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(54) Title: CHEMICAL COMPOUNDS

(57) Abstract: Compounds of the general structural formula and use of the compounds and salts and solvates thereof, as therapeutic agents.

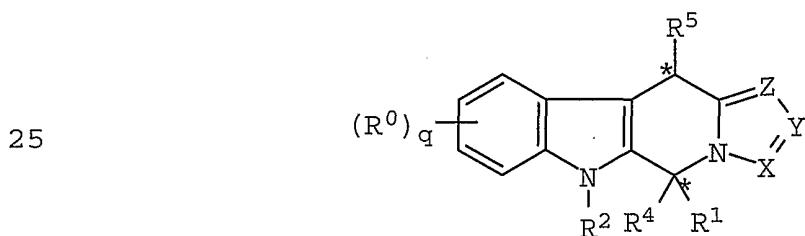
CHEMICAL COMPOUNDS

FIELD AND BACKGROUND OF THE INVENTION

5 This invention relates to a series of compounds, to methods of preparing the compounds, to pharmaceutical compositions containing the compounds, and to their use as therapeutic agents. In particular, the invention relates to compounds that
10 are potent and selective inhibitors of cyclic guanosine 3',5'-monophosphate specific phosphodiesterase (cGMP-specific PDE), in particular PDE5, and have utility in a variety of therapeutic areas wherein such inhibition is considered beneficial, including
15 the treatment of cardiovascular disorders and erectile dysfunction.

SUMMARY OF THE INVENTION

20 The present invention provides compounds of formula (I)



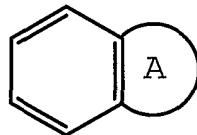
30 wherein R^0 , independently, is selected from the group consisting of halo, C_{1-6} alkyl, aryl, heteroaryl, C_{3-8} cycloalkyl, C_{3-8} heterocycloalkyl, C_{3-8} -cycloalkyl Q , $C(=O)R^a$, $OC(=O)R^a$, $C(=O)OR^a$, C_{1-4} alkylene- NR^aR^b , C_{1-4} alkylene Het , C_{1-4} alkylene $C(=O)OR^a$, $C(=O)-$

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NR^aSO₂R^c, C(=O)C₁₋₄alkyleneHet, C(=O)NR^aR^b, C(=O)NR^aR^c,
 C(=O)NR^aC₁₋₄alkyleneOR^b, C(=O)NR^aC₁₋₄alkyleneHet, OR^a,
 OC₁₋₄alkyleneC(=O)OR^a, OC₁₋₄alkyleneNR^aR^b, OC₁₋₄alkylene-
 Het, OC₁₋₄alkyleneOR^a, OC₁₋₄alkyleneNR^aC(=O)OR^b, NR^aR^b,
 5 NR^aC₁₋₄alkyleneNR^aR^b, NR^aC(=O)R^b, NR^aC(=O)NR^aR^b,
 N(SO₂C₁₋₄alkyl)₂, NR^a(SO₂C₁₋₄alkyl), nitro, trifluoro-
 methyl, trifluoromethoxy, cyano, SO₂NR^aR^b, SO₂R^a, SOR^a,
 SR^a, and OSO₂CF₃;

10 R¹ is selected from the group consisting of
 optionally substituted aryl, optionally substituted
 heteroaryl, an optionally substituted C₃₋₈cycloalkyl
 ring, an optionally substituted C₃₋₈heterocycloalkyl
 ring, an optionally substituted bicyclic ring

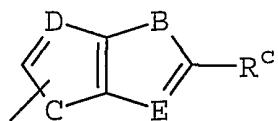
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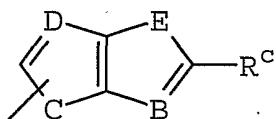
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wherein the fused ring A is a 5- or 6-membered ring,
 saturated or partially or fully unsaturated, and
 comprises carbon atoms and optionally one to three
 heteroatoms selected from oxygen, sulfur, and
 25 nitrogen, hydrogen, C₁₋₆alkyl, arylC₁₋₃alkyl, C₁₋₃-
 alkylenearyl, haloC₁₋₆alkyl, C₁₋₄alkyleneC(=O)OR^a,
 C₁₋₄alkyleneC(=O)NR^aR^b, C₃₋₈cycloalkyl, C₃₋₈cycloalkenyl,
 C₃₋₈heterocycloalkenyl, C₁₋₄alkyleneHet, C₁₋₄alkylene-
 QR^a, C₂₋₆alkenyleneQR^a, C₁₋₄alkyleneQC₁₋₄alkyleneQR^a,
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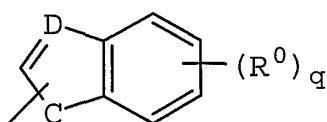
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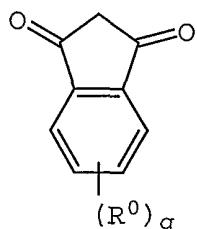
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and a spiro substituent having the structure

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R^2 is selected from the group consisting of hydrogen, C_{1-6} alkyl, C_{3-8} cycloalkyl, C_{3-8} heterocycloalkyl, C_{2-6} alkenyl, C_{1-3} alkylenearyl, aryl C_{1-3} alkyl, $C(=O)R^a$, aryl, heteroaryl, $C(=O)R^a$, $C(=O)NR^aR^b$, $C(=O)-NR^aR^c$, $C(=S)NR^aR^b$, $C(=S)NR^aR^c$, SO_2R^a , $SO_2NR^aR^b$, $S(=O)R^a$, $S(=O)NR^aR^b$, $C(=O)NR^aC_{1-4}$ alkyleneOR^a, $C(=O)NR^aC_{1-4}$ alkyl-eneHet, $C(=O)C_{1-4}$ alkylenearyl, $C(=O)C_{1-4}$ alkylene-

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heteroaryl, C_{1-4} alkylenearyl substituted with one or more of $SO_2NR^aR^b$, NR^aR^b , $C(=O)OR^a$, $NR^aSO_2CF_3$, CN , NO_2 , $(C(=O)R^a$, OR^a , C_{1-4} alkylene NR^aR^b , and OC_{1-4} alkylene NR^aR^b , C_{1-4} alkyleneheteroaryl, C_{1-4} alkyleneHet, C_{1-4} alkylene $C(=O)C_{1-4}$ alkylenearyl, C_{1-4} alkylene $C(=O)C_{1-4}$ alkylene-
heteroaryl, C_{1-4} alkylene $C(=O)Het$, C_{1-4} alkylene $C(=O)NR^aR^b$, C_{1-4} alkylene $NR^aC(=O)R^a$, C_{1-4} alkylene OC_{1-4} alkylene OR^a , C_{1-4} alkylene NR^aR^b , C_{1-4} alkylene $C(=O)OR^a$, and C_{1-4} alkylene OC_{1-4} alkylene $C(=O)OR^a$;

