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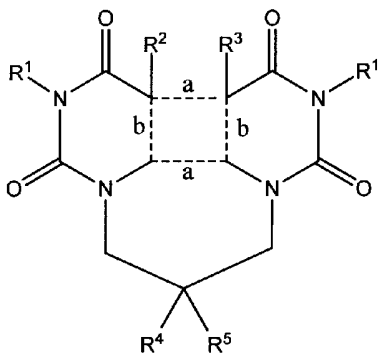
(54) Title: OPEN CHAINED OR FUSED 1,1 '-ALKYLENE-BIS-URACIL DERIVATIVES, USEFUL IN SKIN UV-PROTECTION



(I)

(57) Abstract: The invention provides compounds of formula I; or a salt thereof as described herein. The invention also provides dermatological compositions comprising a compound of formula I or mixtures of one or more compounds of formula I, processes for preparing compounds of formula I, intermediates useful for preparing compounds of formula I and therapeutic methods for protecting skin or DNA from photodamage or repairing photodamaged skin or DNA.

OPEN CHAINED OR FUSED 1 ,1 '-ALKYLENE-BIS-URACIL DERIVATIVES, USEFUL IN SKIN UV-PROTECTION

Cross-reference to Related Applications

This patent application claims the benefit of priority of U.S. application serial No. 61/713,355, filed October 12, 2012, which application is herein incorporated by reference.

Background of the Invention

Skin cancer is the most common cancer diagnosed in the United States and the incidence of skin cancer continues to rise. Epidemiological studies have documented that extensive sun exposure increases the risk of developing non-melanoma skin cancer. Photoprotection is the primary preventative health strategy. Sunscreens are one of the most important forms of photoprotection.

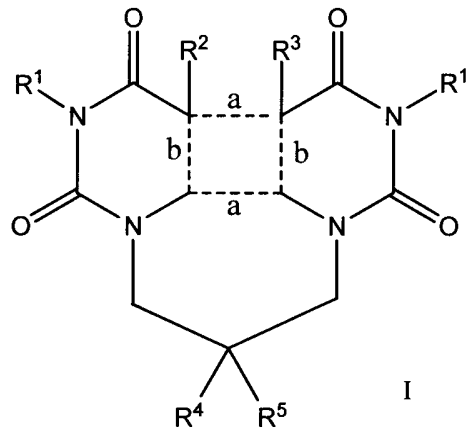
In general, the active ingredients in commercial sunscreens are mostly aromatic hydrocarbons which absorb the light from ultraviolet radiation (UV) and degrade or generate very reactive intermediates *via* free radicals. Such break down products which can be potentially harmful to the skin (*Free Radical Biology & Medicine 2006, 41, 1205–12*). Several recent reports have suggested that current sunscreens may increase cancer risk (*Int J. Environ. Res. Public Health 2007, 4(2)*, 126-31; *FEBS Letters 1993*, 324, 309-13).

Currently there is a need for additional agents or compostions that are useful as sunscreens. There is also a need for agents or compositions comprising said agents that act through unique mechanisms of action or that are effective at lower concentrations or that produce non-toxic photoproducts or less toxic photoproducts or lower concentrations of photoproducts. There is also a need for agents or compositions comprising said agents that prevent or repair DNA damage in the skin or that prevent or repair photo-damage to the skin.

Summary of the Invention

The agents and compositions of the present invention have a unique mechanism of action compared to existing agents and compositions (e.g. sunscreens) in the market. The agents of the present invention absorb UV light and provide photo-protection to the skin. The resulting photo-products initiate the body's natural defense mechanisms by increasing cellular production of DNA repairing enzymes. Thus, the invention provides compounds and compositions that have dual action of providing photo-protection and stimulating repair processes.

In one embodiment, the invention provides a compound of the invention which is a compound of formula I:



I

wherein:

each R^1 is independently H, $(C_1\text{-}C_6)$alkyl, $(C_3\text{-}C_7)$carbocycle or $R_aC(=O)$; or the two R^1 groups together form a $-(C_3\text{-}C_8)$alkyl- group, a $-(C_2\text{-}C_6)$alkyl-Y-$(C_2\text{-}C_6)$alkyl- group or a $-(C_1\text{-}C_6)$alkyl-Y'-$(C_1\text{-}C_6)$alkyl- group; or

the dashed bonds labeled "a" are absent and the dashed bonds labeled "b" are double bonds; or all the dashed bonds are single bonds;

R^2 is H, $(C_1\text{-}C_6)$alkyl or aryl, wherein aryl is optionally substituted with one or more (e.g. 1, 2, 3, 4 or 5) Z^1 groups;

R^3 is H, $(C_1\text{-}C_6)$alkyl or aryl, wherein aryl is optionally substituted with one or more (e.g. 1, 2, 3, 4 or 5) Z^1 groups;

R^4 is hydroxy, carboxy, $(C_1\text{-}C_6)$alkoxycarbonyl, $-OPO_3H_2$, $-OR_c$, or $-NR_dR_e$; and R^5 is H; or R^4 and R^5 taken together are oxo;

Y is O, S, NH, P, P(=O) or POH;

Y' is $Si(R_b)_2$ or $-Si(R_b)_2\text{-}O\text{-}Si(R_b)_2-$;

each R_a is independently $(C_1\text{-}C_6)$alkyl, $(C_3\text{-}C_7)$carbocycle or aryl, wherein aryl is optionally substituted with one or more (e.g. 1, 2, 3, 4 or 5) Z^1 groups;

each R_b is independently $(C_1\text{-}C_6)$alkyl, $(C_3\text{-}C_7)$carbocycle or aryl, wherein aryl is optionally substituted with one or more (e.g. 1, 2, 3, 4 or 5) Z^1 groups;

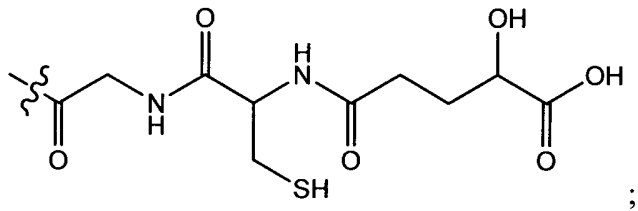
R_c is R_f or a $C_1\text{-}C_{20}$ saturated or $C_2\text{-}C_{20}$ unsaturated carbon chain that is optionally substituted with one or more groups independently selected from oxo (=O), hydroxy, mercapto, $(C_1\text{-}C_6)$alkoxy, $(C_1\text{-}C_6)$alkoxycarbonyl, $(C_1\text{-}C_6)$alkanoyloxy, NR_dR_e, carboxy, and aryl, wherein

aryl is optionally substituted with one or more (e.g. 1, 2, 3, 4 or 5) Z^1 groups;

R_d is H, $(C_1\text{-}C_6)$alkyl, or $(C_1\text{-}C_6)$alkanoyl;

R_e is H or a $C_1\text{-}C_{20}$ saturated or $C_2\text{-}C_{20}$ unsaturated carbon chain that is optionally substituted with one or more groups independently selected from oxo (=O), hydroxy, mercapto, $(C_1\text{-}C_6)$alkoxy, $(C_1\text{-}C_6)$alkoxycarbonyl, $(C_1\text{-}C_6)$alkanoyloxy, NR_dR_e, carboxy, and aryl, wherein aryl is optionally substituted with one or more (e.g. 1, 2, 3, 4 or 5) Z^1 groups;

each R_f, is:



;

each Z^1 is independently selected from $(C_1\text{-}C_6)$alkyl, halogen, -CN, $-OR_{n1}$, $-NR_{q1}R_{r1}$, $-NR_{n1}COR_{p1}$, $-NR_{n1}CO_2R_{p1}$, NO_2, $-C(O)R_{n1}$, $-C(O)OR_{n1}$ and $-C(O)NR_{q1}R_{r1}$, wherein any $(C_1\text{-}C_6)$alkyl of Z^1 is optionally substituted with one or more (e.g. 1, 2, 3, 4, 5 or 6) halogen;

each R_{n1} is independently selected from H and $(C_1\text{-}C_6)$alkyl, wherein any $(C_1\text{-}C_6)$alkyl of R_{n1} is optionally substituted with one or more (e.g. 1, 2, 3, 4, 5 or 6) halogen;

each R_{p1} is independently $(C_1\text{-}C_6)$alkyl; and

R_{q1} and R_{r1} are each independently selected from H and $(C_1\text{-}C_6)$alkyl or R_{q1} and R_{r1} together with the nitrogen to which they are attached form a piperidine, pyrrolidine, morpholine, azetidine, thiomorpholine, piperazine or 4-methylpiperazine;

or a salt thereof.

The invention also provides a composition comprising a compound of formula I or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

The invention also provides a composition comprising a mixture of two or more compounds of formula I, or pharmaceutically acceptable salts thereof, and a pharmaceutically acceptable carrier.

The invention also provides a method for protecting mammal (e.g. human) skin from photo-damage comprising contacting the skin with one or more compounds of formula I or pharmaceutically acceptable salts thereof.

The invention also provides a method for protecting DNA in mammal (e.g. human) skin from photo-damage comprising contacting the skin with one or more compounds of formula I or pharmaceutically acceptable salts thereof.

The invention also provides a method for repairing photo-damage in mammal (e.g. human) skin comprising contacting the skin with one or more compounds of formula I or pharmaceutically acceptable salts thereof.

The invention also provides a method for stimulating DNA repair in mammal (e.g. human) skin comprising contacting the skin with one or more compounds of formula I or pharmaceutically acceptable salts thereof.

The invention also provides a method for preventing skin cancer (e.g. basal cell carcinoma or squamous cell carcinoma) in a mammal (e.g. a human) or reducing the likelihood of contracting skin cancer (e.g. basal cell carcinoma or squamous cell carcinoma) in a mammal (e.g. a human) comprising contacting the skin with one or more compounds of formula I or pharmaceutically acceptable salts thereof.

The invention also provides a method for reversing the signs of skin aging or preventing skin wrinkles in a mammal (e.g. a human) comprising contacting the skin with one or more compounds of formula I or pharmaceutically acceptable salts thereof.

The invention also provides a method for treating xeroderma pigmentosum in a mammal (e.g. a human) comprising contacting the skin with one or more compounds of formula I or pharmaceutically acceptable salts thereof.

The invention also provides a method for treating or preventing ionizing radiation damage in a mammal (e.g. a human) comprising treating the mammal with one or more compounds of formula I or pharmaceutically acceptable salts thereof.

The invention also provides the use of one or more compounds of formula I or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for protecting mammal skin from photo-damage.

The invention also provides the use of one or more compounds of formula I or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for protecting DNA in mammal skin from photo-damage.

The invention also provides the use of one or more compounds of formula I or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for

repairing photo-damage in mammal skin.

The invention also provides the use of one or more compounds of formula I or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for stimulating DNA repair in mammal skin.

The invention also provides the use of one or more compounds of formula I or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for preventing skin cancer (e.g. basal cell carcinoma or squamous cell carcinoma) or reducing the likelihood of developing skin cancer (e.g. basal cell carcinoma or squamous cell carcinoma) in a mammal.

The invention also provides the use of one or more compounds of formula I or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for reversing the signs of skin aging or preventing skin wrinkles in a mammal.

The invention also provides the use of one or more compounds of formula I or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for treating xeroderma pigmentosum in a mammal.

The invention also provides the use of one or more compounds of formula I or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for treating or preventing ionizing radiation damage in a mammal.

The invention also provides processes and intermediates disclosed herein that are useful for preparing compounds of formula I or salts thereof.

Detailed Description

The following definitions are used, unless otherwise described.

The term "alkyl" as used herein refers to straight and branched hydrocarbon groups. Reference to an individual radical such as propyl embraces only the straight chain radical, a branched chain isomer such as isopropyl being specifically referred to.

The term "halo" or "halogen" as used herein refers to fluoro, chloro, bromo and iodo.

