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(54) **THERAPEUTIC COMPOUNDS**

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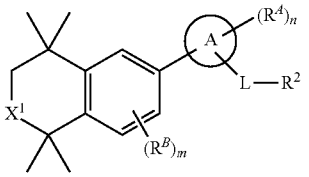
(57) **ABSTRACT**

The invention provides compounds of formula I:

I



and salts thereof, as well as pharmaceutical compositions comprising such compounds. The compounds are useful for treating cancers, Alzheimer's disease, and conditions associated with demyelination.

THERAPEUTIC COMPOUNDS

PRIORITY OF INVENTION

[0001] This application claims priority to U.S. Provisional Application No. 62/449,506, filed 23 Jan. 2017. The entire content of this provisional application is hereby incorporated herein by reference.

GOVERNMENT FUNDING

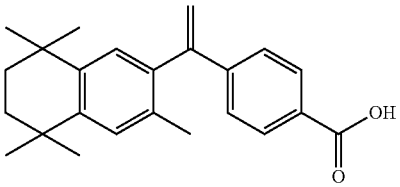
[0002] This invention was made with government support under 1R15CA139364-01A2 awarded by NIH/National Cancer Institute. The government has certain rights in the invention.

BACKGROUND OF THE INVENTION

[0003] The human retinoid X receptors (hRXRs) consist of three identified isoforms (α, β, γ) that function as transcription promoters often in partnership with other members of a larger nuclear receptor (NR) family of transcription regulators including the thyroid receptor (TR), the vitamin D receptor (VDR), the liver X receptor (LXR), the peroxisome proliferator-activated receptor (PPAR), and the retinoic acid receptor (RAR). While 9-cis-retinoic acid (9-cis-RA) and docosahexaenoic acid (DHA) have been shown to bind to hRXRs and promote RXR element (RXRE) regulated transcription (i.e. function as RXR agonists), it is still unclear if RXR has a bona fide endogenous molecular ligand. RXR has been described as the central NR regulator, because it often plays a critical role, either as a permissive or non-permissive partner, in heterodimer complexes that must be formed with the other NRs to regulate their respective response elements.

[0004] Recent studies have identified several RXR-selective-binding molecular ligands (rexinoids) that can modulate not only RXRE regulated transcription but also the heterodimer regulated transcription of other NRs. For instance, RXR is a subordinate partner in the RXR-RAR heterodimer, otherwise referred to as a non-permissive heterodimer, since transcription is not promoted in the RAR unliganded (apo-RAR) heterodimer with RXR. Additionally, the RXR-TR heterodimer is non-permissive. In contrast to these non-permissive heterodimers, permissive heterodimers such as RXR-PPAR allow transcription to be promoted in the presence of either RXR or PPAR agonists. The RXR-LXR heterodimer is also permissive. Hence, there is enormous potential for RXR agonists to activate or repress various biological pathways and effect therapeutic results for various conditions that would benefit from activation or repression of a specific pathway.

[0005] Six rexinoids described in the literature include Bexarotene (60), CD3254 (61), LGD100268 (62), a pyridyl-bexarotene analog (1), an unsaturated bexarotene analog (2), and the mono-fluorinated bexarotene analog (3).



Bexarotene

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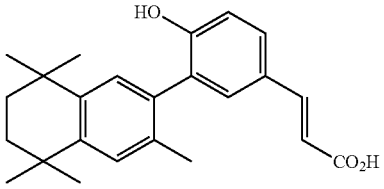
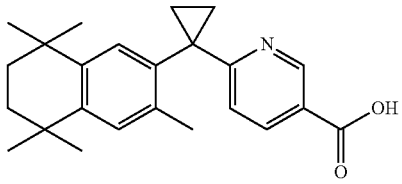
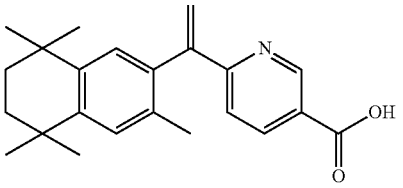


CD 3254



LGD100268

1



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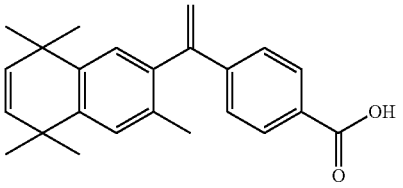

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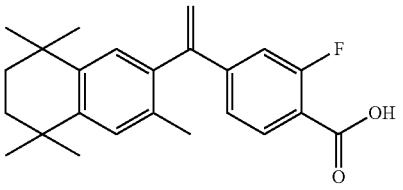


Bexarotene has been documented to have an EC_{50} of 33, 24 and 25 nm for the RXR α,β,γ subtypes, respectively, and a K_d of 14, 21, and 29 nm for the RXR α,β,γ subtypes, respectively, in a CV-1 cell line (Boehm, M. F., et al., "Synthesis and Structure-Activity Relationships of Novel Retinoid X Receptor-Selective Retinoids" *J. Med. Chem.* 1994, 37, 2930-2941). CD3254 appears to have an EC_{50} on the order of 10 nm for the hRXRI3 isoform (Santin, E. P., et al., "Modulating Retinoid X Receptor with a Series of (E)-3-[4-Hydroxy-3-(3-alkoxy-5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalen-2-yl)phenyl]acrylic Acids and Their 4-Alkoxy Isomers" J. Med. Chem. 2009, 52, 3150-3158). LGD100268 and 1 have been documented to have EC_{50}s of 4, 3, and 4 nm and 6, 9, and 5 nm for the RXR α,β,γ subtypes, respectively, and K_ds of 3, 3, and 3 nm and 22, 61, and 39 nm for the RXR α,β,γ subtypes, respectively, in a CV-1 cell line (Boehm, M. F., et al., "Design and Synthesis of Potent Retinoid X Receptor Selective Ligands That Induce Apoptosis in Leukemia Cells" *J. Med. Chem.* 1995, 38, 3146-3155). While the unsaturated-bexarotene analog (2) has been reported, its ability to serve as an RXR agonist has not been published. Finally, the mono-fluorinated bex-

arotene analog (3) has an EC_{50} of 43 nm and a K_d of 12 nm in hRXR in Caco-2 cells (Wagner, C. E., et al., "Modeling, Synthesis and Biological Evaluation of Potential Retinoid X Receptor (RXR) Selective Agonists: Novel Analogues of 4-[1-(3,5,5,8,8-Pentamethyl-5,6,7,8-tetrahydro-2-naphthyl) ethynyl]benzoic Acid (Bexarotene)" *J. Med. Chem.* 2009, 52, 5950-5966).

[0006] Currently there is a need for additional chemical agents that are useful for treating or preventing cancer or treating or preventing Alzheimer's disease. There is also a need for anti-cancer or anti-Alzheimer's agents that have enhanced activity or that have improved pharmacologic properties such as increased solubility or better bioavailability.

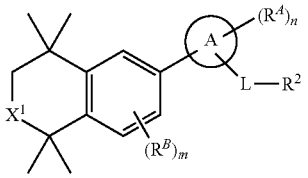
[0007] Additionally, studies suggest that the retinoid X receptor pathway is associated with CNS remyelination processes (see M. Natrajan, et al., *Brain,* 2015, 1-17; and J. K. Huang et al., *Nature Neuroscience,* 2010, 1) Currently there is a need for additional chemical agents that are useful for treating conditions associated with demyelination, such as, for example, multiple sclerosis.