10 X , Y , and Z , independently, are selected from N and CR^3 ;

15 R^3 , independently, is selected from the group consisting of hydrogen, C_{1-10} alkyl, C_{2-10} alkenyl, C_{2-10} alkynyl, aryl, heteroaryl, aryl C_{1-3} alkyl, C_{1-3} alkylenearyl, $C(=O)OR^a$, $C(=O)NR^aR^c$, aryl, C_{1-4} alkylene NR^aR^b , halo, NO_2 , CF_3 , CF_3O , OR^a , $OC(=O)R^a$, OC_{1-4} alkylene $C(=O)OR^a$, C_{1-4} alkylene OC_{1-4} alkylene $C(=O)OR^a$, $C(=O)NR^aSO_2R^c$, $C(=O)C_{1-4}$ alkyleneHet, C_{2-6} alkenylene NR^aR^b , $C(=O)NR^aC_{1-4}$ alkylene OR^b , $C(=O)NR^aC_{1-4}$ alkyleneHet, OC_{2-4} alkylene NR^aR^b , OC_{1-4} alkylene $CH(OR^a)CH_2NR^aR^b$, OC_{2-4} alkylene NR^aOR^a , OC_{2-4} alkylene $NR^aC(=O)OR^b$, NR^aR^b , NR^aC_{1-4} alkylene NR^aR^b , $NR^aC(=O)R^b$, $NR^aC(=O)NR^aR^b$, $N(SO_2C_{1-4}$ alkyl) $_2$, $NR^a(SO_2C_{1-4}$ alkyl), $SO_2NR^aR^b$, OSO_2 trifluoromethyl, $C(=O)R^a$, C_{1-3} alkylene OR^a , CN , and C_{1-6} alkylene $C(=O)OR^a$;

25 R^4 and R^5 , independently, are selected from the group consisting of hydrogen, C_{1-6} alkyl, aryl, heteroaryl, aryl C_{1-3} alkyl, C_{1-3} alkylenearyl, C_{1-3} alkyleneHet, C_{3-8} cycloalkyl, and C_{3-8} heterocycloalkyl;

30 R^a is selected from the group consisting of hydrogen, C_{1-6} alkyl, aryl, aryl C_{1-3} alkyl, C_{1-3} alkylenearyl, heteroaryl, heteroaryl C_{1-3} alkyl, and C_{1-3} alkyleneheteroaryl;

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R^b is selected from the group consisting of hydrogen, C_{1-6} alkyl, C_{3-8} cycloalkyl, C_{1-3} alkyleneN(R^a)₂, aryl, aryl C_{1-3} alkyl, C_{1-3} alkylenearyl, and heteroaryl;

R^c is selected from the group consisting of 5 hydrogen, C_{1-6} alkyl, aryl, heteroaryl, aryl C_{1-3} alkyl, heteroaryl C_{1-3} alkyl, C_{1-3} alkyleneN(R^a)₂, C_{1-6} alkylene-aryl, C_{1-6} alkyleneHet, halo C_{1-6} alkyl, C_{3-8} cycloalkyl, C_{3-8} heterocycloalkyl, Het, C_{1-3} alkyleneheteroaryl, C_{1-6} alkyleneC(=O)OR^a, and C_{1-3} alkyleneC₃₋₈heterocyclo-10 alkyl;

or R^a and R^c are taken together to form a 5- or 6-membered ring, optionally containing at least one heteroatom;

R^d is null or is selected from the group 15 consisting of hydrogen, C_{1-6} alkyl, aryl, heteroaryl, aryl C_{1-3} alkyl, heteroaryl C_{1-3} alkyl, C_{1-3} alkylenearyl, and C_{1-3} alkyleneheteroaryl;

Q is O, S, or NR^a;

B is O, S, or NR^d;

20 C is O, S, or NR^a;

D is CR^a or N;

E is CR^a, C(R^a)₂, or NR^d; and

25 Het represents a 5- or 6-membered heterocyclic ring, saturated or partially or fully unsaturated, containing at least one heteroatom selected from the group consisting of oxygen, nitrogen, and sulfur, and optionally substituted with C_{1-4} alkyl or C(=O)OR^a;

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

30 pharmaceutically acceptable salts and hydrates thereof.

As used herein, the term "alkyl" includes straight chained and branched hydrocarbon groups

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containing the indicated number of carbon atoms, typically methyl, ethyl, and straight chain and branched propyl and butyl groups. The hydrocarbon group can contain up to 16 carbon atoms. The term 5 "alkyl" includes "bridged alkyl," i.e., a C₆-C₁₆ bicyclic or polycyclic hydrocarbon group, for example, norbornyl, adamantyl, bicyclo[2.2.2]octyl, bicyclo[2.2.1]heptyl, bicyclo[3.2.1]octyl, or decahydronaphthyl. The term "cycloalkyl" is defined as 10 a cyclic C₃-C₈ hydrocarbon group, e.g., cyclopropyl, cyclobutyl, cyclohexyl, and cyclopentyl.

The terms "alkenyl" and "alkynyl" are defined identically as "alkyl," except for containing a carbon-carbon double bond or carbon-carbon 15 triple bond, respectively. "Cycloalkenyl" is defined similarly to cycloalkyl, except a carbon-carbon double bond is present in the ring.

The term "alkylene" refers to an alkyl group having a substituent. For example, the term 20 "C₁₋₃alkylenearyl" refers to an alkyl group containing one to three carbon atoms, and substituted with an aryl group. The term "alkenylene" as used herein is similarly defined, and contains the indicated number of carbon atoms and a carbon-carbon double 25 bond, and includes straight chained and branched alkenylene groups, like ethylenylene.

The term "halo" or "halogen" is defined herein to include fluorine, bromine, chlorine, and iodine.

30 The term "haloalkyl" is defined herein as an alkyl group substituted with one or more halo substituents, either fluoro, chloro, bromo, iodo, or combinations thereof. Similarly, "halocycloalkyl"

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is defined as a cycloalkyl group having one or more halo substituents.

