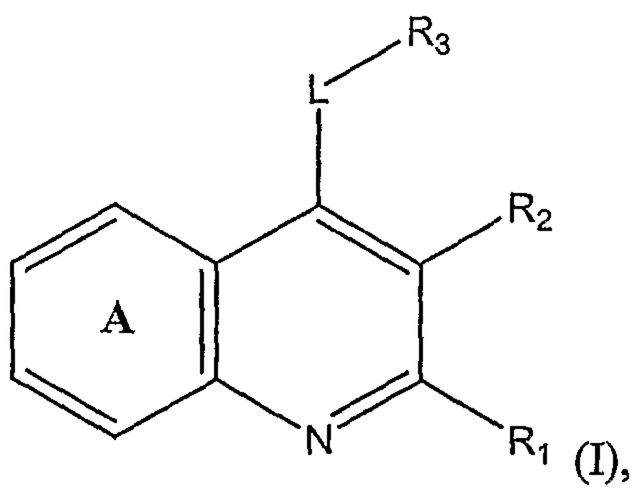
The term "vision impairment" refers to diminished vision, which is often only partially reversible or irreversible upon treatment (e.g., surgery). Particularly severe vision impairment is termed "blindness" or "vision loss", which refers to a complete

loss of vision, vision worse than 20/200 that cannot be improved with corrective lenses, or a visual field of less than 20 degrees diameter (10 degrees radius).

2. Sirtuin Modulators

In one aspect, the invention provides novel sirtuin-modulating compounds for treating and/or preventing a wide variety of diseases and disorders including, for example, diseases or disorders related to aging or stress, diabetes, obesity, neurodegenerative diseases, ocular diseases and disorders, cardiovascular disease, blood clotting disorders, inflammation, cancer, and/or flushing, etc. Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may also be used for treating a disease or disorder in a subject that would benefit from increased mitochondrial activity, for enhancing muscle performance, for increasing muscle ATP levels, or for treating or preventing muscle tissue damage associated with hypoxia or ischemia. Other compounds disclosed herein may be suitable for use in a pharmaceutical composition and/or one or more methods disclosed herein.

In one embodiment, sirtuin-modulating compounds of the invention are represented by Structural Formula (I):



(I),

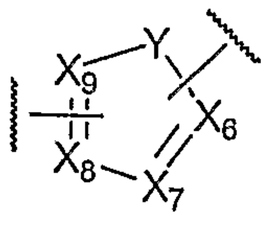
or a salt thereof, where, as valence permits:

Ring A is optionally substituted;

R_1 and R_2 are independently selected from –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted non-aromatic heterocyclic group, halogen, $-OR_4$, -CN, $-CO_2R_4$, $-OCOR_4$, $-OCO_2R_4$, $-C(O)NR_4R_5$, $-OC(O)NR_4R_5$, $-C(O)R_4$, $-COR_4$, $-SR_4$, $-OSO_3H$, $-S(O)_nR_4$, $-S(O)_nOR_4$, $-S(O)_nNR_4R_5$, $-NR_4R_5$, $-NR_4C(O)OR_5$, $-NR_4C(O)R_5$ and $-NO_2$, or R_1 and R_2 taken together with the atoms to which they are attached form an optionally substituted ring;

L is selected from $-CH=CH-C(O)-$, $-CH_2-N(R_4)-C(O)-$, $-C(O)-CH_2-$, $-C(O)NR_4-$, $-C(O)-N(R_4)-C(O)-$, $-C(O)-N(R_4)-N(R_5)-$, $-C(O)-N(R_4)-N(R_5)-C(O)-$,

$-CH_2-N(R_4)-N(R_5)-$, $-N(R_4)-S(O)_2-$, $-S(O)_2-N(R_4)-$, $-N(R_4)-N(R_5)-C(O)-$,



$-N(R_4)-N(R_5)-CH_2$, $-N(R_4)-N(R_5)-$ or ;

R_3, R_4 and R_5 are, independently for each occurrence, –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group or a substituted or unsubstituted non-aromatic heterocyclic group;

Y is selected from O, S, or NR_4;

each of X_6, X_7, X_8 and X_9 is independently selected from CR_7, C, or N, wherein at least two of X_6, X_7, X_8 or X_9 are not N;

each R_7 is independently selected from H or (C_1-C_3)-straight or branched alkyl; and

n is 1 or 2.

In certain embodiments, L is $–NR_4R_5-$, $-C(O)O-$, $–C(O)NR_4-$, $-NR_4C(O)-$, $-NR_4-NR_5-C(O)-$, $-C(O)-NR_4-NR_5-$ or $-CHR_4=CHR_5-$. In certain such embodiments, L is $-C(O)NR_4-$, $-NR_4C(O)-$, $-NR_4-NR_5-C(O)-$, $-C(O)-NR_4-NR_5-$ or $-CHR_4=CHR_5-$.

In certain embodiments, R_4 or R_5 when it appears in L is selected from H and (C_1-C_3)-straight or branched alkyl. In certain embodiments, R_4 and R_5 when they appear in L are H.

In certain embodiments, R_2 is selected from -H and -OH. In certain embodiments, R_2 is -H.

In certain embodiments, R_3 is a substituted or unsubstituted non-aromatic heterocyclic group or a substituted or unsubstituted aryl group, such as a substituted or unsubstituted heteroaryl group.

In certain embodiments, R_3 is an alkyl group substituted with a substituted or unsubstituted non-aromatic heterocyclic group or an alkyl group substituted with a substituted or unsubstituted aryl group.

In certain embodiments, R_1 and R_2 taken together with the atoms to which they are attached form an optionally substituted ring. In particular embodiments, the optionally substituted ring is aromatic, such as a 6-membered aromatic ring.

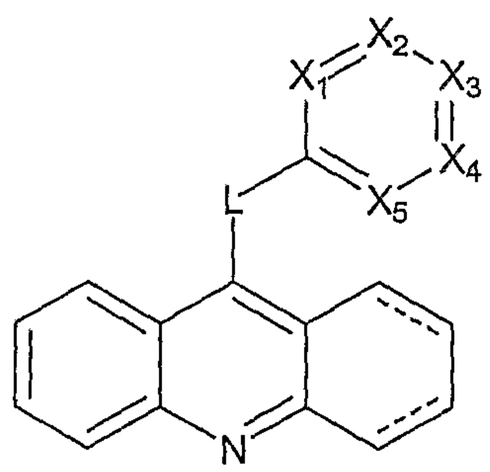
In certain embodiments, R_1 is a substituted or unsubstituted aryl group, such as a substituted or unsubstituted heteroaryl group.

In certain embodiments, R_1 is a substituted or unsubstituted alkyl group, such as a methyl or ethyl group.

In certain embodiments, Ring A is unsubstituted. An exemplary embodiment is where Ring A is unsubstituted and R_1 is a substituted or unsubstituted aryl group.

In certain embodiments, Ring A is substituted, such as with a substituted or unsubstituted alkyl group. An exemplary embodiment is where Ring A is substituted and R_1 is a substituted or unsubstituted alkyl group.

In another embodiment, sirtuin-modulating compounds of the invention are represented by Structural Formula (V):



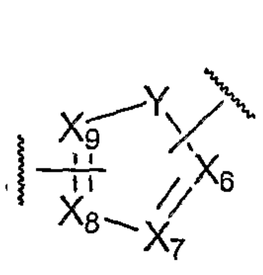
(V),

wherein, as valence permits:

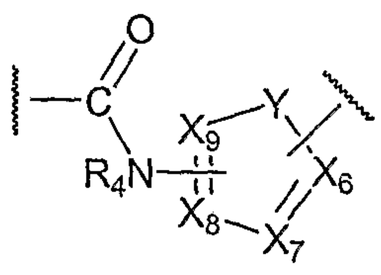
each of X_1, X_2, X_3, X_4 and X_5 is independently selected from N or CR_6, wherein no more than two of X_1, X_2, X_3, X_4 or X_5 are N;

each R_6 is independently selected from H, $-OCH_3$, $-CH_3$, or $-CF_3$;

L is selected from $-CH=CH-C(O)-$, $-CH_2-N(R_4)-C(O)-$, $-C(O)-CH_2-$, $-C(O)-N(R_4)-$, $-C(O)-N(R_4)-CH_2-$, $-C(O)-N(R_4)-CH_2-CH_2-$, $-C(O)-N(R_4)-C(O)-$, $-C(O)-N(R_4)-N(R_5)-$, $-CH_2-N(R_4)-N(R_5)-$, $-N(R_4)-S(O)_2-$, $-S(O)_2-N(R_4)-$, $-N(R_4)-N(R_5)-C(O)-$, $-C(O)-N(R_4)-N(R_5)-C(O)-$, $-N(R_4)-N(R_5)-CH_2$, $-N(R_4)-N(R_5)-$,



, or



;

each of R_4 and R_5 is independently selected from H or CH_3;

Y is selected from O, S, or NR_4;

each of X_6, X_7, X_8 and X_9 is independently selected from CR_7, C, or N, wherein at least two of X_6, X_7, X_8 or X_9 are not N;

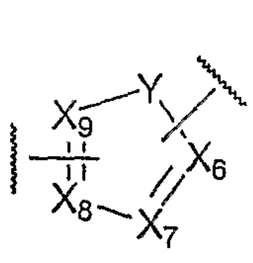
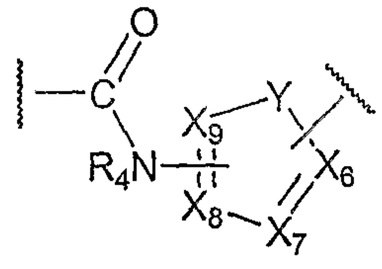
each R_7 is independently selected from H or (C_1-C_3)-straight or branched alkyl; and

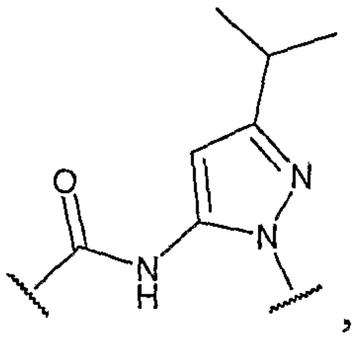
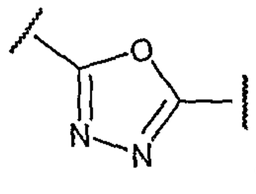
the hashed bonds are either simultaneously present or simultaneously absent.

In certain embodiments, when the hashed bonds are simultaneously present, L is $-N(R_4)-N(R_5)-C(O)-$, and each of X_2, X_3, and X_4 are $-OCH_3$, then R_4 is hydrogen.

In certain embodiments, when the hashed bonds are simultaneously absent and L is $-N(R_4)-N(R_5)-C(O)-$, both X_1 and X_5 are CR_6.

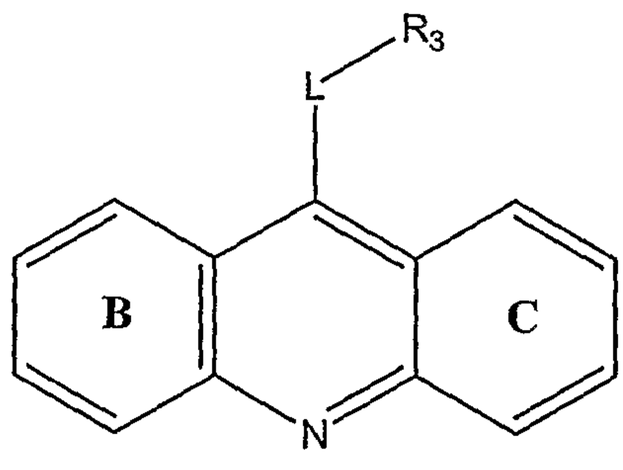
In certain embodiments, L is selected from $-C(O)-N(R_4)-N(R_5)-$, $-CH_2-N(R_4)-N(R_5)-$, $-N(R_4)-N(R_5)-C(O)-$, $-N(R_4)-N(R_5)-$,


, or

; particularly -NH-NH-C(O)-, -NH-NH-, $-N(CH_3)-NH-C(O)-$, $-CH_2-NH-NH-$, -C(O)-NH-NH-,


, or

.

In certain embodiments, such as when L has one of the values described above, no more than one of X_1, X_2, X_3, X_4 and X_5 is N, for example, exactly one of X_1, X_2, X_3, X_4 and X_5 is N. In certain such embodiments, each of X_1, X_2, X_3, X_4 and X_5 is selected from N or CH. In other such embodiments, each of X_1, X_2, X_3, X_4 and X_5 is CR_6, such as where each R_6 is hydrogen. In a particular embodiment, X_1 and X_5 are CH and each of X_2, X_3, and X_4 is $C\text{-}OCH_3$.

In another embodiment, sirtuin-modulating compounds of the invention are represented by Structural Formula (II):


(II),

or a salt thereof, wherein:

Rings B and C are independently optionally substituted;

L is $-NR_4R_5$, $-C(O)O-$, $-C(O)NR_4-$, $-NR_4C(O)-$, $-NR_4-NR_5-C(O)-$, $-C(O)-NR_4-NR_5-$ or $-CHR_4=CHR_5-$; and

R_3, R_4 and R_5 are independently –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group or a substituted or unsubstituted non-aromatic heterocyclic group.

In certain embodiments, L is -C(O)-NR_4-NR_5-.

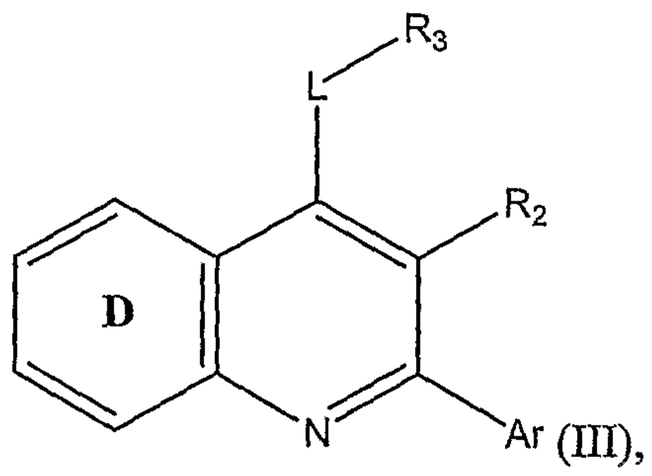
In certain embodiments, R_3 is a substituted or unsubstituted aryl group. In particular embodiments, L is -C(O)-NR_4-NR_5- and R_3 is a substituted or unsubstituted aryl group. Particular R_3 groups are substituted or unsubstituted phenyl or pyridyl groups, such as a pyridyl or an alkoxy-substituted phenyl group (e.g., a trialkoxy-substituted phenyl group such as 3,4,5-trimethoxyphenyl).

In certain embodiments, Ring B and/or Ring C is unsubstituted. Preferably, both Rings B and C are unsubstituted, such as when L is -C(O)-NR_4-NR_5- and/or R_3 is a substituted or unsubstituted aryl group.

In certain embodiments, R_4 and/or R_5 are –H. Preferably, both R_4 and R_5 are -H. In particular embodiments, Rings B and C are unsubstituted when L is -C(O)-NR_4-NR_5- and/or R_3 is a substituted or unsubstituted aryl group.

In certain embodiments, R_2 is selected from -H and -OH. In certain embodiments, R_2 is -H.

In yet another embodiment, sirtuin-modulating compounds of the invention are represented by Structural Formula (III):



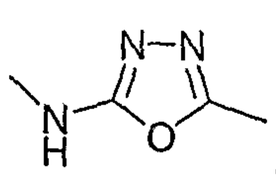
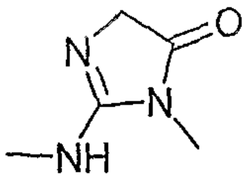
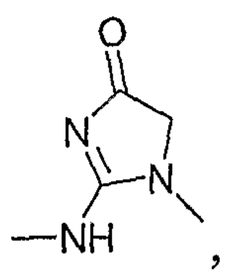
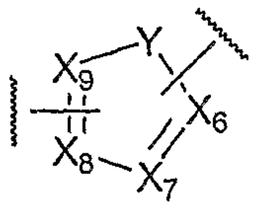
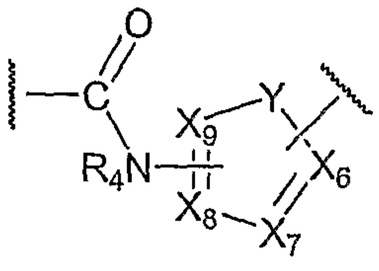
(III),

or a salt thereof, wherein, as valence permits:

Ring D is optionally substituted;

Ar is a substituted or unsubstituted aryl group;

R_2 is selected from –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted non-aromatic heterocyclic group, halogen, -OR_4, -CN, -CO_2R_4, -$OCOR_4$, -OCO_2R_4, -$C(O)NR_4R_5$, -$OC(O)NR_4R_5$, -$C(O)R_4$, -COR_4, -SR_4, -OSO_3H, -$S(O)_nR_4$, -$S(O)_nOR_4$, -$S(O)_nNR_4R_5$, -NR_4R_5, -$NR_4C(O)OR_5$, -$NR_4C(O)R_5$ and -NO_2;

L is selected from -C(O)O-, -C(O)-, -C(O)N(R_4)-, -C(O)-N(R_4)-C(O)-, -C(O)-N(R_4)-N(R_5)-, -C(O)-N(R_4)-N(R_5)-C(O)-, -C(O)-N(R_4)-$S(O)_2$-, -N(R_4)C(O)-, -N(R_4)-$S(O)_2$-, -N(R_4)-$S(O)_2$-N(R_5), -N(R_4)(R_5)-, -N(R_4)-N(R_5)-C(O)-, -N(R_4)-C(O)-N(R_5)-, -N(R_4)-C(O)-N(R_5)-$S(O)_2$, -N(R_4)-C(S)-N(R_5)-, -N(R_4)-C(O)-CH_2-N(R_5)-, -N(R_4)-C(O)-CH=C(CH_3)-, -N(R_4)-C(=N-CN)-N(R_5)-, -N(R_4)-C(=NH)-N(R_5)-, -N(R_4)-, -N(R_4)-CH_2-C(O)-N(R_5)-, -CH_2-, -CH_2-N(R_4)-C(O)-, -CH_2-C(O)-N(R_4)-, -CH(R_4)=CH(R_5)-, -CH=CH-C(O)-, -N(R_4)-N(R_5)-, -CH_2-N(R_4)-N(R_5)-, -$S(O)_2$-N(R_4)-, , , , , or ; such as –NR_4R_5, -C(O)O-, -C(O)NR_4-, -NR_4C(O)-, -NR_4-NR_5-C(O)-, -C(O)-NR_4-NR_5- or -CHR_4=CHR_5-;

each of R_3, R_4 and R_5 is independently selected from –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group or a substituted or unsubstituted non-aromatic heterocyclic group;

Y is selected from O, S, or NR_4;

each of X_6, X_7, X_8 and X_9 is independently selected from CR_7, C, or N, wherein at least two of X_6, X_7, X_8 or X_9 are not N;

each R_7 is independently selected from H or (C_1-C_3)-straight or branched alkyl; and

n is 1 or 2.

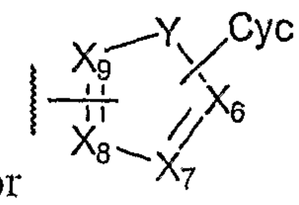
In certain embodiments, R_4 or R_5 when it appears in L is selected from H and (C_1-C_3)-straight or branched alkyl. In certain embodiments, R_4 and R_5 when they appear in L are H.

In certain embodiments, R_2 is selected from H and OH. In certain embodiments, R_2 is H.

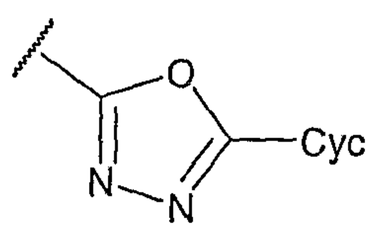
In certain embodiments, R_3 is a substituted or unsubstituted non-aromatic heterocyclic group or a substituted or unsubstituted aryl group, such as a substituted or unsubstituted heteroaryl group.

In certain embodiments, R_3 is selected from –H, Cyc or (C_1-C_2) alkylene-Cyc, wherein when R_3 is –H, L is -C(O)O-; Cyc is selected from a substituted aryl group,

an unsubstituted aryl group, a substituted non-aromatic heterocyclic group or an unsubstituted non-aromatic heterocyclic group; and each of R_4 and R_5 is independently selected from –H or $–CH_3$. In certain such embodiments, L and R_3 taken together form a moiety selected from C(O)-OH, C(O)-N(R_4)-Cyc, C(O)-N(R_4)-$(CH_2)_n$-Cyc, N(R_4)-N(R_5)-C(O)-Cyc, N(R_4)-N(R_5)-Cyc,



CH_2-N(R_4)-N(R_5)-Cyc, C(O)-N(R_4)-N(R_5)-Cyc, or . In particular embodiments, L and R_3 taken together form a moiety selected from -C(O)-OH, -C(O)-NH-$(CH_2)_n$-Cyc, -C(O)-NH-Cyc, -NH-NH-C(O)-Cyc, -NH-NH-Cyc, -N(CH_3)-NH-C(O)-Cyc, -CH_2-NH-NH-Cyc, -C(O)-NH-NH-Cyc, or



, preferably -C(O)-OH, -C(O)-NH-$(CH_2)_n$-Cyc, -C(O)-NH-Cyc, or -NH-NH-C(O)-Cyc, such as -C(O)-NH-$(CH_2)_n$-Cyc where Cyc is unsubstituted. Typically, Cyc is selected from pyridyl or morpholino. In other particular embodiments, L and R_3 taken together form -NH-NH-C(O)-Cyc; and Cyc is phenyl.

In particular embodiments, when L and R_3 are taken together to form C(O)-N(R_4)-Cyc, and Cyc is phenyl, said phenyl is monosubstituted with morpholino.

In particular embodiments, when L and R_3 are taken together to form N(R_4)-N(R_5)-C(O)-Cyc and Cyc is a substituted phenyl, said substituted phenyl is not 3,4,5 trimethoxyphenyl or 4-*N,N* dimethylaminophenyl.

In particular embodiments, when L and R_3 are taken together to form C(O)-N(R_4)-$(CH_2)_2$-Cyc, Cyc is not piperidinyl or piperazinyl.

In particular embodiments, when L and R_3 are taken together to form C(O)-N(R_4)-$(CH_2)_2$-Cyc and Cyc is morpholino, Ar is not furanyl.

In certain embodiments, Ar is unsubstituted. In certain such embodiments, Ar is selected from phenyl, pyridyl, thienyl, or furanyl.

In certain embodiments, ring D is unsubstituted or monosubstituted, particularly when Ar is selected from phenyl, pyridyl, thienyl, or furanyl. When ring D is monosubstituted, the substituent is typically at the 6-position of the ring system. Typical substituents for ring D include a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted non-aromatic

heterocyclic group, halogen, $-OR_4$, -CN, $-CO_2R_4$, $-OCOR_4$, $-OCO_2R_4$, $-C(O)NR_4R_5$, $-OC(O)NR_4R_5$, $-C(O)R_4$, $-COR_4$, $-SR_4$, $-OSO_3H$, $-S(O)_nR_4$, $-S(O)_nOR_4$, $-S(O)_nNR_4R_5$, $-NR_4R_5$, $-NR_4C(O)OR_5$, $-NR_4C(O)R_5$ and $-NO_2$. Preferred substituents include methyl and halo.

In certain embodiments, L is $-C(O)NR_4-$. In certain such embodiments, R_3 is a substituted or unsubstituted heteroaryl group having at least one ring nitrogen atom or a substituted or unsubstituted non-aromatic heterocyclic group having at least one nitrogen atom and or a C_{1-2} alkylene (e.g., unsubstituted alkylene) group substituted by substituted or unsubstituted heteroaryl group having at least one ring nitrogen atom or a substituted or unsubstituted non-aromatic heterocyclic group having at least one nitrogen atom.

In certain embodiments, L is $-NR_4R_5-$.

In certain embodiments, R_3 is a substituted alkyl group or a cyclic group. When R_3 is a substituted alkyl group, it is preferably substituted with a cyclic group. When R_3 is a cyclic group, it is preferably an aryl group (e.g., phenyl) or a non-aromatic heterocyclic group (e.g., morpholino). In a particular embodiment, L is $-C(O)NR_4-$ and R_3 is a substituted alkyl group or a cyclic group. When R_3 is a cyclic group or an alkyl group substituted with a cyclic group, the cyclic group is typically a phenyl or pyridyl group that is unsubstituted or substituted only at one or both of the positions adjacent to where R_3 attaches to L.

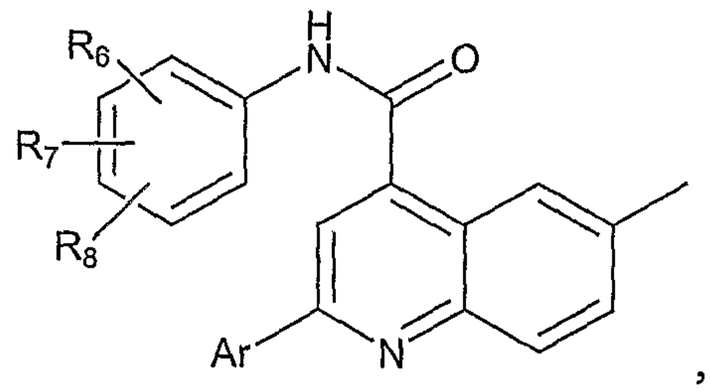
In other certain embodiments, R_3 is a cyclic group substituted at at least one position that is not adjacent to the atom by which R_3 attaches to L. For example, if R_3 is a phenyl or pyridyl group, at least one substituent is *meta* or *para* to the atom where R_3 attaches to L.

In certain embodiments, R_1 is a substituted or unsubstituted heteroaryl group, such as a thienyl or furanyl group. In particular embodiments, R_1 is a substituted or unsubstituted heteroaryl group, such as a thienyl or furanyl group, when L is $-C(O)NR_4-$ and/or R_3 is a substituted alkyl group or a cyclic group. For example, R_1, R_3 and L can have these values when R_3 is a cyclic group or an alkyl group substituted with a cyclic group, the cyclic group is typically a phenyl or pyridyl group that is unsubstituted or substituted only at one or both of the positions adjacent to where R_3 attaches to L.

In certain embodiments, Ring D is unsubstituted or is substituted with a halogen (e.g., Cl, Br, F, I) or an unsubstituted alkyl group (e.g., methyl, ethyl, propyl).

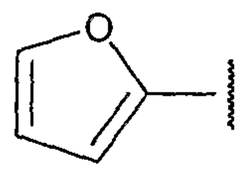
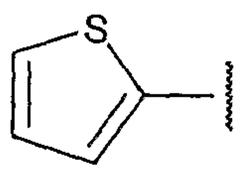
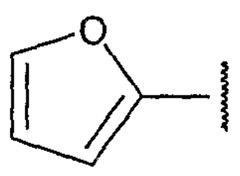
In particular embodiments, Ring D is unsubstituted or is substituted with a halogen or an unsubstituted alkyl group when R_1 is a substituted or unsubstituted heteroaryl group, L is $-C(O)NR_4-$ and/or R_3 is a substituted alkyl group or a cyclic group. In other particular embodiments, Ring D is substituted with a halogen or an unsubstituted alkyl group when R_1 is a substituted or unsubstituted heteroaryl group or a substituted or unsubstituted alkyl group, L is $-C(O)NR_4-$ or $-NR_4R_5-$ and/or R_3 is a substituted alkyl group or a cyclic group.

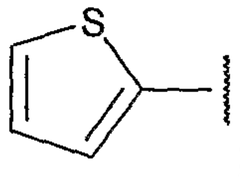
One group of compounds encompassed by Structural Formula (III) are represented by the formula:



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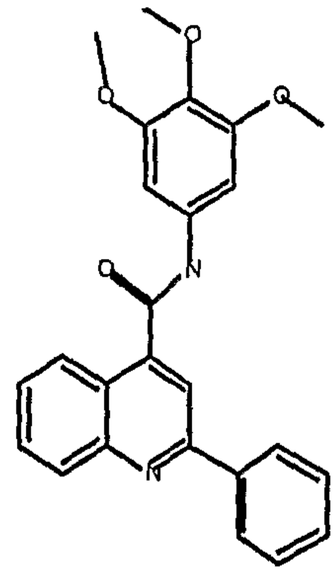
wherein:

Ar is selected from phenyl, , or , such as 

or ; and

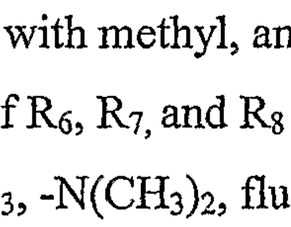
each of R_6, R_7, and R_8 is independently selected from -H, $-CF_3$, -C1-C3 straight or branched alkyl, -O-(C1-C3 straight or branched alkyl), $-O-CF_3$, $-N(C1-C3 straight or branched alkyl)_2$, halo, morpholino, -(C1-C3 straight or branched alkyl)-morpholino, piperazinyl, -(C1-C3 straight or branched alkyl)-piperazinyl, -piperazinyl, $-NH-S(O)_2-$(C1-C3 straight or branched alkyl), or $-NH-S(O)_2-$phenyl, wherein said phenyl, piperazinyl or morpholino is optionally substituted with methyl. In $-N(C1-C3 straight or branched alkyl)_2$, the two alkyl groups may be the same or different.

In certain embodiments, the compound is not



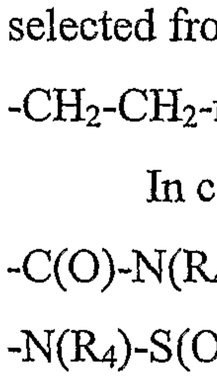
In certain embodiments, at least one of R_6, R_7, or R_8 is not -H. In certain such embodiments, zero or one of R_6, R_7, or R_8 is morpholino, -(C1-C3 straight or branched alkyl)-morpholino, piperazinyl, -(C1-C3 straight or branched alkyl)-piperazinyl, -piperazinyl, or -NH-$S(O)_2$-phenyl, wherein said phenyl, piperazinyl or morpholino is optionally substituted with methyl. In particular embodiments, R_6 is morpholino, -(C1-C3 straight or branched alkyl)-morpholino, piperazinyl, -(C1-C3 straight or branched alkyl)-piperazinyl, -piperazinyl, or -NH-$S(O)_2$-phenyl, wherein said phenyl, piperazinyl or morpholino is optionally substituted with methyl, and R_7 and R_8 are hydrogen. In other particular embodiments, each of R_6, R_7, and R_8 is independently selected from -H, -CF_3, -methyl, -O-methyl, -O-CF_3, -$N(CH_3)_2$, fluoro, morpholino, -CH_2-CH_2-morpholino, piperazinyl-CH_3, -NH-$S(O)_2$-CH_3, or -NH-$S(O)_2$-phenyl-CH_3.

In certain embodiments, L is selected from -C(O)O-, -C(O)-, -C(O)-$N(R_4)$-C(O)-, -C(O)-$N(R_4)$-$N(R_5)$-, -C(O)-$N(R_4)$-$S(O)_2$-, -$N(R_4)$C(O)-, -$N(R_4)$-$S(O)_2$-, -$N(R_4)$-$S(O)_2$-$N(R_5)$, -$N(R_4)(R_5)$-, -$N(R_4)$-$N(R_5)$-C(O)-, -$N(R_4)$-C(O)-$N(R_5)$-, -$N(R_4)$-C(O)-$N(R_5)$-$S(O)_2$, -$N(R_4)$-C(S)-$N(R_5)$-, -$N(R_4)$-C(O)-CH_2-$N(R_5)$-, -$N(R_4)$-C(O)-CH=$C(CH_3)$-, -$N(R_4)$-C(=N-CN)-$N(R_5)$-, -$N(R_4)$-C(=NH)-$N(R_5)$-, -$N(R_4)$-, -$N(R_4)$-CH_2-C(O)-$N(R_5)$-, -CH_2-, -CH_2-$N(R_4)$-C(O)-, -CH_2-C(O)-$N(R_4)$-, -$CH(R_4)$=$CH(R_5)$-, -CH=CH-C(O)-, -$N(R_4)$-$N(R_5)$-, -CH_2-$N(R_4)$-$N(R_5)$-, -$S(O)_2$-$N(R_4)$-,

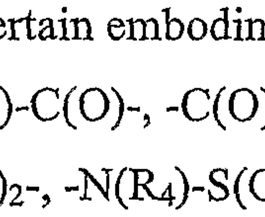


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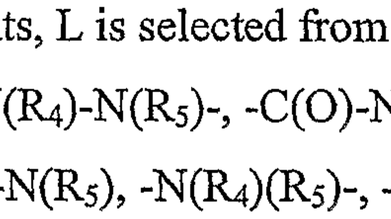
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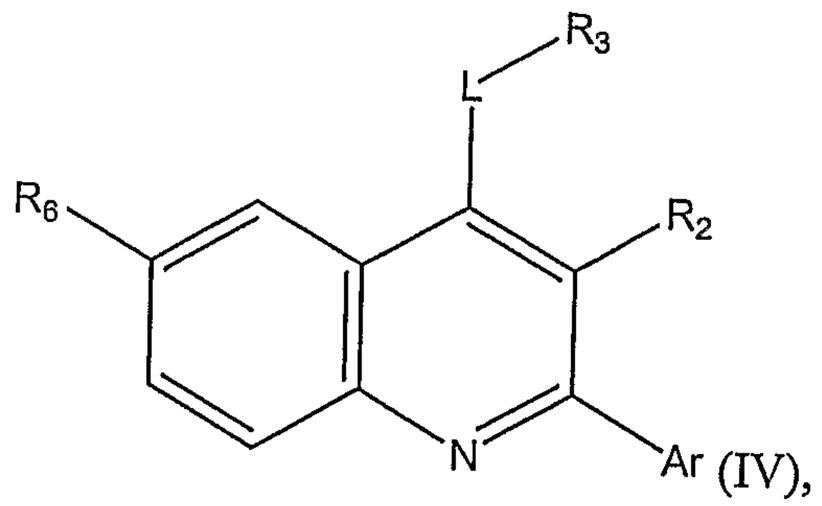


, or



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A particular group of compounds of the invention encompassed by Structural Formula (III) are represented by Structural Formula (IV):



(IV),

or a salt thereof, where R_6 is selected from –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted non-aromatic heterocyclic group, halogen, $-OR_4$, -CN, $-CO_2R_4$, $-OCOR_4$, $-OCO_2R_4$, $-C(O)NR_4R_5$, $-OC(O)NR_4R_5$, $-C(O)R_4$, $-COR_4$, $-SR_4$, $-OSO_3H$, $-S(O)_nR_4$, $-S(O)_nOR_4$, $-S(O)_nNR_4R_5$, $-NR_4R_5$, $-NR_4C(O)OR_5$, $-NR_4C(O)R_5$ and $-NO_2$. Preferred values of R_6 are a halogen or an unsubstituted alkyl group.

Suitable values of Ar, L, R_2 and R_3 are as described above.

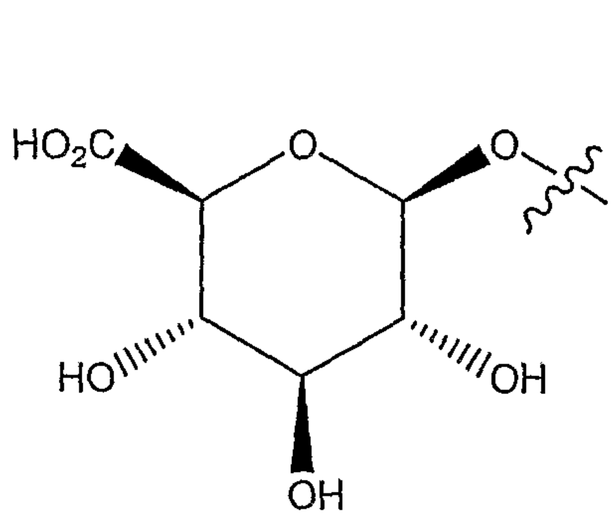
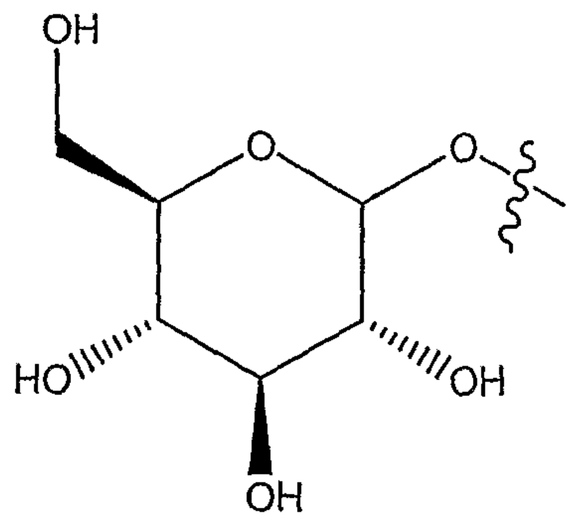
In certain embodiments, the compounds of the invention exclude Compounds 1-11, as shown in the Examples below.

Compounds of the invention, including novel compounds of the invention, can also be used in the methods described herein.

The compounds and salts thereof described herein also include their corresponding hydrates (e.g., hemihydrate, monohydrate, dihydrate, trihydrate, tetrahydrate) and solvates. Suitable solvents for preparation of solvates and hydrates can generally be selected by a skilled artisan.

The compounds and salts thereof can be present in amorphous or crystalline (including co-crystalline and polymorph) forms.

Sirtuin-modulating compounds of the invention having hydroxyl substituents, unless otherwise indicated, also include the related secondary metabolites, such as phosphate, sulfate, acyl (e.g., acetyl, fatty acid acyl) and sugar (e.g., glucuronate, glucose) derivatives. In other words, substituent groups –OH also include $-OSO_3^-M^+$, where M^+ is a suitable cation (preferably H^+, NH_4^+ or an alkali metal ion such as Na^+ or K^+) and sugars such as

and .

These groups are generally cleavable to –OH by hydrolysis or by metabolic (e.g., enzymatic) cleavage.

Sirtuin-modulating compounds of the invention advantageously modulate the level and/or activity of a sirtuin protein, particularly the deacetylase activity of the sirtuin protein.

Separately or in addition to the above properties, certain sirtuin- modulating compounds of the invention do not substantially have one or more of the following activities: inhibition of PI3-kinase, inhibition of aldoreductase, inhibition of tyrosine kinase, transactivation of EGFR tyrosine kinase, coronary dilation, or spasmolytic activity, at concentrations of the compound that are effective for modulating the deacetylation activity of a sirtuin protein (e.g., such as a SIRT1 and/or a SIRT3 protein).

An alkyl group is a straight chained, branched or cyclic non-aromatic hydrocarbon which is completely saturated. Typically, a straight chained or branched alkyl group has from 1 to about 20 carbon atoms, preferably from 1 to about 10, and a cyclic alkyl group has from 3 to about 10 carbon atoms, preferably from 3 to about 8. Examples of straight chained and branched alkyl groups include methyl, ethyl, n-propyl, iso-propyl, n-butyl, sec-butyl, tert-butyl, pentyl, hexyl, pentyl and octyl. A C1-C4 straight chained or branched alkyl group is also referred to as a "lower alkyl" group.

An alkenyl group is a straight chained, branched or cyclic non-aromatic hydrocarbon which contains one or more double bonds. Typically, the double bonds are not located at the terminus of the alkenyl group, such that the double bond is not adjacent to another functional group.

An alkynyl group is a straight chained, branched or cyclic non-aromatic hydrocarbon which contains one or more triple bonds. Typically, the triple bonds are

not located at the terminus of the alkynyl group, such that the triple bond is not adjacent to another functional group.

A cyclic group includes carbocyclic and heterocyclic rings. Such rings can be saturated or unsaturated, including aromatic. Heterocyclic rings typically contain 1 to 4 heteroatoms, although oxygen and sulfur atoms cannot be adjacent to each other.

Aromatic (aryl) groups include carbocyclic aromatic groups such as phenyl, naphthyl, and anthracyl, and heteroaryl groups such as imidazolyl, thienyl, furanyl, pyridyl, pyrimidyl, pyranyl, pyrazolyl, pyrroyl, pyrazinyl, thiazolyl, oxazolyl, and tetrazolyl.

Aromatic groups also include fused polycyclic aromatic ring systems in which a carbocyclic aromatic ring or heteroaryl ring is fused to one or more other heteroaryl rings. Examples include benzothienyl, benzofuranyl, indolyl, quinolinyl, benzothiazole, benzooxazole, benzimidazole, quinolinyl, isoquinolinyl and isoindolyl.

Non-aromatic heterocyclic rings are non-aromatic carbocyclic rings which include one or more heteroatoms such as nitrogen, oxygen or sulfur in the ring. The ring can be five, six, seven or eight-membered. Examples include tetrahydrofuranyl, tetrahyrothiophenyl, morpholino, thiomorpholino, pyrrolidinyl, piperazinyl, piperidinyl, and thiazolidinyl, along with the cyclic form of sugars.

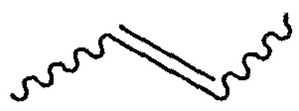
A ring fused to a second ring shares at least one common bond.

Suitable substituents on an alkyl, alkenyl, alkynyl, aryl, non-aromatic heterocyclic or aryl group (carbocyclic and heteroaryl) are those which do not substantially interfere with the ability of the disclosed compounds to have one or more of the properties disclosed herein. A substituent substantially interferes with the properties of a compound when the magnitude of the property is reduced by more than about 50% in a compound with the substituent compared with a compound without the substituent. Examples of suitable substituents include -OH, halogen (-Br, -Cl, -I and -F), $-OR^a$, $-O-COR^a$, $-COR^a$, $-C(O)R^a$, -CN, $-NO^2$, -COOH, $-COOR^a$, $-OCO_2R^a$, $-C(O)NR^aR^b$, $-OC(O)NR^aR^b$, $-SO_3H$, $-NH_2$, $-NHR^a$, $-N(R^aR^b)$, $-COOR^a$, -CHO, $-CONH_2$, $-CONHR^a$, $-CON(R^aR^b)$, $-NHCOR^a$, $-NRCOR^a$, $-NHCONH_2$, $-NHCONR^aH$, $-NHCON(R^aR^b)$, $-NR^cCONH_2$, $-NR^cCONR^aH$, $-NR^cCON(R^aR^b)$, $-C(=NH)-NH_2$, $-C(=NH)-NHR^a$, $-C(=NH)-N(R^aR^b)$, $-C(=NR^c)-NH_2$, $-C(=NR^c)-NHR^a$, $-C(=NR^c)-N(R^aR^b)$, $-NH-C(=NH)-NH_2$, $-NH-C(=NH)-NHR^a$, $-NH-C(=NH)-N(R^aR^b)$, $-NH-C(=NR^c)-NH_2$, $-NH-C(=NR^c)-NHR^a$, $-NH-C(=NR^c)-N(R^aR^b)$, $-NR^dH-C(=NH)-NH_2$, $-NR^d-C(=NH)-NHR^a$, $-NR^d-C(=NH)-N(R^aR^b)$, $-NR^d-C(=NR^c)-NH_2$, $-NR^d-$

$C(=NR^c)$-NHR^a, -NR^d-$C(=NR^c)$-$N(R^aR^b)$, -$NHNH_2$, -$NHNHR^a$, -NHR^aR^b, -SO_2NH_2, -SO_2NHR_a, -$SO_2NR^aR^b$, -$CH=CHR^a$, -$CH=CR^aR^b$, -$CR^c=CR^aR^b$, $CR^c=CHR^a$, -$CR^c=CR^aR^b$, -CCR^a, -SH, -SO_kR^a (k is 0, 1 or 2), -$S(O)_kOR^a$ (k is 0, 1 or 2) and -NH-$C(=NH)$-NH_2. R^a-R^d are each independently an aliphatic, substituted aliphatic, benzyl, substituted benzyl, aromatic or substituted aromatic group, preferably an alkyl, benzylic or aryl group. In addition, -NR^aR^b, taken together, can also form a substituted or unsubstituted non-aromatic heterocyclic group. A non-aromatic heterocyclic group, benzylic group or aryl group can also have an aliphatic or substituted aliphatic group as a substituent. A substituted aliphatic group can also have a non-aromatic heterocyclic ring, a substituted a non-aromatic heterocyclic ring, benzyl, substituted benzyl, aryl or substituted aryl group as a substituent. A substituted aliphatic, non-aromatic heterocyclic group, substituted aryl, or substituted benzyl group can have more than one substituent.

Combinations of substituents and variables envisioned by this invention are only those that result in the formation of stable compounds. As used herein, the term "stable" refers to compounds that possess stability sufficient to allow manufacture and that maintain the integrity of the compound for a sufficient period of time to be useful for the purposes detailed herein.

A hydrogen-bond donating group is a functional group having a partially positively-charged hydrogen atom (e.g., -OH, -NH_2, -SH) or a group (e.g., an ester) that metabolizes into a group capable of donating a hydrogen bond.

Double bonds indicated in a structure as:  are intended to include both the (E)- and (Z)-configuration. Preferably, double bonds are in the (E)-configuration.

A sugar is an aldehyde or ketone derivative of a straight-chain polyhydroxy alcohol, which contains at least three carbon atoms. A sugar can exist as a linear molecule or, preferably, as a cyclic molecule (e.g., in the pyranose or furanose form). Preferably, a sugar is a monosaccharide such as glucose or glucuronic acid. In embodiments of the invention where, for example, prolonged residence of a compound derivatized with a sugar is desired, the sugar is preferably a non-naturally occurring sugar. For example, one or more hydroxyl groups are substituted with another group, such as a halogen (e.g., chlorine). The stereochemical configuration at

one or more carbon atoms can also be altered, as compared to a naturally occurring sugar. One example of a suitable non-naturally occurring sugar is sucralose.

A fatty acid is a carboxylic acid having a long-chained hydrocarbon moiety. Typically, a fatty acid has an even number of carbon atoms ranging from 12 to 24, often from 14 to 20. Fatty acids can be saturated or unsaturated and substituted or unsubstituted, but are typically unsubstituted. Fatty acids can be naturally or non-naturally occurring. In embodiments of the invention where, for example, prolonged residence time of a compound having a fatty acid moiety is desired, the fatty acid is preferably non-naturally occurring. The acyl group of a fatty acid consists of the hydrocarbon moiety and the carbonyl moiety of the carboxylic acid functionality, but excludes the –OH moiety associated with the carboxylic acid functionality.

Also included in the present invention are salts, particularly pharmaceutically acceptable salts, of the sirtuin- modulating compounds described herein. The compounds of the present invention that possess a sufficiently acidic, a sufficiently basic, or both functional groups, can react with any of a number of inorganic bases, and inorganic and organic acids, to form a salt. Alternatively, compounds that are inherently charged, such as those with a quaternary nitrogen, can form a salt with an appropriate counterion (e.g., a halide such as bromide, chloride, or fluoride, particularly bromide).

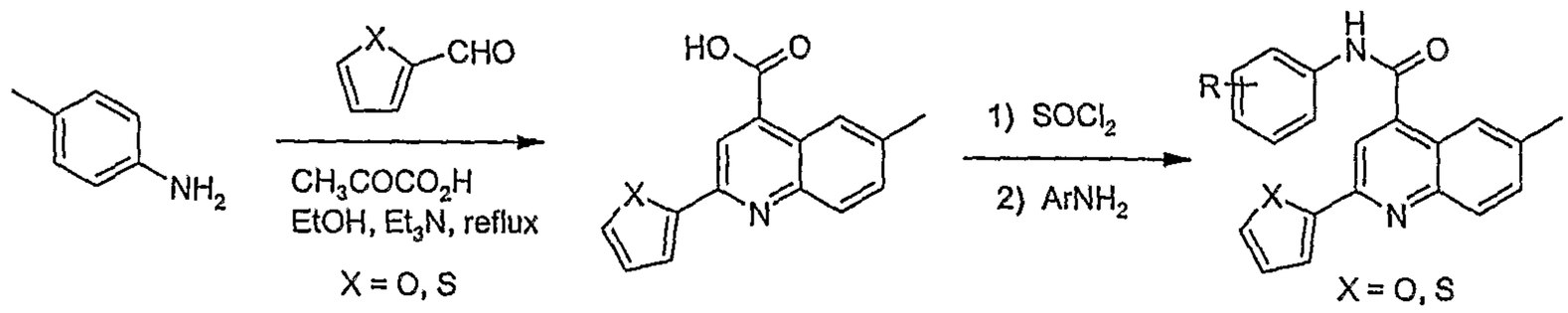
Acids commonly employed to form acid addition salts are inorganic acids such as hydrochloric acid, hydrobromic acid, hydroiodic acid, sulfuric acid, phosphoric acid, and the like, and organic acids such as p-toluenesulfonic acid, methanesulfonic acid, oxalic acid, p-bromophenyl-sulfonic acid, carbonic acid, succinic acid, citric acid, benzoic acid, acetic acid, and the like. Examples of such salts include the sulfate, pyrosulfate, bisulfate, sulfite, bisulfite, phosphate, monohydrogenphosphate, dihydrogenphosphate, metaphosphate, pyrophosphate, chloride, bromide, iodide, acetate, propionate, decanoate, caprylate, acrylate, formate, isobutyrate, caproate, heptanoate, propiolate, oxalate, malonate, succinate, suberate, sebacate, fumarate, maleate, butyne-1,4-dioate, hexyne-1,6-dioate, benzoate, chlorobenzoate, methylbenzoate, dinitrobenzoate, hydroxybenzoate, methoxybenzoate, phthalate, sulfonate, xylenesulfonate, phenylacetate, phenylpropionate, phenylbutyrate, citrate, lactate, gamma-hydroxybutyrate, glycolate, tartrate, methanesulfonate, propanesulfonate, naphthalene-1-sulfonate, naphthalene-2-sulfonate, mandelate, and the like.

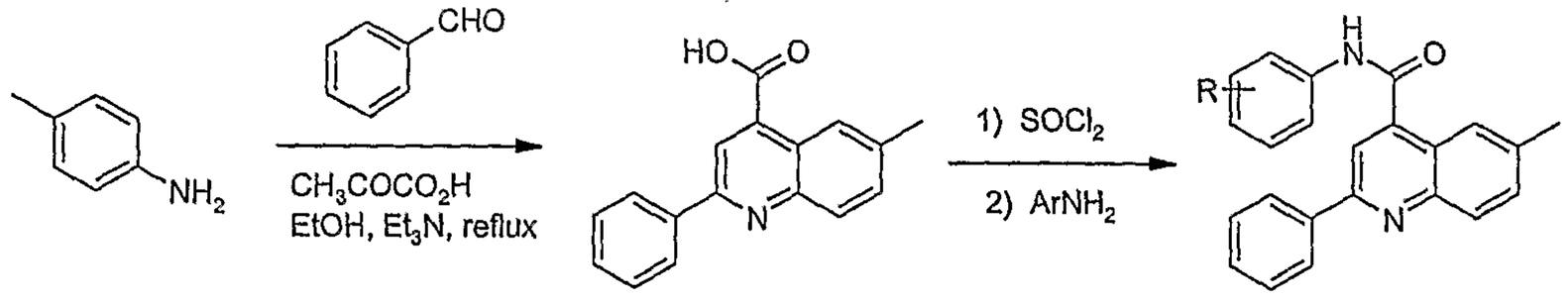
Base addition salts include those derived from inorganic bases, such as ammonium or alkali or alkaline earth metal hydroxides, carbonates, bicarbonates, and the like. Such bases useful in preparing the salts of this invention thus include sodium hydroxide, potassium hydroxide, ammonium hydroxide, potassium carbonate, and the like.

According to another embodiment, the present invention provides methods of producing the above-defined sirtuin-modulating compounds. The compounds may be synthesized using conventional techniques. Advantageously, these compounds are conveniently synthesized from readily available starting materials.

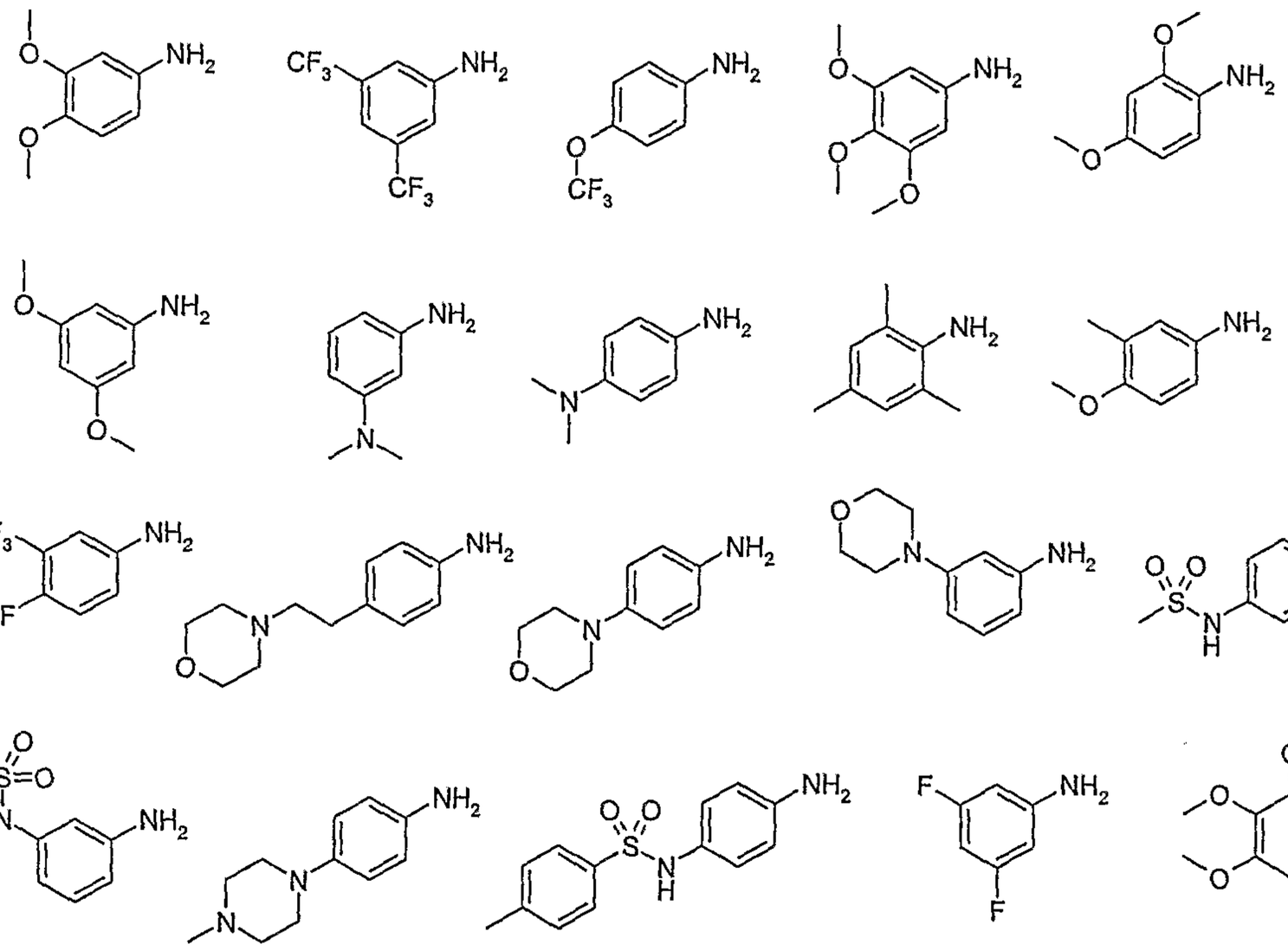
Two general synthetic schemes for certain compounds of the invention are shown below, whereby an aniline is reacted with an aryl aldehyde (e.g., benzaldehyde) in the presence of CH_3COCO_2H under appropriate conditions (e.g., in ethanol and triethylamine) to form a carboxylic acid intermediate. The intermediate is reacted with an aryl amine under appropriate conditions (e.g., with $SOCl_2$) to form the final product. Examples of suitable aryl amines are shown below.

Arylamide quinolines





examples of the aryl amines:



In an exemplary embodiment, a sirtuin-modulating compound may traverse the cytoplasmic membrane of a cell. For example, a compound may have a cell-permeability of at least about 20%, 50%, 75%, 80%, 90% or 95%.

Sirtuin- modulating compounds described herein may also have one or more of the following characteristics: the compound may be essentially non-toxic to a cell or subject; the sirtuin-modulating compound may be an organic molecule or a small molecule of 2000 amu or less, 1000 amu or less; a compound may have a half-life under normal atmospheric conditions of at least about 30 days, 60 days, 120 days, 6 months or 1 year; the compound may have a half-life in solution of at least about 30 days, 60 days, 120 days, 6 months or 1 year; a sirtuin-modulating compound may be more stable in solution than resveratrol by at least a factor of about 50%, 2 fold, 5 fold, 10 fold, 30 fold, 50 fold or 100 fold; a sirtuin-modulating compound may promote deacetylation of the DNA repair factor Ku70; a sirtuin-modulating compound may promote deacetylation of RelA/p65; a compound may increase general turnover rates and enhance the sensitivity of cells to TNF-induced apoptosis.

In certain embodiments, a sirtuin-modulating compound does not have any substantial ability to inhibit a histone deacetylase (HDACs) class I, a HDAC class II, or HDACs I and II, at concentrations (e.g., in vivo) effective for modulating the deacetylase activity of the sirtuin. For instance, in preferred embodiments the sirtuin-modulating compound is a sirtuin-activating compound and is chosen to have an EC_{50} for activating sirtuin deacetylase activity that is at least 5 fold less than the EC_{50} for inhibition of an HDAC I and/or HDAC II, and even more preferably at least 10 fold, 100 fold or even 1000 fold less. Methods for assaying HDAC I and/or HDAC II activity are well known in the art and kits to perform such assays may be purchased commercially. See e.g., BioVision, Inc. (Mountain View, CA; world wide web at biovision.com) and Thomas Scientific (Swedesboro, NJ; world wide web at tomassci.com).

In certain embodiments, a sirtuin-modulating compound does not have any substantial ability to modulate sirtuin homologs. In one embodiment, an activator of a human sirtuin protein may not have any substantial ability to activate a sirtuin protein from lower eukaryotes, particularly yeast or human pathogens, at concentrations (e.g., in vivo) effective for activating the deacetylase activity of human sirtuin. For example, a sirtuin-activating compound may be chosen to have an EC_{50} for activating a human sirtuin, such as SIRT1 and/or SIRT3, deacetylase activity that is at least 5 fold less than the EC_{50} for activating a yeast sirtuin, such as Sir2 (such as Candida, S. cerevisiae, etc.), and even more preferably at least 10 fold, 100 fold or even 1000 fold less. In another embodiment, an inhibitor of a sirtuin

protein from lower eukaryotes, particularly yeast or human pathogens, does not have any substantial ability to inhibit a sirtuin protein from humans at concentrations (e.g., in vivo) effective for inhibiting the deacetylase activity of a sirtuin protein from a lower eukaryote. For example, a sirtuin-inhibiting compound may be chosen to have an IC_{50} for inhibiting a human sirtuin, such as SIRT1 and/or SIRT3, deacetylase activity that is at least 5 fold less than the IC_{50} for inhibiting a yeast sirtuin, such as Sir2 (such as Candida, S. cerevisiae, etc.), and even more preferably at least 10 fold, 100 fold or even 1000 fold less.

In certain embodiments, a sirtuin-modulating compound may have the ability to modulate one or more sirtuin protein homologs, such as, for example, one or more of human SIRT1, SIRT2, SIRT3, SIRT4, SIRT5, SIRT6, or SIRT7. In one embodiment, a sirtuin-modulating compound has the ability to modulate both a SIRT1 and a SIRT3 protein.

In other embodiments, a SIRT1 modulator does not have any substantial ability to modulate other sirtuin protein homologs, such as, for example, one or more of human SIRT2, SIRT3, SIRT4, SIRT5, SIRT6, or SIRT7, at concentrations (e.g., in vivo) effective for modulating the deacetylase activity of human SIRT1. For example, a sirtuin-modulating compound may be chosen to have an ED_{50} for modulating human SIRT1 deacetylase activity that is at least 5 fold less than the ED_{50} for modulating one or more of human SIRT2, SIRT3, SIRT4, SIRT5, SIRT6, or SIRT7, and even more preferably at least 10 fold, 100 fold or even 1000 fold less. In one embodiment, a SIRT1 modulator does not have any substantial ability to modulate a SIRT3 protein.

In other embodiments, a SIRT3 modulator does not have any substantial ability to modulate other sirtuin protein homologs, such as, for example, one or more of human SIRT1, SIRT2, SIRT4, SIRT5, SIRT6, or SIRT7, at concentrations (e.g., in vivo) effective for modulating the deacetylase activity of human SIRT3. For example, a sirtuin-modulating compound may be chosen to have an ED_{50} for modulating human SIRT3 deacetylase activity that is at least 5 fold less than the ED_{50} for modulating one or more of human SIRT1, SIRT2, SIRT4, SIRT5, SIRT6, or SIRT7, and even more preferably at least 10 fold, 100 fold or even 1000 fold less. In one embodiment, a SIRT3 modulator does not have any substantial ability to modulate a SIRT1 protein.

In certain embodiments, a sirtuin-modulating compound may have a binding affinity for a sirtuin protein of about 10^{-9}M, 10^{-10}M, 10^{-11}M, 10^{-12}M or less. A sirtuin-modulating compound may reduce (activator) or increase (inhibitor) the apparent Km of a sirtuin protein for its substrate or NAD+ (or other cofactor) by a factor of at least about 2, 3, 4, 5, 10, 20, 30, 50 or 100. In certain embodiments, Km values are determined using the mass spectrometry assay described herein. Preferred activator compounds reduce the Km of a sirtuin for its substrate or cofactor to a greater extent than caused by resveratrol at a similar concentration or reduce the Km of a sirtuin for its substrate or cofactor similar to that caused by resveratrol at a lower concentration. A sirtuin-modulating compound may increase the Vmax of a sirtuin protein by a factor of at least about 2, 3, 4, 5, 10, 20, 30, 50 or 100. A sirtuin-modulating compound may have an ED50 for modulating the deacetylase activity of a SIRT1 and/or SIRT3 protein of less than about 1 nM, less than about 10 nM, less than about 100 nM, less than about 1 μM, less than about 10 μM, less than about 100 μM, or from about 1-10 nM, from about 10-100 nM, from about 0.1-1 μM, from about 1-10 μM or from about 10-100 μM. A sirtuin-modulating compound may modulate the deacetylase activity of a SIRT1 and/or SIRT3 protein by a factor of at least about 5, 10, 20, 30, 50, or 100, as measured in a cellular assay or in a cell based assay. A sirtuin-activating compound may cause at least about 10%, 30%, 50%, 80%, 2 fold, 5 fold, 10 fold, 50 fold or 100 fold greater induction of the deacetylase activity of a sirtuin protein relative to the same concentration of resveratrol. A sirtuin-modulating compound may have an ED50 for modulating SIRT5 that is at least about 10 fold, 20 fold, 30 fold, 50 fold greater than that for modulating SIRT1 and/or SIRT3.

3. Exemplary Uses

In certain aspects, the invention provides methods for modulating the level and/or activity of a sirtuin protein and methods of use thereof.

In certain embodiments, the invention provides methods for using sirtuin-modulating compounds wherein the sirtuin-modulating compounds activate a sirtuin protein, e.g., increase the level and/or activity of a sirtuin protein. Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be useful for a variety of therapeutic applications including, for example, increasing the lifespan of a cell, and treating and/or preventing a wide variety of diseases and disorders

including, for example, diseases or disorders related to aging or stress, diabetes, obesity, neurodegenerative diseases, cardiovascular disease, blood clotting disorders, inflammation, cancer, and/or flushing, etc. The methods comprise administering to a subject in need thereof a pharmaceutically effective amount of a sirtuin-modulating compound, e.g., a sirtuin-activating compound.

In other embodiments, the invention provides methods for using sirtuin-modulating compounds wherein the sirtuin-modulating compounds decrease sirtuin activity, e.g., decrease the level and/or activity of a sirtuin protein. Sirtuin-modulating compounds that decrease the level and/or activity of a sirtuin protein may be useful for a variety of therapeutic application including, for example, increasing cellular sensitivity to stress (including increasing radiosensitivity and/or chemosensitivity), increasing the amount and/or rate of apoptosis, treatment of cancer (optionally in combination another chemotherapeutic agent), stimulation of appetite, and/or stimulation of weight gain, etc. The methods comprise administering to a subject in need thereof a pharmaceutically effective amount of a sirtuin-modulating compound, e.g., a sirtuin-inhibiting compound.

While Applicants do not wish to be bound by theory, it is believed that activators and inhibitors of the instant invention may interact with a sirtuin at the same location within the sirtuin protein (e.g., active site or site affecting the Km or Vmax of the active site). It is believed that this is the reason why certain classes of sirtuin activators and inhibitors can have substantial structural similarity.

In certain embodiments, the sirtuin-modulating compounds described herein may be taken alone or in combination with other compounds. In one embodiment, a mixture of two or more sirtuin-modulating compounds may be administered to a subject in need thereof. In another embodiment, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be administered with one or more of the following compounds: resveratrol, butein, fisetin, piceatannol, or quercetin. In an exemplary embodiment, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be administered in combination with nicotinic acid. In another embodiment, a sirtuin-modulating compound that decreases the level and/or activity of a sirtuin protein may be administered with one or more of the following compounds: nicotinamide (NAM), suranim; NF023 (a G-protein antagonist); NF279 (a purinergic receptor antagonist); Trolox (6-hydroxy-2,5,7,8,tetramethylchroman-2-carboxylic acid); (-)-

epigallocatechin (hydroxy on sites 3,5,7,3',4', 5'); (-)-epigallocatechin gallate (Hydroxy sites 5,7,3',4',5' and gallate ester on 3); cyanidin choloride (3,5,7,3',4'-pentahydroxyflavylium chloride); delphinidin chloride (3,5,7,3',4',5'-hexahydroxyflavylium chloride); myricetin (cannabiscetin; 3,5,7,3',4',5'-hexahydroxyflavone); 3,7,3',4',5'-pentahydroxyflavone; gossypetin (3,5,7,8,3',4'-hexahydroxyflavone), sirtinol; and splitomicin (see e.g., Howitz et al. (2003) Nature 425:191; Grozinger et al. (2001) J. *Biol. Chem.* 276:38837; Dedalov et al. (2001) *PNAS* 98:15113; and Hirao et al. (2003) *J. Biol. Chem* 278:52773). In yet another embodiment, one or more sirtuin-modulating compounds may be administered with one or more therapeutic agents for the treatment or prevention of various diseases, including, for example, cancer, diabetes, neurodegenerative diseases, cardiovascular disease, blood clotting, inflammation, flushing, obesity, ageing, stress, etc. In various embodiments, combination therapies comprising a sirtuin-modulating compound may refer to (1) pharmaceutical compositions that comprise one or more sirtuin-modulating compounds in combination with one or more therapeutic agents (e.g., one or more therapeutic agents described herein); and (2) co-administration of one or more sirtuin-modulating compounds with one or more therapeutic agents wherein the sirtuin-modulating compound and therapeutic agent have not been formulated in the same compositions (but may be present within the same kit or package, such as a blister pack or other multi-chamber package; connected, separately sealed containers (e.g., foil pouches) that can be separated by the user; or a kit where the sirtuin-modulating compound(s) and other therapeutic agent(s) are in separate vessels). When using separate formulations, the sirtuin-modulating compound may be administered at the same, intermittent, staggered, prior to, subsequent to, or combinations thereof, with the administration of another therapeutic agent.

In certain embodiments, methods for reducing, preventing or treating diseases or disorders using a sirtuin-modulating compound may also comprise increasing the protein level of a sirtuin, such as human SIRT1 and/or SIRT3, or homologs thereof. Increasing protein levels can be achieved by introducing into a cell one or more copies of a nucleic acid that encodes a sirtuin. For example, the level of a sirtuin can be increased in a mammalian cell by introducing into the mammalian cell a nucleic acid encoding the sirtuin, e.g., increasing the level of SIRT1 by introducing a nucleic acid encoding the amino acid sequence set forth in GenBank Accession No. NP_036370 and/or increasing the level of SIRT3 by introducing a nucleic acid

encoding the amino acid sequence set forth in GenBank Accession No. AAH01042. The nucleic acid may be under the control of a promoter that regulates the expression of the SIRT1 and/or SIRT3 nucleic acid. Alternatively, the nucleic acid may be introduced into the cell at a location in the genome that is downstream of a promoter. Methods for increasing the level of a protein using these methods are well known in the art.

A nucleic acid that is introduced into a cell to increase the protein level of a sirtuin may encode a protein that is at least about 80%, 85%, 90%, 95%, 98%, or 99% identical to the sequence of a sirtuin, e.g., SIRT1 (GenBank Accession No. NP_036370) and/or SIRT3 (GenBank Accession No. AAH01042) protein. For example, the nucleic acid encoding the protein may be at least about 80%, 85%, 90%, 95%, 98%, or 99% identical to a nucleic acid encoding a SIRT1 (e.g. GenBank Accession No. NM_012238) and/or SIRT3 (e.g., GenBank Accession No. BC001042) protein. The nucleic acid may also be a nucleic acid that hybridizes, preferably under stringent hybridization conditions, to a nucleic acid encoding a wild-type sirtuin, e.g., SIRT1 (GenBank Accession No. NM_012238) and/or SIRT3 (e.g., GenBank Accession No. BC001042) protein. Stringent hybridization conditions may include hybridization and a wash in 0.2 x SSC at 65 °C. When using a nucleic acid that encodes a protein that is different from a wild-type sirtuin protein, such as a protein that is a fragment of a wild-type sirtuin, the protein is preferably biologically active, e.g., is capable of deacetylation. It is only necessary to express in a cell a portion of the sirtuin that is biologically active. For example, a protein that differs from wild-type SIRT1 having GenBank Accession No. NP_036370, preferably contains the core structure thereof. The core structure sometimes refers to amino acids 62-293 of GenBank Accession No. NP_036370, which are encoded by nucleotides 237 to 932 of GenBank Accession No. NM_012238, which encompasses the NAD binding as well as the substrate binding domains. The core domain of SIRT1 may also refer to about amino acids 261 to 447 of GenBank Accession No. NP_036370, which are encoded by nucleotides 834 to 1394 of GenBank Accession No. NM_012238; to about amino acids 242 to 493 of GenBank Accession No. NP_036370, which are encoded by nucleotides 777 to 1532 of GenBank Accession No. NM_012238; or to about amino acids 254 to 495 of GenBank Accession No. NP_036370, which are encoded by nucleotides 813 to 1538 of GenBank Accession No. NM_012238. Whether a protein

retains a biological function, e.g., deacetylation capabilities, can be determined according to methods known in the art.

In certain embodiments, methods for reducing, preventing or treating diseases or disorders using a sirtuin-modulating compound may also comprise decreasing the protein level of a sirtuin, such as human SIRT1 and/or SIRT3, or homologs thereof. Decreasing a sirtuin protein level can be achieved according to methods known in the art. For example, an siRNA, an antisense nucleic acid, or a ribozyme targeted to the sirtuin can be expressed in the cell. A dominant negative sirtuin mutant, e.g., a mutant that is not capable of deacetylating, may also be used. For example, mutant H363Y of SIRT1, described, e.g., in Luo et al. (2001) Cell 107:137 can be used. Alternatively, agents that inhibit transcription can be used.

Methods for modulating sirtuin protein levels also include methods for modulating the transcription of genes encoding sirtuins, methods for stabilizing/destabilizing the corresponding mRNAs, and other methods known in the art.

Aging/Stress

In one embodiment, the invention provides a method extending the lifespan of a cell, extending the proliferative capacity of a cell, slowing ageing of a cell, promoting the survival of a cell, delaying cellular senescence in a cell, mimicking the effects of calorie restriction, increasing the resistance of a cell to stress, or preventing apoptosis of a cell, by contacting the cell with a sirtuin-modulating compound of the invention that increases the level and/or activity of a sirtuin protein. In an exemplary embodiment, the methods comprise contacting the cell with a sirtuin-activating compound.

The methods described herein may be used to increase the amount of time that cells, particularly primary cells (i.e., cells obtained from an organism, e.g., a human), may be kept alive in a cell culture. Embryonic stem (ES) cells and pluripotent cells, and cells differentiated therefrom, may also be treated with a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein to keep the cells, or progeny thereof, in culture for longer periods of time. Such cells can also be used for transplantation into a subject, e.g., after *ex vivo* modification.

In one embodiment, cells that are intended to be preserved for long periods of time may be treated with a sirtuin-modulating compound that increases the level

and/or activity of a sirtuin protein. The cells may be in suspension (e.g., blood cells, serum, biological growth media, etc.) or in tissues or organs. For example, blood collected from an individual for purposes of transfusion may be treated with a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein to preserve the blood cells for longer periods of time. Additionally, blood to be used for forensic purposes may also be preserved using a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein. Other cells that may be treated to extend their lifespan or protect against apoptosis include cells for consumption, e.g., cells from non-human mammals (such as meat) or plant cells (such as vegetables).

Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may also be applied during developmental and growth phases in mammals, plants, insects or microorganisms, in order to, e.g., alter, retard or accelerate the developmental and/or growth process.

In another embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used to treat cells useful for transplantation or cell therapy, including, for example, solid tissue grafts, organ transplants, cell suspensions, stem cells, bone marrow cells, etc. The cells or tissue may be an autograft, an allograft, a syngraft or a xenograft. The cells or tissue may be treated with the sirtuin-modulating compound prior to administration/implantation, concurrently with administration/implantation, and/or post administration/implantation into a subject. The cells or tissue may be treated prior to removal of the cells from the donor individual, *ex vivo* after removal of the cells or tissue from the donor individual, or post implantation into the recipient. For example, the donor or recipient individual may be treated systemically with a sirtuin-modulating compound or may have a subset of cells/tissue treated locally with a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein. In certain embodiments, the cells or tissue (or donor/recipient individuals) may additionally be treated with another therapeutic agent useful for prolonging graft survival, such as, for example, an immunosuppressive agent, a cytokine, an angiogenic factor, etc.

In yet other embodiments, cells may be treated with a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein *in vivo*, e.g., to increase their lifespan or prevent apoptosis. For example, skin can be protected from

aging (e.g., developing wrinkles, loss of elasticity, etc.) by treating skin or epithelial cells with a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein. In an exemplary embodiment, skin is contacted with a pharmaceutical or cosmetic composition comprising a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein. Exemplary skin afflictions or skin conditions that may be treated in accordance with the methods described herein include disorders or diseases associated with or caused by inflammation, sun damage or natural aging. For example, the compositions find utility in the prevention or treatment of contact dermatitis (including irritant contact dermatitis and allergic contact dermatitis), atopic dermatitis (also known as allergic eczema), actinic keratosis, keratinization disorders (including eczema), epidermolysis bullosa diseases (including penfigus), exfoliative dermatitis, seborrheic dermatitis, erythemas (including erythema multiforme and erythema nodosum), damage caused by the sun or other light sources, discoid lupus erythematosus, dermatomyositis, psoriasis, skin cancer and the effects of natural aging. In another embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used for the treatment of wounds and/or burns to promote healing, including, for example, first-, second- or third-degree burns and/or a thermal, chemical or electrical burns. The formulations may be administered topically, to the skin or mucosal tissue, as an ointment, lotion, cream, microemulsion, gel, solution or the like, as further described herein, within the context of a dosing regimen effective to bring about the desired result.

Topical formulations comprising one or more sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may also be used as preventive, e.g., chemopreventive, compositions. When used in a chemopreventive method, susceptible skin is treated prior to any visible condition in a particular individual.

Sirtuin-modulating compounds may be delivered locally or systemically to a subject. In one embodiment, a sirtuin-modulating compound is delivered locally to a tissue or organ of a subject by injection, topical formulation, etc.

In another embodiment, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be used for treating or preventing a disease or condition induced or exacerbated by cellular senescence in a subject; methods for decreasing the rate of senescence of a subject, e.g., after onset of

senescence; methods for extending the lifespan of a subject; methods for treating or preventing a disease or condition relating to lifespan; methods for treating or preventing a disease or condition relating to the proliferative capacity of cells; and methods for treating or preventing a disease or condition resulting from cell damage or death. In certain embodiments, the method does not act by decreasing the rate of occurrence of diseases that shorten the lifespan of a subject. In certain embodiments, a method does not act by reducing the lethality caused by a disease, such as cancer.

In yet another embodiment, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be administered to a subject in order to generally increase the lifespan of its cells and to protect its cells against stress and/or against apoptosis. It is believed that treating a subject with a compound described herein is similar to subjecting the subject to hormesis, i.e., mild stress that is beneficial to organisms and may extend their lifespan.

Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered to a subject to prevent aging and aging-related consequences or diseases, such as stroke, heart disease, heart failure, arthritis, high blood pressure, and Alzheimer's disease. Other conditions that can be treated include ocular disorders, e.g., associated with the aging of the eye, such as cataracts, glaucoma, and macular degeneration. Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein can also be administered to subjects for treatment of diseases, e.g., chronic diseases, associated with cell death, in order to protect the cells from cell death. Exemplary diseases include those associated with neural cell death, neuronal dysfunction, or muscular cell death or dysfunction, such as Parkinson's disease, Alzheimer's disease, multiple sclerosis, amniotropic lateral sclerosis, and muscular dystrophy; AIDS; fulminant hepatitis; diseases linked to degeneration of the brain, such as Creutzfeld-Jakob disease, retinitis pigmentosa and cerebellar degeneration; myelodysplasis such as aplastic anemia; ischemic diseases such as myocardial infarction and stroke; hepatic diseases such as alcoholic hepatitis, hepatitis B and hepatitis C; joint-diseases such as osteoarthritis; atherosclerosis; alopecia; damage to the skin due to UV light; lichen planus; atrophy of the skin; cataract; and graft rejections. Cell death can also be caused by surgery, drug therapy, chemical exposure or radiation exposure.

Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein can also be administered to a subject suffering from an acute disease,

e.g., damage to an organ or tissue, e.g., a subject suffering from stroke or myocardial infarction or a subject suffering from a spinal cord injury. Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may also be used to repair an alcoholic's liver.

Cardiovascular Disease

In another embodiment, the invention provides a method for treating and/or preventing a cardiovascular disease by administering to a subject in need thereof a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein.

Cardiovascular diseases that can be treated or prevented using the sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein include cardiomyopathy or myocarditis; such as idiopathic cardiomyopathy, metabolic cardiomyopathy, alcoholic cardiomyopathy, drug-induced cardiomyopathy, ischemic cardiomyopathy, and hypertensive cardiomyopathy. Also treatable or preventable using compounds and methods described herein are atheromatous disorders of the major blood vessels (macrovascular disease) such as the aorta, the coronary arteries, the carotid arteries, the cerebrovascular arteries, the renal arteries, the iliac arteries, the femoral arteries, and the popliteal arteries. Other vascular diseases that can be treated or prevented include those related to platelet aggregation, the retinal arterioles, the glomerular arterioles, the vasa nervorum, cardiac arterioles, and associated capillary beds of the eye, the kidney, the heart, and the central and peripheral nervous systems. The sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may also be used for increasing HDL levels in plasma of an individual.

Yet other disorders that may be treated with sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein include restenosis, e.g., following coronary intervention, and disorders relating to an abnormal level of high density and low density cholesterol.

In one embodiment, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be administered as part of a combination therapeutic with another cardiovascular agent including, for example, an anti-arrhythmic agent, an antihypertensive agent, a calcium channel blocker, a cardioplegic solution, a cardiotonic agent, a fibrinolytic agent, a sclerosing solution, a

vasoconstrictor agent, a vasodilator agent, a nitric oxide donor, a potassium channel blocker, a sodium channel blocker, statins, or a naturiuretic agent.

In one embodiment, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be administered as part of a combination therapeutic with an anti-arrhythmia agent. Anti-arrhythmia agents are often organized into four main groups according to their mechanism of action: type I, sodium channel blockade; type II, beta-adrenergic blockade; type III, repolarization prolongation; and type IV, calcium channel blockade. Type I anti-arrhythmic agents include lidocaine, moricizine, mexiletine, tocainide, procainamide, encainide, flecanide, tocainide, phenytoin, propafenone, quinidine, disopyramide, and flecainide. Type II anti-arrhythmic agents include propranolol and esmolol. Type III includes agents that act by prolonging the duration of the action potential, such as amiodarone, artilide, bretylium, clofilium, isobutilide, sotalol, azimilide, dofetilide, dronedarone, ersentilide, ibutilide, tedisamil, and trecetilide. Type IV anti-arrhythmic agents include verapamil, diltaizem, digitalis, adenosine, nickel chloride, and magnesium ions.

In another embodiment, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be administered as part of a combination therapeutic with another cardiovascular agent. Examples of cardiovascular agents include vasodilators, for example, hydralazine; angiotensin converting enzyme inhibitors, for example, captopril; anti-anginal agents, for example, isosorbide nitrate, glyceryl trinitrate and pentaerythritol tetranitrate; anti-arrhythmic agents, for example, quinidine, procainaltide and lignocaine; cardioglycosides, for example, digoxin and digitoxin; calcium antagonists, for example, verapamil and nifedipine; diuretics, such as thiazides and related compounds, for example, bendrofluazide, chlorothiazide, chlorothalidone, hydrochlorothiazide and other diuretics, for example, fursemide and triamterene, and sedatives, for example, nitrazepam, flurazepam and diazepam.