SUMMARY OF THE INVENTION

[0008] This invention provides compounds for treating cancers, Alzheimer's disease, or conditions associated with demyelination.

[0009] Accordingly the invention provides a compound of invention which is a compound of formula I:

I



[0010] wherein:

[0011] X^1 is —CH_2— and ring A is indenyl, naphthyl or 9-10 membered bicyclic heteroaryl;

[0012] or X^1 is —O— and ring A is phenyl, 6-membered heteroaryl, indenyl naphthyl or 9-10 membered bicyclic heteroaryl;

[0013] L is absent, or —CH═CH—;

[0014] R^2 is —COOH, —$B(OH)_2$, or —SO_3H;

[0015] each R^A is independently selected from the group consisting of halo, hydroxy, cyano, nitro, (C_1-C_6)alkyl, (C_3-C_6)cycloalkyl, (C_2-C_6)alkenyl, (C_2-C_6)alkynyl, (C_1-C_6) alkoxy, (C_1-C_6)alkoxycarbonyl, or (C_1-C_6)alkanoyloxy, wherein the (C_1-C_6)alkyl, (C_3-C_6)cycloalkyl, (C_2-C_6)alkenyl, (C_2-C_6)alkynyl, (C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, and (C_1-C_6)alkanoyloxy are optionally substituted with one or more groups independently selected from halo, hydroxy, nitro, cyano, (C_1-C_6)alkoxy, and oxo (═O);

[0016] each R^B is independently selected from the group consisting of halo, hydroxy, cyano, nitro, (C_1-C_6)alkyl, (C_3-C_6)cycloalkyl, (C_2-C_6)alkenyl, (C_2-C_6)alkynyl, (C_1-C_6) alkoxy, (C_1-C_6)alkoxycarbonyl, or (C_1-C_6)alkanoyloxy, wherein the (C_1-C_6)alkyl, (C_3-C_6)cycloalkyl, (C_2-C_6)alkenyl, (C_2-C_6)alkynyl, (C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, and (C_1-C_6)alkanoyloxy are optionally substituted with one or more groups independently selected from halo, hydroxy, nitro, cyano, (C_1-C_6)alkoxy, and oxo (═O);

[0017] n is 0, 1, 2, 3, or 4; and

[0018] m is 0, 1, 2, 3, or 4;

[0019] or a salt thereof.

[0020] The invention also provides a pharmaceutical composition comprising a compound of the invention, or a pharmaceutically acceptable salt thereof, in combination with a pharmaceutically acceptable diluent or carrier.

[0021] The invention also provides a method for inhibiting cancer cell (e.g., glioblastoma multiforme, breast, lung, colon, pancreatic, skin, cutaneous T-cell lymphoma, acute promyelocytic leukemia, ovarian, bladder, kidney, and head and neck cancers, and Kaposi's sarcoma), growth comprising contacting the cell in vitro or in vivo with an effective amount of a compound of the invention, or a salt thereof. The off-label use of bexarotene, a known RXR agonist, and retinoids in other cancers is currently being researched.

[0022] The invention also provides a method for treating cancer (e.g., glioblastoma multiforme, breast, lung, colon, pancreatic, skin, cutaneous T-cell lymphoma, acute promyelocytic leukemia, ovarian, bladder, kidney, and head and neck cancers, and Kaposi's sarcoma) in a mammal (e.g. a human) comprising administering to the mammal an effective amount of a compound of the invention, or a pharmaceutically acceptable salt thereof.

[0023] The invention also provides a method for treating cancer (e.g. glioblastoma multiforme, breast, lung, colon, pancreatic, skin, cutaneous T-cell lymphoma, acute promyelocytic leukemia, ovarian, bladder, kidney, and head and neck cancers, and Kaposi's sarcoma) in a mammal (e.g. a human) in need of such treatment comprising administering to the mammal an effective amount of a compound of the invention, or a pharmaceutically acceptable salt thereof.

[0024] The invention also provides a method for treating cancer (e.g., glioblastoma multiforme, breast, lung, colon, pancreatic, skin, cutaneous T-cell lymphoma, acute promyelocytic leukemia, ovarian, bladder, kidney, and head and neck cancers, and Kaposi's sarcoma) in a mammal (e.g. a human) diagnosed with cancer comprising administering to the mammal an effective amount of a compound of the invention, or a pharmaceutically acceptable salt thereof.

[0025] The invention also provides a method for activating RXR in a cell comprising contacting the cell in vitro or in vivo with an effective amount of a compound of the invention, or a salt thereof. The invention also provides a compound of the invention, or a pharmaceutically acceptable salt thereof, for use in medical therapy.

[0026] The invention also provides a compound of the invention, or a pharmaceutically acceptable salt thereof, for the manufacture of a medicament useful for the treatment of cancer (e.g., glioblastoma multiforme breast, lung, colon, pancreatic, skin, cutaneous T-cell lymphoma, acute promyelocytic leukemia, ovarian, bladder, kidney, and head and neck cancers, and Kaposi's sarcoma) in a mammal (e.g. a human).

[0027] The invention also provides a compound of the invention, or a pharmaceutically acceptable salt thereof, for use in the prophylactic or therapeutic treatment of cancer (e.g., glioblastoma multiforme, breast, lung, colon, pancreatic, skin, cutaneous T-cell lymphoma, acute promyelocytic leukemia, ovarian, bladder, kidney, and head and neck cancers, and Kaposi's sarcoma) in a mammal.

[0028] The invention also provides a method for treating Alzheimer's disease in a human comprising administering to the human an effective amount of compound of the invention, or a pharmaceutically acceptable salt thereof.

[0029] The invention also provides a method for treating Alzheimer's disease in a human in need of such treatment comprising administering to the human an effective amount of compound of the invention, or a pharmaceutically acceptable salt thereof.

[0030] The invention also provides a method for treating Alzheimer's disease in a human diagnosed with Alzheimer's disease comprising administering to the human an effective amount of compound of the invention, or a pharmaceutically acceptable salt thereof.

[0031] The invention also provides a compound of the invention, or a pharmaceutically acceptable salt thereof, for the manufacture of a medicament useful for the treatment of Alzheimer's disease in a human.

[0032] The invention also provides a compound of the invention, or a pharmaceutically acceptable salt thereof, for use in the prophylactic or therapeutic treatment of Alzheimer's disease in a human.

[0033] The invention also provides a method for treating a disease associated with demyelination in a mammal comprising administering to the mammal an effective amount of compound of the invention, or a pharmaceutically acceptable salt thereof.

[0034] The invention also provides processes and novel intermediates that are useful for preparing the compounds of the invention.

DETAILED DESCRIPTION

[0035] The term "activating", such as used in the phrase "activating RXR", means to promote transcriptional activity.

[0036] The term "treatment" or "treating," to the extent it relates to a disease or condition includes preventing the disease or condition from occurring, inhibiting the disease or condition, eliminating the disease or condition, and/or relieving one or more symptoms of the disease or condition.