The term "aryl," alone or in combination, is defined herein as a monocyclic or polycyclic aromatic group, preferably a monocyclic or bicyclic aromatic group, e.g., phenyl or naphthyl. Unless otherwise indicated, an "aryl" group can be unsubstituted or substituted, for example, with one or more, and in particular one to three, halo, alkyl, 5 hydroxyalkyl, alkoxy, alkoxyalkyl, haloalkyl, nitro, amino, alkylamino, acylamino, alkylthio, alkylsulfinyl, and alkylsulfonyl. Exemplary aryl groups include phenyl, naphthyl, tetrahydronaphthyl, 2-chlorophenyl, 3-chlorophenyl, 4-chlorophenyl, 2-10 methylphenyl, 4-methoxyphenyl, 3-trifluoromethylphenyl, 4-nitrophenyl, and the like. The terms "arylC₁₋₃alkyl" and "heteroarylC₁₋₃alkyl" are defined as an aryl or heteroaryl group having a C₁₋₃alkyl substituent.

20 The term "heteroaryl" is defined herein as a monocyclic or bicyclic ring system containing one or two aromatic rings and containing at least one nitrogen, oxygen, or sulfur atom in an aromatic ring, and which can be unsubstituted or substituted, 25 for example, with one or more, and in particular one to three, substituents, like halo, alkyl, hydroxy, hydroxyalkyl, alkoxy, alkoxyalkyl, haloalkyl, nitro, amino, alkylamino, acylamino, alkylthio, alkylsulfinyl, and alkylsulfonyl. Examples of heteroaryl groups include thienyl, furyl, pyridyl, oxazolyl, 30 quinolyl, isoquinolyl, indolyl, triazolyl, isothiazolyl, isoxazolyl, imidizolyl, benzothiazolyl, pyrazinyl, pyrimidinyl, thiazolyl, and thiadiazolyl.

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The term "Het" is defined as monocyclic, bicyclic, and tricyclic groups containing one or more heteroatoms selected from the group consisting of oxygen, nitrogen, and sulfur. A "Het" group also 5 can contain an oxo group (=O) attached to the ring. Nonlimiting examples of Het groups include 1,3-dioxolane, 2-pyrazoline, pyrazolidine, pyrrolidine, piperazine, a pyrroline, 2H-pyran, 4H-pyran, morpholine, thiopholine, piperidine, 1,4-dithiane, and 10 1,4-dioxane.

The term "hydroxy" is defined as -OH.

The term "alkoxy" is defined as -OR, wherein R is alkyl.

15 The term "alkoxyalkyl" is defined as an alkyl group wherein a hydrogen has been replaced by an alkoxy group.

The term "hydroxyalkyl" is defined as a hydroxy group appended to an alkyl group.

20 The term "amino" is defined as -NH₂, and the term "alkylamino" is defined as -NR₂, wherein at least one R is alkyl and the second R is alkyl or hydrogen.

The term "acylamino" is defined as RC(=O)N, wherein R is alkyl or aryl.

25 The term "alkylthio" is defined as -SR, wherein R is alkyl.

The term "alkylsulfinyl" is defined as R-SO₂, wherein R is alkyl.

30 The term "alkylsulfonyl" is defined as R-SO₃, wherein R is alkyl.

The term "nitro" is defined as -NO₂.

The term "trifluoromethyl" is defined as -CF₃.

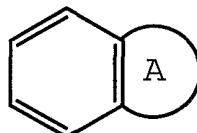
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The term "trifluoromethoxy" is defined as -OCF₃.

The term "cyano" is defined as -CN.

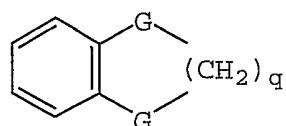
In a preferred embodiment, R⁰ is selected from the group consisting of aryl, Het, OR^a, C(=O)-OR^a, C₁₋₄alkyleneNR^aR^b, OC(=O)R^a, C(=O)R^a, NR^aR^b, C₃₋₈cycloalkyl, C₃₋₈cycloalkylQ, C(=O)NR^aR^b, and C(=O)-NR^aR^c, or two R⁰ groups are taken together with the carbon atoms to which they are attached to form a 5- or 6-membered ring, saturated or partially or fully saturated, optionally substituted and optionally containing one or two heteroatoms selected from oxygen, nitrogen, and sulfur.

In a preferred group of compounds of formula (I), R¹ is represented by



20

wherein the bicyclic ring can represent, for example, naphthalene or indene, or a heterocycle, such as benzoxazole, benzothiazole, benzisoxazole, benzimidazole, quinoline, indole, benzothiophene, or benzofuran, or



30

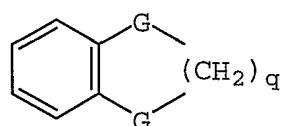
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wherein q is an integer 1 or 2, and G, independently, is $C(R^a)_2$, O, S, or NR^a . The bicyclic ring comprising the R^1 substituent typically is attached to the rest of the molecule by a phenyl ring carbon atom.

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In another preferred group of compounds of formula (I), R^1 is represented by an optionally substituted bicyclic ring

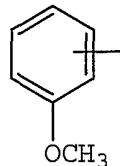
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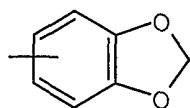
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wherein q is 1 or 2, and G, independently, are $C(R^a)_2$ or O. Especially preferred R^1 substituents include

20

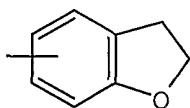


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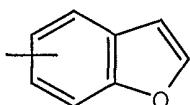
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, and



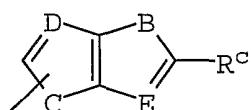
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Within this particular group of compounds, nonlimiting examples of substituents for the bicyclic ring include halogen (e.g., chlorine), C₁₋₃alkyl (e.g., methyl, ethyl, or i-propyl), OR^a (e.g., methoxy, ethoxy, or hydroxy), CO₂R^a, halomethyl or halomethoxy (e.g., trifluoromethyl or trifluoromethoxy), cyano, nitro, and NR^aR^b.