The term "carbocycle" or "carbocyclyl" refers to a single saturated (i.e., cycloalkyl) or a single partially unsaturated (e.g., cycloalkenyl, cycloalkadienyl, etc.) ring having 3 to 7 carbon atoms (i.e. (C_3-C_7)carbocycle). The term "carbocycle" or "carbocyclyl" also includes multiple condensed ring systems (e.g. ring systems comprising 2, 3 or 4 carbocyclic rings). Accordingly, carbocycle includes multicyclic carbocyles having 7 to 12 carbon atoms as a bicycle, and up to

about 20 carbon atoms as a polycycle. Multicyclic carbocyles can be connected to each other via a single carbon atom to form a spiro connection (e.g. spiropentane, spiro[4,5]decane, spiro[4.5]decane, etc), via two adjacent carbon atoms to form a fused connection such as a bicyclo [4,5], [5,5], [5,6] or [6,6] system, or 9 or 10 ring atoms arranged as a bicyclo [5,6] or [6,6] system (e.g. decahydronaphthalene, norsabinane, norcarane) or via two non-adjacent carbon atoms to form a bridged connection (e.g. norbornane, bicyclo[2.2.2]octane, etc). The "carbocycle" or "carbocyclyl" may also be optionally substituted with one or more (e.g. 1, 2 or 3) oxo groups. Non-limiting examples of monocyclic carbocycles include cyclopropyl, cyclobutyl, cyclopentyl, 1-cyclopent-1-enyl, 1-cyclopent-2-enyl, 1-cyclopent-3-enyl, cyclohexyl, 1-cyclohex-1-enyl, 1-cyclohex-2-enyl, 1-cyclohex-3-enyl and cycloheptyl.

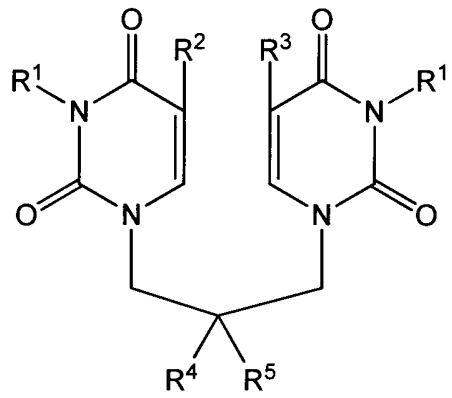
The term "aryl" as used herein refers to a single aromatic ring or a multiple condensed ring system. For example, an aryl group can have 6 to 20 carbon atoms, 6 to 14 carbon atoms, or 6 to 12 carbon atoms. Aryl includes a phenyl radical. Aryl also includes multiple condensed ring systems (e.g. ring systems comprising 2, 3 or 4 rings) having about 9 to 20 carbon atoms in which at least one ring is aromatic. Such multiple condensed ring systems may be optionally substituted with one or more (e.g. 1, 2 or 3) oxo groups on any carbocycle portion of the multiple condensed ring system. It is to be understood that the point of attachment of a multiple condensed ring system, as defined above, can be at any position of the ring system including an aryl or a carbocycle portion of the ring. Typical aryl groups include, but are not limited to, phenyl, indenyl, naphthyl, 1, 2, 3, 4-tetrahydronaphthyl, anthracenyl, and the like.

It will be appreciated by those skilled in the art that compounds of the invention having a chiral center may exist in and be isolated in optically active and racemic forms. Some compounds may exhibit polymorphism. It is to be understood that the present invention encompasses any racemic, optically-active, polymorphic, or stereoisomeric form, or mixtures thereof, of a compound of the invention, which possess the useful properties described herein, it being well known in the art how to prepare optically active forms (for example, by resolution of the racemic form by recrystallization techniques, by synthesis from optically-active starting materials, by chiral synthesis, or by chromatographic separation using a chiral stationary phase.

Specific values listed below for radicals, substituents, and ranges, are for illustration only; they do not exclude other defined values or other values within defined ranges for the radicals and substituents. Specific values listed are values for compounds of formula I as well as

all sub-formulas of formula I (e.g. formulas Ia, and Ib).

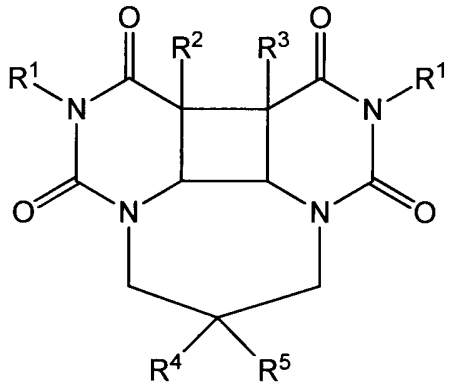
A specific group of compounds of formula I are compounds of formula Ia:



Ia

and salts thereof.

A specific group of compounds of formula I are compounds of formula Ib:



Ib

and salts thereof.

A specific value for R^1 is independently H or $(C_1\text{-}C_6)$alkyl.

A specific value for Y is NH.

A specific value for R^1 is H.

Specifically R^2 and R^3 can each independently be $(C_1\text{-}C_6)$alkyl.

A specific value for R^4 is hydroxyl.

A specific value for R^4 is carboxy.

A specific value for R^4 is $(C_1\text{-}C_6)$alkoxycarbonyl.

A specific value for R^4 is $-OPO_3H_2$.

A specific value for R^4 is $-OR_c$.

A specific value for R^4 is $-NR_dR_e$.

A specific value for R_c is a C_1-C_{20} saturated or C_2-C_{20} unsaturated alkanoyl group that is optionally substituted with one or more groups independently selected from oxo (=O), hydroxy, mercapto, (C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, (C_1-C_6)alkanoyloxy, NR_dR_e, carboxy, and aryl.

A specific value for R_c is a C_1-C_{20} saturated or C_2-C_{20} unsaturated alkanoyl group that is optionally substituted with one or more groups independently selected from oxo (=O), hydroxy, mercapto, carboxy, and aryl, and R_f.

A specific value for R_c is R_f.

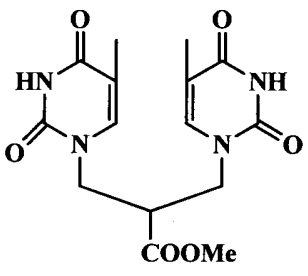
A specific value for R_c is butanoyl, hexadecanoyl, octadecanoyl, benzoyl, 3-phenylprop-2-enoyl, or 3-(4-methoxyphenyl)prop-2-enoyl.

A specific value for R_e is H or a C_1-C_{20} saturated or C_2-C_{20} unsaturated alkanoyl group that is optionally substituted with one or more groups independently selected from oxo (=O), hydroxy, mercapto, (C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, (C_1-C_6)alkanoyloxy, NR_dR_e, carboxy, and aryl.

A specific value for R_e is a C_1-C_{20} saturated or C_2-C_{20} unsaturated alkanoyl group that is optionally substituted with one or more groups independently selected from oxo (=O), hydroxy, mercapto, carboxy, and aryl, and R_f.

A specific value for R_e is butanoyl, hexadecanoyl, octadecanoyl, benzoyl, 3-phenylprop-2-enoyl, or 3-(4-methoxyphenyl)prop-2-enoyl.

A specific compound is a compound which is selected from:



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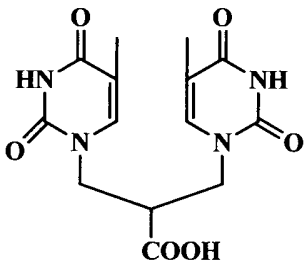

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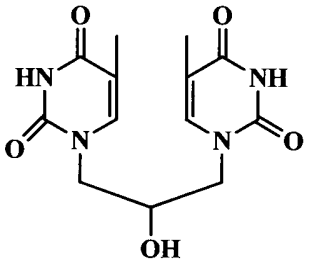

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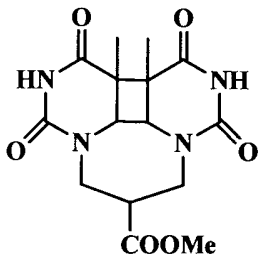

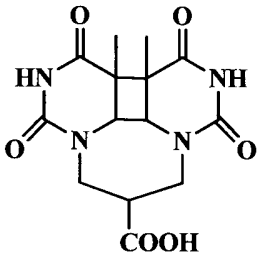

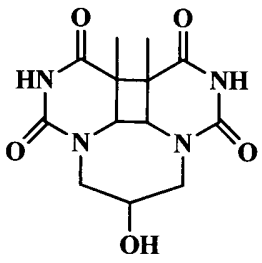

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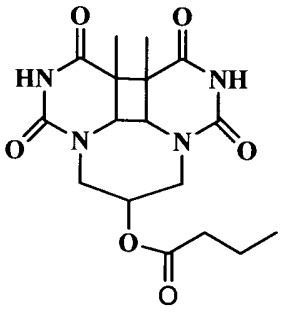

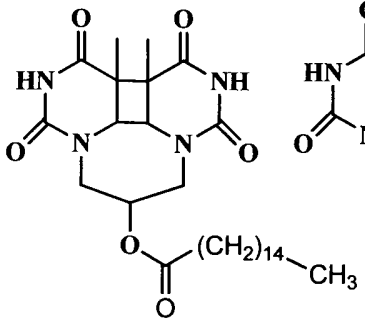

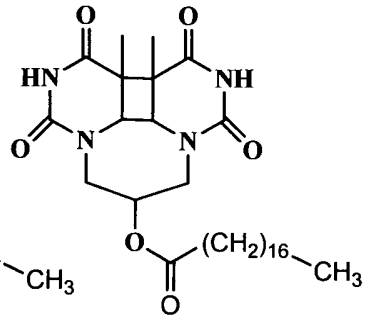

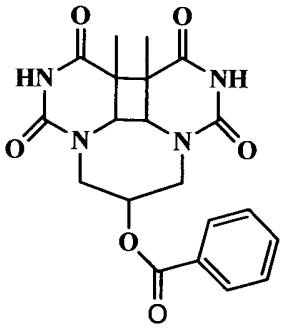

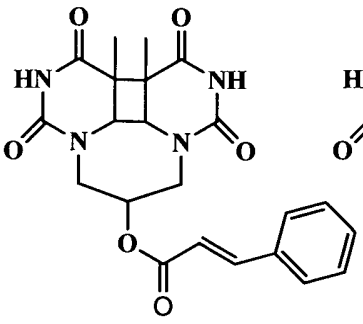

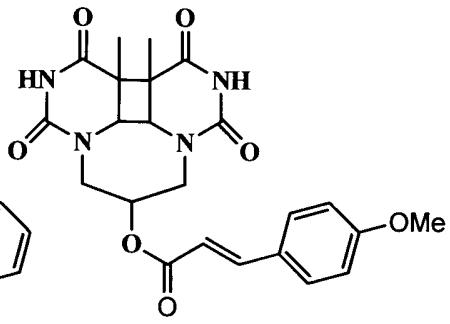

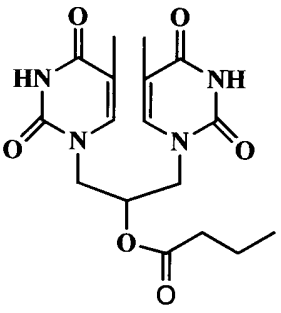

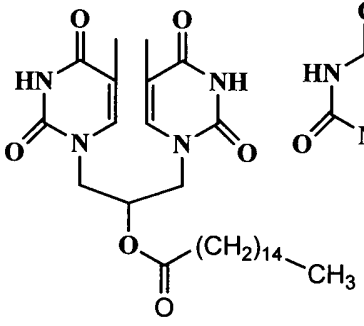

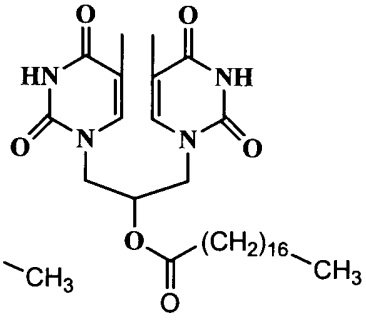

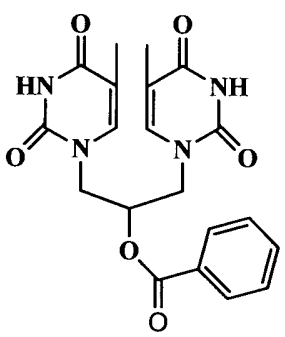

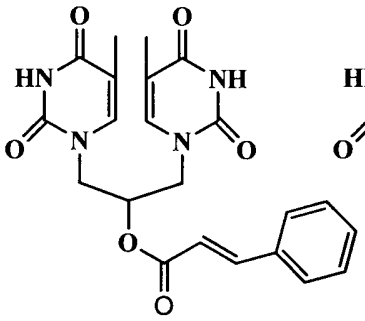

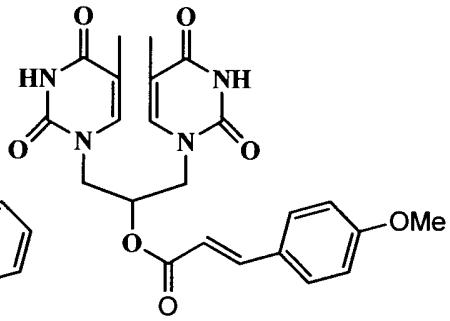
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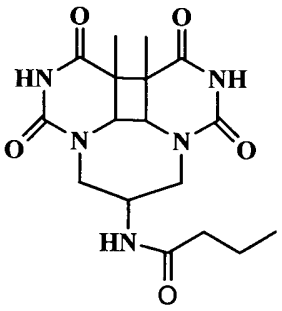