[0037] The term "alkyl", by itself or as part of another substituent, means, unless otherwise stated, a straight or branched chain hydrocarbon radical, having the number of carbon atoms designated.

[0038] The term "alkenyl" refers to an unsaturated alkyl radical having one or more double bonds. Similarly, the term "alkynyl" refers to an unsaturated alkyl radical having one or more triple bonds.

[0039] The term "alkoxy" refers to an alkyl groups attached to the remainder of the molecule via an oxygen atom ("oxy").

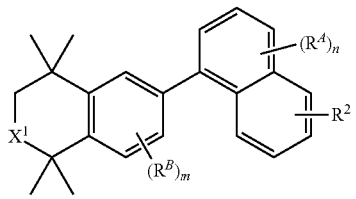
[0040] The term "cycloalkyl" refers to a saturated all carbon ring having 3 to 6 carbon atoms (i.e., $(C_3$-$C_6)$ carbocycle).

[0041] The term "6-membered heteroaryl ring" includes single aromatic rings with at least two carbon atoms and 1, 2, 3, or 4 heteroatoms selected from N, O or S. The term "9-10 membered bicyclic heteroaryl" includes bicyclic systems having at least one single heteroaryl ring, as defined above, with at least five carbon atoms and 1, 2, 3, or 4 heteroatoms selected from N, O or S.

[0042] Specifically, $(C_1$-$C_6)$alkyl can be methyl, ethyl, propyl, isopropyl, butyl, iso-butyl, sec-butyl, pentyl, 3-pentyl, or hexyl; $(C_3$-$C_6)$cycloalkyl can be cyclopropyl, cyclobutyl, cyclopentyl, or cyclohexyl; $(C_1$-$C_6)$alkoxy can be methoxy, ethoxy, propoxy, isopropoxy, butoxy, iso-butoxy, sec-butoxy, pentoxy, 3-pentoxy, or hexyloxy; $(C_2$-$C_6)$ alkenyl can be vinyl, allyl, 1-propenyl, 2-propenyl, 1-butenyl, 2-butenyl, 3-butenyl, 1-pentenyl, 2-pentenyl, 3-pentenyl, 4-pentenyl, 1-hexenyl, 2-hexenyl, 3-hexenyl, 4-hexenyl, or 5-hexenyl; $(C_2$-$C_6)$alkynyl can be ethynyl, 1-propynyl, 2-propynyl, 1-butynyl, 2-butynyl, 3-butynyl, 1-pentynyl, 2-pentynyl, 3-pentynyl, 4-pentynyl, 1-hexynyl, 2-hexynyl, 3-hexynyl, 4-hexynyl, or 5-hexynyl; $(C_1$-$C_6)$ alkanoyl can be acetyl, propanoyl or butanoyl; $(C_1$-$C_6)$ alkoxycarbonyl can be methoxycarbonyl, ethoxycarbonyl, propoxycarbonyl, isopropoxycarbonyl, butoxycarbonyl, pentoxycarbonyl, or hexyloxycarbonyl; $(C_1$-$C_6)$alkanoyloxy can be formyloxy, acetoxy, propanoyloxy, butanoyloxy, isobutanoyloxy, pentanoyloxy, or hexanoyloxy; and heteroaryl can be pyrazinyl, pyridazine, triazine, pyridyl, or pyrimidinyl, or an N-oxide thereof.

[0043] In one embodiment, the invention provides a compound of formula I which is a compound of formula Ia:

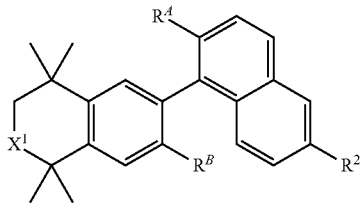
Ia



[0044] or a salt thereof.

[0045] In one embodiment, the invention provides a compound of formula I which is a compound of formula Ib:

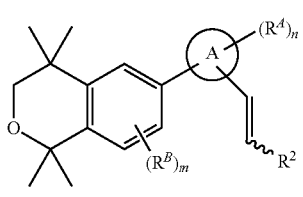
Ib



[0046] or a salt thereof.

[0047] In one embodiment, the invention provides a compound of formula I which is a compound of formula Ic:

Ic



[0048] wherein:

[0049] ring A is phenyl, 6-membered heteroaryl, indenyl naphthyl or 9-10 membered bicyclic heteroaryl;

[0050] L is absent, or —CH═CH—;

R^2 is —COOH, —$B(OH)_2$, or —SO_3H;

[0051] each R^A is independently selected from the group consisting of halo, hydroxy, cyano, nitro, $(C_1$-$C_6)$alkyl, $(C_3$-$C_6)$cycloalkyl, $(C_2$-$C_6)$alkenyl, $(C_2$-$C_6)$alkynyl, $(C_1$-$C_6)$alkoxy, $(C_1$-$C_6)$alkoxycarbonyl, or $(C_1$-$C_6)$alkanoyloxy, wherein the $(C_1$-$C_6)$alkyl, $(C_3$-$C_6)$cycloalkyl, $(C_2$-$C_6)$alkenyl, $(C_2$-$C_6)$alkynyl, $(C_1$-$C_6)$alkoxy, $(C_1$-$C_6)$alkoxycarbonyl, and $(C_1$-$C_6)$alkanoyloxy are optionally substituted with one or more groups independently selected from halo, hydroxy, nitro, cyano, $(C_1$-$C_6)$alkoxy, and oxo (=O);

[0052] each R^B is independently selected from the group consisting of halo, hydroxy, cyano, nitro, $(C_1$-$C_6)$alkyl, $(C_3$-$C_6)$cycloalkyl, $(C_2$-$C_6)$alkenyl, $(C_2$-$C_6)$alkynyl, $(C_1$-$C_6)$alkoxy, $(C_1$-$C_6)$alkoxycarbonyl, or $(C_1$-$C_6)$alkanoyloxy, wherein the $(C_1$-$C_6)$alkyl, $(C_3$-$C_6)$cycloalkyl, $(C_2$-$C_6)$alkenyl, $(C_2$-$C_6)$alkynyl, $(C_1$-$C_6)$alkoxy, $(C_1$-$C_6)$alkoxycarbonyl, and $(C_1$-$C_6)$alkanoyloxy are optionally substituted with one or more groups independently selected from halo, hydroxy, nitro, cyano, $(C_1$-$C_6)$alkoxy, and oxo (=O);

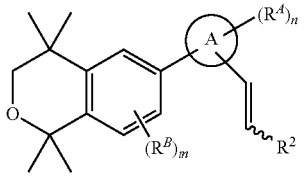
[0053] n is 0, 1, 2, 3, or 4; and

[0054] m is 0, 1, 2, 3, or 4;

[0055] or a salt thereof.

[0056] In one embodiment, the invention provides a compound of formula I which is a compound of formula Id:

Id

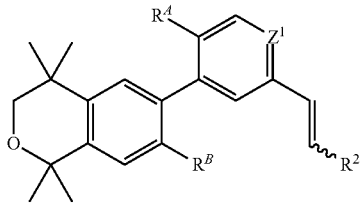


[0057] wherein ring A is phenyl or 6-membered heteroaryl;

[0058] or a salt thereof.

[0059] In one embodiment, the invention provides a compound of formula I which is a compound of formula Ie:

Ie



[0060] wherein Z^1 is N or CH;

[0061] or a salt thereof.