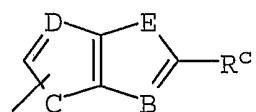
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In other preferred embodiments, R¹ is optionally substituted and selected from the group consisting of C₁₋₄alkyleneQR^a, C₁₋₄alkyleneQC₁₋₄alkyleneQR^a, C₃₋₈cycloalkyl, C₃₋₈cycloalkenyl, C₁₋₆alkyl,

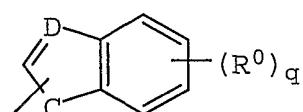
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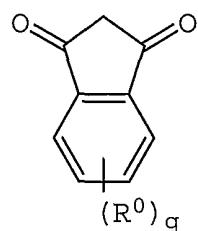
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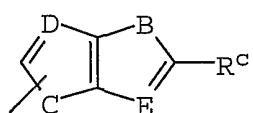
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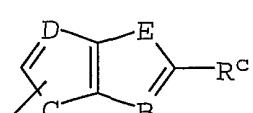
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In a more preferred group of compounds of formula (I), R^1 is represented by

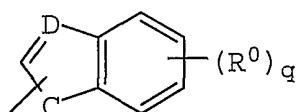


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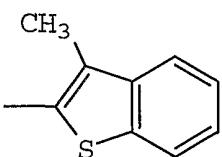


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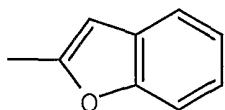
C_{3-8} cycloalkyl, C_{3-8} cycloalkenyl, C_{1-6} alkyl, C_{1-4} alkyl-
eneQR^a, and C_{1-4} alkyleneQC₁₋₄alkyleneQR^a. A preferred
Q is oxygen.

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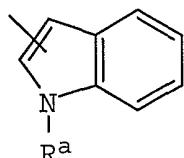
Some preferred R¹ substituents are



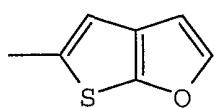
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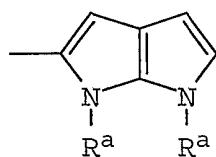


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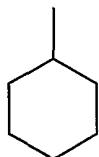
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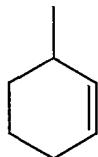
-CH₂OR^a, -CH₂OCH₂OR^a,

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, and

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Within this particular group of compounds, preferred R^a substituents include hydrogen, C₁₋₆alkyl, and benzyl.

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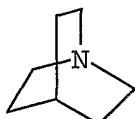
In a preferred embodiment, R² is selected from the group consisting of aryl, heteroaryl, OR^a, NR^aR^b, NR^aR^c, C₁₋₄alkyleneHet, C₁₋₄alkyleneheteroaryl, C₁₋₄alkylenearyl, C₁₋₄alkyleneC(=O)C₁₋₄alkylenearyl, C₁₋₄alkyleneC(=O)OR^a, C₁₋₄alkyleneC(=O)NR^aR^b, C₁₋₄alkyleneC(=O)NR^aR^c, C₁₋₄alkyleneC(=O)Het, C₁₋₄alkyleneNR^aR^b, C₁₋₄alkyleneNR^aR^c, C₁₋₄alkyleneNR^aC(=O)R^a, and C₁₋₄alkyleneOC₁₋₄alkyleneOR^a.

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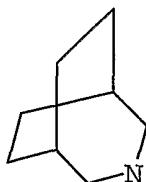
In more preferred embodiments, R^2 is selected from the group consisting of C_{1-4} alkylene-heteroaryl, wherein the heteroaryl group is selected from the group consisting of benzimidazole, a tri-5 azole, and imidazole; C_{1-4} alkyleneHet, wherein Het is selected from the group consisting of piperazine, morpholine, pyrrolidine, pyrrolidone, tetrahydrofuran, piperidine,

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, and

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;

C_{1-4} alkylene C_6H_5 , optionally substituted with one to three groups selected from the group consisting of $C(=O)OR^a$, NR^aR^b , $NR^aSO_2CF_3$, $SO_2NR^aR^b$, CN , OR^a , $C(=O)R^a$, C_{1-4} alkylene NR^aR^b , nitro, OC_{1-4} alkylenearyl, and OC_{1-4} alkylene NR^aR^b ; C_{1-4} alkylene $C(=O)benzyl$; C_{1-4} alkylene $C(=O)OR^a$; C_{1-4} alkylene $C(=O)NR^aR^b$; C_{1-4} alkylene $C(=O)NR^aR^c$; NR^aR^b ; OH ; OC_{1-4} alkyl; C_6H_5 ; C_{1-4} alkylene NR^aR^b ; C_{1-4} alkylene OR^a ; C_{1-4} alkylene $NHC(=O)R^a$; and C_{1-4} alkylene- OC_{1-4} alkylene OR^a .

In preferred embodiments, R^3 is selected from the group consisting of C_{1-6} alkyl, $C(=O)OR^a$, C_{1-4} alkylene $C(=O)OR^a$, CN , C_{1-4} alkylene NR^aR^b , $C(=O)R^a$,

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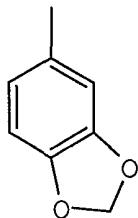
hydrogen, $C(=O)NR^aC_{1-4}$ alkyleneHet, C_{1-4} alkyleneOR^a, CF_3 , $C(=O)NR^aR^c$, aryl, and heteroaryl.

In preferred embodiments, R⁴ and R⁵, independently, are hydrogen, C₁₋₆alkyl, aryl, or heteroaryl.

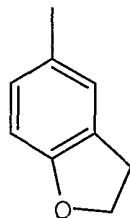
In especially preferred embodiments, R⁰ is selected from the group consisting of halo, methyl, trifluoromethyl, and trifluoromethoxy; R¹ is selected from the group consisting of

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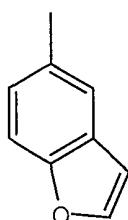
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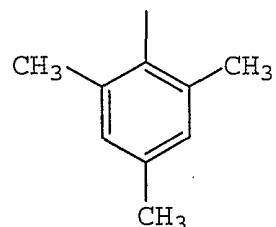
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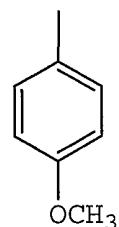
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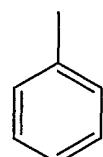
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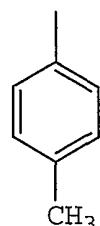
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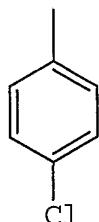
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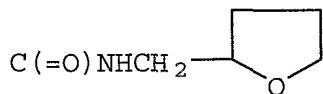
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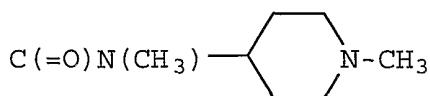
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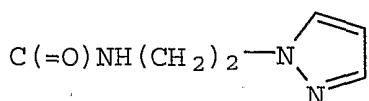
10 R^2 is selected from the group consisting of hydrogen, C_{1-6} alkyl, $C(=O)NR^aR^c$, and C_{1-4} alkyleneHet; R^3 is selected from the group consisting of $C(=O)OC_2H_5$, CH_3 , CN , $(CH_2)_4C(=O)OH$, $C(=O)OCH_3$, $CH_2NHCH_2C_6H_5$, CH_2NH_2 , CHO , H , C_2H_5 , $CH(CH_3)_2$, CH_2OH , $C(=O)NH(CH_2)_2N(CH_3)_2$,
 15 $C(=O)N(CH_3)CH_2CO_2H$,