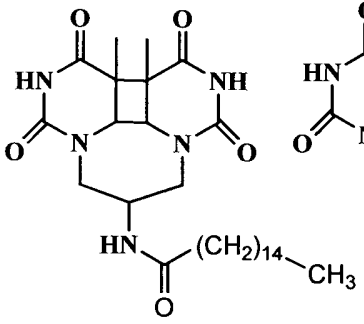
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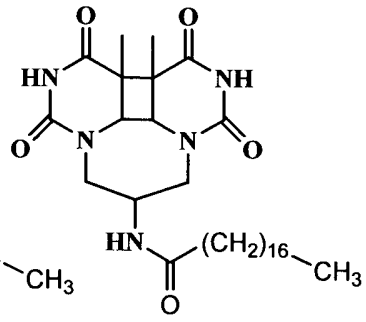
CH3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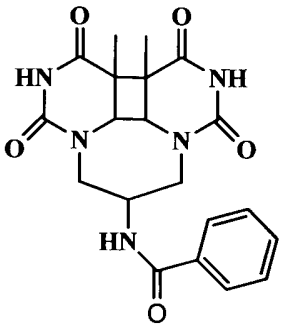

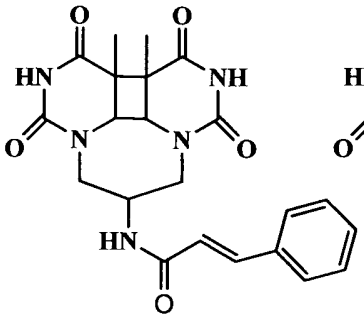

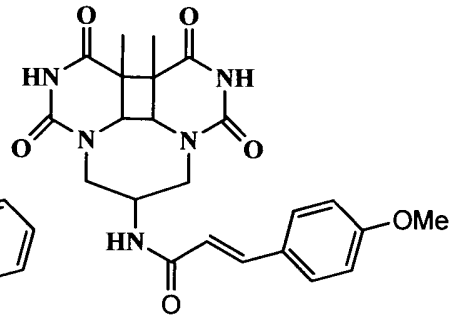
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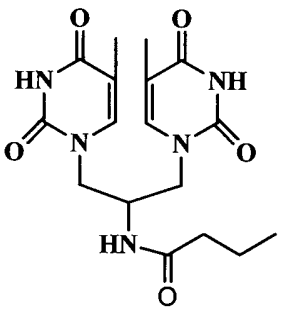

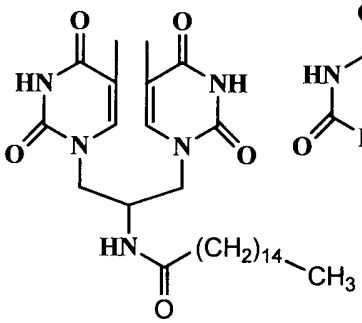
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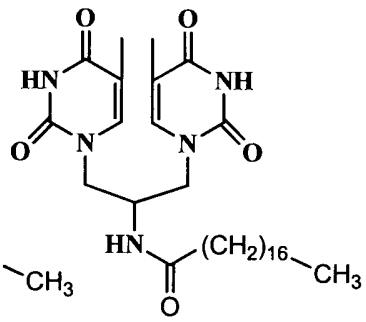
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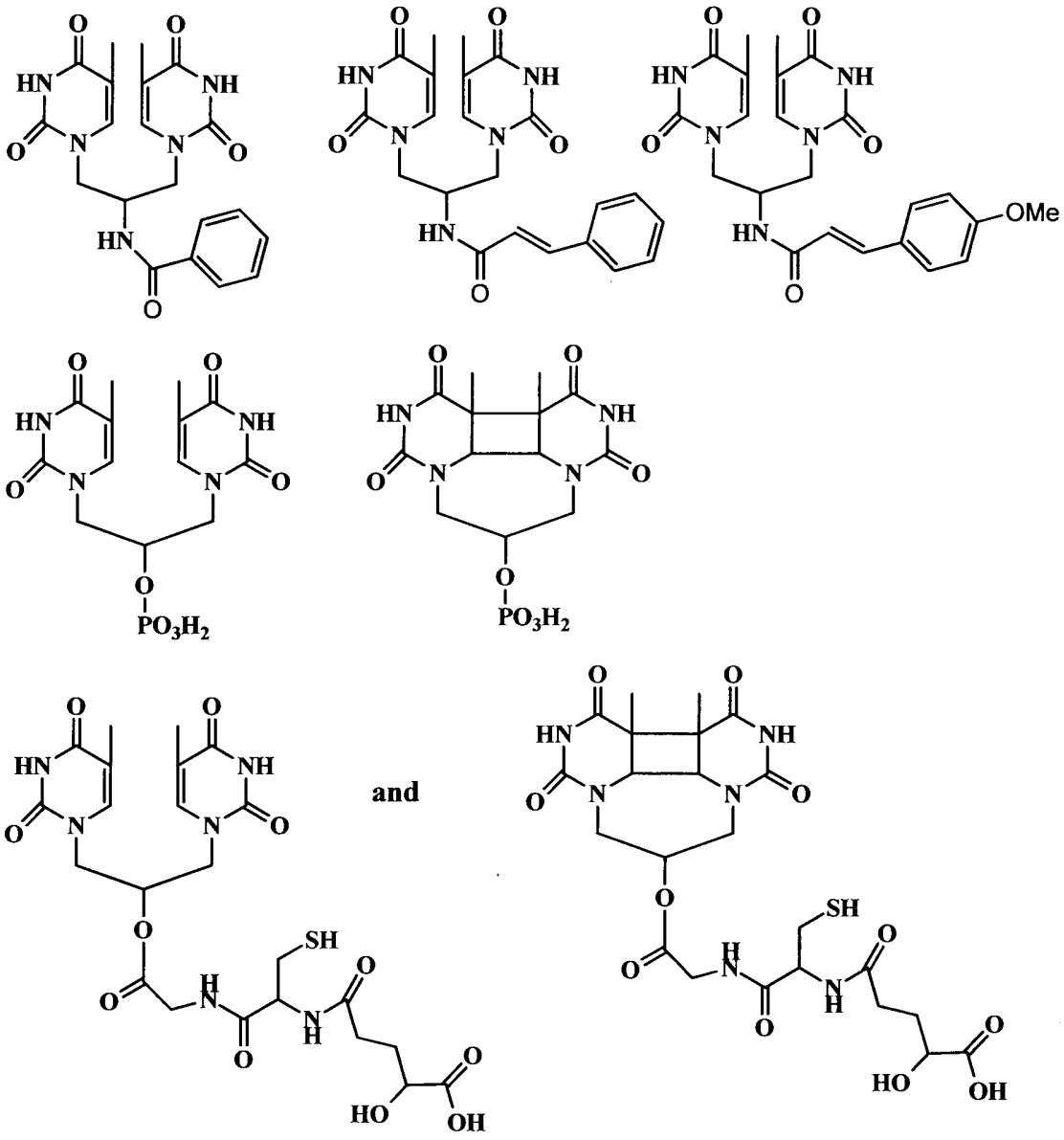
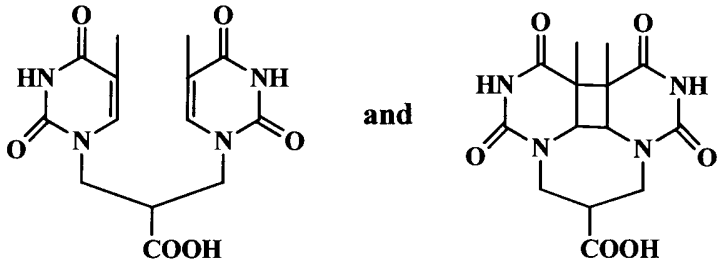


and salts thereof.

A specific compound is a compound which is selected from:



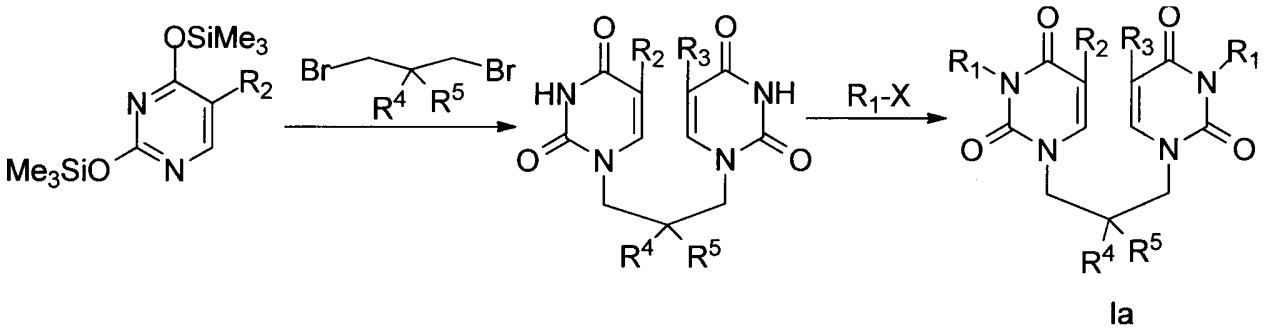
and

16

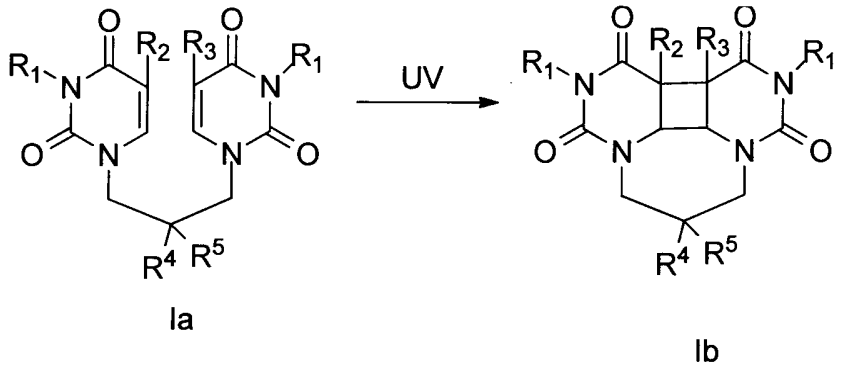
and salts thereof. Specific salts include salts with *N,N*-dimethylaminoethanol or glucosamine.

Processes for preparing compounds of formula I are provided as further embodiments of the invention and are illustrated in Schemes 1 and 2.

Scheme 1



Scheme 2



In cases where compounds are sufficiently basic or acidic, a salt of a compound of the formula can be useful as an intermediate for isolating or purifying a compound of formula I.

Additionally, administration of a compound of formula I as a pharmaceutically or dermatologically acceptable acid or base salt may be appropriate. Examples of pharmaceutically acceptable salts including dermatologically 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-ketoglutarate, and α-glycerophosphate. Suitable inorganic salts may also be formed, including hydrochloride, sulfate, nitrate, bicarbonate, and carbonate salts.

Pharmaceutically acceptable salts which include dermatologically 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.

The compounds of formula I 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. It is to be understood that the term pharmaceutically acceptable carrier also includes carriers that are suitable for topical use as described herein below. In one embodiment of the invention the pharmaceutically acceptable carrier is a dermatologically acceptable carrier.

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.

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.

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.

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.

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.

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.

In general, however, a suitable dose will be in the range of from about 0.5 to about 100 mg/kg, e.g., from about 10 to about 75 mg/kg of body weight per day, such as 3 to about 50 mg per kilogram body weight of the recipient per day, preferably in the range of 6 to 90 mg/kg/day, most preferably in the range of 15 to 60 mg/kg/day.

The compound is conveniently formulated in unit dosage form; for example, containing 5 to 1000 mg, conveniently 10 to 750 mg, most conveniently, 50 to 500 mg of active ingredient per unit dosage form. In one embodiment, the invention provides a composition comprising a compound of the invention formulated in such a unit dosage form.

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.

The compounds of formula I can be formulated as dermatological compositions and applied to a mammalian host, such as a human by a topical route. 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 carrier or a liquid carrier.