[0062] In one embodiment, X^1 is —CH_2—.

[0063] In one embodiment, X^1 is —O—.

[0064] In one embodiment, R^2 is —COOH.

[0065] In one embodiment, ring A is naphthyl.

[0066] In one embodiment, ring A is phenyl.

[0067] In one embodiment ring A is pyridyl.

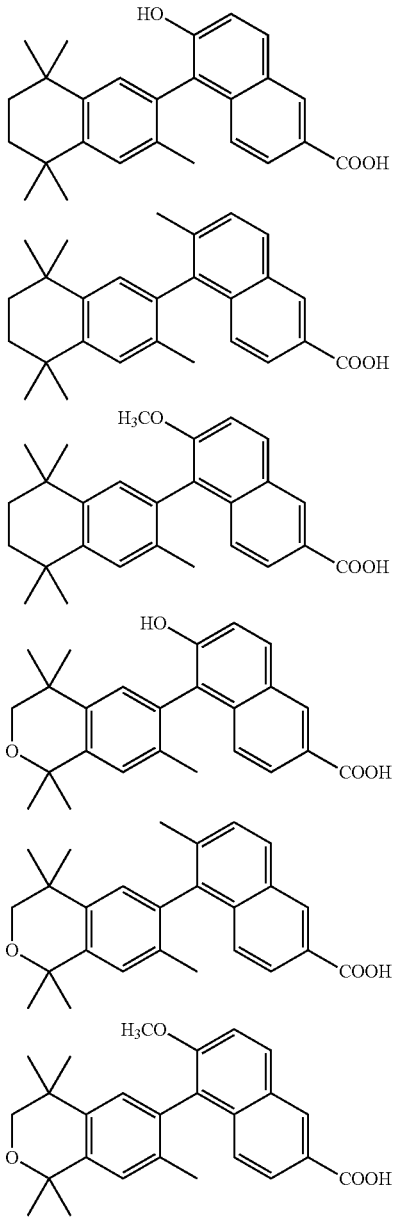
[0068] In one embodiment, R^A is selected from the group consisting of halo, hydroxy, cyano, $(C_1$-$C_6)$alkyl, and $(C_1$-$C_6)$alkoxy, wherein the $(C_1$-$C_6)$alkyl, and $(C_1$-$C_6)$alkoxy are optionally substituted with one or more groups independently selected from halo, hydroxy, nitro, cyano, and oxo (=O).

[0069] In one embodiment, R^A is hydroxyl, fluoro, cyano, methyl, methoxy, or trifluoromethyl.

[0070] In one embodiment, R^B is $(C_1$-$C_6)$alkyl that is optionally substituted with one or more groups independently selected from halo, hydroxy, nitro, cyano, $(C_1$-$C_6)$alkoxy and oxo (=O).

[0071] In one embodiment, R^B is methyl.

[0072] In one embodiment, the invention provides a compound of formula I which is selected from the group consisting of:



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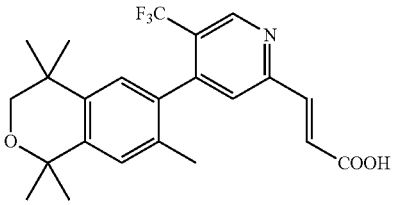

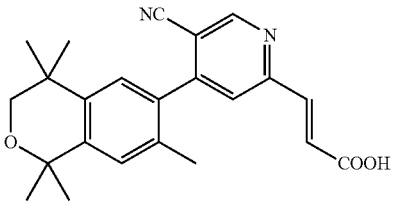

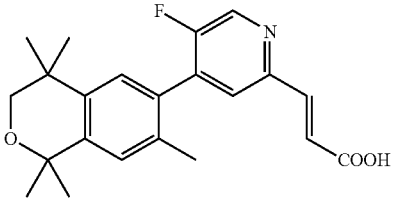

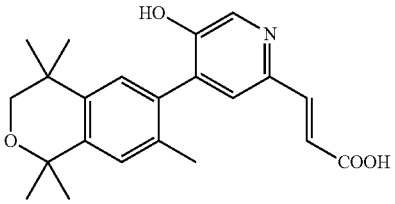

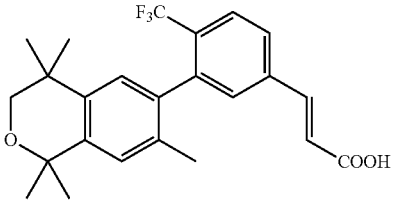

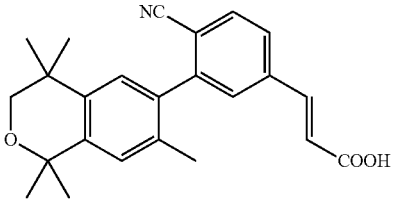

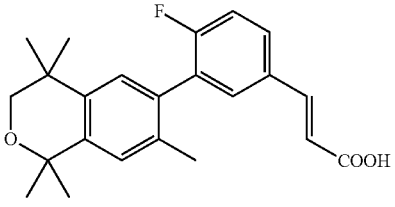

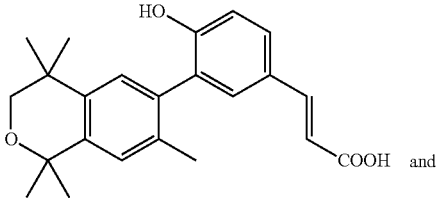

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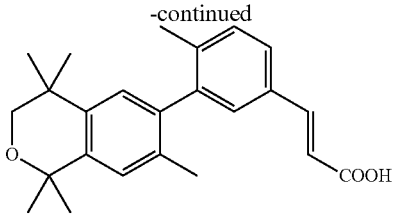
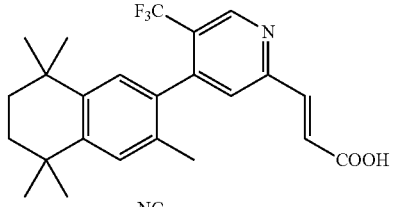
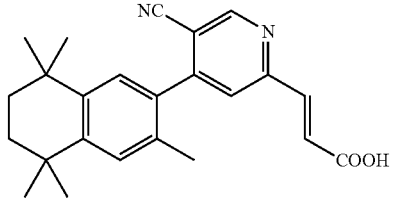
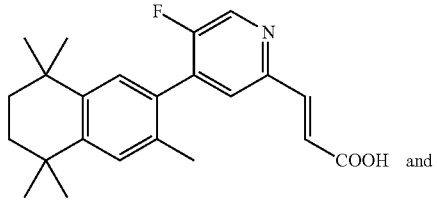


[0073] and salts thereof.

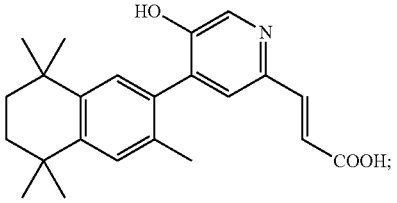
[0074] In one embodiment, the compound of invention is selected from the group consisting of:







and



[0075] and salts thereof.