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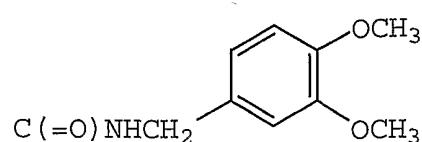
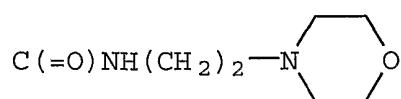
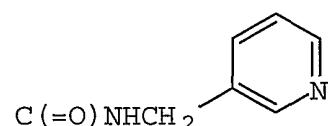
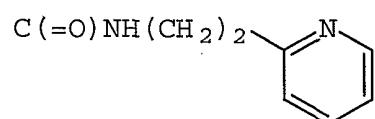
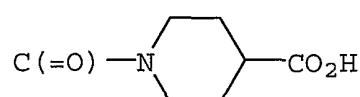
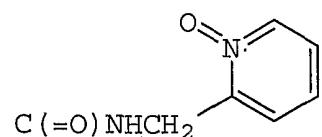


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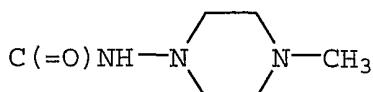
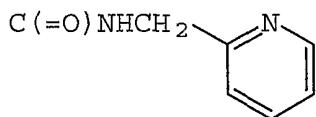


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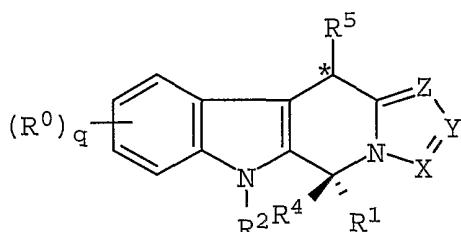
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$\text{C}(\text{=O})\text{NH}(\text{CH}_2)_2\text{NH}_2$, $\text{CH}_2\text{N}(\text{CH}_3)_2$, and $\text{C}(\text{=O})\text{NH}_2$; R^4 and R^5 are selected from the group consisting of hydrogen and C_{1-6} alkyl; and $=\text{Z}-\text{Y}=\text{X}-$ is selected from the group consisting of $=\text{C}(\text{R}^3)-\text{C}(\text{R}^3)=\text{CR}^3-$, $=\text{C}(\text{R}^3)-\text{N}=\text{CR}^3-$, $=\text{C}(\text{R}^3)-\text{N}=\text{N}-$, and $=\text{N}-\text{C}(\text{R}^3)=\text{C}(\text{R}^3)-$.

An especially preferred subclass of compounds within the general scope of formula (I) is represented by compounds of formula (II)

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(II)

and pharmaceutically acceptable salts and solvates (e.g., hydrates) thereof.

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Compounds of formula (I) can contain one or more asymmetric center, and, therefore, can exist as stereoisomers. The present invention includes both mixtures and separate individual stereoisomers

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of the compounds of formula (I). Compounds of formula (I) also can exist in tautomeric forms, and the invention includes both mixtures and separate individual tautomers thereof.

5 Pharmaceutically acceptable salts of the compounds of formula (I) can be acid addition salts formed with pharmaceutically acceptable acids. Examples of suitable salts include, but are not limited to, the hydrochloride, hydrobromide, sulfate, bisulfate, phosphate, hydrogen phosphate, acetate, benzoate, succinate, fumarate, maleate, lactate, citrate, tartrate, gluconate, methanesulfonate, benzenesulfonate, and p-toluenesulfonate salts. The compounds of formula (I) also can provide pharmaceutically acceptable metal salts, in particular alkali metal salts and alkaline earth metal salts, with bases. Examples include the sodium, potassium, magnesium, and calcium salts.

10 Compounds of the present invention are potent and selective inhibitors of cGMP-specific PDE5. Thus, compounds of formula (I) are of interest for use in therapy, specifically for the treatment of a variety of conditions where selective inhibition of PDE5 is considered to be beneficial.

15 Phosphodiesterases (PDEs) catalyze the hydrolysis of cyclic nucleotides, such as cyclic adenosine monophosphate (cAMP) and cyclic guanosine monophosphate (cGMP). The PDEs have been classified into at least seven isoenzyme families and are present in many tissues (J.A. Beavo, *Physiol. Rev.*, 75, p. 725 (1995)).

20 PDE5 inhibition is a particularly attractive target. A potent and selective inhibitor of

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PDE5 provides vasodilating, relaxing, and diuretic effects, all of which are beneficial in the treatment of various disease states. Research in this area has led to several classes of inhibitors based 5 on the cGMP basic structure (E. Sybertz et al., *Expert. Opin. Ther. Pat.*, 7, p. 631 (1997)).

The biochemical, physiological, and clinical effects of PDE5 inhibitors therefore suggest their utility in a variety of disease states in 10 which modulation of smooth muscle, renal, hemostatic, inflammatory, and/or endocrine function is desirable. The compounds of formula (I), therefore, have utility in the treatment of a number of disorders, including stable, unstable, and variant 15 (Prinzmetal) angina, hypertension, pulmonary hypertension, congestive heart failure, acute respiratory distress syndrome, acute and chronic renal failure, atherosclerosis, conditions of reduced blood vessel patency (e.g., postpercutaneous transluminal coronary or carotid angioplasty, or post-bypass surgery graft stenosis), peripheral vascular disease, vascular disorders, such as Raynaud's disease, thrombocythemia, inflammatory diseases, stroke, bronchitis, chronic asthma, allergic asthma, allergic rhinitis, 20 glaucoma, osteoporosis, preterm labor, benign prostatic hypertrophy, peptic ulcer, male erectile dysfunction, female sexual dysfunction, and diseases 25 characterized by disorders of gut motility (e.g., irritable bowel syndrome).

An especially important use is the treatment of male erectile dysfunction, which is one form of impotence and is a common medical problem. Impotence can be defined as a lack of power, in the 30

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male, to copulate, and can involve an inability to achieve penile erection or ejaculation, or both.

The incidence of erectile dysfunction increases with age, with about 50% of men over the age of forty suffering from some degree of erectile dysfunction.

In addition, a further important use is the treatment of female arousal disorder. Female arousal disorders are defined as a recurrent inability to attain or maintain an adequate lubrication/swelling response of sexual excitement until completion of sexual activity. The arousal response consists of vasocongestion in the pelvis, vaginal lubrication, and expansion and swelling of external genitalia.