Useful solid carriers include finely divided solids such as talc, clay, microcrystalline cellulose, silica, alumina, cyclodextrins 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. Additional carriers include vegetable oils, hydrocarbon oils and waxes, silicone oils, animal and marine fats or oils. Adjuvants such as fragrances and additional antimicrobial agents can be added to the composition to optimize the properties for a given use. 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. Cosmetic compositions, may contain conventional ingredients known to those of ordinary skill in the art, such as those described in Kirk-Othmer, Encyclopedia of Chemical Technology, Third Edition (1979), Vol. 7, pages 143-176. Specific ingredients, including typical sunscreens, are listed in, for example, the above mentioned Kirk-Othmer Encyclopedia, at pages 153-154. In addition, topical preparations and cosmetic formulations may be prepared as described in U.S. Pat. Nos. 4,199,576, 4,136,165, and 4,248,861. Examples of additional 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).

The percentage of the compositions and preparations may be varied. In general, a suitable dermatological composition will typically comprise a compound of formula I or a mixture thereof and may conveniently be between about 2-12% of the weight of a dermatological composition. The amount of active compound in such dermatological useful compositions is such that an effective level of compound will be obtained and/or maintained for the desired duration of action.

Skin is the body's largest organ and is constantly under attack due to endogenous and exogenous factors. Amongst all the exogenous factors that cause photo-damage to the skin, ultraviolet radiation plays an important role in damaging the integrity of the skin as

demonstrated by various studies (*Photochemisty and Photobiology* 2002, 76, 561–69).

Sunscreens protect the DNA by reducing the absorption of sun's ultraviolet radiation to the epidermis. In the event of DNA damage, the repair mechanisms become essential for prevention against replication errors. DNA repair enzymes play a major role in reducing the DNA malignancies.

The activity of the enzymes involved in the DNA damage repair is crucial for over all genome integrity. The enzyme *xpc* is an important enzyme involved in the recognition and repair of DNA photoproducts in the nucleotide excision repair (NER) pathway. This particular enzyme (*xpc*) is also known to repair the DNA damage caused by the oxidative stress and UVA radiation [*Mutation Research* (2011) 728 (3) 107–117; *The EMBO Journal* (2006) 25, 4305 – 4315]. Our skin agents not only protect the DNA by absorbing UV light but also have shown to stimulate the essential repair enzyme, *xpc* involved in the first step of the DNA damage-repair signaling cascade.

Upon absorption of UV from sun light, the chemical ingredients present in commercial sunscreens can be broken down to form photo-products which can react with DNA to form cross links that are potentially toxic [Butt, S.T & Christensen, T; *Toxicity and Phototoxicity of Chemical Sun Filters*: Radiat Prot Dosimetry (2000) 91 (1-3): 283-286]. There has been a continuous demand for safer and novel sunscreens that work by unique mechanisms of action like and with the option of added benefits such as anti-aging and DNA repair enzyme stimulation.

The compounds of formula I and dermatological compositions thereof as described above can be used in sunscreens or other cosmetic formulations specifically contemplated for the purpose of protecting skin or DNA in skin from photodamage or for repairing photodamaged skin or photodamaged DNA in the skin. It is apparent to those of ordinary skill in the art that the compositions or formulations can be in many forms, including, but not limited to, for example, solutions, lotions, oils, sprays, creams, pastes, emulsions, sprays, or aerosols and delivered in a suitable manner.

Photodegradation is one of the factors for skin aging apart from the physiological changes that occur in the skin. Skin aging slows down the production of some key components of extra-cellular matrix. The agents of the present invention can not only help protect the skin from UV damage but also initiate the cellular repair processes and therefore can also be used to

stimulate the production of key factors such as collagen, elastin and hyaluronic acid involved in the skin aging processes.

In sunscreen or suntan lotion formulations it may be advantageous to include an effective amount of the compounds described in the present invention (e.g. one or more compounds of formula I) in combination with other conventional sunscreen agents. Other sunscreen agents include but are limited to avobenzone, ecamsule, methylanthranilate, oxybenzone, dioxybenzone and sulisobenzone, octinoxate, homosalate, octocrylene, octylsalate.

It has been determined that the compounds of formula I absorb UV light at the same wavelength that DNA absorbs UV light. Upon exposure of UV light a compound of formula Ia, Ic, or Ie is converted to a corresponding compound of formula Ib, Id or If respectively. Accordingly, the compounds of formula Ia, Ic or Ie may be useful to protect DNA in the skin of a mammal (e.g. a human) from damage such as UV damage (e.g. UV-B) damage. In another embodiment of the invention the compounds of formula Ia, Ic or Ie can protect skin from photodamage. It has also been discovered that compounds of formula Ia, Ic or Ie can stimulate DNA repair enzymes. Accordingly, in another embodiment the compounds of formula Ia, Ic or Ie may be useful for the repair of photodamaged skin or for the repair of photodamaged DNA.

The exposure levels of ionizing radiation has grown significantly with the use of tools like radiation therapy and X-rays. In addition, exposure can also occur at nuclear reactor sites. Exposure to radiation can produce a variety of lesions in DNA including crosslinks and formation of dimers. Accordingly, effective anti-radiation drugs are urgently needed (e.g. drugs that can prevent or treat ionizing radiation damage). Repair of damage to DNA is of central importance to all cells and stimulation of these repair mechanisms may be useful anti-radiation therapy. Certain compounds of the instant invention (e.g. compounds of formula Ia, Ic or Ie) are known to increase the cellular production of DNA repairing enzymes. Accordingly, these compounds may have therapeutic utility for preventing or treating ionizing radiation damage in mammals.

The ability of a compound of the invention to protect DNA from photodamage may be determined using pharmacological models which are well known to the art, or using Test A or Test B described below.

Test A. DNA Protection Assay (solution)

Black tandem cuvettes were used in the following experiments. Black tandem cuvettes (NSG Precision Cells Farmingdale, NY; Cat# 56UV10) are standard 1cm x 3cm cuvettes which have been divided into 2 chambers. Each chamber holds approximately 1.5mL of liquid. All windows and the partitions were polished and 3 sides were wrapped with black electrical tape leaving only one side for the UV light to go through and directing the light through the protective solutions (OUTER CHAMBER) and then onto inner solution (INNER SOLUTION).

DNA (100μg pEGFP-C1 Plasmid DNA – Clontech/Takara) was placed in the INNER CHAMBER and protected by using 10mM of our compound 16/18 or degassed water in the OUTER CHAMBER. The tandem cuvettes were then exposed to 1-300nm UV bulbs in the Rayonet at 4°C. Aliquots (25μL) of the DNA solution were taken at each time point (5, 10 or 15 minute intervals). The irradiated DNA was digested with T4 endonuclease V, an enzyme specific for thymidine dimer damage. The DNA was incubated for 1 hour at 37°C in the presence of 20U (1μL) T4 Endonuclease V and then run on a 1% Agarose gel (1X TBE , 0.5 hr at 50 V). The gel was then stained with Ethidium bromide and visualized using a BioRad Gel Documentation System.

Test B. B. DNA Protection Assay (cream)

A small amount of the cream (0.1cc) was applied to the outside of black tandem cuvettes and a quartz slide, cut to the size of the cuvette, was placed over the cream to make an even layer. The quartz cuvettes are wrapped in black electrical tape, leaving only one side for the UV light to go through and directing the UV light through the protective cream. The DNA was irradiated using cream vehicle alone or compound 16/18 in cream vehicle.

DNA (100μg pEGFP-C1 Plasmid DNA – Clontech/Takara) was placed in the OUTER CHAMBER and protected by the cream applied to the outside of the cuvette. The tandem cuvettes were exposed to 1-300nm UV bulbs in the Rayonette at 4°C. Aliquots (25μL) of the DNA solution were taken at each time point (5, 10 or 15 minute intervals). The irritated DNA was digested with T4 endonuclease V, an enzyme specific for thymidine dimer damage. The DNA was incubated for 1 hour at 37°C in the presence of 20U (1μL) T4 Endonuclease V and then run on a 1% Agarose gel (1X TBE , 0.5 hr at 50 V). The gel was stained with Ethidium bromide and visualized using a BioRad Gel Documentation System.

The ability of a compound of the invention to protect DNA in cells may be determined using pharmacological models which are well known to the art, or using Test C.

Test C. Cell Protection Assay (cream)

RPMI-8226 cells ($2.5x10^6$cells/mL) were placed in 3mL quartz black cuvettes with a stir bar in the bottom of the cuvette to keep the cells in uniform suspension during the experiment. The quartz cuvettes are wrapped in black electrical tape, leaving only one side for UV light to go through. A small amount of the cream (0.1cc) was applied to the outside of the black tandem cuvettes and a quartz slide, cut to the size of the cuvette, was placed over the cream to make an even layer and UV light was directed through the protective cream. The cells were exposed to 1-300nm UV bulb at 4°C in the Rayonette with continuous stirring by a stir plate. At each time point, (15 and 30 minute intervals) a cuvette containing cells was removed from the Rayonette. The cells were protected by using cream vehicle or AR compounds in cream vehicle.

Post exposure, the cells were transferred to sterile 1.7 mL tubes and the cuvettes were washed with 1X 500µL PBS and the contents were transferred to the corresponding sterile 1.7 mL tube. The tubes were centrifuged for 2 minutes at 13K rpm and 4°C, the supernatant was decanted and the cell pellets resuspended in Proteinase K. The tubes were incubated for 3 hrs at 55°C (to overnight) and the DNA was isolated using the Isolation of DNA from Whole Cells Protocol. The isolated DNA was digested with T4 endonuclease V, (1hr, 37°C) and run on a 1% Agarose gel (1X TBE, 1 hr at 50 V). The gel was stained with Ethidium bromide and visualized using a BioRad Gel Documentation System.

The compounds that were examined in for tests A, B and C including compounds of the invention are shown in Table I. The compounds that were tested in tests A, B and C protected DNA from UV-induced damage for longer periods of time when compared to controls. These results demonstrate that compounds of the invention protect DNA from photodamage. Accordingly compounds of the invention may be useful as dermatological agents for the prevention of DNA damage in a variety of forms including sunscreens and cosmetics.

(Compounds that were examined in a test are denoted by an "X")

Compound #	*in vitro assays*		*in vivo*
	plasmid DNA		Mouse skin
	AR in water Test A	AR in cream Test B	AR in cream Test C
15			
16	X	X	
17			X
18	X	X	X
20	X		
21	X		
22			
23			X
24			X

The ability of a compound of the invention to protect animal skin may be determined using pharmacological models which are well known to the art, or using Test D.

Test D. Murine Animal Studies

In accordance with IACUC Code Number: 0902A60149, 6-8 weeks old SKH-1 were housed in RAR housing and did not receive any sunlight prior to the study. The UVA, UVB and Solar Simulated Light (SSL) treatment groups included mice that were left untouched in their cages (no preventative treatment) and mice treated topically on their backs with cream vehicle or AR compounds in the cream vehicle and rubbed with a glove. At 20 minutes post treatment the mice were exposed to 180mJ/cm^2 of UVA, UVB or SSL equivalent to one hour of noon day summer sunlight. One, four, eight and twenty-four hours post UVA, UVB or SSL exposure, the mice were euthanized by IP Ketamine/Xylazine injection and bled. The serum was collected and sent to the Diagnostic Center for Population and Animal Health (DCPAH) at Michigan State

University for 25-Hydroxyvitamin D analysis and the Diagnostic Labs at the University of Minnesota – Veterinary Medical Center for Small Animal Profile Panel.

The no UVA, UVB and SSL treatment groups included mice which were left untouched in their cages (no preventative treatment) and mice treated topically on their backs with cream vehicle and AR compounds in cream vehicle as indicated above. After treatment the mice were placed back into their cages, away from sunlight. One, four, eight and twenty-four hours post treatment, the no UVA, UVB and SSL treated mice were euthanized by IP Ketamine/Xylazine injection and bled. The serum was collected and sent to the Diagnostic Center for Population and Animal Health (DCPAH) at Michigan State University for 25-Hydroxyvitamin D analysis and the Diagnostic Labs at the University of Minnesota – Veterinary Medical Center for Small Animal Liver and Kidney Function Profile.

For the animal groups above, post euthanasia, the dorsal and belly skin was collected and preserved in Zamboni's fixative for future studies. Skin samples are sent to the Masonic Cancer Center Comparative Pathology Shared Resource at the University of Minnesota for H&E staining to look for skin irritation. The skin was analyzed in-house by immunohistostaining (p53, thymine dimer, XPC and other DNA repair enzymes, collagen, elastin, etc.) and confocal microscopy.