Other exemplary cardiovascular agents include, for example, a cyclooxygenase inhibitor such as aspirin or indomethacin, a platelet aggregation inhibitor such as clopidogrel, ticlopidene or aspirin, fibrinogen antagonists or a diuretic such as chlorothiazide, hydrochlorothiazide, flumethiazide, hydroflumethiazide, bendroflumethiazide, methylchlorthiazide, trichloromethiazide, polythiazide or benzthiazide as well as ethacrynic acid tricrynafen, chlorthalidone, furosemide, musolimine, bumetanide, triamterene, amiloride and spironolactone and

salts of such compounds, angiotensin converting enzyme inhibitors such as captopril, zofenopril, fosinopril, enalapril, ceranopril, cilazopril, delapril, pentopril, quinapril, ramipril, lisinopril, and salts of such compounds, angiotensin II antagonists such as losartan, irbesartan or valsartan, thrombolytic agents such as tissue plasminogen activator (tPA), recombinant tPA, streptokinase, urokinase, prourokinase, and anisoylated plasminogen streptokinase activator complex (APSAC, Eminase, Beecham Laboratories), or animal salivary gland plasminogen activators, calcium channel blocking agents such as verapamil, nifedipine or diltiazem, thromboxane receptor antagonists such as ifetroban, prostacyclin mimetics, or phosphodiesterase inhibitors. Such combination products if formulated as a fixed dose employ the compounds of this invention within the dose range described above and the other pharmaceutically active agent within its approved dose range.

Yet other exemplary cardiovascular agents include, for example, vasodilators, e.g., bencyclane, cinnarizine, citicoline, cyclandelate, cyclonicate, ebumamonine, phenoxezyl, flunarizine, ibudilast, ifenprodil, lomerizine, naphlole, nikamate, nosergoline, nimodipine, papaverine, pentifylline, nofedoline, vincamin, vinpocetine, vichizyl, pentoxifylline, prostacyclin derivatives (such as prostaglandin E1 and prostaglandin I2), an endothelin receptor blocking drug (such as bosentan), diltiazem, nicorandil, and nitroglycerin. Examples of the cerebral protecting drug include radical scavengers (such as edaravone, vitamin E, and vitamin C), glutamate antagonists, AMPA antagonists, kainate antagonists, NMDA antagonists, GABA agonists, growth factors, opioid antagonists, phosphatidylcholine precursors, serotonin agonists, Na^+/Ca^{2+} channel inhibitory drugs, and K^+ channel opening drugs. Examples of the brain metabolic stimulants include amantadine, tiapride, and gamma-aminobutyric acid. Examples of the anticoagulant include heparins (such as heparin sodium, heparin potassium, dalteparin sodium, dalteparin calcium, heparin calcium, parnaparin sodium, reviparin sodium, and danaparoid sodium), warfarin, enoxaparin, argatroban, batroxobin, and sodium citrate. Examples of the antiplatelet drug include ticlopidine hydrochloride, dipyridamole, cilostazol, ethyl icosapentate, sarpogrelate hydrochloride, dilazep hydrochloride, trapidil, a nonsteroidal antiinflammatory agent (such as aspirin), beraprostsodium, iloprost, and indobufene. Examples of the thrombolytic drug include urokinase, tissue-type plasminogen activators (such as alteplase, tisokinase, nateplase, pamiteplase, monteplase, and rateplase), and nasaruplase. Examples of the antihypertensive drug include angiotensin converting

enzyme inhibitors (such as captopril, alacepril, lisinopril, imidapril, quinapril, temocapril, delapril, benazepril, cilazapril, trandolapril, enalapril, ceronapril, fosinopril, imadapril, mobertpril, perindopril, ramipril, spirapril, and randolapril), angiotensin II antagonists (such as losartan, candesartan, valsartan, eprosartan, and irbesartan), calcium channel blocking drugs (such as aranidipine, efonidipine, nicardipine, bamidipine, benidipine, manidipine, cilnidipine, nisoldipine, nitrendipine, nifedipine, nilvadipine, felodipine, amlodipine, diltiazem, bepridil, clentiazem, phendilin, galopamil, mibefradil, prenylamine, semotiadil, terodiline, verapamil, cilnidipine, elgodipine, isradipine, lacidipine, lercanidipine, nimodipine, cinnarizine, flunarizine, lidoflazine, lomerizine, bencyclane, etafenone, and perhexiline), β-adrenaline receptor blocking drugs (propranolol, pindolol, indenolol, carteolol, bunitrolol, atenolol, acebutolol, metoprolol, timolol, nipradilol, penbutolol, nadolol, tilisolol, carvedilol, bisoprolol, betaxolol, celiprolol, bopindolol, bevantolol, labetalol, alprenolol, amosulalol, arotinolol, befunolol, bucumolol, bufetolol, buferalol, buprandolol, butylidine, butofilolol, carazolol, cetamolol, cloranolol, dilevalol, epanolol, levobunolol, mepindolol, metipranolol, moprolol, nadoxolol, nevibolol, oxprenolol, practol, pronetalol, sotalol, sufinalol, talindolol, tertalol, toliprolol, xybenolol, and esmolol), α-receptor blocking drugs (such as amosulalol, prazosin, terazosin, doxazosin, bunazosin, urapidil, phentolamine, arotinolol, dapiprazole, fenspiride, indoramin, labetalol, naftopidil, nicergoline, tamsulosin, tolazoline, trimazosin, and yohimbine), sympathetic nerve inhibitors (such as clonidine, guanfacine, guanabenz, methyldopa, and reserpine), hydralazine, todralazine, budralazine, and cadralazine. Examples of the antianginal drug include nitrate drugs (such as amyl nitrite, nitroglycerin, and isosorbide), β-adrenaline receptor blocking drugs (such as propranolol, pindolol, indenolol, carteolol, bunitrolol, atenolol, acebutolol, metoprolol, timolol, nipradilol, penbutolol, nadolol, tilisolol, carvedilol, bisoprolol, betaxolol, celiprolol, bopindolol, bevantolol, labetalol, alprenolol, amosulalol, arotinolol, befunolol, bucumolol, bufetolol, buferalol, buprandolol, butylidine, butofilolol, carazolol, cetamolol, cloranolol, dilevalol, epanolol, levobunolol, mepindolol, metipranolol, moprolol, nadoxolol, nevibolol, oxprenolol, practol, pronetalol, sotalol, sufinalol, talindolol, tertalol, toliprolol, andxybenolol), calcium channel blocking drugs (such as aranidipine, efonidipine, nicardipine, bamidipine, benidipine, manidipine, cilnidipine, nisoldipine, nitrendipine, nifedipine,

nilvadipine, felodipine, amlodipine, diltiazem, bepridil, clentiazem, phendiline, galopamil, mibefradil, prenylamine, semotiadil, terodiline, verapamil, cilnidipine, elgodipine, isradipine, lacidipine, lercanidipine, nimodipine, cinnarizine, flunarizine, lidoflazine, lomerizine, bencyclane, etafenone, and perhexiline) trimetazidine, dipyridamole, etafenone, dilazep, trapidil, nicorandil, enoxaparin, and aspirin. Examples of the diuretic include thiazide diuretics (such as hydrochlorothiazide, methyclothiazide, trichlormethiazide, benzylhydrochlorothiazide, and penflutizide), loop diuretics (such as furosemide, etacrynic acid, bumetanide, piretanide, azosemide, and torasemide), K^+ sparing diuretics (spironolactone, triamterene, andpotassiumcanrenoate), osmotic diuretics (such as isosorbide, D-mannitol, and glycerin), nonthiazide diuretics (such as meticrane, tripamide, chlorthalidone, and mefruside), and acetazolamide. Examples of the cardiotonic include digitalis formulations (such as digitoxin, digoxin, methyldigoxin, deslanoside, vesnarinone, lanatoside C, and proscillaridin), xanthine formulations (such as aminophylline, choline theophylline, diprophylline, and proxyphylline), catecholamine formulations (such as dopamine, dobutamine, and docarpamine), PDE III inhibitors (such as amrinone, olprinone, and milrinone), denopamine, ubidecarenone, pimobendan, levosimendan, aminoethylsulfonic acid, vesnarinone, carperitide, and colforsin daropate. Examples of the antiarrhythmic drug include ajmaline, pirmenol, procainamide, cibenzoline, disopyramide, quinidine, aprindine, mexiletine, lidocaine, phenyloin, pilsicainide, propafenone, flecainide, atenolol, acebutolol, sotalol, propranolol, metoprolol, pindolol, amiodarone, nifekalant, diltiazem, bepridil, and verapamil. Examples of the antihyperlipidemic drug include atorvastatin, simvastatin, pravastatin sodium, fluvastatin sodium, clinofibrate, clofibrate, simfibrate, fenofibrate, bezafibrate, colestimide, and colestyramine. Examples of the immunosuppressant include azathioprine, mizoribine, cyclosporine, tacrolimus, gusperimus, and methotrexate.

Cell Death/Cancer

Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered to subjects who have recently received or are likely to receive a dose of radiation or toxin. In one embodiment, the dose of radiation or toxin is received as part of a work-related or medical procedure, e.g., working in a nuclear power plant, flying an airplane, an X-ray, CAT scan, or the administration of a radioactive dye for medical imaging; in such an embodiment, the

compound is administered as a prophylactic measure. In another embodiment, the radiation or toxin exposure is received unintentionally, e.g., as a result of an industrial accident, habitation in a location of natural radiation, terrorist act, or act of war involving radioactive or toxic material. In such a case, the compound is preferably administered as soon as possible after the exposure to inhibit apoptosis and the subsequent development of acute radiation syndrome.

Sirtuin-modulating compounds may also be used for treating and/or preventing cancer. In certain embodiments, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used for treating and/or preventing cancer. Calorie restriction has been linked to a reduction in the incidence of age-related disorders including cancer (see e.g., Bordone and Guarente, Nat. Rev. Mol. Cell Biol. (2005 epub); Guarente and Picard, Cell 120: 473-82 (2005); Berrigan, et al., Carcinogenesis 23: 817-822 (2002); and Heilbronn and Ravussin, Am. J. Clin. Nutr. 78: 361-369 (2003)). Additionally, the Sir2 protein from yeast has been shown to be required for lifespan extension by glucose restriction (see e.g., Lin et al., Science 289: 2126-2128 (2000); Anderson et al., Nature 423: 181-185 (2003)), a yeast model for calorie restriction. Accordingly, an increase in the level and/or activity of a sirtuin protein may be useful for treating and/or preventing the incidence of age-related disorders, such as, for example, cancer. In other embodiments, sirtuin-modulating compounds that decrease the level and/or activity of a sirtuin protein may be used for treating or preventing cancer. For example, inhibitory compounds may be used to stimulate acetylation of substrates such as p53 and thereby increase apoptosis, as well as to reduce the lifespan of cells and organisms, render them more sensitive to stress, and/or increase the radiosensitivity and/or chemosensitivity of a cell or organism. Thus, inhibitory compounds may be used, e.g., for treating cancer. Exemplary cancers that may be treated using a sirtuin-modulating compound are those of the brain and kidney; hormone-dependent cancers including breast, prostate, testicular, and ovarian cancers; lymphomas, and leukemias. In cancers associated with solid tumors, a modulating compound may be administered directly into the tumor. Cancer of blood cells, e.g., leukemia, can be treated by administering a modulating compound into the blood stream or into the bone marrow. Benign cell growth can also be treated, e.g., warts. Other diseases that can be treated include autoimmune diseases, e.g., systemic lupus erythematosus, scleroderma, and arthritis, in which autoimmune cells should be removed. Viral infections such as herpes, HIV,

adenovirus, and HTLV-1 associated malignant and benign disorders can also be treated by administration of sirtuin-modulating compound. Alternatively, cells can be obtained from a subject, treated ex vivo to remove certain undesirable cells, e.g., cancer cells, and administered back to the same or a different subject.

Chemotherapeutic agents that may be coadministered with modulating compounds described herein as having anti-cancer activity (e.g., compounds that induce apoptosis, compounds that reduce lifespan or compounds that render cells sensitive to stress) include: aminoglutethimide, amsacrine, anastrozole, asparaginase, bcg, bicalutamide, bleomycin, buserelin, busulfan, campothecin, capecitabine, carboplatin, carmustine, chlorambucil, cisplatin, cladribine, clodronate, colchicine, cyclophosphamide, cyproterone, cytarabine, dacarbazine, dactinomycin, daunorubicin, dienestrol, diethylstilbestrol, docetaxel, doxorubicin, epirubicin, estradiol, estramustine, etoposide, exemestane, filgrastim, fludarabine, fludrocortisone, fluorouracil, fluoxymesterone, flutamide, gemcitabine, genistein, goserelin, hydroxyurea, idarubicin, ifosfamide, imatinib, interferon, irinotecan, ironotecan, letrozole, leucovorin, leuprolide, levamisole, lomustine, mechlorethamine, medroxyprogesterone, megestrol, melphalan, mercaptopurine, mesna, methotrexate, mitomycin, mitotane, mitoxantrone, nilutamide, nocodazole, octreotide, oxaliplatin, paclitaxel, pamidronate, pentostatin, plicamycin, porfimer, procarbazine, raltitrexed, rituximab, streptozocin, suramin, tamoxifen, temozolomide, teniposide, testosterone, thioguanine, thiotepa, titanocene dichloride, topotecan, trastuzumab, tretinoin, vinblastine, vincristine, vindesine, and vinorelbine.

These chemotherapeutic agents may be categorized by their mechanism of action into, for example, following groups: anti-metabolites/anti-cancer agents, such as pyrimidine analogs (5-fluorouracil, floxuridine, capecitabine, gemcitabine and cytarabine) and purine analogs, folate antagonists and related inhibitors (mercaptopurine, thioguanine, pentostatin and 2-chlorodeoxyadenosine (cladribine)); antiproliferative/antimitotic agents including natural products such as vinca alkaloids (vinblastine, vincristine, and vinorelbine), microtubule disruptors such as taxane (paclitaxel, docetaxel), vincristin, vinblastin, nocodazole, epothilones and navelbine, epidipodophyllotoxins (teniposide), DNA damaging agents (actinomycin, amsacrine, anthracyclines, bleomycin, busulfan, camptothecin, carboplatin, chlorambucil, cisplatin, cyclophosphamide, cytoxan, dactinomycin, daunorubicin, docetaxel, doxorubicin, epirubicin, hexamethylmelamineoxaliplatin, iphosphamide, melphalan,

merchlorethamine, mitomycin, mitoxantrone, nitrosourea, paclitaxel, plicamycin, procarbazine, teniposide, triethylenethiophosphoramide and etoposide (VP16)); antibiotics such as dactinomycin (actinomycin D), daunorubicin, doxorubicin (adriamycin), idarubicin, anthracyclines, mitoxantrone, bleomycins, plicamycin (mithramycin) and mitomycin; enzymes (L-asparaginase which systemically metabolizes L-asparagine and deprives cells which do not have the capacity to synthesize their own asparagine); antiplatelet agents; antiproliferative/antimitotic alkylating agents such as nitrogen mustards (mechlorethamine, cyclophosphamide and analogs, melphalan, chlorambucil), ethylenimines and methylmelamines (hexamethylmelamine and thiotepa), alkyl sulfonates-busulfan, nitrosoureas (carmustine (BCNU) and analogs, streptozocin), trazenes - dacarbazinine (DTIC); antiproliferative/antimitotic antimetabolites such as folic acid analogs (methotrexate); platinum coordination complexes (cisplatin, carboplatin), procarbazine, hydroxyurea, mitotane, aminoglutethimide; hormones, hormone analogs (estrogen, tamoxifen, goserelin, bicalutamide, nilutamide) and aromatase inhibitors (letrozole, anastrozole); anticoagulants (heparin, synthetic heparin salts and other inhibitors of thrombin); fibrinolytic agents (such as tissue plasminogen activator, streptokinase and urokinase), aspirin, COX-2 inhibitors, dipyridamole, ticlopidine, clopidogrel, abciximab; antimigratory agents; antisecretory agents (breveldin); immunosuppressives (cyclosporine, tacrolimus (FK-506), sirolimus (rapamycin), azathioprine, mycophenolate mofetil); anti-angiogenic compounds (TNP-470, genistein) and growth factor inhibitors (vascular endothelial growth factor (VEGF) inhibitors, fibroblast growth factor (FGF) inhibitors, epidermal growth factor (EGF) inhibitors); angiotensin receptor blocker; nitric oxide donors; anti-sense oligonucleotides; antibodies (trastuzumab); cell cycle inhibitors and differentiation inducers (tretinoin); mTOR inhibitors, topoisomerase inhibitors (doxorubicin (adriamycin), amsacrine, camptothecin, daunorubicin, dactinomycin, eniposide, epirubicin, etoposide, idarubicin, irinotecan (CPT-11) and mitoxantrone, topotecan, irinotecan), corticosteroids (cortisone, dexamethasone, hydrocortisone, methylpednisolone, prednisone, and prenisolone); growth factor signal transduction kinase inhibitors; mitochondrial dysfunction inducers and caspase activators; chromatin disruptors.

These chemotherapeutic agents may be used by themselves with a sirtuin-modulating compound described herein as inducing cell death or reducing lifespan or

increasing sensitivity to stress and/or in combination with other chemotherapeutics agents. Many combinatorial therapies have been developed, including but not limited to those listed in Table 1.

Table 1: Exemplary combinatorial therapies for the treatment of cancer.

Name	Therapeutic agents
ABV	Doxorubicin, Bleomycin, Vinblastine
ABVD	Doxorubicin, Bleomycin, Vinblastine, Dacarbazine
AC (Breast)	Doxorubicin, Cyclophosphamide
AC (Sarcoma)	Doxorubicin, Cisplatin
AC (Neuroblastoma)	Cyclophosphamide, Doxorubicin
ACE	Cyclophosphamide, Doxorubicin, Etoposide
ACe	Cyclophosphamide, Doxorubicin
AD	Doxorubicin, Dacarbazine
AP	Doxorubicin, Cisplatin
ARAC-DNR	Cytarabine, Daunorubicin
B-CAVe	Bleomycin, Lomustine, Doxorubicin, Vinblastine
BCVPP	Carmustine, Cyclophosphamide, Vinblastine, Procarbazine, Prednisone
BEACOPP	Bleomycin, Etoposide, Doxorubicin, Cyclophosphamide, Vincristine, Procarbazine, Prednisone, Filgrastim
BEP	Bleomycin, Etoposide, Cisplatin
BIP	Bleomycin, Cisplatin, Ifosfamide, Mesna
BOMP	Bleomycin, Vincristine, Cisplatin, Mitomycin
CA	Cytarabine, Asparaginase
CABO	Cisplatin, Methotrexate, Bleomycin, Vincristine
CAF	Cyclophosphamide, Doxorubicin, Fluorouracil
CAL-G	Cyclophosphamide, Daunorubicin, Vincristine, Prednisone, Asparaginase
CAMP	Cyclophosphamide, Doxorubicin, Methotrexate, Procarbazine
CAP	Cyclophosphamide, Doxorubicin, Cisplatin
CaT	Carboplatin, Paclitaxel
CAV	Cyclophosphamide, Doxorubicin, Vincristine
CAVE ADD	CAV and Etoposide
CA-VP16	Cyclophosphamide, Doxorubicin, Etoposide
CC	Cyclophosphamide, Carboplatin
CDDP/VP-16	Cisplatin, Etoposide
CEF	Cyclophosphamide, Epirubicin, Fluorouracil
CEPP(B)	Cyclophosphamide, Etoposide, Prednisone, with or without/ Bleomycin
CEV	Cyclophosphamide, Etoposide, Vincristine
CF	Cisplatin, Fluorouracil or Carboplatin Fluorouracil
CHAP	Cyclophosphamide or Cyclophosphamide, Altretamine, Doxorubicin, Cisplatin
ChlVPP	Chlorambucil, Vinblastine, Procarbazine, Prednisone

Name	Therapeutic agents
CHOP	Cyclophosphamide, Doxorubicin, Vincristine, Prednisone
CHOP-BLEO	Add Bleomycin to CHOP
CISCA	Cyclophosphamide, Doxorubicin, Cisplatin
CLD-BOMP	Bleomycin, Cisplatin, Vincristine, Mitomycin
CMF	Methotrexate, Fluorouracil, Cyclophosphamide
CMFP	Cyclophosphamide, Methotrexate, Fluorouracil, Prednisone
CMFVP	Cyclophosphamide, Methotrexate, Fluorouracil, Vincristine, Prednisone
CMV	Cisplatin, Methotrexate, Vinblastine
CNF	Cyclophosphamide, Mitoxantrone, Fluorouracil
CNOP	Cyclophosphamide, Mitoxantrone, Vincristine, Prednisone
COB	Cisplatin, Vincristine, Bleomycin
CODE	Cisplatin, Vincristine, Doxorubicin, Etoposide
COMLA	Cyclophosphamide, Vincristine, Methotrexate, Leucovorin, Cytarabine
COMP	Cyclophosphamide, Vincristine, Methotrexate, Prednisone
Cooper Regimen	Cyclophosphamide, Methotrexate, Fluorouracil, Vincristine, Prednisone
COP	Cyclophosphamide, Vincristine, Prednisone
COPE	Cyclophosphamide, Vincristine, Cisplatin, Etoposide
COPP	Cyclophosphamide, Vincristine, Procarbazine, Prednisone
CP(Chronic lymphocytic leukemia)	Chlorambucil, Prednisone
CP (Ovarian Cancer)	Cyclophosphamide, Cisplatin
CT	Cisplatin, Paclitaxel
CVD	Cisplatin, Vinblastine, Dacarbazine
CVI	Carboplatin, Etoposide, Ifosfamide, Mesna
CVP	Cyclophosphamide, Vincristine, Prednisome
CVPP	Lomustine, Procarbazine, Prednisone
CYVADIC	Cyclophosphamide, Vincristine, Doxorubicin, Dacarbazine
DA	Daunorubicin, Cytarabine
DAT	Daunorubicin, Cytarabine, Thioguanine
DAV	Daunorubicin, Cytarabine, Etoposide
DCT	Daunorubicin, Cytarabine, Thioguanine
DHAP	Cisplatin, Cytarabine, Dexamethasone
DI	Doxorubicin, Ifosfamide
DTIC/Tamoxifen	Dacarbazine, Tamoxifen
DVP	Daunorubicin, Vincristine, Prednisone
EAP	Etoposide, Doxorubicin, Cisplatin
EC	Etoposide, Carboplatin
EFP	Etoposie, Fluorouracil, Cisplatin
ELF	Etoposide, Leucovorin, Fluorouracil
EMA 86	Mitoxantrone, Etoposide, Cytarabine
EP	Etoposide, Cisplatin
EVA	Etoposide, Vinblastine
FAC	Fluorouracil, Doxorubicin, Cyclophosphamide
FAM	Fluorouracil, Doxorubicin, Mitomycin

Name	Therapeutic agents
FAMTX	Methotrexate, Leucovorin, Doxorubicin
FAP	Fluorouracil, Doxorubicin, Cisplatin
F-CL	Fluorouracil, Leucovorin
FEC	Fluorouracil, Cyclophosphamide, Epirubicin
FED	Fluorouracil, Etoposide, Cisplatin
FL	Flutamide, Leuprolide
FZ	Flutamide, Goserelin acetate implant
HDMTX	Methotrexate, Leucovorin
Hexa-CAF	Altretamine, Cyclophosphamide, Methotrexate, Fluorouracil
ICE-T	Ifosfamide, Carboplatin, Etoposide, Paclitaxel, Mesna
IDMTX/6-MP	Methotrexate, Mercaptopurine, Leucovorin
IE	Ifosfamide, Etoposie, Mesna
IfoVP	Ifosfamide, Etoposide, Mesna
IPA	Ifosfamide, Cisplatin, Doxorubicin
M-2	Vincristine, Carmustine, Cyclophosphamide, Prednisone, Melphalan
MAC-III	Methotrexate, Leucovorin, Dactinomycin, Cyclophosphamide
MACC	Methotrexate, Doxorubicin, Cyclophosphamide, Lomustine
MACOP-B	Methotrexate, Leucovorin, Doxorubicin, Cyclophosphamide, Vincristine, Bleomycin, Prednisone
MAID	Mesna, Doxorubicin, Ifosfamide, Dacarbazine
m-BACOD	Bleomycin, Doxorubicin, Cyclophosphamide, Vincristine, Dexamethasone, Methotrexate, Leucovorin
MBC	Methotrexate, Bleomycin, Cisplatin
MC	Mitoxantrone, Cytarabine
MF	Methotrexate, Fluorouracil, Leucovorin
MICE	Ifosfamide, Carboplatin, Etoposide, Mesna
MINE	Mesna, Ifosfamide, Mitoxantrone, Etoposide
mini-BEAM	Carmustine, Etoposide, Cytarabine, Melphalan
MOBP	Bleomycin, Vincristine, Cisplatin, Mitomycin
MOP	Mechlorethamine, Vincristine, Procarbazine
MOPP	Mechlorethamine, Vincristine, Procarbazine, Prednisone
MOPP/ABV	Mechlorethamine, Vincristine, Procarbazine, Prednisone, Doxorubicin, Bleomycin, Vinblastine
MP (multiple myeloma)	Melphalan, Prednisone
MP (prostate cancer)	Mitoxantrone, Prednisone
MTX/6-MO	Methotrexate, Mercaptopurine
MTX/6-MP/VP	Methotrexate, Mercaptopurine, Vincristine, Prednisone
MTX-CDDPAdr	Methotrexate, Leucovorin, Cisplatin, Doxorubicin
MV (breast cancer)	Mitomycin, Vinblastine
MV (acute myelocytic leukemia)	Mitoxantrone, Etoposide
M-VAC Methotrexate	Vinblastine, Doxorubicin, Cisplatin
MVP Mitomycin	Vinblastine, Cisplatin
MVPP	Mechlorethamine, Vinblastine, Procarbazine, Prednisone
NFL	Mitoxantrone, Fluorouracil, Leucovorin

Name	Therapeutic agents
NOVP	Mitoxantrone, Vinblastine, Vincristine
OPA	Vincristine, Prednisone, Doxorubicin
OPPA	Add Procarbazine to OPA.
PAC	Cisplatin, Doxorubicin
PAC-I	Cisplatin, Doxorubicin, Cyclophosphamide
PA-CI	Cisplatin, Doxorubicin
PC	Paclitaxel, Carboplatin or Paclitaxel, Cisplatin
PCV	Lomustine, Procarbazine, Vincristine
PE	Paclitaxel, Estramustine
PFL	Cisplatin, Fluorouracil, Leucovorin
POC	Prednisone, Vincristine, Lomustine
ProMACE	Prednisone, Methotrexate, Leucovorin, Doxorubicin, Cyclophosphamide, Etoposide
ProMACE/cytaBOM	Prednisone, Doxorubicin, Cyclophosphamide, Etoposide, Cytarabine, Bleomycin, Vincristine, Methotrexate, Leucovorin, Cotrimoxazole
PRoMACE/MOPP	Prednisone, Doxorubicin, Cyclophosphamide, Etoposide, Mechlorethamine, Vincristine, Procarbazine, Methotrexate, Leucovorin
Pt/VM	Cisplatin, Teniposide
PVA	Prednisone, Vincristine, Asparaginase
PVB	Cisplatin, Vinblastine, Bleomycin
PVDA	Prednisone, Vincristine, Daunorubicin, Asparaginase
SMF	Streptozocin, Mitomycin, Fluorouracil
TAD	Mechlorethamine, Doxorubicin, Vinblastine, Vincristine, Bleomycin, Etoposide, Prednisone
TCF	Paclitaxel, Cisplatin, Fluorouracil
TIP	Paclitaxel, Ifosfamide, Mesna, Cisplatin
TTT	Methotrexate, Cytarabine, Hydrocortisone
Topo/CTX	Cyclophosphamide, Topotecan, Mesna
VAB-6	Cyclophosphamide, Dactinomycin, Vinblastine, Cisplatin, Bleomycin
VAC	Vincristine, Dactinomycin, Cyclophosphamide
VACAdr	Vincristine, Cyclophosphamide, Doxorubicin, Dactinomycin, Vincristine
VAD	Vincristine, Doxorubicin, Dexamethasone
VATH	Vinblastine, Doxorubicin, Thiotepa, Flouxymesterone
VBAP	Vincristine, Carmustine, Doxorubicin, Prednisone
VBCMP	Vincristine, Carmustine, Melphalan, Cyclophosphamide, Prednisone
VC	Vinorelbine, Cisplatin
VCAP	Vincristine, Cyclophosphamide, Doxorubicin, Prednisone
VD	Vinorelbine, Doxorubicin
VelP	Vinblastine, Cisplatin, Ifosfamide, Mesna
VIP	Etoposide, Cisplatin, Ifosfamide, Mesna
VM	Mitomycin, Vinblastine
VMCP	Vincristine, Melphalan, Cyclophosphamide, Prednisone
VP	Etoposide, Cisplatin

Name	Therapeutic agents
V-TAD	Etoposide, Thioguanine, Daunorubicin, Cytarabine
5 + 2	Cytarabine, Daunorubicin, Mitoxantrone
7 + 3	Cytarabine with/, Daunorubicin or Idarubicin or Mitoxantrone
"8 in 1"	Methylprednisolone, Vincristine, Lomustine, Procarbazine, Hydroxyurea, Cisplatin, Cytarabine, Dacarbazine

In addition to conventional chemotherapeutics, the sirtuin-modulating compounds described herein as capable of inducing cell death or reducing lifespan can also be used with antisense RNA, RNAi or other polynucleotides to inhibit the expression of the cellular components that contribute to unwanted cellular proliferation that are targets of conventional chemotherapy. Such targets are, merely to illustrate, growth factors, growth factor receptors, cell cycle regulatory proteins, transcription factors, or signal transduction kinases.

Combination therapies comprising sirtuin-modulating compounds and a conventional chemotherapeutic agent may be advantageous over combination therapies known in the art because the combination allows the conventional chemotherapeutic agent to exert greater effect at lower dosage. In a preferred embodiment, the effective dose (ED_{50}) for a chemotherapeutic agent, or combination of conventional chemotherapeutic agents, when used in combination with a sirtuin-modulating compound is at least 2 fold less than the ED_{50} for the chemotherapeutic agent alone, and even more preferably at 5 fold, 10 fold or even 25 fold less. Conversely, the therapeutic index (TI) for such chemotherapeutic agent or combination of such chemotherapeutic agent when used in combination with a sirtuin-modulating compound described herein can be at least 2 fold greater than the TI for conventional chemotherapeutic regimen alone, and even more preferably at 5 fold, 10 fold or even 25 fold greater.

Neuronal Diseases/Disorders

In certain aspects, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein can be used to treat patients suffering from neurodegenerative diseases, and traumatic or mechanical injury to the central nervous system (CNS), spinal cord or peripheral nervous system (PNS). Neurodegenerative disease typically involves reductions in the mass and volume of the human brain, which may be due to the atrophy and/or death of brain cells, which are far more profound than those in a healthy person that are attributable to aging.

Neurodegenerative diseases can evolve gradually, after a long period of normal brain function, due to progressive degeneration (e.g., nerve cell dysfunction and death) of specific brain regions. Alternatively, neurodegenerative diseases can have a quick onset, such as those associated with trauma or toxins. The actual onset of brain degeneration may precede clinical expression by many years. Examples of neurodegenerative diseases include, but are not limited to, Alzheimer's disease (AD), Parkinson's disease (PD), Huntington's disease (HD), amyotrophic lateral sclerosis (ALS; Lou Gehrig's disease), diffuse Lewy body disease, chorea-acanthocytosis, primary lateral sclerosis, ocular diseases (ocular neuritis), chemotherapy-induced neuropathies (e.g., from vincristine, paclitaxel, bortezomib), diabetes-induced neuropathies and Friedreich's ataxia. Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein can be used to treat these disorders and others as described below.

AD is a chronic, incurable, and unstoppable CNS disorder that occurs gradually, resulting in memory loss, unusual behavior, personality changes, and a decline in thinking abilities. These losses are related to the death of specific types of brain cells and the breakdown of connections and their supporting network (e.g. glial cells) between them. AD has been described as childhood development in reverse. In most people with AD, symptoms appear after the age 60. The earliest symptoms include loss of recent memory, faulty judgment, and changes in personality. Later in the disease, those with AD may forget how to do simple tasks like washing their hands. Eventually people with AD lose all reasoning abilities and become dependent on other people for their everyday care. Finally, the disease becomes so debilitating that patients are bedridden and typically develop coexisting illnesses.

PD is a chronic, incurable, and unstoppable CNS disorder that occurs gradually and results in uncontrolled body movements, rigidity, tremor, and dyskinesia. These motor system problems are related to the death of brain cells in an area of the brain that produces dopamine, a chemical that helps control muscle activity. In most people with PD, symptoms appear after age 50. The initial symptoms of PD are a pronounced tremor affecting the extremities, notably in the hands or lips. Subsequent characteristic symptoms of PD are stiffness or slowness of movement, a shuffling walk, stooped posture, and impaired balance. There are wide ranging secondary symptoms such as memory loss, dementia, depression, emotional changes, swallowing difficulties, abnormal speech, sexual dysfunction, and bladder

and bowel problems. These symptoms will begin to interfere with routine activities, such as holding a fork or reading a newspaper. Finally, people with PD become so profoundly disabled that they are bedridden.

ALS (motor neuron disease) is a chronic, incurable, and unstoppable CNS disorder that attacks the motor neurons, components of the CNS that connect the brain to the skeletal muscles. In ALS, the motor neurons deteriorate and eventually die, and though a person's brain normally remains fully functioning and alert, the command to move never reaches the muscles. Most people who get ALS are between 40 and 70 years old. The first motor neurons that weaken are those controlling the arms or legs. Those with ALS may have trouble walking, they may drop things, fall, slur their speech, and laugh or cry uncontrollably. Eventually the muscles in the limbs begin to atrophy from disuse. This muscle weakness will become debilitating and a person will need a wheel chair or become unable to function out of bed.

The causes of these neurological diseases have remained largely unknown. They are conventionally defined as distinct diseases, yet clearly show extraordinary similarities in basic processes and commonly demonstrate overlapping symptoms far greater than would be expected by chance alone. Current disease definitions fail to properly deal with the issue of overlap and a new classification of the neurodegenerative disorders has been called for.

HD is another neurodegenerative disease resulting from genetically programmed degeneration of neurons in certain areas of the brain. This degeneration causes uncontrolled movements, loss of intellectual faculties, and emotional disturbance. HD is a familial disease, passed from parent to child through a dominant mutation in the wild-type gene. Some early symptoms of HD are mood swings, depression, irritability or trouble driving, learning new things, remembering a fact, or making a decision. As the disease progresses, concentration on intellectual tasks becomes increasingly difficult and the patient may have difficulty feeding himself or herself and swallowing.

Tay-Sachs disease and Sandhoff disease are glycolipid storage diseases caused by the lack of lysosomal β-hexosaminidase (Gravel et al., in The Metabolic Basis of Inherited Disease, eds. Scriver et al., McGraw-Hill, New York, pp. 2839-2879, 1995). In both disorders, GM2 ganglioside and related glycolipidssubstrates for β-hexosaminidase accumulate in the nervous system and trigger acute

neurodegeneration. In the most severe forms, the onset of symptoms begins in early infancy. A precipitous neurodegenerative course then ensues, with affected infants exhibiting motor dysfunction, seizure, visual loss, and deafness. Death usually occurs by 2-5 years of age. Neuronal loss through an apoptotic mechanism has been demonstrated (Huang et al., Hum. Mol. Genet. 6: 1879-1885, 1997).

It is well-known that apoptosis plays a role in AIDS pathogenesis in the immune system. However, HIV-1 also induces neurological disease. Shi et al. (J. Clin. Invest. 98: 1979-1990, 1996) examined apoptosis induced by HIV-1 infection of the CNS in an in vitro model and in brain tissue from AIDS patients, and found that HIV-1 infection of primary brain cultures induced apoptosis in neurons and astrocytes in vitro. Apoptosis of neurons and astrocytes was also detected in brain tissue from 10/11 AIDS patients, including 5/5 patients with HIV-1 dementia and 4/5 nondemented patients.

There are four main peripheral neuropathies associated with HIV, namely sensory neuropathy, AIDP/CIPD, drug-induced neuropathy and CMV-related.

The most common type of neuropathy associated with AIDS is distal symmetrical polyneuropathy (DSPN). This syndrome is a result of nerve degeneration and is characterized by numbness and a sensation of pins and needles. DSPN causes few serious abnormalities and mostly results in numbness or tingling of the feet and slowed reflexes at the ankles. It generally occurs with more severe immunosuppression and is steadily progressive. Treatment with tricyclic antidepressants relieves symptoms but does not affect the underlying nerve damage.

A less frequent, but more severe type of neuropathy is known as acute or chronic inflammatory demyelinating polyneuropathy (AIDP/CIDP). In AIDP/CIDP there is damage to the fatty membrane covering the nerve impulses. This kind of neuropathy involves inflammation and resembles the muscle deterioration often identified with long-term use of AZT. It can be the first manifestation of HIV infection, where the patient may not complain of pain, but fails to respond to standard reflex tests. This kind of neuropathy may be associated with seroconversion, in which case it can sometimes resolve spontaneously. It can serve as a sign of HIV infection and indicate that it might be time to consider antiviral therapy. AIDP/CIDP may be auto-immune in origin.

Drug-induced, or toxic, neuropathies can be very painful. Antiviral drugs commonly cause peripheral neuropathy, as do other drugs e.g. vincristine, dilantin (an

anti-seizure medication), high-dose vitamins, isoniazid, and folic acid antagonists. Peripheral neuropathy is often used in clinical trials for antivirals as a dose-limiting side effect, which means that more drugs should not be administered. Additionally, the use of such drugs can exacerbate otherwise minor neuropathies. Usually, these drug-induced neuropathies are reversible with the discontinuation of the drug.

CMV causes several neurological syndromes in AIDS, including encephalitis, myelitis, and polyradiculopathy.

Neuronal loss is also a salient feature of prion diseases, such as Creutzfeldt-Jakob disease in human, BSE in cattle (mad cow disease), Scrapie Disease in sheep and goats, and feline spongiform encephalopathy (FSE) in cats. Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be useful for treating or preventing neuronal loss due to these prior diseases.

In another embodiment, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be used to treat or prevent any disease or disorder involving axonopathy. Distal axonopathy is a type of peripheral neuropathy that results from some metabolic or toxic derangement of peripheral nervous system (PNS) neurons. It is the most common response of nerves to metabolic or toxic disturbances, and as such may be caused by metabolic diseases such as diabetes, renal failure, deficiency syndromes such as malnutrition and alcoholism, or the effects of toxins or drugs. The most common cause of distal axonopathy is diabetes, and the most common distal axonopathy is diabetic neuropathy. The most distal portions of axons are usually the first to degenerate, and axonal atrophy advances slowly towards the nerve's cell body. If the noxious stimulus is removed, regeneration is possible, though prognosis decreases depending on the duration and severity of the stimulus. Those with distal axonopathies usually present with symmetrical glove-stocking sensori-motor disturbances. Deep tendon reflexes and autonomic nervous system (ANS) functions are also lost or diminished in affected areas.

Diabetic neuropathies are neuropathic disorders that are associated with diabetes mellitus. These conditions usually result from diabetic microvascular injury involving small blood vessels that supply nerves (vasa nervorum). Relatively common conditions which may be associated with diabetic neuropathy include third nerve palsy; mononeuropathy; mononeuritis multiplex; diabetic amyotrophy; a painful polyneuropathy; autonomic neuropathy; and thoracoabdominal neuropathy. Clinical manifestations of diabetic neuropathy include, for example, sensorimotor

polyneuropathy such as numbness, sensory loss, dysesthesia and nighttime pain; autonomic neuropathy such as delayed gastric emptying or gastroparesis; and cranial neuropathy such as oculomotor (3rd) neuropathies or Mononeuropathies of the thoracic or lumbar spinal nerves.

Peripheral neuropathy is the medical term for damage to nerves of the peripheral nervous system, which may be caused either by diseases of the nerve or from the side-effects of systemic illness. Peripheral neuropathies vary in their presentation and origin, and may affect the nerve or the neuromuscular junction. Major causes of peripheral neuropathy include seizures, nutritional deficiencies, and HIV, though diabetes is the most likely cause. Mechanical pressure from staying in one position for too long, a tumor, intraneural hemorrhage, exposing the body to extreme conditions such as radiation, cold temperatures, or toxic substances can also cause peripheral neuropathy.

In an exemplary embodiment, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be used to treat or prevent multiple sclerosis (MS), including relapsing MS and monosymptomatic MS, and other demyelinating conditions, such as, for example, chromic inflammatory demyelinating polyneuropathy (CIDP), or symptoms associated therewith.

MS is a chronic, often disabling disease of the central nervous system. Various and converging lines of evidence point to the possibility that the disease is caused by a disturbance in the immune function, although the cause of this disturbance has not been established. This disturbance permits cells of the immune system to "attack" myelin, the fat containing insulating sheath that surrounds the nerve axons located in the central nervous system ("CNS"). When myelin is damaged, electrical pulses cannot travel quickly or normally along nerve fiber pathways in the brain and spinal cord. This results in disruption of normal electrical conductivity within the axons, fatigue and disturbances of vision, strength, coordination, balance, sensation, and bladder and bowel function.

As such, MS is now a common and well-known neurological disorder that is characterized by episodic patches of inflammation and demyelination which can occur anywhere in the CNS. However, almost always without any involvement of the peripheral nerves associated therewith. Demyelination produces a situation analogous to that resulting from cracks or tears in an insulator surrounding an electrical cord. That is, when the insulating sheath is disrupted, the circuit is "short circuited" and the

electrical apparatus associated therewith will function intermittently or nor at all. Such loss of myelin surrounding nerve fibers results in short circuits in nerves traversing the brain and the spinal cord that thereby result in symptoms of MS. It is further found that such demyelination occurs in patches, as opposed to along the entire CNS. In addition, such demyelination may be intermittent. Therefore, such plaques are disseminated in both time and space.

It is believed that the pathogenesis involves a local disruption of the blood brain barrier which causes a localized immune and inflammatory response, with consequent damage to myelin and hence to neurons.

Clinically, MS exists in both sexes and can occur at any age. However, its most common presentation is in the relatively young adult, often with a single focal lesion such as a damage of the optic nerve, an area of anesthesia (loss of sensation), or paraesthesia (localize loss of feeling), or muscular weakness. In addition, vertigo, double vision, localized pain, incontinence, and pain in the arms and legs may occur upon flexing of the neck, as well as a large variety of less common symptoms.

An initial attack of MS is often transient, and it may be weeks, months, or years before a further attack occurs. Some individuals may enjoy a stable, relatively event free condition for a great number of years, while other less fortunate ones may experience a continual downhill course ending in complete paralysis. There is, most commonly, a series of remission and relapses, in which each relapse leaves a patient somewhat worse than before. Relapses may be triggered by stressful events, viral infections or toxins. Therein, elevated body temperature, i.e., a fever, will make the condition worse, or as a reduction of temperature by, for example, a cold bath, may make the condition better.

In yet another embodiment, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be used to treat trauma to the nerves, including, trauma due to disease, injury (including surgical intervention), or environmental trauma (e.g., neurotoxins, alcoholism, etc.).

Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may also be useful to prevent, treat, and alleviate symptoms of various PNS disorders, such as the ones described below. The PNS is composed of the nerves that lead to or branch off from the spinal cord and CNS. The peripheral nerves handle a diverse array of functions in the body, including sensory, motor, and autonomic functions. When an individual has a peripheral neuropathy, nerves of the PNS have

been damaged. Nerve damage can arise from a number of causes, such as disease, physical injury, poisoning, or malnutrition. These agents may affect either afferent or efferent nerves. Depending on the cause of damage, the nerve cell axon, its protective myelin sheath, or both may be injured or destroyed.

The term "peripheral neuropathy" encompasses a wide range of disorders in which the nerves outside of the brain and spinal cord—peripheral nerves—have been damaged. Peripheral neuropathy may also be referred to as peripheral neuritis, or if many nerves are involved, the terms polyneuropathy or polyneuritis may be used.

Peripheral neuropathy is a widespread disorder, and there are many underlying causes. Some of these causes are common, such as diabetes, and others are extremely rare, such as acrylamide poisoning and certain inherited disorders. The most common worldwide cause of peripheral neuropathy is leprosy. Leprosy is caused by the bacterium Mycobacterium leprae, which attacks the peripheral nerves of affected people.

Leprosy is extremely rare in the United States, where diabetes is the most commonly known cause of peripheral neuropathy. It has been estimated that more than 17 million people in the United States and Europe have diabetes-related polyneuropathy. Many neuropathies are idiopathic; no known cause can be found. The most common of the inherited peripheral neuropathies in the United States is Charcot-Marie-Tooth disease, which affects approximately 125,000 persons.

Another of the better known peripheral neuropathies is Guillain-Barré syndrome, which arises from complications associated with viral illnesses, such as cytomegalovirus, Epstein-Barr virus, and human immunodeficiency virus (HIV), or bacterial infection, including Campylobacter jejuni and Lyme disease. The worldwide incidence rate is approximately 1.7 cases per 100,000 people annually. Other well-known causes of peripheral neuropathies include chronic alcoholism, infection of the varicella-zoster virus, botulism, and poliomyelitis. Peripheral neuropathy may develop as a primary symptom, or it may be due to another disease. For example, peripheral neuropathy is only one symptom of diseases such as amyloid neuropathy, certain cancers, or inherited neurologic disorders. Such diseases may affect the PNS and the CNS, as well as other body tissues.

Other PNS diseases treatable with sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein include: Brachial Plexus Neuropathies (diseases of the cervical and first thoracic roots, nerve trunks, cords, and peripheral

nerve components of the brachial plexus. Clinical manifestations include regional pain, paresthesia; muscle weakness, and decreased sensation in the upper extremity. These disorders may be associated with trauma, including birth injuries; thoracic outlet syndrome; neoplasms, neuritis, radiotherapy; and other conditions. See Adams et al., Principles of Neurology, 6th ed, pp1351-2); Diabetic Neuropathies (peripheral, autonomic, and cranial nerve disorders that are associated with diabetes mellitus). These conditions usually result from diabetic microvascular injury involving small blood vessels that supply nerves (vasa nervorum). Relatively common conditions which may be associated with diabetic neuropathy include third nerve palsy; mononeuropathy; mononeuritis multiplex; diabetic amyotrophy; a painful polyneuropathy; autonomic neuropathy; and thoracoabdominal neuropathy (see Adams et al., Principles of Neurology, 6th ed, p1325); mononeuropathies (disease or trauma involving a single peripheral nerve in isolation, or out of proportion to evidence of diffuse peripheral nerve dysfunction). Mononeuritis multiplex refers to a condition characterized by multiple isolated nerve injuries. Mononeuropathies may result from a wide variety of causes, including ischemia; traumatic injury; compression; connective tissue diseases; cumulative trauma disorders; and other conditions; Neuralgia (intense or aching pain that occurs along the course or distribution of a peripheral or cranial nerve); Peripheral Nervous System Neoplasms (neoplasms which arise from peripheral nerve tissue). This includes neurofibromas; Schwannomas; granular cell tumors; and malignant peripheral nerve sheath tumors (see DeVita Jr et al., Cancer: Principles and Practice of Oncology, 5th ed, pp1750-1); and Nerve Compression Syndromes (mechanical compression of nerves or nerve roots from internal or external causes). These may result in a conduction block to nerve impulses, due to, for example, myelin sheath dysfunction, or axonal loss. The nerve and nerve sheath injuries may be caused by ischemia; inflammation; or a direct mechanical effect; Neuritis (a general term indicating inflammation of a peripheral or cranial nerve). Clinical manifestation may include pain; paresthesias; paresis; or hyperesthesia; Polyneuropathies (diseases of multiple peripheral nerves). The various forms are categorized by the type of nerve affected (e.g., sensory, motor, or autonomic), by the distribution of nerve injury (e.g., distal vs. proximal), by nerve component primarily affected (e.g., demyelinating vs. axonal), by etiology, or by pattern of inheritance.

In another embodiment, a sirtuin activating compound may be used to treat or prevent chemotherapeutic induced neuropathy. The sirtuin modulating compounds may be administered prior to administration of the chemotherapeutic agent, concurrently with administration of the chemotherapeutic drug, and/or after initiation of administration of the chemotherapeutic drug. If the sirtuin activating compound is administered after the initiation of administration of the chemotherapeutic drug, it is desirable that the sirtuin activating compound be administered prior to, or at the first signs, of chemotherapeutic induced neuropathy.

Chemotherapy drugs can damage any part of the nervous system. Encephalopathy and myelopathy are fortunately very rare. Damage to peripheral nerves is much more common and can be a side effect of treatment experienced by people with cancers, such as lymphoma. Most of the neuropathy affects sensory rather than motor nerves. Thus, the common symptoms are tingling, numbness or a loss of balance. The longest nerves in the body seem to be most sensitive hence the fact that most patients will report numbness or pins and needles in their hands and feet.

The chemotherapy drugs which are most commonly associated with neuropathy, are the Vinca alkaloids (anti-cancer drugs originally derived from a member of the periwinkle - the Vinca plant genus) and a platinum- containing drug called Cisplatin. The Vinca alkaloids include the drugs vinblastine, vincristine and vindesine. Many combination chemotherapy treatments for lymphoma for example CHOP and CVP contain vincristine, which is the drug known to cause this problem most frequently. Indeed, it is the risk of neuropathy that limits the dose of vincristine that can be administered.

Studies that have been performed have shown that most patients will lose some reflexes in their legs as a result of treatment with vincristine and many will experience some degree of tingling (paresthesia) in their fingers and toes. The neuropathy does not usually manifest itself right at the start of the treatment but generally comes on over a period of a few weeks. It is not essential to stop the drug at the first onset of symptoms, but if the neuropathy progresses this may be necessary. It is very important that patients should report such symptoms to their doctors, as the nerve damage is largely reversible if the drug is discontinued. Most doctors will often reduce the dose of vincristine or switch to another form of Vinca alkaloid such as vinblastine or vindesine if the symptoms are mild. Occasionally, the nerves supplying the bowel are affected causing abdominal pain and constipation.

In another embodiment, a sirtuin activating compound may be used to treat or prevent a polyglutamine disease. Huntington's Disease (HD) and Spinocerebellar ataxia type 1 (SCA1) are just two examples of a class of genetic diseases caused by dynamic mutations involving the expansion of triplet sequence repeats. In reference to this common mechanism, these disorders are called trinucleotide repeat diseases. At least 14 such diseases are known to affect human beings. Nine of them, including SCA1 and Huntington's disease, have CAG as the repeated sequence (see Table 2 below). Since CAG codes for an amino acid called glutamine, these nine trinucleotide repeat disorders are collectively known as polyglutamine diseases.

Although the genes involved in different polyglutamine diseases have little in common, the disorders they cause follow a strikingly similar course. Each disease is characterized by a progressive degeneration of a distinct group of nerve cells. The major symptoms of these diseases are similar, although not identical, and usually affect people in midlife. Given the similarities in symptoms, the polyglutamine diseases are hypothesized to progress via common cellular mechanisms. In recent years, scientists have made great strides in unraveling what the mechanisms are.

Above a certain threshold, the greater the number of glutamine repeats in a protein, the earlier the onset of disease and the more severe the symptoms. This suggests that abnormally long glutamine tracts render their host protein toxic to nerve cells.

To test this hypothesis, scientists have generated genetically engineered mice expressing proteins with long polyglutamine tracts. Regardless of whether the mice express full-length proteins or only those portions of the proteins containing the polyglutamine tracts, they develop symptoms of polyglutamine diseases. This suggests that a long polyglutamine tract by itself is damaging to cells and does not have to be part of a functional protein to cause its damage.

For example, it is thought that the symptoms of SCA1 are not directly caused by the loss of normal ataxin-1 function but rather by the interaction between ataxin-1 and another protein called LANP. LANP is needed for nerve cells to communicate with one another and thus for their survival. When the mutant ataxin-1 protein accumulates inside nerve cells, it "traps" the LANP protein, interfering with its normal function. After a while, the absence of LANP function appears to cause nerve cells to malfunction.

Table 2. Summary of Polyglutamine Diseases.

Disease	**Gene name**	**Chromosomal location**	**Pattern of inheritance**	**Protein**	**Normal repeat length**	**Disease repeat length**
Spinobulbar muscular atrophy (Kennedy disease)	*AR*	Xq13–21	X-linked recessive	androgen receptor (AR)	9–36	38–62
Huntington's disease	*HD*	4p16.3	autosomal dominant	huntingtin	6–35	36–121
Dentatorubral-pallidoluysian atrophy (Haw River syndrome)	*DRPLA*	12p13.31	autosomal dominant	atrophin-1	6–35	49–88
Spinocerebellar ataxia type 1	*SCA1*	6p23	autosomal dominant	ataxin-1	6–44	39–82
Spinocerebellar ataxia type 2	*SCA2*	12q24.1	autosomal dominant	ataxin-2	15–31	36–63
Spinocerebellar ataxia type 3 (Machado-Joseph disease)	*SCA3*	14q32.1	autosomal dominant	ataxin-3	12–40	55–84
Spinocerebellar ataxia type 6	*SCA6*	19p13	autosomal dominant	$\alpha 1_A$-voltage-dependent calcium channel subunit	4–18	21–33
Spinocerebellar ataxia type 7	*SCA7*	3p12–13	autosomal dominant	ataxin-7	4–35	37–306
Spinocerebellar ataxia type 17	SCA17	*6q27*	*autosomal dominant*	*TATA binding protein*	*25–42*	45–63

Many transcription factors have also been found in neuronal inclusions in different diseases. It is possible that these transcription factors interact with the polyglutamine-containing proteins and then become trapped in the neuronal inclusions. This in turn might keep the transcription factors from turning genes on and off as needed by the cell. Another observation is hypoacetylation of histones in affected cells. This has led to the hypothesis that Class I/II Histone Deacetylase (HDAC I/II) inhibitors, which are known to increase histone acetylation, may be a novel therapy for polyglutamine diseases (US Patent application 10/476,627; "Method

of treating neurodegenerative, psychiatric, and other disorders with deacetylase inhibitors").

In yet another embodiment, the invention provides a method for treating or preventing neuropathy related to ischemic injuries or diseases, such as, for example, coronary heart disease (including congestive heart failure and myocardial infarctions), stroke, emphysema, hemorrhagic shock, peripheral vascular disease (upper and lower extremities) and transplant related injuries.

In certain embodiments, the invention provides a method to treat a central nervous system cell to prevent damage in response to a decrease in blood flow to the cell. Typically the severity of damage that may be prevented will depend in large part on the degree of reduction in blood flow to the cell and the duration of the reduction. By way of example, the normal amount of perfusion to brain gray matter in humans is about 60 to 70 mL/100 g of brain tissue/min. Death of central nervous system cells typically occurs when the flow of blood falls below approximately 8-10 mL/100 g of brain tissue/min, while at slightly higher levels (i.e. 20-35 mL/100 g of brain tissue/min) the tissue remains alive but not able to function. In one embodiment, apoptotic or necrotic cell death may be prevented. In still a further embodiment, ischemic-mediated damage, such as cytoxic edema or central nervous system tissue anoxemia, may be prevented. In each embodiment, the central nervous system cell may be a spinal cell or a brain cell.

Another aspect encompasses administrating a sirtuin activating compound to a subject to treat a central nervous system ischemic condition. A number of central nervous system ischemic conditions may be treated by the sirtuin activating compounds described herein. In one embodiment, the ischemic condition is a stroke that results in any type of ischemic central nervous system damage, such as apoptotic or necrotic cell death, cytoxic edema or central nervous system tissue anoxia. The stroke may impact any area of the brain or be caused by any etiology commonly known to result in the occurrence of a stroke. In one alternative of this embodiment, the stroke is a brain stem stroke. Generally speaking, brain stem strokes strike the brain stem, which control involuntary life-support functions such as breathing, blood pressure, and heartbeat. In another alternative of this embodiment, the stroke is a cerebellar stroke. Typically, cerebellar strokes impact the cerebellum area of the brain, which controls balance and coordination. In still another embodiment, the stroke is an embolic stroke. In general terms, embolic strokes may impact any region

of the brain and typically result from the blockage of an artery by a vaso-occlusion. In yet another alternative, the stroke may be a hemorrhagic stroke. Like ischemic strokes, hemorrhagic stroke may impact any region of the brain, and typically result from a ruptured blood vessel characterized by a hemorrhage (bleeding) within or surrounding the brain. In a further embodiment, the stroke is a thrombotic stroke. Typically, thrombotic strokes result from the blockage of a blood vessel by accumulated deposits.

In another embodiment, the ischemic condition may result from a disorder that occurs in a part of the subject's body outside of the central nervous system, but yet still causes a reduction in blood flow to the central nervous system. These disorders may include, but are not limited to a peripheral vascular disorder, a venous thrombosis, a pulmonary embolus, arrhythmia (e.g. atrial fibrillation), a myocardial infarction, a transient ischemic attack, unstable angina, or sickle cell anemia. Moreover, the central nervous system ischemic condition may occur as result of the subject undergoing a surgical procedure. By way of example, the subject may be undergoing heart surgery, lung surgery, spinal surgery, brain surgery, vascular surgery, abdominal surgery, or organ transplantation surgery. The organ transplantation surgery may include heart, lung, pancreas, kidney or liver transplantation surgery. Moreover, the central nervous system ischemic condition may occur as a result of a trauma or injury to a part of the subject's body outside the central nervous system. By way of example, the trauma or injury may cause a degree of bleeding that significantly reduces the total volume of blood in the subject's body. Because of this reduced total volume, the amount of blood flow to the central nervous system is concomitantly reduced. By way of further example, the trauma or injury may also result in the formation of a vaso-occlusion that restricts blood flow to the central nervous system.

Of course it is contemplated that the sirtuin activating compounds may be employed to treat the central nervous system ischemic condition irrespective of the cause of the condition. In one embodiment, the ischemic condition results from a vaso-occlusion. The vaso-occlusion may be any type of occlusion, but is typically a cerebral thrombosis or an embolism. In a further embodiment, the ischemic condition may result from a hemorrhage. The hemorrhage may be any type of hemorrhage, but is generally a cerebral hemorrhage or a subararachnoid hemorrhage. In still another embodiment, the ischemic condition may result from the narrowing of a vessel.

Generally speaking, the vessel may narrow as a result of a vasoconstriction such as occurs during vasospasms, or due to arteriosclerosis. In yet another embodiment, the ischemic condition results from an injury to the brain or spinal cord.

In yet another aspect, a sirtuin activating compound may be administered to reduce infarct size of the ischemic core following a central nervous system ischemic condition. Moreover, a sirtuin activating compound may also be beneficially administered to reduce the size of the ischemic penumbra or transitional zone following a central nervous system ischemic condition.

In one embodiment, a combination drug regimen may include drugs or compounds for the treatment or prevention of neurodegenerative disorders or secondary conditions associated with these conditions. Thus, a combination drug regimen may include one or more sirtuin activators and one or more anti-neurodegeneration agents. For example, one or more sirtuin-activating compounds can be combined with an effective amount of one or more of: L-DOPA; a dopamine agonist; an adenosine A_2A receptor antagonist; a COMT inhibitor; a MAO inhibitor; an N-NOS inhibitor; a sodium channel antagonist; a selective N-methyl D-aspartate (NMDA) receptor antagonist; an AMPA/kainate receptor antagonist; a calcium channel antagonist; a GABA-A receptor agonist; an acetyl-choline esterase inhibitor; a matrix metalloprotease inhibitor; a PARP inhibitor; an inhibitor of p38 MAP kinase or c-jun-N-terminal kinases; TPA; NDA antagonists; beta-interferons; growth factors; glutamate inhibitors; and/or as part of a cell therapy.

Exemplary N-NOS inhibitors include 4-(6-amino-pyridin-2-yl)-3-methoxyphenol 6-[4-(2-dimethylamino-ethoxy)-2-methoxy-phenyl]-pyridin-2-yl-amine, 6-[4-(2-dimethylamino-ethoxy)-2,3-dimet-hyl-phenyl]-pyridin-2-yl-amine, 6-[4-(2-pyrrolidinyl-ethoxy)-2,3-dimethyl-p-henyl]-pyridin-2-yl-amine, 6-[4-(4-(n-methyl)piperidinyloxy)-2,3-dimethyl-p-henyl]-pyridin-2-yl-amine, 6-[4-(2-dimethylamino-ethoxy)-3-methoxy-phenyl]-pyridin-2-yl-amine, 6-[4-(2-pyrrolidinyl-ethoxy)-3-methoxy-phenyl]-pyridin-2-yl-amine, 6-{4-[2-(6,7-dimethoxy-3,4-dihydro-1h-isoquinolin-2-yl)-ethoxy]-3-methoxy-phenyl}-pyridin-2-yl-amine, 6-{3-methoxy-4-[2-(4-phenethyl-piper-azin-1-yl)-ethoxy]-phenyl}-pyridin-2-yl-amine, 6-{3-methoxy-4-[2-(4-methyl-piperazin-1-yl)-ethoxy]-phenyl}-pyridin-2-yl-amine, 6-{4-[2-(4-dimethylamin-o-piperidin-1-yl)-ethoxy]-3-methoxy-phenyl}-pyridin-2-yl-amine, 6-[4-(2-dimethylamino-ethoxy)-3-ethoxy-phenyl]-pyridin-2-yl-amine, 6-[4-(2-pyrrolidinyl-ethoxy)-3-ethoxy-phenyl]-pyridin-2-yl-amine, 6-[4-(2-dimethylamino-

ethoxy)-2-isopropyl-phenyl]-pyridin-2-yl-amine, 4-(6-amino-pyridin-yl)-3-cyclopropyl-phenol 6-[2-cyclopropyl-4-(2-dimethy-lamino-ethoxy)-phenyl]-pyridin-2-yl-amine, 6-[2-cyclopropyl-4-(2-pyrrolidin-1-yl-ethoxy)-phenyl]-pyridin-2-yl-amine, 3-[3-(6-amino-pyridin-2yl)-4-cycl-opropyl-phenoxy]-pyrrolidine-1-carboxylic acid tert-butyl ester 6-[2-cyclopropyl-4-(1-methyl-pyrrolidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 4-(6-amino-pyridin-2-yl)-3-cyclobutyl-phenol 6-[2-cyclobutyl-4-(2-dime-thylamino-ethoxy)-phenyl]-pyridin-2-yl-amine, 6-[2-cyclobutyl-4-(2-pyrrolid-in-1-yl-ethoxy)-phenyl]-pyridin-2-yl-amine, 6-[2-cyclobutyl-4-(1-methyl-pyr-rolidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 4-(6-amino-pyridin-2-yl)-3-cyclopentyl-phenol 6-[2-cyclopentyl-4-(2-dimethylamino-ethoxy)-phenyl]-pyrid-in-2-yl-amine, 6-[2-cyclopentyl-4-(2-pyrrolidin-1yl-ethoxy)-phenyl]-pyridin-2-yl-amine, 3-[4-(6-amino-pyridin-2yl)-3-methoxy-phenoxy]-pyrrolidine-1-ca-rboxylic acid tert butyl ester 6-[4-(1-methyl-pyrrolidin-3-yl-oxy)-2-metho-xy-phenyl]-pyridin-2-yl-amine, 4-[4-(6-amino-pyridin-2yl)-3-methoxy-phenoxy-]-piperidine-1-carboxylic acid tert butyl ester 6-[2-methoxy-4-(1-methyl-p-iperidin-4-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[4-(allyloxy)-2-methoxy-ph-enyl]-pyridin-2-yl-amine, 4-(6-amino-pyridin-2-yl)-3-methoxy-6-allyl-phenol 12 and 4-(6-amino-pyridin-2-yl)-3-methoxy-2-allyl-phenol 13 4-(6-amino-pyridin-2-yl)-3-methoxy-6-propyl-phenol 6-[4-(2-dimethylamino-ethoxy)-2-methoxy-5-propyl-phenyl]-pyridin-yl-amine, 6-[2-isopropyl-4-(pyrrolidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-isopropyl-4-(piperidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-isopropyl-4-(1-methyl-azetidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-isopropyl-4-(1-methyl-piperidin-4-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-isopropyl-4-(1-methyl-pyrrolidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amin-e 6-[2-isopropyl-4-(1-methyl-pyrrolidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-isopropyl-4-(2-methyl-2-aza-bicyclo[2.2.1]hept-5-yl-oxy)-phenyl]-p-yridin-2-yl-amine, 6-[4-(2-dimethylamino-ethoxy)-2-methoxy-phenyl]-pyridin-2-yl-amine, 6-{4-[2-(benzyl-methyl-amino)-ethoxy]-2-methoxy-phenyl}-pyridin-2-yl-amine, 6-[2-methoxy-4-(2-pyrrolidin-1-yl-ethoxy)-phenyl]-pyridin-2-yl-amine, 2-(6-amino-pyridin-2-yl)-5-(2-dimethylamino-ethoxy)-phenol 2-[4-(6-amino-pyridin-2-yl)-3-methoxy-phenoxy]-acetamide 6-[4-(2-amino-ethoxy)-2-methoxy-phenyl]-pyridin-2-yl-amine, 6-{4-[2-(3,4-dihydro-1h-isoquinolin-2-yl)-ethoxy]-2-methoxy-phenyl}-pyrid-in-2-yl-amine, 2-[4-(6-amino-pyridin-2-yl)-3-methoxy-phenoxy]-ethanol 6-{2-methoxy-4-[2-(2,2,6,6-tetramethyl-piperidin-1-yl)-ethoxy]-phenyl}-py-ridin-2-yl-amine, 6-{4-[2-(2,5-dimethyl-pyrrolidin-1-yl)-ethoxy]-

2-methoxy-phenyl}-pyridin-2-yl-amine, 6-{4-[2-(2,5-dimethyl-pyrrolidin-1-yl)-ethoxy]-2-methoxy-phenyl}-pyridin-2-yl-amine, 2-[4-(6-amino-pyridin-2-yl)-3-methoxy-phenoxy]-1-(2,2,6,6-tetramethyl-piperidin-1-yl)-ethanone 6-[2-methoxy-4-(1-methyl-pyrrolidin-2-yl-methoxy)-phenyl]-pyridin-2-yl-amine, 6-[4-(2-dimethylamino-ethoxy)-2-propoxy-phenyl]-pyridin-2-yl-amine, 6-{4-[2-(benzyl-methyl-amino)-ethoxy]-2-propoxy-phenyl}-pyridin-2-yl-amin-e 6-[4-(2-ethoxy-ethoxy)-2-methoxy-phenyl]-pyridin-2-yl-amine, 6-[4-(2-dimethylamino-ethoxy)-2-isopropoxy-phenyl]-pyridin-2-yl-amine, 6-[4-(2-ethoxy-ethoxy)-2-isopropoxy-phenyl]-pyridin-2-yl-amine, 6-[2-methoxy-4-(3-methyl-butoxy)-phenyl]-pyridin-2-yl-amine, 6-[4-(2-dimethylamino-ethoxy)-2-ethoxy-phenyl]-pyridin-2-yl-amine, 6-{4-[2-(benzyl-methyl-amino)-ethoxy]-2-ethoxy-phenyl}-pyridin-2-yl-amine, 6-[2-ethoxy-4-(3-methyl-butoxy)-phenyl]-pyridin-2-yl-amine, 1-(6-amino-3-aza-bicyclo[3.1.0]hex-3-yl)-2-[4-(6-amino-pyridin-2-yl)-3-et-hoxy-phenoxy]-ethanone 6-[2-ethoxy-4-(2-pyrrolidin-1-yl-ethoxy)-phenyl]-py-ridin-2-yl-amine, 3-{2-[4-(6-amino-pyridin-2-yl)-3-ethoxy-phenoxy]-ethyl}-3-aza-bicyclo[3.1.0]hex-6-yl-amine, 1-(6-amino-3-aza-bicyclo[3.1.0]hex-3-yl)-2-[4-(6-amino-pyridin-2-yl)-3-methoxy-phenoxy]-ethanone 3-{2-[4-(6-amino-pyridin-2-yl)-3-methoxy-phenoxy]-ethyl}-3-aza-bicyclo[3.-1.0]hex-6-yl-amine, 6-[2-isopropoxy-4-(2-pyrrolidin-1-yl-ethoxy)-phenyl]-py-ridin-2-yl-amine, 6-{4-[2-(benzyl-methyl-amino)-ethoxy]-2-isopropoxy-phenyl-}-pyridin-2-yl-amine, 6-[4-(2-dimethylamino-ethoxy)-2-methoxy-5-propyl-phen-yl]-pyridin-2-yl-amine, 6-[5-allyl-4-(2-dimethylamino-ethoxy)-2-methoxy-phe-nyl]-pyridin-2-yl-amine, 6-[5-allyl-2-methoxy-4-(2-pyrrolidin-1-yl-ethoxy)-phenyl]-pyridin-2-yl-amine, 6-[3-allyl-4-(2-dimethylamino-ethoxy)-2-methoxy-phenyl]-pyridin-2-yl-amine, 6-[2-methoxy-4-(pyrrolidin-3-yl-oxy)-phenyl]-p-yridin-2-yl-amine, 6-[2-methoxy-4-(1-methyl-pyrrolidin-3-yl-oxy)-phenyl]-py-ridin-2-yl-amine, 6-[2-ethoxy-4-(pyrrolidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-isopropoxy-4-(pyrrolidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-methoxy-4-(piperidin-4-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-methoxy-4-(2,2,6,6-tetramethyl-piperidin-4-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-isopropoxy-4-(pyrrolidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 3-[4-(6-amino-pyridin-2-yl)-3-methoxy-phenoxy]-azetidine-1-carboxylic acid tert-butyl ester 6-[4-(azetidin-3-yl-oxy)-2-methoxy-phenyl]-pyridin-2-yl-amine, 6-[2-methoxy-4-(1-methyl-azetidin-3-yl-oxy)-phenyl]-pyridin-2-y-l-amine, 6-[2-isopropoxy-4-(pyrrolidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-isopropoxy-4-(pyrrolidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-methoxy-4-(pyrrolidin-3-yl-

oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-methoxy-4-(1-methyl-pyrrolidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-methoxy-4-(1-methyl-pyrrolidin-3-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[2-methoxy-4-(2-methyl-2-aza-bicyclo[2.2.1]hept-5-yl-oxy)-phenyl]-pyrid-in-2-yl-amine, 6-[2-methoxy-4-(1-methyl-piperidin-4-yl-oxy)-phenyl]-pyridin-2-yl-amine, 6-[4-(1-ethyl-piperidin-4-yl-oxy)-2-methoxy-phenyl]-pyridin-2-yl-amine, 6-[5-allyl-2-methoxy-4-(1-methyl-pyrrolidin-3-yl-oxy)-phenyl]-pyr-idin-2-yl-amine, 6-[4-(2-dimethylamino-ethoxy)-2,6-dimethyl-phenyl]-pyridin-2-yl-amine, 6-[2,6-dimethyl-4-(3-piperidin-1-yl-propoxy)-phenyl]-pyridin-2-yl-amine, 6-[2,6-dimethyl-4-(2-pyrrolidin-1-yl-ethoxy)-phenyl]-pyridin-2-y-l-amine, 6-{2,6-dimethyl-4-[3-(4-methyl-piperazin-1-yl)-propoxy]-phenyl}-py-ridin-2-yl-amine, 6-[2,6-dimethyl-4-(2-morpholin-4-yl-ethoxy)-phenyl]-pyrid-in-2-yl-amine, 6-{4-[2-(benzyl-methyl-amino)-ethoxy]-2,6-dimethyl-phenyl}-p-yridin-2-yl-amine, 2-[4-(6-amino-pyridin-2-yl)-3,5-dimethyl-phenoxy]-acetam-ide 6-[4-(2-amino-ethoxy)-2,6-dimethyl-phenyl]-pyridin-2-yl-amine, 6-[2-isopropyl-4-(2-pyrrolidin-1-yl-ethoxy)-phenyl]-pyridin-2-yl-amine, 2-(2,5-dimethyl-pyrrolidin-1-yl)-6-[2-isopropyl-4-(2-pyrrolidin-1-yl-etho-xy)-phenyl]-pyridine 6-{4-[2-(3,5-dimethyl-piperidin-1-yl)-ethoxy]-2-isopropyl-phenyl}-pyridin-2-yl-amine, 6-[4-(2-dimethylamino-ethoxy)-2-isopropyl-phenyl]-pyridin-2-yl-amine, 6-[2-tert-butyl-4-(2-dimethylamino-ethoxy)-phen-yl]-pyridin-2-yl-amine, 6-[2-tert-butyl-4-(2-pyrrolidin-1-yl-ethoxy)-phenyl-]-pyridin-2-yl-amine, 6-[4-(2-pyrrolidinyl-ethoxy)-2,5-dimethyl-phenyl]-pyr-idin-2-yl-amine, 6-[4-(2-dimethylamino-ethoxy)-2,5-dimethyl-phenyl]-pyridin-2-yl-amine, 6-[4-(2-(4-phenethylpiperazin-1-yl)-ethoxy)-2,5-dimethyl-pheny-l]-pyridin-2-yl-amine, 6-[2-cyclopropyl-4-(2-dimethylamino-1-methyl-ethoxy)-phenyl]-pyridin-2-yl-amine, 6-[cyclobutyl-4-(2-dimethylamino-1-methyl-etho-xy)-phenyl]-pyridin-2-yl-amine, 6-[4-(allyloxy)-2-cyclobutyl-phenyl]-pyridi-n-2ylamine, 2-allyl-4-(6-amino-pyridin-2-yl)-3-cyclobutyl-phenol and 2-allyl-4-(6-amino-pyridin-2-yl)-5-cyclobutyl-phenol 4-(6-amino-pyridin-2yl)-5-cyclobutyl-2-propyl-phenol 4-(6-amino-pyridin-2yl)-3-cyclobutyl-2-propyl-phenol 6-[2-cyclobutyl-4-(2-dimethylamino-1-methyl-ethoxy)-5-propyl-phenyl]-pyri-din-2-yl-amine, 6-[2-cyclobutyl-4-(2-dimethylamino-1-methyl-ethoxy)-3-propy-l-phenyl]-pyridin-2-yl-amine, 6-[2-cyclobutyl-4-(2-dimethylamino-ethoxy)-5-propyl-phenyl]-pyridin-2-yl-amine, 6-[2-cyclobutyl-4-(2-dimethylamino-ethox-y)-3-propyl-phenyl]-pyridin-2-yl-amine, 6-[2-cyclobutyl-4-(1-methyl-pyrrolidin-3-yl-oxy)-5-propyl-phenyl]-pyridin-2-yl-amine, 6-[cyclobutyl-4-(1-methy-l-pyrrolidin-3-yl-oxy)-3-propyl-phenyl]-pyridin-2-yl-amine, 2-(4-benzyloxy-5-

hydroxy-2-methoxy-phenyl)-6-(2,5-dimethyl-pyrrol-1-yl)-p-yridine 6-[4-(2-dimethylamino-ethoxy)-5-ethoxy-2-methoxy-phenyl]-pyridin-2-yl-amine, 6-[5-ethyl-2-methoxy-4-(1-methyl-piperidin-4-yl-oxy)-phenyl]-pyr-idin-2-yl-amine, 6-[5-ethyl-2-methoxy-4-(piperidin-4-yl-oxy)-phenyl]-pyridi-n-2-yl-amine, 6-[2,5-dimethoxy-4-(1-methyl-pyrrolidin-3-yl-oxy)-phenyl]-pyr-idin-2-yl-amine, 6-[4-(2-dimethylamino-ethoxy)-5-ethyl-2-methoxy-phenyl]-py-ridin-2-yl-amine.

Exemplary NMDA receptor antagonist include (+)-(1S, 2S)-1-(4-hydroxy-phenyl)-2-(4-hydroxy-4-phenylpiperidino)-1-pro-panol, (1S, 2S)-1-(4-hydroxy-3-methoxyphenyl)-2-(4-hydroxy-4-phenylpiperi-dino)-1-propanol, (3R, 4S)-3-(4-(4-fluorophenyl)-4-hydroxypiperidin-1-yl-)-chroman-4,7-diol, (1R*, 2R*)-1-(4-hydroxy-3-methylphenyl)-2-(4-(4-fluoro-phenyl)-4-hydroxypiperidin-1-yl)-propan-1-ol-mesylate or a pharmaceutically acceptable acid addition salt thereof.

Exemplary dopamine agonist include ropininole; L-dopa decarboxylase inhibitors such as carbidopa or benserazide, bromocriptine, dihydroergocryptine, etisulergine, AF-14, alaptide, pergolide, piribedil; dopamine D1 receptor agonists such as A-68939, A-77636, dihydrexine, and SKF-38393; dopamine D2 receptor agonists such as carbergoline, lisuride, N-0434, naxagolide, PD-118440, pramipexole, quinpirole and ropinirole; dopamine/β-adrenegeric receptor agonists such as DPDMS and dopexamine; dopamine/5-HT uptake inhibitor/5-HT-1A agonists such as roxindole; dopamine/opiate receptor agonists such as NIH-10494; α2-adrenergic antagonist/dopamine agonists such as terguride; α2-adrenergic antagonist/dopamine D2 agonists such as ergolines and talipexole; dopamine uptake inhibitors such as GBR-12909, GBR-13069, GYKI-52895, and NS-2141; monoamine oxidase-B inhibitors such as selegiline, N-(2-butyl)-N-methylpropargylamine, N-methyl-N-(2-pentyl)propargylamine, AGN-1133, ergot derivatives, lazabemide, LU-53439, MD-280040 and mofegiline; and COMT inhibitors such as CGP-28014.

Exemplary acetyl cholinesterase inhibitors include donepizil, 1-(2-methyl-1H-benzimida-zol-5-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(2-phenyl-1H-benzimidazol-5-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-pr-opanone; 1-(1-ethyl-2-methyl-1H-benzimidazol-5-yl)-3-[1-(phenylmethyl)-4-p-iperidinyl]-1-propanone; 1-(2-methyl-6-benzothiazolyl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(2-methyl-6-benzothiazolyl)-3-[1-[(2-methyl-4-thiazolyl)methyl]-4-piperidinyl]-1-propanone; 1-(5-methyl-benzo[b]thie-n-2-yl)-3-[1-(phenylmethyl)4-piperidinyl]-1-

propanone; 1-(6-methyl-benzo[b]thien-2-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-prop-anone; 1-(3,5-dimethyl-benzo[b]thien-2-yl)-3-[1-(phenylmethyl)-4-piperidin-yl]-1-propanone; 1-(benzo[b]thien-2-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(benzofuran-2-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-pro-panone; 1-(1-phenylsulfonyl-6-methyl-indol-2-yl)-3-[1-(phenylmethyl)-4-pip-eridinyl]-1-propanone; 1-(6-methyl-indol-2-yl)-3-[1-(phenylmethyl)-4-piper-idinyl]-1-propanone; 1-(1-phenylsulfonyl-5-amino-indol-2-yl)-3-[1-(phenylm-ethyl)-4-piperidinyl]-1-propanone; 1-(5-amino-indol-2-yl)-3-[1-(phenylmet-hyl)-4-piperidinyl]-1-propanone; and 1-(5-acetylamino-indol-2-yl)-3-[1-(ph-enylmethyl)-4-piperidinyl]-1-propanone.