It is envisioned, therefore, that compounds of formula (I) are useful in the treatment of male erectile dysfunction and female arousal disorder. Thus, the present invention concerns the use of compounds of formula (I), or a pharmaceutically acceptable salt thereof, or a pharmaceutical composition containing either entity, for the manufacture of a medicament for the curative or prophylactic treatment of erectile dysfunction in a male animal and arousal disorder in a female animal, including humans.

The term "treatment" includes preventing, lowering, stopping, or reversing the progression or severity of the condition or symptoms being treated. As such, the term "treatment" includes both medical therapeutic and/or prophylactic administration, as appropriate.

It also is understood that "a compound of formula (I)," or a physiologically acceptable salt

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or solvate thereof, can be administered as the neat compound, or as a pharmaceutical composition containing either entity.

5 Although the compounds of the invention are envisioned primarily for the treatment of sexual dysfunction in humans, such as male erectile dysfunction and female arousal disorder, they also can be used for the treatment of other disease states.

10 A further aspect of the present invention, therefore, is providing a compound of formula (I) for use in the treatment of stable, unstable, and variant (Prinzmetal) angina, hypertension, pulmonary hypertension, chronic obstructive pulmonary disease, congestive heart failure, acute respiratory distress 15 syndrome, acute and chronic renal failure, atherosclerosis, conditions of reduced blood vessel patency (e.g., post-PTCA or post-bypass graft stenosis), peripheral vascular disease, vascular disorders such as Raynaud's disease, thrombocythemia, inflammatory 20 diseases, prophylaxis of myocardial infarction, prophylaxis of stroke, stroke, bronchitis, chronic asthma, allergic asthma, allergic rhinitis, glaucoma, osteoporosis, preterm labor, benign prostatic 25 hypertrophy, male and female erectile dysfunction, or diseases characterized by disorders of gut motility (e.g., IBS).

30 According to another aspect of the present invention, there is provided the use of a compound of formula (I) for the manufacture of a medicament for the treatment of the above-noted conditions and disorders.

 In a further aspect, the present invention provides a method of treating the above-noted con-

- 25 -

ditions and disorders in a human or nonhuman animal body which comprises administering to said body a therapeutically effective amount of a compound of formula (I).

5 Compounds of the invention can be administered by any suitable route, for example by oral, buccal, inhalation, sublingual, rectal, vaginal, transurethral, nasal, topical, percutaneous, i.e., transdermal, or parenteral (including intravenous, 10 intramuscular, subcutaneous, and intracoronary) administration. Parenteral administration can be accomplished using a needle and syringe, or using a high pressure technique, like POWDERJECT™.

15 Oral administration of a compound of the invention is the preferred route. Oral administration is the most convenient and avoids the disadvantages associated with other routes of administration. For patients suffering from a swallowing disorder or from impairment of drug absorption after 20 oral administration, the drug can be administered parenterally, e.g., sublingually or buccally.

25 Compounds and pharmaceutical compositions suitable for use in the present invention include those wherein the active ingredient is administered in an effective amount to achieve its intended purpose. More specifically, a "therapeutically effective amount" means an amount effective to prevent development of, or to alleviate the existing symptoms of, the subject being treated. Determination 30 of the effective amounts is well within the capability of those skilled in the art, especially in light of the detailed disclosure provided herein.

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A "therapeutically effective dose" refers to that amount of the compound that results in achieving the desired effect. Toxicity and therapeutic efficacy of such compounds can be determined 5 by standard pharmaceutical procedures in cell cultures or experimental animals, e.g., for determining the LD₅₀ (the dose lethal to 50% of the population) and the ED₅₀ (the dose therapeutically effective in 50% of the population). The dose ratio between 10 toxic and therapeutic effects is the therapeutic index, which is expressed as the ratio between LD₅₀ and ED₅₀. Compounds which exhibit high therapeutic indices are preferred. The data obtained from such data can be used in formulating a range of dosage 15 for use in humans. The dosage of such compounds preferably lies within a range of circulating concentrations that include the ED₅₀ with little or no toxicity. The dosage can vary within this range depending upon the dosage form employed, and the 20 route of administration utilized.

The exact formulation, route of administration, and dosage can be chosen by the individual physician in view of the patient's condition. Dosage amount and interval can be adjusted individually to provide plasma levels of the active moiety 25 which are sufficient to maintain the therapeutic effects.

The amount of composition administered is dependent on the subject being treated, on the 30 subject's weight, the severity of the affliction, the manner of administration, and the judgment of the prescribing physician.

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Specifically, for administration to a human in the curative or prophylactic treatment of the conditions and disorders identified above, oral dosages of a compound of formula (I) generally are 5 about 0.5 to about 1000 mg daily for an average adult patient (70 kg). Thus, for a typical adult patient, individual tablets or capsules contain 0.2 to 500 mg of active compound, in a suitable pharmaceutically acceptable vehicle or carrier, for administration in single or multiple doses, once or 10 several times per day. Dosages for intravenous, buccal, or sublingual administration typically are 0.1 to 500 mg per single dose as required. In practice, the physician determines the actual dosing 15 regimen which is most suitable for an individual patient, and the dosage varies with the age, weight, and response of the particular patient. The above dosages are exemplary of the average case, but there can be individual instances in which higher or lower 20 dosages are merited, and such are within the scope of this invention.

For human use, a compound of the formula (I) can be administered alone, but generally is administered in admixture with a pharmaceutical carrier selected with regard to the intended route 25 of administration and standard pharmaceutical practice. Pharmaceutical compositions for use in accordance with the present invention thus can be formulated in a conventional manner using one or 30 more physiologically acceptable carriers comprising excipients and auxiliaries that facilitate processing of compounds of formula (I) into preparations which can be used pharmaceutically.

These pharmaceutical compositions can be manufactured in a conventional manner, e.g., by conventional mixing, dissolving, granulating, dragee-making, levigating, emulsifying, encapsulating, entrapping, or lyophilizing processes. Proper formulation is dependent upon the route of administration chosen. When a therapeutically effective amount of a compound of the present invention is administered orally, the composition typically is in the form of a tablet, capsule, powder, solution, or elixir. When administered in tablet form, the composition can additionally contain a solid carrier, such as a gelatin or an adjuvant. The tablet, capsule, and powder contain about 5% to about 95% compound of the present invention, and preferably from about 25% to about 90% compound of the present invention. When administered in liquid form, a liquid carrier such as water, petroleum, or oils of animal or plant origin can be added. The liquid form of the composition can further contain physiological saline solution, dextrose or other saccharide solutions, or glycols. When administered in liquid form, the composition contains about 0.5% to about 90% by weight of a compound of the present invention, and preferably about 1% to about 50% of a compound of the present invention.