Murine animal model testing results:

Compound **17** (5% w/w based on acid) in cream vehicle was topically applied topically to *SKH-1* hairless mouse dorsal skin and exposed to UVB light. Approximately 100 µl (0.1 cc) of each formulation was applied to mouse dorsal skin 20 minutes prior to UVB exposure. The treatment groups received the standard dose of 6 KJ/m^2 and were harvested 4 hours after irradiation. At harvest, dorsal skins were removed and fixed in zamboni fixative. 5% (w/w based on acid) of compound **17** in cream vehicle protected against thymine dimer formation as compared to the UV only control.

The ability of a compound of the invention to protect human skin may be determined using pharmacological models which are well known to the art, or using Test E.

Test E. Human Skin Study

Human skin was obtained from the University of Minnesota BioNet Tissue Procurement Facility and stored on ice or in cell culture media until ready to be used. All samples were kept

away from sunlight. The skin was cut into pieces and placed in 6-well cell culture plates with a small amount of culture media at the bottom of the well but not enough to cover the top of the tissue. Using a gloved hand, the skin was rubbed with cream vehicle or AR drug in the cream vehicle. At 20 minutes post treatment the skin was exposed to 180mJ/cm^2 of UVA, UVB or Solar Simulated Light (SSL) equivalent to one hour of noon day summer sunlight. Post UVA, UVB or SSL exposure, additional media was placed in the bottom of the wells and the plates moved to the tissue culture incubator (37°C, 5% CO_2). Samples were removed from the incubator and placed in Zamboni's fixative for future studies at one, four, eight and twenty-four hours post UVA, UVB or SSL exposure.

Samples not exposed to UVA, UVB or SSL light were placed into 6-well plates with a small amount of cell culture media but not enough to cover the top of the tissue and stored in the cell culture incubator. The skin samples not exposed to UVA, UVB or SSL light were treated with cream vehicle and AR in cream vehicle as indicated above. At 20 minutes post treatment, the skin (in the plates) was moved into the cell culture incubator (37°C, 5% CO_2). Samples were removed from the incubator and placed in Zamboni's fixative for future studies at one, four, eight and twenty-four hours post treatment.

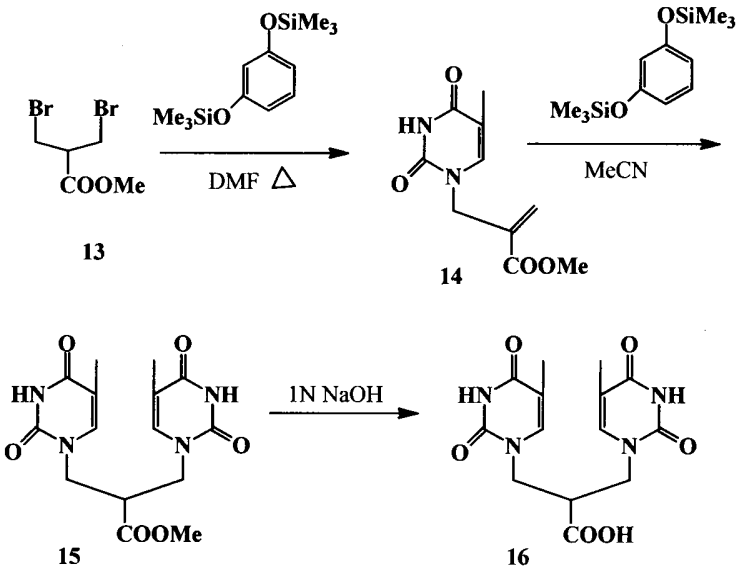
All skin samples were analyzed in-house by immunohistostaining (p53, thymine dimer, XPC and other DNA repair enzymes, collagen, elastin, etc.) and confocal microscopy.

The invention will now be illustrated by the following non-limiting Examples.

Examples

All chemicals were purchased from Sigma Chemicals, St. Louis, MO. All compounds were characterized by 1H NMR, 13C NMR, mass and melting point analysis. Nuclear Magnetic Resonance spectra were recorded on a Varian XL 600 MHz instrument. All 1H and ^{13}C NMR experiments are reported in units, parts per million (ppm), and were measured relative to residual DMSO in the deuterated solvent. All coupling constants were reported in Hz. Melting points were determined on Mel-Temp II apparatus and are uncorrected. Mass analyses were performed on Agilent LC-TOF 1100 mass spectrometer equipped with either an ESI or APCI source.

Example 1: Preparation of compounds **15** and **16**



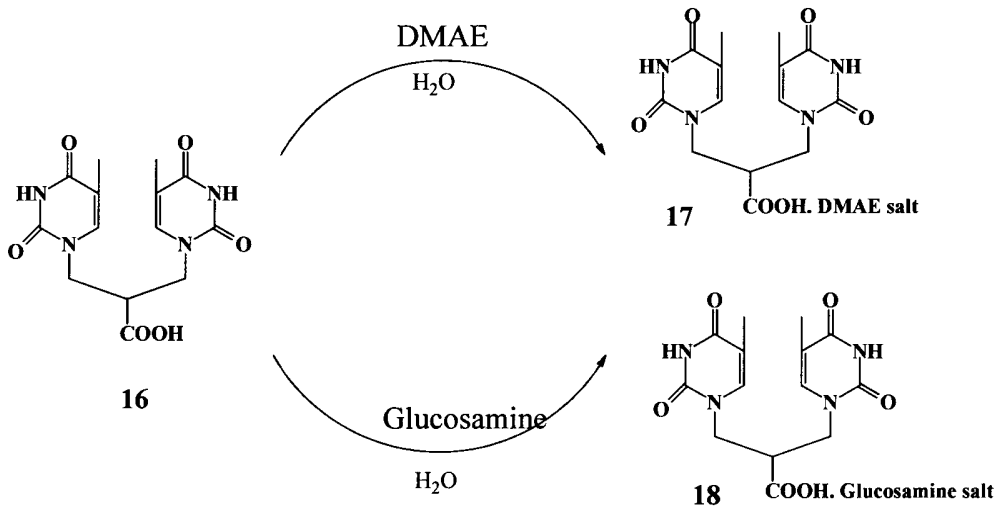
To a solution of *O,O'*-Bis(trimethylsilyl)-thymine (0.401 g, 1.482 mmol) in anhydrous DMF was added the dibromoester, **13** (0.255 g, 0.988 mmol) at RT and the reaction was heated to 75-80 ^0C. The reaction mass was evaporated to give an oily residue which was purified by SiO_2 flash chromatography to give the compound **14** (0.143 g, 64.7%) as an off white solid. ^1H NMR (600 MHz, DMSO-d^6): δ 11.09 (s, 1H), 7.23 (s, 1H), 6.26 (s, 1H), 5.52 (s, 1H), 4.01 (s, 2H), 3.43 (s, 3H), 1.85 (s, 3H); Mass (ESI-MS): 224.36 (M+).

To a solution of compound **14** (0.125 g, 0.558 mmol) in acetonitrile (30 mL) was added the *O,O'*-Bis(trimethylsilyl)-thymine (0.181 g, 0.669 mmol) at RT and the reaction was stirred at RT. The reaction mass was evaporated to give the crude solid which was purified by SiO_2 flash

chromatography to give the compound **15** (0.139 g, 71.28%) as an off white solid. ^{1}H NMR (600 MHz, DMSO-d^6): δ 11.25 (s, 2H), 7. 46 (s, 2H), 3.83 (d, 4H), 3.54 (s, 3H), 3.43 (m , 1H), 1.71 (s, 6H); ^{13}C NMR (150 MHz, DMSO-d^6): δ 174.12, 164.51, 151.35, 139.24, 53.11, 50.23, 40.34, 15.21, 15.18; Mass (ESI-MS): 351.75 (M+H).

To a solution of compound **15** (0.113 g, 0.322 mmol) in water (10 mL) was added 1N NaOH (10 mL) at 0 ^{0}C and stirred carefully for 2-3 h. The pH of the reaction was adjusted to acidic (pH-2) and the precipitated reaction mass was filtered, washed with dioxane-MeOH (1:1, 20 mL) and dried under vacuum to give the compound **16** (0.072 g, 66.71%) as a white solid. ^{1}H NMR (600 MHz, DMSO-d^6): δ 12. 81 (s. 1H), 11.24 (s, 2H), 7.44 (s, 2H), 3.81 (d, 4H), 3.15 (m, 1H), 1.70 (s, 6H); ^{13}C NMR (150 MHz, DMSO-d^6): δ 179.25, 164.87, 152.33, 140.27, 51.47, 42.33, 16.22, 16.20; Mass (ESI-MS): 335.13 (M-H).

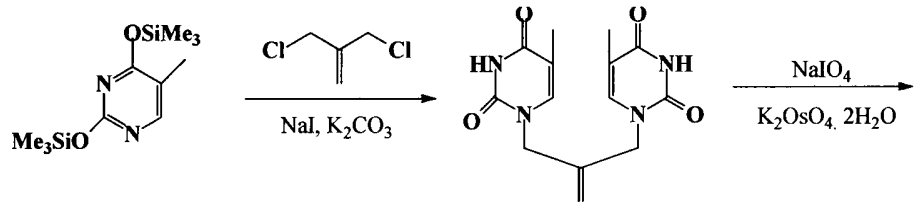
Example 2: Preparation of salts **17** and **18**



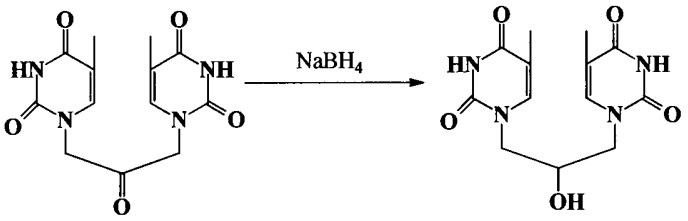
To a solution of the acid **16** (0.105 g, 0.312 mmol) in water (20 mL) was slowly added *N,N*-dimethylaminoethanol (DMAE) (0.027 g, 0.312 mmol)) at RT. The contents were stirred for 1-2 h at RT. The solvent was lyophilized to give an amorphous solid which was washed with diethyl ether (25 mL) and dried under vacuum to give the DMAE salt of the acid **17**, as an off white powder. (0.125 g, 94%).^{1}H NMR (600 MHz, DMSO-d^6): δ 10.76 (s, 2H), 7.16 (s, 2H), 3.71 (d, 4H), 3.42 (d, 2H), 3.01 (m, 1H), 2.71 (d, 2H), 2.44 (s, 6H), 1.63 (s, 6H); Mass (ESI-MS): 335.46 (M-H)

To a solution of the acid **16** (0.125 g, 0.372 mmol)) in water (20mL) was slowly added glucosamine (0.066 g, 0.372 mmol) at RT. The contents were stirred for 1-2 h at RT. The solvent was lyophilized to give an amorphous solid and washed with diethyl ether (30 mL). The solids were dried under vacuum to give the glucosamine salt of the acid **18**, as a white powder (0.173 g, 90.57%). ^{1}H NMR (600 MHz, DMSO-d^6): 11.12 (s, 2H), 7.21 (s, 2H), 5.65 (d, 1H), 4.12-3.81 (m , 1H), 4.01- 2.91 (m, 1H), 3.73 (d, 4H), 3.66 (m, 1H), 3.45 (m, 1H), 1.71 (s, 6H); Mass (ESI-MS): 335.87 (M-H).

Example 3: Preparation of compound **21**



19



20 **21**

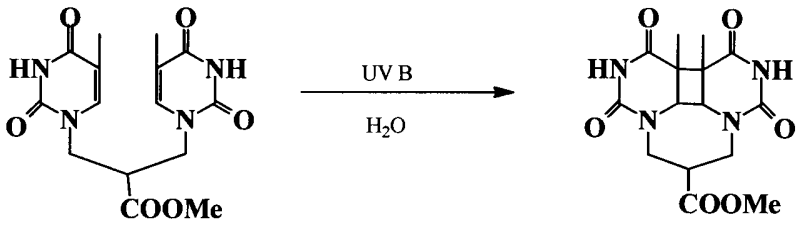
To a solution of *O,O'*-Bis(trimethylsilyl)-thymine (1.186 g, 4.392 mmol) was added 3-chloro-(2-chloromethyl)prop-1-ene (0.252 g, 1.640 mmol), NaI (20 mG, 0.157 mmol) and potassium carbonate (0.559 g, 3.992 mmol) in anhydrous DMF (50 mL). The mixture was heated to 80 ^{0}C and stirred overnight. DMF was evaporated and the residue was purified by SiO_2 flash chromatography to give the compound **19** as a white solid (0.345 g, 56.3%). ^{1}H NMR (600 MHz, DMSO-d^6): 11.23 (s, 2H), 7.01 (s, 2H), 5.45 (s, 1H), 5.21 (s, 1H), 5.65 (d, 1H), 3.81 (s, 4H); 1.75 (s, 6H); Mass (ESI-MS): 304.71 (M+).