1-(6-quinolyl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(5-indolyl)-3-[1-(phenylmethyl)-4-piperidiny-l]-1-propanone; 1-(5-benzthienyl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-pro-panone; 1-(6-quinazolyl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(6-benzoxazolyl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(5-benzofuranyl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(5-methyl-benzimidazol-2-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propa-none; 1-(6-methyl-benzimidazol-2-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(5-chloro-benzo[b]thien-2-yl)-3-[1-(phenylmethyl)-4-piperidin-yl]-1-propanone; 1-(5-azaindol-2-yl)-3-[1-(phenylmethyl)4-piperidinyl]-1-p-ropanone; 1-(6-azabenzo[b]thien-2-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(1H-2-oxo-pyrrolo[2',3',5,6]benzo[b]thieno-2-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(6-methyl-benzothiazol-2-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(6-methoxy-indol-2-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(6-methoxy-benzo[b]thien-2-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-pro-panone; 1-(6-acetylamino-benzo[b]thien-2-yl)-3-[1-(phenylmethyl)-4-piperidinyl]-1-propanone; 1-(5-acetylamino-benzo[b]thien-2-yl)-3-[1-(phenylmethyl-)-4-piperidinyl]-1-propanone; 6-hydroxy-3-[2-[1-(phenylmethyl)-4-piperidin-yl]ethyl]-1,2-benzisoxazole; 5-methyl-3-[2-[1-(phenylmethyl)-4-piperidinyl-]ethyl]-1,2-benzisoxazole; 6-methoxy-3[2-[1(phenylmethyl)-4-piperidinyl]et-hyl]-1,2-benzisoxazole; 6-acetamide-3-[2-[1-(phenylmethyl)-4-piperidinyl]-ethyl]-1,2-benzisoxazole; 6-amino-3-[2-[1-(phenymethyl)-4-piperidinyl]ethy-l]-1,2-benzisoxazole; 6-(4-morpholinyl)-3-[2-[1-(phenylmethyl)-4-piperidin-yl]ethyl]-1,2-benzisoxazole; 5,7-dihydro-3-[2-[1-(phenylmethyl)-4-piperidi-nyl]ethyl]-6H-pyrrolo[4,5-f]-1,2-benzisoxazol-6-one; 3-[2-[1-(phenylmethyl)-4-piperidinyl]ethyl]-1,2-benzisothiazole; 3-[2-[1-(phenylmethyl)-4-piperidinyl]ethenyl]-1,2-

benzisoxazole; 6-phenylamino-3-[2-[1-(phenylmethyl)-4-piperidinyl]ethyl]-1,2,-benzisoxaz-ole; 6-(2-thiazoly)-3-[2-[1-(phenylmethyl)-4-piperidinyl]ethyl]-1,2-benzis-oxazole; 6-(2-oxazolyl)-3-[2-[1-(phenylmethyl)-4-piperidinyl]ethyl]-1,2-benzisoxazole; 6-pyrrolidinyl-3-[2-[1-(phenylmethyl)-4-piperidinyl]ethyl]-1,-2-benzisoxazole; 5,7-dihydro-5,5-dimethyl-3-[2-[1-(phenylmethyl)-4-piperidinyl]ethyl]-6H-pyrrolo[4,5-f]-1,2-benzisoxazole-6-one; 6,8-dihydro-3-[2-[1-(phenylmethyl)-4-piperidinyl]ethyl]-7H-pyrrolo[5,4-g]-1,2-benzisoxazole-7-one; 3-[2-[1-(phenylmethyl)-4-piperidinyl]ethyl]-5,6,-8-trihydro-7H-isoxazolo[4,5-g]-quinolin-7-one; 1-benzyl-4-((5,6-dimethoxy-1-indanon)-2-yl)methylpiperidine, 1-benzyl-4-((5,6-dimethoxy-1-indanon)-2-ylidenyl)methylpiperidine, 1-benzyl-4-((5-methoxy-1-indanon)-2-yl)methylp-iperidine, 1-benzyl-4-((5,6-diethoxy-1-indanon)-2-yl)methylpiperidine, 1-benzyl-4-((5,6-methnylenedioxy-1-indanon)-2-yl)methylpiperidine, 1-(m-nitrobenzyl)-4-((5,6-dimethoxy-1-indanon)-2-yl)methylpiperidine, 1-cyclohexymethyl-4-((5,6-dimethoxy-1-indanon)-2-yl)methylpiperidine, 1-(m-florobenzyl)-4-((5,6-dimethoxy-1-indanon)-2-yl)methylpiperidine, 1-benzyl-4-((5,6-dimethoxy-1-indanon)-2-yl)propylpiperidine, and 1-benzyl-4-((5-isopropoxy-6-methoxy-1-indanon)-2-yl)methylpiperidine.

Exemplary calcium channel antagonists include diltiazem, omega-conotoxin GVIA, methoxyverapamil, amlodipine, felodipine, lacidipine, and mibefradil.

Exemplary GABA-A receptor modulators include clomethiazole; IDDB; gaboxadol (4,5,6,7-tetrahydroisoxazolo[5,4-c]pyridin-3-ol); ganaxolone (3α-hydroxy-3β-methyl-5α-pregnan-20-one); fengabine (2-[(butylimino)-(2-chlorophenyl)methyl]-4-chlorophenol); 2-(4-methoxyphenyl)-2,5,6,7,8,9-hexahydro-pyrazolo[4,3-c]cinnolin-3-one; 7-cyclobutyl-6-(2-methyl-2H-1,2,4-triazol-3-ylmethoxy)-3-phenyl-1,2,4-triazolo[4,3-b]pyridazine; (3-fluoro-4-methylphenyl)-N-({-1-[(2-methylphenyl)methyl]-benzimidazol-2-yl}methyl)-N-pentylcarboxamide; and 3-(aminomethyl)-5-methylhexanoic acid.

Exemplary potassium channel openers include diazoxide, flupirtine, pinacidil, levcromakalim, rilmakalim, chromakalim, PCO-400 and SKP-450 (2-[2"(1", 3"-dioxolone)-2-methyl]-4-(2'-oxo-1'-pyrrolidinyl)-6-nitro-2H-1-benzopyra-n).

Exemplary AMPA/kainate receptor antagonists include 6-cyano-7-nitroquinoxalin-2,3-di-one (CNQX); 6-nitro-7-sulphamoylbenzo[f]quinoxaline-2,3-dione (NBQX); 6,7-dinitroquinoxaline-2,3-dione (DNQX); 1-(4-aminophenyl)-4-

methyl-7,8-m-ethylenedioxy-5H-2,3-benzodiazepine hydrochloride; and 2,3-dihydroxy-6-nitro-7-sulfamoylbenzo-[f]quinoxaline.

Exemplary sodium channel antagonists include ajmaline, procainamide, flecainide and riluzole.

Exemplary matrix-metalloprotease inhibitors include 4-[4-(4-fluorophenoxy)benzenesulfon-ylamino]tetrahydropyran-4-carboxylic acid hydroxyamide; 5-Methyl-5-(4-(4'-fluorophenoxy)-phenoxy)-pyrimidine-2,4,6-trione; 5-n-Butyl-5-(4-(4'-fluorophenoxy)-phenoxy)-pyrimidine-2,4,6-trione and prinomistat.

Poly(ADP ribose) polymerase (PARP) is an abundant nuclear enzyme which is activated by DNA strand single breaks to synthesize poly (ADP ribose) from NAD. Under normal conditions, PARP is involved in base excision repair caused by oxidative stress via the activation and recruitment of DNA repair enzymes in the nucleus. Thus, PARP plays a role in cell necrosis and DNA repair. PARP also participates in regulating cytokine expression that mediates inflammation. Under conditions where DNA damage is excessive (such as by acute excessive exposure to a pathological insult), PARP is over-activated, resulting in cell-based energetic failure characterized by NAD depletion and leading to ATP consumption, cellular necrosis, tissue injury, and organ damage/failure. PARP is thought to contribute to neurodegeneration by depleting nicotinamide adenine dinucleotide (NAD+) which then reduces adenosine triphosphate (ATP; Cosi and Marien, Ann. N.Y. Acad. Sci., 890:227, 1999) contributing to cell death which can be prevented by PARP inhibitors. Exemplory PARP inhibitors can be found in Southan and Szabo, Current Medicinal Chemistry, 10:321, 2003.

Exemplary inhibitors of p38 MAP kinase and c-jun-N-terminal kinases include pyridyl imidazoles, such as PD 169316, isomeric PD 169316, SB 203580, SB 202190, SB 220026, and RWJ 67657. Others are described in US Patent 6,288,089, and incorporated by reference herein.

In an exemplary embodiment, a combination therapy for treating or preventing MS comprises a therapeutically effective amount of one or more sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein and one or more of Avonex® (interferon beta-1a), Tysabri® (natalizumab), or Fumaderm® (BG-12/Oral Fumarate).

In another embodiment, a combination therapy for treating or preventing diabetic neuropathy or conditions associated therewith comprises a therapeutically

effective amount of one or more sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein and one or more of tricyclic antidepressants (TCAs) (including, for example, imipramine, amytriptyline, desipramine and nortriptyline), serotonin reuptake inhibitors (SSRIs) (including, for example, fluoxetine, paroxetine, sertralene, and citalopram) and antiepileptic drugs (AEDs) (including, for example, gabapentin, carbamazepine, and topimirate).

In another embodiment, the invention provides a method for treating or preventing a polyglutamine disease using a combination comprising at least one sirtuin activating compound and at least one HDAC I/II inhibitor. Examples of HDAC I/II inhibitors include hydroxamic acids, cyclic peptides, benzamides, short-chain fatty acids, and depudecin.

Examples of hydroxamic acids and hydroxamic acid derivatives, but are not limited to, trichostatin A (TSA), suberoylanilide hydroxamic acid (SAHA), oxamflatin, suberic bishydroxamic acid (SBHA), m-carboxy-cinnamic acid bishydroxamic acid (CBHA), valproic acid and pyroxamide. TSA was isolated as an antifungi antibiotic (Tsuji et al (1976) J. Antibiot (Tokyo) 29:1-6) and found to be a potent inhibitor of mammalian HDAC (Yoshida et al. (1990) J. Biol. Chem. 265:17174-17179). The finding that TSA-resistant cell lines have an altered HDAC evidences that this enzyme is an important target for TSA. Other hydroxamic acid-based HDAC inhibitors, SAHA, SBHA, and CBHA are synthetic compounds that are able to inhibit HDAC at micromolar concentration or lower in vitro or in vivo. Glick et al. (1999) Cancer Res. 59:4392-4399. These hydroxamic acid-based HDAC inhibitors all possess an essential structural feature: a polar hydroxamic terminal linked through a hydrophobic methylene spacer (e.g. 6 carbon at length) to another polar site which is attached to a terminal hydrophobic moiety (e.g., benzene ring). Compounds developed having such essential features also fall within the scope of the hydroxamic acids that may be used as HDAC inhibitors.

Cyclic peptides used as HDAC inhibitors are mainly cyclic tetrapeptides. Examples of cyclic peptides include, but are not limited to, trapoxin A, apicidin and depsipeptide. Trapoxin A is a cyclic tetrapeptide that contains a 2-amino-8-oxo-9,10-epoxy-decanoyl (AOE) moiety. Kijima et al. (1993) J. Biol. Chem. 268:22429-22435. Apicidin is a fungal metabolite that exhibits potent, broad-spectrum antiprotozoal activitity and inhibits HDAC activity at nanomolar concentrations. Darkin-Rattray et al. (1996) Proc. Natl. Acad. Sci. USA. 93;13143-13147. Depsipeptide is isolated from

Chromobacterium violaceum, and has been shown to inhibit HDAC activity at micromolar concentrations.

Examples of benzamides include but are not limited to MS-27-275. Saito et al. (1990) Proc. Natl. Acad. Sci. USA. 96:4592-4597. Examples of short-chain fatty acids include but are not limited to butyrates (e.g., butyric acid, arginine butyrate and phenylbutyrate (PB)). Newmark et al. (1994) Cancer Lett. 78:1-5; and Carducci et al. (1997) Anticancer Res. 17:3972-3973. In addition, depudecin which has been shown to inhibit HDAC at micromolar concentrations (Kwon et al. (1998) Proc. Natl. Acad. Sci. USA. 95:3356-3361) also falls within the scope of histone deacetylase inhibitor as described herein.

Blood Coagulation Disorders

In other aspects, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein can be used to treat or prevent blood coagulation disorders (or hemostatic disorders). As used interchangeably herein, the terms "hemostasis", "blood coagulation," and "blood clotting" refer to the control of bleeding, including the physiological properties of vasoconstriction and coagulation. Blood coagulation assists in maintaining the integrity of mammalian circulation after injury, inflammation, disease, congenital defect, dysfunction or other disruption. After initiation of clotting, blood coagulation proceeds through the sequential activation of certain plasma proenzymes to their enzyme forms (see, for example, Coleman, R. W. et al. (eds.) *Hemostasis and Thrombosis, Second Edition*, (1987)). These plasma glycoproteins, including Factor XII, Factor XI, Factor IX, Factor X, Factor VII, and prothrombin, are zymogens of serine proteases. Most of these blood clotting enzymes are effective on a physiological scale only when assembled in complexes on membrane surfaces with protein cofactors such as Factor VIII and Factor V. Other blood factors modulate and localize clot formation, or dissolve blood clots. Activated protein C is a specific enzyme that inactivates procoagulant components. Calcium ions are involved in many of the component reactions. Blood coagulation follows either the intrinsic pathway, where all of the protein components are present in blood, or the extrinsic pathway, where the cell-membrane protein tissue factor plays a critical role. Clot formation occurs when fibrinogen is cleaved by thrombin to form fibrin. Blood clots are composed of activated platelets and fibrin.

Further, the formation of blood clots does not only limit bleeding in case of an injury (hemostasis), but may lead to serious organ damage and death in the context of

atherosclerotic diseases by occlusion of an important artery or vein. Thrombosis is thus blood clot formation at the wrong time and place. It involves a cascade of complicated and regulated biochemical reactions between circulating blood proteins (coagulation factors), blood cells (in particular platelets), and elements of an injured vessel wall.

Accordingly, the present invention provides anticoagulation and antithrombotic treatments aiming at inhibiting the formation of blood clots in order to prevent or treat blood coagulation disorders, such as myocardial infarction, stroke, loss of a limb by peripheral artery disease or pulmonary embolism.

As used interchangeably herein, "modulating or modulation of hemostasis" and "regulating or regulation of hemostasis" includes the induction (e.g., stimulation or increase) of hemostasis, as well as the inhibition (e.g., reduction or decrease) of hemostasis.

In one aspect, the invention provides a method for reducing or inhibiting hemostasis in a subject by administering a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein. The compositions and methods disclosed herein are useful for the treatment or prevention of thrombotic disorders. As used herein, the term "thrombotic disorder" includes any disorder or condition characterized by excessive or unwanted coagulation or hemostatic activity, or a hypercoagulable state. Thrombotic disorders include diseases or disorders involving platelet adhesion and thrombus formation, and may manifest as an increased propensity to form thromboses, e.g., an increased number of thromboses, thrombosis at an early age, a familial tendency towards thrombosis, and thrombosis at unusual sites. Examples of thrombotic disorders include, but are not limited to, thromboembolism, deep vein thrombosis, pulmonary embolism, stroke, myocardial infarction, miscarriage, thrombophilia associated with anti-thrombin III deficiency, protein C deficiency, protein S deficiency, resistance to activated protein C, dysfibrinogenemia, fibrinolytic disorders, homocystinuria, pregnancy, inflammatory disorders, myeloproliferative disorders, arteriosclerosis, angina, e.g., unstable angina, disseminated intravascular coagulation, thrombotic thrombocytopenic purpura, cancer metastasis, sickle cell disease, glomerular nephritis, and drug induced thrombocytopenia (including, for example, heparin induced thrombocytopenia). In addition, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered to prevent thrombotic events or to prevent re-

occlusion during or after therapeutic clot lysis or procedures such as angioplasty or surgery.

In another embodiment, a combination drug regimen may include drugs or compounds for the treatment or prevention of blood coagulation disorders or secondary conditions associated with these conditions. Thus, a combination drug regimen may include one or more sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein and one or more anti-coagulation or anti-thrombosis agents. For example, one or more sirtuin-modulating compounds can be combined with an effective amount of one or more of: aspirin, heparin, and oral Warfarin that inhibits Vit K-dependent factors, low molecular weight heparins that inhibit factors X and II, thrombin inhibitors, inhibitors of platelet GP IIbIIIa receptors, inhibitors of tissue factor (TF), inhibitors of human von Willebrand factor, inhibitors of one or more factors involved in hemostasis (in particular in the coagulation cascade). In addition, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein can be combined with thrombolytic agents, such as t-PA, streptokinase, reptilase, TNK-t-PA, and staphylokinase.

Weight Control

In another aspect, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used for treating or preventing weight gain or obesity in a subject. For example, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used, for example, to treat or prevent hereditary obesity, dietary obesity, hormone related obesity, obesity related to the administration of medication, to reduce the weight of a subject, or to reduce or prevent weight gain in a subject. A subject in need of such a treatment may be a subject who is obese, likely to become obese, overweight, or likely to become overweight. Subjects who are likely to become obese or overweight can be identified, for example, based on family history, genetics, diet, activity level, medication intake, or various combinations thereof.

In yet other embodiments, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered to subjects suffering from a variety of other diseases and conditions that may be treated or prevented by promoting weight loss in the subject. Such diseases include, for example, high blood pressure, hypertension, high blood cholesterol, dyslipidemia, type 2 diabetes, insulin resistance, glucose intolerance, hyperinsulinemia, coronary heart disease, angina

pectoris, congestive heart failure, stroke, gallstones, cholescystitis and cholelithiasis, gout, osteoarthritis, obstructive sleep apnea and respiratory problems, some types of cancer (such as endometrial, breast, prostate, and colon), complications of pregnancy, poor female reproductive health (such as menstrual irregularities, infertility, irregular ovulation), bladder control problems (such as stress incontinence); uric acid nephrolithiasis; psychological disorders (such as depression, eating disorders, distorted body image, and low self esteem). Stunkard AJ, Wadden TA. (Editors) Obesity: theory and therapy, Second Edition. New York: Raven Press, 1993. Finally, patients with AIDS can develop lipodystrophy or insulin resistance in response to combination therapies for AIDS.

In another embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used for inhibiting adipogenesis or fat cell differentiation, whether in vitro or in vivo. In particular, high circulating levels of insulin and/or insulin like growth factor (IGF) 1 will be prevented from recruiting preadipocytes to differentiate into adipocytes. Such methods may be used for treating or preventing obesity.

In other embodiments, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used for reducing appetite and/or increasing satiety, thereby causing weight loss or avoidance of weight gain. A subject in need of such a treatment may be a subject who is overweight, obese or a subject likely to become overweight or obese. The method may comprise administering daily or, every other day, or once a week, a dose, e.g., in the form of a pill, to a subject. The dose may be an "appetite reducing dose."

In other embodiments, a sirtuin-modulating compound that decreases the level and/or activity of a sirtuin protein may be used to stimulate appetite and/or weight gain. A method may comprise administering to a subject, such as a subject in need thereof, a pharmaceutically effective amount of a sirtuin-modulating agent that decreases the level and/or activity of a sirtuin protein, such as SIRT1 and/or SIRT3. A subject in need of such a treatment may be a subject who has cachexia or may be likely to develop cachexia. A combination of agents may also be administered. A method may further comprise monitoring in the subject the state of the disease or of activation of sirtuins, for example, in adipose tissue.

Methods for stimulating fat accumulation in cells may be used in vitro, to establish cell models of weight gain, which may be used, e.g., for identifying other drugs that prevent weight gain.

Also provided are methods for modulating adipogenesis or fat cell differentiation, whether in vitro or in vivo. In particular, high circulating levels of insulin and/or insulin like growth factor (IGF) 1 will be prevented from recruiting preadipocytes to differentiate into adipocytes. Such methods may be used to modulate obesity. A method for stimulating adipogenesis may comprise contacting a cell with a sirtuin-modulating agent that decreases the level and/or activity of a sirtuin protein.

In another embodiment, the invention provides methods of decreasing fat or lipid metabolism in a subject by administering a sirtuin-modulating compound that decreases the level and/or activity of a sirtuin protein. The method includes administering to a subject an amount of a sirtuin-modulating compound, e.g., in an amount effective to decrease mobilization of fat to the blood from WAT cells and/or to decrease fat burning by BAT cells.

Methods for promoting appetite and/or weight gain may include, for example, prior identifying a subject as being in need of decreased fat or lipid metabolism, e.g., by weighing the subject, determining the BMI of the subject, or evaluating fat content of the subject or sirtuin activity in cells of the subject. The method may also include monitoring the subject, e.g., during and/or after administration of a sirtuin-modulating compound. The administering can include one or more dosages, e.g., delivered in boluses or continuously. Monitoring can include evaluating a hormone or a metabolite. Exemplary hormones include leptin, adiponectin, resistin, and insulin. Exemplary metabolites include triglyercides, cholesterol, and fatty acids.

In one embodiment, a sirtuin-modulating compound that decreases the level and/or activity of a sirtuin protein may be used to modulate (e.g., increase) the amount of subcutaneous fat in a tissue, e.g., in facial tissue or in other surface-associated tissue of the neck, hand, leg, or lips. The sirtuin-modulating compound may be used to increase the rigidity, water retention, or support properties of the tissue. For example, the sirtuin-modulating compound can be applied topically, e.g., in association with another agent, e.g., for surface-associated tissue treatment. The sirtuin-modulating compound may also be injected subcutaneously, e.g., within the region where an alteration in subcutaneous fat is desired.

A method for modulating weight may further comprise monitoring the weight of the subject and/or the level of modulation of sirtuins, for example, in adipose tissue.

In an exemplary embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered as a combination therapy for treating or preventing weight gain or obesity. For example, one or more sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered in combination with one or more anti-obesity agents. Exemplary anti-obesity agents include, for example, phenylpropanolamine, ephedrine, pseudoephedrine, phentermine, a cholecystokinin-A agonist, a monoamine reuptake inhibitor (such as sibutramine), a sympathomimetic agent, a serotonergic agent (such as dexfenfluramine or fenfluramine), a dopamine agonist (such as bromocriptine), a melanocyte-stimulating hormone receptor agonist or mimetic, a melanocyte-stimulating hormone analog, a cannabinoid receptor antagonist, a melanin concentrating hormone antagonist, the OB protein (leptin), a leptin analog, a leptin receptor agonist, a galanin antagonist or a GI lipase inhibitor or decreaser (such as orlistat). Other anorectic agents include bombesin agonists, dehydroepiandrosterone or analogs thereof, glucocorticoid receptor agonists and antagonists, orexin receptor antagonists, urocortin binding protein antagonists, agonists of the glucagon-like peptide-1 receptor such as Exendin and ciliary neurotrophic factors such as Axokine.

In another embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered to reduce drug-induced weight gain. For example, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be administered as a combination therapy with medications that may stimulate appetite or cause weight gain, in particular, weight gain due to factors other than water retention. Examples of medications that may cause weight gain, include for example, diabetes treatments, including, for example, sulfonylureas (such as glipizide and glyburide), thiazolidinediones (such as pioglitazone and rosiglitazone), meglitinides, nateglinide, repaglinide, sulphonylurea medicines, and insulin; anti-depressants, including, for example, tricyclic antidepressants (such as amitriptyline and imipramine), irreversible monoamine oxidase inhibitors (MAOIs), selective serotonin reuptake inhibitors (SSRIs), bupropion, paroxetine, and mirtazapine; steroids, such as, for example, prednisone; hormone therapy; lithium carbonate; valproic acid; carbamazepine; chlorpromazine;

thiothixene; beta blockers (such as propranolo); alpha blockers (such as clonidine, prazosin and terazosin); and contraceptives including oral contraceptives (birth control pills) or other contraceptives containing estrogen and/or progesterone (Depo-Provera, Norplant, Ortho), testosterone or Megestrol. In another exemplary embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered as part of a smoking cessation program to prevent weight gain or reduce weight already gained.

Metabolic Disorders/Diabetes

In another aspect, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used for treating or preventing a metabolic disorder, such as insulin-resistance, a pre-diabetic state, type II diabetes, and/or complications thereof. Administration of a sirtuin-modulating compounds that increases the level and/or activity of a sirtuin protein may increase insulin sensitivity and/or decrease insulin levels in a subject. A subject in need of such a treatment may be a subject who has insulin resistance or other precursor symptom of type II diabetes, who has type II diabetes, or who is likely to develop any of these conditions. For example, the subject may be a subject having insulin resistance, e.g., having high circulating levels of insulin and/or associated conditions, such as hyperlipidemia, dyslipogenesis, hypercholesterolemia, impaired glucose tolerance, high blood glucose sugar level, other manifestations of syndrome X, hypertension, atherosclerosis and lipodystrophy.

In an exemplary embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered as a combination therapy for treating or preventing a metabolic disorder. For example, one or more sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered in combination with one or more anti-diabetic agents. Exemplary anti-diabetic agents include, for example, an aldose reductase inhibitor, a glycogen phosphorylase inhibitor, a sorbitol dehydrogenase inhibitor, a protein tyrosine phosphatase 1B inhibitor, a dipeptidyl protease inhibitor, insulin (including orally bioavailable insulin preparations), an insulin mimetic, metformin, acarbose, a peroxisome proliferator-activated receptor-γ (PPAR-γ) ligand such as troglitazone, rosaglitazone, pioglitazone or GW-1929, a sulfonylurea, glipazide, glyburide, or chlorpropamide wherein the amounts of the first and second compounds result in a therapeutic effect. Other anti-diabetic agents include a glucosidase inhibitor, a

glucagon-like peptide-1 (GLP-1), insulin, a PPAR α/γ dual agonist, a meglitimide and an αP2 inhibitor. In an exemplary embodiment, an anti-diabetic agent may be a dipeptidyl peptidase IV (DP-IV or DPP-IV) inhibitor, such as, for example LAF237 from Novartis (NVP DPP728; 1-[[[2-[(5-cyanopyridin-2-yl)amino] ethyl]amino]acetyl]-2- cyano-(S)- pyrrolidine) or MK-04301 from Merck (see e.g., Hughes et al., Biochemistry 38: 11597-603 (1999)).

Inflammatory Diseases

In other aspects, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein can be used to treat or prevent a disease or disorder associated with inflammation. Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered prior to the onset of, at, or after the initiation of inflammation. When used prophylactically, the compounds are preferably provided in advance of any inflammatory response or symptom. Administration of the compounds may prevent or attenuate inflammatory responses or symptoms.

Exemplary inflammatory conditions include, for example, multiple sclerosis, rheumatoid arthritis, psoriatic arthritis, degenerative joint disease, spondouloarthropathies, gouty arthritis, systemic lupus erythematosus, juvenile arthritis, rheumatoid arthritis, osteoarthritis, osteoporosis, diabetes (e.g., insulin dependent diabetes mellitus or juvenile onset diabetes), menstrual cramps, cystic fibrosis, inflammatory bowel disease, irritable bowel syndrome, Crohn's disease, mucous colitis, ulcerative colitis, gastritis, esophagitis, pancreatitis, peritonitis, Alzheimer's disease, shock, ankylosing spondylitis, gastritis, conjunctivitis, pancreatis (acute or chronic), multiple organ injury syndrome (e.g., secondary to septicemia or trauma), myocardial infarction, atherosclerosis, stroke, reperfusion injury (e.g., due to cardiopulmonary bypass or kidney dialysis), acute glomerulonephritis, vasculitis, thermal injury (i.e., sunburn), necrotizing enterocolitis, granulocyte transfusion associated syndrome, and/or Sjogren's syndrome. Exemplary inflammatory conditions of the skin include, for example, eczema, atopic dermatitis, contact dermatitis, urticaria, schleroderma, psoriasis, and dermatosis with acute inflammatory components.

In another embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used to treat or prevent allergies and respiratory conditions, including asthma, bronchitis, pulmonary fibrosis, allergic

rhinitis, oxygen toxicity, emphysema, chronic bronchitis, acute respiratory distress syndrome, and any chronic obstructive pulmonary disease (COPD). The compounds may be used to treat chronic hepatitis infection, including hepatitis B and hepatitis C.

Additionally, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used to treat autoimmune diseases and/or inflammation associated with autoimmune diseases such as organ-tissue autoimmune diseases (e.g., Raynaud's syndrome), scleroderma, myasthenia gravis, transplant rejection, endotoxin shock, sepsis, psoriasis, eczema, dermatitis, multiple sclerosis, autoimmune thyroiditis, uveitis, systemic lupus erythematosis, Addison's disease, autoimmune polyglandular disease (also known as autoimmune polyglandular syndrome), and Grave's disease.

In certain embodiments, one or more sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be taken alone or in combination with other compounds useful for treating or preventing inflammation. Exemplary anti-inflammatory agents include, for example, steroids (e.g., cortisol, cortisone, fludrocortisone, prednisone, 6α-methylprednisone, triamcinolone, betamethasone or dexamethasone), nonsteroidal antiinflammatory drugs (NSAIDS (e.g., aspirin, acetaminophen, tolmetin, ibuprofen, mefenamic acid, piroxicam, nabumetone, rofecoxib, celecoxib, etodolac or nimesulide). In another embodiment, the other therapeutic agent is an antibiotic (e.g., vancomycin, penicillin, amoxicillin, ampicillin, cefotaxime, ceftriaxone, cefixime, rifampinmetronidazole, doxycycline or streptomycin). In another embodiment, the other therapeutic agent is a PDE4 inhibitor (e.g., roflumilast or rolipram). In another embodiment, the other therapeutic agent is an antihistamine (e.g., cyclizine, hydroxyzine, promethazine or diphenhydramine). In another embodiment, the other therapeutic agent is an anti-malarial (e.g., artemisinin, artemether, artsunate, chloroquine phosphate, mefloquine hydrochloride, doxycycline hyclate, proguanil hydrochloride, atovaquone or halofantrine). In one embodiment, the other therapeutic agent is drotrecogin alfa.

Further examples of anti-inflammatory agents include, for example, aceclofenac, acemetacin, e-acetamidocaproic acid, acetaminophen, acetaminosalol, acetanilide, acetylsalicylic acid, S-adenosylmethionine, alclofenac, alclometasone, alfentanil, algestone, allylprodine, alminoprofen, aloxiprin, alphaprodine, aluminum bis(acetylsalicylate), amcinonide, amfenac, aminochlorthenoxazin, 3-amino-4-

hydroxybutyric acid, 2-amino-4-picoline, aminopropylon, aminopyrine, amixetrine, ammonium salicylate, ampiroxicam, amtolmetin guacil, anileridine, antipyrine, antrafenine, apazone, beclomethasone, bendazac, benorylate, benoxaprofen, benzpiperylon, benzydamine, benzylmorphine, bermoprofen, betamethasone, betamethasone-17-valerate, bezitramide, α-bisabolol, bromfenac, p-bromoacetanilide, 5-bromosalicylic acid acetate, bromosaligenin, bucetin, bucloxic acid, bucolome, budesonide, bufexamac, bumadizon, buprenorphine, butacetin, butibufen, butorphanol, carbamazepine, carbiphene, carprofen, carsalam, chlorobutanol, chloroprednisone, chlorthenoxazin, choline salicylate, cinchophen, cinmetacin, ciramadol, clidanac, clobetasol, clocortolone, clometacin, clonitazene, clonixin, clopirac, cloprednol, clove, codeine, codeine methyl bromide, codeine phosphate, codeine sulfate, cortisone, cortivazol, cropropamide, crotethamide, cyclazocine, deflazacort, dehydrotestosterone, desomorphine, desonide, desoximetasone, dexamethasone, dexamethasone-21-isonicotinate, dexoxadrol, dextromoramide, dextropropoxyphene, deoxycorticosterone, dezocine, diampromide, diamorphone, diclofenac, difenamizole, difenpiramide, diflorasone, diflucortolone, diflunisal, difluprednate, dihydrocodeine, dihydrocodeinone enol acetate, dihydromorphine, dihydroxyaluminum acetylsalicylate, dimenoxadol, dimepheptanol, dimethylthiambutene, dioxaphetyl butyrate, dipipanone, diprocetyl, dipyrone, ditazol, droxicam, emorfazone, enfenamic acid, enoxolone, epirizole, eptazocine, etersalate, ethenzamide, ethoheptazine, ethoxazene, ethylmethylthiambutene, ethylmorphine, etodolac, etofenamate, etonitazene, eugenol, felbinac, fenbufen, fenclozic acid, fendosal, fenoprofen, fentanyl, fentiazac, fepradinol, feprazone, floctafenine, fluazacort, flucloronide, flufenamic acid, flumethasone, flunisolide, flunixin, flunoxaprofen, fluocinolone acetonide, fluocinonide, fluocinolone acetonide, fluocortin butyl, fluocortolone, fluoresone, fluorometholone, fluperolone, flupirtine, fluprednidene, fluprednisolone, fluproquazone, flurandrenolide, flurbiprofen, fluticasone, formocortal, fosfosal, gentisic acid, glafenine, glucametacin, glycol salicylate, guaiazulene, halcinonide, halobetasol, halometasone, haloprednone, heroin, hydrocodone, hydrocortamate, hydrocortisone, hydrocortisone acetate, hydrocortisone succinate, hydrocortisone hemisuccinate, hydrocortisone 21-lysinate, hydrocortisone cypionate, hydromorphone, hydroxypethidine, ibufenac, ibuprofen, ibuproxam, imidazole

salicylate, indomethacin, indoprofen, isofezolac, isoflupredone, isoflupredone acetate, isoladol, isomethadone, isonixin, isoxepac, isoxicam, ketobemidone, ketoprofen, ketorolac, p-lactophenetide, lefetamine, levallorphan, levorphanol, levophenacyl-morphan, lofentanil, lonazolac, lornoxicam, loxoprofen, lysine acetylsalicylate, mazipredone, meclofenamic acid, medrysone, mefenamic acid, meloxicam, meperidine, meprednisone, meptazinol, mesalamine, metazocine, methadone, methotrimeprazine, methylprednisolone, methylprednisolone acetate, methylprednisolone sodium succinate, methylprednisolone suleptnate, metiazinic acid, metofoline, metopon, mofebutazone, mofezolac, mometasone, morazone, morphine, morphine hydrochloride, morphine sulfate, morpholine salicylate, myrophine, nabumetone, nalbuphine, nalorphine, 1-naphthyl salicylate, naproxen, narceine, nefopam, nicomorphine, nifenazone, niflumic acid, nimesulide, 5'-nitro-2'-propoxyacetanilide, norlevorphanol, normethadone, normorphine, norpipanone, olsalazine, opium, oxaceprol, oxametacine, oxaprozin, oxycodone, oxymorphone, oxyphenbutazone, papaveretum, paramethasone, paranyline, parsalmide, pentazocine, perisoxal, phenacetin, phenadoxone, phenazocine, phenazopyridine hydrochloride, phenocoll, phenoperidine, phenopyrazone, phenomorphan, phenyl acetylsalicylate, phenylbutazone, phenyl salicylate, phenyramidol, piketoprofen, piminodine, pipebuzone, piperylone, pirazolac, piritramide, piroxicam, pirprofen, pranoprofen, prednicarbate, prednisolone, prednisone, prednival, prednylidene, proglumetacin, proheptazine, promedol, propacetamol, properidine, propiram, propoxyphene, propyphenazone, proquazone, protizinic acid, proxazole, ramifenazone, remifentanil, rimazolium metilsulfate, salacetamide, salicin, salicylamide, salicylamide o-acetic acid, salicylic acid, salicylsulfuric acid, salsalate, salverine, simetride, sufentanil, sulfasalazine, sulindac, superoxide dismutase, suprofen, suxibuzone, talniflumate, tenidap, tenoxicam, terofenamate, tetrandrine, thiazolinobutazone, tiaprofenic acid, tiaramide, tilidine, tinoridine, tixocortol, tolfenamic acid, tolmetin, tramadol, triamcinolone, triamcinolone acetonide, tropesin, viminol, xenbucin, ximoprofen, zaltoprofen and zomepirac.

In an exemplary embodiment, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be administered with a selective COX-2 inhibitor for treating or preventing inflammation. Exemplary selective COX-2 inhibitors include, for example, deracoxib, parecoxib, celecoxib, valdecoxib, rofecoxib, etoricoxib, lumiracoxib, 2-(3,5-difluorophenyl)-3-[4-

(methylsulfonyl)phenyl]-2-cyclopenten-1-one, (S)-6,8-dichloro-2-(trifluoromethyl)-2H-1-benzopyran-3-carboxylic acid, 2-(3,4-difluorophenyl)-4-(3-hydroxy-3-methyl-1-butoxy)-5-[4-(methylsulfonyl)phenyl]-3-(2H)-pyridazinone, 4-[5-(4-fluorophenyl)-3-(trifluoromethyl)-1H-pyrazol-1-yl]benzenesulfonamide, tert-butyl 1 benzyl-4-[(4-oxopiperidin-1-yl}sulfonyl]piperidine-4-carboxylate, 4-[5-(phenyl)-3-(trifluoromethyl)-1H-pyrazol-1-yl]benzenesulfonamide, salts and prodrugs thereof.

Flushing

In another aspect, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used for reducing the incidence or severity of flushing and/or hot flashes which are symptoms of a disorder. For instance, the subject method includes the use of sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein, alone or in combination with other agents, for reducing incidence or severity of flushing and/or hot flashes in cancer patients. In other embodiments, the method provides for the use of sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein to reduce the incidence or severity of flushing and/or hot flashes in menopausal and post-menopausal woman.

In another aspect, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used as a therapy for reducing the incidence or severity of flushing and/or hot flashes which are side-effects of another drug therapy, e.g., drug-induced flushing. In certain embodiments, a method for treating and/or preventing drug-induced flushing comprises administering to a patient in need thereof a formulation comprising at least one flushing inducing compound and at least one sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein. In other embodiments, a method for treating drug induced flushing comprises separately administering one or more compounds that induce flushing and one or more sirtuin-modulating compounds, e.g., wherein the sirtuin-modulating compound and flushing inducing agent have not been formulated in the same compositions. When using separate formulations, the sirtuin-modulating compound may be administered (1) at the same as administration of the flushing inducing agent, (2) intermittently with the flushing inducing agent, (3) staggered relative to administration of the flushing inducing agent, (4) prior to administration of the flushing inducing agent, (5) subsequent to administration of the flushing inducing agent, and (6) various combination thereof. Exemplary flushing inducing agents

include, for example, niacin, faloxifene, antidepressants, anti-psychotics, chemotherapeutics, calcium channel blockers, and antibiotics.

In one embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used to reduce flushing side effects of a vasodilator or an antilipemic agent (including anticholesteremic agents and lipotropic agents). In an exemplary embodiment, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be used to reduce flushing associated with the administration of niacin.

Nicotinic acid, 3-pyridinecarboxylic acid or niacin, is an antilipidemic agent that is marketed under, for example, the trade names Nicolar®, SloNiacin®, Nicobid® and Time Release Niacin®. Nicotinic acid has been used for many years in the treatment of lipidemic disorders such as hyperlipidemia, hypercholesterolemia and atherosclerosis. This compound has long been known to exhibit the beneficial effects of reducing total cholesterol, low density lipoproteins or "LDL cholesterol," triglycerides and apolipoprotein a (Lp(a)) in the human body, while increasing desirable high density lipoproteins or "HDL cholesterol".

Typical doses range from about 1 gram to about 3 grams daily. Nicotinic acid is normally administered two to four times per day after meals, depending upon the dosage form selected. Nicotinic acid is currently commercially available in two dosage forms. One dosage form is an immediate or rapid release tablet which should be administered three or four times per day. Immediate release ("IR") nicotinic acid formulations generally release nearly all of their nicotinic acid within about 30 to 60 minutes following ingestion. The other dosage form is a sustained release form which is suitable for administration two to four times per day. In contrast to IR formulations, sustained release ("SR") nicotinic acid formulations are designed to release significant quantities of drug for absorption into the blood stream over specific timed intervals in order to maintain therapeutic levels of nicotinic acid over an extended period such as 12 or 24 hours after ingestion.

As used herein, the term “nicotinic acid” is meant to encompass nicotinic acid or a compound other than nicotinic acid itself which the body metabolizes into nicotinic acid, thus producing essentially the same effect as nicotinic acid. Exemplary compounds that produce an effect similar to that of nicotinic acid include, for example, nicotinyl alcohol tartrate, d-glucitol hexanicotinate, aluminum nicotinate,

niceritrol and d,l-alpha-tocopheryl nicotinate. Each such compound will be collectively referred to herein as "nicotinic acid."

In another embodiment, the invention provides a method for treating and/or preventing hyperlipidemia with reduced flushing side effects. The method comprises the steps of administering to a subject in need thereof a therapeutically effective amount of nicotinic acid and a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein in an amount sufficient to reduce flushing. In an exemplary embodiment, the nicotinic acid and/or sirtuin-modulating compound may be administered nocturnally.

In another representative embodiment, the method involves the use of sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein to reduce flushing side effects of raloxifene. Raloxifene acts like estrogen in certain places in the body, but is not a hormone. It helps prevent osteoporosis in women who have reached menopause. Osteoporosis causes bones to gradually grow thin, fragile, and more likely to break. Evista slows down the loss of bone mass that occurs with menopause, lowering the risk of spine fractures due to osteoporosis. A common side effect of raloxifene is hot flashes (sweating and flushing). This can be uncomfortable for women who already have hot flashes due to menopause.

In another representative embodiment, the method involves the use of sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein to reduce flushing side effects of antidepressants or anti-psychotic agent. For instance, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein can be used in conjunction (administered separately or together) with a serotonin reuptake inhibitor, a 5HT2 receptor antagonist, an anticonvulsant, a norepinephrine reuptake inhibitor, an α-adrenoreceptor antagonist, an NK-3 antagonist, an NK-1 receptor antagonist, a PDE4 inhibitor, an Neuropeptide Y5 Receptor Antagonists, a D4 receptor antagonist, a 5HT1A receptor antagonist, a 5HT1D receptor antagonist, a CRF antagonist, a monoamine oxidase inhibitor, or a sedative-hypnotic drug.

In certain embodiments, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used as part of a treatment with a serotonin reuptake inhibitor (SRI) to reduce flushing. In certain preferred embodiments, the SRI is a selective serotonin reuptake inhibitor (SSRI), such as a fluoxetinoid

(fluoxetine, norfluoxetine) or a nefazodonoid (nefazodone, hydroxynefazodone, oxonefazodone). Other exemplary SSRI's include duloxetine, venlafaxine, milnacipran, citalopram, fluvoxamine, paroxetine and sertraline. The sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein can also be used as part of a treatment with sedative-hypnotic drug, such as selected from a benzodiazepine (such as alprazolam, chlordiazepoxide, clonazepam, chlorazepate, clobazam, diazepam, halazepam, lorazepam, oxazepam and prazepam), zolpidem, and barbiturates. In still other embodiments, a sirtuin-modulating compound that increases the level and/or activity of a sirtuin protein may be used as part of a treatment with a 5-HT1A receptor partial agonist, such as selected from buspirone, flesinoxan, gepirone and ipsapirone. Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein can also used as part of a treatment with a norepinephrine reuptake inhibitor, such as selected from tertiary amine tricyclics and secondary amine tricyclics. Exemplary tertiary amine tricyclic include amitriptyline, clomipramine, doxepin, imipramine and trimipramine. Exemplary secondary amine tricyclic include amoxapine, desipramine, maprotiline, nortriptyline and protriptyline. In certain embodiments, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used as part of a treatment with a monoamine oxidase inhibitor, such as selected from isocarboxazid, phenelzine, tranylcypromine, selegiline and moclobemide.

In still another representative embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used to reduce flushing side effects of chemotherapeutic agents, such as cyclophosphamide, tamoxifen.

In another embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used to reduce flushing side effects of calcium channel blockers, such as amlodipine.

In another embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used to reduce flushing side effects of antibiotics. For example, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein can be used in combination with levofloxacin. Levofloxacin is used to treat infections of the sinuses, skin, lungs, ears, airways, bones, and joints caused by susceptible bacteria. Levofloxacin also is frequently used to treat urinary infections, including those resistant to other antibiotics, as well as prostatitis. Levofloxacin is effective in treating infectious diarrheas caused by E. coli,

campylobacter jejuni, and shigella bacteria. Levofloxacin also can be used to treat various obstetric infections, including mastitis.

Ocular Disorders

One aspect of the present invention is a method for inhibiting, reducing or otherwise treating vision impairment by administering to a patient a therapeutic dosage of sirtuin modulator selected from a compound disclosed herein, or a pharmaceutically acceptable salt, prodrug or a metabolic derivative thereof.

In certain aspects of the invention, the vision impairment is caused by damage to the optic nerve or central nervous system. In particular embodiments, optic nerve damage is caused by high intraocular pressure, such as that created by glaucoma. In other particular embodiments, optic nerve damage is caused by swelling of the nerve, which is often associated with an infection or an immune (e.g., autoimmune) response such as in optic neuritis.

Glaucoma describes a group of disorders which are associated with a visual field defect, cupping of the optic disc, and optic nerve damage. These are commonly referred to as glaucomatous optic neuropathies. Most glaucomas are usually, but not always, associated with a rise in intraocular pressure. Exemplary forms of glaucoma include Glaucoma and Penetrating Keratoplasty, Acute Angle Closure, Chronic Angle Closure, Chronic Open Angle, Angle Recession, Aphakic and Pseudophakic, Drug-Induced, Hyphema, Intraocular Tumors, Juvenile, Lens-Particle, Low Tension, Malignant, Neovascular, Phacolytic, Phacomorphic, Pigmentary, Plateau Iris, Primary Congenital, Primary Open Angle, Pseudoexfoliation, Secondary Congenital, Adult Suspect, Unilateral, Uveitic, Ocular Hypertension, Ocular Hypotony, Posner-Schlossman Syndrome and Scleral Expansion Procedure in Ocular Hypertension & Primary Open-angle Glaucoma.

Intraocular pressure can also be increased by various surgical procedures, such as phacoemulsification (i.e., cataract surgery) and implanation of structures such as an artificial lens. In addition, spinal surgeries in particular, or any surgery in which the patient is prone for an extended period of time can lead to increased interoccular pressure.

Optic neuritis (ON) is inflammation of the optic nerve and causes acute loss of vision. It is highly associated with multiple sclerosis (MS) as 15-25% of MS patients initially present with ON, and 50-75% of ON patients are diagnosed with MS. ON is

also associated with infection (e.g., viral infection, meningitis, syphilis), inflammation (e.g., from a vaccine), infiltration and ischemia.

Another condition leading to optic nerve damage is anterior ischemic optic neuropathy (AION). There are two types of AION. Arteritic AION is due to giant cell arteritis (vasculitis) and leads to acute vision loss. Non-arteritic AION encompasses all cases of ischemic optic neuropathy other than those due to giant cell arteritis. The pathophysiology of AION is unclear although it appears to incorporate both inflammatory and ischemic mechanisms.

Other damage to the optic nerve is typically associated with demyleination, inflammation, ischemia, toxins, or trauma to the optic nerve. Exemplary conditions where the optic nerve is damaged include Demyelinating Optic Neuropathy (Optic Neuritis, Retrobulbar Optic Neuritis), Optic Nerve Sheath Meningioma, Adult Optic Neuritis, Childhood Optic Neuritis, Anterior Ischemic Optic Neuropathy, Posterior Ischemic Optic Neuropathy, Compressive Optic Neuropathy, Papilledema, Pseudopapilledema and Toxic/Nutritional Optic Neuropathy.

Other neurological conditions associated with vision loss, albeit not directly associated with damage to the optic nerve, include Amblyopia, Bells Palsy, Chronic Progressive External Ophthalmoplegia, Multiple Sclerosis, Pseudotumor Cerebri and Trigeminal Neuralgia.

In certain aspects of the invention, the vision impairment is caused by retinal damage. In particular embodiments, retinal damage is caused by disturbances in blood flow to the eye (e.g., arteriosclerosis, vasculitis). In particular embodiments, retinal damage is caused by disrupton of the macula (e.g., exudative or non-exudative macular degeneration).

Exemplary retinal diseases include Exudative Age Related Macular Degeneration, Nonexudative Age Related Macular Degeneration, Retinal Electronic Prosthesis and RPE Transplantation Age Related Macular Degeneration, Acute Multifocal Placoid Pigment Epitheliopathy, Acute Retinal Necrosis, Best Disease, Branch Retinal Artery Occlusion, Branch Retinal Vein Occlusion, Cancer Associated and Related Autoimmune Retinopathies, Central Retinal Artery Occlusion, Central Retinal Vein Occlusion, Central Serous Chorioretinopathy, Eales Disease, Epimacular Membrane, Lattice Degeneration, Macroaneurysm, Diabetic Macular Edema, Irvine-Gass Macular Edema, Macular Hole, Subretinal Neovascular Membranes, Diffuse Unilateral Subacute Neuroretinitis, Nonpseudophakic Cystoid Macular Edema,

Presumed Ocular Histoplasmosis Syndrome, Exudative Retinal Detachment, Postoperative Retinal Detachment, Proliferative Retinal Detachment, Rhegmatogenous Retinal Detachment, Tractional Retinal Detachment, Retinitis Pigmentosa, CMV Retinitis, Retinoblastoma, Retinopathy of Prematurity, Birdshot Retinopathy, Background Diabetic Retinopathy, Proliferative Diabetic Retinopathy, Hemoglobinopathies Retinopathy, Purtscher Retinopathy, Valsalva Retinopathy, Juvenile Retinoschisis, Senile Retinoschisis, Terson Syndrome and White Dot Syndromes.

Other exemplary diseases include ocular bacterial infections (e.g. conjunctivitis, keratitis, tuberculosis, syphilis, gonorrhea), viral infections (e.g. Ocular Herpes Simplex Virus, Varicella Zoster Virus, Cytomegalovirus retinitis, Human Immunodeficiency Virus (HIV)) as well as progressive outer retinal necrosis secondary to HIV or other HIV-associated and other immunodeficiency-associated ocular diseases. In addition, ocular diseases include fungal infections (e.g. Candida choroiditis, histoplasmosis), protozoal infections (e.g. toxoplasmosis) and others such as ocular toxocariasis and sarcoidosis.

One aspect of the invention is a method for inhibiting, reducing or treating vision impairment in a subject undergoing treatment with a chemotherapeutic drug (e.g., a neurotoxic drug, a drug that raises intraocular pressure such as a steroid), by administering to the subject in need of such treatment a therapeutic dosage of a sirtuin modulator disclosed herein.

Another aspect of the invention is a method for inhibiting, reducing or treating vision impairment in a subject undergoing surgery, including ocular or other surgeries performed in the prone position such as spinal cord surgery, by administering to the subject in need of such treatment a therapeutic dosage of a sirtuin modulator disclosed herein. Ocular surgeries include cataract, iridotomy and lens replacements.

Another aspect of the invention is the treatment, including inhibition and prophylactic treatment, of age related ocular diseases include cataracts, dry eye, retinal damage and the like, by administering to the subject in need of such treatment a therapeutic dosage of a sirtuin modulator disclosed herein.

The formation of cataracts is associated with several biochemical changes in the lens of the eye, such as decreased levels of antioxidants ascorbic acid and glutathione, increased lipid, amino acid and protein oxidation, increased sodium and calcium, loss of amino acids and decreased lens metabolism. The lens, which lacks

blood vessels, is suspended in extracellular fluids in the anterior part of the eye. Nutrients, such as ascorbic acid, glutathione, vitamin E, selenium, bioflavonoids and carotenoids are required to maintain the transparency of the lens. Low levels of selenium results in an increase of free radical-inducing hydrogen peroxide, which is neutralized by the selenium-dependent antioxidant enzyme glutathione peroxidase. Lens-protective glutathione peroxidase is also dependent on the amino acids methionine, cysteine, glycine and glutamic acid.

Cataracts can also develop due to an inability to properly metabolize galactose found in dairy products that contain lactose, a disaccharide composed of the monosaccharide galactose and glucose. Cataracts can be prevented, delayed, slowed and possibly even reversed if detected early and metabolically corrected.

Retinal damage is attributed, *inter alia*, to free radical initiated reactions in glaucoma, diabetic retinopathy and age-related macular degeneration (AMD). The eye is a part of the central nervous system and has limited regenerative capability. The retina is composed of numerous nerve cells which contain the highest concentration of polyunsaturated fatty acids (PFA) and subject to oxidation. Free radicals are generated by UV light entering the eye and mitochondria in the rods and cones, which generate the energy necessary to transform light into visual impulses. Free radicals cause peroxidation of the PFA by hydroxyl or superoxide radicals which in turn propagate additional free radicals. The free radicals cause temporary or permanent damage to retinal tissue.

Glaucoma is usually viewed as a disorder that causes an elevated intraocular pressure (IOP) that results in permanent damage to the retinal nerve fibers, but a sixth of all glaucoma cases do not develop an elevated IOP. This disorder is now perceived as one of reduced vascular perfusion and an increase in neurotoxic factors. Recent studies have implicated elevated levels of glutamate, nitric oxide and peroxynitirite in the eye as the causes of the death of retinal ganglion cells. Neuroprotective agents may be the future of glaucoma care. For example, nitric oxide synthase inhibitors block the formation of peroxynitrite from nitric oxide and superoxide. In a recent study, animals treated with aminoguanidine, a nitric oxide synthase inhibitor, had a reduction in the loss of retinal ganglion cells. It was concluded that nitric oxide in the eye caused cytotoxicity in many tissues and neurotoxicity in the central nervous system.

Diabetic retinopathy occurs when the underlying blood vessels develop microvascular abnormalities consisting primarily of microaneurysms and intraretinal hemorrhages. Oxidative metabolites are directly involved with the pathogenesis of diabetic retinopathy and free radicals augment the generation of growth factors that lead to enhanced proliferative activity. Nitric oxide produced by endothelial cells of the vessels may also cause smooth muscle cells to relax and result in vasodilation of segments of the vessel. Ischemia and hypoxia of the retina occur after thickening of the arterial basement membrane, endothelial proliferation and loss of pericytes. The inadequate oxygenation causes capillary obliteration or nonperfusion, arteriolar-venular shunts, sluggish blood flow and an impaired ability of RBCs to release oxygen. Lipid peroxidation of the retinal tissues also occurs as a result of free radical damage.

The macula is responsible for our acute central vision and composed of light-sensing cells (cones) while the underlying retinal pigment epithelium (RPE) and choroid nourish and help remove waste materials. The RPE nourishes the cones with the vitamin A substrate for the photosensitive pigments and digests the cones shed outer tips. RPE is exposed to high levels of UV radiation, and secretes factors that inhibit angiogenesis. The choroid contains a dense vascular network that provides nutrients and removes the waste materials.

In AMD, the shed cone tips become indigestible by the RPE, where the cells swell and die after collecting too much undigested material. Collections of undigested waste material, called drusen, form under the RPE. Photoxic damage also causes the accumulation of lipofuscin in RPE cells. The intracellular lipofuscin and accumulation of drusen in Bruch's membrane interferes with the transport of oxygen and nutrients to the retinal tissues, and ultimately leads to RPE and photoreceptor dysfunction. In exudative AMD, blood vessels grow from the choriocapillaris through defects in Bruch's membrane and may grow under the RPE, detaching it from the choroid, and leaking fluid or bleeding.

Macular pigment, one of the protective factors that prevent sunlight from damaging the retina, is formed by the accumulation of nutritionally derived carotenoids, such as lutein, the fatty yellow pigment that serves as a delivery vehicle for other important nutrients and zeaxanthin. Antioxidants such as vitamins C and E, beta-carotene and lutein, as well as zinc, selenium and copper, are all found in the

healthy macula. In addition to providing nourishment, these antioxidants protect against free radical damage that initiates macular degeneration.

Another aspect of the invention is the prevention or treatment of damage to the eye caused by stress, chemical insult or radiation, by administering to the subject in need of such treatment a therapeutic dosage of a sirtuin modulator disclosed herein. Radiation or electromagnetic damage to the eye can include that caused by CRT's or exposure to sunlight or UV.

In one embodiment, a combination drug regimen may include drugs or compounds for the treatment or prevention of ocular disorders or secondary conditions associated with these conditions. Thus, a combination drug regimen may include one or more sirtuin activators and one or more therapeutic agents for the treatment of an ocular disorder. For example, one or more sirtuin-activating compounds can be combined with an effective amount of one or more of: an agent that reduces intraocular pressure, an agent for treating glaucoma, an agent for treating optic neuritis, an agent for treating CMV Retinopathy, an agent for treating multiple sclerosis, and/or an antibiotic, etc.

In one embodiment, a sirtuin modulator can be administered in conjunction with a therapy for reducing intraocular pressure. One group of therapies involves blocking aqueous production. For example, topical beta-adrenergic antagonists (timolol and betaxolol) decrease aqueous production. Topical timolol causes IOP to fall in 30 minutes with peak effects in 1-2 hours. A reasonable regimen is Timoptic 0.5%, one drop every 30 minutes for 2 doses. The carbonic anhydrase inhibitor, acetazolamide, also decreases aqueous production and should be given in conjunction with topical beta-antagonists. An initial dose of 500 mg is administered followed by 250 mg every 6 hours. This medication may be given orally, intramuscularly, or intravenously. In addition, alpha 2-agonists (e.g., Apraclonidine) act by decreasing aqueous production. Their effects are additive to topically administered beta-blockers. They have been approved for use in controlling an acute rise in pressure following anterior chamber laser procedures, but has been reported effective in treating acute closed-angle glaucoma. A reasonable regimen is 1 drop every 30 minutes for 2 doses.

A second group of therapies for reducing intraocular pressure involve reducing vitreous volume. Hyperosmotic agents can be used to treat an acute attack. These agents draw water out of the globe by making the blood hyperosmolar. Oral glycerol in a dose of 1 mL/kg in a cold 50% solution (mixed with lemon juice to make it more

palatable) often is used. Glycerol is converted to glucose in the liver; persons with diabetes may need additional insulin if they become hyperglycemic after receiving glycerol. Oral isosorbide is a metabolically inert alcohol that also can be used as an osmotic agent for patients with acute angle-closure glaucoma. Usual dose is 100 g taken p.o. (220 cc of a 45% solution). This inert alcohol should not be confused with isosorbide dinitrate, a nitrate-based cardiac medication used for angina and for congestive heart failure. Intravenous mannitol in a dose of 1.0-1.5 mg/kg also is effective and is well tolerated in patients with nausea and vomiting. These hyperosmotic agents should be used with caution in any patient with a history of congestive heart failure.

A third group of therapies involve facilitating aqueous outflow from the eye. Miotic agents pull the iris from the iridocorneal angle and may help to relieve the obstruction of the trabecular meshwork by the peripheral iris. Pilocarpine 2% (blue eyes)-4% (brown eyes) can be administered every 15 minutes for the first 1-2 hours. More frequent administration or higher doses may precipitate a systemic cholinergic crisis. NSAIDS are sometimes used to reduce inflammation.

Exemplary therapeutic agents for reducing intraocular pressure include ALPHAGAN® P (Allergan) (brimonidine tartrate ophthalmic solution), AZOPT® (Alcon) (brinzolamide ophthalmic suspension), BETAGAN® (Allergan) (levobunolol hydrochloride ophthalmic solution, USP), BETIMOL® (Vistakon) (timolol ophthalmic solution), BETOPTIC S® (Alcon) (betaxolol HCl), BRIMONIDINE TARTRATE (Bausch & Lomb), CARTEOLOL HYDROCHLORIDE (Bausch & Lomb), COSOPT® (Merck) (dorzolamide hydrochloride-timolol maleate ophthalmic solution), LUMIGAN® (Allergan) (bimatoprost ophthalmic solution), OPTIPRANOLOL® (Bausch & Lomb) (metipranolol ophthalmic solution), TIMOLOL GFS (Falcon) (timolol maleate ophthalmic gel forming solution), TIMOPTIC® (Merck) (timolol maleate ophthalmic solution), TRAVATAN® (Alcon) (travoprost ophthalmic solution), TRUSOPT® (Merck) (dorzolamide hydrochloride ophthalmic solution) and XALATAN® (Pharmacia & Upjohn) (latanoprost ophthalmic solution).

In one embodiment, a sirtuin modulator can be administered in conjunction with a therapy for treating and/or preventing glaucoma. An example of a glaucoma drug is DARANIDE® Tablets (Merck) (Dichlorphenamide).

In one embodiment, a sirtuin modulator can be administered in conjunction with a therapy for treating and/or preventing optic neuritis. Examples of drugs for optic neuritis include DECADRON® Phosphate Injection (Merck) (Dexamethasone Sodium Phosphate), DEPO-MEDROL® (Pharmacia & Upjohn)(methylprednisolone acetate), HYDROCORTONE® Tablets (Merck) (Hydrocortisone), ORAPRED® (Biomarin) (prednisolone sodium phosphate oral solution) and PEDIAPRED® (Celltech) (prednisolone sodium phosphate, USP).

In one embodiment, a sirtuin modulator can be administered in conjunction with a therapy for treating and/or preventing CMV Retinopathy. Treatments for CMV retinopathy include CYTOVENE® (ganciclovir capsules) and VALCYTE® (Roche Laboratories) (valganciclovir hydrochloride tablets).

In one embodiment, a sirtuin modulator can be administered in conjunction with a therapy for treating and/or preventing multiple sclerosis. Examples of such drugs include DANTRIUM® (Procter & Gamble Pharmaceuticals) (dantrolene sodium), NOVANTRONE® (Serono) (mitoxantrone), AVONEX® (Biogen Idec) (Interferon beta-1a), BETASERON® (Berlex) (Interferon beta-1b), COPAXONE® (Teva Neuroscience) (glatiramer acetate injection) and REBIF® (Pfizer) (interferon beta-1a).

In addition, macrolide and/or mycophenolic acid, which has multiple activities, can be co-administered with a sirtuin modulator. Macrolide antibiotics include tacrolimus, cyclosporine, sirolimus, everolimus, ascomycin, erythromycin, azithromycin, clarithromycin, clindamycin, lincomycin, dirithromycin, josamycin, spiramycin, diacetyl-midecamycin, tylosin, roxithromycin, ABT-773, telithromycin, leucomycins, and lincosamide.

Mitochondrial-Associated Diseases and Disorders

In certain embodiments, the invention provides methods for treating diseases or disorders that would benefit from increased mitochondrial activity. The methods involve administering to a subject in need thereof a therapeutically effective amount of a sirtuin activating compound. Increased mitochondrial activity refers to increasing activity of the mitochondria while maintaining the overall numbers of mitochondria (e.g., mitochondrial mass), increasing the numbers of mitochondria thereby increasing mitochondrial activity (e.g., by stimulating mitochondrial biogenesis), or combinations thereof. In certain embodiments, diseases and disorders that would

benefit from increased mitochondrial activity include diseases or disorders associated with mitochondrial dysfunction.

In certain embodiments, methods for treating diseases or disorders that would benefit from increased mitochondrial activity may comprise identifying a subject suffering from a mitochondrial dysfunction. Methods for diagnosing a mitochondrial dysfunction may involve molecular genetic, pathologic and/or biochemical analysis are summarized in Cohen and Gold, Cleveland Clinic Journal of Medicine, 68: 625-642 (2001). One method for diagnosing a mitochondrial dysfunction is the Thor-Byrne-ier scale (see e.g., Cohen and Gold, *supra*; Collin S. et al., Eur Neurol. 36: 260-267 (1996)). Other methods for determining mitochondrial number and function include, for example, enzymatic assays (e.g., a mitochondrial enzyme or an ATP biosynthesis factor such as an ETC enzyme or a Krebs cycle enzyme), determination or mitochondrial mass, mitochondrial volume, and/or mitochondrial number, quantification of mitochondrial DNA, monitoring intracellular calcium homeostasis and/or cellular responses to perturbations of this homeostasis, evaluation of response to an apoptogenic stimulus, determination of free radical production. Such methods are known in the art and are described, for example, in U.S. Patent Publication No. 2002/0049176 and references cited therein.

Mitochondria are critical for the survival and proper function of almost all types of eukaryotic cells. Mitochondria in virtually any cell type can have congenital or acquired defects that affect their function. Thus, the clinically significant signs and symptoms of mitochondrial defects affecting respiratory chain function are heterogeneous and variable depending on the distribution of defective mitochondria among cells and the severity of their deficits, and upon physiological demands upon the affected cells. Nondividing tissues with high energy requirements, e.g. nervous tissue, skeletal muscle and cardiac muscle are particularly susceptible to mitochondrial respiratory chain dysfunction, but any organ system can be affected.

Diseases and disorders associated with mitochondrial dysfunction include diseases and disorders in which deficits in mitochondrial respiratory chain activity contribute to the development of pathophysiology of such diseases or disorders in a mammal. This includes 1) congenital genetic deficiencies in activity of one or more components of the mitochondrial respiratory chain; and 2) acquired deficiencies in the activity of one or more components of the mitochondrial respiratory chain, wherein such deficiencies are caused by a) oxidative damage during aging; b) elevated

intracellular calcium; c) exposure of affected cells to nitric oxide; d) hypoxia or ischemia; e) microtubule-associated deficits in axonal transport of mitochondria, or f) expression of mitochondrial uncoupling proteins.

Diseases or disorders that would benefit from increased mitochondrial activity generally include for example, diseases in which free radical mediated oxidative injury leads to tissue degeneration, diseases in which cells inappropriately undergo apoptosis, and diseases in which cells fail to undergo apoptosis. Exemplary diseases or disorders that would benefit from increased mitochondrial activity include, for example, AD (Alzheimer's Disease), ADPD (Alzheimer's Disease and Parkinsons's Disease), AMDF (Ataxia, Myoclonus and Deafness), auto-immune disease, cancer, CIPO (Chronic Intestinal Pseudoobstruction with myopathy and Ophthalmoplegia), congenital muscular dystrophy, CPEO (Chronic Progressive External Ophthalmoplegia), DEAF (Maternally inherited DEAFness or aminoglycoside-induced DEAFness), DEMCHO (Dementia and Chorea), diabetes mellitus (Type I or Type II), DIDMOAD (Diabetes Insipidus, Diabetes Mellitus, Optic Atrophy, Deafness), DMDF (Diabetes Mellitus and Deafness), dystonia, Exercise Intolerance, ESOC (Epilepsy, Strokes, Optic atrophy, and Cognitive decline), FBSN (Familial Bilateral Striatal Necrosis), FICP (Fatal Infantile Cardiomyopathy Plus, a MELAS-associated cardiomyopathy), GER (Gastrointestinal Reflux), HD (Huntington's Disease), KSS (Kearns Sayre Syndrome), "later-onset" myopathy, LDYT (Leber's hereditary optic neuropathy and DYsTonia), Leigh's Syndrome, LHON (Leber Hereditary Optic Neuropathy), LIMM (Lethal Infantile Mitochondrial Myopathy), MDM (Myopathy and Diabetes Mellitus), MELAS (Mitochondrial Encephalomyopathy, Lactic Acidosis, and Stroke-like episodes), MEPR (Myoclonic Epilepsy and Psychomotor Regression), MERME (MERRF/MELAS overlap disease), MERRF (Myoclonic Epilepsy and Ragged Red Muscle Fibers), MHCM (Maternally Inherited Hypertrophic CardioMyopathy), MICM (Maternally Inherited Cardiomyopathy), MILS (Maternally Inherited Leigh Syndrome), Mitochondrial Encephalocardiomyopathy, Mitochondrial Encephalomyopathy, MM (Mitochondrial Myopathy), MMC (Maternal Myopathy and Cardiomyopathy), MNGIE (Myopathy and external ophthalmoplegia, Neuropathy, Gastro-Intestinal, Encephalopathy), Multisystem Mitochondrial Disorder (myopathy, encephalopathy, blindness, hearing loss, peripheral neuropathy), NARP (Neurogenic muscle weakness, Ataxia, and Retinitis Pigmentosa; alternate phenotype at this locus is reported as Leigh Disease),

PD (Parkinson's Disease), Pearson's Syndrome, PEM (Progressive Encephalopathy), PEO (Progressive External Ophthalmoplegia), PME (Progressive Myoclonus Epilepsy), PMPS (Pearson Marrow-Pancreas Syndrome), psoriasis, RTT (Rett Syndrome), schizophrenia, SIDS (Sudden Infant Death Syndrome), SNHL (Sensorineural Hearing Loss), Varied Familial Presentation (clinical manifestations range from spastic paraparesis to multisystem progressive disorder & fatal cardiomyopathy to truncal ataxia, dysarthria, severe hearing loss, mental regression, ptosis, ophthalmoparesis, distal cyclones, and diabetes mellitus), or Wolfram syndrome.

Other diseases and disorders that would benefit from increased mitochondrial activity include, for example, Friedreich's ataxia and other ataxias, amyotrophic lateral sclerosis (ALS) and other motor neuron diseases, macular degeneration, epilepsy, Alpers syndrome, Multiple mitochondrial DNA deletion syndrome, MtDNA depletion syndrome, Complex I deficiency, Complex II (SDH) deficiency, Complex III deficiency, Cytochrome c oxidase (COX, Complex IV) deficiency, Complex V deficiency, Adenine Nucleotide Translocator (ANT) deficiency, Pyruvate dehydrogenase (PDH) deficiency, Ethylmalonic aciduria with lactic acidemia, 3-Methyl glutaconic aciduria with lactic acidemia, Refractory epilepsy with declines during infection, Asperger syndrome with declines during infection, Autism with declines during infection, Attention deficit hyperactivity disorder (ADHD), Cerebral palsy with declines during infection, Dyslexia with declines during infection, materially inherited thrombocytopenia and leukemia syndrome, MARIAHS syndrome (Mitrochondrial ataxia, recurrent infections, aphasia, hypouricemia/hypomyelination, seizures, and dicarboxylic aciduria), ND6 dystonia, Cyclic vomiting syndrome with declines during infection, 3-Hydroxy isobutryic aciduria with lactic acidemia, Diabetes mellitus with lactic acidemia, Uridine responsive neurologic syndrome (URNS), Dilated cardiomyopathy, Splenic Lymphoma, and Renal Tubular Acidosis/Diabetes/Ataxis syndrome.

In other embodiments, the invention provides methods for treating a subject suffering from mitochondrial disorders arising from, but not limited to, post-traumatic head injury and cerebral edema, stroke (invention methods useful for preventing or preventing reperfusion injury), Lewy body dementia, hepatorenal syndrome, acute liver failure, NASH (non-alcoholic steatohepatitis), Anti-metastasis/prodifferentiation therapy of cancer, idiopathic congestive heart failure, atrial fibrilation (non-valvular),

Wolff-Parkinson-White Syndrome, idiopathic heart block, prevention of reperfusion injury in acute myocardial infarctions, familial migraines, irritable bowel syndrome, secondary prevention of non-Q wave myocardial infarctions, Premenstrual syndrome, Prevention of renal failure in hepatorenal syndrome, anti-phospholipid antibody syndrome, eclampsia/pre-eclampsia, oopause infertility, ischemic heart disease/angina, and Shy-Drager and unclassified dysautonomia syndromes.

In still another embodiment, there are provided methods for the treatment of mitochondrial disorders associated with pharmacological drug-related side effects. Types of pharmaceutical agents that are associated with mitochondrial disorders include reverse transcriptase inhibitors, protease inhibitors, inhibitors of DHOD, and the like. Examples of reverse transcriptase inhibitors include, for example, Azidothymidine (AZT), Stavudine (D4T), Zalcitabine (ddC), Didanosine (DDI), Fluoroiodoarauracil (FIAU), Lamivudine (3TC), Abacavir and the like. Examples of protease inhibitors include, for example, Ritonavir, Indinavir, Saquinavir, Nelfinavir and the like. Examples of inhibitors of dihydroorotate dehydrogenase (DHOD) include, for example, Leflunomide, Brequinar, and the like.

Reverse transcriptase inhibitors not only inhibit reverse transcriptase but also polymerase gamma which is required for mitochondrial function. Inhibition of polymerase gamma activity (e.g., with a reverse transcriptase inhibitor) therefore leads to mitochondrial dysfunction and/or a reduced mitochondrial mass which manifests itself in patients as hyperlactatemia. This type of condition may benefit from an increase in the number of mitochondria and/or an improvement in mitochondrial function, e.g., by administration of a sirtuin activating compound.

Common symptoms of mitochondrial diseases include cardiomyopathy, muscle weakness and atrophy, developmental delays (involving motor, language, cognitive or executive function), ataxia, epilepsy, renal tubular acidosis, peripheral neuropathy, optic neuropathy, autonomic neuropathy, neurogenic bowel dysfunction, sensorineural deafness, neurogenic bladder dysfunction, dilating cardiomyopathy, migraine, hepatic failure, lactic acidemia, and diabetes mellitus.

In certain embodiments, the invention provides methods for treating a disease or disorder that would benefit from increased mitochondrial activity that involves administering to a subject in need thereof one or more sirtuin activating compounds in combination with another therapeutic agent such as, for example, an agent useful for treating mitochondrial dysfunction (such as antioxidants, vitamins, or respiratory

chain cofactors), an agent useful for reducing a symptom associated with a disease or disorder involving mitochondrial dysfunction (such as, an anti-seizure agent, an agent useful for alleviating neuropathic pain, an agent for treating cardiac dysfunction), a cardiovascular agent (as described further below), a chemotherapeutic agent (as described further below), or an anti-neurodegeneration agent (as described further below). In an exemplary embodiment, the invention provides methods for treating a disease or disorder that would benefit from increased mitochondrial activity that involves administering to a subject in need thereof one or more sirtuin activating compounds in combination with one or more of the following: coenzyme Q_{10}, L-carnitine, thiamine, riboflavin, niacinamide, folate, vitamin E, selenium, lipoic acid, or prednisone. Compositions comprising such combinations are also provided herein.

In exemplary embodiments, the invention provides methods for treating diseases or disorders that would benefit from increased mitochondrial acitivty by administering to a subject a therapeutically effective amount of a sirtuin activating compound. Exemplary diseases or disorders include, for example, neuromuscular disorders (e.g., Friedreich's Ataxia, muscular dystrophy, multiple sclerosis, etc.), disorders of neuronal instability (e.g., seizure disorders, migrane, etc.), developmental delay, neurodegenerative disorders (e.g., Alzheimer's Disease, Parkinson's Disease, amyotrophic lateral sclerosis, etc.), ischemia, renal tubular acidosis, age-related neurodegeneration and cognitive decline, chemotherapy fatigue, age-related or chemotherapy-induced menopause or irregularities of menstrual cycling or ovulation, mitochondrial myopathies, mitochondrial damage (e.g., calcium accumulation, excitotoxicity, nitric oxide exposure, hypoxia, etc.), and mitochondrial deregulation.

A gene defect underlying Friedreich's Ataxia (FA), the most common hereditary ataxia, was recently identified and is designated "frataxin". In FA, after a period of normal development, deficits in coordination develop which progress to paralysis and death, typically between the ages of 30 and 40. The tissues affected most severely are the spinal cord, peripheral nerves, myocardium, and pancreas. Patients typically lose motor control and are confined to wheel chairs, and are commonly afflicted with heart failure and diabetes. The genetic basis for FA involves GAA trinucleotide repeats in an intron region of the gene encoding frataxin. The presence of these repeats results in reduced transcription and expression of the gene. Frataxin is involved in regulation of mitochondrial iron content. When cellular frataxin content is subnormal, excess iron accumulates in mitochondria, promoting

oxidative damage and consequent mitochondrial degeneration and dysfunction. When intermediate numbers of GAA repeats are present in the frataxin gene intron, the severe clinical phenotype of ataxia may not develop. However, these intermediate-length trinucleotide extensions are found in 25 to 30% of patients with non-insulin dependent diabetes mellitus, compared to about 5% of the nondiabetic population. In certain embodiments, sirtuin activating compounds may be used for treating patients with disorders related to deficiencies or defects in frataxin, including Friedreich's Ataxia, myocardial dysfunction, diabetes mellitus and complications of diabetes like peripheral neuropathy.

Muscular dystrophy refers to a family of diseases involving deterioration of neuromuscular structure and function, often resulting in atrophy of skeletal muscle and myocardial dysfunction. In the case of Duchenne muscular dystrophy, mutations or deficits in a specific protein, dystrophin, are implicated in its etiology. Mice with their dystrophin genes inactivated display some characteristics of muscular dystrophy, and have an approximately 50% deficit in mitochondrial respiratory chain activity. A final common pathway for neuromuscular degeneration in most cases is calcium-mediated impairment of mitochondrial function. In certain embodiments, sirtuin activating compounds may be used for reducing the rate of decline in muscular functional capacities and for improving muscular functional status in patients with muscular dystrophy.

Multiple sclerosis (MS) is a neuromuscular disease characterized by focal inflammatory and autoimmune degeneration of cerebral white matter. Periodic exacerbations or attacks are significantly correlated with upper respiratory tract and other infections, both bacterial and viral, indicating that mitochondrial dysfunction plays a role in MS. Depression of neuronal mitochondrial respiratory chain activity caused by Nitric Oxide (produced by astrocytes and other cells involved in inflammation) is implicated as a molecular mechanism contributing to MS. In certain embodiments, sirtuin activating compounds may be used for treatment of patients with multiple sclerosis, both prophylactically and during episodes of disease exacerbation.

Epilepsy is often present in patients with mitochondrial cytopathies, involving a range of seizure severity and frequency, e.g. absence, tonic, atonic, myoclonic, and status epilepticus, occurring in isolated episodes or many times daily. In certain embodiments, sirtuin activating compounds may be used for treating patients with

seizures secondary to mitochondrial dysfunction, including reducing frequency and severity of seizure activity.

Metabolic studies on patients with recurrent migraine headaches indicate that deficits in mitochondrial activity are commonly associated with this disorder, manifesting as impaired-oxidative phosphorylation and excess lactate production. Such deficits are not necessarily due to genetic defects in mitochondrial DNA. Migraineurs are hypersensitive to nitric oxide, an endogenous inhibitor of Cytochrome c Oxidase. In addition, patients with mitochondrial cytopathies, e.g. MELAS, often have recurrent migraines. In certain embodiments, sirtuin activating compounds may be used for treating patients with recurrent migraine headaches, including headaches refractory to ergot compounds or serotonin receptor antagonists.

Delays in neurological or neuropsychological development are often found in children with mitochondrial diseases. Development and remodeling of neural connections requires intensive biosynthetic activity, particularly involving synthesis of neuronal membranes and myelin, both of which require pyrimidine nucleotides as cofactors. Uridine nucleotides are involved inactivation and transfer of sugars to glycolipids and glycoproteins. Cytidine nucleotides are derived from uridine nucleotides, and are crucial for synthesis of major membrane phospholipid constituents like phosphatidylcholine, which receives its choline moiety from cytidine diphosphocholine. In the case of mitochondrial dysfunction (due to either mitochondrial DNA defects or any of the acquired or conditional deficits like exicitoxic or nitric oxide-mediated mitochondrial dysfunction) or other conditions resulting in impaired pyrimidine synthesis, cell proliferation and axonal extension is impaired at crucial stages in development of neuronal interconnections and circuits, resulting in delayed or arrested development of neuropsychological functions like language, motor, social, executive function, and cognitive skills. In autism for example, magnetic resonance spectroscopy measurements of cerebral phosphate compounds indicates that there is global undersynthesis of membranes and membrane precursors indicated by reduced levels of uridine diphospho-sugars, and cytidine nucleotide derivatives involved in membrane synthesis. Disorders characterized by developmental delay include Rett's Syndrome, pervasive developmental delay (or PDD-NOS "pervasive developmental delay not otherwise specified" to distinguish it from specific subcategories like autism), autism, Asperger's Syndrome, and Attention Deficit/Hyperactivity Disorder (ADHD), which is becoming recognized as a delay or

lag in development of neural circuitry underlying executive functions. In certain embodiments, sirtuin activating compounds may be useful for treating treating patients with neurodevelopmental delays (e.g., involving motor, language, executive function, and cognitive skills), or other delays or arrests of neurological and neuropsychological development in the nervous system and somatic development in non-neural tissues like muscle and endocrine glands.

The two most significant severe neurodegenerative diseases associated with aging, Alzheimer's Disease (AD) and Parkinson's Disease (PD), both involve mitochondrial dysfunction in their pathogenesis. Complex I deficiencies in particular are frequently found not only in the nigrostriatal neurons that degenerate in Parkinson's disease, but also in peripheral tissues and cells like muscle and platelets of Parkinson's Disease patients. In Alzheimer's Disease, mitochondrial respiratory chain activity is often depressed, especially Complex IV (Cytochrome c Oxidase). Moreover, mitochondrial respiratory function altogether is depressed as a consequence of aging, further amplifying the deleterious sequelae of additional molecular lesions affecting respiratory chain function. Other factors in addition to primary mitochondrial dysfunction underlie neurodegeneration in AD, PD, and related disorders. Excitotoxic stimulation and nitric oxide are implicated in both diseases, factors which both exacerbate mitochondrial respiratory chain deficits and whose deleterious actions are exaggerated on a background of respiratory chain dysfunction. Huntington's Disease also involves mitochondrial dysfunction in affected brain regions, with cooperative interactions of excitotoxic stimulation and mitochondrial dysfunction contributing to neuronal degeneration. In certain embodiments, sirtuin activating compounds may be useful for treating and attenuating progression of age-related neurodegenerative diseases including AD and PD.

One of the major genetic defects in patients with Amyotrophic Lateral Sclerosis (ALS or Lou Gehrig's Disease) is mutation or deficiency in Copper-Zinc Superoxide Dismutase (SOD 1), an antioxidant enzyme. Mitochondria both produce and are primary targets for reactive oxygen species. Inefficient transfer of electrons to oxygen in mitochondria is the most significant physiological source of free radicals in mammalian systems. Deficiencies in antioxidants or antioxidant enzymes can result in or exacerbate mitochondrial degeneration. Mice transgenic for mutated SOD1 develop symptoms and pathology similar to those in human ALS. The development of the disease in these animals has been shown to involve oxidative destruction of

mitochondria followed by functional decline of motor neurons and onset of clinical symptoms. Skeletal muscle from ALS patients has low mitochondrial Complex I activity. In certain embodiments, sirtuin activating compounds may be useful for treating ALS, for reversing or slowing the progression of clinical symptoms.

Oxygen deficiency results in both direct inhibition of mitochondrial respiratory chain activity by depriving cells of a terminal electron acceptor for Cytochrome c reoxidation at Complex IV, and indirectly, especially in the nervous system, via secondary post-anoxic excitotoxicity and nitric oxide formation. In conditions like cerebral anoxia, angina or sickle cell anemia crises, tissues are relatively hypoxic. In such cases, compounds that increase mitochondrial activity provide protection of affected tissues from deleterious effects of hypoxia, attenuate secondary delayed cell death, and accelerate recovery from hypoxic tissue stress and injury. In certain embodiments, sirtuin activating compounds may be useful for preventing delayed cell death (apoptosis in regions like the hippocampus or cortex occurring about 2 to 5 days after an episode of cerebral ischemia) after ischemic or hypoxic insult to the brain.