[0076] In cases where compounds are sufficiently basic or acidic, a salt of a compound of the invention can be useful as an intermediate for isolating or purifying a compound of the invention. Additionally, administration of a compound of the invention as a pharmaceutically acceptable acid or base salt may be appropriate. Examples of pharmaceutically acceptable salts are organic acid addition salts formed with acids which form a physiological acceptable anion, for example, tosylate, methanesulfonate, acetate, citrate, malonate, tartrate, succinate, benzoate, ascorbate, α-keto-glutarate, and α-glycerophosphate. Suitable inorganic salts may also be formed, including hydrochloride, sulfate, nitrate, bicarbonate, and carbonate salts.

[0077] Pharmaceutically acceptable salts may be obtained using standard procedures well known in the art, for example by reacting a sufficiently basic compound such as an amine with a suitable acid affording a physiologically

acceptable anion. Alkali metal (for example, sodium, potassium or lithium) or alkaline earth metal (for example calcium) salts of carboxylic acids can also be made.

[0078] The compounds of the invention can be formulated as pharmaceutical compositions and administered to a mammalian host, such as a human patient in a variety of forms adapted to the chosen route of administration, i.e., orally or parenterally, by intravenous, intramuscular, topical or subcutaneous routes.

[0079] Thus, the present compounds may be systemically administered, e.g., orally, in combination with a pharmaceutically acceptable vehicle such as an inert diluent or an assimilable edible carrier. They may be enclosed in hard or soft shell gelatin capsules, may be compressed into tablets, or may be incorporated directly with the food of the patient's diet. For oral therapeutic administration, the active compound may be combined with one or more excipients and used in the form of ingestible tablets, buccal tablets, troches, capsules, elixirs, suspensions, syrups, wafers, and the like. Such compositions and preparations should contain at least 0.1% of active compound. The percentage of the compositions and preparations may, of course, be varied and may conveniently be between about 2 to about 60% of the weight of a given unit dosage form. The amount of active compound in such therapeutically useful compositions is such that an effective dosage level will be obtained.

[0080] The tablets, troches, pills, capsules, and the like may also contain the following: binders such as gum tragacanth, acacia, corn starch or gelatin; excipients such as dicalcium phosphate; a disintegrating agent such as corn starch, potato starch, alginic acid and the like; a lubricant such as magnesium stearate; and a sweetening agent such as sucrose, fructose, lactose or aspartame or a flavoring agent such as peppermint, oil of wintergreen, or cherry flavoring may be added. When the unit dosage form is a capsule, it may contain, in addition to materials of the above type, a liquid carrier, such as a vegetable oil or a polyethylene glycol. Various other materials may be present as coatings or to otherwise modify the physical form of the solid unit dosage form. For instance, tablets, pills, or capsules may be coated with gelatin, wax, shellac or sugar and the like. A syrup or elixir may contain the active compound, sucrose or fructose as a sweetening agent, methyl and propylparabens as preservatives, a dye and flavoring such as cherry or orange flavor. Of course, any material used in preparing any unit dosage form should be pharmaceutically acceptable and substantially non-toxic in the amounts employed. In addition, the active compound may be incorporated into sustained-release preparations and devices.

[0081] The active compound may also be administered intravenously or intraperitoneally by infusion or injection. Solutions of the active compound or its salts can be prepared in water, optionally mixed with a nontoxic surfactant. Dispersions can also be prepared in glycerol, liquid polyethylene glycols, triacetin, and mixtures thereof and in oils. Under ordinary conditions of storage and use, these preparations contain a preservative to prevent the growth of microorganisms.

[0082] The pharmaceutical dosage forms suitable for injection or infusion can include sterile aqueous solutions or dispersions or sterile powders comprising the active ingredient which are adapted for the extemporaneous preparation of sterile injectable or infusible solutions or dispersions, optionally encapsulated in liposomes. In all cases, the ultimate dosage form should be sterile, fluid and stable under the conditions of manufacture and storage. The liquid carrier or vehicle can be a solvent or liquid dispersion medium comprising, for example, water, ethanol, a polyol (for example, glycerol, propylene glycol, liquid polyethylene glycols, and the like), vegetable oils, nontoxic glyceryl esters, and suitable mixtures thereof. The proper fluidity can be maintained, for example, by the formation of liposomes, by the maintenance of the required particle size in the case of dispersions or by the use of surfactants. The prevention of the action of microorganisms can be brought about by various antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, sorbic acid, thimerosal, and the like. In many cases, it will be preferable to include isotonic agents, for example, sugars, buffers or sodium chloride. Prolonged absorption of the injectable compositions can be brought about by the use in the compositions of agents delaying absorption, for example, aluminum monostearate and gelatin.

[0083] Sterile injectable solutions are prepared by incorporating the active compound in the required amount in the appropriate solvent with various of the other ingredients enumerated above, as required, followed by filter sterilization. In the case of sterile powders for the preparation of sterile injectable solutions, the preferred methods of preparation are vacuum drying and the freeze drying techniques, which yield a powder of the active ingredient plus any additional desired ingredient present in the previously sterile-filtered solutions.

[0084] For topical administration, the present compounds may be applied in pure form, i.e., when they are liquids. However, it will generally be desirable to administer them to the skin as compositions or formulations, in combination with a dermatologically acceptable carrier, which may be a solid or a liquid.

[0085] Useful solid carriers include finely divided solids such as talc, clay, microcrystalline cellulose, silica, alumina and the like. Useful liquid carriers include water, alcohols or glycols or water-alcohol/glycol blends, in which the present compounds can be dissolved or dispersed at effective levels, optionally with the aid of non-toxic surfactants. Adjuvants such as fragrances and additional antimicrobial agents can be added to optimize the properties for a given use. The resultant liquid compositions can be applied from absorbent pads, used to impregnate bandages and other dressings, or sprayed onto the affected area using pump-type or aerosol sprayers.

[0086] Thickeners such as synthetic polymers, fatty acids, fatty acid salts and esters, fatty alcohols, modified celluloses or modified mineral materials can also be employed with liquid carriers to form spreadable pastes, gels, ointments, soaps, and the like, for application directly to the skin of the user.

[0087] Examples of useful dermatological compositions which can be used to deliver the compounds of the invention to the skin are known to the art; for example, see Jacquet et al. (U.S. Pat. No. 4,608,392), Geria (U.S. Pat. No. 4,992,478), Smith et al. (U.S. Pat. No. 4,559,157) and Wortzman (U.S. Pat. No. 4,820,508).

[0088] Useful dosages of the compounds of the invention can be determined by comparing their in vitro activity, and in vivo activity in animal models. Methods for the extrapolation of effective dosages in mice, and other animals, to humans are known to the art; for example, see U.S. Pat. No.

4,938,949. Compounds that are non-toxic and non-mutagenic at typical dose levels will have useful doses. (Mortelmans, K.; Zeiger, E. "The Ames *Salmonella*/microsome mutagenicity assay." Mutat. Res. 2000, 455, 29-60.)

[0089] The amount of the compound, or an active salt or derivative thereof, required for use in treatment will vary not only with the particular salt selected but also with the route of administration, the nature of the condition being treated and the age and condition of the patient and will be ultimately at the discretion of the attendant physician or clinician.