When a therapeutically effective amount of a compound of the present invention is administered by intravenous, cutaneous, or subcutaneous injection, the composition is in the form of a pyrogen-free, parenterally acceptable aqueous solution. The preparation of such parenterally acceptable solutions, having due regard to pH, isotonicity, stabil-

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ity, and the like, is within the skill in the art. A preferred composition for intravenous, cutaneous, or subcutaneous injection typically contains, in addition to a compound of the present invention, an isotonic vehicle.

For oral administration, the compounds can be formulated readily by combining a compound of formula (I) with pharmaceutically acceptable carriers well known in the art. Such carriers enable the present compounds to be formulated as tablets, pills, dragees, capsules, liquids, gels, syrups, slurries, suspensions and the like, for oral ingestion by a patient to be treated. Pharmaceutical preparations for oral use can be obtained by adding a compound of formula (I) with a solid excipient, optionally grinding a resulting mixture, and processing the mixture of granules, after adding suitable auxiliaries, if desired, to obtain tablets or dragee cores. Suitable excipients include, for example, fillers and cellulose preparations. If desired, disintegrating agents can be added.

For administration by inhalation, compounds of the present invention are conveniently delivered in the form of an aerosol spray presentation from pressurized packs or a nebulizer, with the use of a suitable propellant. In the case of a pressurized aerosol, the dosage unit can be determined by providing a valve to deliver a metered amount. Capsules and cartridges of, e.g., gelatin, for use in an inhaler or insufflator can be formulated containing a powder mix of the compound and a suitable powder base such as lactose or starch.

- 30 -

The compounds can be formulated for parenteral administration by injection, e.g., by bolus injection or continuous infusion. Formulations for injection can be presented in unit dosage 5 form, e.g., in ampules or in multidose containers, with an added preservative. The compositions can take such forms as suspensions, solutions, or emulsions in oily or aqueous vehicles, and can contain formulatory agents such as suspending, stabilizing, 10 and/or dispersing agents.

Pharmaceutical formulations for parenteral administration include aqueous solutions of the active compounds in water-soluble form. Additionally, suspensions of the active compounds can be 15 prepared as appropriate oily injection suspensions. Suitable lipophilic solvents or vehicles include fatty oils or synthetic fatty acid esters. Aqueous injection suspensions can contain substances which increase the viscosity of the suspension. Optionally, the suspension also can contain suitable 20 stabilizers or agents that increase the solubility of the compounds and allow for the preparation of highly concentrated solutions. Alternatively, a present composition can be in powder form for 25 constitution with a suitable vehicle, e.g., sterile pyrogen-free water, before use.

Compounds of the present invention also can be formulated in rectal compositions, such as suppositories or retention enemas, e.g., containing 30 conventional suppository bases. In addition to the formulations described previously, the compounds also can be formulated as a depot preparation. Such long-acting formulations can be administered by

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implantation (for example, subcutaneously or intra-muscularly) or by intramuscular injection. Thus, for example, the compounds can be formulated with suitable polymeric or hydrophobic materials (for 5 example, as an emulsion in an acceptable oil) or ion exchange resins, or as sparingly soluble derivatives, for example, as a sparingly soluble salt.

Many of the compounds of the present invention can be provided as salts with pharmaceutically compatible counterions. Such pharmaceutically acceptable base addition salts are those salts that 10 retain the biological effectiveness and properties of the free acids, and that are obtained by reaction with suitable inorganic or organic bases.

15 In particular, a compound of formula (I) can be administered orally, buccally, or sublingually in the form of tablets containing excipients, such as starch or lactose, or in capsules or ovules, either alone or in admixture with excipients, or in 20 the form of elixirs or suspensions containing flavoring or coloring agents. Such liquid preparations can be prepared with pharmaceutically acceptable additives, such as suspending agents. A compound also can be injected parenterally, for example, 25 intravenously, intramuscularly, subcutaneously, or intracoronarily. For parenteral administration, the compound is best used in the form of a sterile aqueous solution which can contain other substances, for example, salts, or monosaccharides, 30 such as mannitol or glucose, to make the solution isotonic with blood.

For veterinary use, a compound of formula (I) or a nontoxic salt thereof, is administered as a

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suitably acceptable formulation in accordance with normal veterinary practice. The veterinarian can readily determine the dosing regimen and route of administration that is most appropriate for a

5 particular animal.

Thus, the invention provides in a further aspect a pharmaceutical composition comprising a compound of the formula (I), together with a pharmaceutically acceptable diluent or carrier therefor.

10 There is further provided by the present invention a process of preparing a pharmaceutical composition comprising a compound of formula (I), which process comprises mixing a compound of formula (I), together with a pharmaceutically acceptable diluent or

15 carrier therefor.

In a particular embodiment, the invention includes a pharmaceutical composition for the curative or prophylactic treatment of erectile dysfunction in a male animal, or arousal disorder in a

20 female animal, including humans, comprising a compound of formula (I) or a pharmaceutically acceptable salt thereof, together with a pharmaceutically acceptable diluent or carrier.

Compounds of formula (I) can be prepared by any suitable method known in the art, or by the following processes which form part of the present invention. In the methods below, R⁰, R¹, R², R³, R⁴, and R⁵, as well as X, Y, and Z, are defined as in structural formula (I) above. In particular, compounds of structural formula (I) can be prepared according to the following synthetic schemes.

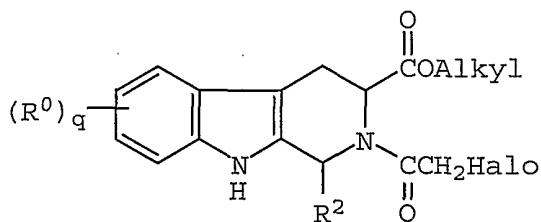
30 Methods A and B can be used to prepare compounds wherein X, Y, and Z are carbon. Method C can be

- 33 -

used to prepare compounds wherein X and Y are carbon and Z is nitrogen.

5 Daugan U.S. Patent No. 5,859,006, incorporated herein by reference, discloses preparation of a compound of structural formula (III):

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(III)

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The compounds of structural formula (I) can be prepared in an analogous manner as a compound of structural formula (III) using appropriately substituted R¹ starting materials.