Acidosis due to renal dysfunction is often observed in patients with mitochondrial disease, whether the underlying respiratory chain dysfunction is congenital or induced by ischemia or cytotoxic agents like cisplatin. Renal tubular acidosis often requires administration of exogenous sodium bicarbonate to maintain blood and tissue pH. In certain embodiments, sirtuin activating compounds may be useful for treating renal tubular acidosis and other forms of renal dysfunction caused by mitochondrial respiratory chain deficits.

During normal aging, there is a progressive decline in mitochondrial respiratory chain function. Beginning about age 40, there is an exponential rise in accumulation of mitochondrial DNA defects in humans, and a concurrent decline in nuclear-regulated elements of mitochondrial respiratory activity. Many mitochondrial DNA lesions have a selection advantage during mitochondrial turnover, especially in postmitotic cells. The proposed mechanism is that mitochondria with a defective respiratory chain produce less oxidative damage to themselves than do mitochondria with intact functional respiratory chains (mitochondrial respiration is the primary source of free radicals in the body). Therefore, normally-functioning mitochondria accumulate oxidative damage to membrane lipids more rapidly than do defective mitochondria, and are therefore "tagged" for degradation by lysosomes. Since

mitochondria within cells have a half life of about 10 days, a selection advantage can result in rapid replacement of functional mitochondria with those with diminished respiratory activity, especially in slowly dividing cells. The net result is that once a mutation in a gene for a mitochondrial protein that reduces oxidative damage to mitochondria occurs, such defective mitochondria will rapidly populate the cell, diminishing or eliminating its respiratory capabilities. The accumulation of such cells results in aging or degenerative disease at the organismal level. This is consistent with the progressive mosaic appearance of cells with defective electron transport activity in muscle, with cells almost devoid of Cytochrome c Oxidase (COX) activity interspersed randomly amidst cells with normal activity, and a higher incidence of COX-negative cells in biopsies from older subjects. The organism, during aging, or in a variety of mitochondrial diseases, is thus faced with a situation in which irreplaceable postmitotic cells (e.g. neurons, skeletal and cardiac muscle) must be preserved and their function maintained to a significant degree, in the face of an inexorable progressive decline in mitochondrial respiratory chain function. Neurons with dysfunctional mitochondria become progressively more sensitive to insults like excitotoxic injury. Mitochondrial failure contributes to most degenerative diseases (especially neurodegeneration) that accompany aging. Congenital mitochondrial diseases often involve early-onset neurodegeneration similar in fundamental mechanism to disorders that occur during aging of people born with normal mitochondria. In certain embodiments, sirtuin activating compounds may be useful for treating or attenuating cognitive decline and other degenerative consequences of aging.

Mitochondrial DNA damage is more extensive and persists longer than nuclear DNA damage in cells subjected to oxidative stress or cancer chemotherapy agents like cisplatin due to both greater vulnerability and less efficient repair of mitochondrial DNA. Although mitochondrial DNA may be more sensitive to damage than nuclear DNA, it is relatively resistant, in some situations, to mutagenesis by chemical carcinogens. This is because mitochondria respond to some types of mitochondrial DNA damage by destroying their defective genomes rather than attempting to repair them. This results in global mitochondrial dysfunction for a period after cytotoxic chemotherapy. Clinical use of chemotherapy agents like cisplatin, mitomycin, and cytoxan is often accompanied by debilitating "chemotherapy fatigue", prolonged periods of weakness and exercise intolerance

which may persist even after recovery from hematologic and gastrointestinal toxicities of such agents. In certain embodiments, sirtuin activating compounds may be useful for treatment and prevention of side effects of cancer chemotherapy related to mitochondrial dysfunction.

A crucial function of the ovary is to maintain integrity of the mitochondrial genome in oocytes, since mitochondria passed onto a fetus are all derived from those present in oocytes at the time of conception. Deletions in mitochondrial DNA become detectable around the age of menopause, and are also associated with abnormal menstrual cycles. Since cells cannot directly detect and respond to defects in mitochondrial DNA, but can only detect secondary effects that affect the cytoplasm, like impaired respiration, redox status, or deficits in pyrimidine synthesis, such products of mitochondrial function participate as a signal for oocyte selection and follicular atresia, ultimately triggering menopause when maintenance of mitochondrial genomic fidelity and functional activity can no longer be guaranteed. This is analogous to apoptosis in cells with DNA damage, which undergo an active process of cellular suicide when genomic fidelity can no longer be achieved by repair processes. Women with mitochondrial cytopathies affecting the gonads often undergo premature menopause or display primary cycling abnormalities. Cytotoxic cancer chemotherapy often induces premature menopause, with a consequent increased risk of osteoporosis. Chemotherapy-induced amenorrhea is generally due to primary ovarian failure. The incidence of chemotherapy-induced amenorrhea increases as a function of age in premenopausal women receiving chemotherapy, pointing toward mitochondrial involvement. Inhibitors of mitochondrial respiration or protein synthesis inhibit hormone-induced ovulation, and furthermore inhibit production of ovarian steroid hormones in response to pituitary gonadotropins. Women with Down's syndrome typically undergo menopause prematurely, and also are subject to early onset of Alzheimer-like dementia. Low activity of cytochrome oxidase is consistently found in tissues of Down's patients and in late-onset Alzheimer's Disease. Appropriate support of mitochondrial function or compensation for mitochondrial dysfunction therefore is useful for protecting against age-related or chemotherapy-induced menopause or irregularities of menstrual cycling or ovulation. In certain embodiments, sirtuin activating compounds may be useful for treating and preventing amenorrhea, irregular ovulation, menopause, or secondary consequences of menopause.

In certain embodiments, sirtuin modulating compounds may be useful for treatment mitochondrial myopathies. Mitochondrial myopathies range from mild, slowly progressive weakness of the extraocular muscles to severe, fatal infantile myopathies and multisystem encephalomyopathies. Some syndromes have been defined, with some overlap between them. Established syndromes affecting muscle include progressive external ophthalmoplegia, the Kearns-Sayre syndrome (with ophthalmoplegia, pigmentary retinopathy, cardiac conduction defects, cerebellar ataxia, and sensorineural deafness), the MELAS syndrome (mitochondrial encephalomyopathy, lactic acidosis, and stroke-like episodes), the MERFF syndrome (myoclonic epilepsy and ragged red fibers), limb-girdle distribution weakness, and infantile myopathy (benign or severe and fatal). Muscle biopsy specimens stained with modified Gomori's trichrome stain show ragged red fibers due to excessive accumulation of mitochondria. Biochemical defects in substrate transport and utilization, the Krebs cycle, oxidative phosphorylation, or the respiratory chain are detectable. Numerous mitochondrial DNA point mutations and deletions have been described, transmitted in a maternal, nonmendelian inheritance pattern. Mutations in nuclear-encoded mitochondrial enzymes occur.

In certain embodiments, sirtuin activating compounds may be useful for treating patients suffering from toxic damage to mitochondria, such as, toxic damage due to calcium accumulation, excitotoxicity, nitric oxide exposure, drug induced toxic damage, or hypoxia.

A fundamental mechanism of cell injury, especially in excitable tissues, involves excessive calcium entry into cells, as a result of either leakage through the plasma membrane or defects in intracellular calcium handling mechanisms. Mitochondria are major sites of calcium sequestration, and preferentially utilize energy from the respiratory chain for taking up calcium rather than for ATP synthesis, which results in a downward spiral of mitochondrial failure, since calcium uptake into mitochondria results in diminished capabilities for energy transduction.

Excessive stimulation of neurons with excitatory amino acids is a common mechanism of cell death or injury in the central nervous system. Activation of glutamate receptors, especially of the subtype designated NMDA receptors, results in mitochondrial dysfunction, in part through elevation of intracellular calcium during excitotoxic stimulation. Conversely, deficits in mitochondrial respiration and oxidative phosphorylation sensitizes cells to excitotoxic stimuli, resulting in cell death

or injury during exposure to levels of excitotoxic neurotransmitters or toxins that would be innocuous to normal cells.

Nitric oxide (about 1 micromolar) inhibits cytochrome oxidase (Complex IV) and thereby inhibits mitochondrial respiration; moreover, prolonged exposure to nitric oxide (NO) irreversibly reduces Complex I activity. Physiological or pathophysiological concentrations of NO thereby inhibit pyrimidine biosynthesis. Nitric oxide is implicated in a variety of neurodegenerative disorders including inflammatory and autoimmune diseases of the central nervous system, and is involved in mediation of excitotoxic and post-hypoxic damage to neurons.

Oxygen is the terminal electron acceptor in the respiratory chain. Oxygen deficiency impairs electron transport chain activity, resulting in diminished pyrimidine synthesis as well as diminished ATP synthesis via oxidative phosphorylation. Human cells proliferate and retain viability under virtually anaerobic conditions if provided with uridine and pyruvate (or a similarly effective agent for oxidizing NADH to optimize glycolytic ATP production).

In certain embodiments, sirtuin activating compounds may be useful for treating diseases or disorders associated with mitochondrial deregulation.

Transcription of mitochondrial DNA encoding respiratory chain components requires nuclear factors. In neuronal axons, mitochondria must shuttle back and forth to the nucleus in order to maintain respiratory chain activity. If axonal transport is impaired by hypoxia or by drugs like taxol which affect microtubule stability, mitochondria distant from the nucleus undergo loss of cytochrome oxidase activity. Accordingly, treatment with a sirtuin activating compound may be useful for promoting nuclear-mitochondrial interactions.

Mitochondria are the primary source of free radicals and reactive oxygen species, due to spillover from the mitochondrial respiratory chain, especially when defects in one or more respiratory chain components impairs orderly transfer of electrons from metabolic intermediates to molecular oxygen. To reduce oxidative damage, cells can compensate by expressing mitochondrial uncoupling proteins (UCP), of which several have been identified. UCP-2 is transcribed in response to oxidative damage, inflammatory cytokines, or excess lipid loads, e.g. fatty liver and steatohepatitis. UCPs reduce spillover of reactive oxygen species from mitochondria by discharging proton gradients across the mitochondrial inner membrane, in effect

wasting energy produced by metabolism and rendering cells vulnerable to energy stress as a trade-off for reduced oxidative injury.

Muscle Performance

In other embodiments, the invention provides methods for enhancing muscle performance by administering a therapeutically effective amount of a sirtuin activating compound. For example, sirtuin activating compounds may be useful for improving physical endurance (e.g., ability to perform a physical task such as exercise, physical labor, sports activities, etc.), inhibiting or retarding physical fatigues, enhancing blood oxygen levels, enhancing energy in healthy individuals, enhance working capacity and endurance, reducing muscle fatigue, reducing stress, enhancing cardiac and cardiovascular function, improving sexual ability, increasing muscle ATP levels, and/or reducing lactic acid in blood. In certain embodiments, the methods involve administering an amount of a sirtuin activating compound that increase mitochondrial activity, increase mitochondrial biogenesis, and/or increase mitochondrial mass.

Sports performance refers to the ability of the athlete's muscles to perform when participating in sports activities. Enhanced sports performance, strength, speed and endurance are measured by an increase in muscular contraction strength, increase in amplitude of muscle contraction, shortening of muscle reaction time between stimulation and contraction. Athlete refers to an individual who participates in sports at any level and who seeks to achieve an improved level of strength, speed and endurance in their performance, such as, for example, body builders, bicyclists, long distance runners, short distance runners, etc. An athlete may be hard training, that is, performs sports activities intensely more than three days a week or for competition. An athlete may also be a fitness enthusiast who seeks to improve general health and well-being, improve energy levels, who works out for about 1-2 hours about 3 times a week. Enhanced sports performance in manifested by the ability to overcome muscle fatigue, ability to maintain activity for longer periods of time, and have a more effective workout.

In the arena of athlete muscle performance, it is desirable to create conditions that permit competition or training at higher levels of resistance for a prolonged period of time. However, acute and intense anaerobic use of skeletal muscles often results in impaired athletic performance, with losses in force and work output, and increased onset of muscle fatigue, soreness, and dysfunction. It is now recognized that

even a single exhaustive exercise session, or for that matter any acute trauma to the body such as muscle injury, resistance or exhaustive muscle exercise, or elective surgery, is characterized by perturbed metabolism that affects muscle performance in both short and long term phases. Both muscle metabolic/enzymatic activity and gene expression are affected. For example, disruption of skeletal muscle nitrogen metabolism as well as depletion of sources of metabolic energy occur during extensive muscle activity. Amino acids, including branched-chain amino acids, are released from muscles followed by their deamination to elevate serum ammonia and local oxidation as muscle fuel sources, which augments metabolic acidosis. In addition, there is a decline in catalytic efficiency of muscle contraction events, as well as an alteration of enzymatic activities of nitrogen and energy metabolism. Further, protein catabolism is initiated where rate of protein synthesis is decreased coupled with an increase in the degradation of non-contractible protein. These metabolic processes are also accompanied by free radical generation which further damages muscle cells.

Recovery from fatigue during acute and extended exercise requires reversal of metabolic and non-metabolic fatiguing factors. Known factors that participate in human muscle fatigue, such as lactate, ammonia, hydrogen ion, etc., provide an incomplete and unsatisfactory explanation of the fatigue/recovery process, and it is likely that additional unknown agents participate (Baker et al., J. Appl. Physiol. 74:2294-2300, 1993; Bazzarre et al., J Am. Coll. Nutr. 11:505-511, 1992; Dohm et al., Fed. Proc. 44:348-352, 1985; Edwards In: Biochemistry of Exercise, Proceedings of the Fifth International Symposium on the Biochemistry of Exercise (Kutrgen, Vogel, Poormans, eds.), 1983; MacDougall et al., Acta Physiol. Scand. 146:403-404, 1992; Walser et al., Kidney Int. 32:123-128, 1987). Several studies have also analyzed the effects of nutritional supplements and herbal supplements in enhancing muscle performance.

Aside from muscle performance during endurance exercise, free radicals and oxidative stress parameters are affected in pathophysiological states. A substantial body of data now suggests that oxidative stress contributes to muscle wasting or atrophy in pathophysiological states (reviewed in Clarkson, P. M. Antioxidants and physical performance. Crit. Rev. Food Sci. Nutr. 35: 31-41; 1995; Powers, S. K.; Lennon, S. L. Analysis of cellular responses to free radicals: Focus on exercise and skeletal muscle. Proc. Nutr. Soc. 58: 1025-1033; 1999). For example, with respect to

muscular disorders where both muscle endurance and function are compensated, the role of nitric oxide (NO), has been implicated. In muscular dystrophies, especially those due to defects in proteins that make up the dystrophin-glycoprotein complex (DGC), the enzyme that synthesizes NO, nitric oxide synthase (NOS), has been associated. Recent studies of dystrophies related to DGC defects suggest that one mechanism of cellular injury is functional ischemia related to alterations in cellular NOS and disruption of a normal protective action of NO. This protective action is the prevention of local ischemia during contraction-induced increases in sympathetic vasoconstriction. Rando (Microsc Res Tech 55(4):223-35, 2001), has shown that oxidative injury precedes pathologic changes and that muscle cells with defects in the DGC have an increased susceptibility to oxidant challenges. Excessive lipid peroxidation due to free radicals has also been shown to be a factor in myopathic diseases such as McArdle's disease (Russo et al., Med Hypotheses. 39(2):147-51, 1992). Furthermore, mitochondrial dysfunction is a well-known correlate of age-related muscle wasting (sarcopenia) and free radical damage has been suggested, though poorly investigated, as a contributing factor (reviewed in Navarro, A.; Lopez-Cepero, J. M.; Sanchez del Pino, M. L. Front. Biosci. 6: D26-44; 2001). Other indications include acute sarcopenia, for example muscle atrophy and/or cachexia associated with burns, bed rest, limb immobilization, or major thoracic, abdominal, and/or orthopedic surgery. It is contemplated that the methods of the present invention will also be effective in the treatment of muscle related pathological conditions.

In certain embodiments, the invention provides novel dietary compositions comprising sirtuin modulators, a method for their preparation, and a method of using the compositions for improvement of sports performance. Accordingly, provided are therapeutic compositions, foods and beverages that have actions of improving physical endurance and/or inhibiting physical fatigues for those people involved in broadly-defined exercises including sports requiring endurance and labors requiring repeated muscle exertions. Such dietary compositions may additional comprise electrolytes, caffeine, vitamins, carbohydrates, etc.

Other Uses

Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used for treating or preventing viral infections (such as

infections by influenza, herpes or papilloma virus) or as antifungal agents. In certain embodiments, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered as part of a combination drug therapy with another therapeutic agent for the treatment of viral diseases, including, for example, acyclovir, ganciclovir and zidovudine. In another embodiment, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be administered as part of a combination drug therapy with another anti-fungal agent including, for example, topical anti-fungals such as ciclopirox, clotrimazole, econazole, miconazole, nystatin, oxiconazole, terconazole, and tolnaftate, or systemic anti-fungal such as fluconazole (Diflucan), itraconazole (Sporanox), ketoconazole (Nizoral), and miconazole (Monistat I.V.).

Subjects that may be treated as described herein include eukaryotes, such as mammals, e.g., humans, ovines, bovines, equines, porcines, canines, felines, non-human primate, mice, and rats. Cells that may be treated include eukaryotic cells, e.g., from a subject described above, or plant cells, yeast cells and prokaryotic cells, e.g., bacterial cells. For example, modulating compounds may be administered to farm animals to improve their ability to withstand farming conditions longer.

Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may also be used to increase lifespan, stress resistance, and resistance to apoptosis in plants. In one embodiment, a compound is applied to plants, e.g., on a periodic basis, or to fungi. In another embodiment, plants are genetically modified to produce a compound. In another embodiment, plants and fruits are treated with a compound prior to picking and shipping to increase resistance to damage during shipping. Plant seeds may also be contacted with compounds described herein, e.g., to preserve them.

In other embodiments, sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may be used for modulating lifespan in yeast cells. Situations in which it may be desirable to extend the lifespan of yeast cells include any process in which yeast is used, e.g., the making of beer, yogurt, and bakery items, e.g., bread. Use of yeast having an extended lifespan can result in using less yeast or in having the yeast be active for longer periods of time. Yeast or other mammalian cells used for recombinantly producing proteins may also be treated as described herein.

Sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may also be used to increase lifespan, stress resistance and resistance to apoptosis in insects. In this embodiment, compounds would be applied to useful insects, e.g., bees and other insects that are involved in pollination of plants. In a specific embodiment, a compound would be applied to bees involved in the production of honey. Generally, the methods described herein may be applied to any organism, e.g., eukaryote, that may have commercial importance. For example, they can be applied to fish (aquaculture) and birds (e.g., chicken and fowl).

Higher doses of sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein may also be used as a pesticide by interfering with the regulation of silenced genes and the regulation of apoptosis during development. In this embodiment, a compound may be applied to plants using a method known in the art that ensures the compound is bio-available to insect larvae, and not to plants.

At least in view of the link between reproduction and longevity (Longo and Finch, Science, 2002), sirtuin-modulating compounds that increase the level and/or activity of a sirtuin protein can be applied to affect the reproduction of organisms such as insects, animals and microorganisms.

4. Assays

Yet other methods contemplated herein include screening methods for identifying compounds or agents that modulate sirtuins. An agent may be a nucleic acid, such as an aptamer. Assays may be conducted in a cell based or cell free format. For example, an assay may comprise incubating (or contacting) a sirtuin with a test agent under conditions in which a sirtuin can be modulated by an agent known to modulate the sirtuin, and monitoring or determining the level of modulation of the sirtuin in the presence of the test agent relative to the absence of the test agent. The level of modulation of a sirtuin can be determined by determining its ability to deacetylate a substrate. Exemplary substrates are acetylated peptides which can be obtained from BIOMOL (Plymouth Meeting, PA). Preferred substrates include peptides of p53, such as those comprising an acetylated K382. A particularly preferred substrate is the Fluor de Lys-SIRT1 (BIOMOL), i.e., the acetylated peptide Arg-His-Lys-Lys. Other substrates are peptides from human histones H3 and H4 or an acetylated amino acid (see Fig. 5). Substrates may be fluorogenic. The sirtuin may be SIRT1, Sir2, SIRT3, or a portion thereof. For example, recombinant SIRT1

can be obtained from BIOMOL. The reaction may be conducted for about 30 minutes and stopped, e.g., with nicotinamide. The HDAC fluorescent activity assay/drug discovery kit (AK-500, BIOMOL Research Laboratories) may be used to determine the level of acetylation. Similar assays are described in Bitterman et al. (2002) J. Biol. Chem. 277:45099. The level of modulation of the sirtuin in an assay may be compared to the level of modulation of the sirtuin in the presence of one or more (separately or simultaneously) compounds described herein, which may serve as positive or negative controls. Sirtuins for use in the assays may be full length sirtuin proteins or portions thereof. Since it has been shown herein that activating compounds appear to interact with the N-terminus of SIRT1, proteins for use in the assays include N-terminal portions of sirtuins, e.g., about amino acids 1-176 or 1-255 of SIRT1; about amino acids 1-174 or 1-252 of Sir2.

In one embodiment, a screening assay comprises (i) contacting a sirtuin with a test agent and an acetylated substrate under conditions appropriate for the sirtuin to deacetylate the substrate in the absence of the test agent ; and (ii) determining the level of acetylation of the substrate, wherein a lower level of acetylation of the substrate in the presence of the test agent relative to the absence of the test agent indicates that the test agent stimulates deacetylation by the sirtuin, whereas a higher level of acetylation of the substrate in the presence of the test agent relative to the absence of the test agent indicates that the test agent inhibits deacetylation by the sirtuin.

Methods for identifying an agent that modulates, e.g., stimulates or inhibits, sirtuins *in vivo* may comprise (i) contacting a cell with a test agent and a substrate that is capable of entering a cell in the presence of an inhibitor of class I and class II HDACs under conditions appropriate for the sirtuin to deacetylate the substrate in the absence of the test agent ; and (ii) determining the level of acetylation of the substrate, wherein a lower level of acetylation of the substrate in the presence of the test agent relative to the absence of the test agent indicates that the test agent stimulates deacetylation by the sirtuin, whereas a higher level of acetylation of the substrate in the presence of the test agent relative to the absence of the test agent indicates that the test agent inhibits deacetylation by the sirtuin. A preferred substrate is an acetylated peptide, which is also preferably fluorogenic, as further described herein. The method may further comprise lysing the cells to determine the level of acetylation of the substrate. Substrates may be added to cells at a concentration ranging from about

1μM to about 10mM, preferably from about 10μM to 1mM, even more preferably from about 100μM to 1mM, such as about 200μM. A preferred substrate is an acetylated lysine, e.g., ϵ-acetyl lysine (Fluor de Lys, FdL) or Fluor de Lys-SIRT1. A preferred inhibitor of class I and class II HDACs is trichostatin A (TSA), which may be used at concentrations ranging from about 0.01 to 100μM, preferably from about 0.1 to 10μM, such as 1μM. Incubation of cells with the test compound and the substrate may be conducted for about 10 minutes to 5 hours, preferably for about 1-3 hours. Since TSA inhibits all class I and class II HDACs, and that certain substrates, e.g., Fluor de Lys, is a poor substrate for SIRT2 and even less a substrate for SIRT3-7, such an assay may be used to identify modulators of SIRT1 *in vivo*.

5. Pharmaceutical Compositions

The sirtuin-modulating compounds described herein may be formulated in a conventional manner using one or more physiologically acceptable carriers or excipients. For example, sirtuin-modulating compounds and their physiologically acceptable salts and solvates may be formulated for administration by, for example, injection (e.g. SubQ, IM, IP), inhalation or insufflation (either through the mouth or the nose) or oral, buccal, sublingual, transdermal, nasal, parenteral or rectal administration. In one embodiment, a sirtuin-modulating compound may be administered locally, at the site where the target cells are present, i.e., in a specific tissue, organ, or fluid (e.g., blood, cerebrospinal fluid, etc.).

Sirtuin-modulating compounds can be formulated for a variety of modes of administration, including systemic and topical or localized administration. Techniques and formulations generally may be found in Remington's Pharmaceutical Sciences, Meade Publishing Co., Easton, PA. For parenteral administration, injection is preferred, including intramuscular, intravenous, intraperitoneal, and subcutaneous. For injection, the compounds can be formulated in liquid solutions, preferably in physiologically compatible buffers such as Hank's solution or Ringer's solution. In addition, the compounds may be formulated in solid form and redissolved or suspended immediately prior to use. Lyophilized forms are also included.

For oral administration, the pharmaceutical compositions may take the form of, for example, tablets, lozanges, or capsules prepared by conventional means with pharmaceutically acceptable excipients such as binding agents (e.g., pregelatinised maize starch, polyvinylpyrrolidone or hydroxypropyl methylcellulose); fillers (e.g.,

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

For administration by inhalation (e.g., pulmonary delivery), sirtuin-modulating compounds may be conveniently delivered in the form of an aerosol spray presentation from pressurized packs or a nebuliser, with the use of a suitable propellant, e.g., dichlorodifluoromethane, trichlorofluoromethane, dichlorotetrafluoroethane, carbon dioxide or other suitable gas. In the case of a pressurized aerosol the dosage unit may be determined by providing a valve to deliver a metered amount. Capsules and cartridges of e.g., gelatin, for use in an inhaler or insufflator may be formulated containing a powder mix of the compound and a suitable powder base such as lactose or starch.

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

Sirtuin-modulating compounds may also be formulated in rectal compositions such as suppositories or retention enemas, e.g., containing conventional suppository bases such as cocoa butter or other glycerides.

In addition to the formulations described previously, sirtuin-modulating compounds may also be formulated as a depot preparation. Such long acting formulations may be administered by implantation (for example subcutaneously or intramuscularly) or by intramuscular injection. Thus, for example, sirtuin-modulating compounds may be formulated with suitable polymeric or hydrophobic materials (for example as an emulsion in an acceptable oil) or ion exchange resins, or as sparingly soluble derivatives, for example, as a sparingly soluble salt. Controlled release formula also includes patches.

In certain embodiments, the compounds described herein can be formulated for delivery to the central nervous system (CNS) (reviewed in Begley, Pharmacology & Therapeutics 104: 29-45 (2004)). Conventional approaches for drug delivery to the CNS include: neurosurgical strategies (e.g., intracerebral injection or intracerebroventricular infusion); molecular manipulation of the agent (e.g., production of a chimeric fusion protein that comprises a transport peptide that has an affinity for an endothelial cell surface molecule in combination with an agent that is itself incapable of crossing the BBB) in an attempt to exploit one of the endogenous transport pathways of the BBB; pharmacological strategies designed to increase the lipid solubility of an agent (e.g., conjugation of water-soluble agents to lipid or cholesterol carriers); and the transitory disruption of the integrity of the BBB by hyperosmotic disruption (resulting from the infusion of a mannitol solution into the carotid artery or the use of a biologically active agent such as an angiotensin peptide).

One possibility to achieve sustained release kinetics is embedding or encapsulating the active compound into nanoparticles. Nanoparticles can be administrated as powder, as a powder mixture with added excipients or as suspensions. Colloidal suspensions of nanoparticles can easily be administrated through a cannula with small diameter.

Nanoparticles are particles with a diameter from about 5 nm to up to about 1000 nm. The term "nanoparticles" as it is used hereinafter refers to particles formed by a polymeric matrix in which the active compound is dispersed, also known as "nanospheres", and also refers to nanoparticles which are composed of a core containing the active compound which is surrounded by a polymeric membrane, also

known as "nanocapsules". In certain embodiments, nanoparticles are preferred having a diameter from about 50 nm to about 500 nm, in particular from about 100 nm to about 200 nm.

Nanoparticles can be prepared by in situ polymerization of dispersed monomers or by using preformed polymers. Since polymers prepared in situ are often not biodegradable and/or contain toxicological serious byproducts, nanoparticles from preformed polymers are preferred. Nanoparticles from preformed polymers can be prepared by different techniques, e.g., by emulsion evaporation, solvent displacement, salting-out, mechanical grinding, microprecipitation, and by emulsification diffusion.

With the methods described above, nanoparticles can be formed with various types of polymers. For use in the method of the present invention, nanoparticles made from biocompatible polymers are preferred. The term "biocompatible" refers to material that after introduction into a biological environment has no serious effects to the biological environment. From biocompatible polymers those polymers are especially preferred which are also biodegradable. The term "biodegradable" refers to material that after introduction into a biological environment is enzymatically or chemically degraded into smaller molecules, which can be eliminated subsequently. Examples are polyesters from hydroxycarboxylic acids such as poly(lactic acid) (PLA), poly(glycolic acid) (PGA), polycaprolactone (PCL), copolymers of lactic acid and glycolic acid (PLGA), copolymers of lactic acid and caprolactone, polyepsilon caprolactone, polyhyroxy butyric acid and poly(ortho)esters, polyurethanes, polyanhydrides, polyacetals, polydihydropyrans, polycyanoacrylates, natural polymers such as alginate and other polysaccharides including dextran and cellulose, collagen and albumin.

Suitable surface modifiers can preferably be selected from known organic and inorganic pharmaceutical excipients. Such excipients include various polymers, low molecular weight oligomers, natural products and surfactants. Preferred surface modifiers include nonionic and ionic surfactants. Representative examples of surface modifiers include gelatin, casein, lecithin (phosphatides), gum acacia, cholesterol, tragacanth, stearic acid, benzalkonium chloride, calcium stearate, glycerol monostearate, cetostearyl alcohol, cetomacrogol emulsifying wax, sorbitan esters, polyoxyethylene alkyl ethers, e.g., macrogol ethers such as cetomacrogol 1000, polyoxyethylene castor oil derivatives, polyoxyethylene sorbitan fatty acid esters, e.g., the commercially available TweensTM, polyethylene glycols, polyoxyethylene

stearates, colloidal silicon dioxide, phosphates, sodium dodecylsulfate, carboxymethylcellulose calcium, carboxymethylcellulose sodium, methylcellulose, hydroxyethylcellulose, hydroxy propylcellulose, hydroxypropylmethylcellulose phthalate, noncrystalline cellulose, magnesium aluminum silicate, triethanolamine, polyvinyl alcohol, and polyvinylpyrrolidone (PVP). Most of these surface modifiers are known pharmaceutical excipients and are described in detail in the Handbook of Pharmaceutical Excipients, published jointly by the American Pharmaceutical Association and The Pharmaceutical Society of Great Britain, the Pharmaceutical Press, 1986.

Further description on preparing nanoparticles can be found, for example, in US Patent No. 6,264,922, the contents of which are incorporated herein by reference.

Liposomes are a further drug delivery system which is easily injectable. Accordingly, in the method of invention the active compounds can also be administered in the form of a liposome delivery system. Liposomes are well-known by a person skilled in the art. Liposomes can be formed from a variety of phospholipids, such as cholesterol, stearylamine of phosphatidylcholines. Liposomes being usable for the method of invention encompass all types of liposomes including, but not limited to, small unilamellar vesicles, large unilamellar vesicles and multilamellar vesicles.

Liposomes are used for a variety of therapeutic purposes, and in particular, for carrying therapeutic agents to target cells. Advantageously, liposome-drug formulations offer the potential of improved drug-delivery properties, which include, for example, controlled drug release. An extended circulation time is often needed for liposomes to reach a target region, cell or site. In particular, this is necessary where the target region, cell or site is not located near the site of administration. For example, when liposomes are administered systemically, it is desirable to coat the liposomes with a hydrophilic agent, for example, a coating of hydrophilic polymer chains such as polyethylene glycol (PEG) to extend the blood circulation lifetime of the liposomes. Such surface-modified liposomes are commonly referred to as "long circulating" or "sterically stabilized" liposomes.

One surface modification to a liposome is the attachment of PEG chains, typically having a molecular weight from about 1000 daltons (Da) to about 5000 Da, and to about 5 mole percent (%) of the lipids making up the liposomes (see, for example, Stealth Liposomes, CRC Press, Lasic, D. and Martin, F., eds., Boca Raton,

Fla., (1995)), and the cited references therein. The pharmacokinetics exhibited by such liposomes are characterized by a dose-independent reduction in uptake of liposomes by the liver and spleen via the mononuclear phagocyte system (MPS), and significantly prolonged blood circulation time, as compared to non-surface-modified liposomes, which tend to be rapidly removed from the blood and accumulated in the liver and spleen.

In certain embodiments, the complex is shielded to increase the circulatory half-life of the complex or shielded to increase the resistance of nucleic acid to degradation, for example degradation by nucleases.

As used herein, the term "shielding", and its cognates such as "shielded", refers to the ability of "shielding moieties" to reduce the non-specific interaction of the complexes described herein with serum complement or with other species present in serum in vitro or in vivo. Shielding moieties may decrease the complex interaction with or binding to these species through one or more mechanisms, including, for example, non-specific steric or non-specific electronic interactions. Examples of such interactions include non-specific electrostatic interactions, charge interactions, Van der Waals interactions, steric-hindrance and the like. For a moiety to act as a shielding moiety, the mechanism or mechanisms by which it may reduce interaction with, association with or binding to the serum complement or other species does not have to be identified. One can determine whether a moiety can act as a shielding moiety by determining whether or to what extent a complex binds serum species.

It should be noted that "shielding moieties" can be multifunctional. For example, a shielding moiety may also function as, for example, a targeting factor. A shielding moiety may also be referred to as multifunctional with respect to the mechanism(s) by which it shields the complex. While not wishing to be limited by proposed mechanism or theory, examples of such a multifunctional shielding moiety are pH sensitive endosomal membrane-disruptive synthetic polymers, such as PPAA or PEAA. Certain poly(alkylacrylic acids) have been shown to disrupt endosomal membranes while leaving the-outer cell surface membrane intact (Stayton et al. (2000) J. Controll. Release 65:203-220; Murthy et al. (1999) J. Controll. Release 61:137-143; WO 99/34831), thereby increasing cellular bioavailability and functioning as a targeting factor. However, PPAA reduces binding of serum complement to complexes in which it is incorporated, thus functioning as a shielding moiety.

Another way to produce a formulation, particularly a solution, of a sirtuin modulator such as resveratrol or a derivative thereof, is through the use of cyclodextrin. By cyclodextrin is meant α-, β-, or γ-cyclodextrin. Cyclodextrins are described in detail in Pitha et al., U.S. Pat. No. 4,727,064, which is incorporated herein by reference. Cyclodextrins are cyclic oligomers of glucose; these compounds form inclusion complexes with any drug whose molecule can fit into the lipophile-seeking cavities of the cyclodextrin molecule.

The cyclodextrin of the compositions according to the invention may be α-, β-, or γ-cyclodextrin. α-cyclodextrin contains six glucopyranose units; β-cyclodextrin contains seven glucopyranose units; and γ-cyclodextrin contains eight glucopyranose units. The molecule is believed to form a truncated cone having a core opening of 4.7-5.3 angstroms, 6.0-6.5 angstroms, and 7.5-8.3 angstroms in α-, β-, or γ-cyclodextrin respectively. The composition according to the invention may comprise a mixture of two or more of the α-, β-, or γ-cyclodextrins. Typically, however, the composition according to the invention will comprise only one of the α-, β-, or γ-cyclodextrins.

Most preferred cyclodextrins in the compositions according to the invention are amorphous cyclodextrin compounds. By amorphous cyclodextrin is meant non-crystalline mixtures of cyclodextrins wherein the mixture is prepared from α-, β-, or γ-cyclodextrin. In general, the amorphous cyclodextrin is prepared by non-selective alkylation of the desired cyclodextrin species. Suitable alkylation agents for this purpose include but are not limited to propylene oxide, glycidol, iodoacetarnide, chloroacetate, and 2-diethylaminoethlychloride. Reactions are carried out to yield mixtures containing a plurality of components thereby preventing crystallization of the cyclodextrin. Various alkylated cyclodextrins can be made and of course will vary, depending upon the starting species of cyclodextrin and the alkylating agent used. Among the amorphous cyclodextrins suitable for compositions according to the invention are hydroxypropyl, hydroxyethyl, glucosyl, maltosyl and maltotriosyl derivatives of β-cyclodextrin, carboxyamidomethyl-β-cyclodextrin, carboxymethyl-β-cyclodextrin, hydroxypropyl-β-cyclodextrin and diethylamino-β-cyclodextrin.

One example of resveratrol dissolved in the presence of a cyclodextrin is provided in Marier *et al.*, *J. Pharmacol. Exp. Therap.* 302:369-373 (2002), the contents of which are incorporated herein by reference, where a 6 mg/mL solution of

resveratrol was prepared using 0.9% saline containing 20% hydroxylpropyl-β-cyclodextrin.

As mentioned above, the compositions of matter of the invention comprise an aqueous preparation of preferably substituted amorphous cyclodextrin and one or more sirtuin modulators. The relative amounts of sirtuin modulators and cyclodextrin will vary depending upon the relative amount of each of the sirtuin modulators and the effect of the cyclodextrin on the compound. In general, the ratio of the weight of compound of the sirtuin modulators to the weight of cyclodextrin compound will be in a range between 1:1 and 1:100. A weight to weight ratio in a range of 1:5 to 1:50 and more preferably in a range of 1:10 to 1:20 of the compound selected from sirtuin modulators to cyclodextrin are believed to be the most effective for increased circulating availability of the sirtuin modulator.

Importantly, if the aqueous solution comprising the sirtuin modulators and a cyclodextrin is to be administered parenterally, especially via the intravenous route, a cyclodextrin will be substantially free of pyrogenic contaminants. Various forms of cyclodextrin, such as forms of amorphous cyclodextrin, may be purchased from a number of vendors including Sigma-Aldrich, Inc. (St. Louis, Mo., USA). A method for the production of hydroxypropyl-β-cyclodextrin is disclosed in Pitha et al., U.S. Pat. No. 4,727,064 which is incorporated herein by reference.

Additional description of the use of cyclodextrin for solubilizing compounds can be found in US 2005/0026849, the contents of which are incorporated herein by reference.

Rapidly disintegrating or dissolving dosage forms are useful for the rapid absorption, particularly buccal and sublingual absorption, of pharmaceutically active agents. Fast melt dosage forms are beneficial to patients, such as aged and pediatric patients, who have difficulty in swallowing typical solid dosage forms, such as caplets and tablets. Additionally, fast melt dosage forms circumvent drawbacks associated with, for example, chewable dosage forms, wherein the length of time an active agent remains in a patient's mouth plays an important role in determining the amount of taste masking and the extent to which a patient may object to throat grittiness of the active agent.

To overcome such problems manufacturers have developed a number of fast melt solid dose oral formulations. These are available from manufacturers including

Cima Labs, Fuisz Technologies Ltd., Prographarm, R. P. Scherer, Yamanouchi-Shaklee, and McNeil-PPC, Inc. All of these manufacturers market different types of rapidly dissolving solid oral dosage forms. See e.g., patents and publications by Cima Labs such as U.S. Pat. No. 5,607,697, 5,503,846, 5,223,264, 5,401,513, 5,219,574, and 5,178,878, WO 98/46215, WO 98/14179; patents to Fuisz Technologies, now part of BioVail, such as U.S. Pat. No. 5,871,781, 5,869,098, 5,866,163, 5,851,553, 5,622,719, 5,567,439, and 5,587,172; U.S. Pat. No. 5,464,632 to Prographarm; patents to R. P. Scherer such as U.S. Pat. No. 4,642,903, 5,188,825, 5,631,023 and 5,827,541; patents to Yamanouchi-Shaklee such as U.S. Pat. No. 5,576,014 and 5,446,464; patents to Janssen such as U.S. Pat. No. 5,807,576, 5,635,210, 5,595,761, 5,587,180 and 5,776,491; U.S. Pat. Nos. 5,639,475 and 5,709,886 to Eurand America, Inc.; U.S. Pat. Nos. 5,807,578 and 5,807,577 to L.A.B. Pharmaceutical Research; patents to Schering Corporation such as U.S. Pat. Nos. 5,112,616 and 5,073,374; U.S. Pat. No. 4,616,047 to Laboratoire L. LaFon; U.S. Pat. No. 5,501,861 to Takeda Chemicals Inc., Ltd.; and U.S. Pat. No. 6,316,029 to Elan.

In one example of fast melt tablet preparation, granules for fast melt tablets made by either the spray drying or pre-compacting processes are mixed with excipients and compressed into tablets using conventional tablet making machinery. The granules can be combined with a variety of carriers including low density, high moldability saccharides, low moldability saccharides, polyol combinations, and then directly compressed into a tablet that exhibits an improved dissolution and disintegration profile.

The tablets according to the present invention typically have a hardness of about 2 to about 6 Strong-Cobb units (scu). Tablets within this hardness range disintegrate or dissolve rapidly when chewed. Additionally, the tablets rapidly disentegrate in water. On average, a typical 1.1 to 1.5 gram tablet disintegrates in 1-3 minutes without stirring. This rapid disintegration facilitates delivery of the active material.

The granules used to make the tablets can be, for example, mixtures of low density alkali earth metal salts or carbohydrates. For example, a mixture of alkali earth metal salts includes a combination of calcium carbonate and magnesium hydroxide. Similarly, a fast melt tablet can be prepared according to the methods of the present invention that incorporates the use of A) spray dried extra light calcium carbonate/maltodextrin, B) magnesium hydroxide and C) a eutectic polyol

combination including Sorbitol Instant, xylitol and mannitol. These materials have been combined to produce a low density tablet that dissolves very readily and promotes the fast disintegration of the active ingredient. Additionally, the pre-compacted and spray dried granules can be combined in the same tablet.

For fast melt tablet preparation, a sirtuin modulator useful in the present invention can be in a form such as solid, particulate, granular, crystalline, oily or solution. The sirtuin modulator for use in the present invention may be a spray dried product or an adsorbate that has been pre-compacted to a harder granular form that reduces the medicament taste. A pharmaceutical active ingredient for use in the present invention may be spray dried with a carrier that prevents the active ingredient from being easily extracted from the tablet when chewed.

In addition to being directly added to the tablets of the present invention, the medicament drug itself can be processed by the pre-compaction process to achieve an increased density prior to being incorporated into the formulation.

The pre-compaction process used in the present invention can be used to deliver poorly soluble pharmaceutical materials so as to improve the release of such pharmaceutical materials over traditional dosage forms. This could allow for the use of lower dosage levels to deliver equivalent bioavailable levels of drug and thereby lower toxicity levels of both currently marketed drug and new chemical entities. Poorly soluble pharmaceutical materials can be used in the form of nanoparticles, which are nanometer-sized particles.

In addition to the active ingredient and the granules prepared from low density alkali earth metal salts and/or water soluble carbohydrates, the fast melt tablets can be formulated using conventional carriers or excipients and well established pharmaceutical techniques. Conventional carriers or excipients include, but are not limited to, diluents, binders, adhesives (i.e., cellulose derivatives and acrylic derivatives), lubricants (i.e., magnesium or calcium stearate, vegetable oils, polyethylene glycols, talc, sodium lauryl sulphate, polyoxy ethylene monostearate), disintegrants, colorants, flavorings, preservatives, sweeteners and miscellaneous materials such as buffers and adsorbents.

Additional description of the preparation of fast melt tablets can be found, for example, in U.S. Pat. No. 5,939,091, the contents of which are incorporated herein by reference.

Pharmaceutical compositions (including cosmetic preparations) may comprise from about 0.00001 to 100% such as from 0.001 to 10% or from 0.1% to 5% by weight of one or more sirtuin-modulating compounds described herein.

In one embodiment, a sirtuin-modulating compound described herein, is incorporated into a topical formulation containing a topical carrier that is generally suited to topical drug administration and comprising any such material known in the art. The topical carrier may be selected so as to provide the composition in the desired form, e.g., as an ointment, lotion, cream, microemulsion, gel, oil, solution, or the like, and may be comprised of a material of either naturally occurring or synthetic origin. It is preferable that the selected carrier not adversely affect the active agent or other components of the topical formulation. Examples of suitable topical carriers for use herein include water, alcohols and other nontoxic organic solvents, glycerin, mineral oil, silicone, petroleum jelly, lanolin, fatty acids, vegetable oils, parabens, waxes, and the like.

Formulations may be colorless, odorless ointments, lotions, creams, microemulsions and gels.

Sirtuin-modulating compounds may be incorporated into ointments, which generally are semisolid preparations which are typically based on petrolatum or other petroleum derivatives. The specific ointment base to be used, as will be appreciated by those skilled in the art, is one that will provide for optimum drug delivery, and, preferably, will provide for other desired characteristics as well, e.g., emolliency or the like. As with other carriers or vehicles, an ointment base should be inert, stable, nonirritating and nonsensitizing. As explained in Remington's (*supra*) ointment bases may be grouped in four classes: oleaginous bases; emulsifiable bases; emulsion bases; and water-soluble bases. Oleaginous ointment bases include, for example, vegetable oils, fats obtained from animals, and semisolid hydrocarbons obtained from petroleum. Emulsifiable ointment bases, also known as absorbent ointment bases, contain little or no water and include, for example, hydroxystearin sulfate, anhydrous lanolin and hydrophilic petrolatum. Emulsion ointment bases are either water-in-oil (W/O) emulsions or oil-in-water (O/W) emulsions, and include, for example, cetyl alcohol, glyceryl monostearate, lanolin and stearic acid. Exemplary water-soluble ointment bases are prepared from polyethylene glycols (PEGs) of varying molecular weight; again, reference may be had to Remington's, *supra*, for further information.

Sirtuin-modulating compounds may be incorporated into lotions, which generally are preparations to be applied to the skin surface without friction, and are typically liquid or semiliquid preparations in which solid particles, including the active agent, are present in a water or alcohol base. Lotions are usually suspensions of solids, and may comprise a liquid oily emulsion of the oil-in-water type. Lotions are preferred formulations for treating large body areas, because of the ease of applying a more fluid composition. It is generally necessary that the insoluble matter in a lotion be finely divided. Lotions will typically contain suspending agents to produce better dispersions as well as compounds useful for localizing and holding the active agent in contact with the skin, e.g., methylcellulose, sodium carboxymethylcellulose, or the like. An exemplary lotion formulation for use in conjunction with the present method contains propylene glycol mixed with a hydrophilic petrolatum such as that which may be obtained under the trademark Aquaphor^{RTM} from Beiersdorf, Inc. (Norwalk, Conn.).

Sirtuin-modulating compounds may be incorporated into creams, which generally are viscous liquid or semisolid emulsions, either oil-in-water or water-in-oil. Cream bases are water-washable, and contain an oil phase, an emulsifier and an aqueous phase. The oil phase is generally comprised of petrolatum and a fatty alcohol such as cetyl or stearyl alcohol; the aqueous phase usually, although not necessarily, exceeds the oil phase in volume, and generally contains a humectant. The emulsifier in a cream formulation, as explained in Remington 's, *supra*, is generally a nonionic, anionic, cationic or amphoteric surfactant.

Sirtuin-modulating compounds may be incorporated into microemulsions, which generally are thermodynamically stable, isotropically clear dispersions of two immiscible liquids, such as oil and water, stabilized by an interfacial film of surfactant molecules (Encyclopedia of Pharmaceutical Technology (New York: Marcel Dekker, 1992), volume 9). For the preparation of microemulsions, surfactant (emulsifier), co-surfactant (co-emulsifier), an oil phase and a water phase are necessary. Suitable surfactants include any surfactants that are useful in the preparation of emulsions, e.g., emulsifiers that are typically used in the preparation of creams. The co-surfactant (or "co-emulsifer") is generally selected from the group of polyglycerol derivatives, glycerol derivatives and fatty alcohols. Preferred emulsifier/co-emulsifier combinations are generally although not necessarily selected from: glyceryl monostearate and polyoxyethylene stearate; polyethylene glycol and

ethylene glycol palmitostearate; and caprilic and capric triglycerides and oleoyl macrogolglycerides. The water phase includes not only water but also, typically, buffers, glucose, propylene glycol, polyethylene glycols, preferably lower molecular weight polyethylene glycols (e.g., PEG 300 and PEG 400), and/or glycerol, and the like, while the oil phase will generally comprise, for example, fatty acid esters, modified vegetable oils, silicone oils, mixtures of mono- di- and triglycerides, mono- and di-esters of PEG (e.g., oleoyl macrogol glycerides), etc.

Sirtuin-modulating compounds may be incorporated into gel formulations, which generally are semisolid systems consisting of either suspensions made up of small inorganic particles (two-phase systems) or large organic molecules distributed substantially uniformly throughout a carrier liquid (single phase gels). Single phase gels can be made, for example, by combining the active agent, a carrier liquid and a suitable gelling agent such as tragacanth (at 2 to 5%), sodium alginate (at 2-10%), gelatin (at 2-15%), methylcellulose (at 3-5%), sodium carboxymethylcellulose (at 2-5%), carbomer (at 0.3-5%) or polyvinyl alcohol (at 10-20%) together and mixing until a characteristic semisolid product is produced. Other suitable gelling agents include methylhydroxycellulose, polyoxyethylene-polyoxypropylene, hydroxyethylcellulose and gelatin. Although gels commonly employ aqueous carrier liquid, alcohols and oils can be used as the carrier liquid as well.

Various additives, known to those skilled in the art, may be included in formulations, e.g., topical formulations. Examples of additives include, but are not limited to, solubilizers, skin permeation enhancers, opacifiers, preservatives (e.g., anti-oxidants), gelling agents, buffering agents, surfactants (particularly nonionic and amphoteric surfactants), emulsifiers, emollients, thickening agents, stabilizers, humectants, colorants, fragrance, and the like. Inclusion of solubilizers and/or skin permeation enhancers is particularly preferred, along with emulsifiers, emollients and preservatives. An optimum topical formulation comprises approximately: 2 wt. % to 60 wt. %, preferably 2 wt. % to 50 wt. %, solubilizer and/or skin permeation enhancer; 2 wt. % to 50 wt. %, preferably 2 wt. % to 20 wt. %, emulsifiers; 2 wt. % to 20 wt. % emollient; and 0.01 to 0.2 wt. % preservative, with the active agent and carrier (e.g., water) making of the remainder of the formulation.

A skin permeation enhancer serves to facilitate passage of therapeutic levels of active agent to pass through a reasonably sized area of unbroken skin. Suitable enhancers are well known in the art and include, for example: lower alkanols such as

methanol ethanol and 2-propanol; alkyl methyl sulfoxides such as dimethylsulfoxide (DMSO), decylmethylsulfoxide (C_{10} MSO) and tetradecylmethyl sulfboxide; pyrrolidones such as 2-pyrrolidone, N-methyl-2-pyrrolidone and N-(-hydroxyethyl)pyrrolidone; urea; N,N-diethyl-m-toluamide; C_2 -C_6 alkanediols; miscellaneous solvents such as dimethyl formamide (DMF), N,N-dimethylacetamide (DMA) and tetrahydrofurfuryl alcohol; and the 1-substituted azacycloheptan-2-ones, particularly 1-n-dodecylcyclazacycloheptan-2-one (laurocapram; available under the trademark Azone^{RTM} from Whitby Research Incorporated, Richmond, Va.).

Examples of solubilizers include, but are not limited to, the following: hydrophilic ethers such as diethylene glycol monoethyl ether (ethoxydiglycol, available commercially as Transcutol^{RTM}) and diethylene glycol monoethyl ether oleate (available commercially as Softcutol^{RTM}); polyethylene castor oil derivatives such as polyoxy 35 castor oil, polyoxy 40 hydrogenated castor oil, etc.; polyethylene glycol, particularly lower molecular weight polyethylene glycols such as PEG 300 and PEG 400, and polyethylene glycol derivatives such as PEG-8 caprylic/capric glycerides (available commercially as Labrasol^{RTM}); alkyl methyl sulfoxides such as DMSO; pyrrolidones such as 2-pyrrolidone and N-methyl-2-pyrrolidone; and DMA. Many solubilizers can also act as absorption enhancers. A single solubilizer may be incorporated into the formulation, or a mixture of solubilizers may be incorporated therein.

Suitable emulsifiers and co-emulsifiers include, without limitation, those emulsifiers and co-emulsifiers described with respect to microemulsion formulations. Emollients include, for example, propylene glycol, glycerol, isopropyl myristate, polypropylene glycol-2 (PPG-2) myristyl ether propionate, and the like.

Other active agents may also be included in formulations, e.g., other anti-inflammatory agents, analgesics, antimicrobial agents, antifungal agents, antibiotics, vitamins, antioxidants, and sunblock agents commonly found in sunscreen formulations including, but not limited to, anthranilates, benzophenones (particularly benzophenone-3), camphor derivatives, cinnamates (e.g., octyl methoxycinnamate), dibenzoyl methanes (e.g., butyl methoxydibenzoyl methane), p-aminobenzoic acid (PABA) and derivatives thereof, and salicylates (e.g., octyl salicylate).

In certain topical formulations, the active agent is present in an amount in the range of approximately 0.25 wt. % to 75 wt. % of the formulation, preferably in the range of approximately 0.25 wt. % to 30 wt. % of the formulation, more preferably in

the range of approximately 0.5 wt. % to 15 wt. % of the formulation, and most preferably in the range of approximately 1.0 wt. % to 10 wt. % of the formulation.

Topical skin treatment compositions can be packaged in a suitable container to suit its viscosity and intended use by the consumer. For example, a lotion or cream can be packaged in a bottle or a roll-ball applicator, or a propellant-driven aerosol device or a container fitted with a pump suitable for finger operation. When the composition is a cream, it can simply be stored in a non-deformable bottle or squeeze container, such as a tube or a lidded jar. The composition may also be included in capsules such as those described in U.S. Pat. No. 5,063,507. Accordingly, also provided are closed containers containing a cosmetically acceptable composition as herein defined.

In an alternative embodiment, a pharmaceutical formulation is provided for oral or parenteral administration, in which case the formulation may comprises a modulating compound-containing microemulsion as described above, but may contain alternative pharmaceutically acceptable carriers, vehicles, additives, etc. particularly suited to oral or parenteral drug administration. Alternatively, a modulating compound-containing microemulsion may be administered orally or parenterally substantially as described above, without modification.

Phospholipids complexes, e.g., resveratrol-phospholipid complexes, and their preparation are described in U.S. Patent Application Publication No. 2004/116386. Methods for stabilizing active components using polyol/polymer microcapsules, and their preparation are described in US20040108608. Processes for dissolving lipophilic compounds in aqueous solution with amphiphilic block copolymers are described in WO 04/035013.

Conditions of the eye can be treated or prevented by, e.g., systemic, topical, intraocular injection of a sirtuin-modulating compound, or by insertion of a sustained release device that releases a sirtuin-modulating compound. A sirtuin-modulating compound that increases or decreases the level and/or activity of a sirtuin protein may be delivered in a pharmaceutically acceptable ophthalmic vehicle, such that the compound is maintained in contact with the ocular surface for a sufficient time period to allow the compound to penetrate the corneal and internal regions of the eye, as for example the anterior chamber, posterior chamber, vitreous body, aqueous humor, vitreous humor, cornea, iris/ciliary, lens, choroid/retina and sclera. The pharmaceutically-acceptable ophthalmic vehicle may, for example, be an ointment,

vegetable oil or an encapsulating material. Alternatively, the compounds of the invention may be injected directly into the vitreous and aqueous humour. In a further alternative, the compounds may be administered systemically, such as by intravenous infusion or injection, for treatment of the eye.

Sirtuin-modulating compounds described herein may be stored in oxygen free environment according to methods in the art. For example, resveratrol or analog thereof can be prepared in an airtight capsule for oral administration, such as Capsugel from Pfizer, Inc.

Cells, e.g., treated *ex vivo* with a sirtuin-modulating compound, can be administered according to methods for administering a graft to a subject, which may be accompanied, e.g., by administration of an immunosuppressant drug, e.g., cyclosporin A. For general principles in medicinal formulation, the reader is referred to Cell Therapy: Stem Cell Transplantation, Gene Therapy, and Cellular Immunotherapy, by G. Morstyn & W. Sheridan eds, Cambridge University Press, 1996; and Hematopoietic Stem Cell Therapy, E. D. Ball, J. Lister & P. Law, Churchill Livingstone, 2000.

Toxicity and therapeutic efficacy of sirtuin-modulating compounds can be determined by standard pharmaceutical procedures in cell cultures or experimental animals. The LD_{50} is the dose lethal to 50% of the population. The ED_{50} is the dose therapeutically effective in 50% of the population. The dose ratio between toxic and therapeutic effects (LD_{50}/ED_{50}) is the therapeutic index. Sirtuin-modulating compounds that exhibit large therapeutic indexes are preferred. While sirtuin-modulating compounds that exhibit toxic side effects may be used, care should be taken to design a delivery system that targets such compounds to the site of affected tissue in order to minimize potential damage to uninfected cells and, thereby, reduce side effects.

The data obtained from the cell culture assays and animal studies can be used in formulating a range of dosage for use in humans. The dosage of such compounds may lie within a range of circulating concentrations that include the ED_{50} with little or no toxicity. The dosage may vary within this range depending upon the dosage form employed and the route of administration utilized. For any compound, the therapeutically effective dose can be estimated initially from cell culture assays. A dose may be formulated in animal models to achieve a circulating plasma concentration range that includes the IC_{50} (i.e., the concentration of the test compound

that achieves a half-maximal inhibition of symptoms) as determined in cell culture. Such information can be used to more accurately determine useful doses in humans. Levels in plasma may be measured, for example, by high performance liquid chromatography.

6. Kits

Also provided herein are kits, e.g., kits for therapeutic purposes or kits for modulating the lifespan of cells or modulating apoptosis. A kit may comprise one or more sirtuin-modulating compounds, e.g., in premeasured doses. A kit may optionally comprise devices for contacting cells with the compounds and instructions for use. Devices include syringes, stents and other devices for introducing a sirtuin-modulating compound into a subject (e.g., the blood vessel of a subject) or applying it to the skin of a subject.

Another type of kit contemplated by the invention are kits for identifying sirtuin-modulating compounds. Such kits contain (1) a sirtuin or sirtuin-containing material and (2) a sirtuin-modulating compound of the invention, which are in separate vessels. Such kits can be used, for example, to perform a competition-type assay to test other compounds (typically provided by the user) for sirtuin-modulating activity. In certain embodiments, these kits further comprise means for determining sirtuin activity (e.g., a peptide with an appropriate indicator, such as those disclosed in the Exemplification).

The practice of the present methods will employ, unless otherwise indicated, conventional techniques of cell biology, cell culture, molecular biology, transgenic biology, microbiology, recombinant DNA, and immunology, which are within the skill of the art. Such techniques are explained fully in the literature. See, for example, Molecular Cloning A Laboratory Manual, 2nd Ed., ed. by Sambrook, Fritsch and Maniatis (Cold Spring Harbor Laboratory Press: 1989); DNA Cloning, Volumes I and II (D. N. Glover ed., 1985); Oligonucleotide Synthesis (M. J. Gait ed., 1984); Mullis et al. U.S. Patent No: 4,683,195; Nucleic Acid Hybridization (B. D. Hames & S. J. Higgins eds. 1984); Transcription And Translation (B. D. Hames & S. J. Higgins eds. 1984); Culture Of Animal Cells (R. I. Freshney, Alan R. Liss, Inc., 1987); Immobilized Cells And Enzymes (IRL Press, 1986); B. Perbal, A Practical Guide To Molecular Cloning (1984); the treatise, Methods In Enzymology (Academic Press, Inc., N.Y.); Gene Transfer Vectors For Mammalian Cells (J. H. Miller and M. P.

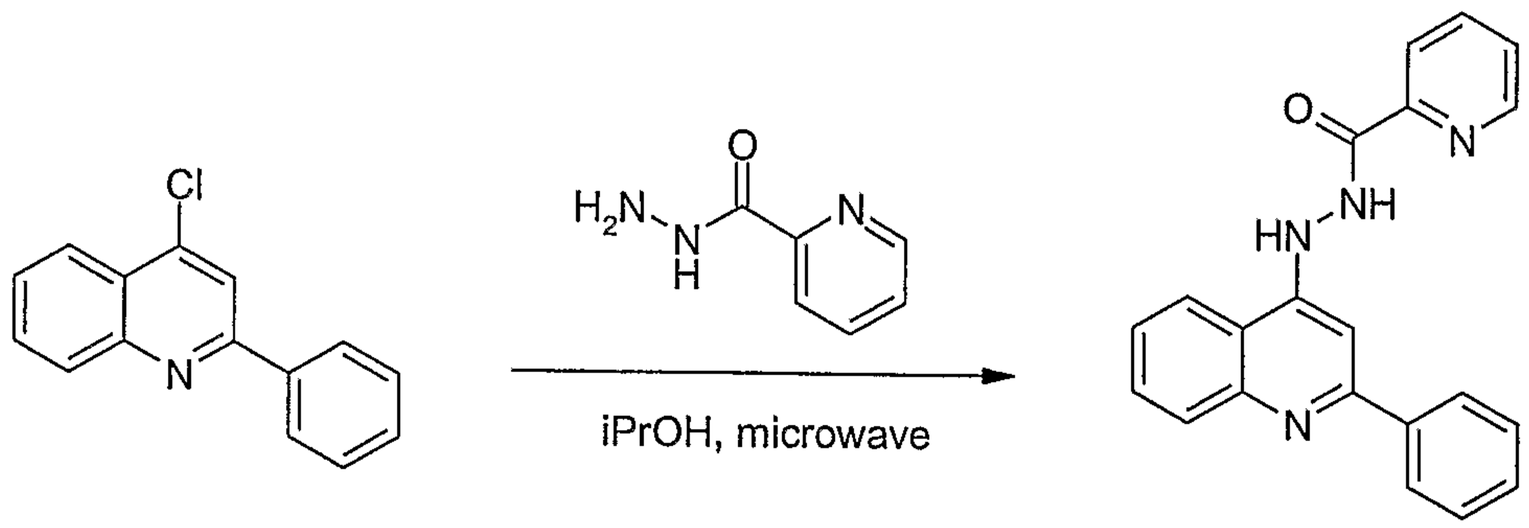
Calos eds., 1987, Cold Spring Harbor Laboratory); Methods In Enzymology, Vols. 154 and 155 (Wu et al. eds.), Immunochemical Methods In Cell And Molecular Biology (Mayer and Walker, eds., Academic Press, London, 1987); Handbook Of Experimental Immunology, Volumes I-IV (D. M. Weir and C. C. Blackwell, eds., 1986); Manipulating the Mouse Embryo, (Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y., 1986).

EXEMPLIFICATION

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

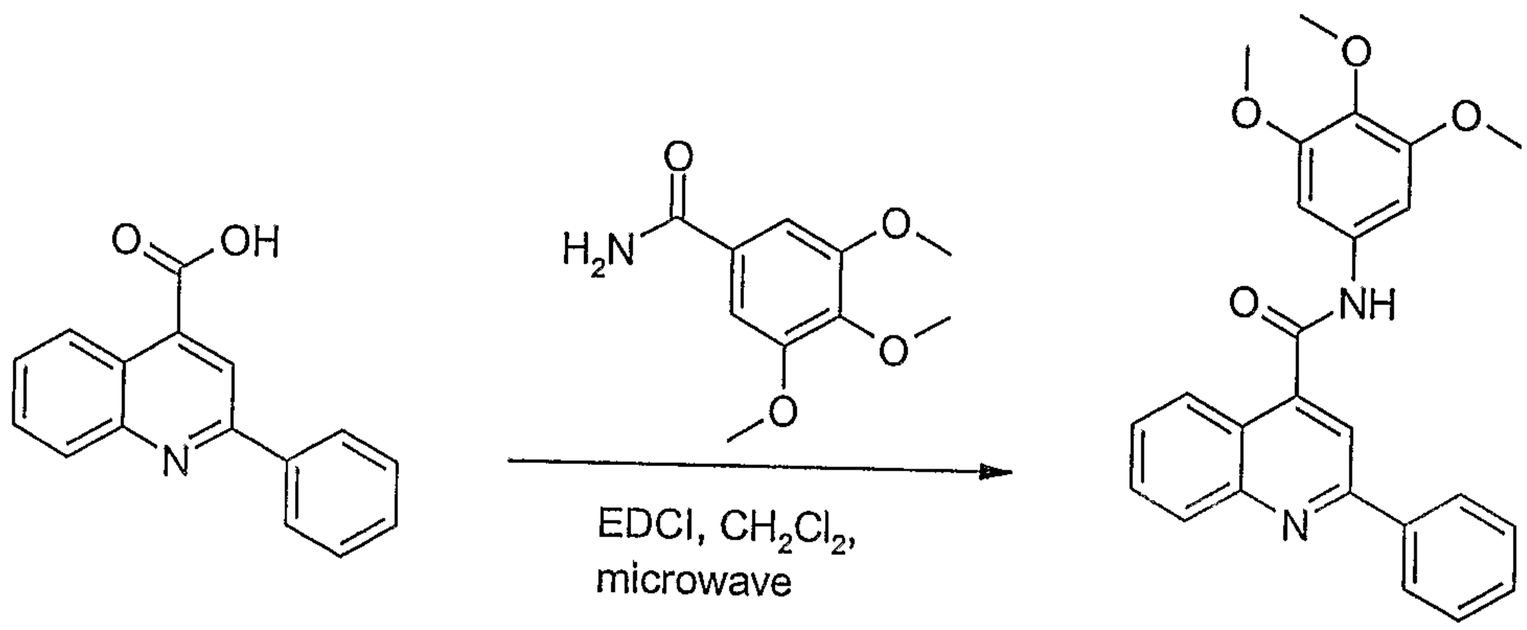
EXAMPLE 1: Synthesis and Characterization of Sirtuin Modulators

Synthesis of Compounds 22, 23, 24, 25 and 26:



A microwave vial was charged with 4-chloro-2-phenylquinoline (0.050 g, 0.2 mmol), 2-picolinyl hydrazide (0.029 g, 0.2mmol) and 1 mL of iso-propanol. The mixture was subjected to microwave irradiation for 15 minutes at 165 °C. Upon cooling, a precipitate formed, which was filtered, washed with CH_2Cl_2 and dried under high vacuum to afford the desired product. Calc'd for C21H15N4O: 340.39, [M+H]+ = 341.

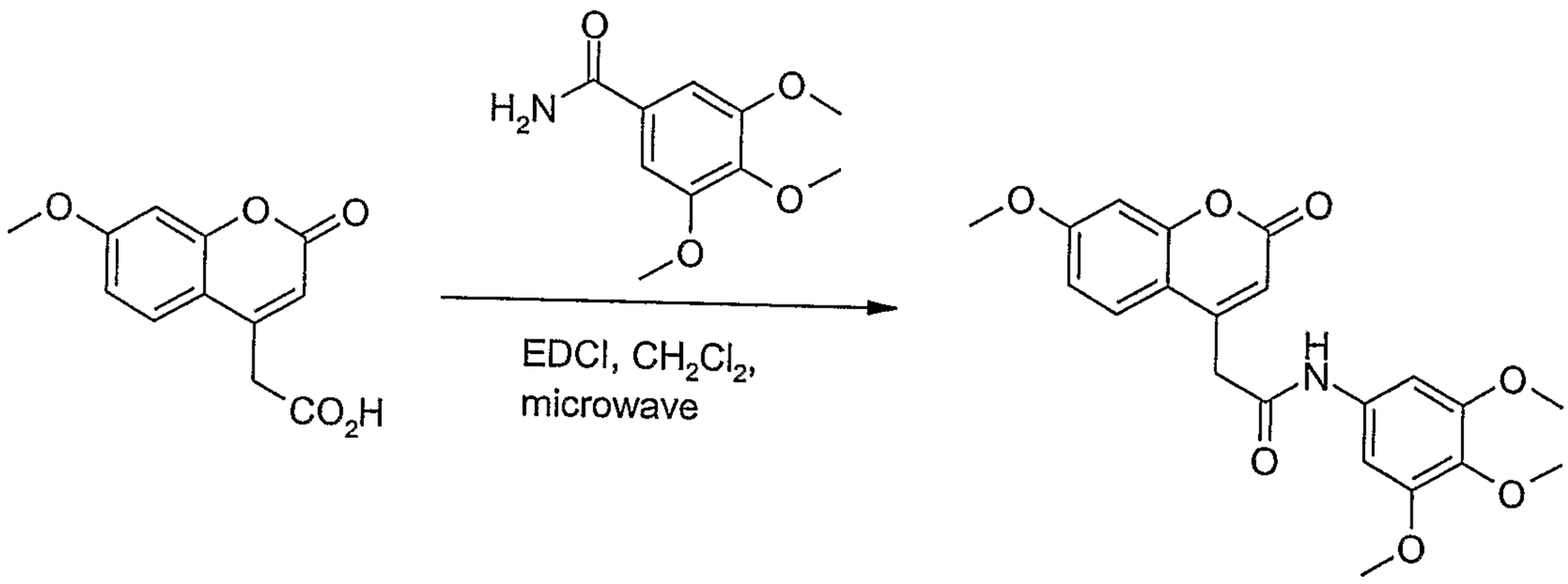
Synthesis of Compounds 27 and 29:



A microwave vial was charged with 2-phenyl-4-quinoline-carboxylic acid (0.1 g, 0.4 mmol), 3,4,5-trimethoxyaniline (0.073 g, 0.4 mmol), EDCI (0.10 g, 0.5 mmol) and 2 mL of CH_2Cl_2. The mixture was subjected to microwave irradiation for 15 minutes at 100 °C. The reaction mixture was partitioned between water and CH_2Cl_2. The organic layer was washed with brine and dried over $MgSO_4$. The crude product was purified by silica chromatography (3-10% MeOH/ CH_2Cl_2) to afford the desired product.

Calc'd for C25H22N2O4: 414.5, [M+H]+ = 415.

Synthesis of Compound 28:

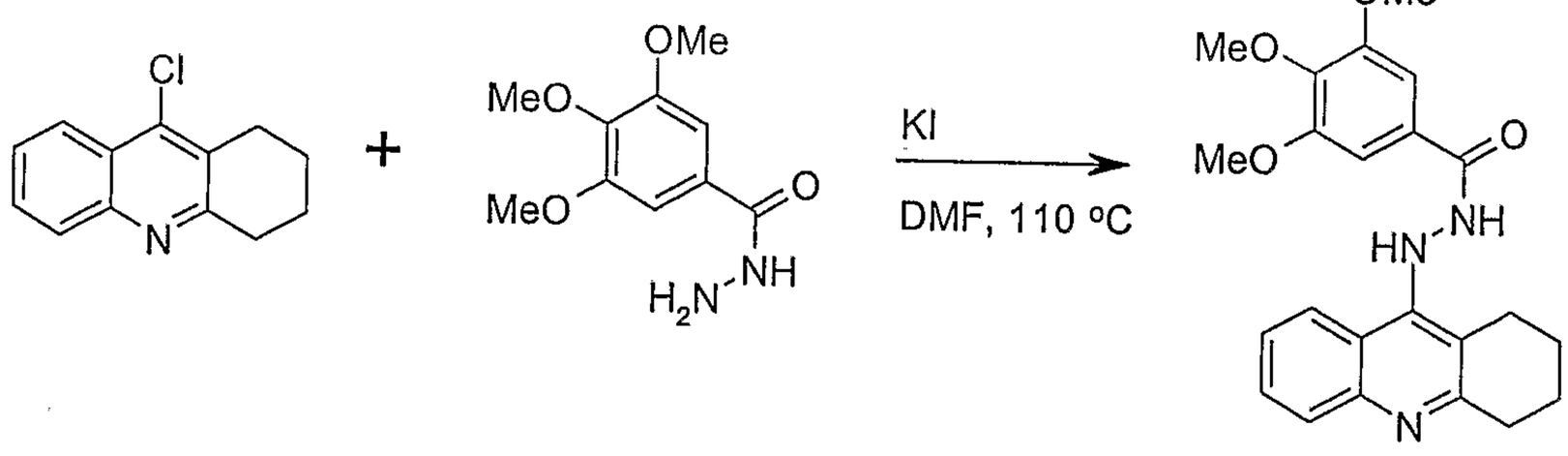


To a solution of 7-methoxycoumarin-4-acetic acid (0.10 g, 0.4 mmol) in 2 mL of CH_2Cl_2 was added EDCI (0.11 g, 0.6 mmol) and 3,4,5-trimethoxyaniline (0.078 g, 0.4 mmol). The mixture was stirred at room temperature for 16 h. The reaction mixture was partitioned between CH_2Cl_2 and brine. The aqueous layer was extracted with

CH_2Cl_2 and the combined organic extracts were washed with brine and dried over $MgSO_4$.

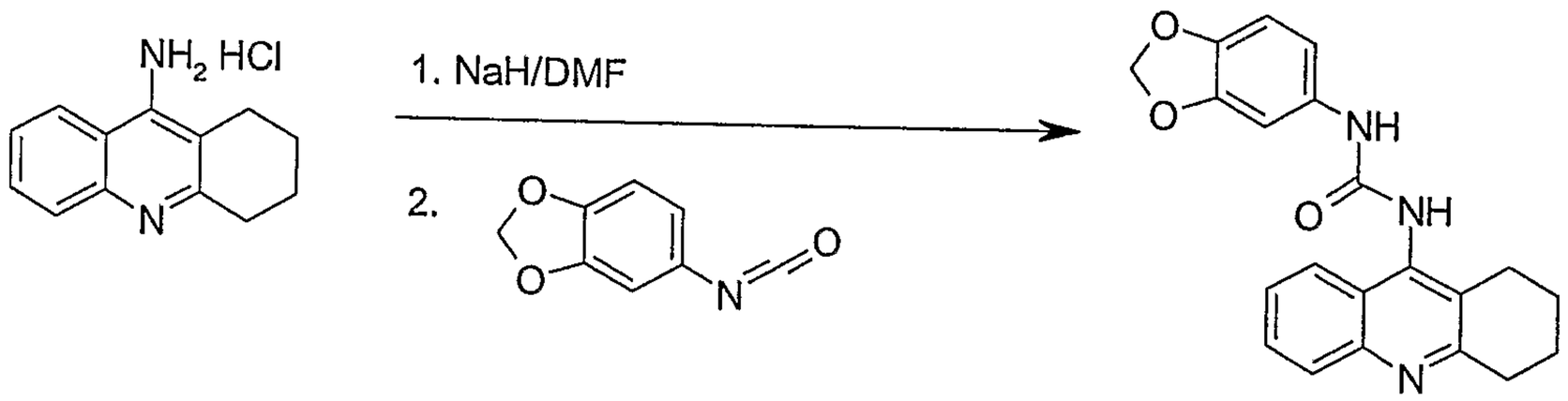
The crude product was purified by silica chromatography (1-10% MeOH/ CH_2Cl_2) to afford the desired product. Calc'd for C21H21NO7: 399.4, [M+H]+ = 400.

Synthesis of Compounds162, 120, 121, 122, 131 and 163:



9-chloro-5,6,7,8-tetrahydroacridine (217 mg, 1 mmol), 3,4,5-trimethoxybenzohydrazide (226 mg, 1 mmol), catalytic KI (5 mg) and 5 mL dry DMF were placed in a 40 mL vial. The reaction mixture was heated with a 110 ^{0}C oil bath and magnetically stirred for 12 hours. The reaction crude initially became clear and then gradually turned into a yellow suspension. After the reaction was cooled to room temperature, the crude product was filtered and collected and was then recrystallized using MeOH to afford the pure product (Calc'd for C23H25N3O4: 407.2, [M+H]+ found: 408.2).

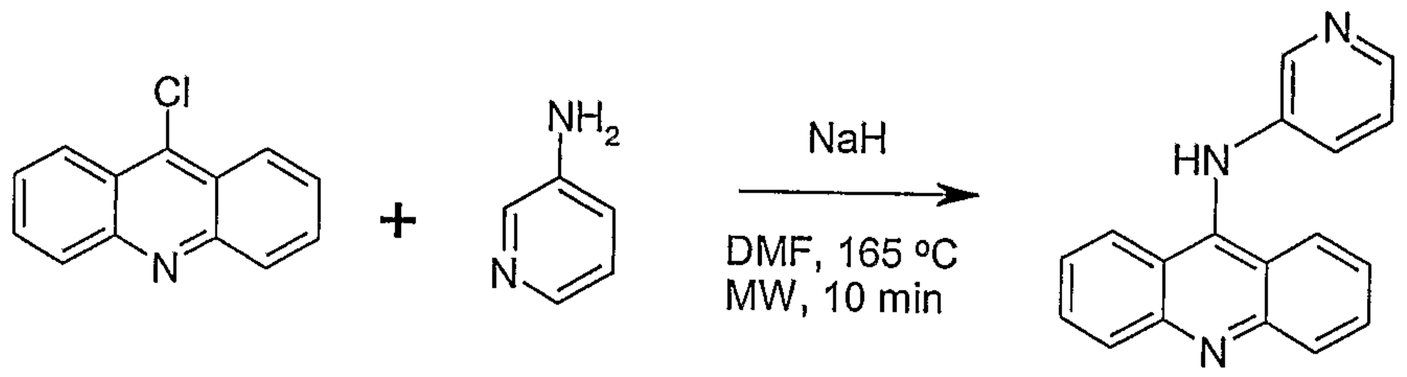
Synthesis of Compounds 123, 124, 145, 146, 147, 148, 149, 150, 153, 156, 157, 166, 158, and 167:



In a 40 mL vial, 5,6,7,8-tetrahydroacridin-9-amine hydrochloride (234 mg, 1.0 mmol) and NaH (120 mg, 60% dispersion in mineral oil, 3 mmol) in 5 mL DMF was stirred

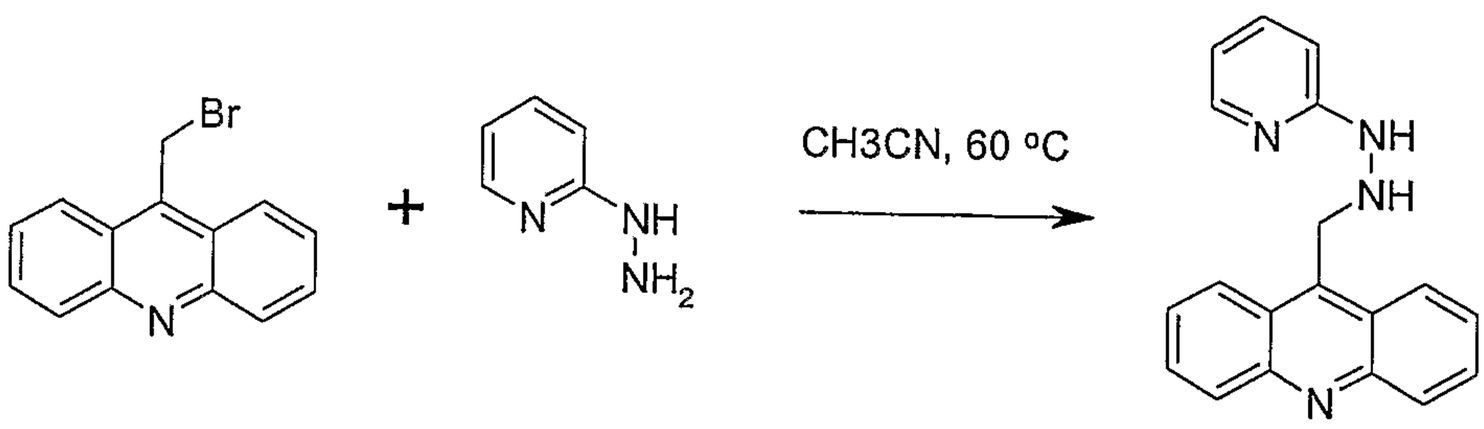
at r.t. for 30 minutes. 3,4-(methylenedioxy)phenyl isocyanate (163 mg, mw=163.1, 1 mmol) was then added in one shot. The reaction mixture was brought up to 60 °C and held overnight. After cooling to room temperature, the reaction crude was poured into 100 mL water and extracted with 100 mL of AcOEt. Solid was formed between organic and aqueous layers, which was isolated and found to be a mixture of product and starting materials. The crude product was then suspended in 10 mL MeOH at 60 °C overnight and then filtered while hot to collect the pure product (Calc'd for C21H19N3O3: 361.1, [M+H]+ found: 362.1).

Synthesis of Compounds 151, 152 and 116:



Pyridin-3-amine (75 mg, 0.8 mmol), was added to a mixture of sodium hydride (36 mg, 60% dispersion in mineral oil, 0.9 mmol) in dry DMF (5 mL). The mixture was stirred at r.t. for 5 minutes and 9-chloroacridine (171 mg, 0.8 mmol) was added, and the mixture was brought up to 165 ^{0}C (MW) for 10 min. The mixture was cooled to r.t. and addition of 20 ml water gave a precipitate of the product, which was isolated by filtration (Calc'd for C18H13N3: 271.1, [M+H]+ found: 272.1).