[0090] The desired dose may conveniently be presented in a single dose or as divided doses administered at appropriate intervals, for example, as two, three, four or more sub-doses per day. The sub-dose itself may be further divided, e.g., into a number of discrete loosely spaced administrations; such as multiple inhalations from an insufflator or by application of a plurality of drops into the eye.

[0091] Compounds of the invention can also be administered in combination with other therapeutic agents. In certain embodiments, compounds of the invention can be administered in combination with agents that are useful for the treatment of breast cancer. (Yen, W. et al. "Synergistic effect of a retinoid X receptor-selective ligand bexarotene (LGD1069, Targretin) and paclitaxel (Taxol) in mammary carcinoma" Breast Cancer Research and Treatment, 2004, 88, 141-148.) In certain embodiments, compounds of the invention can be administered in combination with agents that are useful for the treatment of lung cancer. (Yen, W.-C.; Corpuz, M. R.; Prudente, R. Y.; Cooke, T. A.; Bissonnette, R. P.; Negro-Vilar, A.; Lamph, W. W. "A Selective Retinoid X Receptor Agonist Bexarotene (Targretin) Prevents and Overcomes Acquired Paclitaxel (Taxol) Resistance in Human Non-Small Cell Lung Cancer." Clin. Cancer Res. 2004, 10, 8656-8664.). In certain embodiments, compounds of the invention can be administered in combination with agents that are useful for the treatment of glioblastoma multiforme. (Heo, J., et al., *Clin Exp Metastasis,* 2016, 33, 417-429) In certain embodiments, compounds of the invention can be administered in combination with agents that are useful for the treatment of diabetes. (Mukherjee, R.; Davies, P. J. A.; Crombie, D. L.; Bischoff, E. D.; Cesario, R. M.; Jow, L.; Hamanns, L. G.; Boehm, M. F.; Mondon, C. E.; Nadzan, A. M.; Paterniti, J. R.; Heyman, R. A. "Sensitization of diabetic and obese mice to insulin by retinoid X receptor agonists." Nature 1997, 386, 407-410.) Accordingly, in one embodiment the invention also provides a composition comprising a compound of the invention, or a pharmaceutically acceptable salt thereof, at least one other therapeutic agent, and a pharmaceutically acceptable diluent or carrier. The invention also provides a kit comprising a compound of the invention, or a pharmaceutically acceptable salt thereof, at least one other therapeutic agent, packaging material, and instructions for administering the compound of the invention or the pharmaceutically acceptable salt thereof and the other therapeutic agent or agents to an animal to treat cancer or diabetes.

[0092] The ability of a compound of the invention to act as an RXR agonist (e.g. to promote or activate RXR, i.e., promote or activate RXR regulated gene expression) may be determined using pharmacological models which are well known to the art, or using Test A or Test B described below.

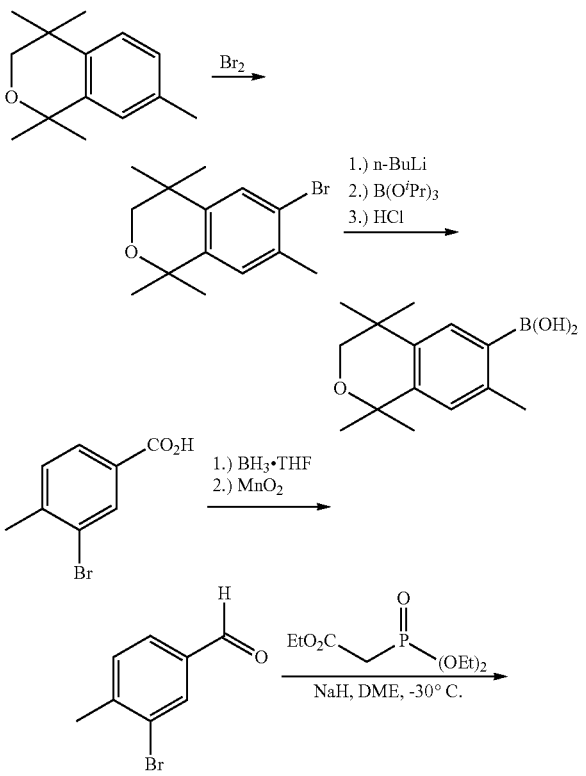
Test A. RXR Selective Agonist Assay (Mammalian Two-Hybrid Assay).

[0093] Compounds will be tested for RXR selective agonist activity via a mammalian two-hybrid assay in human colon cancer cells, HCT-116. The cell line is transfected with pCMVhRXR binding domain vector (BD), hRXR activation domain (AD), pFR-Luc reporter gene containing BD-binding sites, and a *renilla* control plasmid. Cells are transfected for 7 hours utilizing a liposome-mediated transfection protocol then exposed to either the ethanol vehicle or 10^{-7} M Bexarotene or the indicted analog. After 24 hours the cells are lysed and a luciferase assay is completed. Analog dependent RXR binding and homodimerization, as measured by luciferase output, is compared to the parent compound Bexarotene.

Test B. RXR Agonist Assay (RXRE-Luciferase Based Assay).

[0094] Compounds will be tested for RXR agonist activity via an RXRE-luciferase based system utilizing human colon cancer cells HCT-116. The cell line is transfected with hRXRα, an RXRE luciferase reporter gene, *renilla* control plasmid, and carrier DNA (pTZ18U). Cells are transfected for 7 hours utilizing a liposome-mediated transfection protocol then exposed to either the ethanol vehicle or 10^{-7} M Bexarotene or the indicted analog. After 24 hours the cells are lysed and a luciferase assay is completed. Analog dependent, RXR-mediated transcription, as measured by luciferase output, is compared to the parent compound Bexarotene.

[0095] Compounds of invention can be prepared using known methods or using procedures analogous to those described herein. For example, compounds of invention can be prepared as illustrated in the following scheme.



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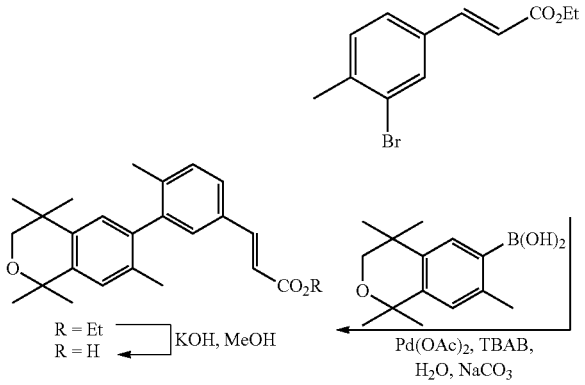


[0096] The invention will now be illustrated by the following non-limiting Example.

Example 1

[0097] The following illustrate representative pharmaceutical dosage forms, containing a compound of the invention, or a salt thereof ('Compound X'), for therapeutic or prophylactic use in humans.