Compound **19** (0.301 g, 0.99 mmol) was dissolved in a mixture of THF-H_2O (1:0.5 ratio; 30 mL). Sodium-periodate (1.059 g, 4.948 mmol) was added in portion and stirred for 10 min at RT. Potassium osmate(VI) dihydrate (0.036 g, 0.099 mmol) was added to the reaction mass and stirred overnight at RT. The solvents were evaporated and methanol (10 mL) was added to

dissolve the product and filtered. The filtrate were evaporated and the residue was purified by SiO_2 flash chromatography to give the compound **20** as a white solid (0.125 g, 41.31%). ^1H NMR (600 MHz, DMSO-d^6): 11.12 (s, 2H), 6.31 (s, 2H), 4.13 (s, 4H), 1.81 (s, 6H); ^{13}C NMR (150 MHz, DMSO-d^6): δ 198.12, 163.34, 151.17, 140.57, 110.34, 55.73, 15.23, 15.22; Mass (ESI-MS): 304.63 (M+); m.p: 320-331 ^0C

The compound **20** (0.158 g, 0.516 mmol) was suspended in H_2O (20 mL) and cooled to 0 ^0C. Sodiumborohydride (0.191 g, 5.613 mmol) was carefully added to the reaction mixture in two portions. The reaction was stirred for 2 h at 0 ^0C and slowly brought to RT. Methanol (10 mL) was carefully introduced followed by the addition of H_2O (25 mL) to precipitate the solids. The compound was recrystallized using a mixture of water and ethanol (1:1) to give the compound **21** as a white solid (0.105 g, 66.03%). ^1H NMR (600 MHz, DMSO-d^6): 11.01 (s, 2H), 6.45 (s, 2H), 4.66-3.33 (m, 6H), 2.11 (s, 6H); ^{13}C NMR (150 MHz, DMSO-d^6): δ 165.37, 150.43, 142.51, 111.57, 65.77, 1.23, 15.31, 15.28; Mass (ESI-MS): 308.71 (M+); m.p: 319-322 ^0C

Example 4: Preparation of compound **22**

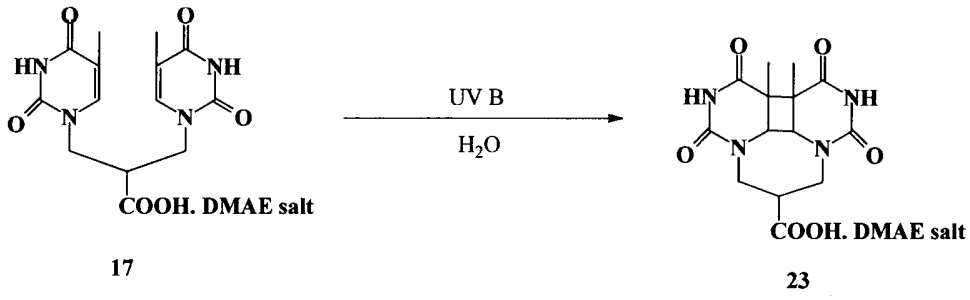


15 **22**

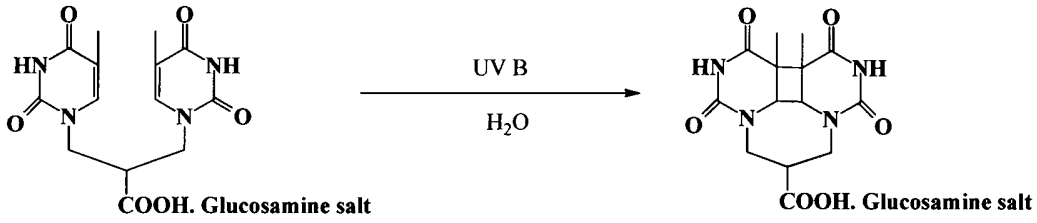
A solution of **15** (0.052g, 0.148 mmol) was dissolved in deionized water (100 mL, degassed) at 90 ^0C, allowed to cool to room temperature in a 500 mL Pyrex flask. A stream of nitrogen was bubbled throughout the cooling to room temperature. The solution was irradiated at 300 nm in a Rayonet RPR 208 reactor and the reaction was monitored for the absorption at 270 nm with a 50:1 aliquot test solution every 1 h until reaction was complete (6 h). The irradiation was stopped and the round bottom flask was ca. taken out of the reactor. The pH was adjusted to 9 with aq.$NaHCO_3$. $KMnO_4$ (10 mg, 1.3 eqv) was added and stirred at room temperature for 4-5 h. Saturated aq. NaSH (10 mL) precipitated MnO_2 which was removed by filtration. The carbonates in the filtrates were decomposed by careful addition of formic acid.

Concentration of the solution to 30 mL furnished the photodimer as a crude product which was recrystallized from water to give the white solid **22** (0.025 g, 48.07%). ^{1}H NMR (600 MHz, DMSO-d^6): δ 10.35 (s, 2H), 4.01 (d, 2H), 3.76 (d, 4H), 3.54 (s, 3H), 3.21 (m, 1H), 1.35 (s, 6H); ^{13}C NMR (150 MHz, DMSO-d^6): δ 173.21, 161.15, 151.35, 57.13, 40.45, 15.33, 15.28; Mass (ESI-MS): 351.25 (M+H).

Example 5: Preparation of salts **23** and **24**



17 **23**



18 **24**

A solution of DMAE salt of the acid, **17** (0.095g, 0.223 mmol) was dissolved in deionized water (100 mL, degassed) in a 500 mL Pyrex flask. A stream of nitrogen was bubbled throughout the cooling to room temperature. The solution was irradiated at 300 nm in a Rayonet RPR 208 reactor and the reaction was monitored for the absorption at 270 nm with a 50:1 aliquot test solution every 1 h until reaction was complete (6 h). The irradiation was stopped and the round bottom flask was ca. taken out of the reactor. The pH was adjusted to 9 with aq.$NaHCO_3$. $KMnO_4$ (10 mg, 1.3 eqv) was added and stirred at room temperature for 4-5 h. Saturated aq. NaSH (10 mL) precipitated MnO_2 which was removed by filtration. The carbonates in the filtrates were decomposed by careful addition of formic acid. Concentration of the solution to 30 mL furnished the photodimer as a crude product which was recrystallized from water to give the white solid **23** (0.054 g, 56.84%). ^{1}H NMR (600 MHz, DMSO-d^6): δ 10.22 (s,

2H), 4.22 (d, 2H), 3.97-3.86 (d, 4H), 3.76 (d, 4H), 3.54 (s, 3H), 3.21 (m, 1H), 3.11 (m, 1H), 2.61 (d, 2H), 2.47 (s, 6H), 1.31 (s, 6H); ^{13}C NMR (150 MHz, DMSO-d^6): δ 179.31, 161.60, 153.54, 59.13, 65.12, 59.10, 58.64, 52.34, 47.25, 46.67, 41.45, 14.31, 14.27; Mass (ESI-MS): 335.65 (M+H).

Compound **24** was prepared from the glucosamine salt of the acid (**18**) in following the procedure described for compound **23** in Scheme 9. ^{1}H NMR (600 MHz, DMSO-d^6): δ 11.23 (s, 2H), 5.54 (d, 1H), 4.22-3.95 (m , 1H), 4.11- 3.01 (m, 1H), 3.43 (d, 4H), 3.76 (m, 1H), 3.55 (m, 1H), 1.71 (s, 6H); ^{13}C NMR (150 MHz, DMSO-d^6): δ 178.35, 161.75, 152.34, 100.12, 59.33, 71.23, 74.24, 66.21, 65.23, 63.15, 59.56, 58.34, 57. 43, 52.71, 47.35, 46.61, 41.51, 14.23, 14.19; Mass (ESI-MS): 335.55 (M+H).

Example 6. The following illustrate representative pharmaceutical dosage forms, containing a compound of formula I ('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
Sodium chloride	4.5
1.0 N 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
1.0 N 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

Example 7. The following illustrates a representative dermatological formulation containing a compound as described in Formula I ('Compound X'), for therapeutic or prophylactic use in humans.

Cream: 2-12% Active ingredients (Compound X)
and 88-98% Inactive ingredients

Inactive Ingredients	**% (w/w)**
Water	64.90
Hexadecan-1-ol ($C_{16}H_{34}O$,Cetyl alcohol)	3.0
Octadecan-1-ol ($C_{18}H_{38}O$, Stearyl alcohol)	8.5
Isopropyl myristate ($C_{17}H_{34}O_2$)	1.0
Glycerine	0.2
Propylene glycol	20.0
Polysorbate 20 (TWEEN 20)	2.0
Isopropyl palmitate	0.2
Benzoic Acid	0.2
Total for inactive ingredients	**100.00**

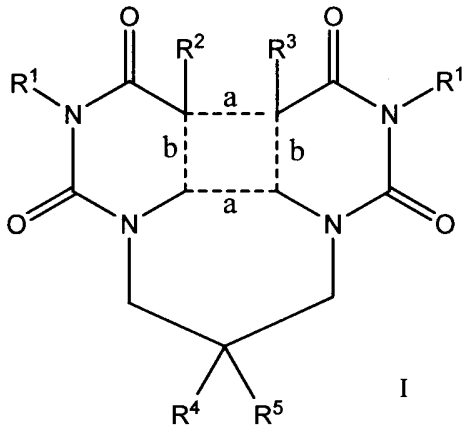
The above formulations may be obtained by conventional procedures well known in the pharmaceutical art.

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.

CLAIMS

What is claimed is:

1. A compound of formula I:



I

wherein:

each R^1 is independently H, $(C_1\text{-}C_6)$alkyl, $(C_3\text{-}C_7)$carbocycle or $R_aC(=O)$; or the two R^1 groups together form a $-(C_3\text{-}C_8)$alkyl- group, a $-(C_2\text{-}C_6)$alkyl-Y-$(C_2\text{-}C_6)$alkyl- group or a $-(C_1\text{-}C_6)$alkyl-Y'-$(C_1\text{-}C_6)$alkyl- group; or

the dashed bonds labeled "a" are absent and the dashed bonds labeled "b" are double bonds; or all the dashed bonds are single bonds;

R^2 is H, $(C_1\text{-}C_6)$alkyl or aryl, wherein aryl is optionally substituted with one or more (e.g. 1, 2, 3, 4 or 5) Z^1 groups;

R^3 is H, $(C_1\text{-}C_6)$alkyl or aryl, wherein aryl is optionally substituted with one or more (e.g. 1, 2, 3, 4 or 5) Z^1 groups;

R^4 is hydroxy, carboxy, $(C_1\text{-}C_6)$alkoxycarbonyl, $-OPO_3H_2$, $-OR_c$, or $-NR_dR_e$; and R^5 is H; or R^4 and R^5 taken together are oxo;

Y is O, S, NH, P, P(=O) or POH;

Y' is $Si(R_b)_2$ or $-Si(R_b)_2\text{-}O\text{-}Si(R_b)_2-$;

each R_a is independently $(C_1\text{-}C_6)$alkyl, $(C_3\text{-}C_7)$carbocycle or aryl, wherein aryl is optionally substituted with one or more (e.g. 1, 2, 3, 4 or 5) Z^1 groups;

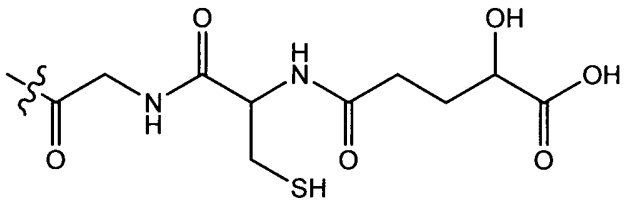
each R_b is independently $(C_1\text{-}C_6)$alkyl, $(C_3\text{-}C_7)$carbocycle or aryl, wherein aryl is optionally substituted with one or more (e.g. 1, 2, 3, 4 or 5) Z^1 groups;

R_c is R_f or a C_1-C_{20} saturated or C_2-C_{20} unsaturated carbon chain that is optionally substituted with one or more groups independently selected from oxo (=O), hydroxy, mercapto, (C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, (C_1-C_6)alkanoyloxy, NR_dR_e, carboxy, and aryl, wherein aryl is optionally substituted with one or more (e.g. 1, 2, 3, 4 or 5) Z^1 groups;

R_d is H, (C_1-C_6)alkyl, or (C_1-C_6)alkanoyl;