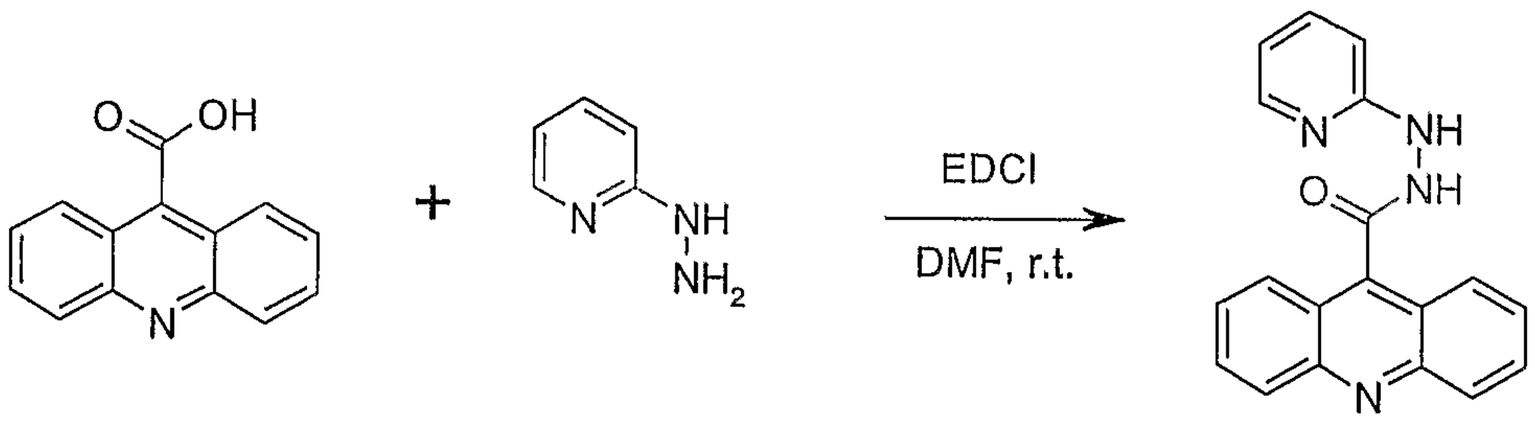
Synthesis of Compound 132:



In a 40 mL vial, 9-(bromomethyl)acridine (272 mg, 1 mmol) in 10 mL CH_3CN (suspension) was added to a solution of 2-(pyridin-2-yl)hydrazine (327 mg, 3 mmol). The reaction mixture was heated and magnetically stirred (60 ^{0}C oil bath) for 24 hours. The reaction initially turned clear but soon became cloudy, and remained so throughout the reaction. At the end of the reaction, the mixture was cooled to room

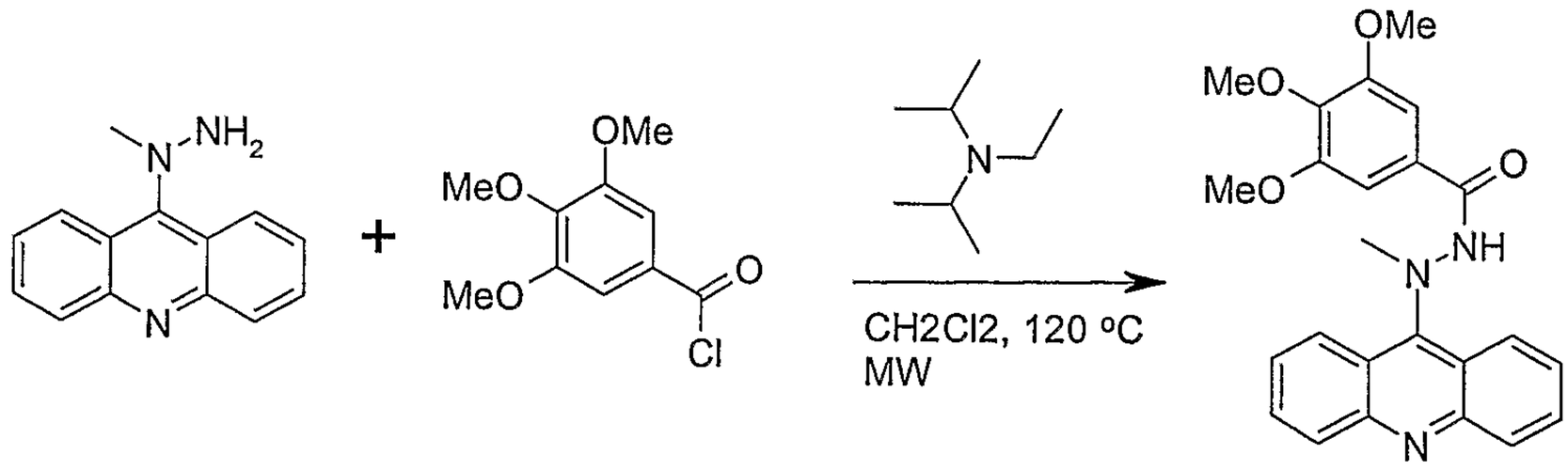
temperature and filtered to collect crude product. The crude product was washed with CH_2Cl_2 and dried, leaving the pure desired product (Calc'd for C19H16N4: 300.1, [M-H]+ found: 299.1).

Synthesis of Compound 133:



In a 40 mL vial, acridine-9-carboxylic acid (200 mg, 0.9 mmol) in 5 mL DMF (suspension) was added to 248 mg of EDCI (MW 191.71, 1.3 mmol) followed by the addition of 2-(pyridin-2-yl)hydrazine (109 mg, 1 mmol). The reaction mixture was magnetically stirred at room temperature and gradually turned clear. After stirred at room temp for 2 hours, 25 mL of water was then added dropwise and the resulting precipitate was isolated and found to be the desired product (Calc'd for C19H14N4O: 314.1, [M+H]+ found: 315.1).

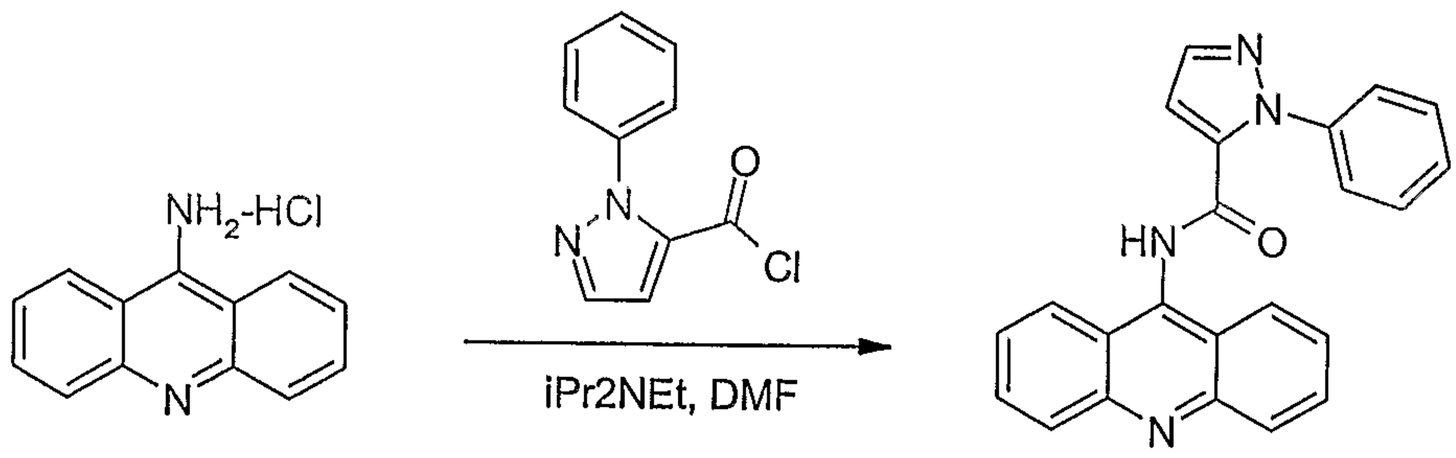
Synthesis of Compounds 154 and 155:



A mixture of 1-(acridin-9-yl)-1-methylhydrazine (88 mg, 0.39 mmol), 3,4,5-trimethoxybenzoyl chloride (90 mg, 0.39 mmol), N-ethyl-N-isopropylpropan-2-amine (203 ul, mw=129.25, d=0.742, 3 eq.) in 5 mL CH_2Cl_2 was heated to 120 ^{0}C (MW) for 10 min. Reaction crude was then poured into 100 mL water and extracted with 100 mL AcOEt. The organic solution was separated and washed again with 100 mL brine and further dried with Na_2SO_4. The organic solvent was evaporated under vacuum. The crude product was purified using Isco Combiflash (4% MeOH in CH2Cl2) to

provide the pure desired product (Calc'd for C24H23N3O4: 417.2, [M+H]+ found: 418.2).

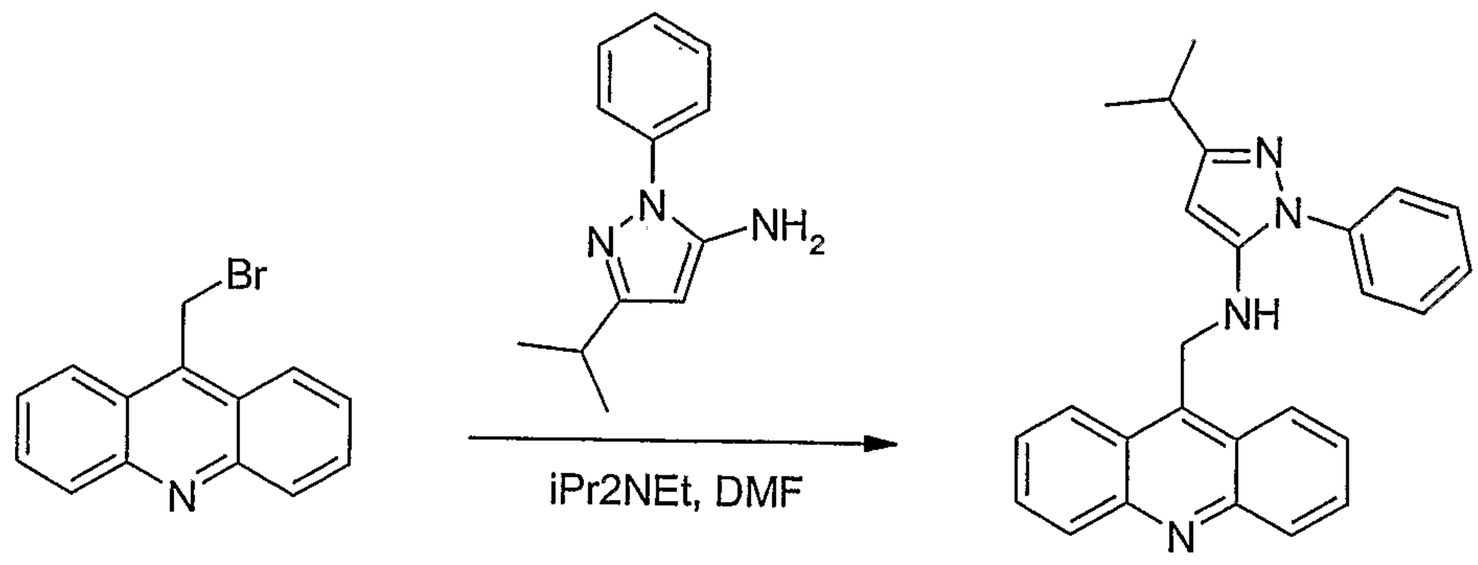
Synthesis of Compound 119:



To a solution of 9-aminoacridine HCl salt, hydrate (0.3 g 1.2 mmol) in 6 mL of DMF was added diisopropylethylamine (0.34 g, 2.7 mmol, 0.46 mL) and 1-phenyl-1H-pyrazole-5-carbonyl chloride (0.27 g, 1.3 mmol). The reaction was stirred at room temperature for 2 h. An additional equivalent of the acid chloride was then added (0.4 mL) and the reaction was stirred at room temperature for 16 h. The reaction was partitioned between water and EtOAc. The aqueous layer was extracted with EtOAc, and the combined organic extracts were washed with brine and dried over $MgSO_4$. The crude material was purified by silica chromatography (1-10% $MeOH/CH_2Cl_2$) to afford the desired product.

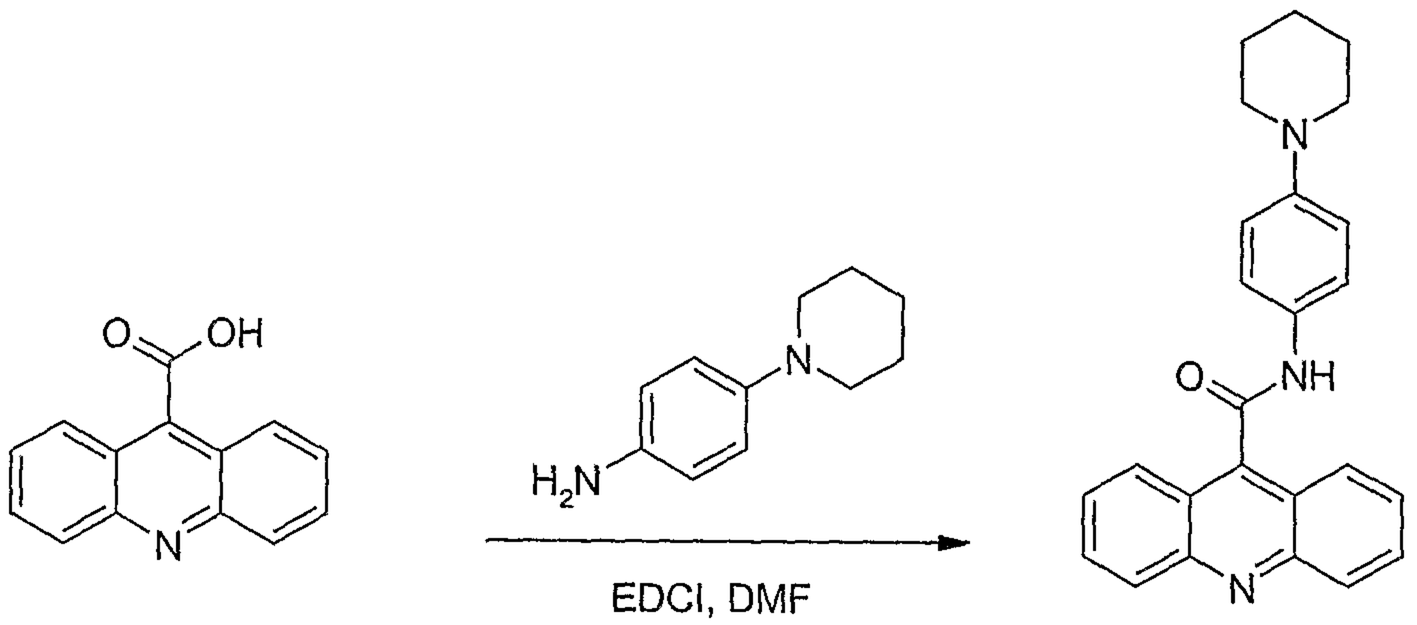
(Calc'd for C23H16N4O: 364.4, [M+H]+ found: 365)

Synthesis of Compounds 125, 126 and 127:



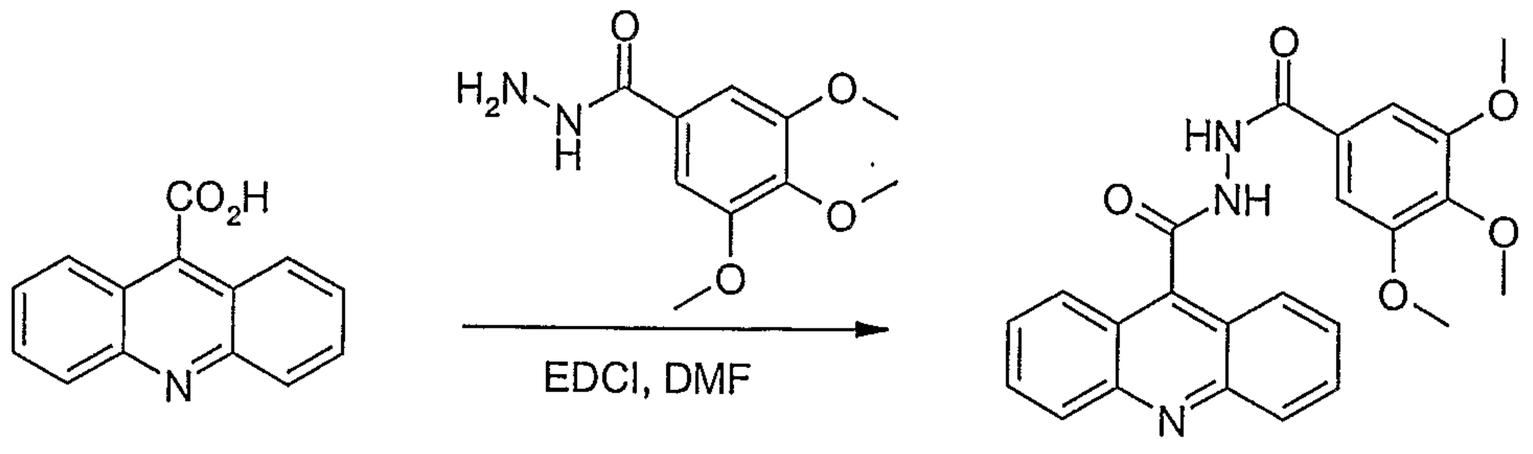
To a solution of 9-bromomethylacridine (0.2 g, 0.7 mmo) in 4 mL of DMF was added diisopropylethylamine (0.14 g, 1.1 mmol, 0.2 mL) and 3-isopropyl-1-pheynyl-1H-pyrazol-5-amine (0.18 g, 0.9 mmol). The reaction was stirred at 40 °C for 8 h. Upon cooling, the reaction mixture was partitioned between water and EtOAc. The aqueous layer was washed with EtOAc, and the combined organic extracts were washed with brine and dried over $MgSO_4$. The crude material was purified by silica chromatography (0-40% Hexanes/EtOAc) to afford the desired product.
(Calc'd for C26H24N4: 392.5, [M+H]+ found: 393)

Synthesis of Compounds 117, 128, 129, 130, 135, 136, 165, 138, 139, 141, 143, 159, and 160:



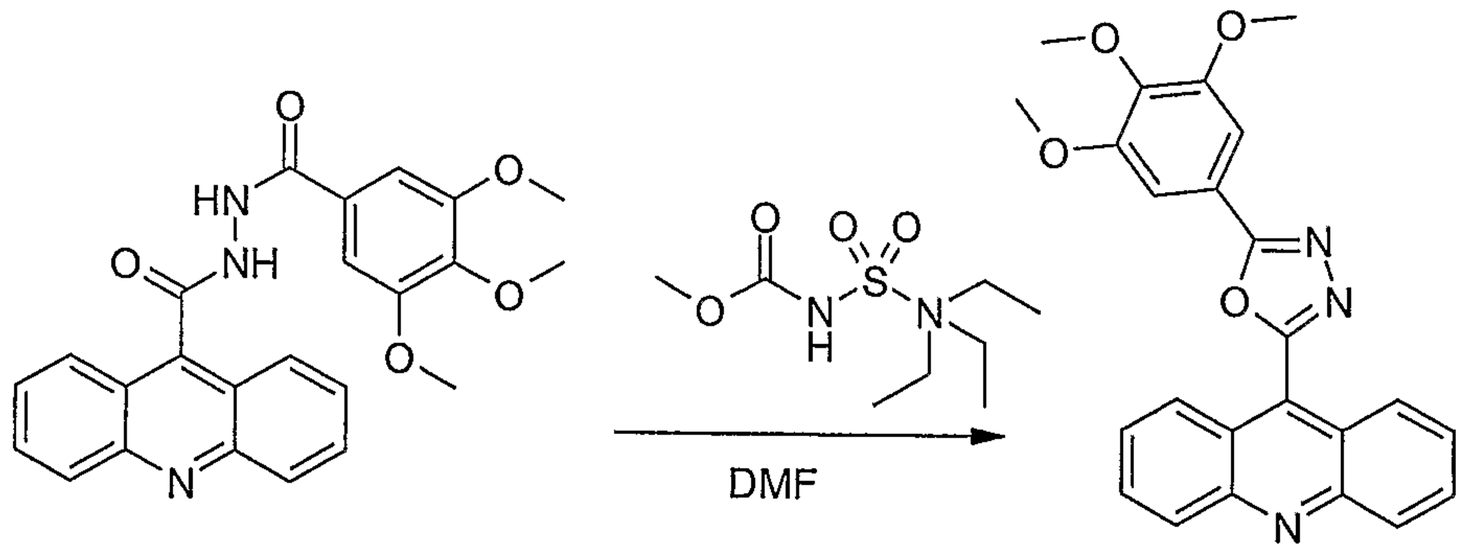
To a solution of 9-acridine carboxylic acid (0.2 g, 0.9 mmol) in 5 mL of DMF was added EDCI (0.23 g, 1.3 mmol) and N-(4-aminophenyl)piperidine (0.17 g, 1.0 mmol). The reaction mixture was stirred at room temperature for 16 h. The mixture was diluted with water and EtOAc to produce a precipitate. The solid was washed with water and EtOAc, and dried under high vacuum to afford the desired product.

Synthesis of Compounds 134, 164 and 140:



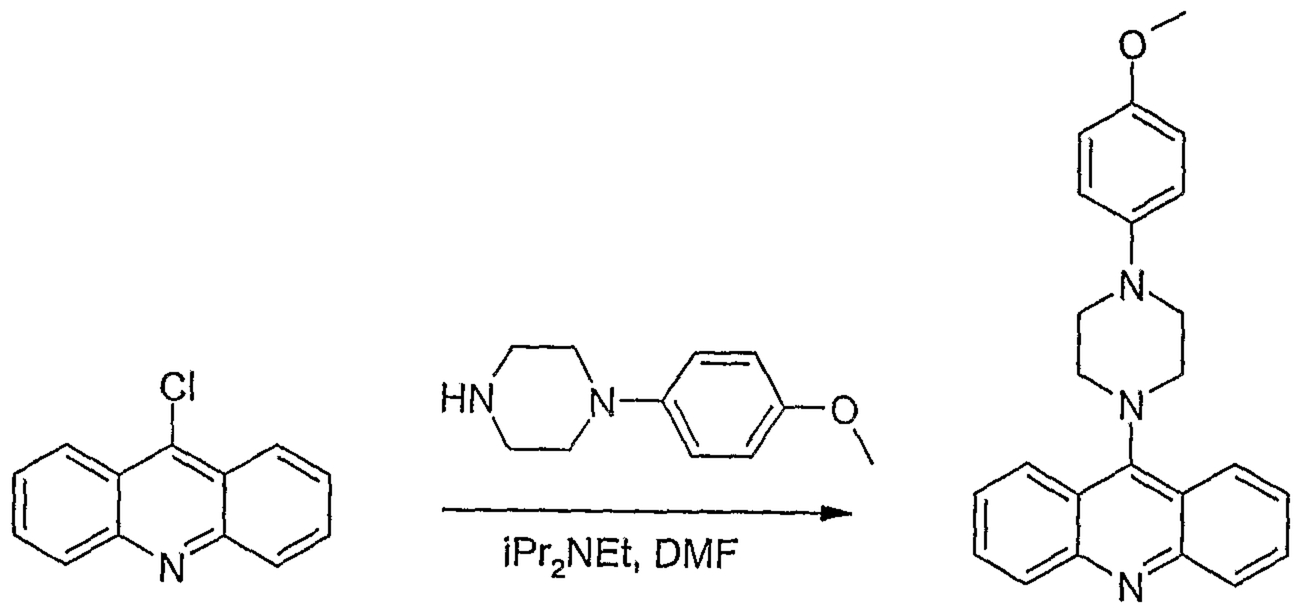
To a mixture of 9-acridine carboxylic acid (0.2 g, 0.9 mmol) in 4 mL of DMF was added EDCI (0.26 g, 1.3 mmol) and 3,4,5-trimethoxybenzhydrazide (0.21 g, 1.0 mmol). The reaction was stirred at room temperature for 16 h. The reaction solution was diluted with water, and the resulting precipitate was filtered, washed with EtOAc and dried to afford the desired product. (Calc'd for C21H13F2N3O2: 377.3, [M+H]+ found: 378)

Synthesis of Compounds 220 and 142:



To a solution of the acridine (0.075 g, 0.17 mmol) in 1.5 mL of DMF was added the Burgess reagent (0.14 g, 0.6 mmol). The reaction was stirred at 150 °C for 4 h. Upon cooling, the reaction mixture was partitioned between water and EtOAc. The aqueous layer was washed with brine and dried over MgSO4. The crude material was purified by silica chromatography (1-10% MeOH/CH2Cl2) to afford the desired product. (Calc'd for C24H19N3O4: 413.4, [M+H]+ found: 414)

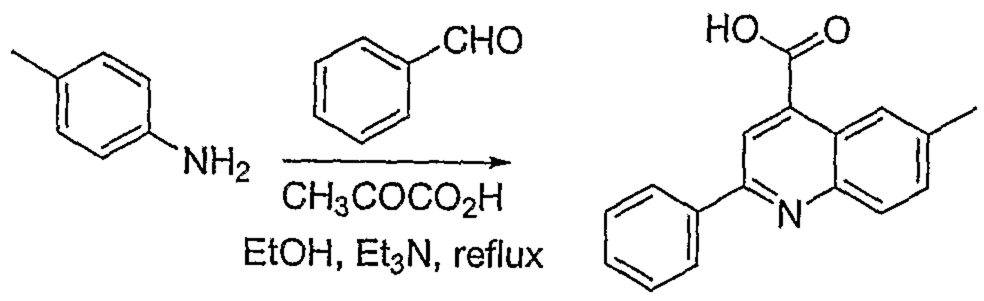
Synthesis of Compound 144:



A microwave vial was charge with 9-chloroacridine (0.1 g, 0.5 mmol), 1-(4-methoxyphenyl)piperazine-HCl (0.12 g, 0.5 mmol), diisopropylethylamine (0.15 g, 1.2 mmol) and 1.5 mL of DMF. The reaction mixture was subjected to microwave irradiation for 10 minutes at 125 °C. The reaction mixture was partitioned between brine and EtOAc. The aqueous layer was extracted with EtOAc, and the combined organic extracts were washed with brine and dried over MgSO4. The crude product was purified by silica chromatography (2-8% MeOH/CH2Cl2) to afford the deisred product.

(Calc'd for C24H23N3O: 369.5, [M+H]+ found: 370)

Phenyl Quinoline analogue

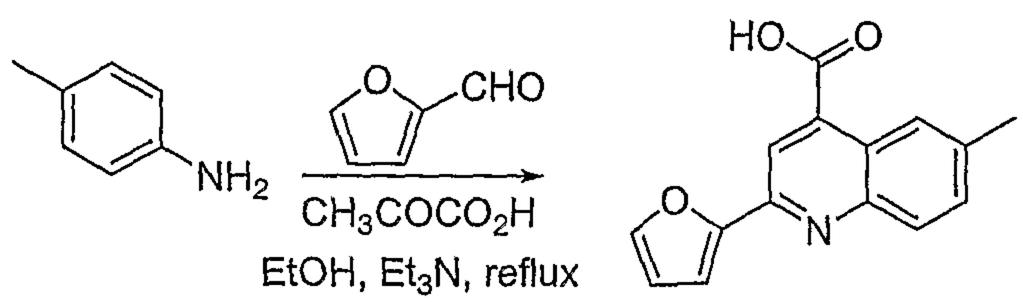


In a 500 ml two necked round bottom flask, 10 gm of p-toluidne (0.0933 moles, 1 eq) was taken and dissolved in 200 ml of ethanol. To this solution, 9.9 gm of benzaldehyde (0.0933 mol, 1eq), pyruvic acid (8.2 gm, 0.0933 mol, 1 eq), and 9.4 gm of triethylamine (0.0933 mol, 1eq) were added at room temperature. The reaction mixture was then refluxed at 80^0C for 5 h and stirred overnight at room temperature under nitrogen. The progress of the reaction was monitored by TLC. After absence of starting material, the solvent was removed on rotavapor. The crude mixture was

diluted with dichloromethane, washed with water and brine thrice. The combined organic layers were dried over sodium sulfate and concentrated under reduced pressure to give crude phenyl quinoline compound which was purified further by column chromatography. Column purification gave 10.5 gm of pure phenyl-quinoline acid. (42% yield). M^+ 264.

(^{1}H NMR, 200MHz, CD3OD): δ 2.50 (s, 3 H), 7.77-7.82 (m, 3H), 7.85 (s, 1H), 8.05-8.23 (m, 3H), 8.38-8.42 (m, 2H).

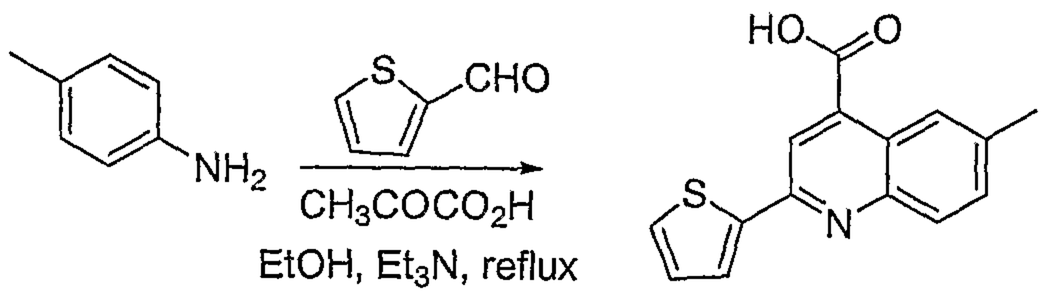
Furyl Quinoline analogue



In a 500 ml two necked round bottom flask, 10 gm of p-toluidine (0.0933 moles, 1 eq) was taken and dissolved in 200 ml of ethanol. To this solution, 89.67 gm of furfuraldehyde (0.0933 mol, 1eq), pyruvic acid (8.2 gm, 0.0933 mol, 1 eq), and 9.4 gm of triethylamine (0.0933 mol, 1eq) were added at room temperature. The reaction mixture was then refluxed at 80^{0}C for 5 h and stirred overnight at room temperature under nitrogen. The progress of the reaction was monitored by TLC. After absence of starting material, the solvent was removed on rotavapor. The crude mixture was diluted with dichloromethane, washed with water and brine thrice. The combined organic layers were dried over sodium sulfate and concentrated under reduced pressure to give crude phenyl quinoline compound which was purified further by column chromatography. Column purification gave 11.2 gm of pure phenyl-quinoline acid. (47% yield). M^+ 254.

(^{1}H NMR, 200MHz, CD3OD): δ 2.50 (s, 3H), 6.72-6.78 (m, 1H), 7.40 (dd, 1H), 7.65-7.70 (m, 1H), 7.90-8.05 (m, 2H), 8.20-8.35 (m, 2H).

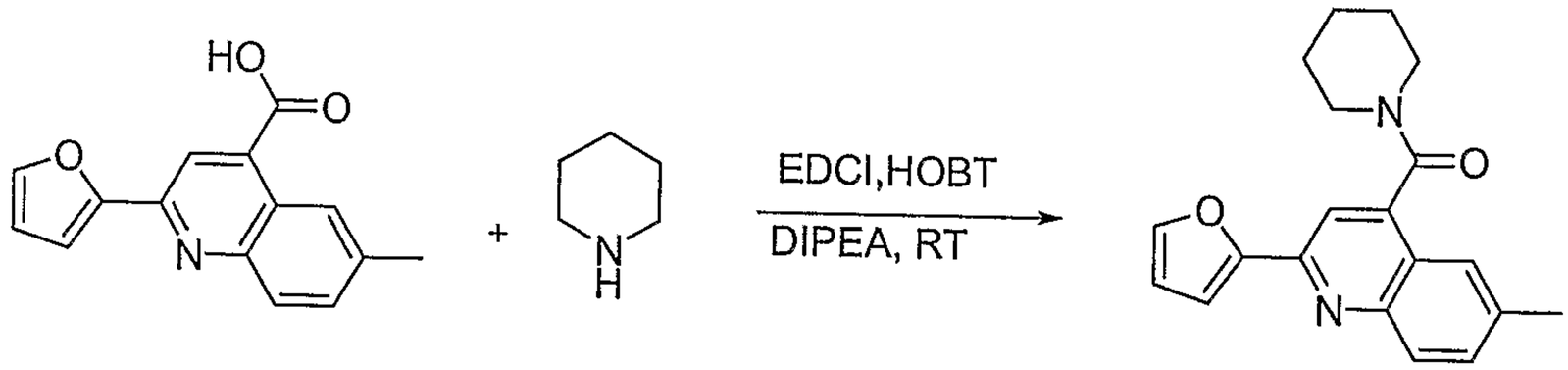
Thiophene Quinoline analogue



In a 500 ml two necked round bottom flask, 10 gm of p-toluidine (0.0933 moles, 1 eq) was taken and dissolved in 275 ml of ethanol. To this solution, 10.44 gm of 2-thiophene aldehyde (0.0933 mol, 1eq), pyruvic acid (8.2 gm, 0.0933 mol, 1 eq), and 9.4 gm of triethylamine (0.0933 mol, 1eq) were added at room temperature. The reaction mixture was then refluxed at 80^0C for 5 h and stirred overnight at room temperature under nitrogen. The progress of the reaction was monitored by TLC. After absence of starting material, the solvent was removed on rotavapor. The crude mixture was diluted with dichloromethane, washed with water and brine thrice. The combined organic layers were dried over sodium sulfate and concentrated under reduced pressure to give crude phenyl quinoline compound which was purified further by column chromatography. Column purification gave 12 gm of pure phenyl-quinoline acid. (48% yield). M^+ 270.

(^{1}H NMR, 200MHz, CD3OD): δ 2.50 (s, 3H), 7.45-7.60 (m, 2H), 7.62-7.75 (dd, 1H), 8.0-8.15 (m, 1H), 8.20-8.40 (m, 2H), 8.45 (s, 1H)

Synthesis and characterization of Compound 30:



S. No	Name of the material	Quantity	Molecular weight	Moles	1. Molar ratio
1.	Furan acid	150mg	253	0.0005928	1.0
2.	Piperidine	75mg	85	0.0008893	1.5
3.	EDCI	170mg	191.71	0.0008892	1.5
4.	HOBT	161mg	136.11	0.0011856	2.0
5.	DIPEA	176mg	129.28	0.0013634	2.3

PROCEDURE:

150 mg (0.0005928 moles, 1 eq) of the furan acid compound was dissolved in 20ml DCM. 75 mg (0.0008893 moles, 1.5 eq) of piperdine was added to the mixture. Then, under cooling conditions, 170 mg (0.0008892 moles, 1.5 eq) of EDCI and 161 mg (0.0011856 moles, 2 eq) of HOBT was added to the mixture. 176 mg (0.001363 moles, 2.3 eq) of DIPEA charged into the mixture. The reaction was maintained at room temperature overnight, by which time the starting material had disappeared.

Work up:

The reaction mixture was dissolved in DCM and extracted with 50 ml of water 2 times and washed once with brine and dried over sodium sulfate and concentrated. The product was purified by column chromatography. 30mg of the product was obtained from this experiment.

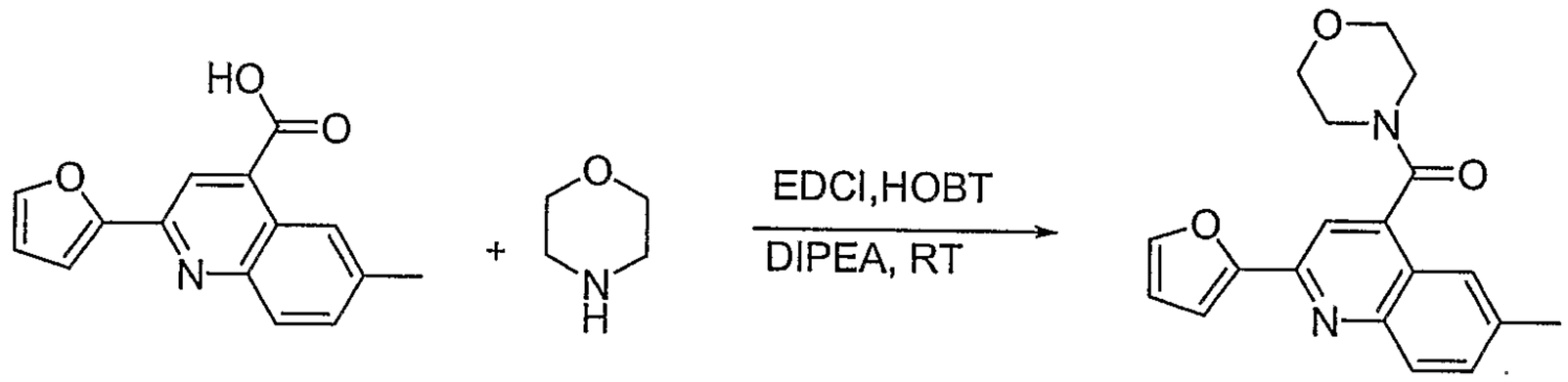
ANALYTICAL DATA:

HNMR: COMPLIES (CD_3OD, 200 MHz); MASS: COMPLIES (320.4)

HNMR: 2.85(3H,s) ; 1-1.9(2H, 2t) ; 7.0(1H,s) ; 7.9(1H,s) ; 8.1(1H,t) ; 8.25(1H,s); 8.4(1H, t); 8.5(1H, s)

HPLC PURITY: 97.431%

Synthesis and characterization of Compound 35:



S.no:	Name of the material	Quantity	Molecular weight	Moles	Mole ratio
1.	Furan acid	150mg	253	0.0005928	1.0
2.	Morpholine	77mg	87	0.0008893	1.5
3.	EDCI	170mg	191.71	0.0008892	1.5
4.	HOBT	161mg	136.11	0.0011856	2.0
5.	DIPEA	176mg	129.28	0.0013634	2.3

PROCEDURE:

150 mg (0.00059 moles, 1 eq) of the furan acid compound was dissolved in 20 ml DCM. 77mg (0.00088moles, 1.5eq) of morpholine was added to the mixture. Then, under cooling conditions, 170 mg (0.00088 moles, 1.5 eq) of EDCI and 161mg (0.00118moles, 2eq) of HOBT was added to the mixture. 176 mg (0.00136 moles, 2.3 eq) of DIPEA charged into the mixture. The reaction was maintained overnight at room temperature until the starting material disappeared.

The reaction mixture was dissolved in DCM and extracted with 50ml of water 2 times and washed once with brine. The DCM layer was dried over sodium sulfate and concentrated. The product was purified by column chromatography.

30mg of the product was obtained from this experiment.

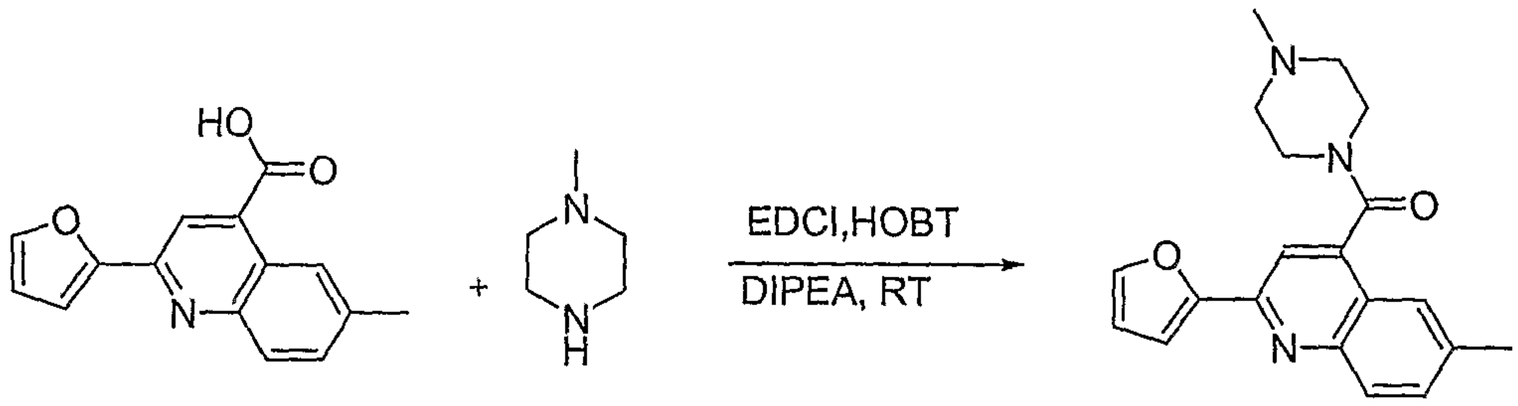
ANALYTICAL DATA:

MASS SPECTRUM: COMPLIES (322.4)

HNMR: CD_3OD, 2.8(3H,s) ; 4.0(2H,t) ; 3.8(2H,t) ; 7.0(1H,s) ; 7.9(1H,s) ; 8.1(1H,t) ; 8.25(1H,s) ; 8.4(1H,t); 8.5(1H, s)

HPLC PURITY: 96.330%

Synthesis and characterization of Compound 33:



S.no:	Name of the material	Quantity	Molecular weight	Moles	Mole ratio
1.	Furan acid	150mg	253	0.0005928	1.0
2.	N-methyl piperazine	88mg	100	0.0008893	1.5
3.	EDCI	170mg	191.71	0.0008892	1.5
4.	HOBT	161mg	136.11	0.0011856	2.0
5.	DIPEA	176mg	129.28	0.0013634	2.3

PROCEDURE:

150 mg (0.00059 moles, 1 eq) of the furan acid compound was dissolved in 20 ml DCM. 88mg (0.00088moles, 1.5eq) of N-methyl piperazine was added to the mixture. Then, under cooling conditions, 170 mg (0.00088 moles, 1.5 eq) of EDCI and 161 mg (0.00118 moles, 2 eq) of HOBT was added to the mixture. 176 mg (0.00136 moles, 2.3 eq) of DIPEA charged into the mixture. The reaction was maintained overnight at room temperature until the starting material disappeared.

The reaction mixture was dissolved in DCM and extracted with 50 ml of water 2 times and washed once with brine. The DCM layer was dried over sodium sulfate and concentrated. The product was purified by column chromatography. 35 mg of the product was obtained from this experiment. Actual yield: 0.1991gm, yield obtained: 35mg; % yield: 17.5.

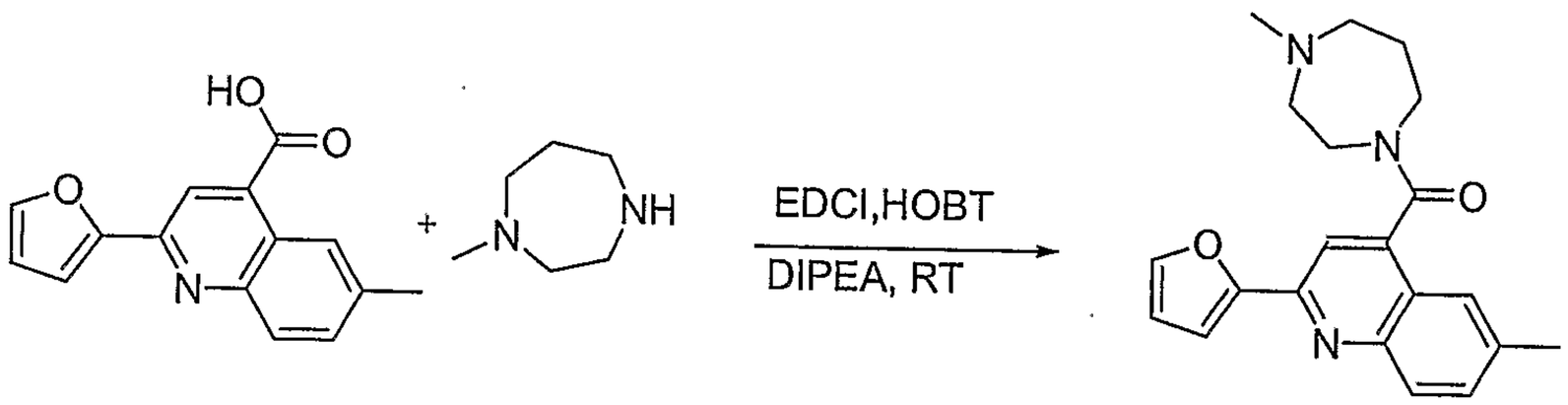
ANALYTICAL DATA:

MASS SPECTRUM: COMPLIES (336)

HNMR: CD_3OD, 3.1(3H,s) ; 1.1(3H,s) ; 3.5(2H,t of t), 3.6(2H,t of t) ; 7.0(1H,s) ; 7.9(1H,s) ; 8.1(1H,t) ; 8.25(1H,s) ; 8.4(1H,t) ; 8.5(1H,s)

HPLC PURITY: 95.861%

Synthesis and characterization of Compound 38:



S.no:	Name of the material	Quantity	Molecular weight	Moles	Mole ratio
1.	Furan acid	150mg	253	0.0005928	1.0
2.	N-methyl homo piperazine	101mg	114	0.0008893	1.5
3.	EDCI	170mg	191.71	0.0008892	1.5

4.	HOBT	161mg	136.11	0.0011856	2.0
5.	DIPEA	176mg	129.28	0.0013634	2.3

PROCEDURE:

150 mg (0.00059 moles, 1 eq) of the furan acid compound was dissolved in 20 ml DCM. 101 mg (0.00088 moles, 1.5 eq) of N-methyl homopiperazine was added to the mixture. Then, under cooling conditions, 170 mg (0.00088 moles, 1.5 eq) of EDCI and 161 mg (0.00118 moles, 2 eq) of HOBT was added to the mixture. 176mg (0.00136 moles, 2.3 eq) of DIPEA charged into the mixture. The reaction was maintained overnight at room temperature until the starting material disappeared.

The reaction mixture was dissolved in DCM and extracted with 50ml of water 2 times and washed once with brine. The DCM layer was dried over sodium sulfate and concentrated. The product was purified by column chromatography. 35mg of product was obtained from this experiment. Actual yield: 0.2068g, yield obtained: 35mg: % yield: 16.9.

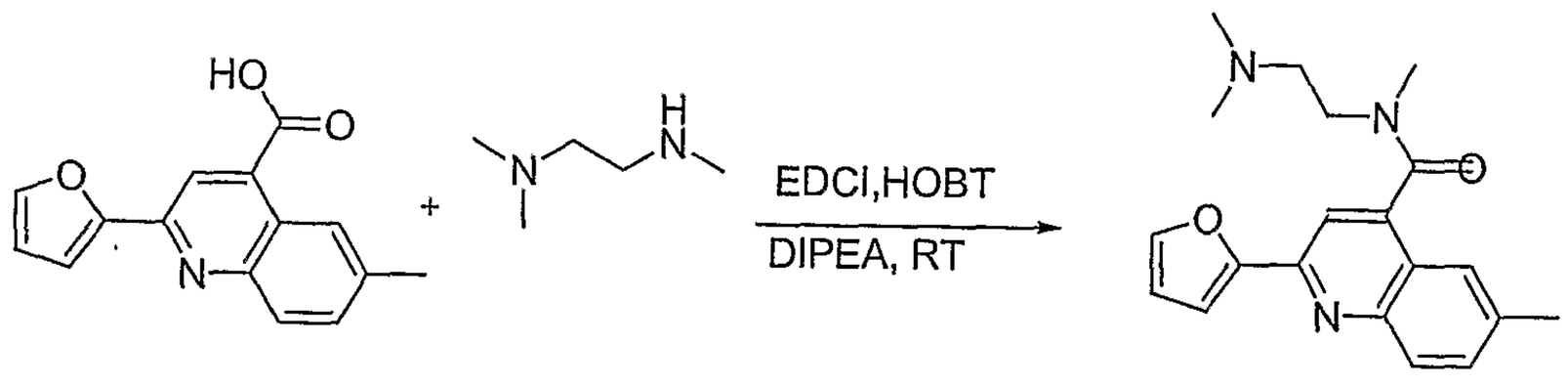
ANALYTICAL DATA:

MASS SPECTRUM: COMPLIES (349.4)

HNMR: CD_3OD, 2.8(3H,s) ; 3.0(3H,s) ; 3.2(2H,t of t), 3.3(2H,t of t) ; 3.8(2H,m) ; 7.0 (1H,s) ; 7.9(1H,s) ; 8.1(1H,t) ; 8.25 (1H,s) ; 8.4(1H,t) ;8.5(1H,s)

HPLC PURITY: 97.368%

Synthesis and characterization of Compound 32:



S.no:	Name of the material	Quantity	Molecular weight	Moles	Mole ratio
2.	Furan acid	150mg	253	0.0005928	1.0
2.	N,N,N-Tri methyl ethyl methyl amine	90mg	102	0.0008893	1.5
3.	EDCI	170mg	191.71	0.0008892	1.5
4.	HOBT	161mg	136.11	0.0011856	2.0
5.	DIPEA	176mg	129.28	0.0013634	2.3

PROCEDURE:

150 mg (0.00059 moles, 1 eq) of the furan acid compound was dissolved in 20 ml DCM. 90mg (0.00088 moles, 1.5 eq) of N,N,N-Tri methyl ethyl methyl amine was added to the mixture. Then, under cooling conditions, 170 mg (0.00088 moles, 1.5 eq) of EDCI and 161 mg (0.00118 moles, 2 eq) of HOBT was added to the mixture. 176 mg (0.00136 moles, 2.3 eq) of DIPEA charged into the mixture. The reaction was maintained overnight at room temperature until the starting material disappeared.

The reaction mixture was dissolved in DCM and extracted with 50 ml of water 2 times and washed once with brine. The DCM layer was dried over sodium sulfate and concentrated. The product was purified by column chromatography. 30 mg of the product was obtained from this experiment. Actual yield: 0.173 g, yield obtained: 30 mg, % yield: 17.3%.

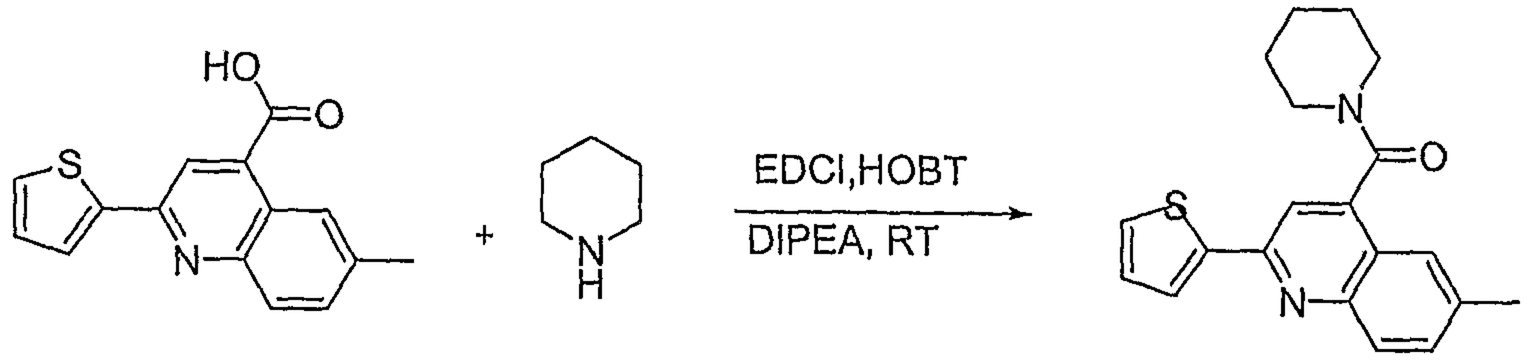
ANALYTICAL DATA:

MASS SPECTRUM: COMPLIES (293)

HNMR: CD_3OD, 2.8(3H,s) ; 3.1(2H,t of t) ; 3.2(3H,s), 3.8 (3H,s) ; 3.825(3H,m) ; 7.0 (1H,s) ; 7.9(1H,s) ; 8.1(1H,t) ; 8.25 (1H,s) ; 8.4(1H,t) ;9(1H,s)

HPLC PURITY: 99.815%

Synthesis and characterization of Compound 48:



s.no	Name of the material	Quantity	Molecular weight	Moles	2. Molar ratio
1.	Thiophene acid	150mg	253	0.0005576	1.o
2,	Piperadine	71mg	85	0.0008364	1.5
3.	EDCI	160mg	191.71	0.0008364	1.5
4.	HOBT	151mg	136.11	0.0011152	2.0
5.	DIPEA	165mg	129.28	0.0012825	2.3

PROCEDURE:

150 mg (0.000555 moles, 1 eq) of the thiophene acid compound was dissolved in 20ml DCM. 71 mg (0.0008364 moles, 1.5 eq) of piperdine was added to the mixture. Then, under cooling conditions, 160 mg (0.0008364 moles, 1.5 eq) of EDCI and 151 mg (0.0011856 moles, 2 eq) of HOBT was added to the mixture. 165 mg (0.001363 moles, 2.3 eq) of DIPEA was charged into the mixture. The reaction was maintained at room temperature overnight until the starting material disappeared.

The reaction mixture was dissolved in DCM and extracted with 50ml of water 2 times, washed once with brine and dried over sodium sulfate and concentrated. The product was purified by column chromatography. 35 mg of the product was obtained from this experiment. Actual yield: 0.187 g; yield obtained: 35 mg; % yield: 18.7.

ANALYTICAL DATA:

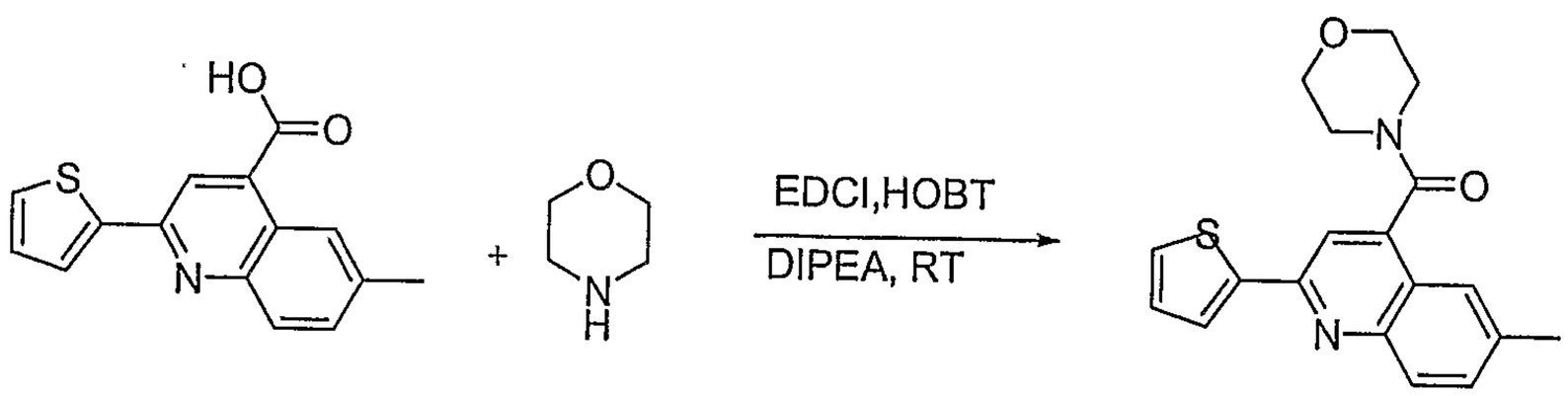
HNMR: COMPLIES (CD3OD, 200MHz)

MASS: COMPLIES (336.45)

HNMR:- 2.8(3H,s) ; 1-1.9(2H, 2t) ; 7.0(1H,s) ; 7.9(1H,s) ; 8.1(1H,t) ; 8.25(1H,s) ; 8.4(1H, t); 8.5(1H, s)

HPLC: 97.431%

Synthesis and characterization of Compound 172:



S.no:	Name of the material	Quantity	Molecular weight	Moles	Mole ratio
3.	Thiophene acid	150mg	269	0.0005576	1.0
2.	Morpholine	73mg	87	0.000836	1.5
3.	EDCI	160g	191.71	0.000836	1.5
4.	HOBT	151mg	136.11	0.001115	2.0
5.	DIPEA	165mg	129.28	0.001282	2.3

PROCEDURE:

150 mg (0.00055 moles, 1 eq) of the thiophene acid compound was dissolved in 20ml DCM. 73mg (.000836 moles, 1.5 eq) of morpholine was added to the mixture. Then, under cooling conditions, 160 mg (0.00083 moles, 1.5 eq) EDCI and 151 mg (0.00011 moles, 1.2 eq) of HOBT was added to the mixture. 165 mg (0.00128 moles, 2.3 eq) DIPEA was charged into the mixture. The reaction was maintained overnight at room temperature until the starting material disappeared.

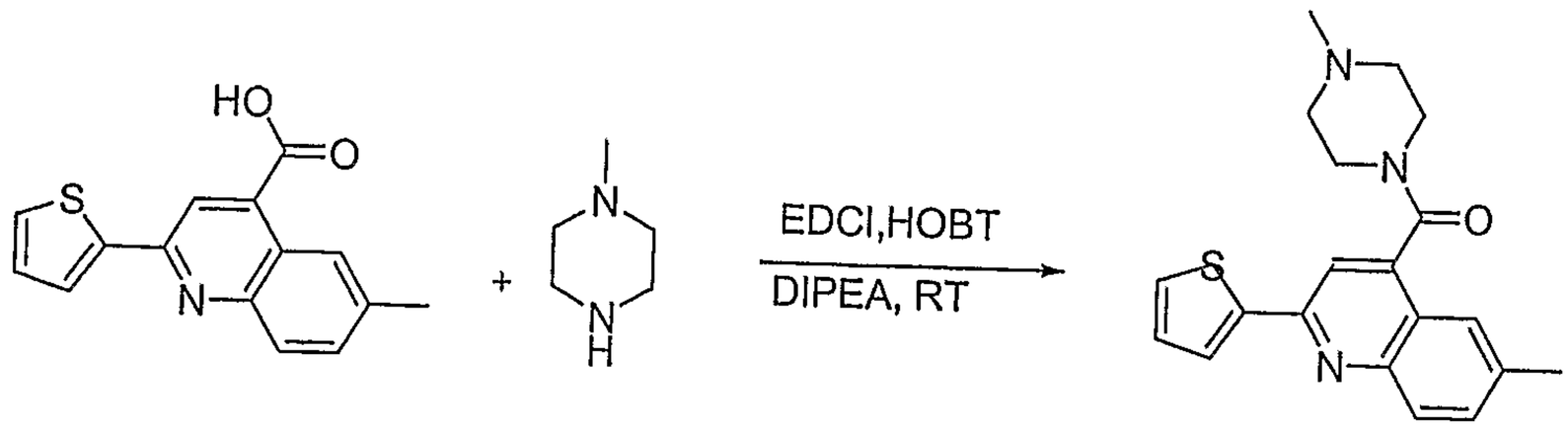
The reaction mixture was dissolved in DCM and extracted with 50ml of water 2 times and washed once with brine. The DCM layer was dried over sodium sulfate and concentrated. The product was purified by column chromatography. 40 mg of product was obtained from the experiment. Actual yield, 0.1887; yield obtained 40; % yield, 21.

ANALYTICAL DATA:

MASS SPECTRUM: COMPLIES (338.42)

HNMR: CD_3OD, 2.6(3H,m) ; 3.95(10H,m) ; 7.5(1H,t) ;7.8(1H,s) ; 8.1(1H,d) ; 8.2(1H,d) ; 8.4(1H,s) ;8.5(1H,s) 8.2(dd,1H)

Synthesis and characterization of Compound 49:



S.no:	Name of the material	Quantity	Molecular weight	Moles	Mole ratio
4.	Thiophene acid	150mg	269	0.0005576	1.0
2.	N-methyl piperazine	83mg	100	0.000836	1.5
3.	EDCI	160mg	191.71	0.000836	1.5
4.	HOBT	151mg	136.11	0.001115	2.0
5.	DIPEA	165mg	129.28	0.001282	2.3

PROCEDURE:

150 mg (0.00055 moles, 1 eq) of the thiophene acid compound was dissolved in 20ml DCM. 88 mg (0.00083 moles, 1.5 eq) of N-methyl piperazine was added to the mixture. Then, under cooling conditions, 160 mg (0.00083 moles, 1.5 eq) of EDCI and 151 mg (0.00118 moles, 2 eq) of HOBT was added to the mixture. 165 mg (0.00136 moles, 2.3 eq) of DIPEA charged into the mixture. The reaction was maintained overnight at room temperature until the starting material disappeared.

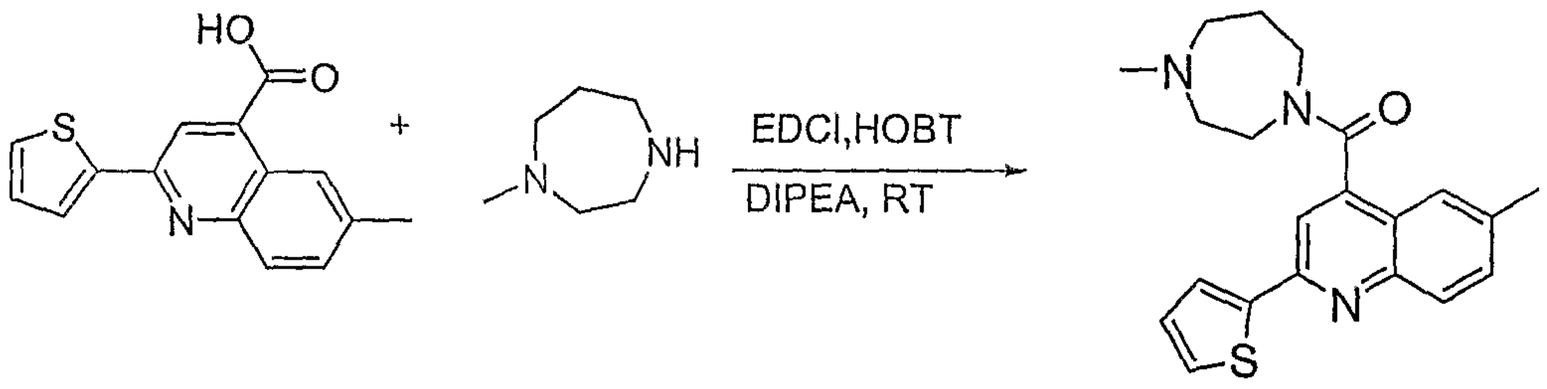
The reaction mixture was dissolved in DCM and extracted with 50ml of water 2 times and washed once with brine. The DCM layer was dried over sodium sulfate and concentrated. The product was purified by column chromatography. 30 mg of the product was obtained from this experiment. Actual yield: 0.1959 g, yield obtained: 30 mg, % yield: 15.3.

ANALYTICAL DATA:

MASS SPECTRUM: COMPLIES (351.4)

HNMR: CD_3OD, 2.1(3H,s) ; 1.9(3H,s) ; 3.0(8H,m),6.7(1H,s); 7.0(1H,s) ; 7.2(2H,d-d) ; 7.5(2H,d-d)

Synthesis and characterization of Compound 50:



5

RAW MATERIALS/INPUTS

S.no:	Name of the material	Quantity	Molecular weight	Moles	Mole ratio
5.	Thiophene acid	150mg	269	0.000557	1.0
2.	N-methyl Homo piperazine	95mg	114	0.000836	1.5
3.	EDCI	160mg	191.71	0.000836	1.5
4.	HOBT	151mg	136.11	0.001115	2.0
5.	DIPEA	165mg	129.28	0.00128	2.3

PROCEDURE:

10 150 (0.00055 moles, 1 eq) of the thiophene acid compound was dissolved in 20ml DCM. 95 mg (0.00083 moles, 1.5 eq) of N-methyl homopiperazine was added to the mixture. Then, under cooling conditions, 160 mg (0.00083 moles, 1.5 eq) of EDCI and 151 mg (0.00111 moles, 2 eq) of HOBT was added to the mixture. 165 mg (0.00136 moles, 2.3 eq) of DIPEA was charged into the mixture. The reaction 15 was maintained overnight at room temperature until the starting material disappeared.

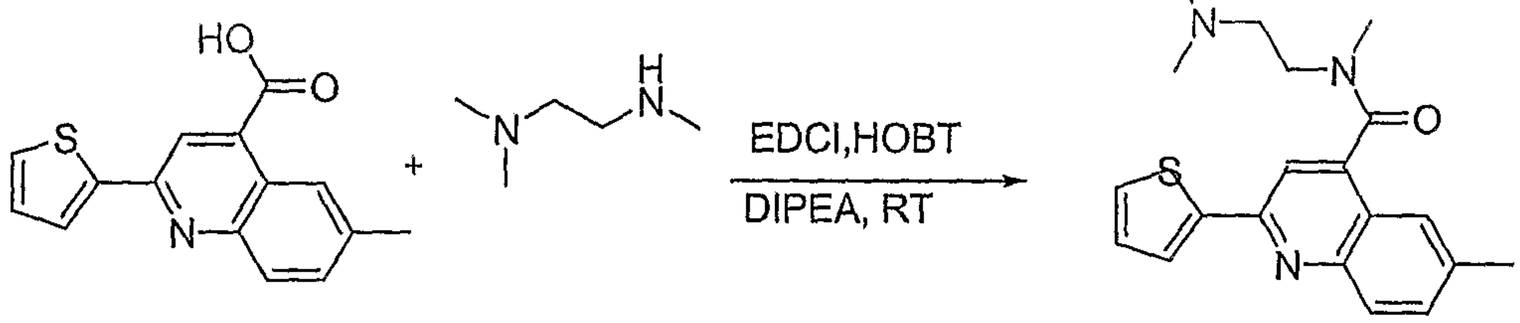
The reaction mixture was dissolved in DCM and extracted with 50ml of water 2 times and washed once with brine. The DCM layer was dried over sodium sulfate and concentrated. The product was purified by column chromatography. 40 mg of the product was obtained from this experiment. Actual yield: 0.2035 g, yield obtained: 20 40mg, % yield: 19.5.

ANALYTICAL DATA:

MASS SPECTRUM: COMPLIES (365.4)

HNMR: CD_3OD, 1.2(3H,s) ; 2.7(3H,s) ; 3.5(m,2H) ; 3.6(2H,t-t) ; 7.2(1H,s) ; 7.3(1H,s) , 7.9(1H,s) ; 8.0(1H,d-d) ; 8.1(1H, d-d) ; 8.2(1H,d-d); 8.5(1H, d-d).

Synthesis and characterization of Compound 51:



S.no:	Name of the material	Quantity	Molecular weight	Moles	Mole ratio
6.	Furan acid	150mg	269	0.0005576	1.0
2.	N,N,N-Tri methyl ethyl methyl amine	85mg	102	0.000836	1.5
3.	EDCI	160mg	191.71	0.000836	1.5
4.	HOBT	151mg	136.11	0.001115	2.0
5.	DIPEA	165mg	129.28	0.001282	2.3

PROCEDURE:

150 mg (0.00055 moles, 1 eq) of the furan acid compound was dissolved in 20 ml DCM. 85 mg (0.00088 moles, 1.5 eq) of N,N,N-Tri methyl ethyl methyl amine was added to the mixture. Then, under cooling conditions, 160 mg (0.00083 moles, 1.5 eq) of EDCI and 151 mg (0.00118 moles, 2 eq) of HOBT was added to the mixture. 165 mg (0.00136 moles, 2.3 eq) of DIPEA charged into the mixture. The reaction was maintained overnight at room temperature until the starting material disappeared.

The reaction mixture was dissolved in DCM and extracted with 50 ml of water 2 times and washed once with brine. The DCM layer was dried over sodium sulfate

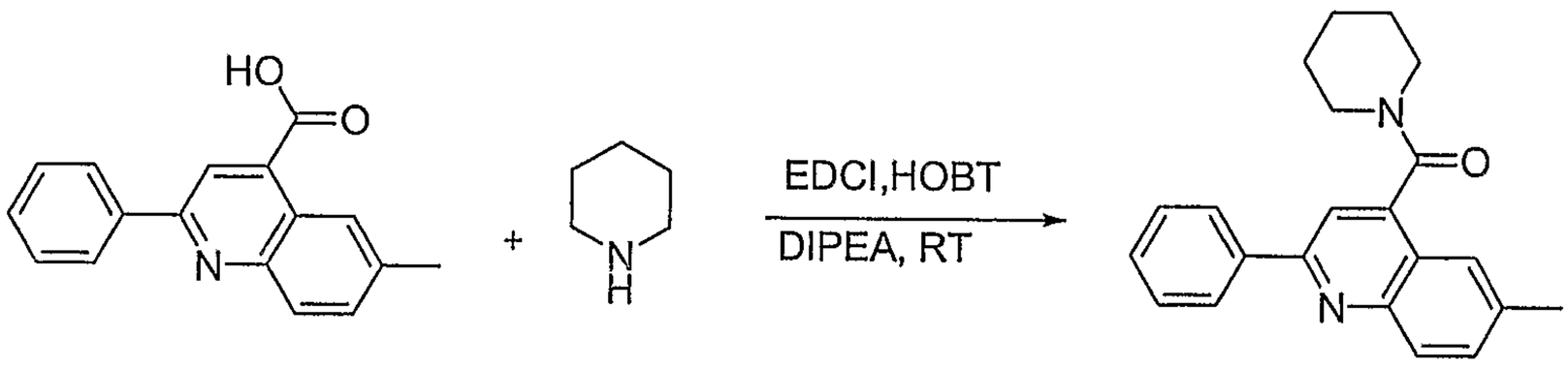
and concentrated. The product was purified by column chromatography. 35 mg of the product was obtained from this experiment. Actual yield: 0.1971g, yield obtained: 35mg, % yield: 17.3.

ANALYTICAL DATA:

MASS SPECTRUM: COMPLIES (353.48)

HNMR: CD_3OD, 2.8(3H,s) ;2.9(2H,s) ; 3.1(3H,s) ; 3.9(3H,s) ; 7.5 (1H,t) ; 7.8(1H,s) ; 8.1(2H,d) ; 8.25 (2H,d) ; 8.4(1H,d) ;8.9(1H,s)

Synthesis and characterization of Compound 39:



s.no	Name of the material	Quantity	Molecular weight	Moles	3. Molar ratio
1.	Phenyl acid	150mg	263	0.0005703	1.0
2,	Piperidine	72mg	85	0.0008554	1.5
3.	EDCI	163mg	191.71	0.0008554	1.5
4.	HOBT	155mg	136.11	0.001140	2.0
5.	DIPEA	169mg	129.28	0.001311	2.3

PROCEDURE:

150 mg (0.0005703 moles, 1 eq) of the phenyl acid compound was dissolved in 20 ml DCM. 72 mg (0.000855 moles, 1.5 eq) of piperidine was added to the mixture. Then, under cooling conditions, 163 mg (0.0008892 moles, 1.5 eq) of EDCI, 155 mg (0.00114 moles, 2 eq) of HOBT was added to the mixture. 169 mg (0.001363 moles, 2.3 eq) of DIPEA charged into the mixture. The reaction was maintained at room temperature overnight until the starting material disappeared.

The reaction mixture was dissolved in DCM and extracted with 50ml of water 2 times, washed once with brine and dried over sodium sulfate and concentrated. The product was purified by column chromatography. 30mg of the product was obtained from this experiment. Actual yield: 0.1888; Yield obtained: 30 mg; % yield:15.8.

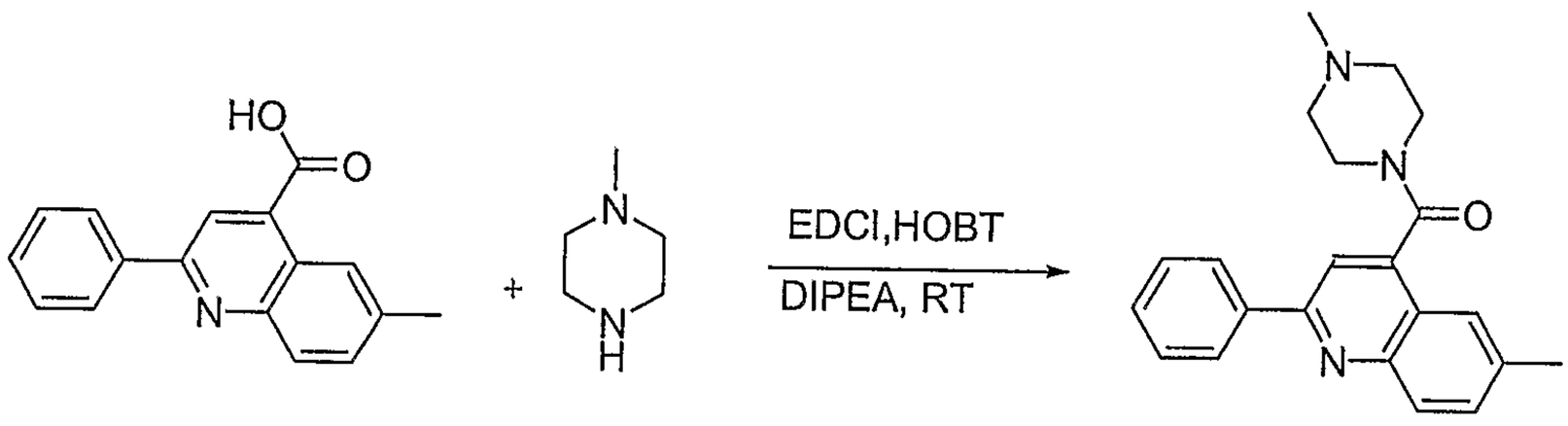
ANALYTICAL DATA:

HNMR: COMPLIES (CD_3OD, 200MHz)

MASS: COMPLIES (320.4)

HNMR: 2.8(3H,s) ; 1-1.9(2H, 2t) ; 3.2(2H,t) ; 4.0(2H,s) ; 7.8(2H,d) ; 7.9(1H,s) ; 8.1(2H,d-d) ; 8.5(2H,d)

Synthesis and characterization of Compound 41:



S.no:	Name of the material	Quantity	Molecular weight	Moles	Mole ratio
7.	Phenyl acid	150mg	263	0.0005703	1.0
2.	N-methyl piperazine	85mg	100	0.0008554	1.5
3.	EDCI	163mg	191.71	0.0008554	1.5
4.	HOBT	155mg	131.11	0.001140	2.0
5.	DIPEA	169mg	129.28	0.001311	2.3

PROCEDURE:

150 mg (0.00057 moles, 1 eq) of the phenyl acid compound was dissolved in 20 ml DCM. 85 mg (0.00085 moles, 1.5 eq) of N-methyl piperazine was added to the mixture. Then, under cooling conditions, 163 mg (0.00085 moles, 1.5 eq) of EDCI and 155 mg (0.00114 moles, 2 eq) of HOBT was added to the mixture. 169 mg

(0.00136 moles, 2.3 eq) of DIPEA charged into the mixture. The reaction was maintained overnight at room temperature until the starting material disappeared.

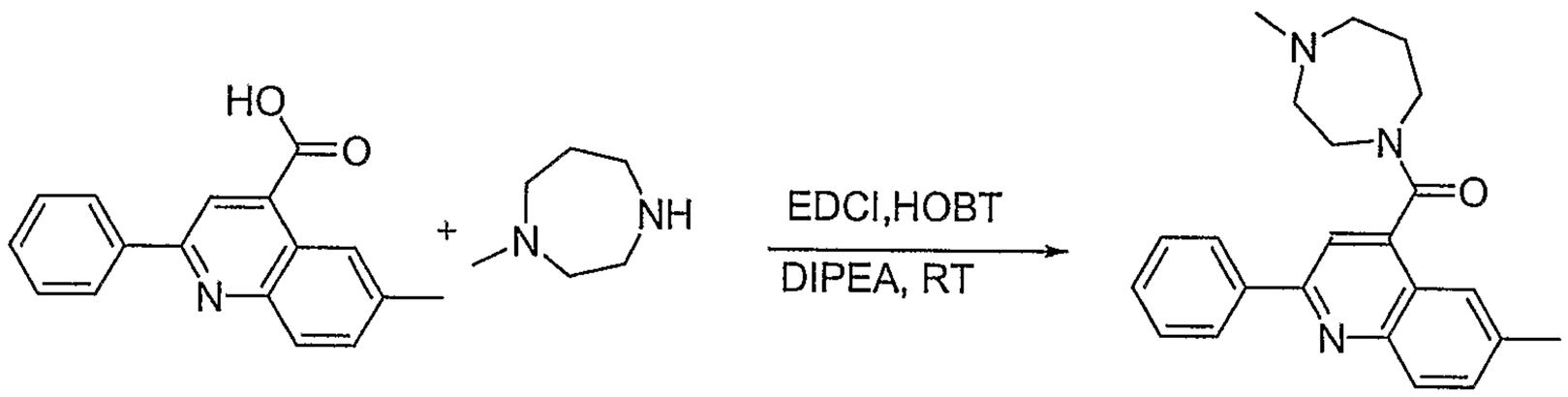
The reaction mixture was dissolved in DCM and extracted with 50 ml of water 2 times and washed once with brine. The DCM layer was dried over sodium sulfate and concentrated. The product was purified by column chromatography. 35 mg of the product was obtained from this experiment. Actual yield: 0.1973 g, yield obtained: 35mg, % yield: 17.5.

ANALYTICAL DATA:

MASS SPECTRUM: COMPLIES (346)

HNMR: CD_3OD, 2.8(3H,s) ; 3.1(3H,s) ; 3.4(4H,t of t), 3.8(4H,t of t) ; 7.8(2H,d) ; 8.0(1H,s) ; 8.1(2H,t) ; 8.4(2H,d) ; 8.5(2H,d)

Synthesis and characterization of Compound 42:



S.no:	Name of the material	Quantity	Molecular weight	Moles	Mole ratio
8.	Phenyl acid	150mg	263	0.0005703	1.0
2.	N-methyl homo piperazine	97mg	114	0.0008554	1.5
3.	EDCI	163mg	191.71	0.0008554	1.5
4.	HOBT	155mg	136.11	0.001140	2.0
5.	DIPEA	169mg	129.28	0.001311	2.3

PROCEDURE:

150 mg (0.00057 moles, 1 eq) of the phenyl acid compound was dissolved in 20 ml DCM. 97 mg (0.0008554 moles, 1.5 eq) of N-methyl Homo piperazine was added to the mixture. Then, under cooling conditions, 163 mg (0.00085 moles, 1.5 eq) of EDCI and 155 mg (0.00118 moles, 2 eq) of HOBT was added to the mixture. 169 mg (0.00136 moles, 2.3 eq) of DIPEA was charged into the mixture. The reaction was maintained overnight at room temperature until the starting material disappeared.

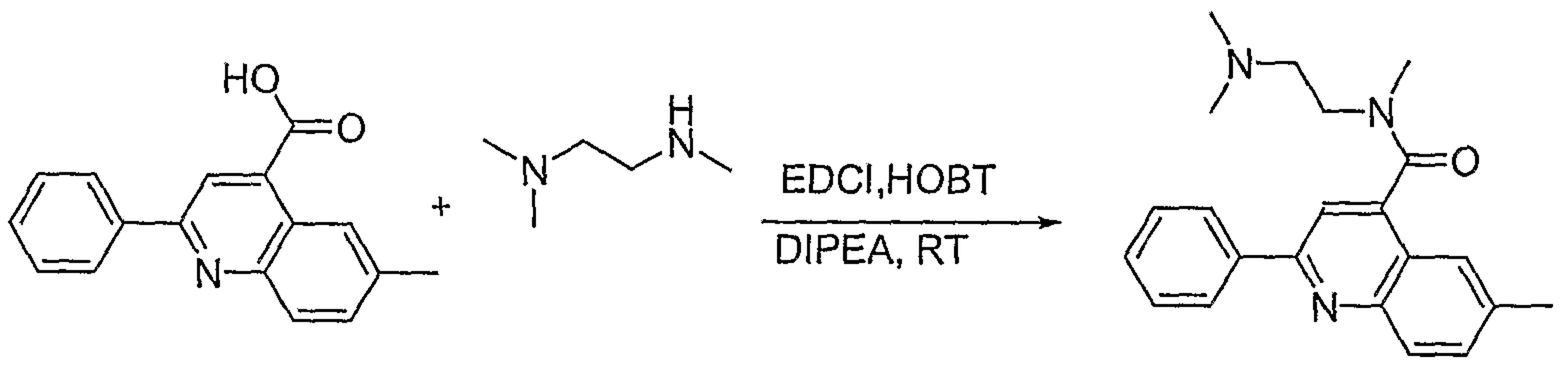
The reaction mixture was dissolved in DCM and extracted with 50ml of water 2 times and washed once with brine. The DCM layer was dried over sodium sulfate and concentrated. The product was purified by column chromatography. 30 mg of the product was obtained from this experiment. Actual yield: 0.2053 g, yield obtained: 30 mg, % yield: 14.6.

ANALYTICAL DATA:

MASS SPECTRUM: COMPLIES (360)

HNMR: CD_3OD, 2.8(3H,s) ; 3.0(3H,s) ; 3.2(4H,m), 3.3(2H,t of t) ; 3.8(2H,m) ; 7.8 (2H,d) ; 8.1(3H,s) ; 8.25 (3H,t) ; 8.3(2H,s) ;8.4(2H,s).

Synthesis and characterization of Compound 43:



S.no:	Name of the material	Quantity	Molecular weight	Moles	Mole ratio
9.	Phenyl acid	150mg	263	0.0005703	1.0
2.	N,N,N-Tri methyl	187mg	102	0.0008554	1.5

	ethyl methyl amine				
3.	EDCI	163mg	191.71	0.0008554	1.5
4.	HOBT	155mg	136.11	0.001140	2.0
5.	DIPEA	169mg	129.28	0.001311	2.3

PROCEDURE:

150 mg (0.00057 moles, 1 eq) of the phenyl acid compound was dissolved in 20 ml DCM. 87 mg (0.00085 moles, 1.5 eq) of N,N,N-Tri methyl ethyl methyl amine was added to the mixture. Then, under cooling conditions, 163 mg (0.00085 moles, 1.5 eq) of EDCI, 155 mg (0.00118 moles, 2 eq) of HOBT was added to the mixture. 169 mg (0.00136 moles, 2.3 eq) of DIPEA charged into the mixture. The reaction was maintained overnight at room temperature until the starting material disappeared.