(i) Tablet 1	mg/tablet
Compound X =	100.0
Lactose	77.5
Povidone	15.0
Croscarmellose sodium	12.0
Microcrystalline cellulose	92.5
Magnesium stearate	3.0
	300.0

(ii) Tablet 2	mg/tablet
Compound X =	20.0
Microcrystalline cellulose	410.0
Starch	50.0
Sodium starch glycolate	15.0
Magnesium stearate	5.0
	500.0

(iii) Capsule	mg/capsule
Compound X =	10.0
Colloidal silicon dioxide	1.5
Lactose	465.5
Pregelatinized starch	120.0
Magnesium stearate	3.0
	600.0

(iv) Injection 1 (1 mg/ml)	mg/ml
Compound X = (free acid form)	1.0
Dibasic sodium phosphate	12.0
Monobasic sodium phosphate	0.7

-continued

Sodium chloride	4.5
1.0N Sodium hydroxide solution (pH adjustment to 7.0-7.5)	q.s.
Water for injection	q.s. ad 1 mL

(v) Injection 2 (10 mg/ml)	mg/ml
Compound X = (free acid form)	10.0
Monobasic sodium phosphate	0.3
Dibasic sodium phosphate	1.1
Polyethylene glycol 400	200.0
1.0N Sodium hydroxide solution (pH adjustment to 7.0-7.5)	q.s.
Water for injection	q.s. ad 1 mL

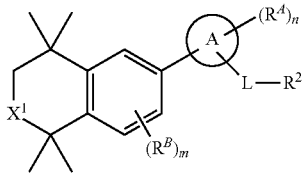
(vi) Aerosol	mg/can
Compound X =	20.0
Oleic acid	10.0
Trichloromonofluoromethane	5,000.0
Dichlorodifluoromethane	10,000.0
Dichlorotetrafluoroethane	5,000.0

[0098] The above formulations may be obtained by conventional procedures well known in the pharmaceutical art.

[0099] All publications, patents, and patent documents are incorporated by reference herein, as though individually incorporated by reference. The invention has been described with reference to various specific and preferred embodiments and techniques. However, it should be understood that many variations and modifications may be made while remaining within the spirit and scope of the invention.

What is claimed is:

1. A compound of formula I:



I

wherein:

X^1 is —CH_2— and ring A is indenyl, naphthyl or 9-10 membered bicyclic heteroaryl;

or X^1 is —O— and ring A is phenyl, 6-membered heteroaryl, indenyl, naphthyl or 9-10 membered bicyclic heteroaryl;

L is absent, or —CH═CH—;

R^2 is —COOH, —$B(OH)_2$, or —SO_3H;

each R^A is independently selected from the group consisting of halo, hydroxy, cyano, nitro, (C_1-C_6)alkyl, (C_3-C_6)cycloalkyl, (C_2-C_6)alkenyl, (C_2-C_6)alkynyl, (C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, or (C_1-C_6)alkanoyloxy, wherein the (C_1-C_6)alkyl, (C_3-C_6)cycloalkyl, (C_2-C_6)alkenyl, (C_2-C_6)alkynyl, (C_1-C_6) alkoxy, (C_1-C_6)alkoxycarbonyl, and (C_1-C_6) alkanoyloxy are optionally substituted with one or more groups independently selected from halo, hydroxy, nitro, cyano, (C_1-C_6)alkoxy, and oxo (═O);

each R^B is independently selected from the group consisting of halo, hydroxy, cyano, nitro, (C_1-C_6)alkyl, (C_3-C_6)cycloalkyl, (C_2-C_6)alkenyl, (C_2-C_6)alkynyl,

(C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, or (C_1-C_6)alkanoyloxy, wherein the (C_1-C_6)alkyl, (C_3-C_6)cycloalkyl, (C_2-C_6)alkenyl, (C_2-C_6)alkynyl, (C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, and (C_1-C_6)alkanoyloxy are optionally substituted with one or more groups independently selected from halo, hydroxy, nitro, cyano, (C_1-C_6)alkoxy, and oxo (=O);

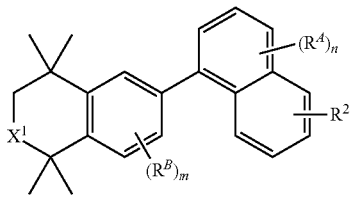
n is 0, 1, 2, 3, or 4; and

m is 0, 1, 2, or 3;

or a salt thereof.

2. The compound of claim **1**, which is a compound of formula Ia:

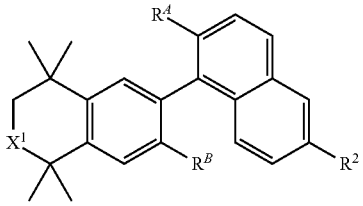
Ia



or a salt thereof.

3. The compound of claim **1**, which is a compound of formula Ib:

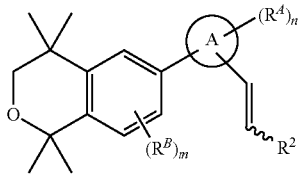
Ib



or a salt thereof.

4. The compound of claim **1**, which is a compound of formula Ic:

Ic



wherein:

ring A is phenyl, 6-membered heteroaryl, indenyl, naphthyl or 9-10 membered bicyclic heteroaryl;

L is absent, or —CH=CH—;

R^2 is —COOH, —$B(OH)_2$, or —SO_3H;

each R^A is independently selected from the group consisting of halo, hydroxy, cyano, nitro, (C_1-C_6)alkyl, (C_3-C_6)cycloalkyl, (C_2-C_6)alkenyl, (C_2-C_6)alkynyl, (C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, or (C_1-C_6)alkanoyloxy, wherein the (C_1-C_6)alkyl, (C_3-C_6)cycloalkyl, (C_2-C_6)alkenyl, (C_2-C_6)alkynyl, (C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, and (C_1-C_6)alkanoyloxy are optionally substituted with one or more groups independently selected from halo, hydroxy, nitro, cyano, (C_1-C_6)alkoxy, and oxo (=O);

each R^B is independently selected from the group consisting of halo, hydroxy, cyano, nitro, (C_1-C_6)alkyl, (C_3-C_6)cycloalkyl, (C_2-C_6)alkenyl, (C_2-C_6)alkynyl, (C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, or (C_1-C_6)alkanoyloxy, wherein the (C_1-C_6)alkyl, (C_3-C_6)cycloalkyl, (C_2-C_6)alkenyl, (C_2-C_6)alkynyl, (C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, and (C_1-C_6)alkanoyloxy are optionally substituted with one or more groups independently selected from halo, hydroxy, nitro, cyano, (C_1-C_6)alkoxy, and oxo (=O);

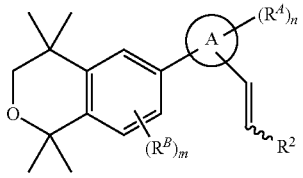
n is 0, 1, 2, 3, or 4; and

m is 0, 1, 2, 3, or 4;

or a salt thereof.

5. The compound of claim **1**, which is a compound of formula Id:

Id

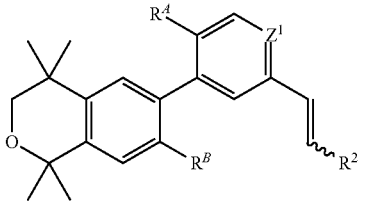


wherein ring A is phenyl or 6-membered heteroaryl;

or a salt thereof.

6. The compound of claim **1**, which is a compound of formula Ie:

Ie



wherein Z^1 is N or CH;

or a salt thereof.