R_e is H or a C_1-C_{20} saturated or C_2-C_{20} unsaturated carbon chain that is optionally substituted with one or more groups independently selected from oxo (=O), hydroxy, mercapto, (C_1-C_6)alkoxy, (C_1-C_6)alkoxycarbonyl, (C_1-C_6)alkanoyloxy, NR_dR_e, carboxy, and aryl, wherein aryl is optionally substituted with one or more (e.g. 1, 2, 3, 4 or 5) Z^1 groups;

each R_f is:



;

each Z^1 is independently selected from (C_1-C_6)alkyl, halogen, -CN, -OR_{n1}, -$NR_{q1}R_{r1}$, -$NR_{n1}COR_{p1}$, -$NR_{n1}CO_2R_{p1}$, NO_2, -$C(O)R_{n1}$, -$C(O)OR_{n1}$ and -$C(O)NR_{q1}R_{r1}$, wherein any (C_1-C_6)alkyl of Z^1 is optionally substituted with one or more (e.g. 1, 2, 3, 4, 5 or 6) halogen;

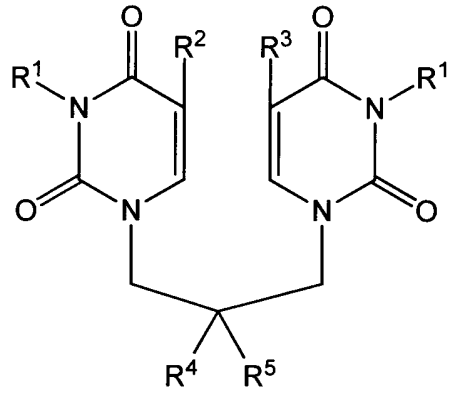
each R_{n1} is independently selected from H and (C_1-C_6)alkyl, wherein any (C_1-C_6)alkyl of R_{n1} is optionally substituted with one or more (e.g. 1, 2, 3, 4, 5 or 6) halogen;

each R_{p1} is independently (C_1-C_6)alkyl; and

R_{q1} and R_{r1} are each independently selected from H and (C_1-C_6)alkyl or R_{q1} and R_{r1} together with the nitrogen to which they are attached form a piperidine, pyrrolidine, morpholine, azetidine, thiomorpholine, piperazine or 4-methylpiperazine;

or a salt thereof.

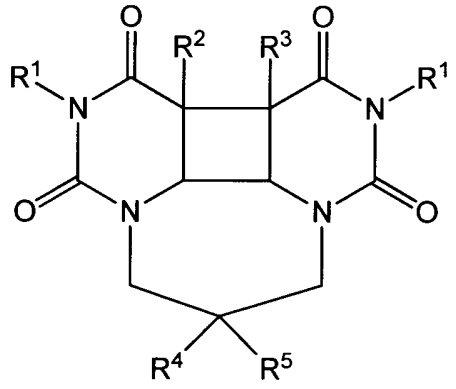
2. The compound of claim 1 which is a compound of formula Ia:



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 wherein each R^1 is independently H or $(C_1\text{-}C_6)$alkyl.

5. The compound of any one of claims 1-4 wherein Y is NH.

6. The compound of any one of claims 1-5 wherein each R^1 is H.

7. The compound of any one of claims 1-6 wherein R^2 and R^3 are each independently $(C_1\text{-}C_6)$alkyl.

8. The compound of any one of claims 1-7 wherein R^4 is hydroxyl.

9. The compound of any one of claims 1-7 wherein R^4 is carboxy.

10. The compound of any one of claims 1-7 wherein R^4 is $(C_1\text{-}C_6)$alkoxycarbonyl.

11. The compound of any one of claims 1-7 wherein R^4 is $-OPO_3H_2$.

12. The compound of any one of claims 1-7 wherein R^4 is $-OR_c$.

13. The compound of any one of claims 1-7 wherein R^4 is $-NR_dR_e$.

14. The compound of any one of claims 1-7 and 12 wherein R_c is a $C_1\text{-}C_{20}$ saturated or $C_2\text{-}C_{20}$ unsaturated alkanoyl group that is optionally substituted with one or more groups independently selected from oxo (=O), hydroxy, mercapto, $(C_1\text{-}C_6)$alkoxy, $(C_1\text{-}C_6)$alkoxycarbonyl, $(C_1\text{-}C_6)$alkanoyloxy, NR_dR_e, carboxy, and aryl.

15. The compound of any one of claims 1-7 and 12 wherein R_c is a $C_1\text{-}C_{20}$ saturated or $C_2\text{-}C_{20}$ unsaturated alkanoyl group that is optionally substituted with one or more groups independently selected from oxo (=O), hydroxy, mercapto, carboxy, and aryl, and R_f.

16. The compound of any one of claims 1-7 and 12 wherein R_c is R_f.

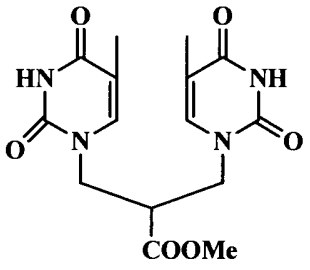
17. The compound of any one of claims 1-7 and 12 wherein R_c is butanoyl, hexadecanoyl, octadecanoyl, benzoyl, 3-phenylprop-2-enoyl, or 3-(4-methoxyphenyl)prop-2-enoyl.

18. The compound of any one of claims 1-7 and 13 wherein R_e is H or a $C_1\text{-}C_{20}$ saturated or $C_2\text{-}C_{20}$ unsaturated alkanoyl group that is optionally substituted with one or more groups independently selected from oxo (=O), hydroxy, mercapto, $(C_1\text{-}C_6)$alkoxy, $(C_1\text{-}C_6)$alkoxycarbonyl, $(C_1\text{-}C_6)$alkanoyloxy, NR_dR_e, carboxy, and aryl.

19. The compound of any one of claims 1-7 and 13 wherein R_e is a C_1-C_{20} saturated or C_2-C_{20} unsaturated alkanoyl group that is optionally substituted with one or more groups independently selected from oxo (=O), hydroxy, mercapto, carboxy, and aryl, and R_f.

20. The compound of any one of claims 1-7 and 13 wherein R_e is butanoyl, hexadecanoyl, octadecanoyl, benzoyl, 3-phenylprop-2-enoyl, or 3-(4-methoxyphenyl)prop-2-enoyl.

21. The compound of claim 1 which is selected from:



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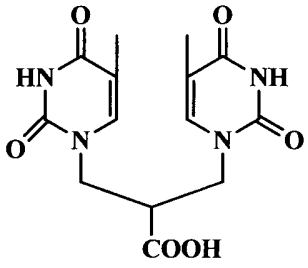

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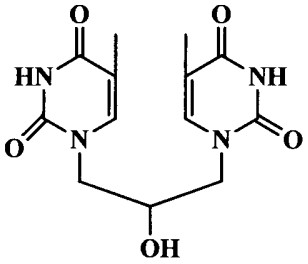

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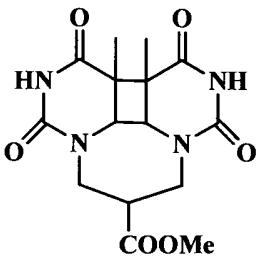

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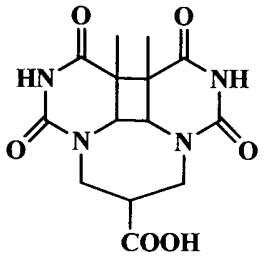

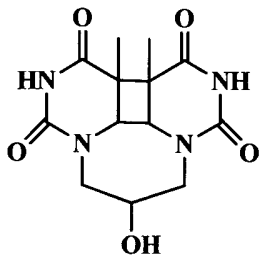

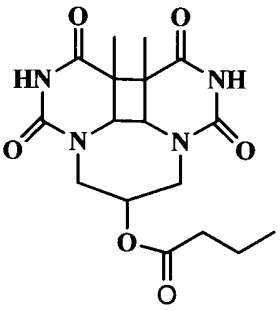

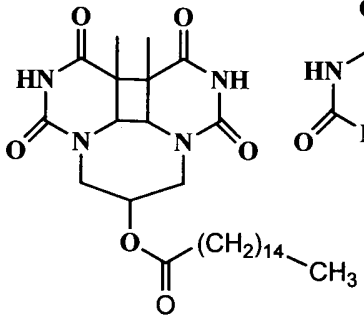

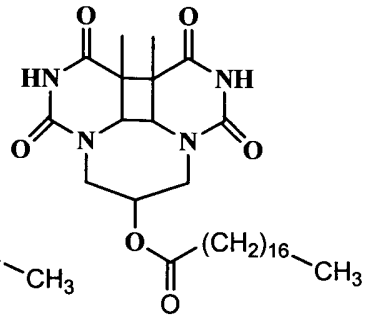

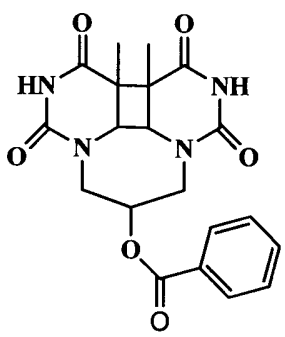

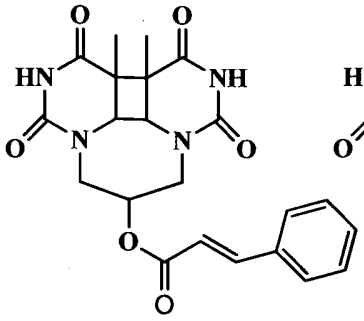

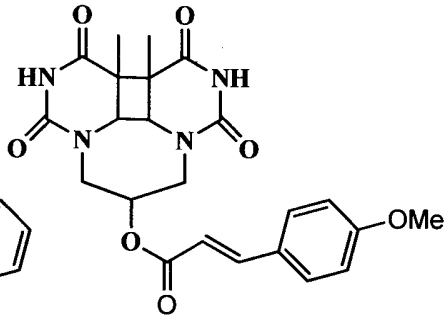
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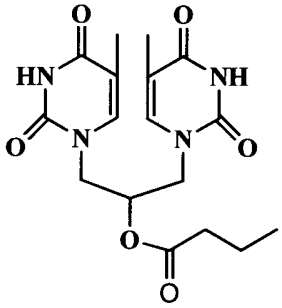

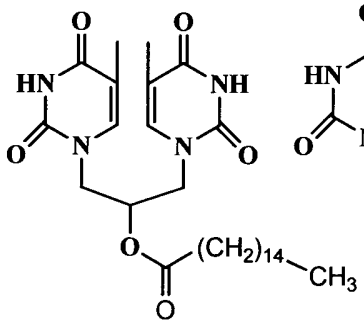
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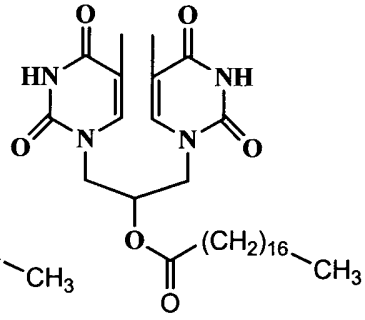
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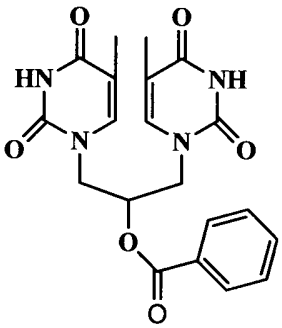

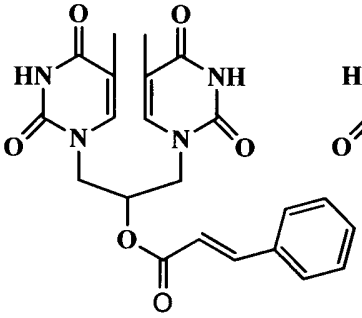

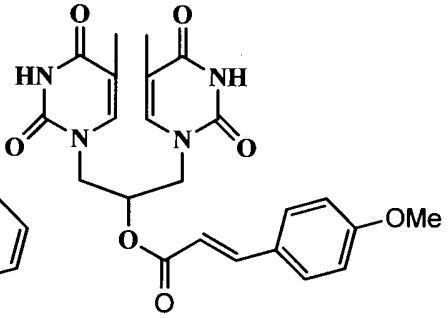
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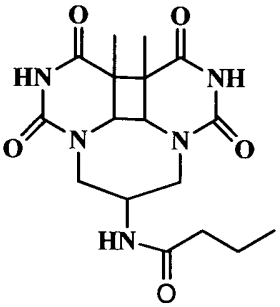