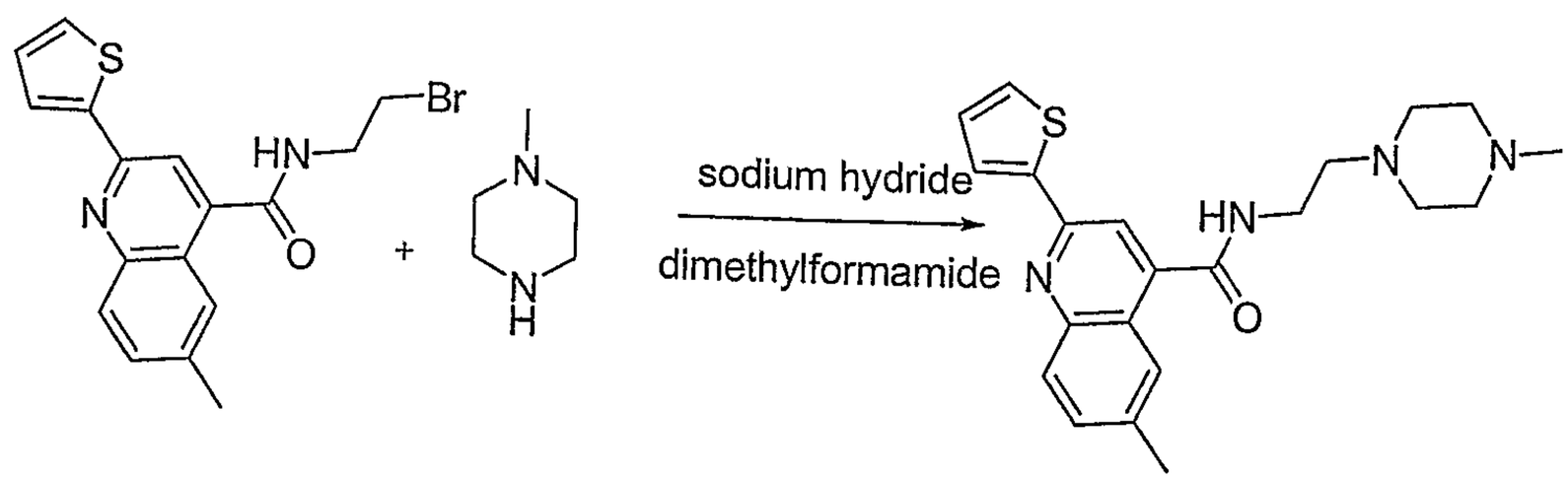
The reaction mixture was dissolved in DCM and extracted with 50 ml of water 2 times and washed once with brine. The DCM layer was dried over sodium sulfate and concentrated. The product was purified by column chromatography. 40 mg of the product was obtained from this experiment. Actual yield: 0.1973 g, yield obtained: 40mg, % yield: 20.

ANALYTICAL DATA:

MASS SPECTRUM: COMPLIES (293)

HNMR: CD_3OD, 2.8(3H,s) ; 3.1(9H,s) ; 3.5(2H,s),; 7.8 (3H,d) ; 8.0(2H,s) ; 8.1(2H,d) ; 8.2(2H,d) ; 8.8(2H,s).

Synthesis and characterization of Compound 55:



PROCEDURE:

150 mg (0.0004 moles, 1 eq) of the thiophene bromo ethyl compound was dissolved in 20 ml DMF. 60 mg (0.0006 moles, 1.5 eq) of N-methyl piperazine was added to the mixture. 33 mg (0.0014 moles, 3.5 eq) of sodium hydride was added to the mixture. The mixture was refluxed for 3 hrs.

DMF was removed from the reaction mass and partitioned between ethyl acetate and water and given a brine wash. The organic layer was dried over sodium sulfate. The product was purified by column chromatography. 30 mg of the product was obtained from this experiment.

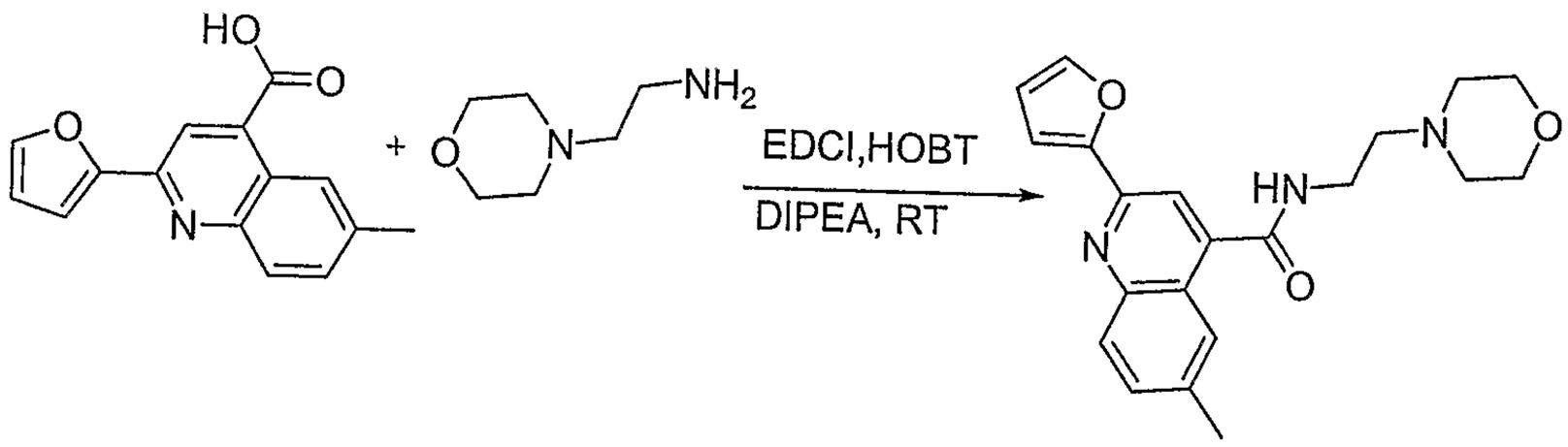
ANALYTICAL DATA:

MASS: COMPLIES (394)

HNMR DATA: CD_3OD, 2.8(3H,s) ; 3.8(8H,m) ; 7.1(2H,s) ; 7.9(2H,s) ; 8.1(3H,t) ; 8.8(1H,s) ;

HPLC:93.33%

Synthesis and characterization of Compound 37:



PROCEDURE:

150 mg (0.0005928 moles, 1 eq) of the furan acid compound was dissolved in 20ml DCM. 115 mg (0.0008893 moles, 1.5 eq) of Morpholine ethylamine was added to it. Then under cooling conditions 170 mg (0.0008892 moles, 1.5 eq) of EDCI, 161 mg (0.0011856 moles, 2 eq) of HOBT was added to it. 176 mg (0.001363 moles, 2.3 eq) of DIPEA was charged to the mixture. The reaction was maintained at room temperature overnight until the starting material had disappeared.

The reaction mixture was dissolved in DCM and extracted with 50 ml of water 2 times, washed once with brine and dried over sodium sulfate and concentrated. The product was purified by column chromatography. Actual yield: 0. 216 g; yield obtained: 60 mg, % yield: 27.6.

ANALYTICAL DATA:

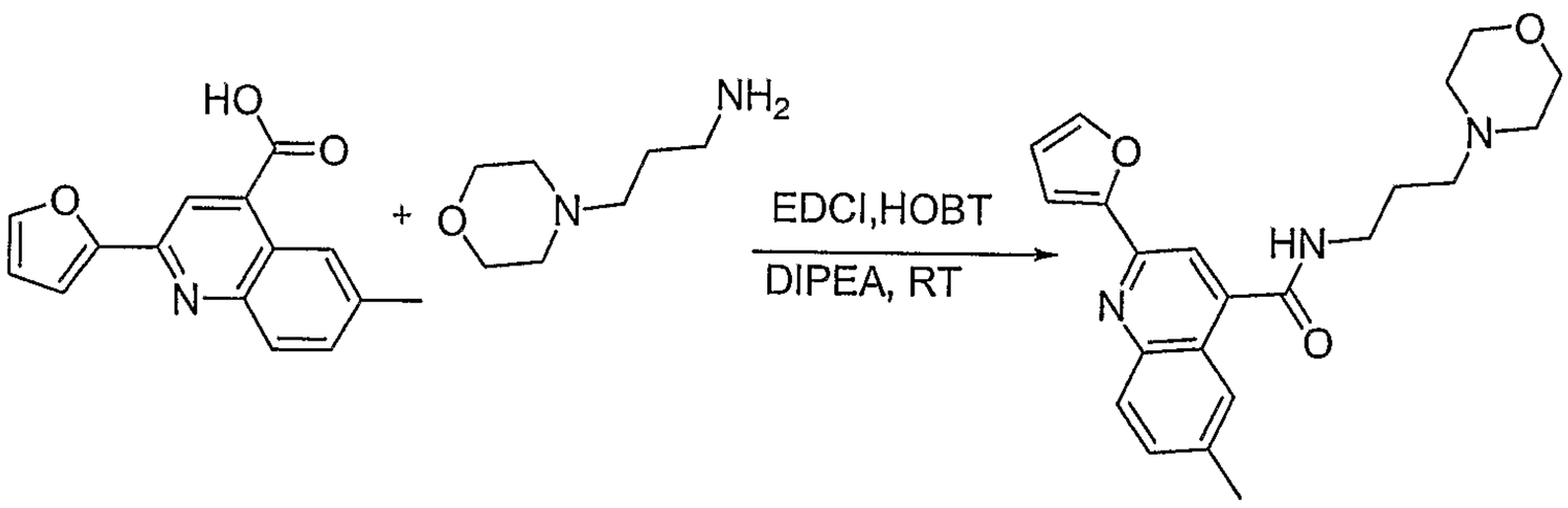
HNMR: COMPLIES (CD_3OD, 200MHz)

MASS: COMPLIES (365.5)

HNMR: 2.8(3H,s); 3.6(4H,m); 4.0(4H,m); 7.0(1H,s); 8.0(2H,t); 8.1(3H,m); 8.8(1H,s)

HPLC: - 97.16%

Synthesis and characterization of Compound 31:



PROCEDURE:

150 mg (0.0005928 moles, 1 eq) of the furan acid compound was dissolved in 20 ml DCM. 128 mg (0.00088 moles, 1.5 eq) of Morpholine propylamine was added to the mixture. Then in cooling conditions 170 mg (0.00088 moles, 1.5 eq) of EDCI and 161 mg (0.0011856 moles, 2 eq) of HOBT was added to it. 176 mg (0.001363 moles, 2.3 eq) of DIPEA was charged into the mixture. The reaction was maintained at room temperature overnight until the starting material had disappeared.

The reaction mixture was dissolved in DCM and extracted with 50ml of water 2 times, washed once with brine and dried over sodium sulfate and concentrated. The product was purified by column chromatography. 45 mg of the product was obtained from this experiment. Actual yield: 0.233 g; yield obtained: 45 mg, % yield: 19.2.

ANALYTICAL DATA:

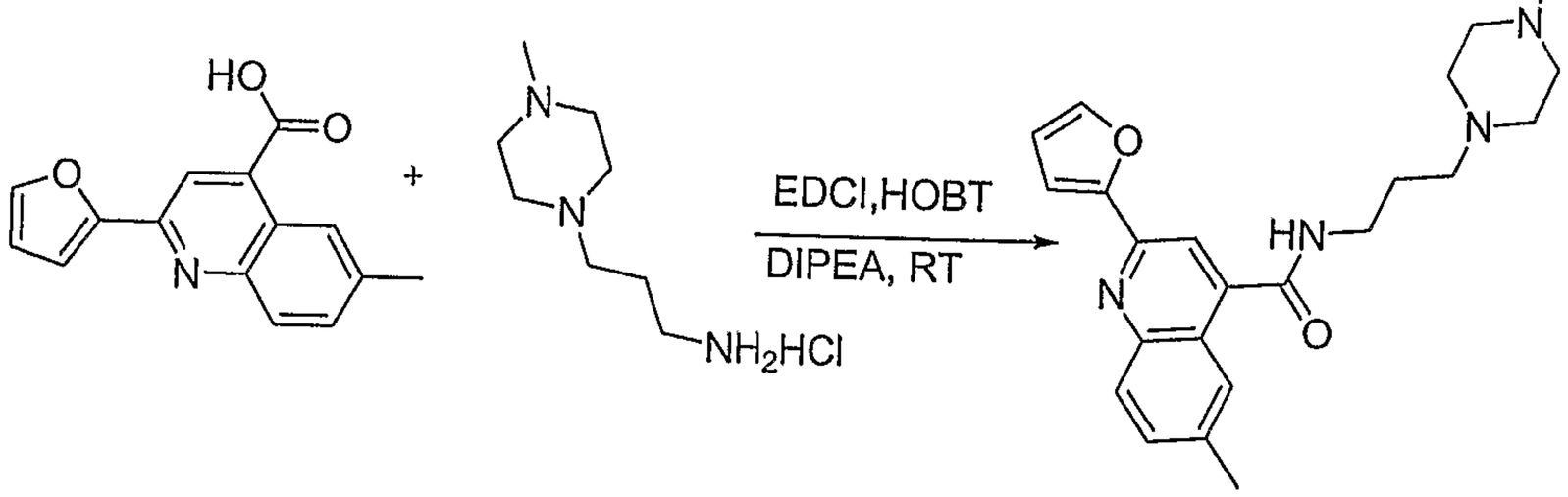
HNMR: COMPLIES (CD3OD, 200MHz)

MASS: COMPLIES (379.0)

HNMR: 2.1(2H,m); 2.8(3H,s); 3.3(5H,m); 3.9(2H,t); 4.1(2H,d); 7.0(1H,s)
8.0(2H,d); 8.2(4H,d); 8.3(1H,d); 8.6(2H,s)

HPLC: - 99.54%

Synthesis and characterization of Compound 47:



PROCEDURE:

150 mg (0.0005928 moles, 1 eq) of the furan acid compound was dissolved in 20ml DCM. 172 mg (0.00088 moles, 1.5 eq) of N-methyl piperazine propyl amine compound was added to the mixture. Then in cooling conditions 227 mg (0.00118 moles, 2.0 eq) of EDCI and 169 mg (0.00124 moles, 2.1 eq) of HOBT was added to it. 176mg (0.001363 moles, 2.3 eq) of DIPEA was charged into the mixture. The reaction was maintained at room temperature overnight until the starting material had disappeared.

The reaction mixture was dissolved in DCM and extracted with 50ml of water 2 times, washed once with brine and dried over sodium sulfate and concentrated. The product was purified by column chromatography. 40 mg of the product was obtained from this experiment. Actual yield: 0.233 g; yield obtained: 40 mg; % yield: 17.16.

ANALYTICAL DATA:

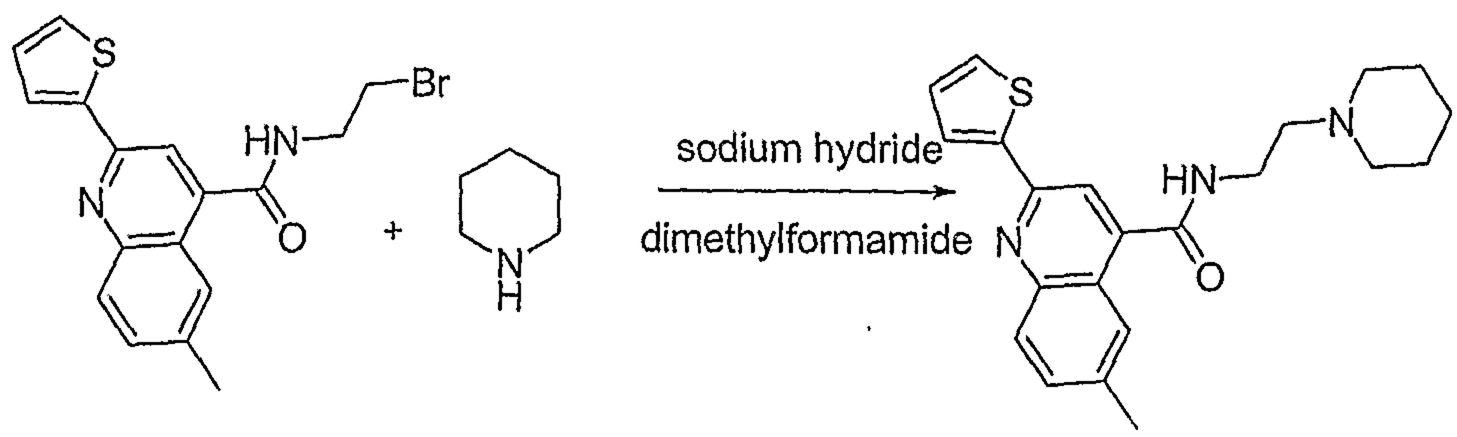
HNMR: COMPLIES (CD3OD, 200MHz)

MASS: COMPLIES (393.0)

HNMR: - 1.1(7H,m); 2.8(3H,s); 3.2(3H,s); 3.8(8H,t); 7.0(1H,s)
8.1(1H,d); 8.2(3H,d); 8.6(1H,s); 8.6(2H,s)

HPLC: - 91.02%

Synthesis and characterization of Compound 52:



PROCEDURE:

150 mg (0.0004 moles, 1 eq) of the thiophene bromo ethyl compound was dissolved in 20ml DMF. 51 mg (0.0006 moles, 1.5 eq) of Piperdine was added to the mixture. 33 mg (0.0014 moles, 3.5 eq) of sodium hydride was added to it. The mixture was refluxed for 3 hrs.

DMF was removed from the reaction mass and partitioned between ethyl acetate and water and given a brine wash. The organic layer was dried over sodium sulfate. The product was purified by column chromatography. 50 mg of the product was obtained from this experiment.

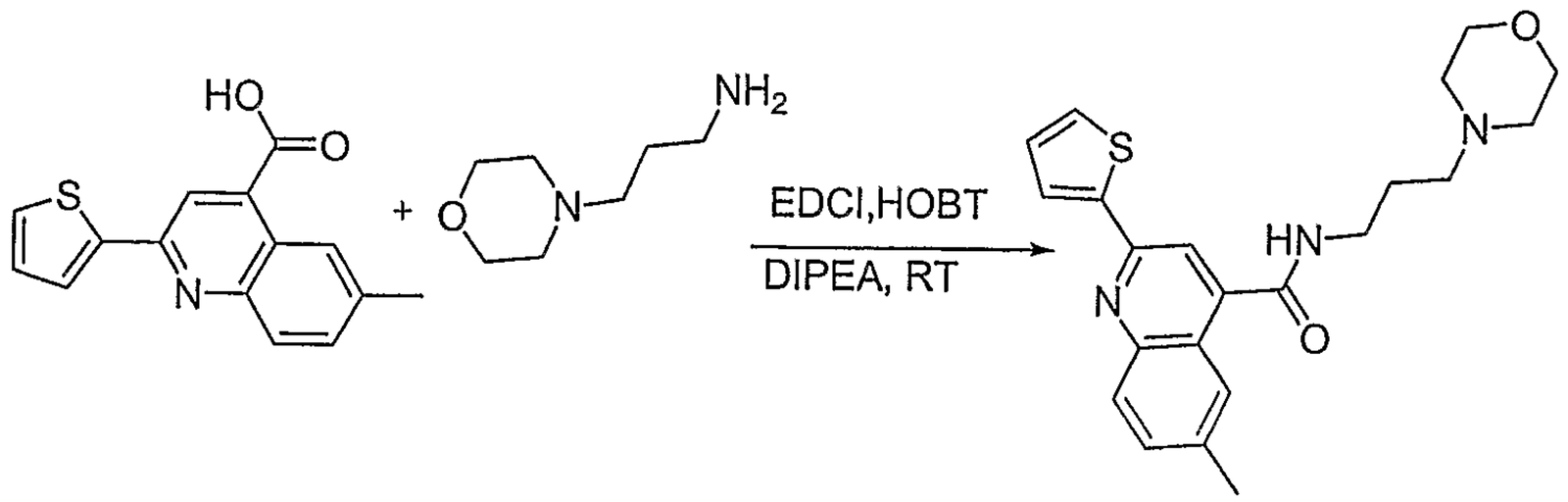
ANALYTICAL DATA:

MASS: COMPLIES (379)

HNMR DATA:- CD3OD, 1.1(2H,t) ; 2.0(5H,s) ; 2.8(3H,s) ; 3.1(2H,s) ; 3.2(2H,s) ;3.7(2H,d) ; 4.0(2H,s) ; 7.5(1H,s) ;8.0(1H,d) ;8.2(2H,d) ;8,5(1H,d) ;8.6(1H,s); 8.9(1H,s)

HPLC:99.18%

Synthesis and characterization of Compound 53:



PROCEDURE:

150 mg (0.00055 moles, 1 eq) of the thiophene acid compound was dissolved in 20ml DCM. 120 mg (0.00083 moles, 1.5 eq) of Morpholine propylamine was added to the mixture. Then in cooling conditions 160 mg (0.000836 moles, 1.5 eq) of EDCI and 151 mg (0.00111 moles, 2 eq) of HOBT was added to it. 180 mg (0.001394 moles, 2.3 eq) of DIPEA was charged into the mixture. The reaction was maintained at room temperature overnight until the startin material disappeared.

The reaction mixture was dissolved in DCM and extracted with 50ml of water 2 times, washed once with brine and dried over sodium sulfate and concentrated. The product was purified by column chromatography. 65 mg of the product was obtained from this experiment. Actual yield: 0.2202 g; yield: 65mg; % yield: 29.5.

ANALYTICAL DATA:

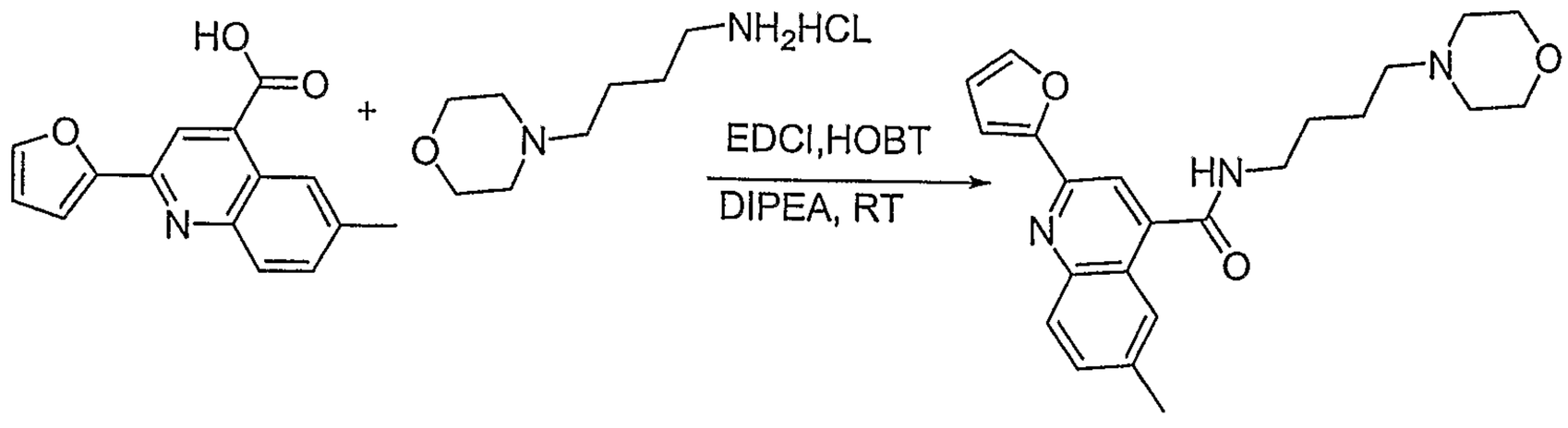
HNMR: COMPLIES (CD3OD, 200MHz)

MASS: COMPLIES (395.52)

HNMR: - 2.1(2H,m) ;2.8(3H,s);3.1(2H,d) ;3.3(2H,d) ; 3.6(4H,m); 4.0(2H,t);4.1(2H,d) 7.5(1H,t); 8.0(2H,d); 8.2(2H,d);8.4(1H,d) ; 8.6(1H,s)

HPLC: - 99.11%

Synthesis and characterization of Compound 54:



PROCEDURE:

150 mg (0.0005928 moles, 1 eq) of the furan acid compound was dissolved in 20 ml DCM. 123mg (0.00059 moles, 1 eq) of Morpholine was added to the mixture. Then in cooling conditions 170 mg (0.00088 moles, 1.5 eq) of EDCI and 161 mg (0.0011856 moles, 2 eq) of HOBT was added to it. 176 mg (0.001363 moles, 2.3 eq) of DIPEA was charged to into the mixture. The reaction was maintained at room temperature overnight until the starting material had disappeared.

The reaction mixture was dissolved in DCM and extracted with 50 ml of water 2 times, washed once with brine and dried over sodium sulfate and concentrated. The product was purified by column chromatography. 43 mg of the product was obtained from this experiment. Actual yield: 0.23265 g; yield obtained: 43 mg, % yield: 18.48.

ANALYTICAL DATA:

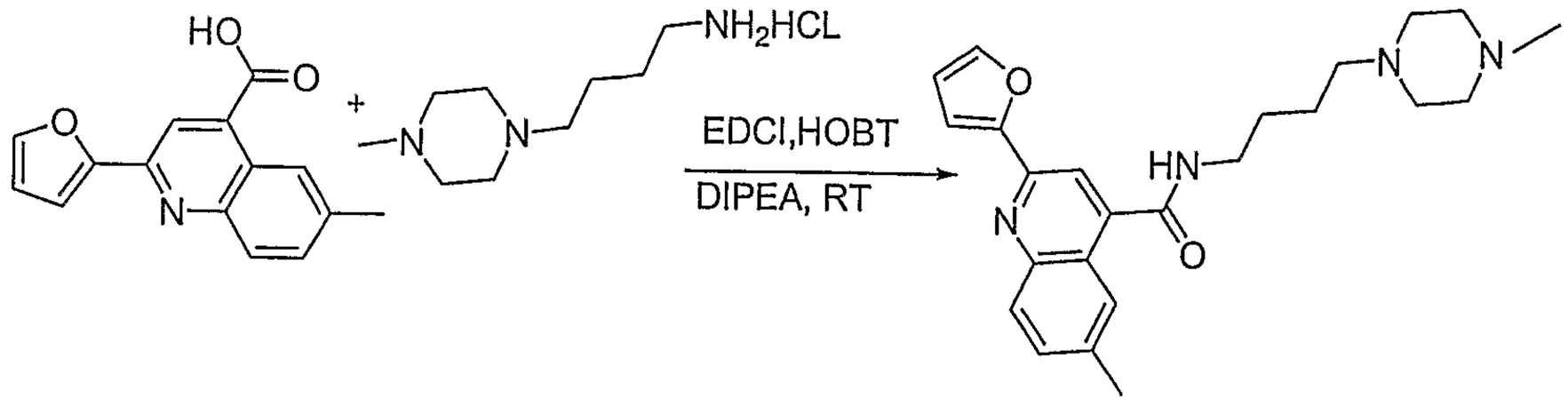
HNMR: COMPLIES (CD3OD, 200MHz)

MASS: COMPLIES (393)

HNMR: 1.9(2H,t);2.0(2H,t); 2.8(3H,s) ; 3.1(3H,m) ; 3.5(4H,m) ; 3.8(2H,t) ; 4.1(2H,d) 7.0(1H,s) ;8.0(3H,d);8.2(1H,s) ; 8.5(1H,s)

HPLC: - 98.68%

Synthesis and characterization of Compound 17:



PROCEDURE:

150 mg (0.0005928 moles, 1 eq) of the furan acid compound was dissolved in 20 ml DCM. 131 mg (0.00059 moles, 1 eq) of Methyl piperazine was added to the mixture. Then in cooling conditions 170 mg (0.00088 moles, 1.5 eq) of EDCI and 161 mg (0.0011856 moles, 2 eq) of HOBT was added to it. 176 mg (0.001363 moles, 2.3 eq) of DIPEA was charged into the mixture. The reaction was maintained at room temperature overnight until the starting material had disappeared.

The reaction mixture was dissolved in DCM and extracted with 50ml of water 2 times, washed once with brine and dried over sodium sulfate and concentrated. The product was purified by column chromatography. 20 mg of the product was obtained from this experiment. Actual yield: 2.40; yield obtained: 20 mg; % yield: 8.3.

ANALYTICAL DATA:

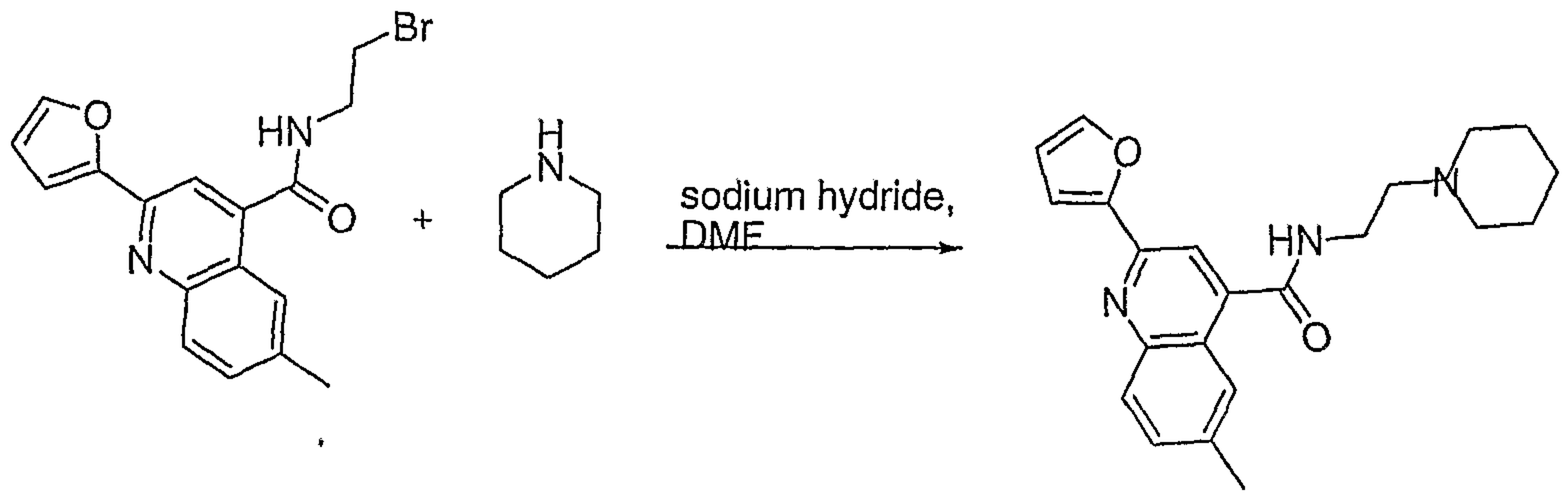
HNMR: COMPLIES (CD3OD, 200MHz)

MASS: COMPLIES (406.3)

HNMR: - 1.8(3H,s); 1.95(1H,s);2.1(3H,s); 2.4(4H,m) ; 2.45(4H,m) ; 3.5(2H,s) ; 6.8(1H,s) ; 7.3(1H,s) ; 7.6(2H,D) ;8.0(3H,d)

HPLC: - 96.68%

Synthesis and characterization of Compound 34:



PROCEDURE:

200 mg (0.00055 moles, 1 eq) of the furan bromo ethyl compound was dissolved in 20 ml of DMF. 71 mg (0.00083 moles, 1.5 eq) of piperadine was added to the mixture. 46 mg (0.00194 moles, 3.5 eq) of sodium hydride was added to it. The mixture was refluxed for 3 hr.

DMF was removed from the reaction mixture and partitioned between ethyl acetate (40ml) and water (50ml) twice. The combined organic layers was washed with brine and dried over sodium sulfate. The solvent was removed under reduced pressure. The product was purified by column chromatography. 35 mg of the product (as an HCl salt) was obtained from this experiment.

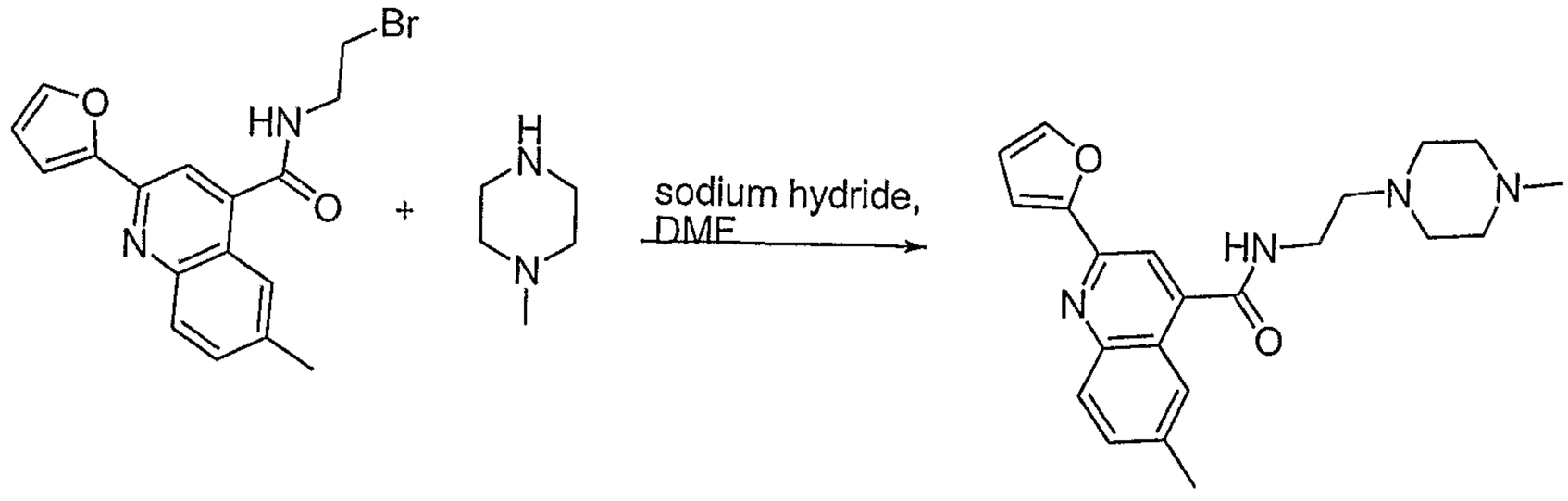
ANALYTICAL DATA:

HNMR: COMPLIES (CD3OD, 200MHz)

MASS: COMPLIES (363.0)

HNMR: - 2.0(6H,m); 2.68(3H,s); 3.2(2H,m); 3.45(2H,t); 3.8(2H,m); 4.0(2H,t) ; 7.0(1H,d) ; 8.0(1H,d) ; 8.2(1H,d) ; 8.3-8.45(3H,m) ;8.8(1H,s)

Synthesis and characterization of Compound 36:



PROCEDURE:

150 mg (0.00041 moles, 1 eq) of the furan bromo ethyl compound was dissolved in 20 ml of DMF. 62 mg (0.00062 moles, 1.5 eq) of N-methylpiperazine was added to the mixture. 35 mg (0.00146 moles, 3.5 eq) of sodium hydride was added to it. The mixture was refluxed for 3 hr.

DMF was removed from the reaction mixture and partitioned between ethyl acetate (40 ml) and water (50 ml) twice. The combined organic layers were washed with brine and dried over sodium sulfate. The solvent was removed under reduced pressure. The product was purified by column chromatography. 65 mg of the product was obtained from this experiment.

ANALYTICAL DATA:

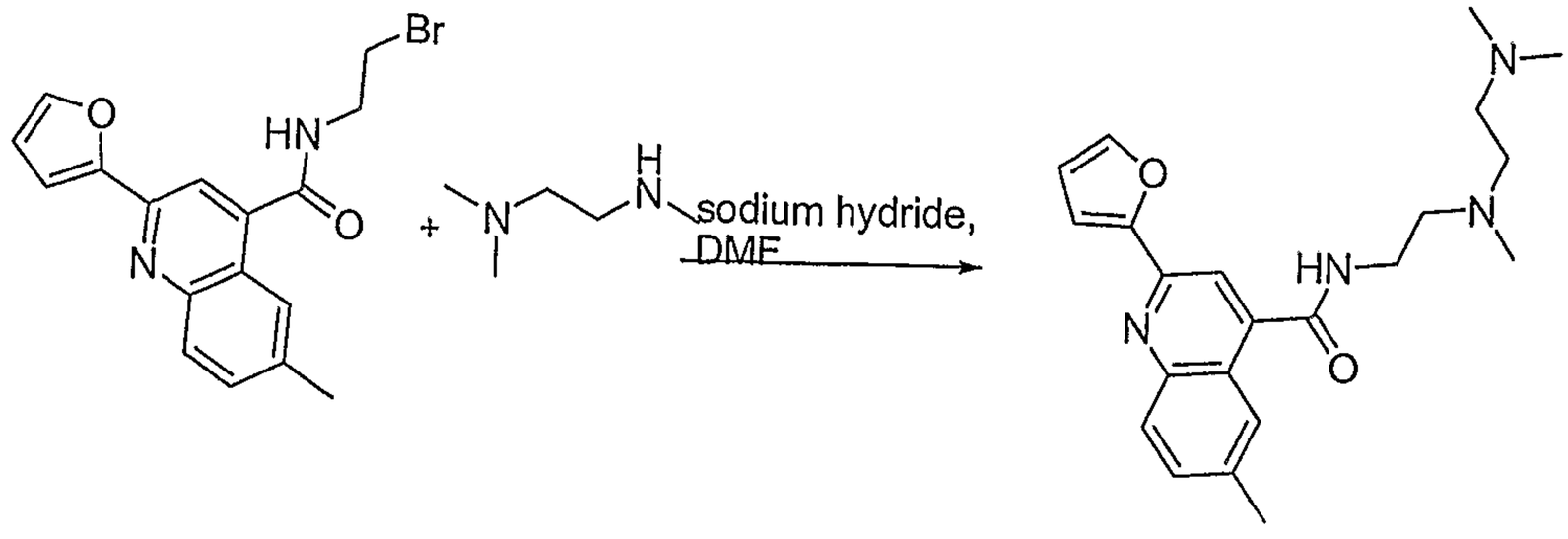
HNMR: COMPLIES (CD3OD, 200MHz)

MASS: COMPLIES (378.5)

HNMR: - 2.68(3H,s); 3.1(3H,s); 3.45(3H,s); 3.6(3H,s); 4.0(4H,s); 7.0(1H,s) ; 8.0(1H,d) ; 8.2(3H,m)

HPLC: - 96.88%

Synthesis and characterization of Compound 46:



PROCEDURE:

150 mg (0.00041 moles, 1 eq) of the furan bromo ethyl compound was dissolved in 20 ml of DMF. 64 mg (0.00062 moles, 1.5 eq) of N,N,N-Trimethylethylmethylamine was added to the mixture. 35 mg (0.00146 moles, 3.5 eq) of sodium hydride was added to it. The mixture was refluxed for 3 hr.

DMF was removed from the reaction mixture and partitioned between ethyl acetate (40ml) and water (50ml) twice. The combined organic layers were washed with brine and dried over sodium sulfate. The solvent was removed under reduced pressure. The product was purified by column chromatography. 25 mg of the product was obtained from this experiment.

ANALYTICAL DATA:

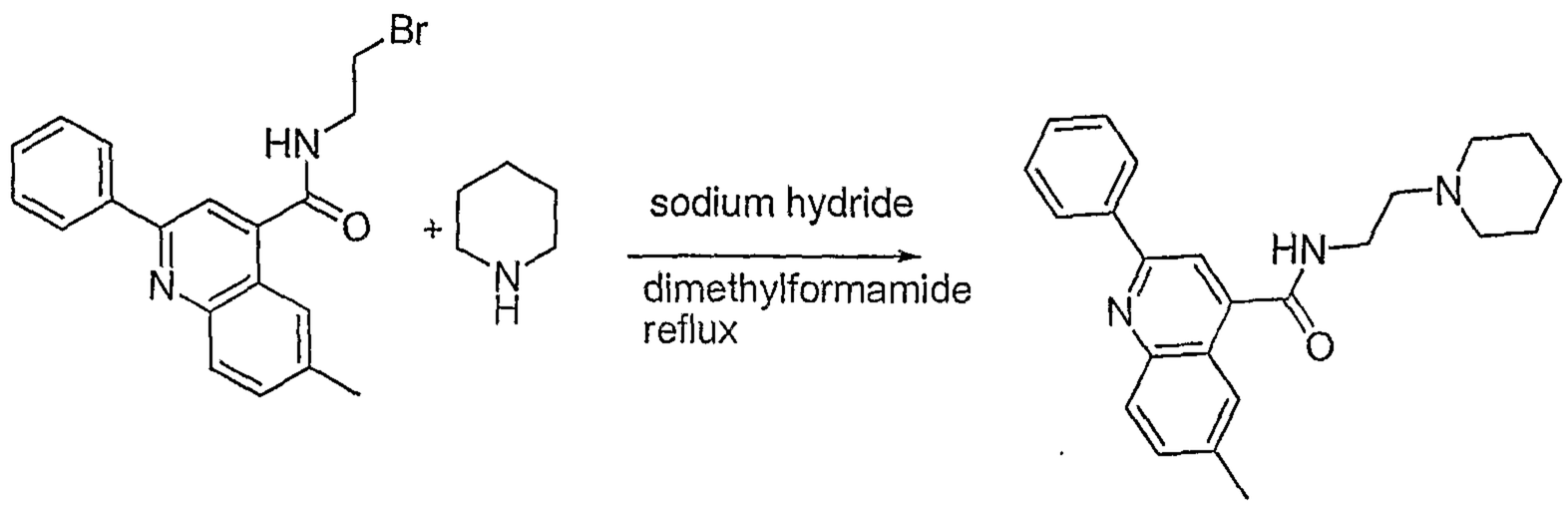
HNMR: COMPLIES (CD3OD, 200MHz)

MASS: COMPLIES (381.1)

HNMR: 3.0(9H,d); 3.9(8H,m); 6.8(2H,s); 7.3(2H,s) ; 8.0(3H,d) ; 9.1(1H,s)

HPLC: 96.26%

Synthesis and characterization of Compound 40:



PROCEDURE:

150 mg (0.000406 moles, 1 eq) of the phenyl bromo ethyl compound was dissolved in DMF. 51 mg (0.000609 moles, 1.5 eq) of piperidine was added to the mixture. 34 mg (0.00142 moles, 3.5 eq) of sodium hydride was added to it. The mixture was refluxed for 3 hrs.

DMF was removed from the reaction mixture and the crude partitioned between ethyl acetate (40 ml) and water (50 ml) twice. The organic layer was dried over sodium sulfate and concentrated. The product was purified by column chromatography. 42 mg of the product was obtained from this experiment for a 27.6% yield.

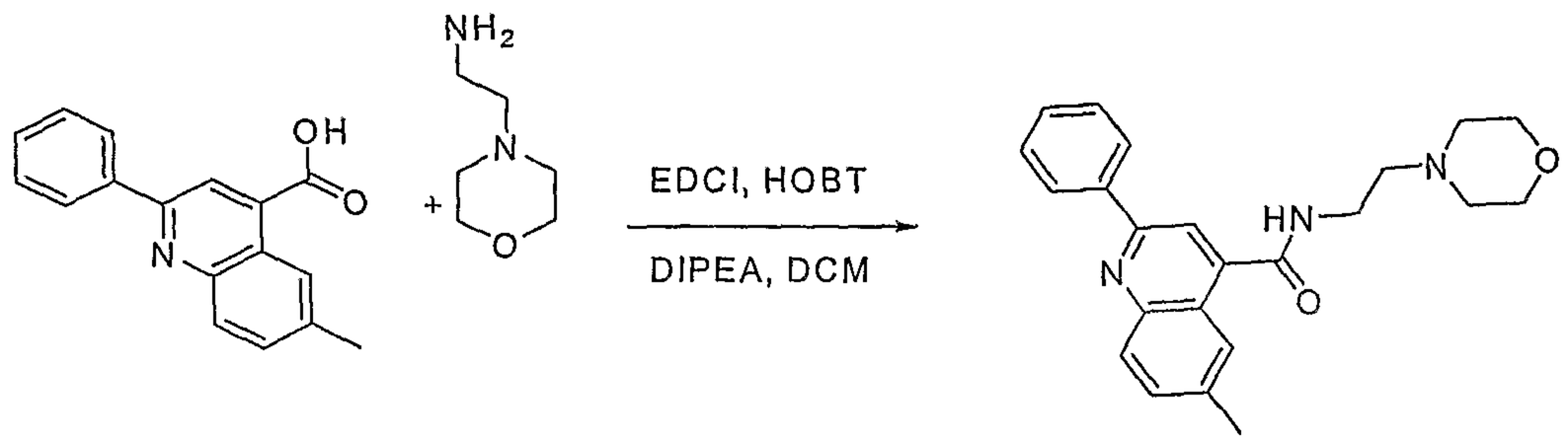
ANALYTICAL DATA:

MASS SPECTRUM: complies

HNMR (CD3OD):1.2(4H,m); 1.5(2H, s), 2.00 (4H, m), 2.80 (3H, s), 3.1(3H, m), 3.30 (2H, t), 3.40 (2H, t), 4.00 (2H, t), 7.80 (2H, m), 8.1 (2H, m), 8.31 (3H, m), 8.84 (1H, s).

HPLC Purity: 99.39%

Synthesis and characterization of Compound 15:



PROCEDURE:

150 mg (0.0004703 moles, 1 eq) of the phenyl acid compound was dissolved in DCM (20 ml). 111 mg (0.000854 moles, 1.5 eq) of morpholinoethylamine was added to the mixture. 163 mg (0.000852 moles, 1.5 eq) of EDCI and 155 mg (0.001140 moles, 2.0 eq) of HOBT was added to the mixture under cooling conditions. 169 mg (0.001311 moles, 2.3 eq) was charged into the mixture and the reaction mixture was maintained at room temperature until the starting material was completely consumed.

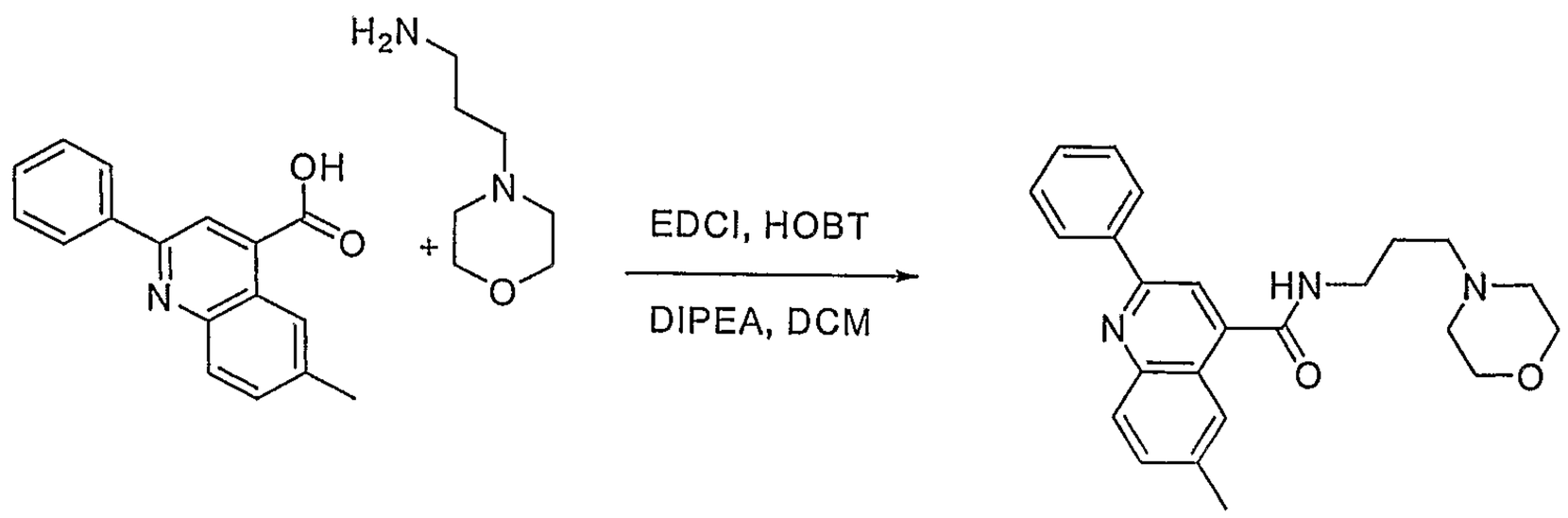
The reaction mixture was dissolved in DCM and partitioned between water and DCM. The organic layer was separated and washed with saturated NaCl solution. The organic layer was dried over Na_2SO_4, filtered and the solvent was removed under reduced pressure. The obtained crude residue was purified by column chromatography using silicagel to obtain 40 mg of the pure compound for a 18.6% yield.

MASS SPECTRUM:-375.7 (M+, 100)

HNMR (CD3OD):- 2.82 (3H, s), 3.11 (1H, m), 3.64 (2H, t), 3.72 (2H, t), 4.10 (5H, m), 7.92 (3H, m), 8.14 (1H, m), 8.30 (3H, m), 8.95 (1H, s).

HPLC Purity: 99.06%

Synthesis and characterization of Compound 169:



PROCEDURE:

150 mg (0.0004703 moles, 1 eq) of the phenyl acid compound was dissolved in DCM (20 ml). 123 mg (0.000854 moles, 1.5 eq) of morpholinopropylamine was added to the mixture. 163 mg (0.000852 moles, 1.5 eq) of EDCI and 155 mg (0.001140 moles, 2.0 eq) of HOBT were added to the mixture under cooling conditions. 169 mg (0.001311 moles, 2.3 eq) was charged into it and the reaction mixture was maintained at room temperature until the starting material was completely consumed.

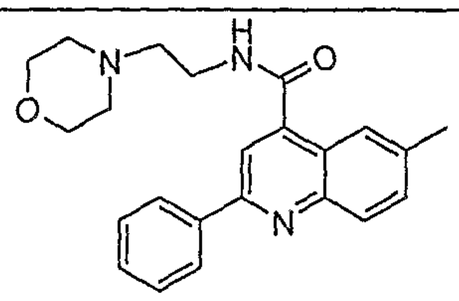
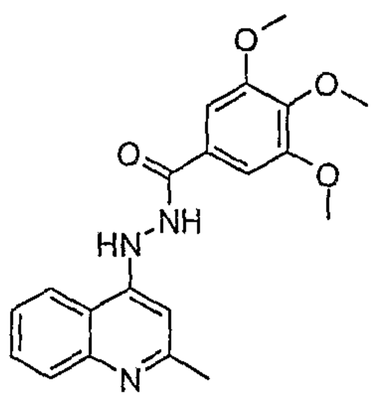
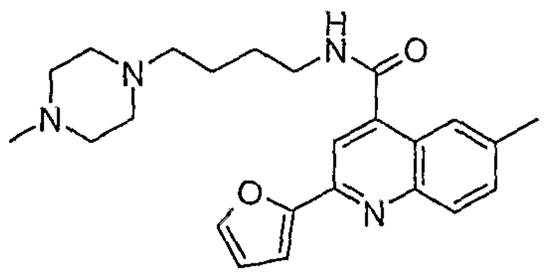
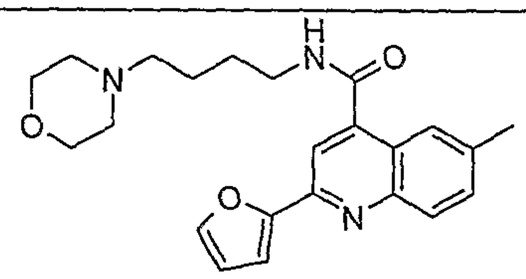
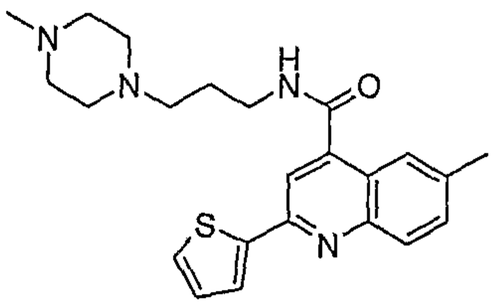
The reaction mixture was dissolved in DCM and partitioned between water and DCM. The organic layer was separated and washed with satuated NaCl solution. The organic layer was dried over Na_2SO_4, filtered and the solvent was removed under reduced pressure. The obtained crude residue was purified by column chromatography using silicagel to obtain 40 mg of the pure compound for a 19.1% yield.

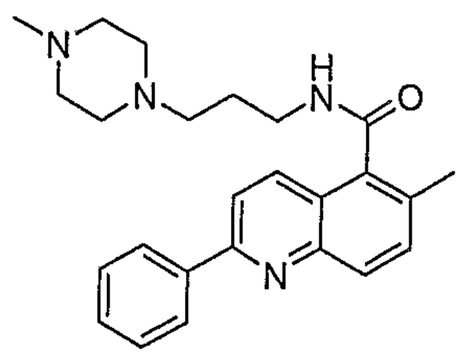
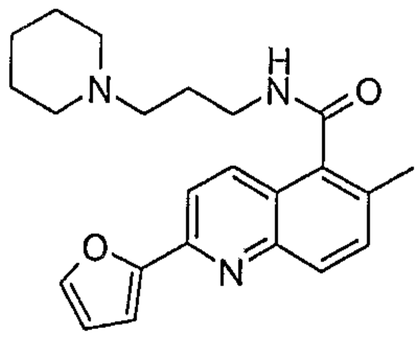
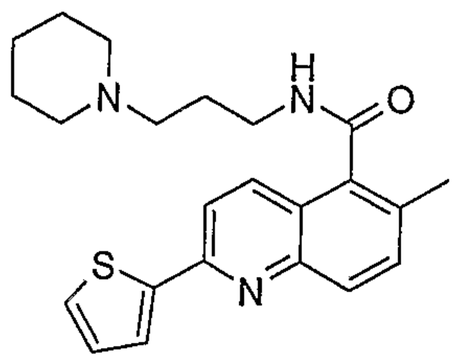
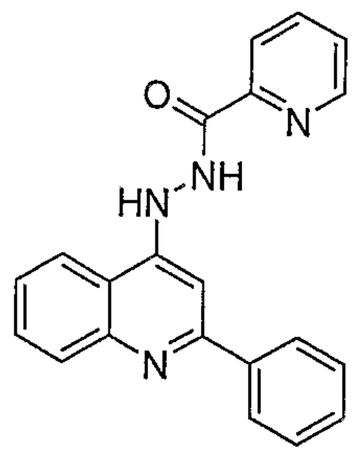
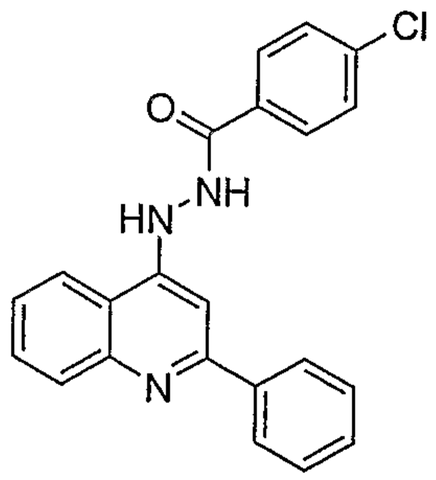
MASS SPECTRUM:-390.7 (M+, 100)

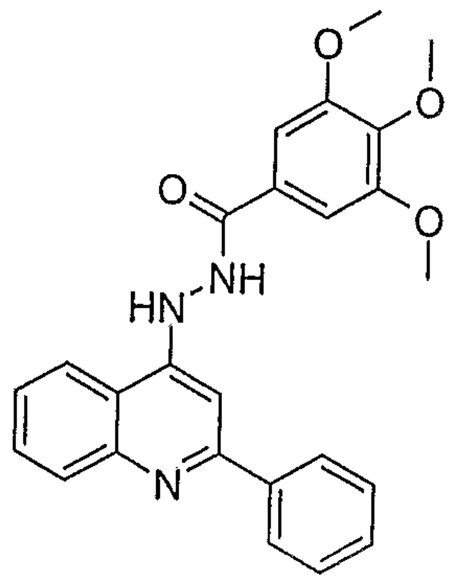
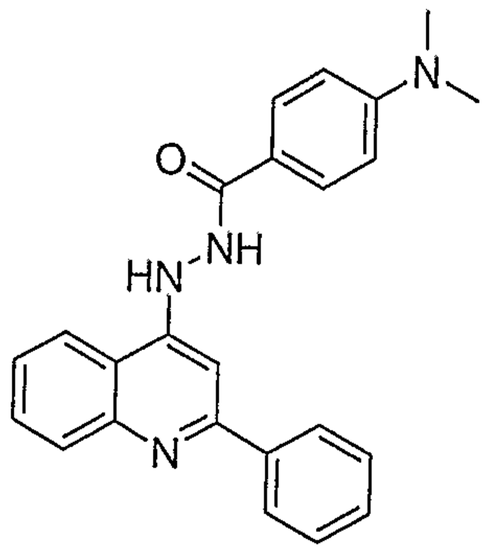
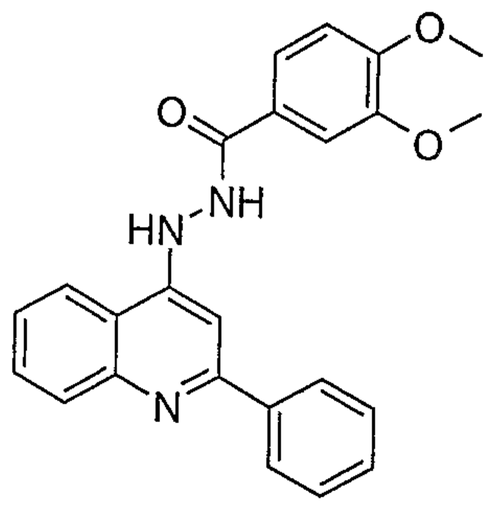
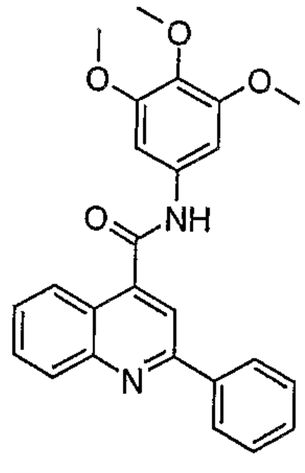
HNMR (CD3OD):- 2.1(2H, m), 2.83 (3H, s), 3.13 (2H, t), 3.22 (2H, t), 3.56 (4H, m), 3.82 (2H, t), 4.12 (2H, m), 7.82 (2H, m), 8.34 (4H m), 8.68 (2H, m).

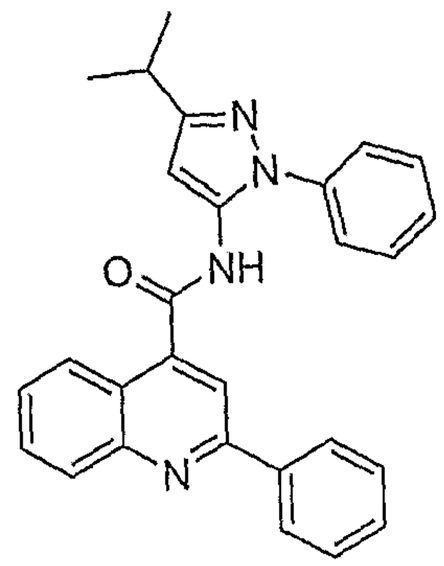
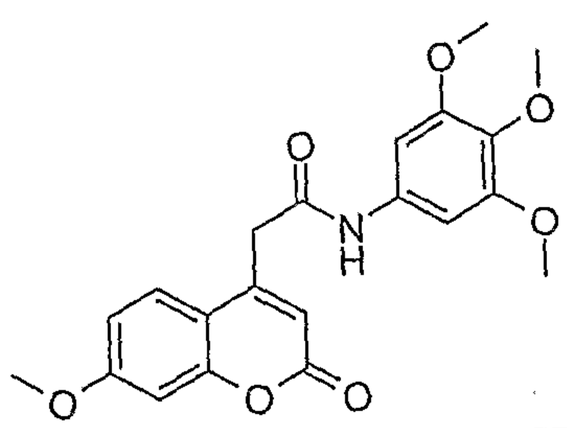
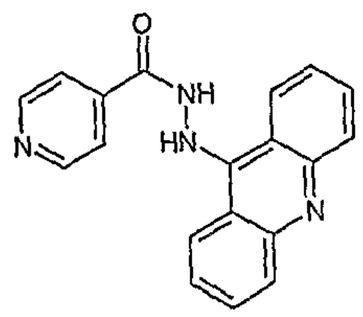
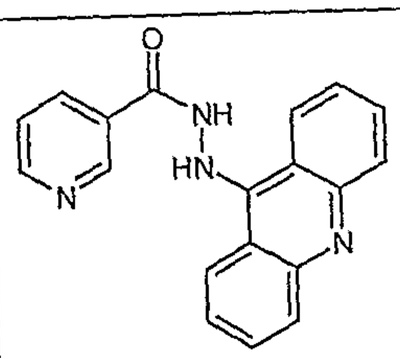
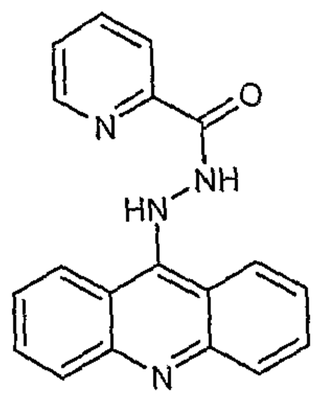
HPLC Purity: 99.19%

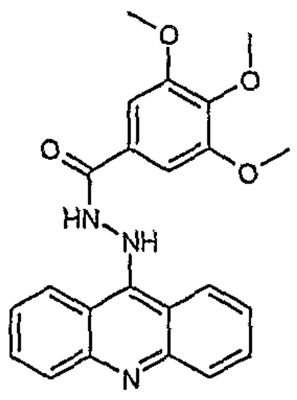
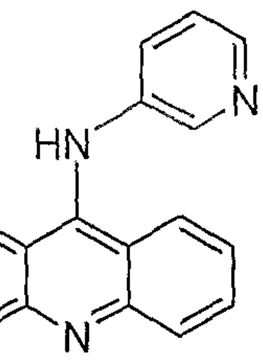
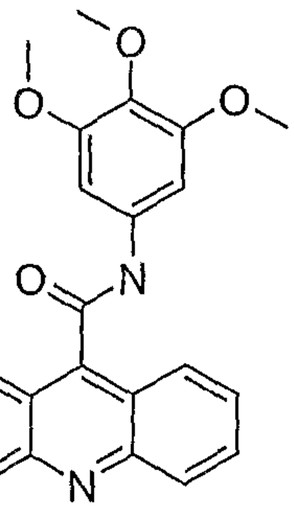
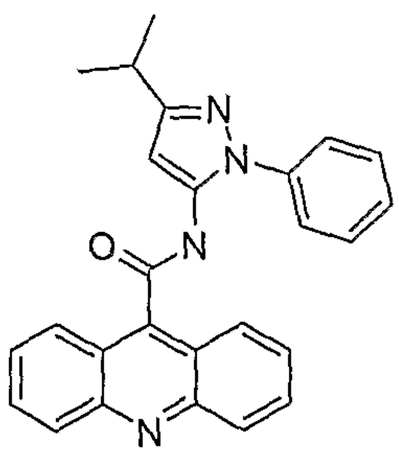
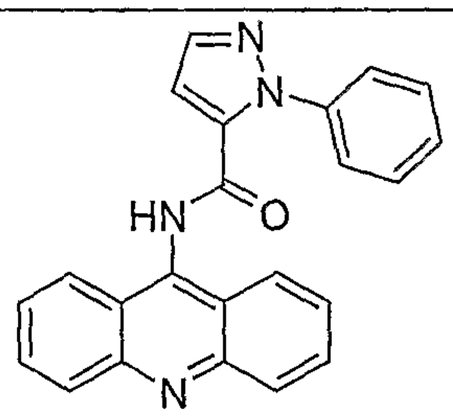
Table 3. Mass Spectrometric Characterization of Synthesized Compounds

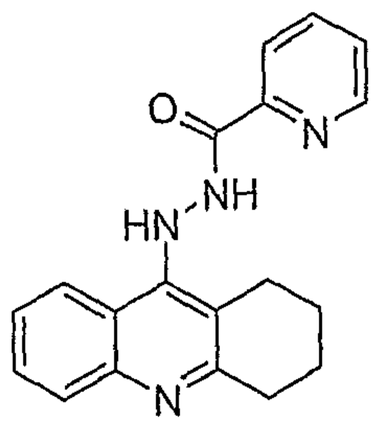
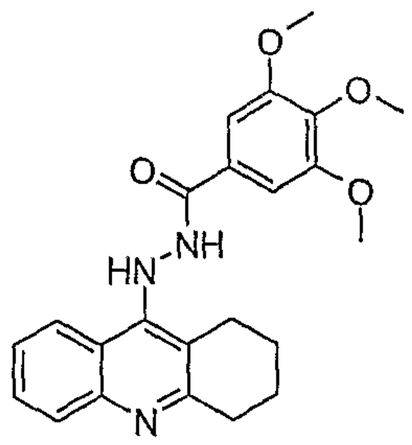
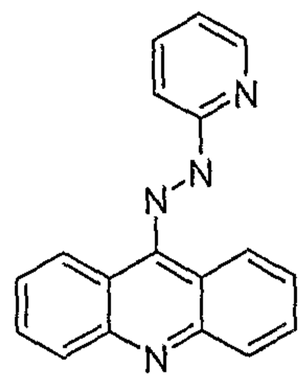
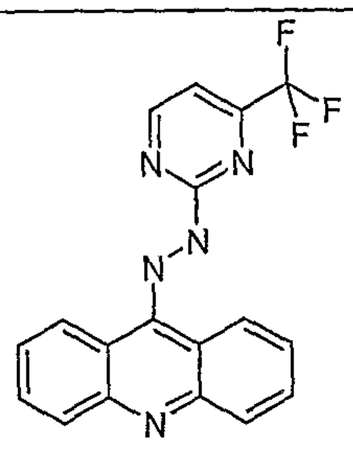
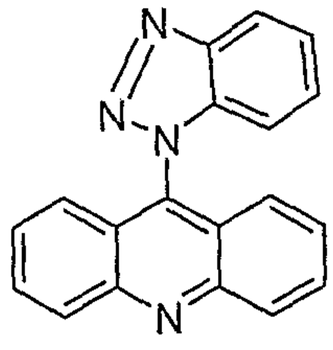
SRT#	Structure	Calc'd	[M+H]+
15		$C_{23}H_{25}N_3O_2$ Calc'd 375.2	376
16		$C_{23}H_{21}N_3O_4$ Calc'd 403.15	404
17		$C_{24}H_{30}N_4O_2$ Calc'd 406.53	407
161		$C_{23}H_{27}N_3O_3$ Calc'd 393.47	394
18		$C_{23}H_{28}N_4OS$ Calc'd 408.6	409

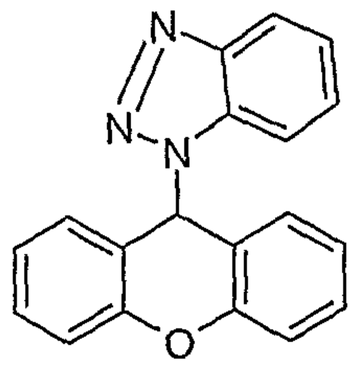
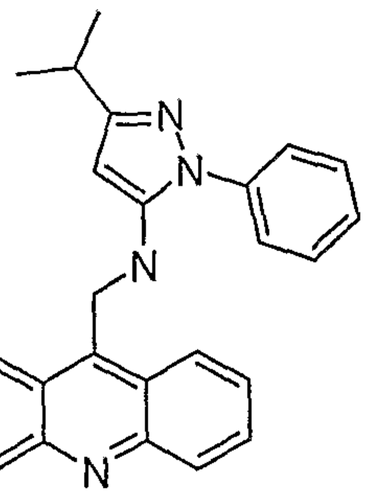
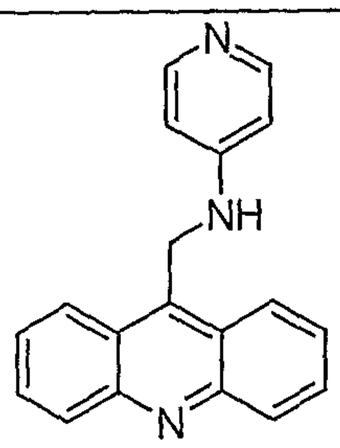
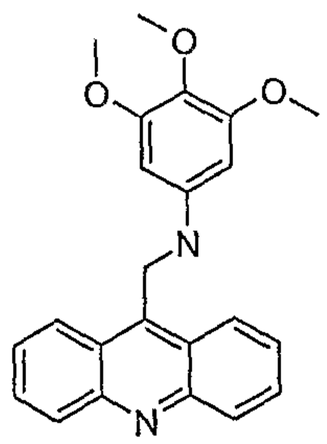
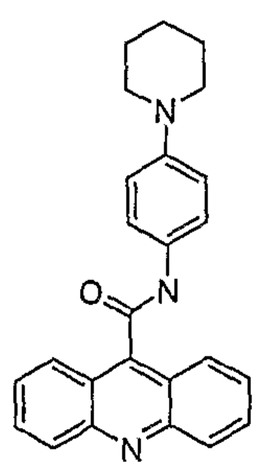
19		$C_{25}H_{32}N_4O$ Calc'd 404.5	405
20		$C_{23}H_{27}N_3O_2$ Calc'd 377.5	378
21		$C_{23}H_{27}N_3OS$ Calc'd 393.5	394
22		$C_{21}H_{16}N_4O$ Calc'd 340.4	341
23		$C_{22}H_{16}ClN_3O$ Calc'd 373.85	374

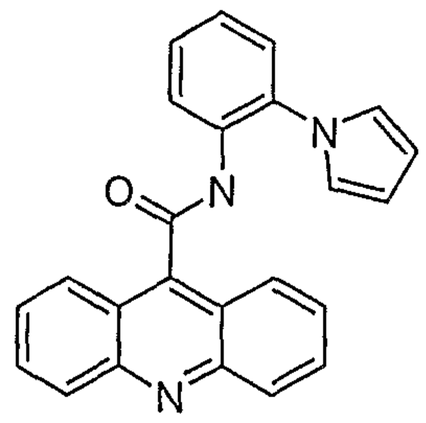
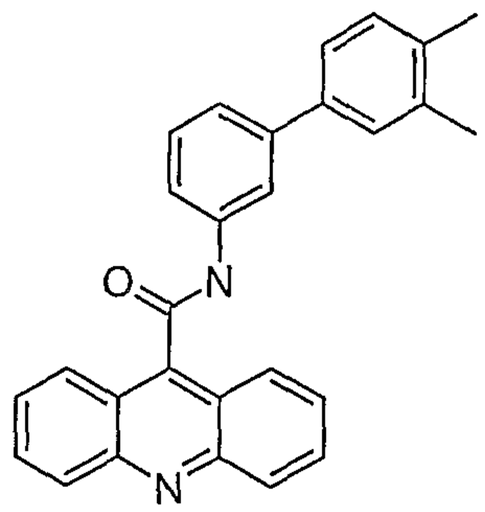
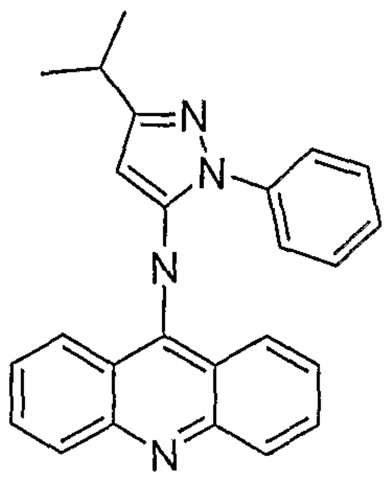
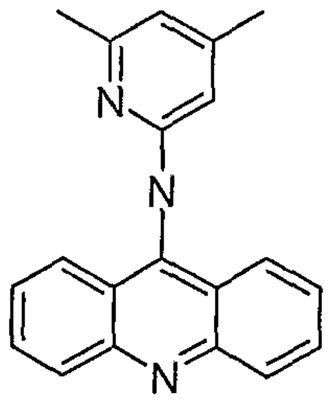
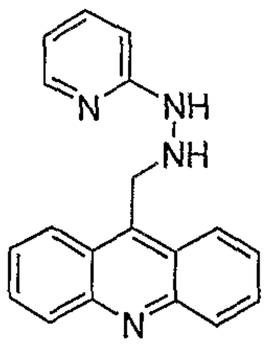
24		$C_{25}H_{23}N_3O_4$ Calc'd 429.5	430
25		$C_{24}H_{22}N_4O$ Calc'd 382.5	383
26		$C_{24}H_{21}N_3O_3$ Calc'd 399.4	400
27		$C_{25}H_{22}N_2O_4$ Calc'd 414.5	415

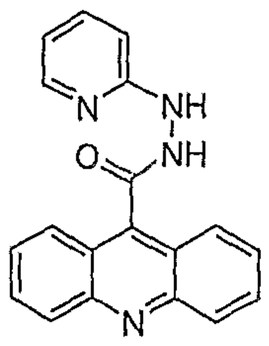
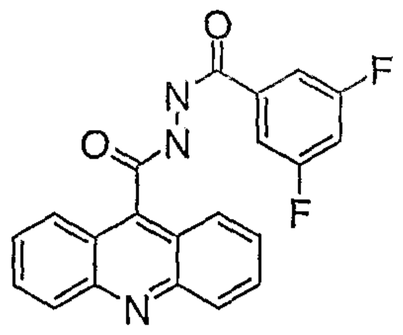
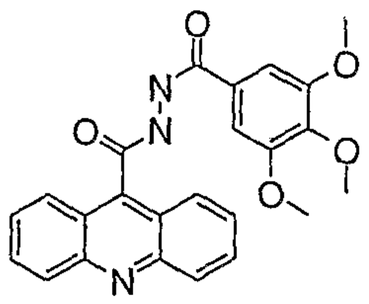
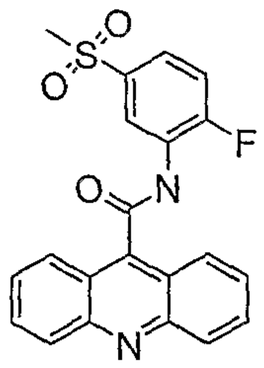
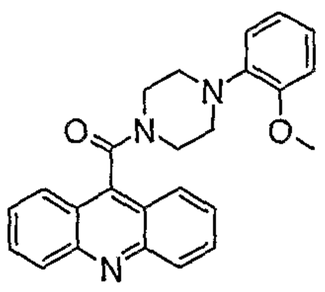
29		$C_{28}H_{24}N_4O$ Calc'd 432.5	433
28		$C_{21}H_{21}NO_7$ Calc'd 399.4	400
10		$C_{19}H_{14}N_4O$ Calc'd 314.3	315
11		$C_{19}H_{14}N_4O$ Calc'd 314.3	315
2			

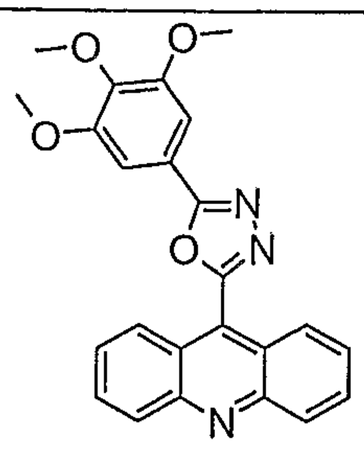
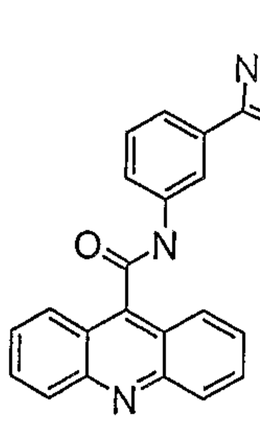
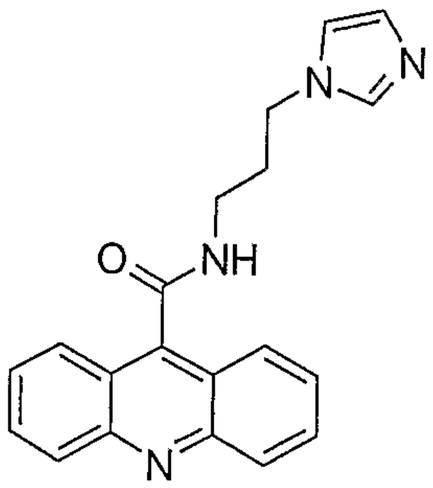
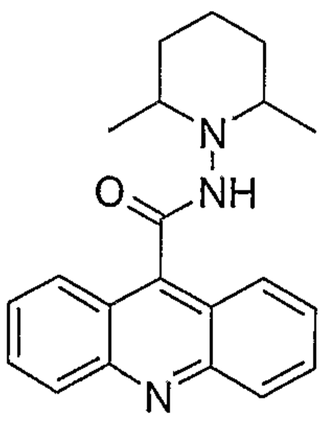
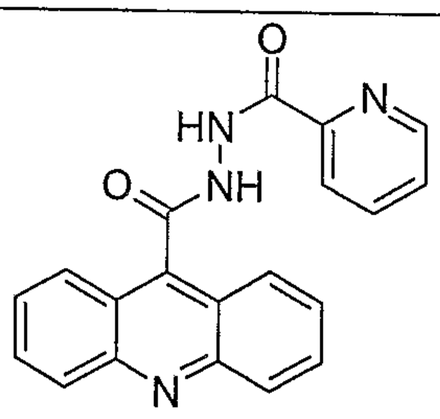
3		$C_{23}H_{21}N_3O_4$ Calc'd 403.4	404
116		$C_{18}H_{13}N_3$ Calc'd 271.1	272
117		$C_{23}H_{20}N_2O_4$ Calc'd 388.4	389
118		$C_{26}H_{22}N_4O$ Calc'd 406.5	407
119		$C_{23}H_{16}N_4O$ Calc'd 364.4	365

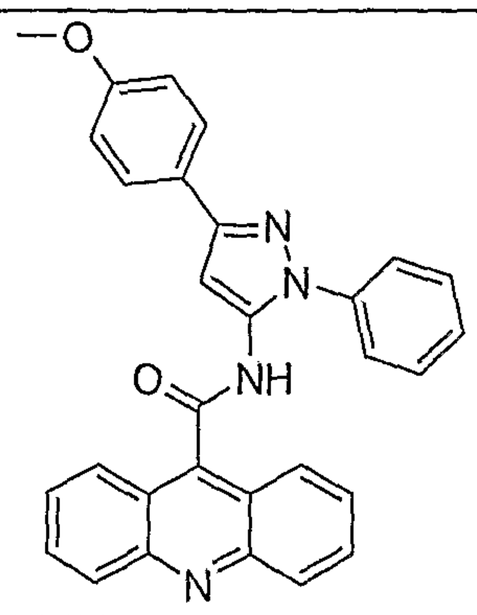
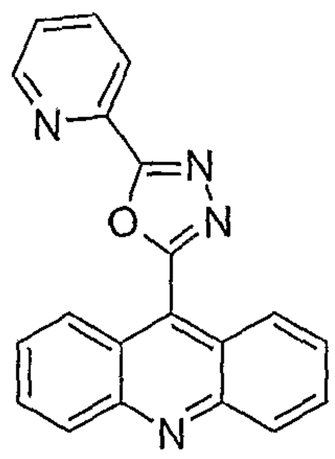
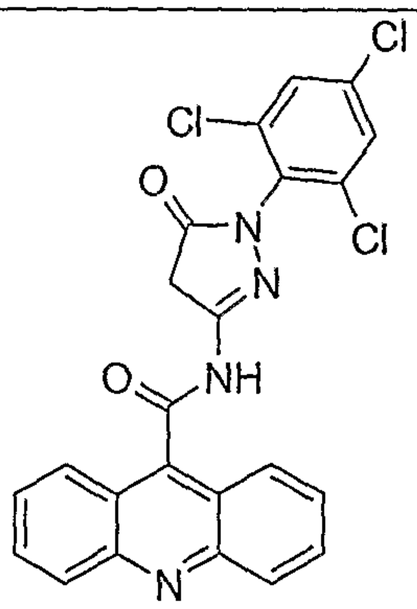
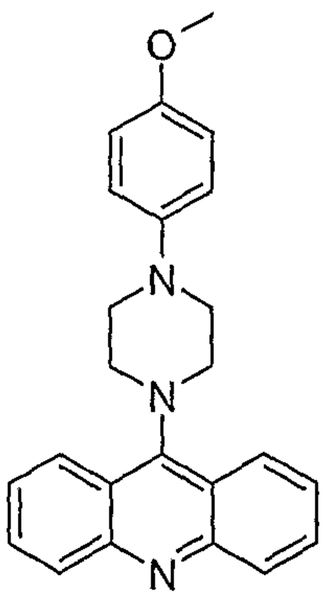
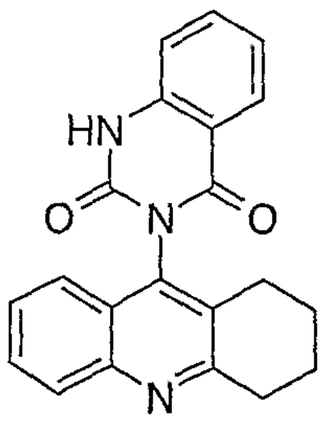
162		$C_{19}H_{18}N_4O$ Calc'd 318.1	319.1
120		$C_{23}H_{25}N_3O_4$ Calc'd 407.2	408.2
121		$C_{18}H_{14}N_4$ Calc'd 286.1	287.1
122		$C_{18}H_{12}F_3N_5$ Calc'd 355.1	356.1
123		$C_{19}H_{12}N_4$ Calc'd 296.1	297.1