7. The compound of claim **1**, wherein X^1 is —CH_2—.

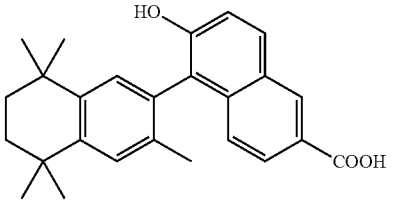
8. The compound of claim **1**, wherein X^1 is —O—.

9. The compound of claim **1**, wherein R^2 is —COOH.

10. The compound of claim **1**, wherein ring A is naphthyl.

11. The compound of claim **1**, wherein ring A is phenyl.

12. The compound of claim **1** that is selected from the group consisting of:



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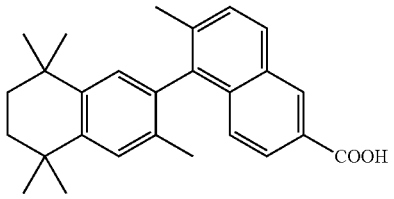

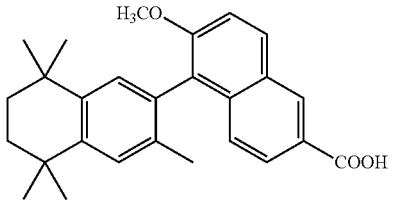

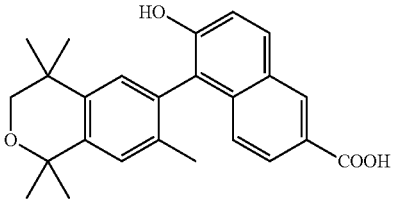

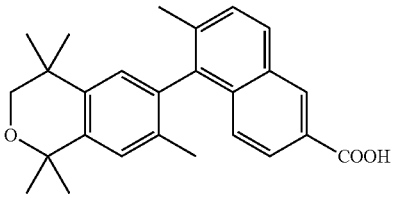

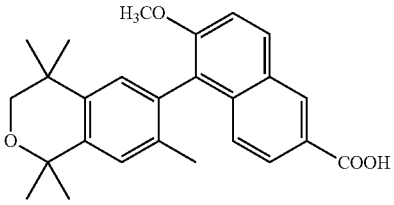

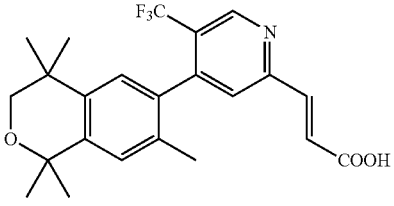

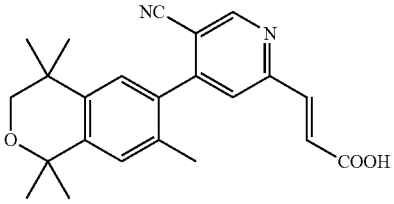

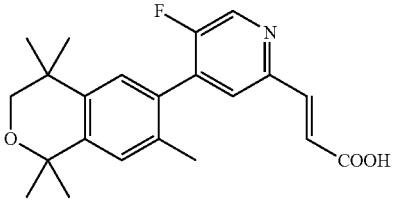

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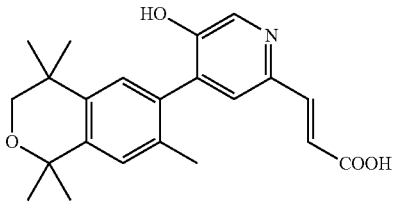
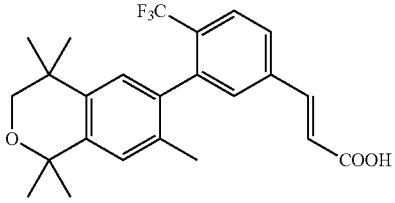
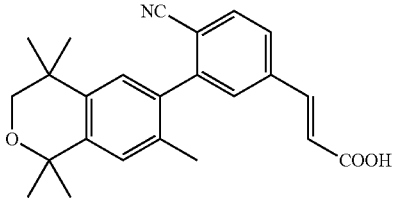
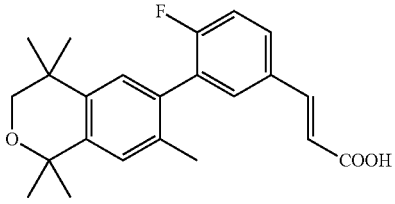
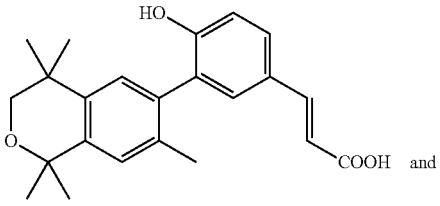
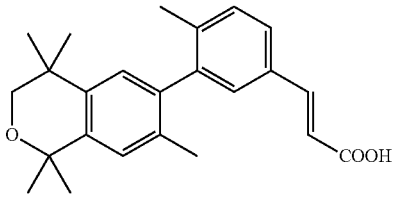






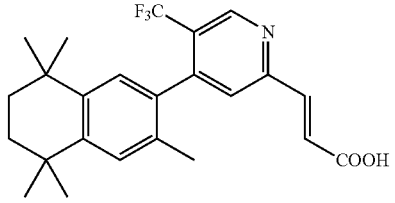






or a salt thereof.

13. A compound selected from the group consisting of:



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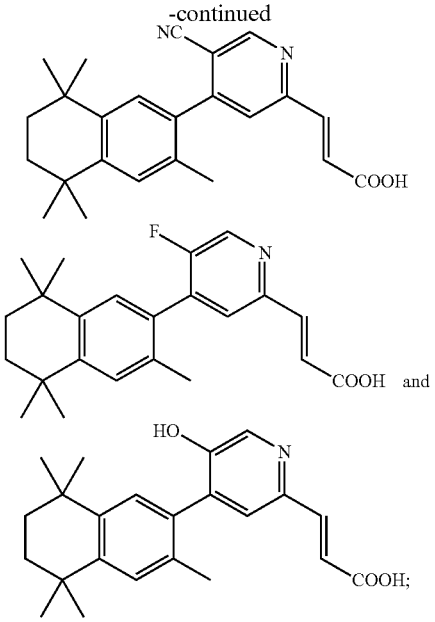

or a salt thereof.

14. A pharmaceutical composition comprising a compound as described in claim **1**, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable diluent or carrier.

15. A method for inhibiting cancer cell growth comprising contacting the cell in vitro or in vivo with an effective amount of a compound as described in claim **1**, or a salt thereof.

16. A method for treating cancer in a mammal comprising administering to the mammal an effective amount of compound as described in claim **1**, or a pharmaceutically acceptable salt thereof.

17. The method of claim **16** wherein the cancer is glioblastoma multiforme, breast, lung, colon, pancreatic, skin, cutaneous T-cell lymphoma, acute promyelocytic leukemia, ovarian, bladder, kidney, head and neck cancers, or Kaposi's sarcoma.

18. A method for activating RXR in a cell comprising contacting the cell in vitro or in vivo with an effective amount of a compound as described in claim **1**, or a salt thereof.

19. A method for treating Alzheimer's disease in a human comprising administering to the human an effective amount of compound of claim **1**, or a pharmaceutically acceptable salt.

20. A method for treating a disease associated with demyelination in a mammal comprising administering to the mammal an effective amount of compound as described in claim **1**, or a pharmaceutically acceptable salt.

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