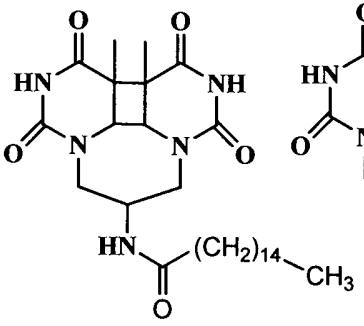
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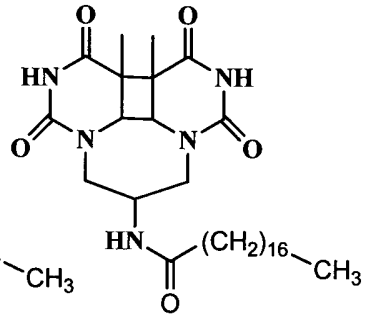
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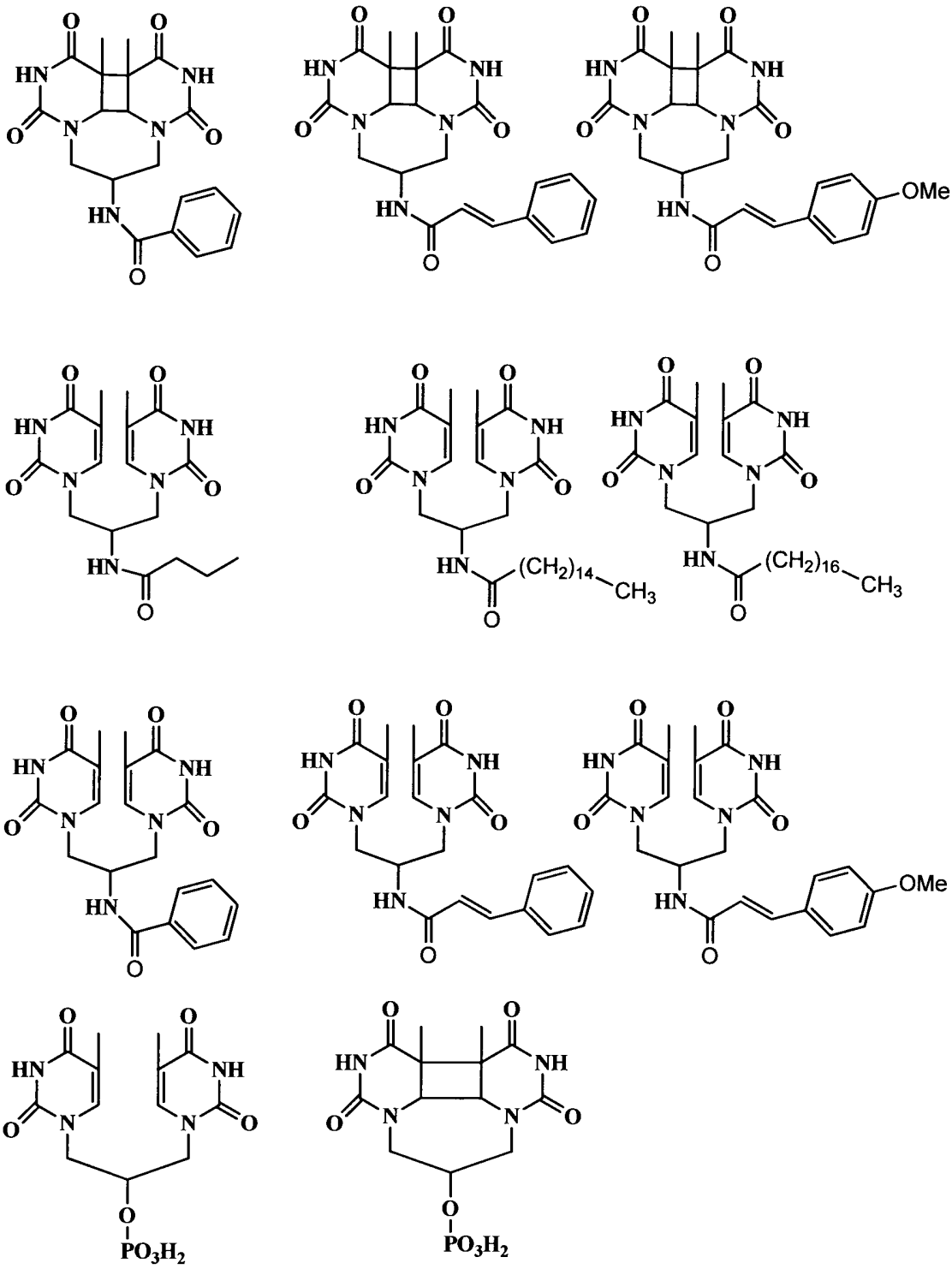
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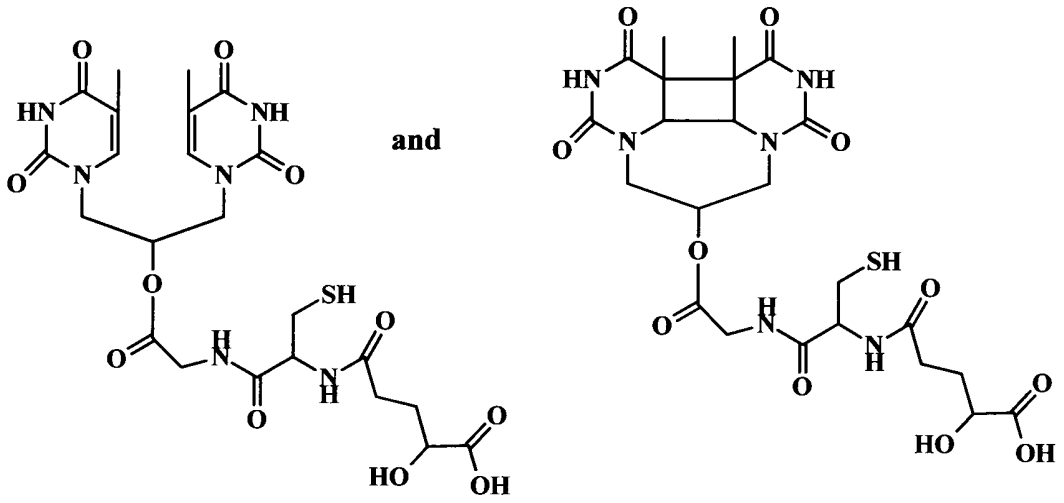
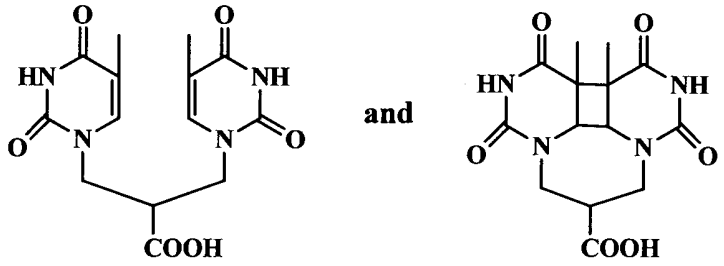


and salts thereof.

22. The compound of claim 1 which is selected from:



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and salts thereof.

23. The compound of claim 22 which is a salt with *N,N*-dimethylaminoethanol or glucosamine.

24. A composition comprising a compound of any one of claims 1-23 or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

25. A composition comprising a mixture of two or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, and a pharmaceutically acceptable carrier.

26. The composition of claim 24 or 25 for stimulating DNA repair in a mammal skin.

27. A method of protecting mammal skin from photo-damage comprising contacting the skin with one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, or a composition as described in any one of claims 24-25.

28. A method of protecting DNA in mammal skin from photo-damage comprising contacting the skin with one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, or a composition as described in any one of claims 24-25.

29. A method of repairing photo-damage in a mammal skin comprising contacting the skin with one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, or a composition as described in any one of claims 24-25.

30. A method of stimulating DNA repair in a mammal skin comprising contacting the skin with one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, or a composition as described in any one of claims 24-25.

31. A method of preventing skin cancer in mammal or reducing the likelihood of contracting skin cancer in a mammal comprising contacting the skin with one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, or a composition as described in any one of claims 24-25.

32. The method of claim 31 wherein the skin cancer is basal cell carcinoma or squamous cell carcinoma.

33. A method of reversing the signs of skin aging or preventing skin wrinkles in a mammal comprising contacting the skin with one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, or a composition as described in any one of claims 24-25.

34. A method of treating xeroderma pigmentosum in a mammal comprising contacting the skin with one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, or a composition as described in any one of claims 24-25.

35. The method of claim 34 wherein the mammal is being treated with an immunosuppressant agent.

36. The method of claim 35 wherein the immunosuppressant agent is a transplant rejection agent or an anti-HIV agent.

37. A method of treating or preventing ionizing radiation damage in a mammal comprising treating the mammal with one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, or a composition as described in any one of claims 24-25.

38. A compound as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, or a composition as described in any one of claims 24-25, for use in medical therapy.

39. The use of one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for protecting mammal skin from photo-damage.

40. The use of one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for protecting DNA in mammal skin from photo-damage.

41. The use of one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for repairing photo-damage in mammal skin.

42. The use of one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for stimulating DNA repair in mammal skin.

43. The use of one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for preventing skin cancer or reducing the likelihood of developing skin cancer in a mammal.

44. The use of claim 43 wherein the skin cancer is basal cell carcinoma or squamous cell carcinoma.

45. The use of one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for reversing the signs of skin aging or preventing skin wrinkles in a mammal.

46. The use of one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for treating xeroderma pigmentosum in a mammal.

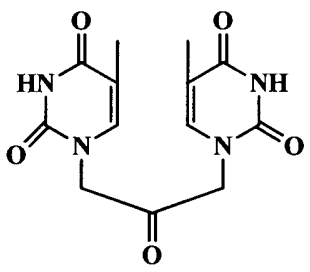
47. The use of claim 46 wherein the mammal being treated for xerdoma pigmentosum is also being treated with an immunosuppressant agent.

48. The use of claim 47 wherein the immunosuppressant agent is a transplant rejection agent or an anti-HIV agent.

49. The use of one or more compounds as described in any one of claims 1-23 or pharmaceutically acceptable salts thereof, for the manufacture of a medicament useful for

treating or preventing ionizing radiation damage in a mammal.

50. The compound of any one of claims 1-23 which is not:



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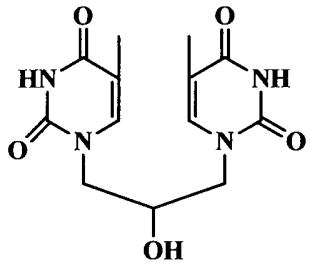
or



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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/064656

A. CLASSIFICATION OF SUBJECT MATTER
INV. C07D487/04
ADD. A61P17/00 A61K31/517

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C07D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, CHEM ABS Data, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	RAJCHEL, ANDRZEJ; GOLANKIEWICZ, KRZYSZTOF: "Photodimers derived from 5-alkyluracils linked in 1,1'-positions with propanone", POLISH JOURNAL OF CHEMISTRY, vol. 54, no. 1, 1980, pages 123-120, XP9174830, page 123; table 2 -----	1-21, 24-49
X	KOZIOL, ANNA E.; RAJCHEL, ANDRZEJ: "A cis-syn photodimer of thymine: thy[1(CH2-CHOH-CH2)1']thy", ACTA CRYSTALLOGRAPHICA, SECTION B: STRUCTURAL CRYSTALLOGRAPHY AND CRYSTAL CHEMISTRY, vol. B38, no. 3, 1982, pages 999-1001, XP002717416, page 1000; figure 1 -----	1-21, 24-49

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[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 December 2013	17/12/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Menegaki, Fotini

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/064656

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ITAHARA ET AL: "NMR and UV Study of 1,1'-([alpha],[omega]-Alkanediyl)bis[thymine] and 1,1'-([alpha],[omega]-Alkanediyl)bis[uracil]", BULLETIN OF THE CHEMICAL SOCIETY OF JAPAN, CHEMICAL SOCIETY OF JAPAN, TOKYO, JP, vol. 70, no. 9, 1 January 1997 (1997-01-01), pages 2239-2248, XP009169314, ISSN: 0009-2673 page 2240; table 3; compound 5a -----	1-50
A	ZARNOWSKI J ET AL: "Base-base interaction in nucleic acids. VII. NMR properties of 1,1'-polymethylenebispyrimidine derivatives with bulky substituents", BULLETIN DE L'ACADEMIE POLONAISE DE SCIENCES. SERIE DESSCIENCES CHIMIQUES, WARSZAW, PL, vol. 22, no. 2, 1 January 1974 (1974-01-01), pages 123-128, XP009169407, ISSN: 0001-4095 tables I, II -----	1-50