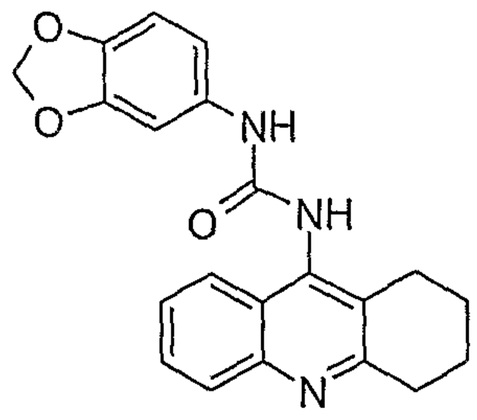
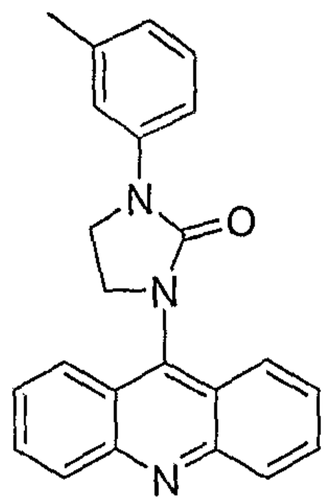
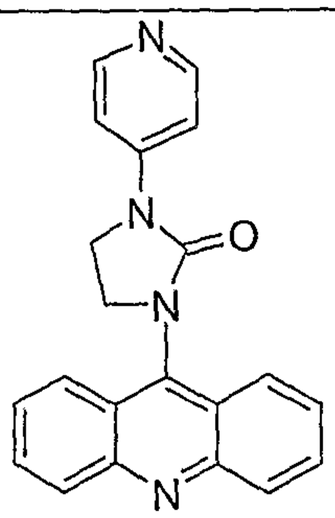
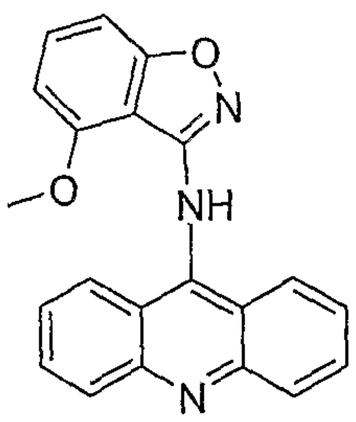
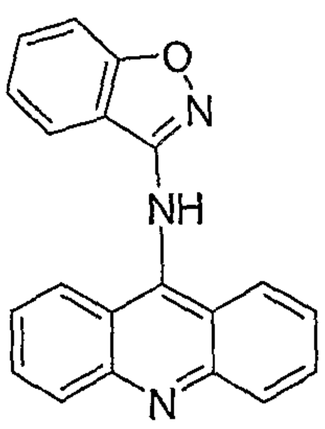
124		$C_{19}H_{13}N_3O$ Calc'd 299.1	297.1
125		$C_{26}H_{24}N_4$ Calc'd 392.5	393
126		$C_{19}H_{15}N_3$ Calc'd 285.3	286
127		$C_{23}H_{22}N_2O_3$ Calc'd 374.4	375
128		$C_{25}H_{23}N_3O$ Calc'd 381.5	382

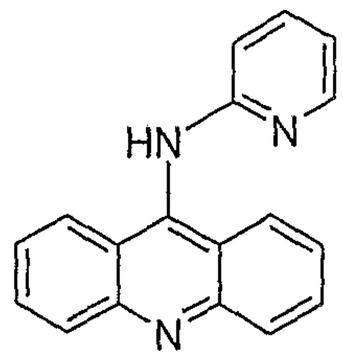
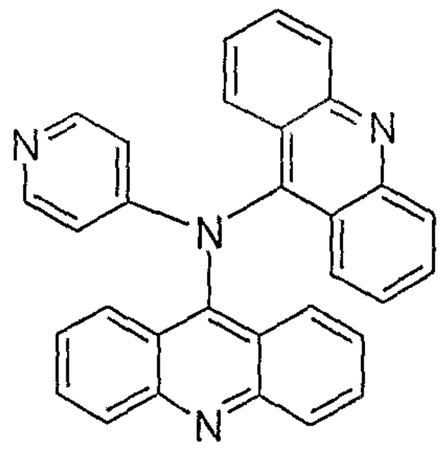
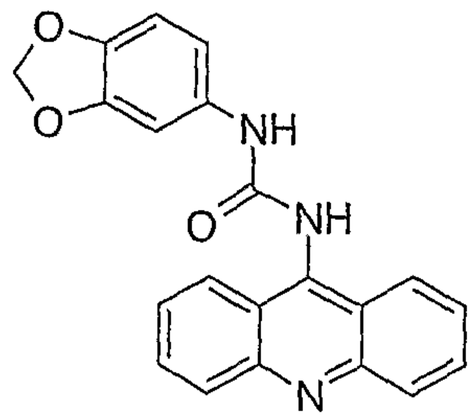
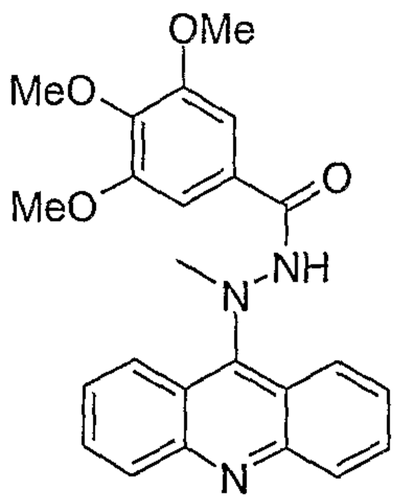
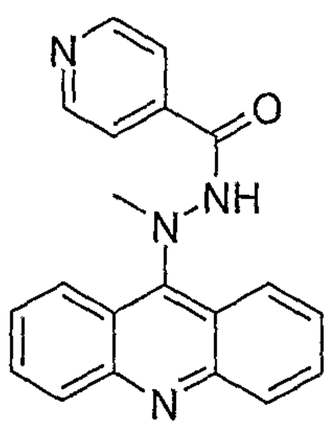
129		$C_{24}H_{17}N_3O$ Calc'd 363.4	364
130		$C_{28}H_{22}N_2O$ Calc'd 402.5	403
131		$C_{25}H_{22}N_4$ Calc'd 378.2	379.2
163		$C_{20}H_{17}N_3$ Calc'd 299.1	300.1
132		$C_{19}H_{16}N_4$ Calc'd 300.1	299.1

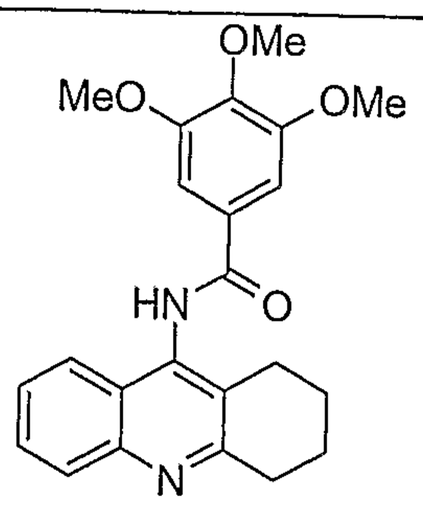
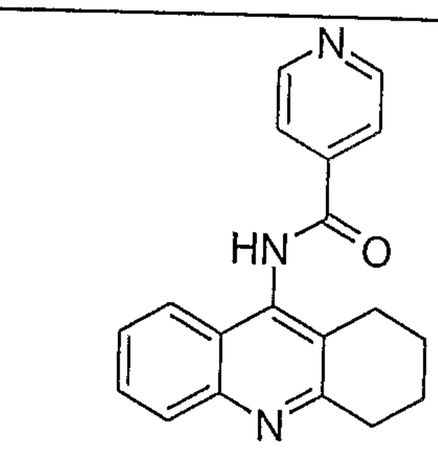
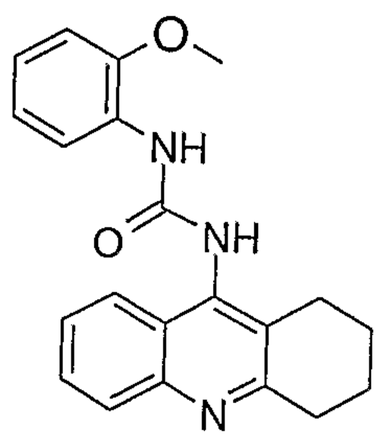
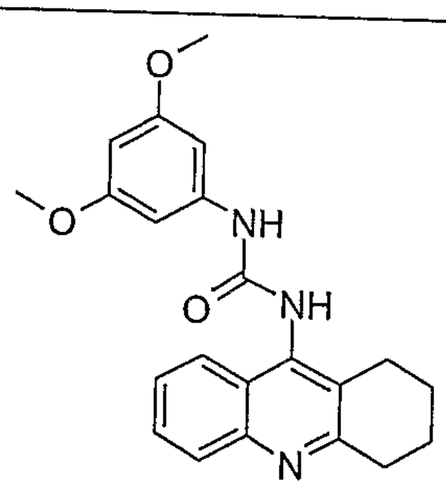
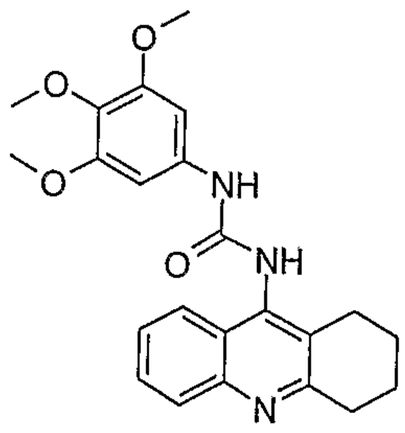
133		$C_{19}H_{14}N_4O$ Calc'd 314.1	315.1
134		$C_{21}H_{13}F_2N_3O_2$ Calc'd 377.3	378
164		$C_{24}H_{21}N_3O_5$ Calc'd 431.4	432
135		$C_{21}H_{15}FN_2O_3S$ Calc'd 394.4	395
136		$C_{25}H_{23}N_3O_2$ Calc'd 397.5	398

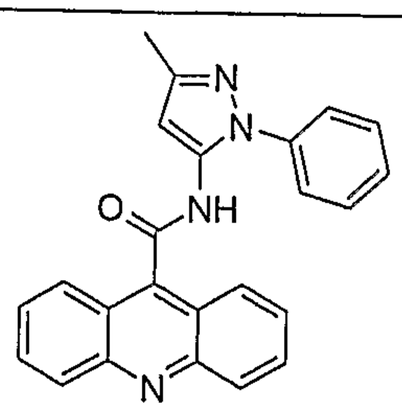
137		$C_{24}H_{19}N_3O_4$ Calc'd 413.4	414
165		$C_{24}H_{17}N_3OS$ Calc'd 395.5	396
138		$C_{20}H_{18}N_4O$ Calc'd 330.4	331
139		$C_{21}H_{23}N_3O$ Calc'd 333.4	334
140		$C_{20}H_{14}N_4O_2$ Calc'd 342.4	343

141		$C_{30}H_{22}N_4O_2$ Calc'd 470.5	471
142		$C_{21}H_{12}N_4O$ Calc'd 324.3	325
143		$C_{23}H_{13}Cl_3N_4O_2$ Calc'd 483.7	483
144		$C_{24}H_{23}N_3O$ Calc'd 369.5	370
145		$C_{21}H_{17}N_3O_2$ Calc'd 343.1	344.1

146		$C_{21}H_{19}N_3O_3$ Calc'd 361.1	362.1
147		$C_{23}H_{19}N_3O$ Calc'd 353.2	354.2
148		$C_{21}H_{16}N_4O$ Calc'd 341.1	341.1
149		$C_{21}H_{15}N_3O_2$ Calc'd 341.1	342.1
150		$C_{20}H_{13}N_3O$ Calc'd 311.1	312.1

151		$C_{18}H_{13}N_3$ Calc'd 271.1	272.1
152		$C_{31}H_{20}N_4$ Calc'd 448.2	449.1
153		$C_{21}H_{15}N_3O_3$ Calc'd 357.1	358.1
154		$C_{24}H_{23}N_3O_4$ Calc'd 417.2	418.2
155		$C_{20}H_{16}N_4O$ Calc'd 328.1	329.1

156		$C_{23}H_{24}N_2O_4$ Calc'd 392.2	393.2
157		$C_{19}H_{17}N_3O$ Calc'd 303.1	304.1
158		$C_{21}H_{19}N_3O_3$ Calc'd 361.1	362.1
159		$C_{22}H_{23}N_3O_3$ Calc'd 377.2	378.2
167		$C_{23}H_{25}N_3O_4$ Calc'd 407.2	408.2

159		$C_{24}H_{18}N_4O$ Calc'd 378.4	379

EXAMPLE 2: Identification of Sirtuin Modulators Using SIRT1

A fluorescence polarization or mass spectrometry based assay was used to identify modulators of SIRT1 activity. The same assay may be used to identify modulators of any sirtuin protein. The fluorescence polarization assays utilizes one of two different peptides based on a fragment of p53, a known sirtuin deacetylation target. Compounds were tested using a substrate containing peptide 1 having 20 amino acid residues as follows: Ac-EE-K(biotin)-GQSTSSHSK(Ac)NleSTEG–K(MR121)-EE-NH_2 (SEQ ID NO: 1) wherein K(biotin) is a biotinolated lysine residue, K(Ac) is an acetylated lysine residue, Nle is norleucine and K(MR121) is a lysine residue modified by an MR121 fluorophore. This peptide is labeled with the fluorophore MR121 (excitation 635 nm/emission 680 nm) at the C-termini and biotin at the N-termini. The sequence of the peptide substrates are based on p53 with several modifications. In particular, all arginine and leucine residues other than the acetylated lysine residues have replaced with serine so that the peptides are not susceptible to trypsin cleavage in the absence of deacetylation. In addition, the methionine residues naturally present in the sequences have been replaced with the norleucine because the methionine may be susceptible to oxidation during synthesis and purification. As an alternative substrate in the assay, the following peptide 2 has also been used: Ac-EE-K(biotin)-GQSTSSHSK(Ac)NleSTEG–K(5TMR)-EE-NH2 (SEQ ID NO: 2) wherein K(Ac) is an acetylated lysine residue and Nle is a norleucine. The peptide is labeled with the fluorophore 5TMR (excitation 540 nm/emission 580 nm) at the C-terminus. The sequence of the peptide substrate is also based on p53 with several modifications. In addition, the methionine residue naturally present in the sequence was replaced with the norleucine because the methionine may be susceptible to oxidation during synthesis and purification.

The peptide substrates were exposed to a sirtuin protein in the presence of NAD^+ to allow deacetylation of the substrate and render it sensitive to cleavage by

trypsin. Trypsin was then added and the reaction was carried to completion (i.e., the deacetylated substrate is cleaved) releasing the MR121 or 5TMR fragment. Streptavidin is then added to the reaction where it can bind both the uncleaved substrate (i.e., any remaining acetylated substrate) and the non-fluorescent portion of the cleaved peptide substrate (i.e., the biotin containing fragment). The fluorescence polarization signal observed for the full length peptide substrates bound to streptavidin was higher than the fluorescence polarization signal observed for the released MR121 or 5TMR C-terminal fragment. In this way, the fluorescence polarization obtained is inversely proportional to the level of deacetylation (e.g., the signal is inversely proportional to the activity of the sirtuin protein). Results were read on a microplate fluorescence polarization reader (Molecular Devices Spectramax MD) with appropriate excitation and emission filters.

The fluorescence polarization assays using peptide 1 is conducted as follows: 0.5 μM peptide substrate and 150 μM βNAD$^+$ is incubated with 0.1 μg/mL of SIRT1 for 60 minutes at 37°C in a reaction buffer (25 mM Tris-acetate pH8, 137 mM Na-Ac, 2.7 mM K-Ac, 1 mM Mg-Ac, 0.05% Tween-20, 0.1% Pluronic F127, 10 mM $CaCl_2$, 5 mM DTT, 0.025% BSA, 0.15 mM Nicotinamide). Test compounds were solubilized in DMSO and added to the reaction at 11 concentrations ranging from 0.7 μM to 100 μM.

Fluorescence polarization assays using peptide 2 is conducted as follows: 0.5 μM peptide substrate and 120 μM βNAD$^+$ were incubated with 3 nM SIRT1 for 20 minutes at 25°C in a reaction buffer (25 mM Tris-acetate pH8, 137 mM Na-Ac, 2.7 mM K-Ac, 1 mM Mg-Ac, 0.05% Tween-20, 0.1% Pluronic F127, 10 mM $CaCl_2$, 5 mM DTT, 0.025% BSA). Test compounds 19-56 were solubilized in DMSO and added to the reaction at 10 concentrations ranging from 300 μM to 0.15 μM in three-fold dilutions.

After the incubation with SIRT1, nicotinamide was added to the reaction to a final concentration of 3 mM to stop the deacetylation reaction and 0.5 μg/mL of trypsin was added to cleave the deacetylated substrate. The reaction was incubated for 30 minutes at 37°C in the presence of 1 μM streptavidin. Fluorescent polarization was determined at excitation (650 nm) and emission (680 nm) wavelengths. The level of activity of the sirtuin protein in the presence of the various concentrations of test compound is then determined and may be compared to the level of activity of the

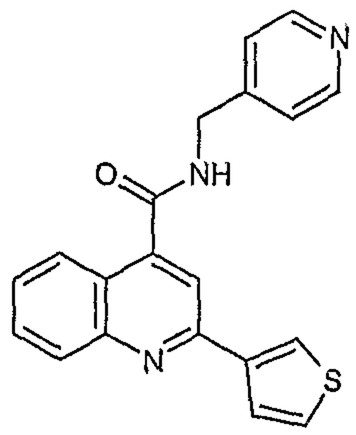
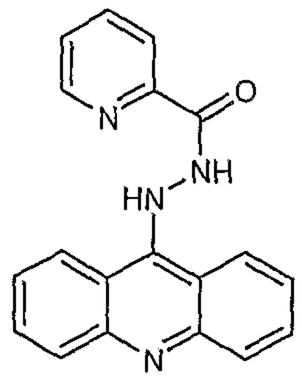
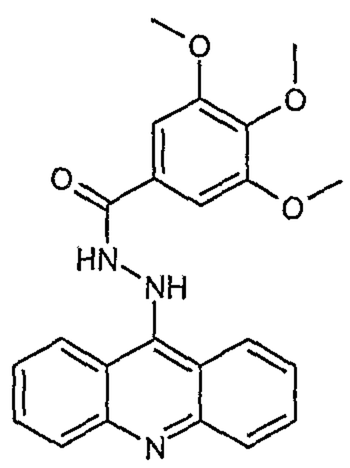
sirtuin protein in the absence of the test compound, and/or the level of activity of the sirtuin proteins in the negative control (e.g., level of inhibition) and positive control (e.g., level of activation) described below.

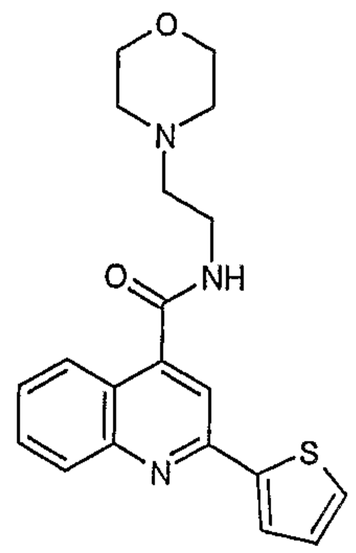
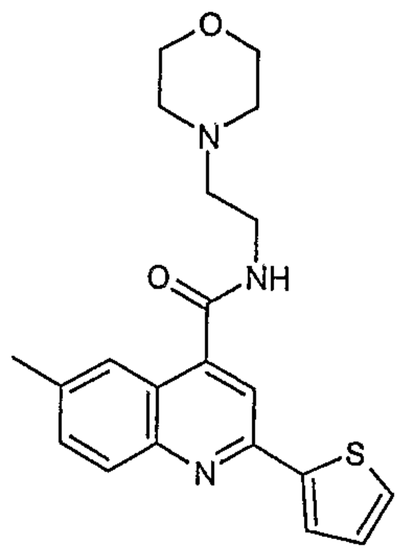
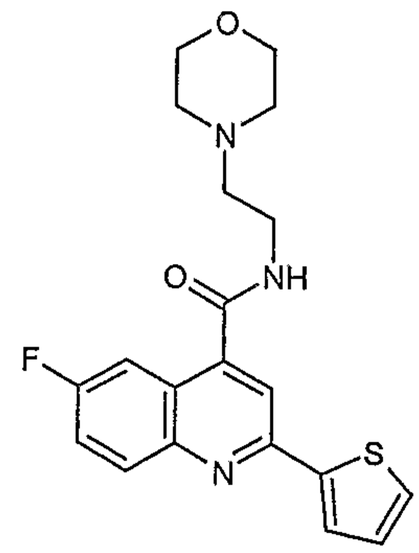
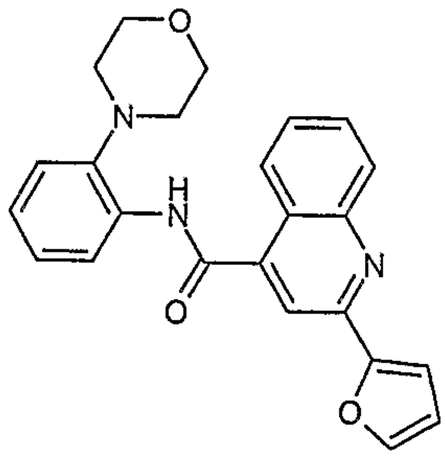
For the Fluorescence Polarization assays, a control for inhibition of sirtuin activity is conducted by adding 1 μL of 500 mM nicotinamide as a negative control at the start of the reaction (e.g., permits determination of maximum sirtuin inhibition). A control for activation of sirtuin activity was conducted using 3 nM of sirtuin protein, with 1 μL of DMSO in place of compound, to reach baseline deacetylation of the substrate (e.g., to determine normalized sirtuin activity).

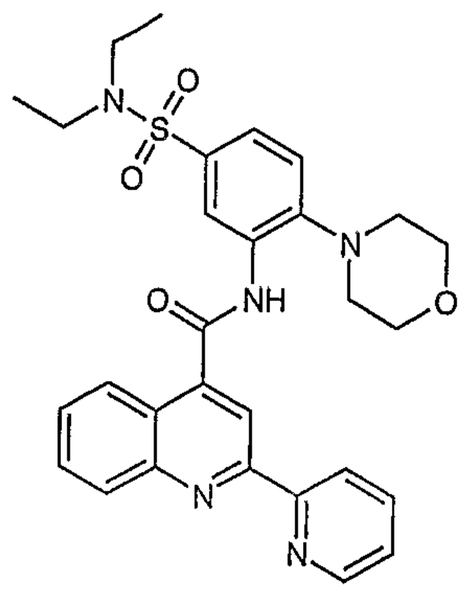
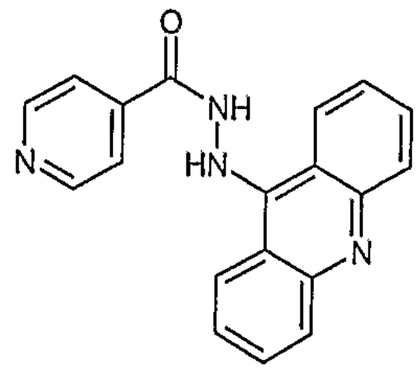
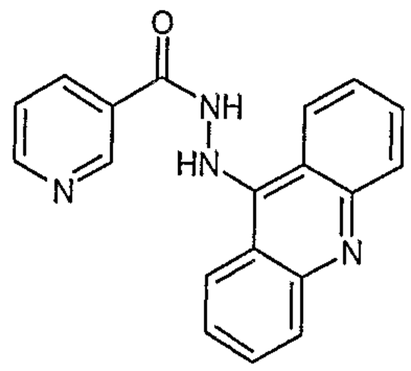
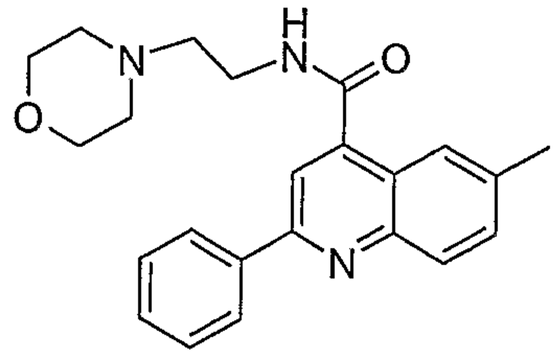
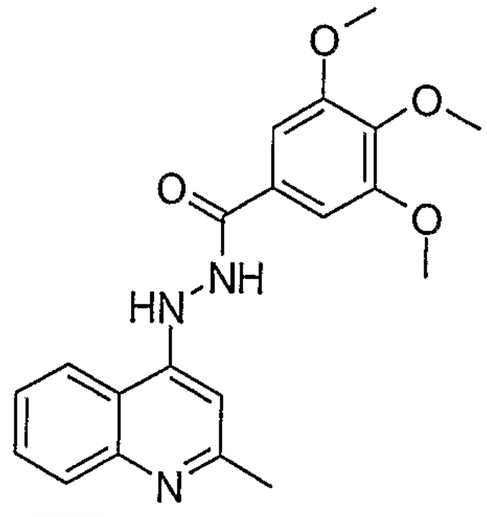
For each of the above assays, SIRT1 protein was expressed and purified as follows. The SirT1 gene was cloned into a T7-promoter containing vector and transformed into BL21(DE3). The protein was expressed by induction with 1 mM IPTG as an N-terminal His-tag fusion protein at 18°C overnight and harvested at 30,000 x g. Cells were lysed with lysozyme in lysis buffer (50 mM Tris-HCl, 2 mM Tris[2-carboxyethyl] phosphine (TCEP), 10 μM $ZnCl_2$, 200 mM NaCl) and further treated with sonication for 10 min for complete lysis. The protein was purified over a Ni-NTA column (Amersham) and fractions containing pure protein were pooled, concentrated and run over a sizing column (Sephadex S200 26/60 global). The peak containing soluble protein was collected and run on an Ion-exchange column (MonoQ). Gradient elution (200 mM - 500 mM NaCl) yielded pure protein. This protein was concentrated and dialyzed against dialysis buffer (20 mM Tris-HCl, 2 mM TCEP) overnight. The protein was aliquoted and frozen at -80°C until further use.

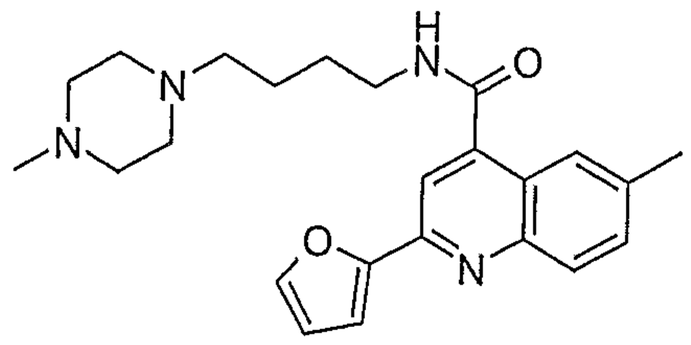
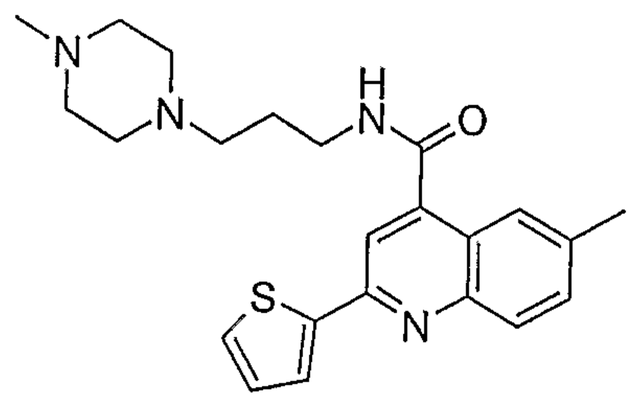
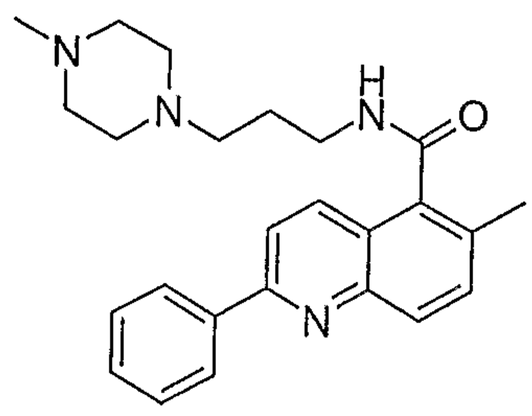
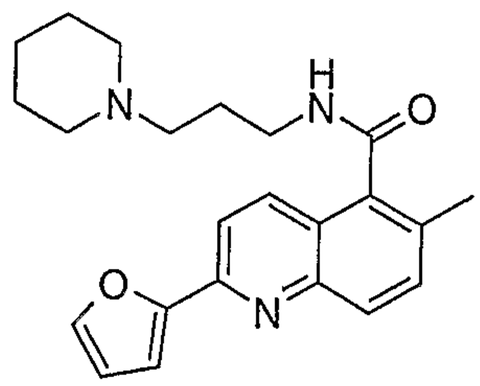
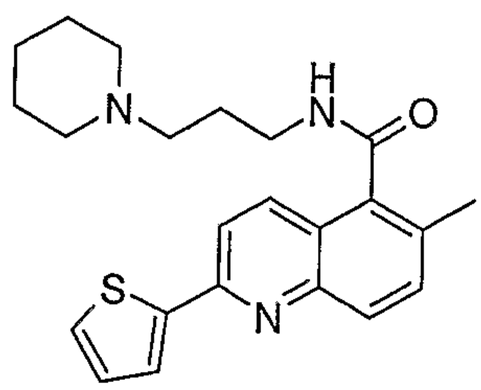
Sirtuin modulating compounds that activated SIRT1 were identified using the assay described above and are shown below in Table 4. Sirtuin modulating compounds that inhibited SIRT1 were identified using the assay described above and are shown below in Table 5. The ED_{50} values for the activating compounds are represented by A (ED_{50} = <50 μM), B (ED_{50} = 51-100 μM), C (ED_{50} = 101-150 μM), and D (ED_{50} = >150 μM). NT denotes compounds that were not tested, often times due to solubility issues. The ED_{50} of resveratrol for activation of SIRT1 is 16 μM. Similarly, the IC_{50} values for the inhibiting compounds are represented by A (IC_{50} = <50 μM), B (IC_{50} = 51-100 μM), C (IC_{50} = 101-150 μM), and D (IC_{50} = >150 μM).

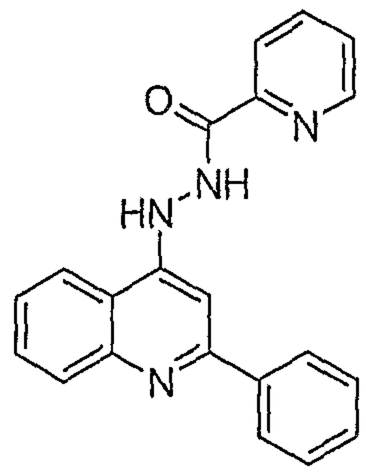
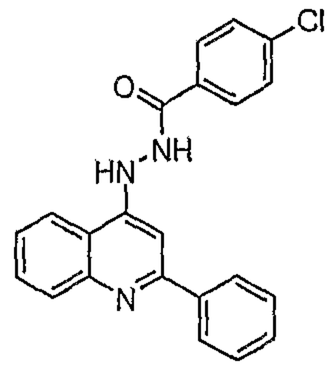
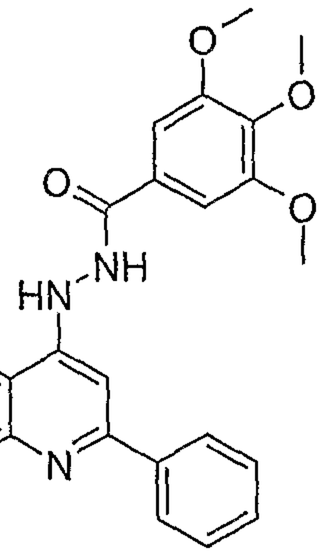
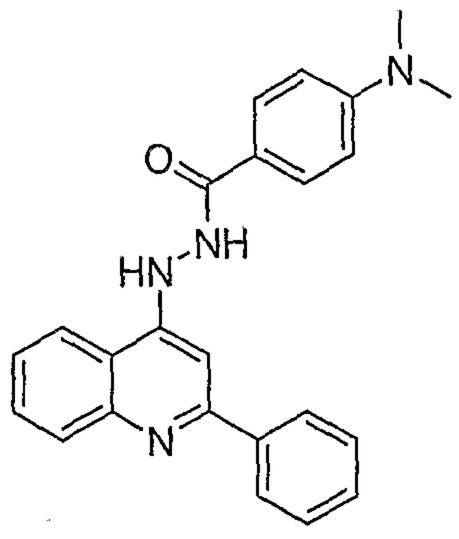
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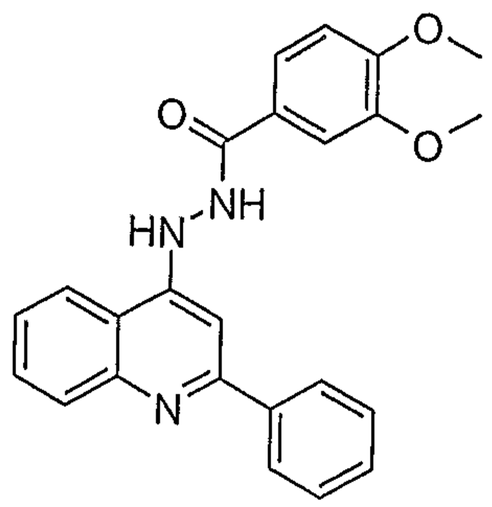
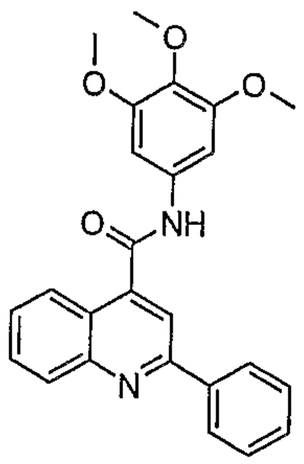
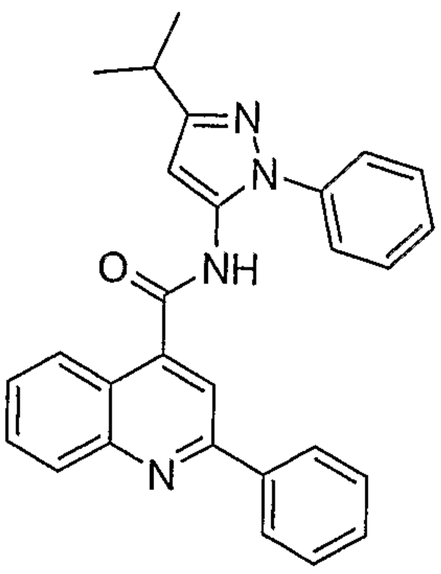
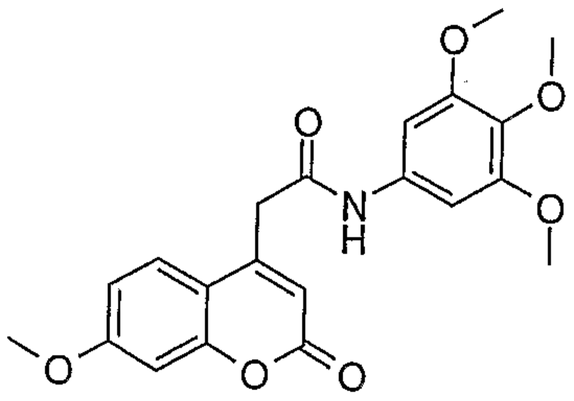
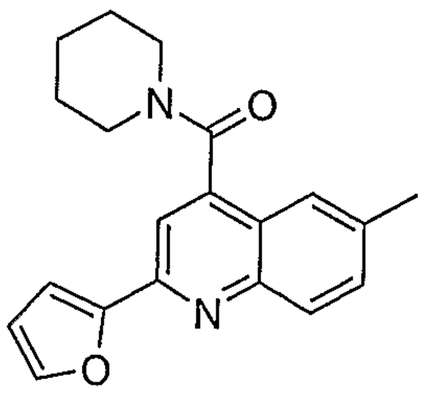
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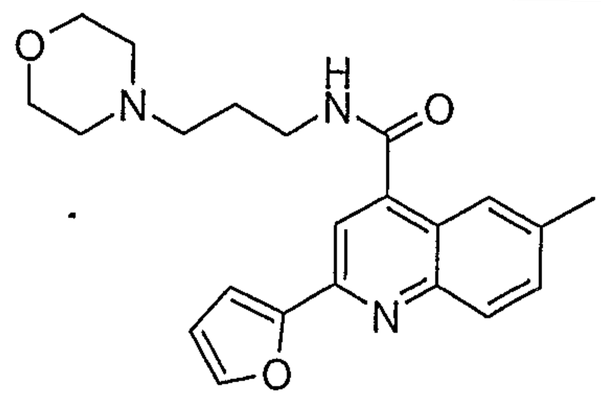
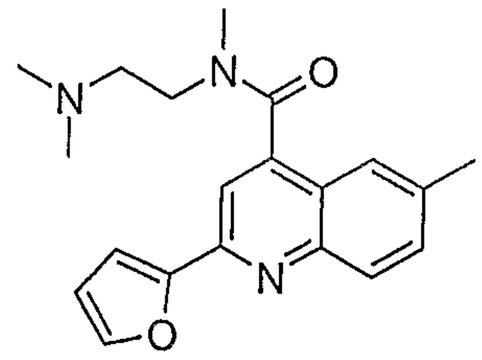
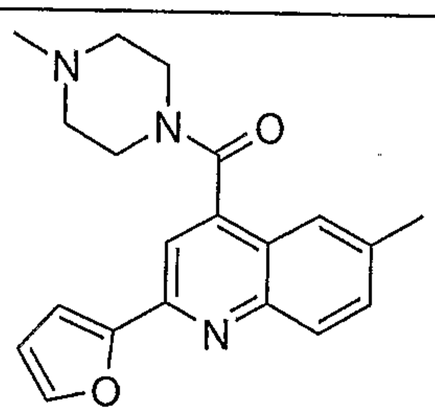
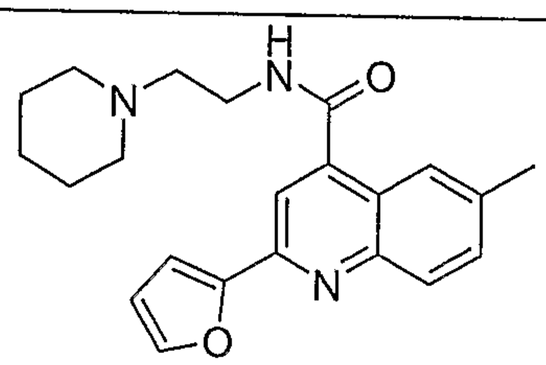
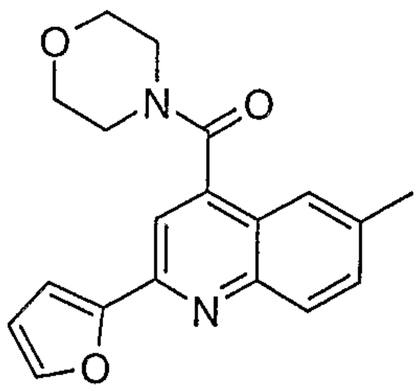
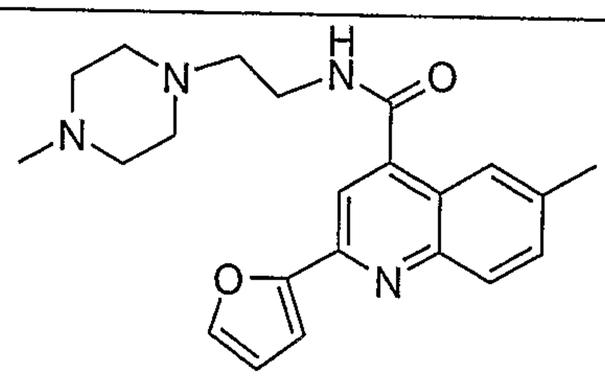
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8		A

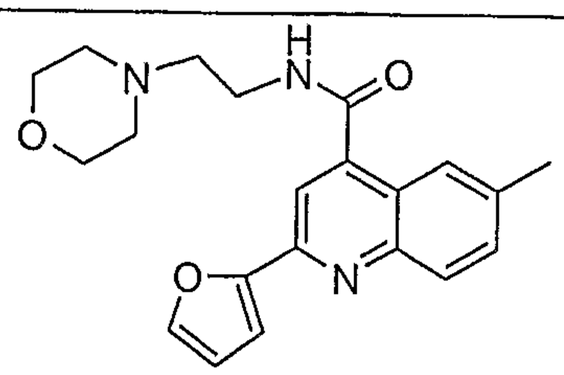
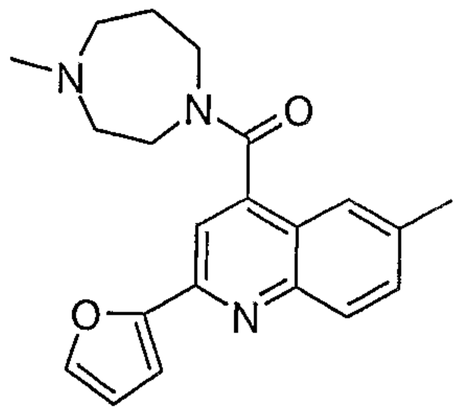
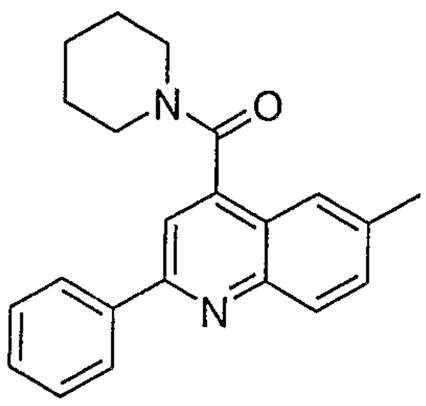
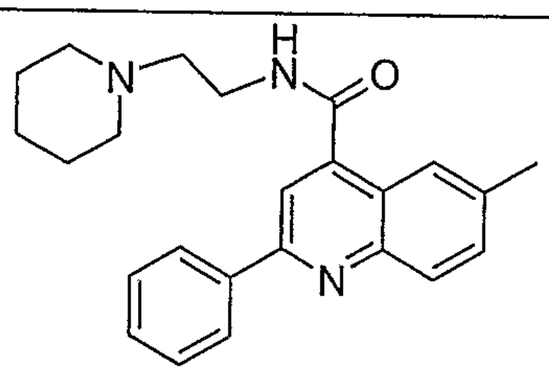
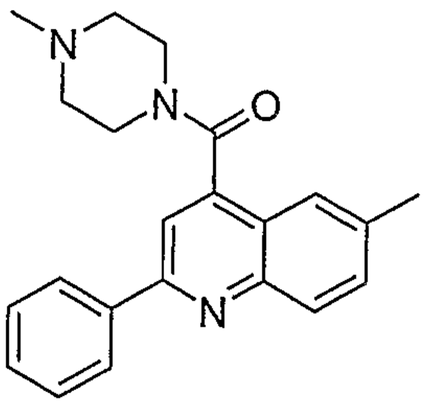
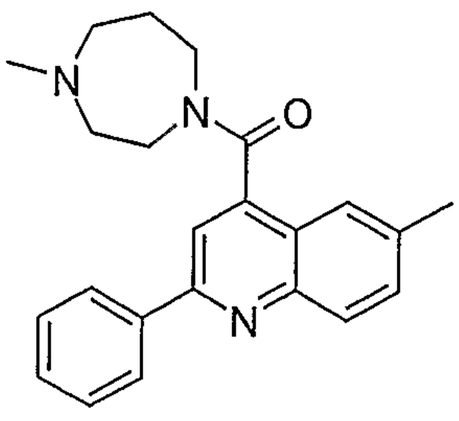
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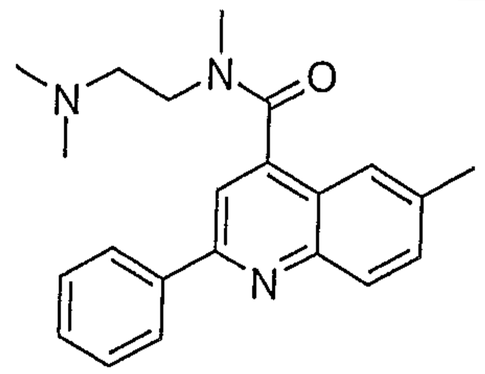
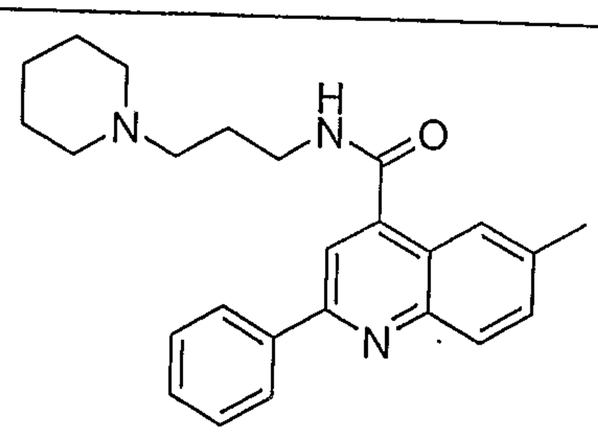
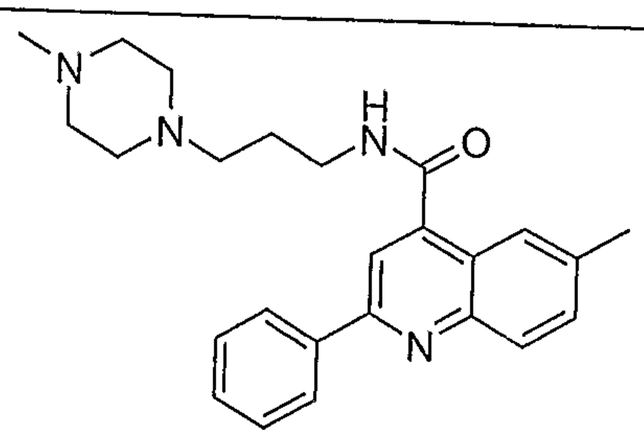
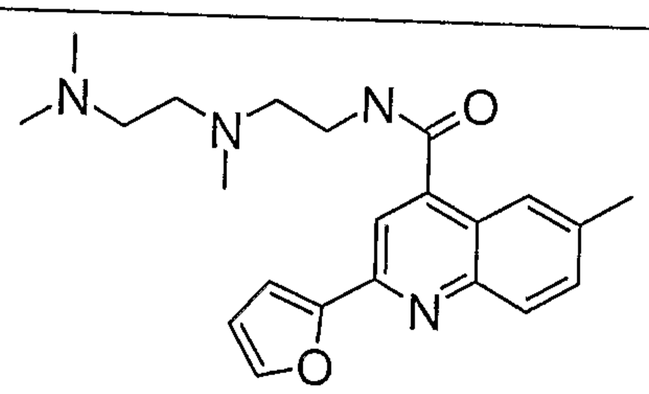
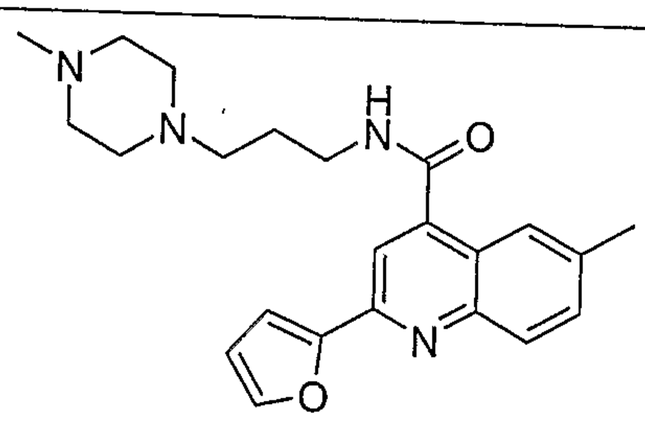
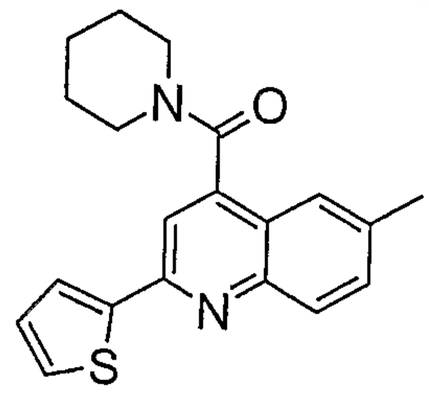
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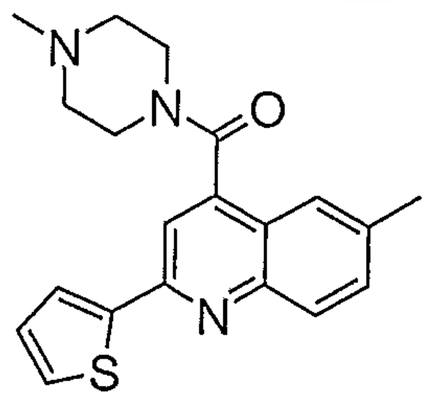
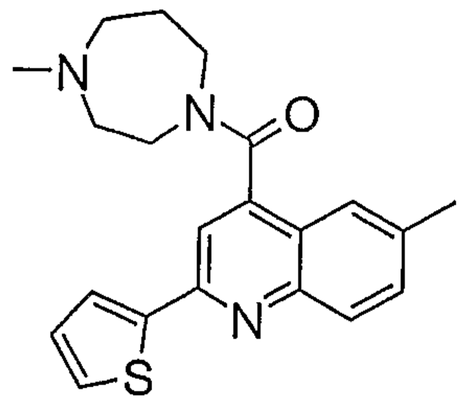
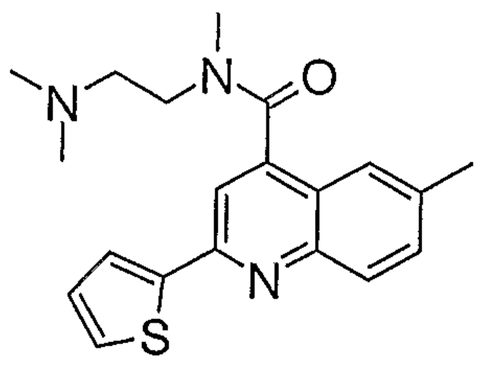
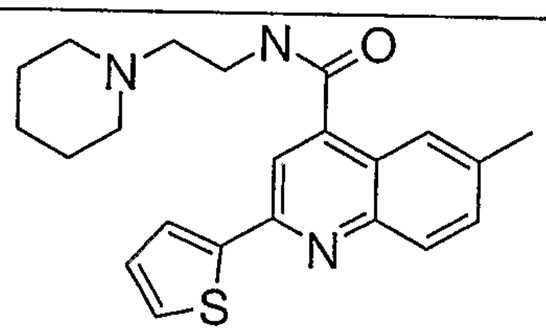
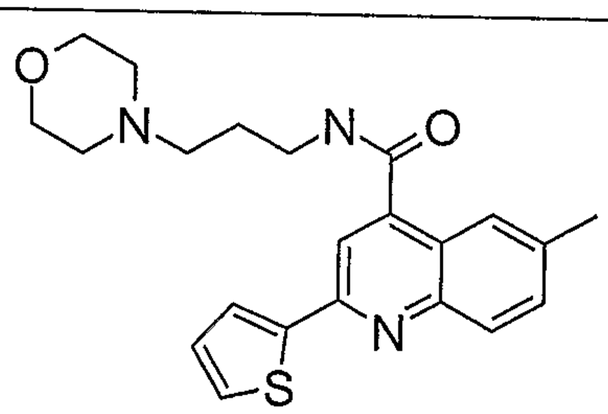
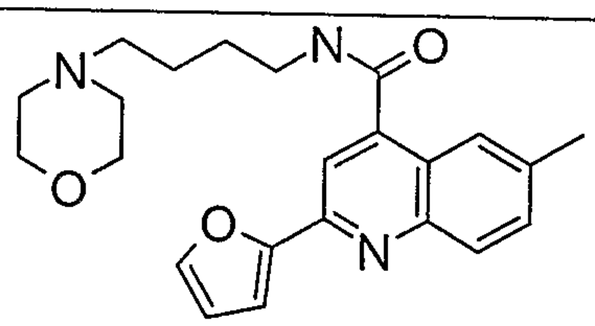
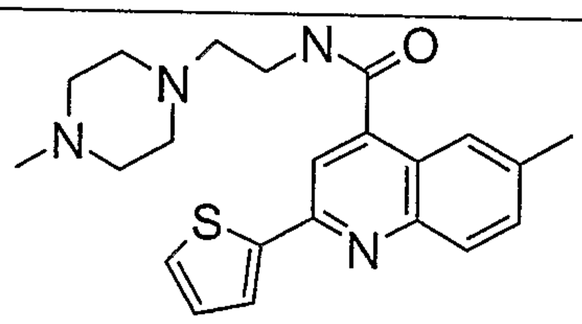
COMPOUND NO	STRUCTURE	ED_{50}
22		A
23		A
24		D
25		D

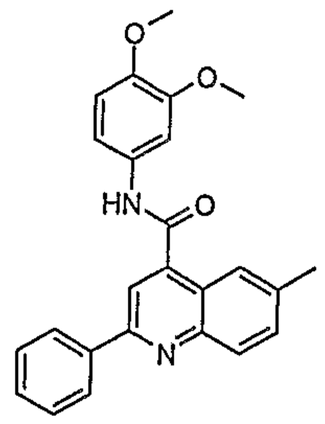
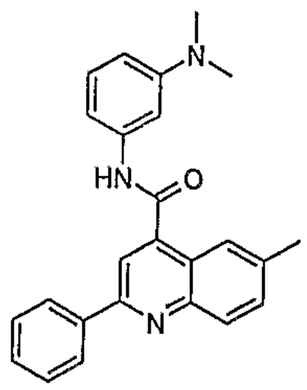
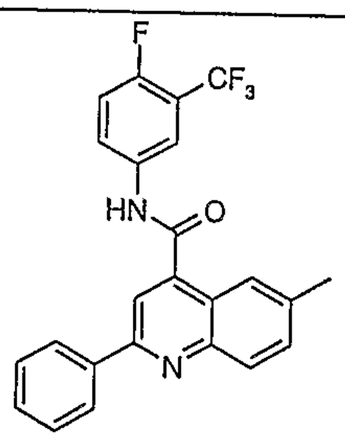
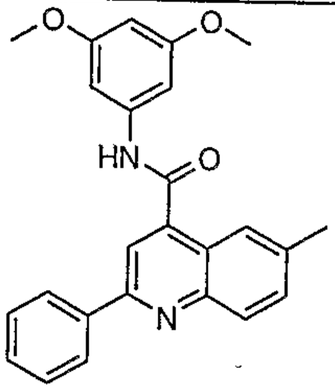
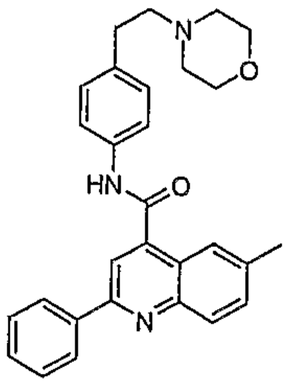
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28		D
29		D
30		D

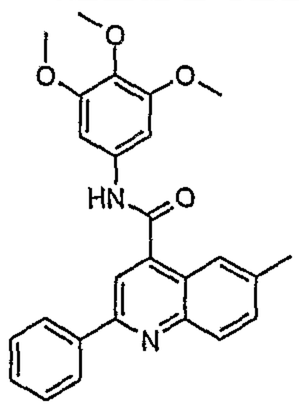
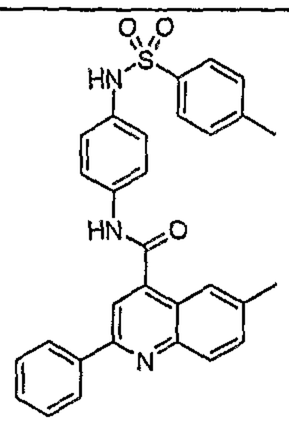
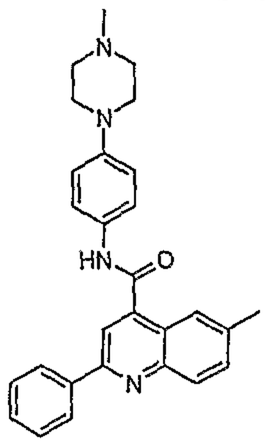
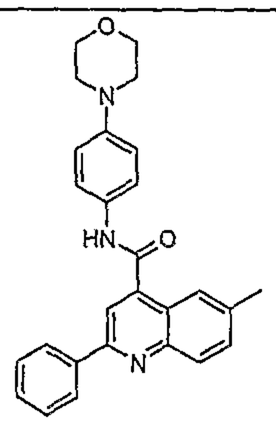
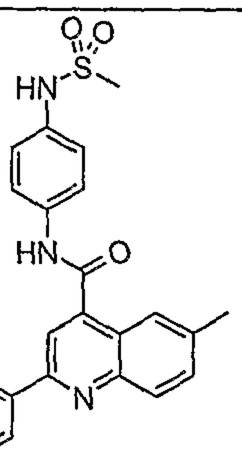
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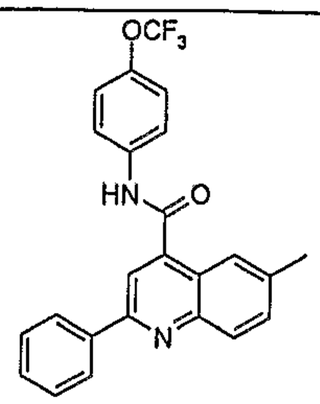
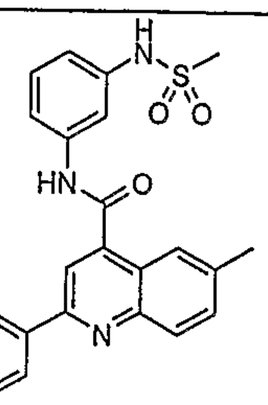
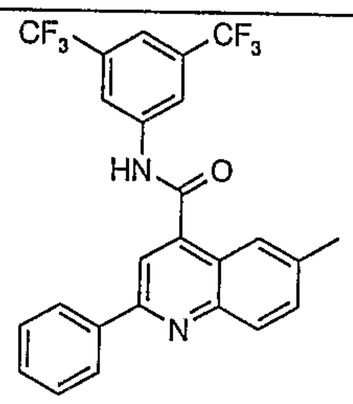
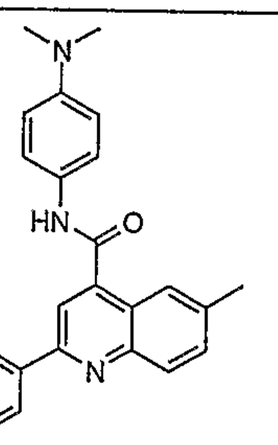
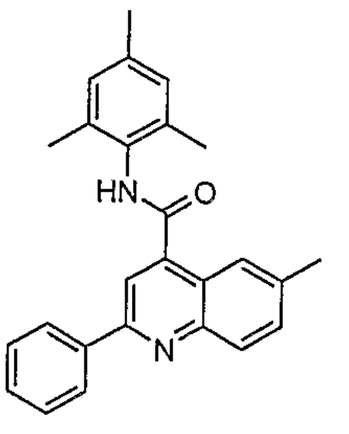
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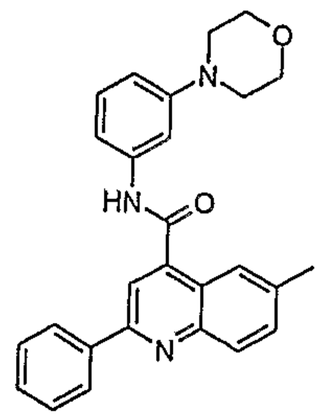
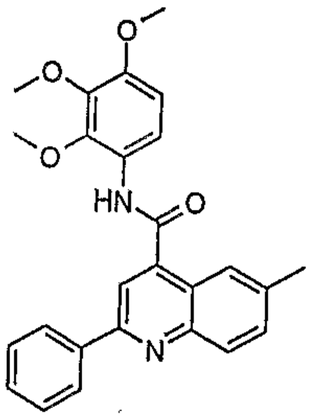
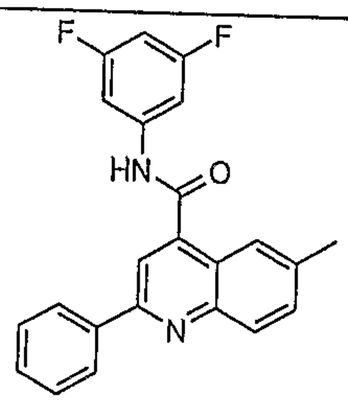
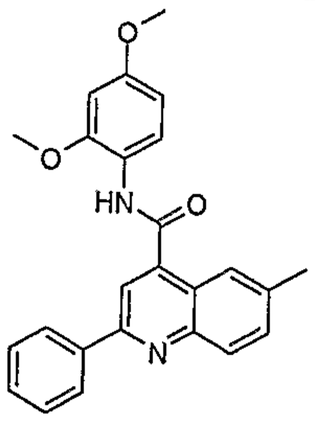
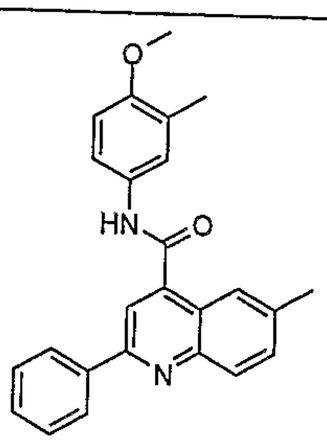
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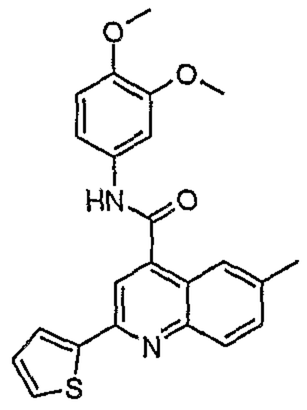
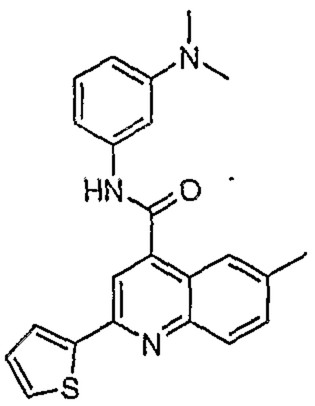
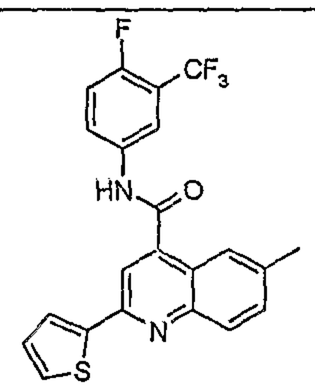
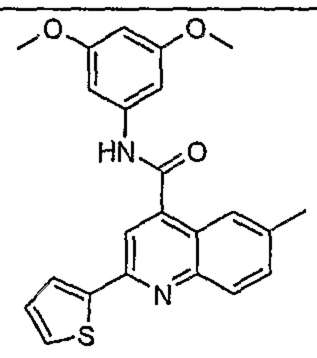
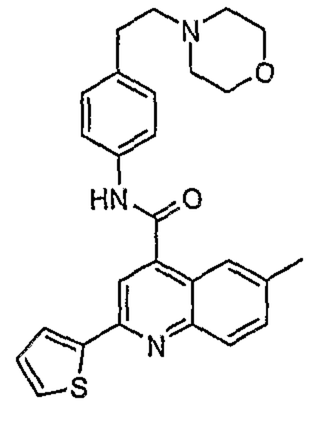
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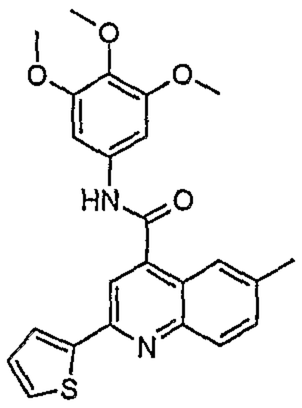
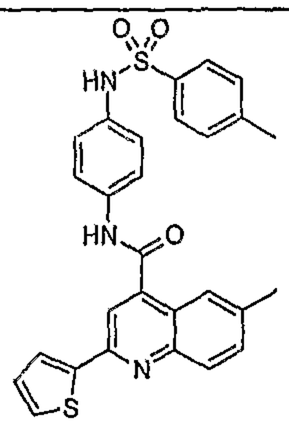
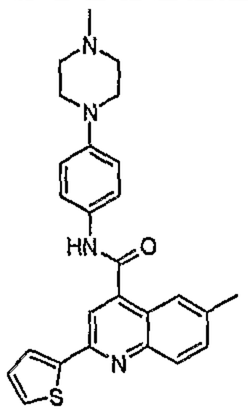
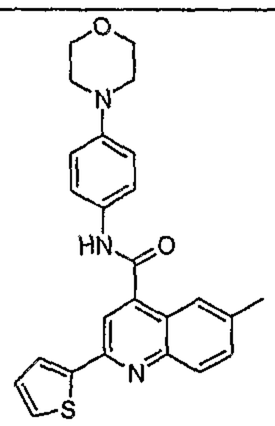
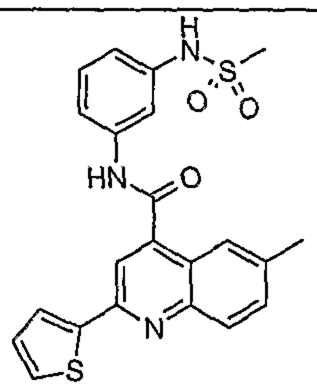
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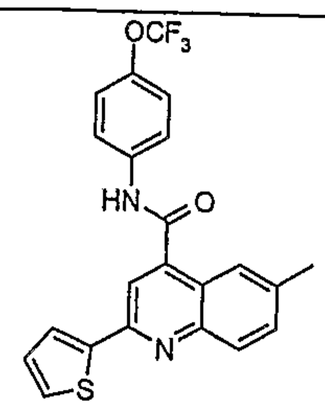
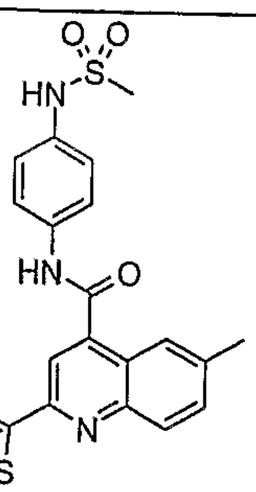
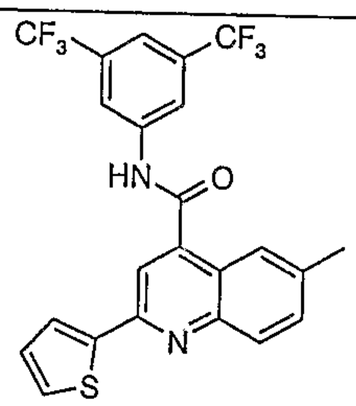
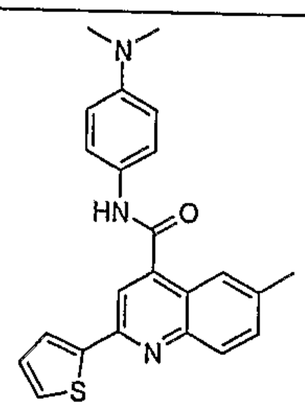
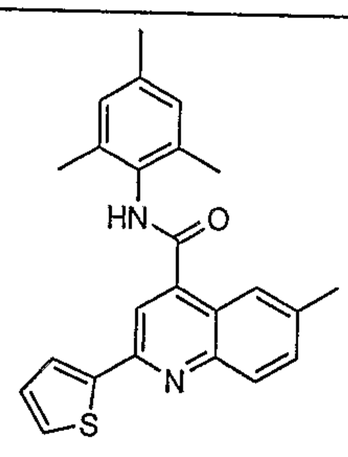
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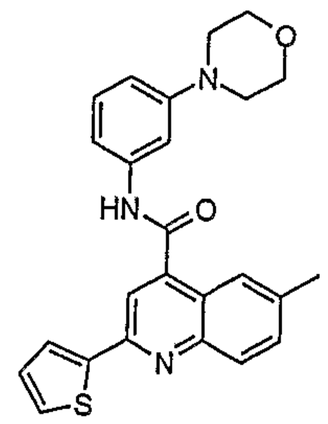
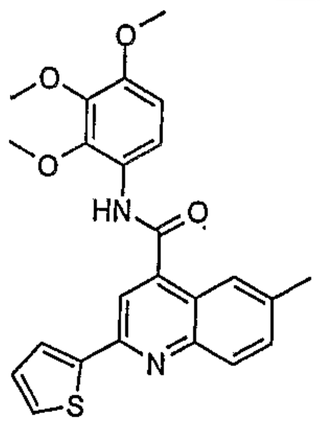
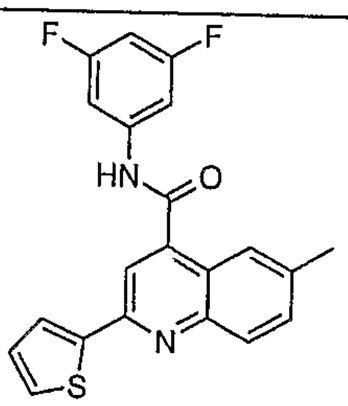
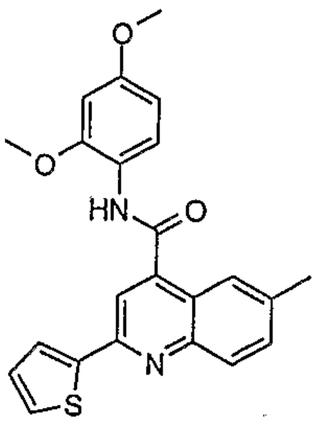
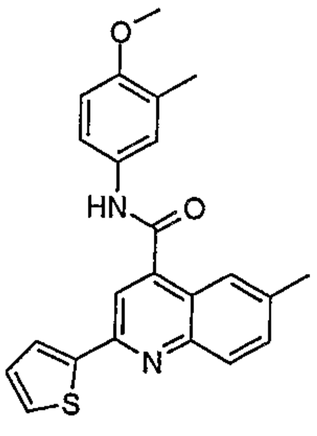
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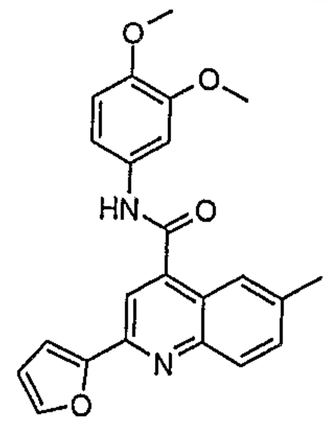
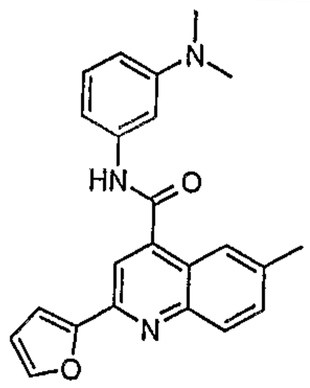
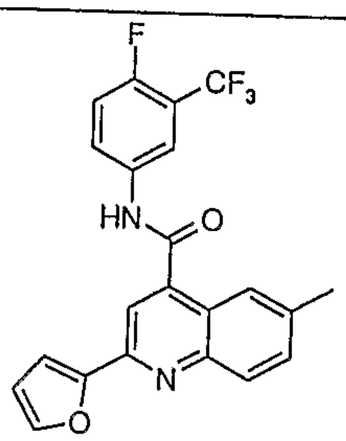
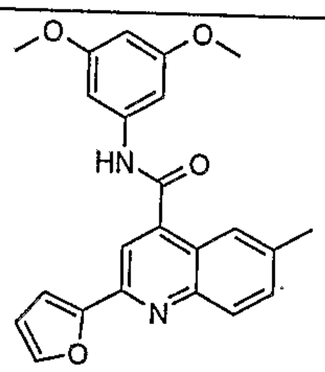
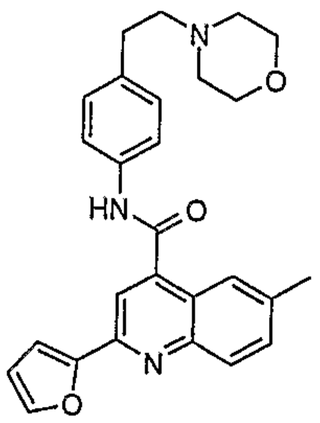
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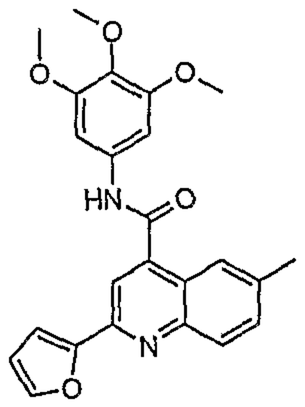
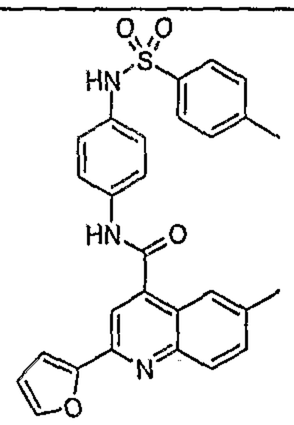
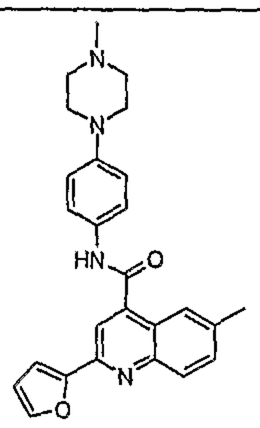
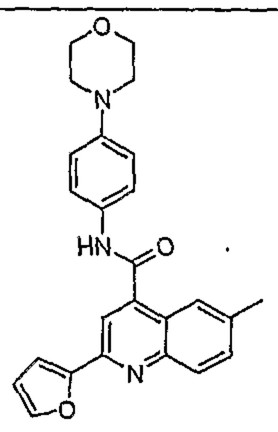
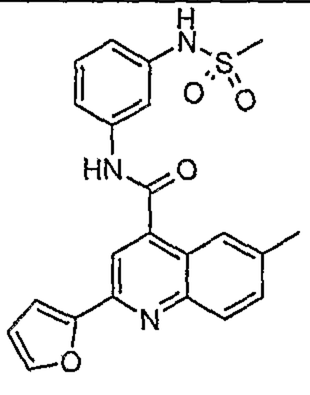
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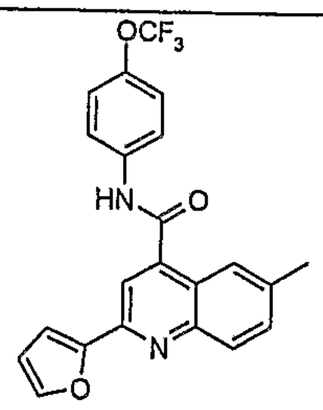
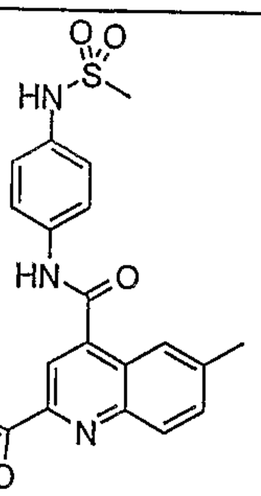
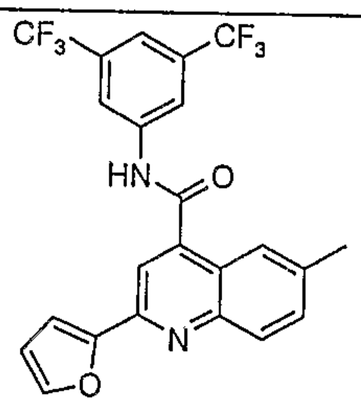
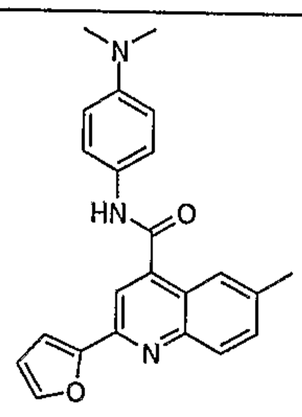
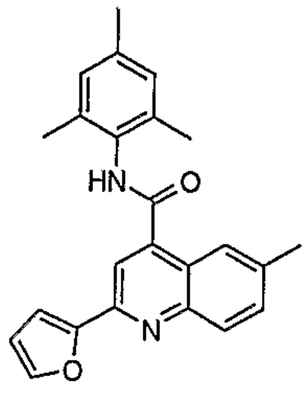
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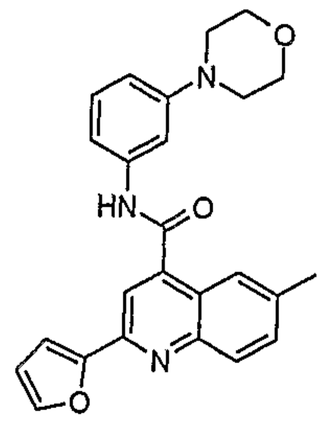
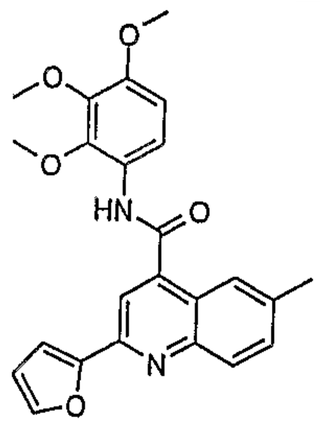
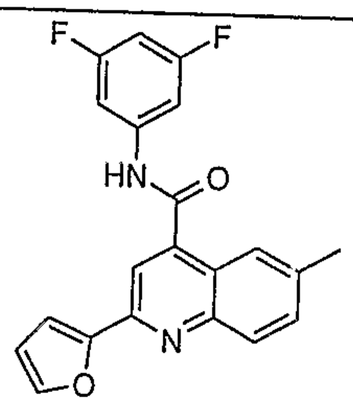
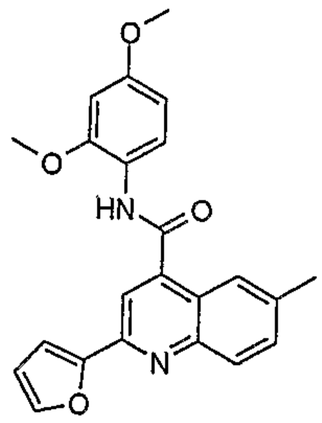
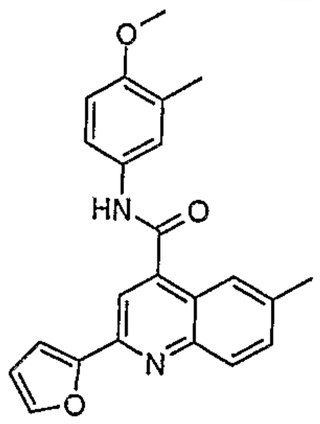
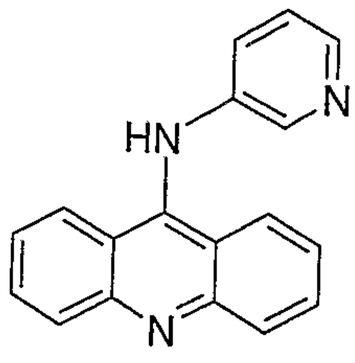
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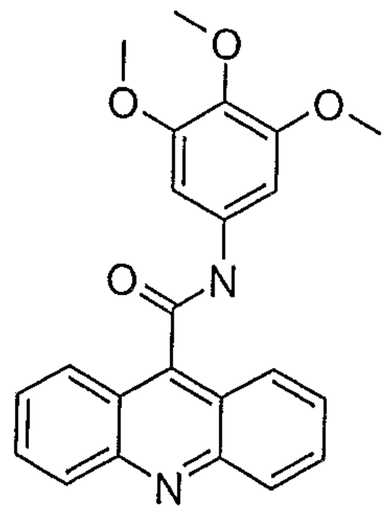
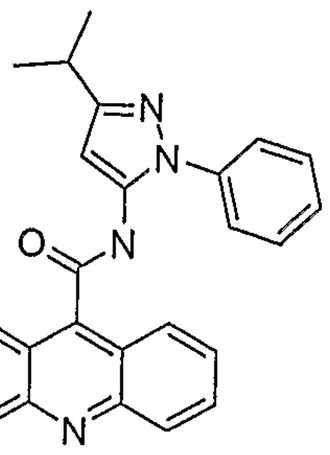
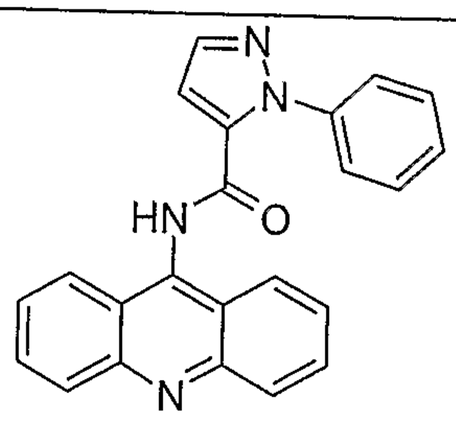
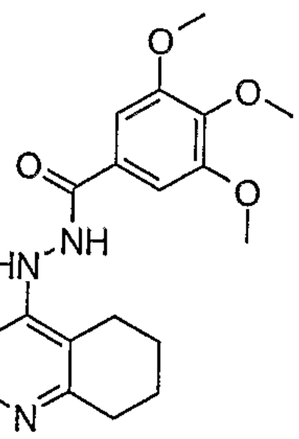
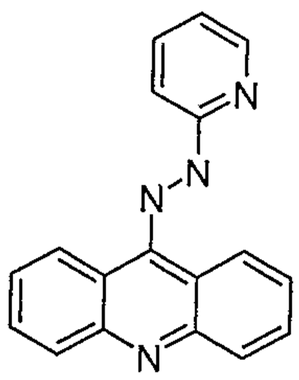
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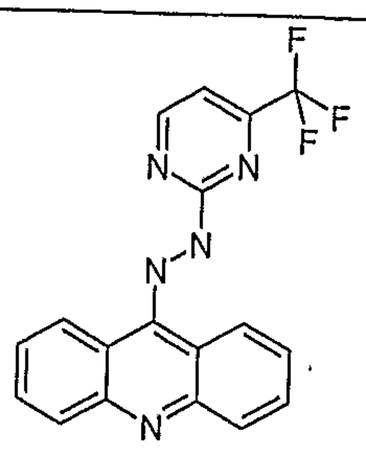
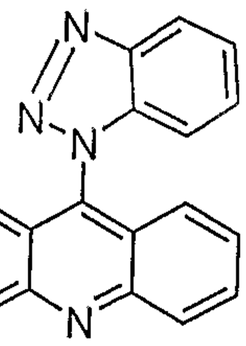
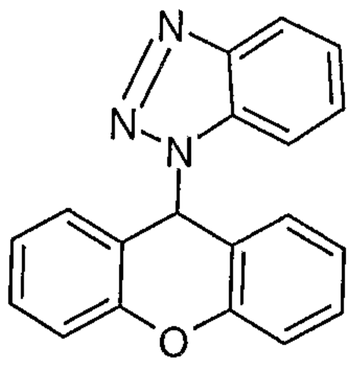
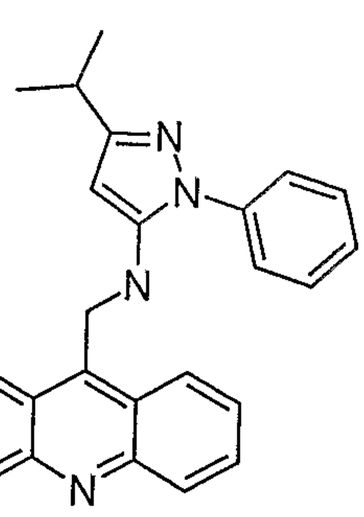
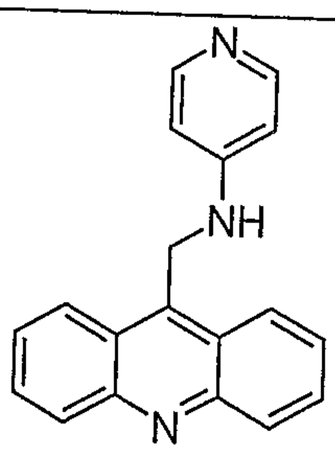
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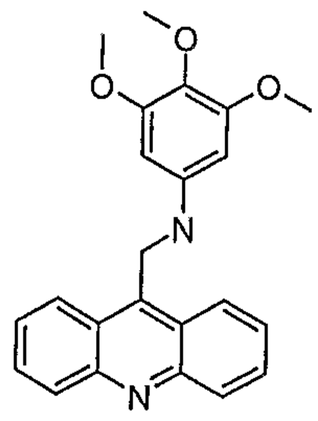
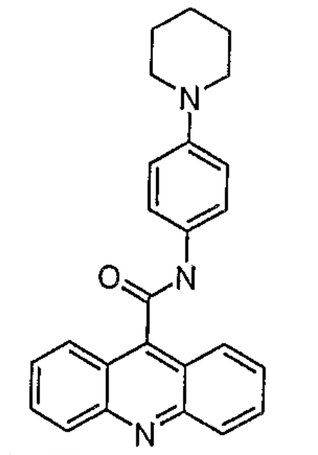
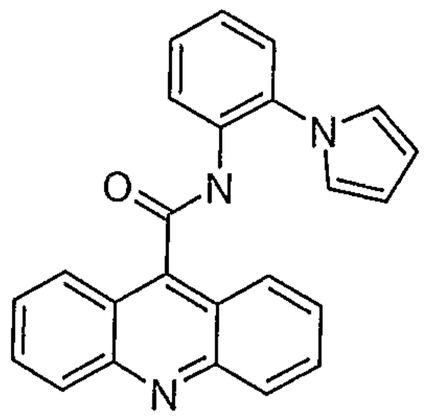
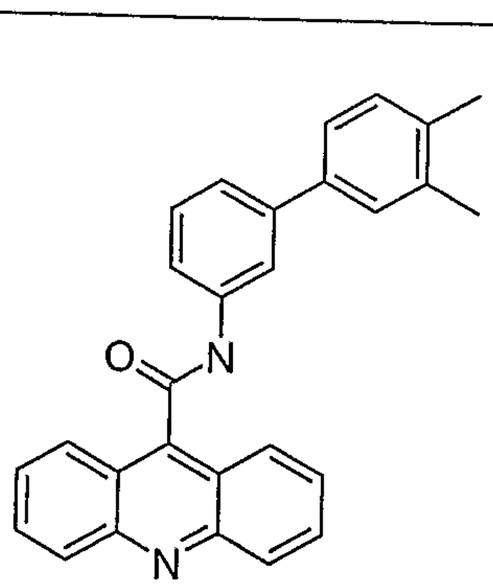
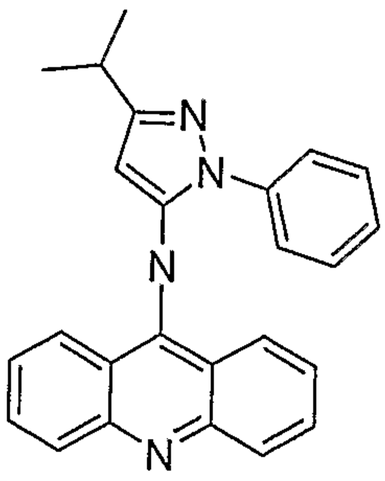
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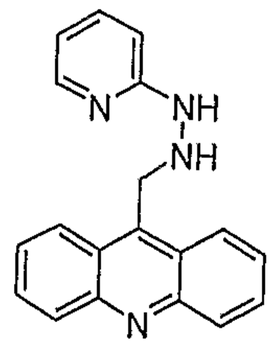
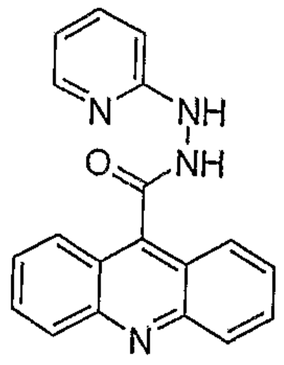
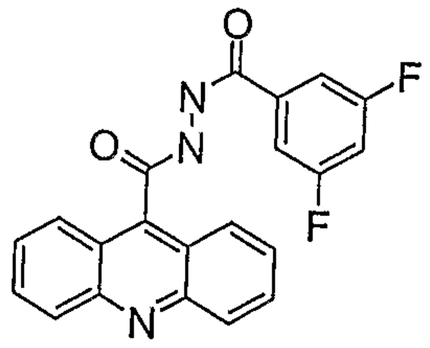
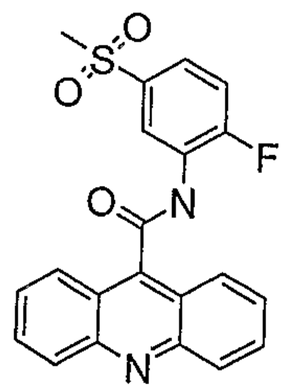
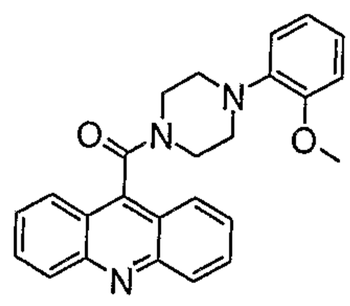
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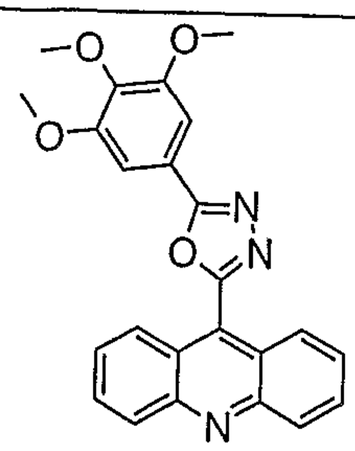
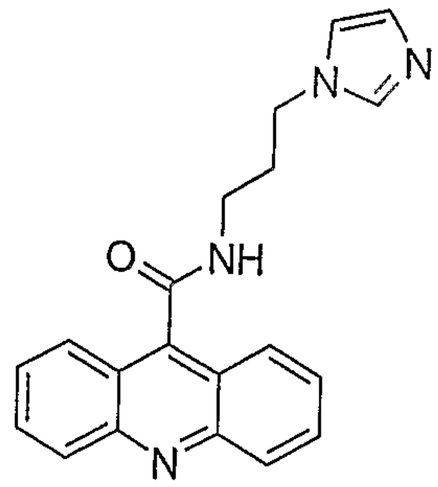
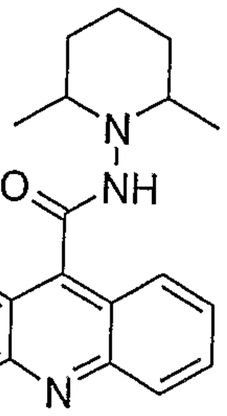
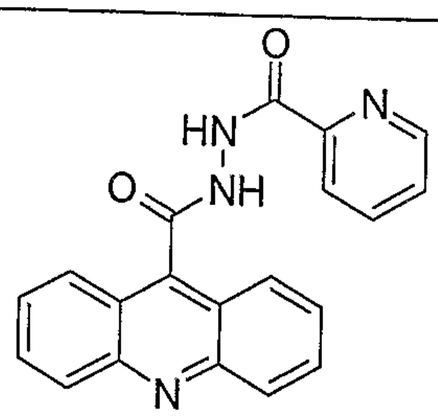
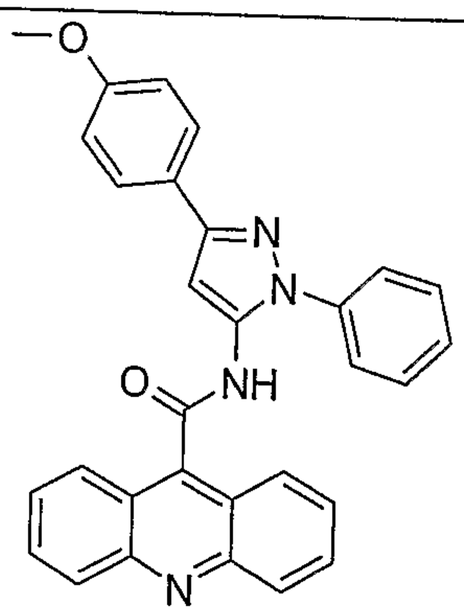
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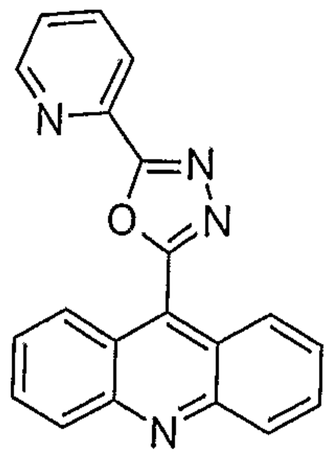
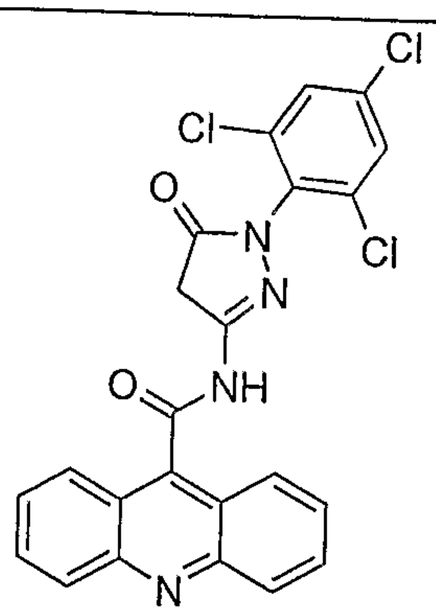
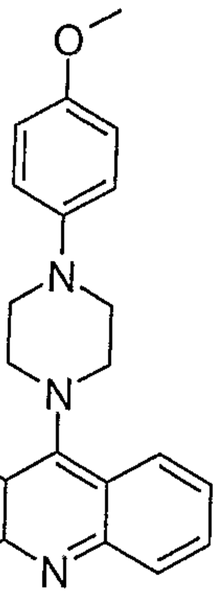
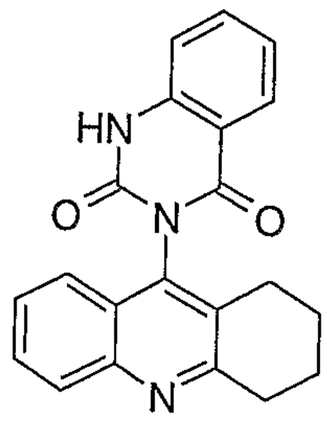
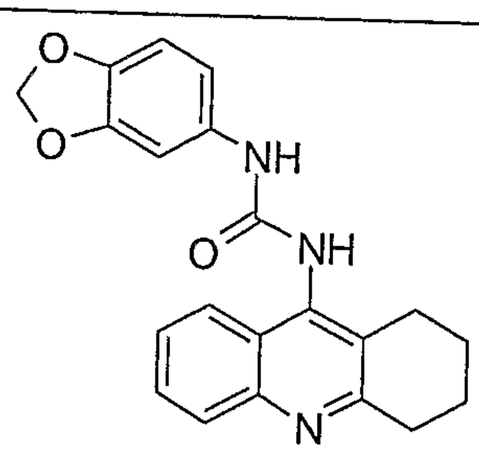
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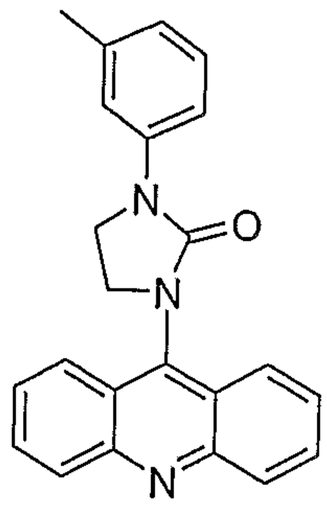
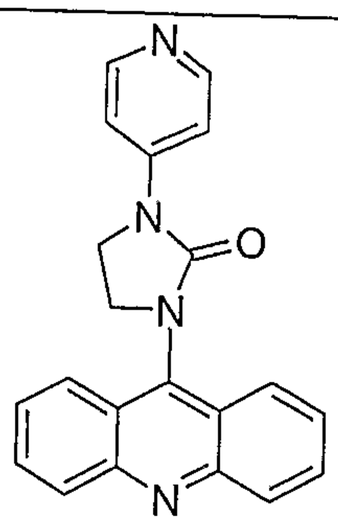
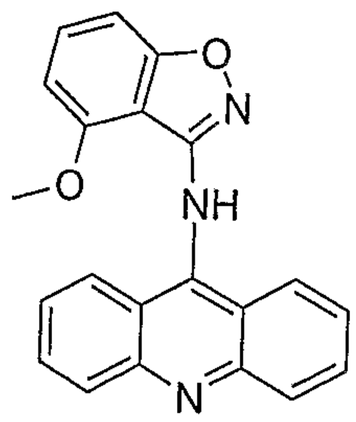
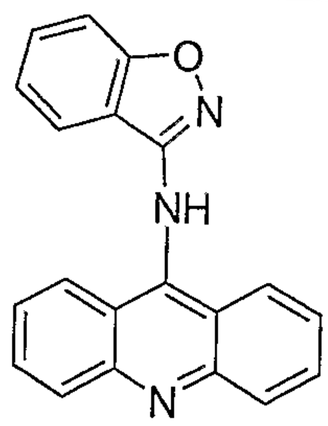
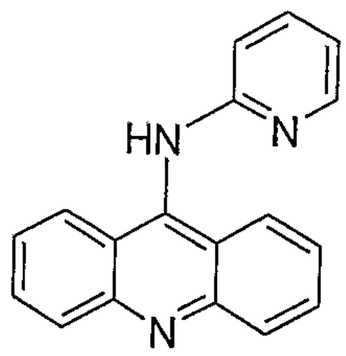
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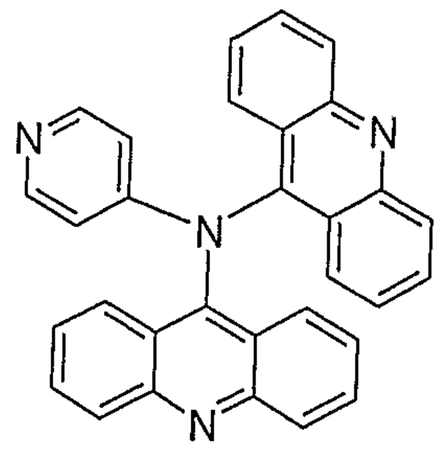
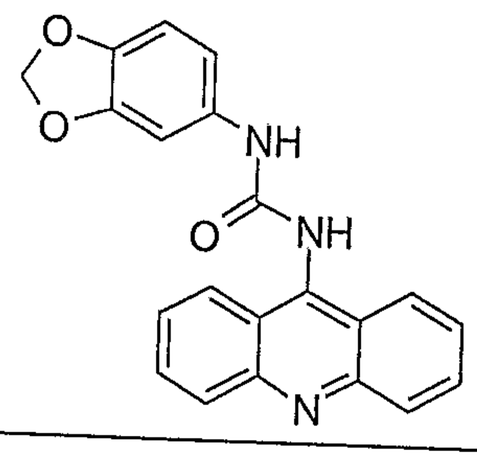
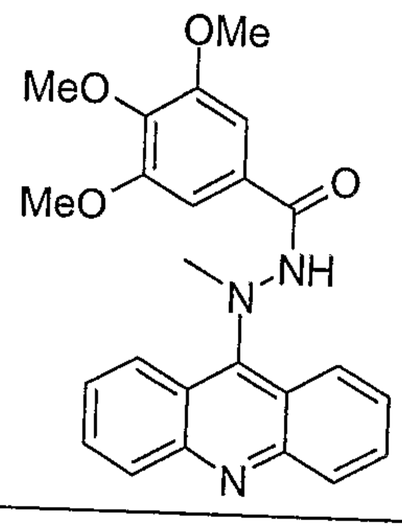
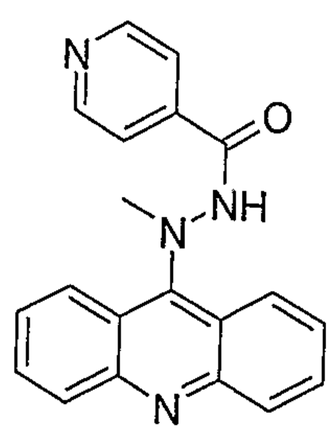
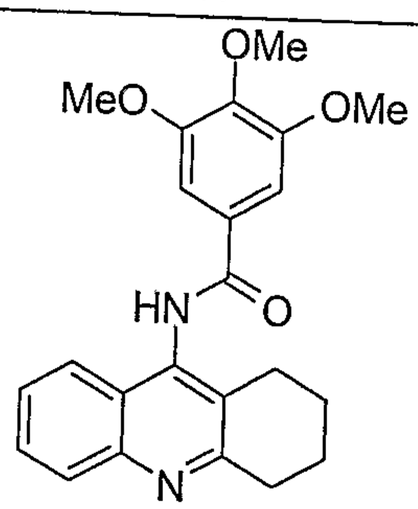
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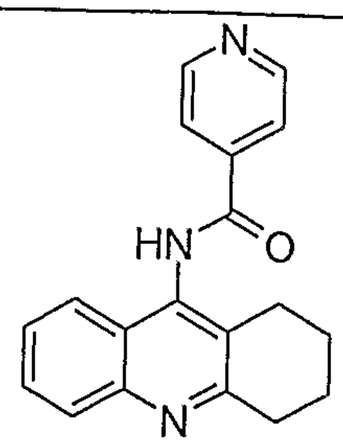
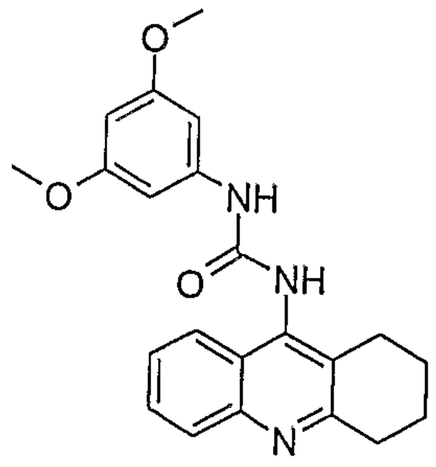
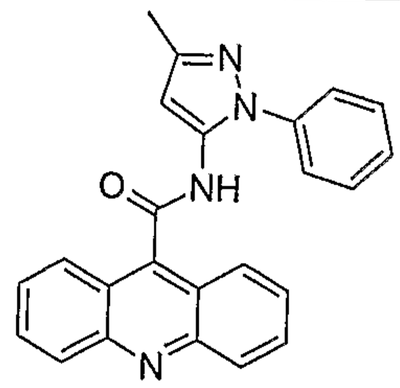
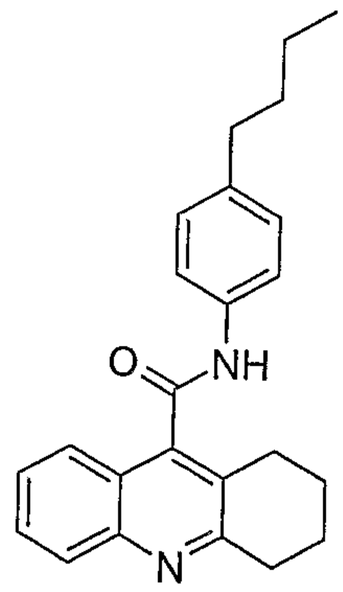
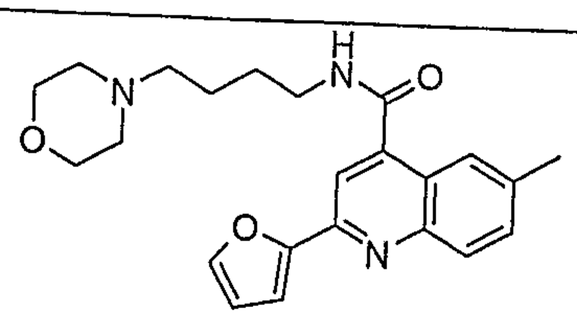
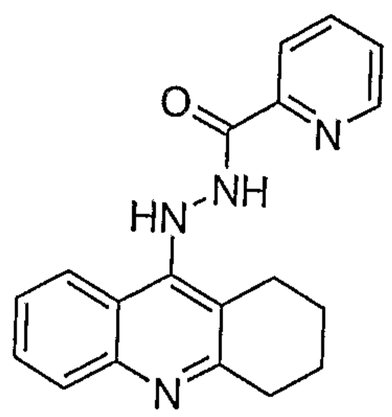
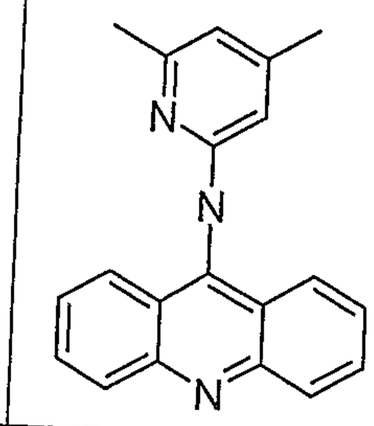
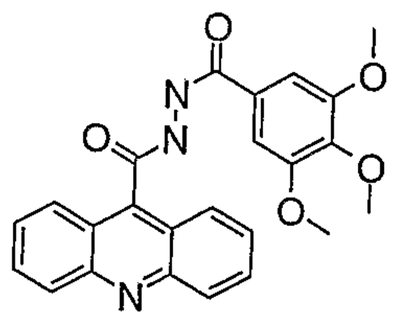
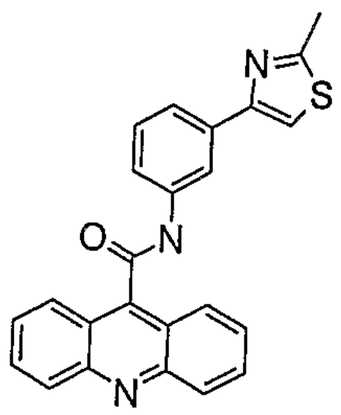
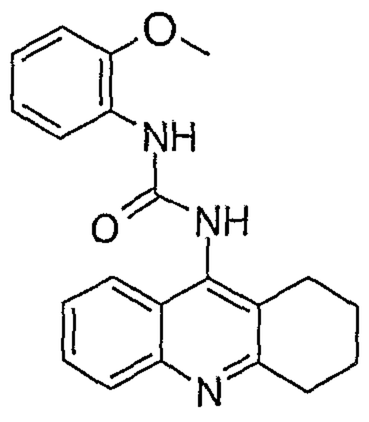
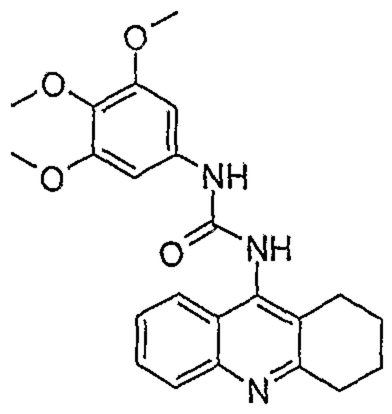
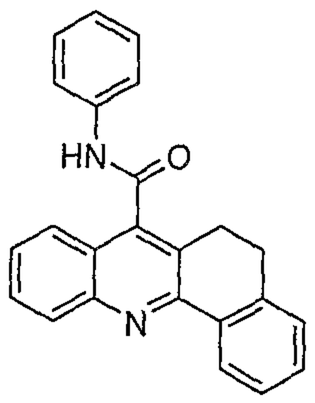
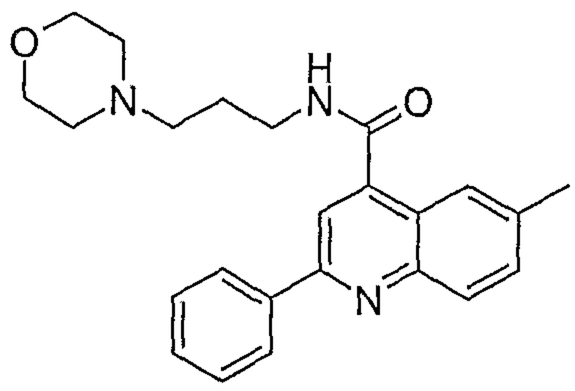
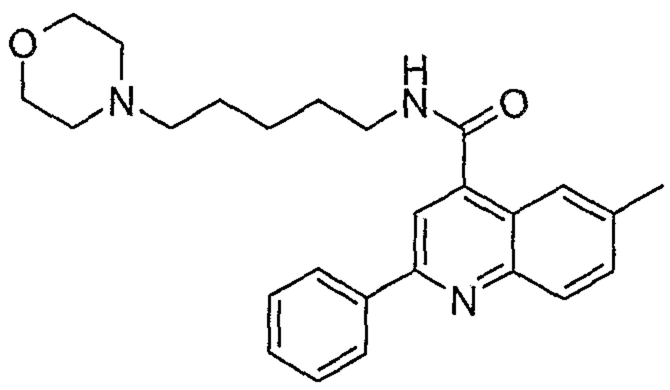
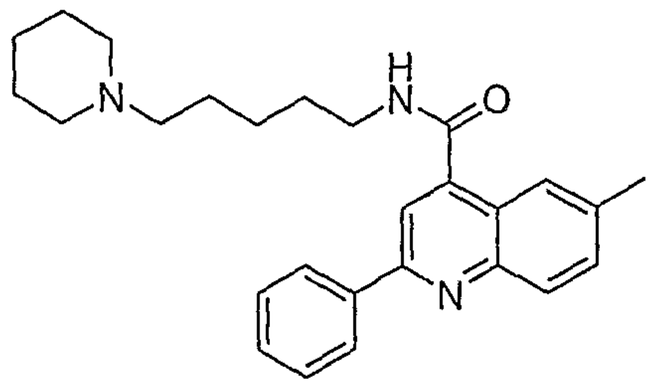
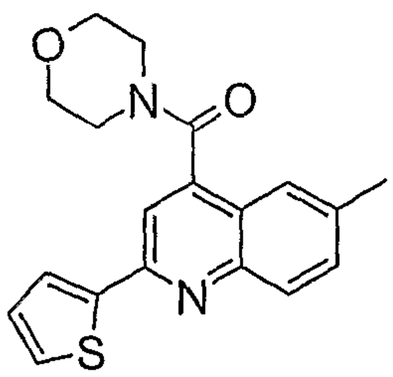
157		D
158		NT
159		NT
160		D

Table 5.

COMPOUND NO	STRUCTURE	IC_{50}
161		D
162		A
163		D
164		A
165		D

166		D
167		C
168		D
169		D
170		D

171		D
172		D

EXAMPLE 3: Identification of Sirtuin Modulators Using SIRT3

A fluorescence polarization assay was used to identify modulators of SIRT3 activity. The same assay may be used to identify modulators of any sirtuin protein. The assay utilizes a peptide substrate based on a fragment of Histone H4, a known sirtuin deacetylation target. The substrate contains a peptide having 14 amino acid residues as follows: Biotin-GASSHSK(Ac)VLK(MR121) (SEQ ID NO: 3) wherein K(Ac) is an acetylated lysine residue. The peptide is labeled with the fluorophore MR121 (excitation 635 nm/emission 680 nm) at the C-terminus and biotin at the N-terminus.

The peptide substrate is exposed to a sirtuin protein in the presence of NAD^+ to allow deacetylation of the substrate and render it sensitive to cleavage by trypsin. Trypsin is then added and the reaction is carried to completion (i.e., the deacetylated substrate is cleaved) releasing the MR121 fragment. Streptavidin is then added to the reaction where it can bind both the uncleaved substrate (i.e., any remaining acetylated substrate) and the non-fluorescent portion of the cleaved peptide substrate (i.e., the biotin containing fragment). The fluorescence polarization signal observed for the full length peptide substrate bound to streptavidin is higher than the fluorescence polarization signal observed for the released MR121 C-terminal fragment. Therefore, the fluorescence polarization obtained is inversely proportional to the level of deacetylation (e.g., the signal is inversely proportional to the activity of the sirtuin protein). Results are read on a microplate fluorescence polarization reader (Molecular Devices Spectramax MD) with appropriate excitation and emission filters.

The fluorescence polarization assays may be conducted as follows: 0.5 μM peptide substrate and 50 μM βNAD$^+$ is incubated with 2 nM of SIRT3 for 60 minutes at 37°C in a reaction buffer (25 mM Tris-acetate pH8, 137 mM Na-Ac, 2.7 mM K-Ac, 1 mM Mg-Ac, 0.1% Pluronic F127, 10 mM $CaCl_2$, 1 mM TCEP, 0.025% BSA). Test compounds are solubilized in DMSO and are added to the reaction at 11 concentrations ranging from 0.7 μM to 100 μM. The SIRT3 protein used in the assays corresponded to amino acid residues 102-399 of human SIRT3 with an N-terminal His-tag. The protein was overexpressed in E. coli and purified on a nickel chelate column using standard techniques. After the 60 minute incubation with SIRT3, nicotinamide is added to the reaction to a final concentration of 3 mM to stop the deacetylation reaction and 0.5 μg/mL of trypsin is added to cleave the deacetylated substrate. The reaction is incubated for 30 minutes at 37°C in the presence of 1 mM streptavidin. Fluorescent polarization is determined at excitation (650 nm) and emissions (680 nm) wavelengths. The level of activity of the sirtuin protein in the presence of the various concentrations of test compound are then determined and may be compared to the level of activity of the sirtuin protein in the absence of the test compound, and/or the level of activity of the sirtuin proteins in the negative control (e.g., level of inhibition) and positive control (e.g., level of activation) described below.

A control for inhibition of sirtuin activity is conducted by adding 30 mM nicotinamide at the start of the reaction (e.g., permits determination of maximum sirtuin inhibition). A control for activation of sirtuin activity is conducted using 0.5 μg/mL of sirtuin protein to reach baseline deacetylation of the substrate (e.g., to determine normalized sirtuin activity).

Sirtuin modulating compounds that activated SIRT3 were identified using the assay described above and are shown below in Table 6. Sirtuin modulating compounds that inhibited SIRT3 were identified using the assay described above and are shown below in Table 7. The ED_{50} values for the activating compounds are represented by A (ED_{50} = <50 μM), B (ED_{50} = 51-100 μM), C (ED_{50} = 101-150 μM), and D (ED_{50} = >150 μM). The ED_{50} of resveratrol for activation of SIRT1 is 16 μM. Similarly, the IC_{50} values for the inhibiting compounds are represented by A (IC_{50} = <50 μM), B (IC_{50} = 51-100 μM), C (IC_{50} = 101-150 μM), and D (IC_{50} = >150 μM).

Table 6.

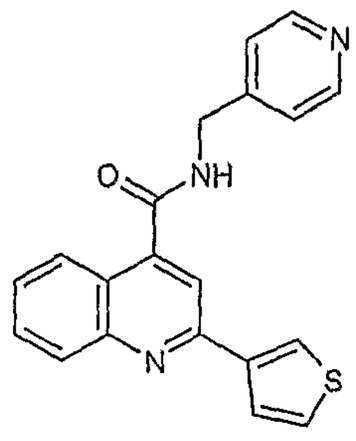
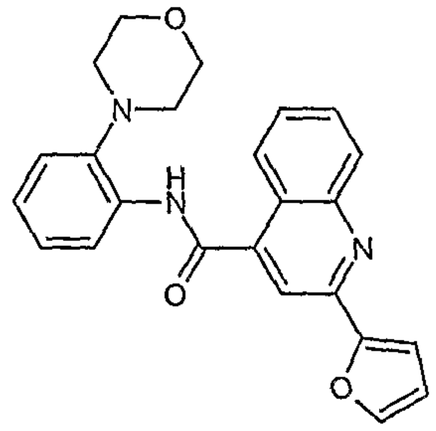
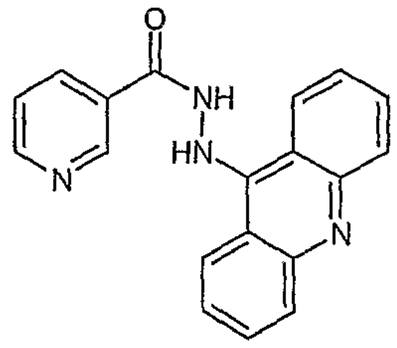
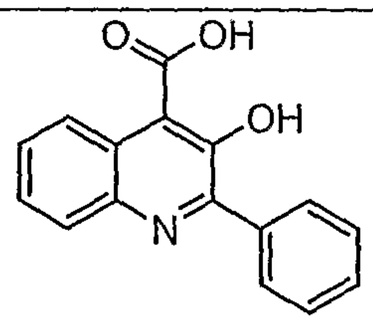
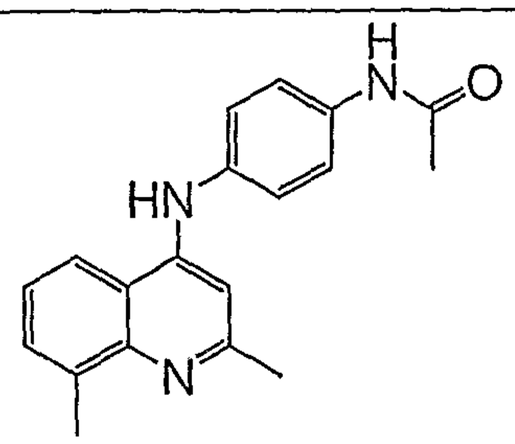
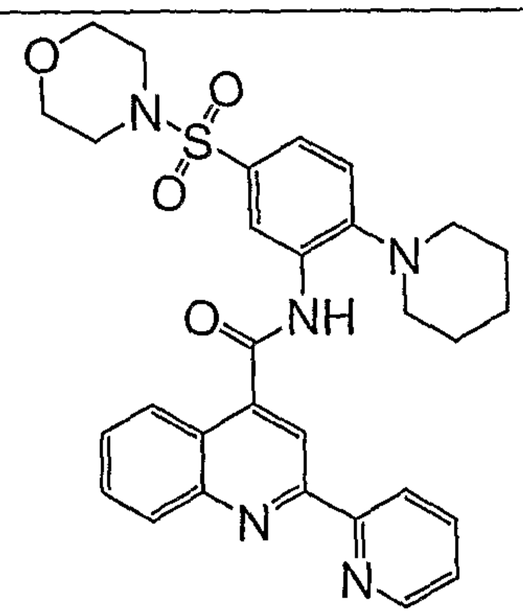
COMPOUND NO	STRUCTURE	ED_{50}
1		B
8		A
11		B
12		B

Table 7.

COMPOUND NO	STRUCTURE	IC_{50}
13		C
14		N/A

EXAMPLE 4: Mass Spectrometry Assay

The mass spectrometry based assay utilizes a peptide having 20 amino acid residues as follows: Ac-EE-K(biotin)-GQSTSSHSK(Ac)NleSTEG–K(5TMR)-EE-NH2 (SEQ ID NO: 2) wherein K(Ac) is an acetylated lysine residue and Nle is a norleucine. The peptide is labeled with the fluorophore 5TMR (excitation 540 nm/emission 580 nm) at the C-terminus. The sequence of the peptide substrate is based on p53 with several modifications. In addition, the methionine residue naturally present in the sequence was replaced with the norleucine because the methionine may be susceptible to oxidation during synthesis and purification.

The mass spectrometry assay is conducted as follows: 0.5 μM peptide substrate and 120 μM βNAD^+ is incubated with 10 nM SIRT1 for 25 minutes at 25°C in a reaction buffer (50 mM Tris-acetate pH 8, 137 mM NaCl, 2.7 mM KCl, 1 mM $MgCl_2$, 5 mM DTT, 0.05% BSA). Test compounds may be added to the reaction as described above. The SirT1 gene is cloned into a T7-promoter containing vector and transformed into BL21(DE3). After the 25 minute incubation with SIRT1, 10 μL of 10% formic acid is added to stop the reaction. Reactions are sealed and frozen for

later mass spec analysis. Determination of the mass of the substrate peptide allows for precise determination of the degree of acetylation (i.e. starting material) as compared to deacetylated peptide (product).

For the mass spectrometry based assay, a control for inhibition of sirtuin activity is conducted by adding 1 μL of 500 mM nicotinamide as a negative control at the start of the reaction (e.g., permits determination of maximum sirtuin inhibition). A control for activation of sirtuin activity is conducted using 10 nM of sirtuin protein, with 1 μL of DMSO in place of compound, to determinine the amount of deacteylation of the substrate at a given timepoint within the linear range of the assay. This timepoint is the same as that used for test compounds and, within the linear range, the endpoint represents a change in velocity.

EXAMPLE 5: Cell-based Assays of Sirtuin Activity

Fat mobilization assay. 3T3 L1 cells are plated with 2 ml of 30,000 cells/ml in Dulbecco's Modified Eagle Medium (DMEM)/10% newborn calf serum in 24-well plates. Individual wells are then allowed to differentiate by addition of 100 nM Rosiglitazone. Undifferentiated control cells are maintained in fresh DMEM/10% newborn calf serum throughout the duration of the assay. At 48 hours (2 days), adipogenesis is initiated by addition of DMEM/10% fetal calf serum/0.5 mM 3-isobutyl-1-methylxanthine (IBMX)/1 μM dexamethasone. At 96 hours (4 days), adipogenesis is allowed to progress by removal of the media and adding 2 ml of DMEM/10% fetal calf serum to each well along with either 10 μg/mL insulin or 100 nM Rosiglitazone. At 144 hours (6 days) and 192 hours (8 days), all wells are changed to DMEM/10% fetal calf serum.

At 240 hours (10 days from the original cell plating), test compounds at a range of concentrations are added to individual wells in triplicate along with 100 nM Rosiglitazone. Three wells of undifferentiated cells are maintained in DMEM/10% newborn calf serum and three wells of differentiated control cells are maintained in fresh DMEM/10% newborn calf serum with 100 nM Rosiglitazone. As a positive control for fat mobilization, resveratrol (a SIRT1 activator) is used at concentrations ranging in three fold dilutions from 100 μM to 0.4 μM.

At 312 hours (13 days), the media is removed and cells are washed twice with PBS. 0.5 mL of Oil Red O solution (supplied in Adipogenesis Assay Kit, Cat.#

ECM950, Chemicon International, Temecula, CA) is added per well, including wells that have no cells as background control. Plates are incubated for 15 minutes at room temperature, and then the Oil Red O staining solution is removed and the wells are washed 3 times with 1 mL wash solution (Adipogenesis Assay Kit). After the last wash is removed, stained plates are visualized, scanned or photographed. Dye is extracted (Adipogenesis Assay Kit) and quantified in a plate reader at 520 nM. Quantitative and visual results are shown in Figure 16.

Primary dorsal root ganglion (DRG) cell protection assay. Test compounds are tested in an axon protection assay as described (Araki et al. (2004) Science 305(5686):1010-3). Briefly, mouse DRG explants from E12.5 embryos are cultured in the presence of 1 nM nerve growth factor. Non-neuronal cells are removed from the cultures by adding 5-fluorouracil to the culture medium. Test compounds are added 12 to 24 hours prior to axon transections. Transection of neurites was performed at 10-20 days *in vitro* (DIV) using an 18-guage needle to remove the neuronal cell bodies.

EQUIVALENTS

The present invention provides among other things sirtuin-activating compounds and methods of use thereof. While specific embodiments of the subject invention have been discussed, the above specification is illustrative and not restrictive. Many variations of the invention will become apparent to those skilled in the art upon review of this specification. The full scope of the invention should be determined by reference to the claims, along with their full scope of equivalents, and the specification, along with such variations.

INCORPORATION BY REFERENCE

All publications and patents mentioned herein, including those items listed below, are hereby incorporated by reference in their entirety as if each individual publication or patent was specifically and individually indicated to be incorporated by reference. In case of conflict, the present application, including any definitions herein, will control.

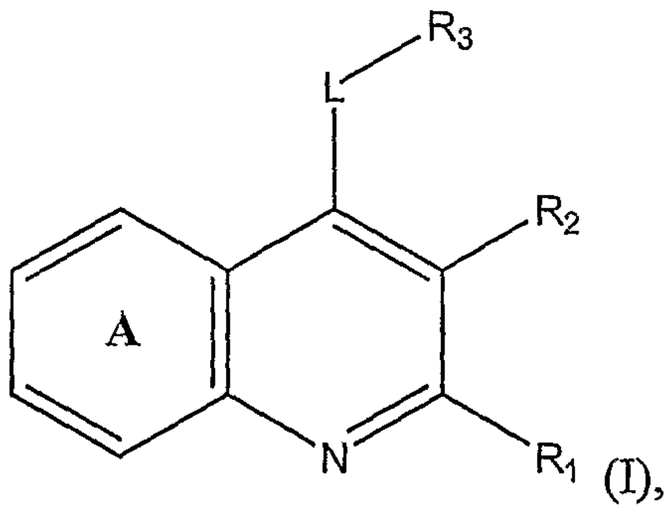
Also incorporated by reference in their entirety are any polynucleotide and polypeptide sequences which reference an accession number correlating to an entry in

a public database, such as those maintained by The Institute for Genomic Research (TIGR) (www.tigr.org) and/or the National Center for Biotechnology Information (NCBI) (www.ncbi.nlm.nih.gov).

Also incorporated by reference are the following: PCT Publications WO 2005/002672; 2005/002555; and 2004/016726.

What is claimed is:

1. A compound represented by Structural Formula (I):



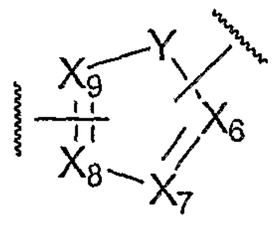
(I),

or a salt thereof, wherein, as valence permits:

Ring A is optionally substituted;

R_1 and R_2 are independently selected from–H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted non-aromatic heterocyclic group, halogen, $-OR_4$, -CN, $-CO_2R_4$, $-OCOR_4$, $-OCO_2R_4$, $-C(O)NR_4R_5$, $-OC(O)NR_4R_5$, $-C(O)R_4$, $-COR_4$, $-SR_4$, $-OSO_3H$, $-S(O)_nR_4$, $-S(O)_nOR_4$, $-S(O)_nNR_4R_5$, $-NR_4R_5$, $-NR_4C(O)OR_5$, $-NR_4C(O)R_5$ and $-NO_2$, or R_1 and R_2 taken together with the atoms to which they are attached form an optionally substituted ring;

L is selected from $-CH=CH-C(O)-$, $-CH_2-N(R_4)-C(O)-$, $-C(O)-CH_2-$, $-C(O)NR_4-$, $-C(O)-N(R_4)-C(O)-$, $-C(O)-N(R_4)-N(R_5)-$, $-C(O)-N(R_4)-N(R_5)-C(O)-$, $-CH_2-N(R_4)-N(R_5)-$, $-N(R_4)-S(O)_2-$, $-S(O)_2-N(R_4)-$, $-N(R_4)-N(R_5)-C(O)-$,



$-N(R_4)-N(R_5)-CH_2$, $-N(R_4)-N(R_5)-$ or ;

R_3, R_4 and R_5 are, independently for each occurrence, –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group or a substituted or unsubstituted non-aromatic heterocyclic group;

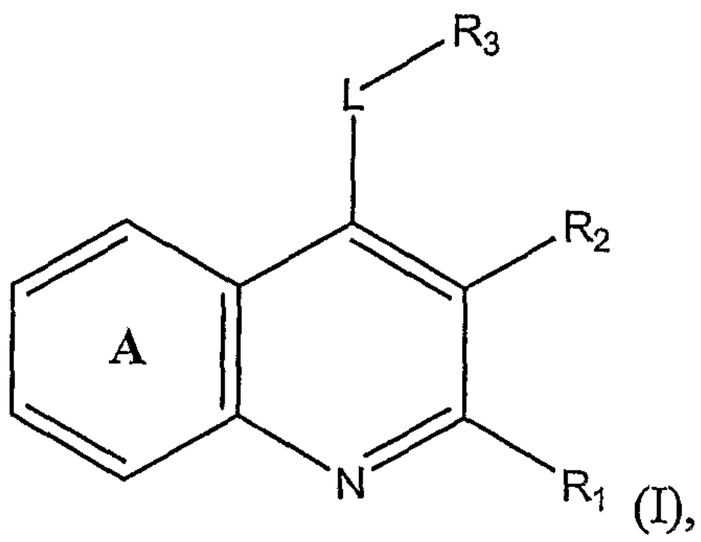
Y is selected from O, S, or NR_4;

each of X_6, X_7, X_8 and X_9 is independently selected from CR_7, C, or N, wherein at least two of X_6, X_7, X_8 or X_9 are not N;

each R_7 is independently selected from H or (C_1-C_3)-straight or branched alkyl; and

n is 1 or 2.

2. A compound represented by Structural Formula (I):



(I),

or a salt thereof, wherein, as valence permits:

Ring A is optionally substituted;

R_1 and R_2 are independently selected from –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted non-aromatic heterocyclic group, halogen, -OR_4, -CN, -CO_2R_4, -$OCOR_4$, -OCO_2R_4, -$C(O)NR_4R_5$, -$OC(O)NR_4R_5$, -$C(O)R_4$, -COR_4, -SR_4, -OSO_3H, -$S(O)_nR_4$, -$S(O)_nOR_4$, -$S(O)_nNR_4R_5$, -NR_4R_5, -$NR_4C(O)OR_5$, -$NR_4C(O)R_5$ and -NO_2, or R_1 and R_2 taken together with the atoms to which they are attached form an optionally substituted ring;

L is –$C(O)NR_4$-, -$NR_4C(O)$-, -NR_4-NR_5-C(O)-, -C(O)-NR_4-NR_5- or -CHR_4=CHR_5-;

R_3, R_4 and R_5 are independently –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group or a substituted or unsubstituted non-aromatic heterocyclic group; and

n is 1 or 2.

3. The compound of claim 2, wherein R_1 and R_2 taken together with the atoms to which they are attached form an optionally substituted ring.

4. The compound of claim 3, wherein R_1 and R_2 taken together with the atoms to which they are attached form an optionally substituted aromatic ring.

5. The compound of claim 4, wherein R_1 and R_2 taken together with the atoms to which they are attached form an optionally substituted 6-membered aromatic ring.

6. The compound of claim 2, wherein R_1 is a substituted or unsubstituted aryl group.

7. The compound of claim 6, wherein R_1 is a substituted or unsubstituted heteroaryl group.

8. The compound of claim 1, wherein R_1 is a substituted or unsubstituted alkyl group or a substituted or unsubstituted aryl group.

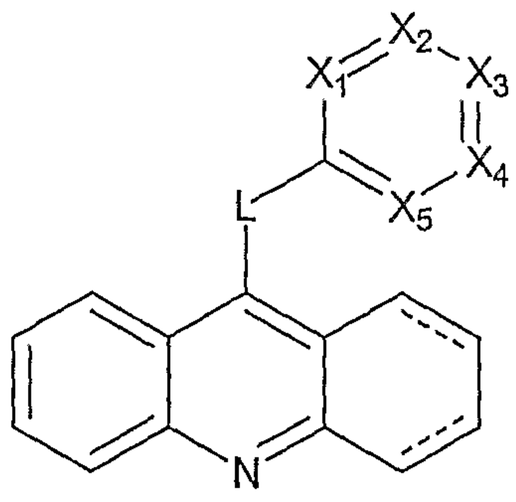
9. The compound of claim 8, wherein R_3 is a substituted or unsubstituted cyclic group or an alkyl group substituted with a substituted or unsubstituted cyclic group.

10. The compound of claim 9, wherein the cyclic group comprises at least one substituent not adjacent to the atom by which the cyclic group attaches to L or the alkyl group.

11. The compound of claim 10, wherein Ring A is substituted.

12. The compound of claim 9, wherein the cyclic group is unsubstituted or the cyclic group is substituted only at one or both positions adjacent to the atom by which the cyclic group attaches to L or the alkyl group.

13. A compound represented by Structural Formula (V):



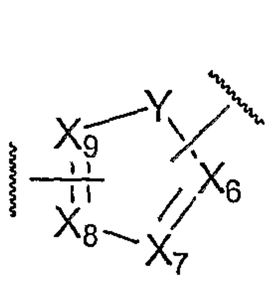
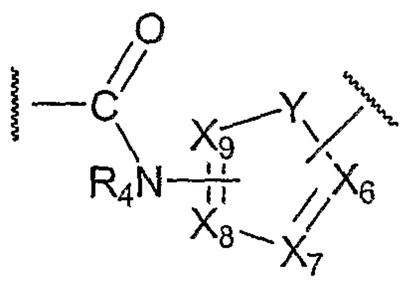
(V),

wherein, as valence permits:

each of X_1, X_2, X_3, X_4 and X_5 is independently selected from N or CR_6, wherein no more than two of X_1, X_2, X_3, X_4 or X_5 are N;

each R_6 is independently selected from H, $-OCH_3$, $-CH_3$, or $-CF_3$;

L is selected from $-CH=CH-C(O)-$, $-CH_2-N(R_4)-C(O)-$, $-C(O)-CH_2-$, $-C(O)-N(R_4)-$, $-C(O)-N(R_4)-CH_2-$, $-C(O)-N(R_4)-CH_2-CH_2-$, $-C(O)-N(R_4)-C(O)-$, $-C(O)-N(R_4)-N(R_5)-$, $-CH_2-N(R_4)-N(R_5)-$, $-N(R_4)-S(O)_2-$, $-S(O)_2-N(R_4)-$, $-N(R_4)-N(R_5)-C(O)-$, $-C(O)-N(R_4)-N(R_5)-C(O)-$, $-N(R_4)-N(R_5)-CH_2$,

$-N(R_4)-N(R_5)-$,  , or  ;

each of R_4 and R_5 is independently selected from H or CH_3;

Y is selected from O, S, or NR_4;

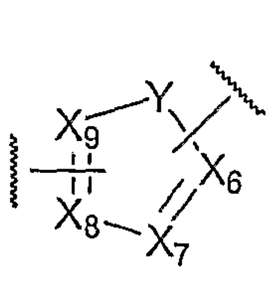
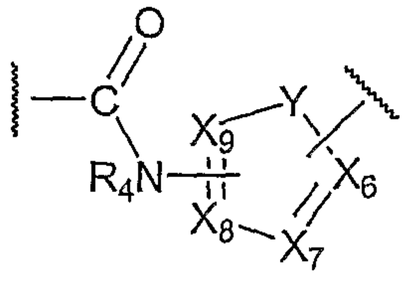
each of X_6, X_7, X_8 and X_9 is independently selected from CR_7, C, or N, wherein at least two of X_6, X_7, X_8 or X_9 are not N;

each R_7 is independently selected from H or (C_1-C_3)-straight or branched alkyl; and

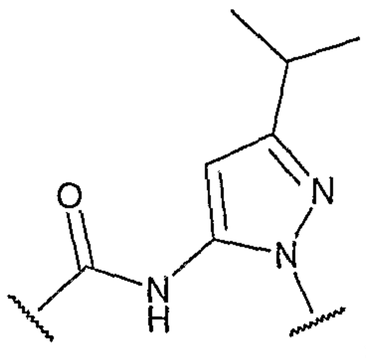
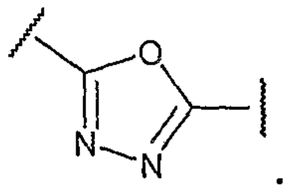
the hashed bonds are either simultaneously present or simultaneously absent.

14. The compound of claim 13, wherein when the hashed bonds are simultaneously present, L is $-N(R_4)-N(R_5)-C(O)-$ and each of X_2, X_3, and X_4 are $-OCH_3$, then R_4 is hydrogen; and when the hashed bonds are simultaneously absent, and L is $-N(R_4)-N(R_5)-C(O)-$, X_1 and X_5 are CR_6.

15. The compound of claim 13, wherein L is selected from -C(O)-N(R_4)-N(R_5)-, -CH_2-N(R_4)-N(R_5)-, -N(R_4)-N(R_5)-C(O)-, -N(R_4)-N(R_5)-,


, or

.

16. The compound of claim 15, wherein L is selected from -NH-NH-C(O)-, -NH-NH-, -N(CH_3)-NH-C(O)-, -CH_2-NH-NH-, -C(O)-NH-NH-,


, or

.

17. The compound of any one of claims 13 to 16, wherein no more than one of X_1, X_2, X_3, X_4 and X_5 is N.

18. The compound of claim 17, wherein one of X_1, X_2, X_3, X_4 and X_5 is N.

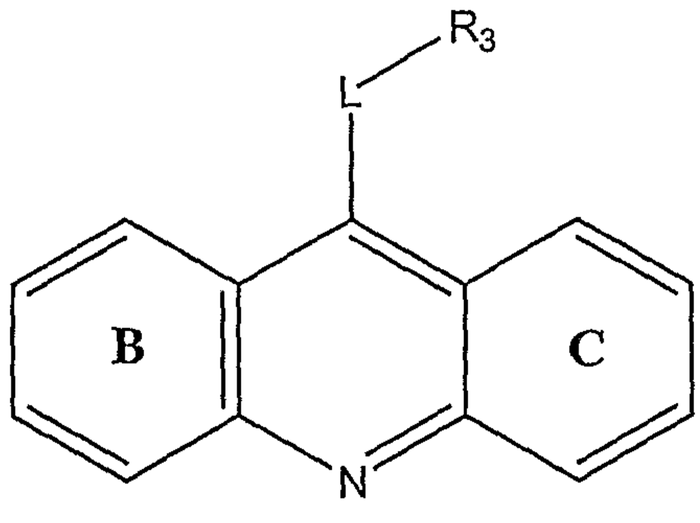
19. The compound of claim 18, wherein each of X_1, X_2, X_3, X_4 and X_5 is selected from N or CH.

20. The compound of claim 17, wherein each of X_1, X_2, X_3, X_4 and X_5 is CR_6.

21. The compound of claim 20, wherein each R_6 is hydrogen.

22. The compound according to claim 20, wherein X_1 and X_5 are CH and each of X_2, X_3, and X_4 is C-OCH_3.

23. A compound represented by Structural Formula (II):



(II),

or a salt thereof, wherein:

Rings B and C are independently optionally substituted;

L is $-C(O)NR_4-$, $-NR_4C(O)-$, $-NR_4-NR_5-C(O)-$, $-C(O)-NR_4-NR_5-$ or $-CHR_4=CHR_5-$; and

R_3, R_4 and R_5 are independently –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group or a substituted or unsubstituted non-aromatic heterocyclic group.

24. The compound of claim 23, wherein L is $-C(O)-NR_4-NR_5-$.

25. The compound of claim 24, wherein R_3 is a substituted or unsubstituted aryl group.

26. The compound of claim 25, wherein Rings B and C are unsubstituted.

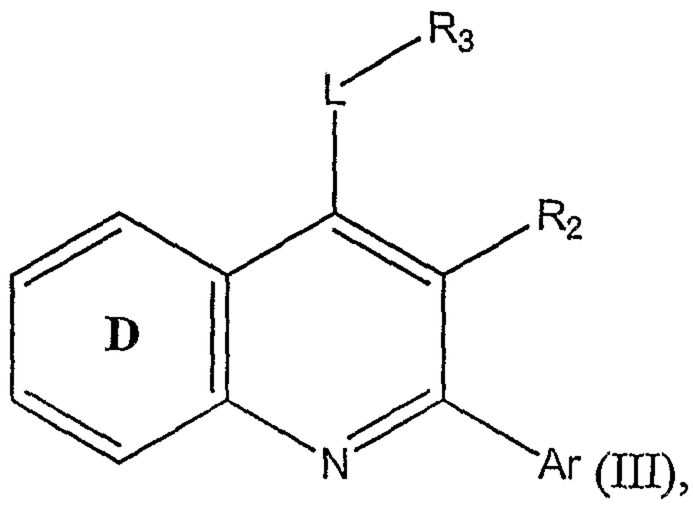
27. The compound of claim 26, wherein R_3 is a substituted or unsubstituted phenyl or pyridyl group.

28. The compound of claim 27, wherein R_3 is a pyridyl or an alkoxy-substituted phenyl group.

29. The compound of claim 28, wherein the alkoxy-substituted phenyl group is a trialkoxy-substituted phenyl group.

30. The compound of claim 28, wherein R_4 and R_5 are each –H.

31. A compound represented by Structural Formula (III):



(III),

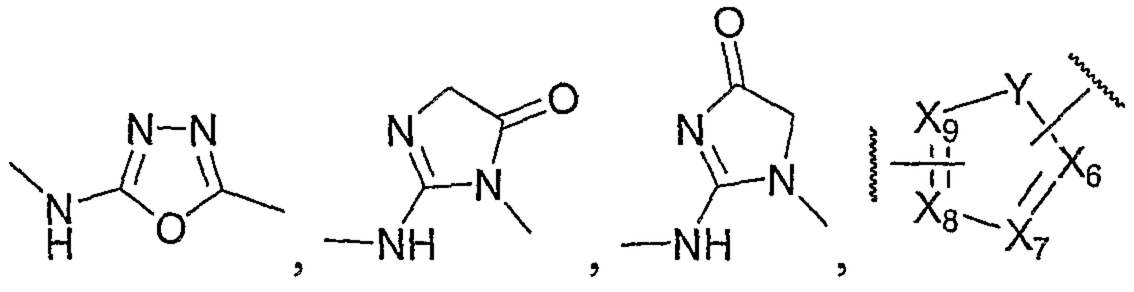
or a salt thereof, wherein, as valence permits:

Ring D is optionally substituted;

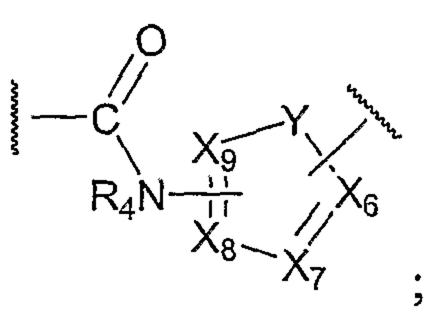
Ar is a substituted or unsubstituted aryl group;

R_2 is selected from –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted non-aromatic heterocyclic group, halogen, $-OR_4$, -CN, $-CO_2R_4$, $-OCOR_4$, $-OCO_2R_4$, $-C(O)NR_4R_5$, $-OC(O)NR_4R_5$, $-C(O)R_4$, $-COR_4$, $-SR_4$, $-OSO_3H$, $-S(O)_nR_4$, $-S(O)_nOR_4$, $-S(O)_nNR_4R_5$, $-NR_4R_5$, $-NR_4C(O)OR_5$, $-NR_4C(O)R_5$ and $-NO_2$;

L is selected from $-C(O)O-$, $-C(O)-$, $-C(O)N(R_4)-$, $-C(O)-N(R_4)-C(O)-$, $-C(O)-N(R_4)-N(R_5)-$, $-C(O)-N(R_4)-N(R_5)-C(O)-$, $-C(O)-N(R_4)-S(O)_2-$, $-N(R_4)C(O)-$, $-N(R_4)-S(O)_2-$, $-N(R_4)-S(O)_2-N(R_5)$, $-N(R_4)(R_5)-$, $-N(R_4)-N(R_5)-C(O)-$, $-N(R_4)-C(O)-N(R_5)-$, $-N(R_4)-C(O)-N(R_5)-S(O)_2$, $-N(R_4)-C(S)-N(R_5)-$, $-N(R_4)-C(O)-CH_2-N(R_5)-$, $-N(R_4)-C(O)-CH=C(CH_3)-$, $-N(R_4)-C(=N-CN)-N(R_5)-$, $-N(R_4)-C(=NH)-N(R_5)-$, $-N(R_4)-$, $-N(R_4)-CH_2-C(O)-N(R_5)-$, $-CH_2-$, $-CH_2-N(R_4)-C(O)-$, $-CH_2-C(O)-N(R_4)-$, $-CH(R_4)=CH(R_5)-$, $-CH=CH-C(O)-$, $-N(R_4)-N(R_5)-$, $-CH_2-N(R_4)-N(R_5)-$, $-S(O)_2-N(R_4)-$,



, or



;

each of R_3, R_4 and R_5 is independently selected from –H, a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group or a substituted or unsubstituted non-aromatic heterocyclic group;

Y is selected from O, S, or NR_4;

each of X_6, X_7, X_8 and X_9 is independently selected from CR_7, C, or N, wherein at least two of X_6, X_7, X_8 or X_9 are not N;

each R_7 is independently selected from H or (C_1-C_3)-straight or branched alkyl; and

n is 1 or 2.

32. The compound of claim 31, wherein L is selected from -C(O)NR_4-, -NR_4C(O)-, -NR_4-NR_5-C(O)-, -C(O)-NR_4-NR_5- or -CHR_4=CHR_5-.

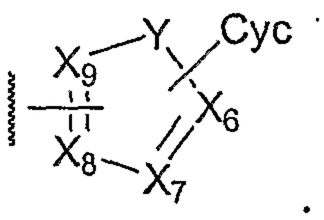
33. The compound of claim 31 or 32, wherein:

R_3 is selected from –H, Cyc or (C_1-C_2) alkylene-Cyc, wherein when R_3 is –H, L is -C(O)O-;

Cyc is selected from a substituted aryl group, an unsubstituted aryl group, a substituted non-aromatic heterocyclic group or an unsubstituted non-aromatic heterocyclic group; and

each of R_4 and R_5 is independently selected from –H or $–CH_3$.

34. The compound of claim 33, wherein L and R_3 taken together form a moiety selected from C(O)-OH, C(O)-N(R_4)-Cyc, C(O)-N(R_4)-(CH_2)$_n$-Cyc, N(R_4)-N(R_5)-C(O)-Cyc, N(R_4)-N(R_5)-Cyc, CH_2-N(R_4)-N(R_5)-Cyc,

C(O)-N(R_4)-N(R_5)-Cyc, or 

.

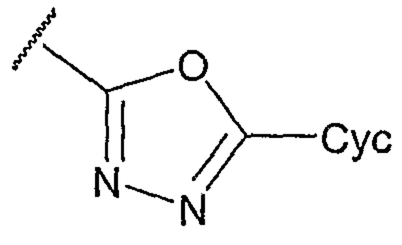
35. The compound of claim 34, wherein:

when L and R_3 are taken together to form C(O)-N(R_4)-Cyc, and Cyc is phenyl, said phenyl is monosubstituted with morpholino;

when L and R_3 are taken together to form $N(R_4)$-$N(R_5)$-C(O)-Cyc and Cyc is a substituted phenyl, said substituted phenyl is not 3,4,5 trimethoxyphenyl or 4-*N,N* dimethylaminophenyl;

when L and R_3 are taken together to form C(O)-$N(R_4)$-$(CH_2)_2$-Cyc, Cyc is not piperidinyl or piperazinyl; and

when L and R_3 are taken together to form C(O)-$N(R_4)$-$(CH_2)_2$-Cyc and Cyc is morpholino, Ar is not furanyl.

36. The compound of claim 34, wherein L and R_3 taken together form a moiety selected from -C(O)-OH, -C(O)-NH-$(CH_2)_n$-Cyc, -C(O)-NH-Cyc, -NH-NH-C(O)-Cyc, -NH-NH-Cyc, -$N(CH_3)$-NH-C(O)-Cyc, -CH_2-NH-NH-Cyc, -C(O)-NH-NH-Cyc, or 

.

37. The compound of claim 36, wherein L and R_3 taken together form a moiety selected from -C(O)-OH, -C(O)-NH-$(CH_2)_n$-Cyc, -C(O)-NH-Cyc, or -NH-NH-C(O)-Cyc.

38. The compound of claim 37, wherein L and R_3 taken together form -C(O)-NH-$(CH_2)_n$-Cyc; and Cyc is unsubstituted.

39. The compound of claim 38, wherein Cyc is selected from pyridyl or morpholino.

40. The compound of claim 37, wherein L and R_3 taken together form -NH-NH-C(O)-Cyc; and Cyc is phenyl.

41. The compound of claim 34, wherein Ar is unsubstituted.

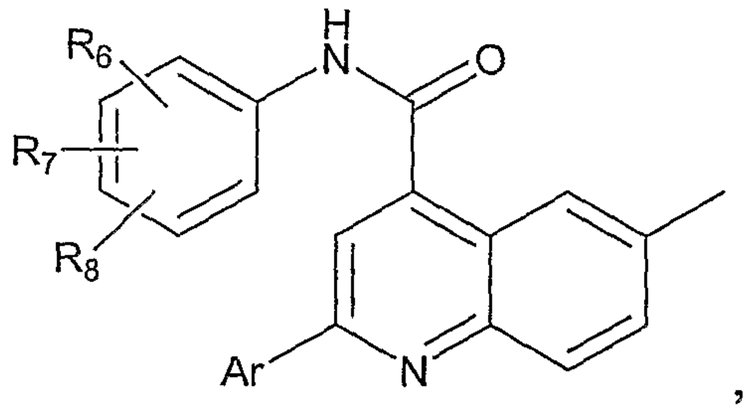
42. The compound of claim 41, wherein Ar is selected from phenyl, pyridyl, thienyl, or furanyl.

43. The compound of claim 41, wherein ring D is unsubstituted or monosubstituted.

44. The compound of claim 43, wherein ring D is monosubstituted with a substituent selected from a substituted or unsubstituted alkyl group, a substituted or unsubstituted aryl group, a substituted or unsubstituted non-aromatic heterocyclic group, halogen, $-OR_4$, -CN, $-CO_2R_4$, $-OCOR_4$, $-OCO_2R_4$, $-C(O)NR_4R_5$, $-OC(O)NR_4R_5$, $-C(O)R_4$, $-COR_4$, $-SR_4$, $-OSO_3H$, $-S(O)_nR_4$, $-S(O)_nOR_4$, $-S(O)_nNR_4R_5$, $-NR_4R_5$, $-NR_4C(O)OR_5$, $-NR_4C(O)R_5$ and $-NO_2$.

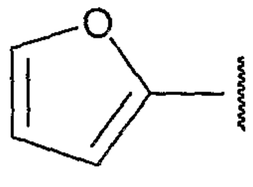
45. The compound of claim 44, wherein said substituent is selected from methyl or halo.

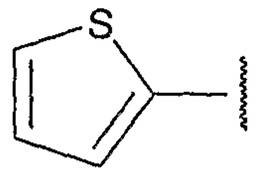
46. The compound of claim 33, having the formula:



,

wherein:

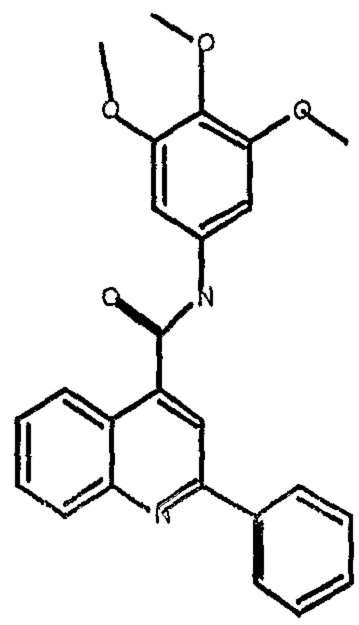
Ar is selected from phenyl, 

, or 

; and

each of R_6, R_7, and R_8 is independently selected from -H, $-CF_3$, -C1-C3 straight or branched alkyl, -O-(C1-C3 straight or branched alkyl), $-O-CF_3$, -N(C1-C3 straight or branched alkyl)$_2$, halo, morpholino, -(C1-C3 straight or branched alkyl)-morpholino, piperazinyl, -(C1-C3 straight or branched alkyl)-piperazinyl, -piperazinyl, $-NH-S(O)_2$-(C1-C3 straight or branched alkyl), or $-NH-S(O)_2$-phenyl, wherein said phenyl, piperazinyl or morpholino is optionally substituted with methyl.

47. The compound of claim 46, wherein said compound is not



48. The compound of claim 46, wherein at least one of R_6, R_7, or R_8 is not -H.

49. The compound of claim 48, wherein zero or one of R_6, R_7, or R_8 is morpholino, -(C1-C3 straight or branched alkyl)-morpholino, piperazinyl, -(C1-C3 straight or branched alkyl)-piperazinyl, -piperazinyl, or -NH-$S(O)_2$-phenyl, wherein said phenyl, piperazinyl or morpholino is optionally substituted with methyl.

50. The compound of claim 49, wherein R_6 is morpholino, -(C1-C3 straight or branched alkyl)-morpholino, piperazinyl, -(C1-C3 straight or branched alkyl)-piperazinyl, -piperazinyl, or -NH-$S(O)_2$-phenyl, wherein said phenyl, piperazinyl or morpholino is optionally substituted with methyl, and R_7 and R_8 are hydrogen.

51. The compound of claim 49, wherein each of R_6, R_7, and R_8 is independently selected from -H, -CF_3, -methyl, -O-methyl, -O-CF_3, -$N(CH_3)_2$, fluoro, morpholino, -CH_2-CH_2-morpholino, piperazinyl-CH_3, -NH-$S(O)_2$-CH_3, or -NH-$S(O)_2$-phenyl-CH_3.

52. A composition comprising a compound of any of claims 1-51 wherein the composition is pyrogen-free.

53. A pharmaceutical composition comprising a pharmaceutically acceptable carrier or diluent and a compound of any of claims 1-51.

54. A packaged pharmaceutical comprising a compound of any of claims 1-51 and instructions for using the compound to modulate a sirtuin.

55. A method for promoting survival of a eukaryotic cell comprising contacting the cell with at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

56. The method of claim 55, wherein the compound increases the lifespan of the cell.

57. The method of claim 55, wherein the compound increases the cell's ability to resist stress.

58. The method of claim 57, wherein the stress is one or more of the following: heatshock, osmotic stress, DNA damage, inadequate salt level, inadequate nitrogen level, or inadequate nutrient level.

59. The method of claim 55, wherein the compound mimics the effect of nutrient restriction on the cell.

60. The method of claim 55, wherein the eukaryotic cell is a mammalian cell.

61. A method for treating or preventing a disease or disorder associated with cell death or aging in a subject, comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

62. The method of claim 61, wherein the aging-related disease is stroke, a cardiovascular disease, arthritis, high blood pressure, or Alzheimer's disease.

63. A method for treating or preventing insulin resistance, a metabolic syndrome, diabetes, or complications thereof, or for increasing insulin sensitivity in a

subject, comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

64. A method for reducing the weight of a subject, or preventing weight gain in a subject, comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

65. The method of claim 64, wherein said subject does not reduce calorie consumption, increase activity or a combination thereof to an extent sufficient to cause weight loss in the absence of a sirtuin activating compound.

66. A method for preventing the differentiation of a pre-adipocyte, comprising contacting the pre-adipocyte with at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

67. A method for prolonging the lifespan of a subject comprising administering to a subject a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

68. A method for treating or preventing a neurodegenerative disorder in a subject, comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

69. The method of claim 68, wherein the neurodegenerative disorder is selected from Alzheimer's disease (AD), Parkinson's disease (PD), Huntington disease (HD), amyotrophic lateral sclerosis (ALS; Lou Gehrig's disease), diffuse Lewy body disease, chorea-acanthocytosis, primary lateral sclerosis, Multiple Sclerosis (MS) and Friedreich's ataxia.

70. A method for treating or preventing a blood coagulation disorder in a subject, comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

71. The method of claim 70, wherein the blood coagulation disorder is selected from thromboembolism, deep vein thrombosis, pulmonary embolism, stroke, myocardial infarction, miscarriage, thrombophilia associated with anti-thrombin III deficiency, protein C deficiency, protein S deficiency, resistance to activated protein C, dysfibrinogenemia, fibrinolytic disorders, homocystinuria, pregnancy, inflammatory disorders, myeloproliferative disorders, arteriosclerosis, angina, disseminated intravascular coagulation, thrombotic thrombocytopenic purpura, cancer metastasis, sickle cell disease, glomerular nephritis, drug induced thrombocytopenia, and re-occlusion during or after therapeutic clot lysis or procedures such as angioplasty or surgery.

72. A method for treating or preventing an ocular disease or disorder, comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

73. The method of claim 72, wherein the ocular disease or disorder is selected from vision impairment, glaucoma, optic neuritis, macular degeneration, or anterior ischemic optic neuropathy.

74. The method of claim73, wherein the vision impairment is caused by damage to the optic nerve or central nervous sytem.

75. The method of claim 74, wherein the damage is caused by high intraocular pressure, swelling of the optic nerve, or ischemia.

76. The method of claim 73, wherein the vision impairment is caused by retinal damage.

77. The method of claim 76, wherein the damage is caused by disturbances in blood flow to the retina or disruption of the macula.

78. A method for treating or preventing chemotherapeutic induced neuropathy comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

79. The method of claim 78, wherein the chemotherapeutic comprises a vinka alkaloid or cisplatin.

80. A method for treating or preventing neuropathy associated with an ischemic event or disease comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51 or a pharmaceutically acceptable salt or prodrug thereof.

81. The method of claim 80, wherein the ischemic event is a stroke, coronary heart disease (including congestive heart failure or myocardial infarction), stroke, emphysema, hemorrhagic shock, arrhythmia (e.g. atrial fibrillation), peripheral vascular disease, or transplant related injuries.

82. A method for treating or preventing a polyglutamine disease comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

83. The method of claim 82, wherein the polyglutamine disease is spinobulbar muscular atrophy (Kennedy disease), Huntington's disease, dentatorubralpallidoluysian atrophy (Haw River syndrome), spinocerebellar ataxia type 1, spinocerebellar ataxia type 2, spinocerebellar ataxia type 3 (Machado-Joseph disease), spinocerebellar ataxia type 6, spinocerebellar ataxia type 7, or spinocerebellar ataxia type 17.

84. The method of claim 83, wherein the method further comprises administering a therapeutically effective amount of an HDAC I/II inhibitor.

85. A method for treating a disease or disorder in a subject that would benefit from increased mitochondrial activity, comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

86. The method of claim 85, further comprising administering to the subject one or more of the following: a vitamin, cofactor or antioxidant.

87. The method of claim 85, further comprising administering to the subject onr or more of the following: coenzyme Q_{10}, L-carnitine, thiamine, riboflavin, niacinamide, folate, vitamin E, selenium, lipoic acid, or prednisone.

88. The method of claim 85, further comprising administering to the subject one or more agents that alleviate a symptom of the disease or disorder.

89. The method of claim 88, wherein the agent alleviates seizures, neuropathic pain or cardiac dysfunction.

90. The method of claim 85, wherein the disorder is associated with administration of a pharmaceutical agent that decreases mitochondrial activity.

91. The method of claim 90, wherein the pharmaceutical agent is a reverse transcriptase inhibitor, a protease inhibitor, or an inhibitor or dihydroorotate dehydrogenase (DHOD).

92. A method for enhancing motor performance or muscle endurance, decreasing fatigue, or increasing recovery from fatigue, comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

93. The method of claim 92, wherein the subject is an athlete.

94. The method of claim 92, wherein the fatigue is associated with administration of a chemotherapeutic.

95. A method for treating or preventing a condition wherein motor performance or muscle endurance is reduced, comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

96. The method of claim 95, wherein the condition is a muscle dystrophy, a neuromuscular disorder, McArdle's disease, myasthenia gravis, a muscle injury, multiple sclerosis, amyotrophic lateral sclerosis, or age-related sarcopenia.

97. A method for treating or preventing muscle tissue damage associated with hypoxia or ischemia, comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

98. A method for increasing muscle ATP levels in a subject, comprising administering to a subject in need thereof a therapeutically effective amount of at

least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

99. The method of any one of claims 52-98, wherein said compound increases at least one of the level or activity of a sirtuin protein.

100. The method of claim 99, wherein the compound increases deacetylase activity of the sirtuin protein.

101. The method of claim 99, wherein the sirtuin protein is a mammalian protein.

102. The method of claim 99, wherein the sirtuin protein is human SIRT1.

103. The method of claim 99, wherein the sirtuin protein is human SIRT3.

104. The method of claim 99, wherein the compound does not substantially have one or more of the following activities: inhibition of PI3-kinase, inhibition of aldoreductase, inhibition of tyrosine kinase, transactivation of EGFR tyrosine kinase, coronary dilation, or spasmolytic activity, at concentrations of the compound that are effective for increasing the deacetylation activity of a SIRT1 and/or SIRT3 protein.

105. A method for treating or preventing cancer in a subject, comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

106. The method of claim 105, further comprising administering to the subject a chemotherapeutic agent.

107. A method for stimulating weight gain in a subject, comprising administering to a subject in need thereof a therapeutically effective amount of at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

108. A method for increasing the radiosensitivty or chemosensitivity of a cell comprising contacting the cell with at least one compound of any of claims 1-51, or a pharmaceutically acceptable salt or prodrug thereof.

109. The method of claim 108, wherein the cell is a mammalian cell.

110. The method of anyone of claims 105-109, wherein said compound decreases at least one of the level or activity of a sirtuin protein.

111. The method of claim 110, wherein the compound decreases deacetylase activity of the sirtuin protein.

112. The method of claim 110, wherein the sirtuin protein is a mammalian protein.

113. The method of claim 110, wherein the sirtuin protein is human SIRT1.

114. The method of claim 110, wherein the sirtuin protein is human SIRT3.