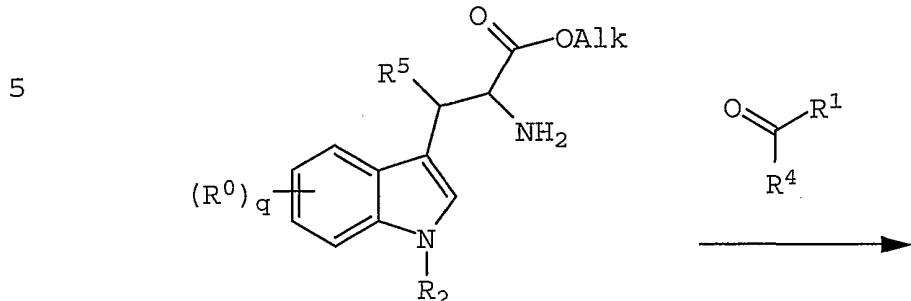
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In the following Methods A and B, treatment of a tetrahydro-β-carboline-3-carboxylic acid (IV) with an activated acetylene in acetic anhydride yields an indolizino[6,7-b]indole (V) (see, F.M. Hershenson, *J. Org. Chem.*, 37, 3111 (1972)). The resulting 3-methyl group on the indolizino[6,7-b]indole can be oxidized to an aldehyde (VI) under a variety of conditions. See, M.R. Johnson et al., *J. Org. Chem.*, 57, 4414 (1992); M.R. Johnson, *J. Org. Chem.*, 62, 1168 (1997); F.-P. Montforts et al., *Angew. Chem.*, 97, 767 (1985); T. Thyrann et al., *Tetrahedron Lett.*, 36, 4345 (1995). Further reactions at the aldehyde functionality provide additional compounds of structural formula (I).

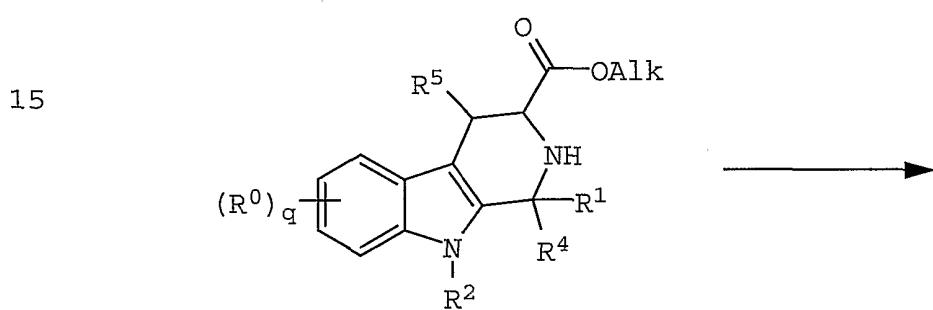
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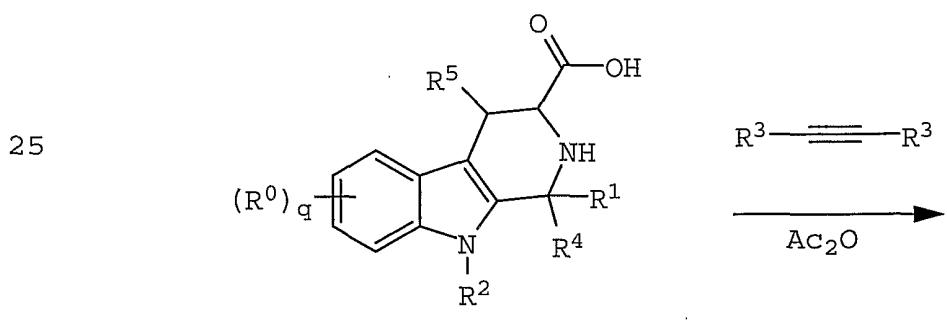
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Method A

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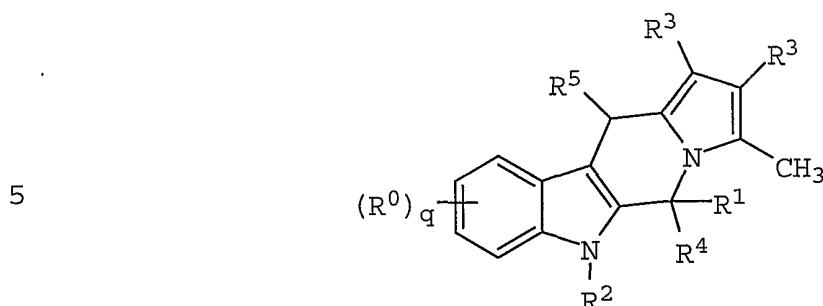


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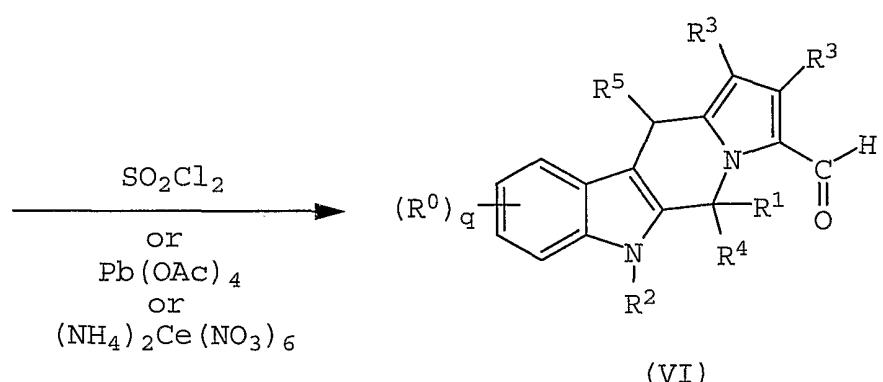


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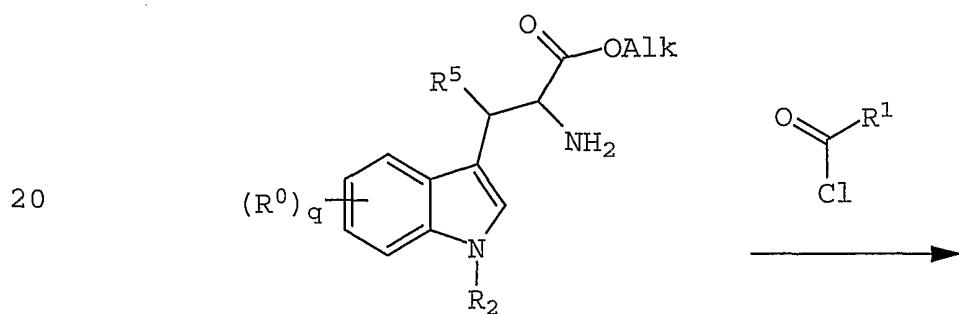


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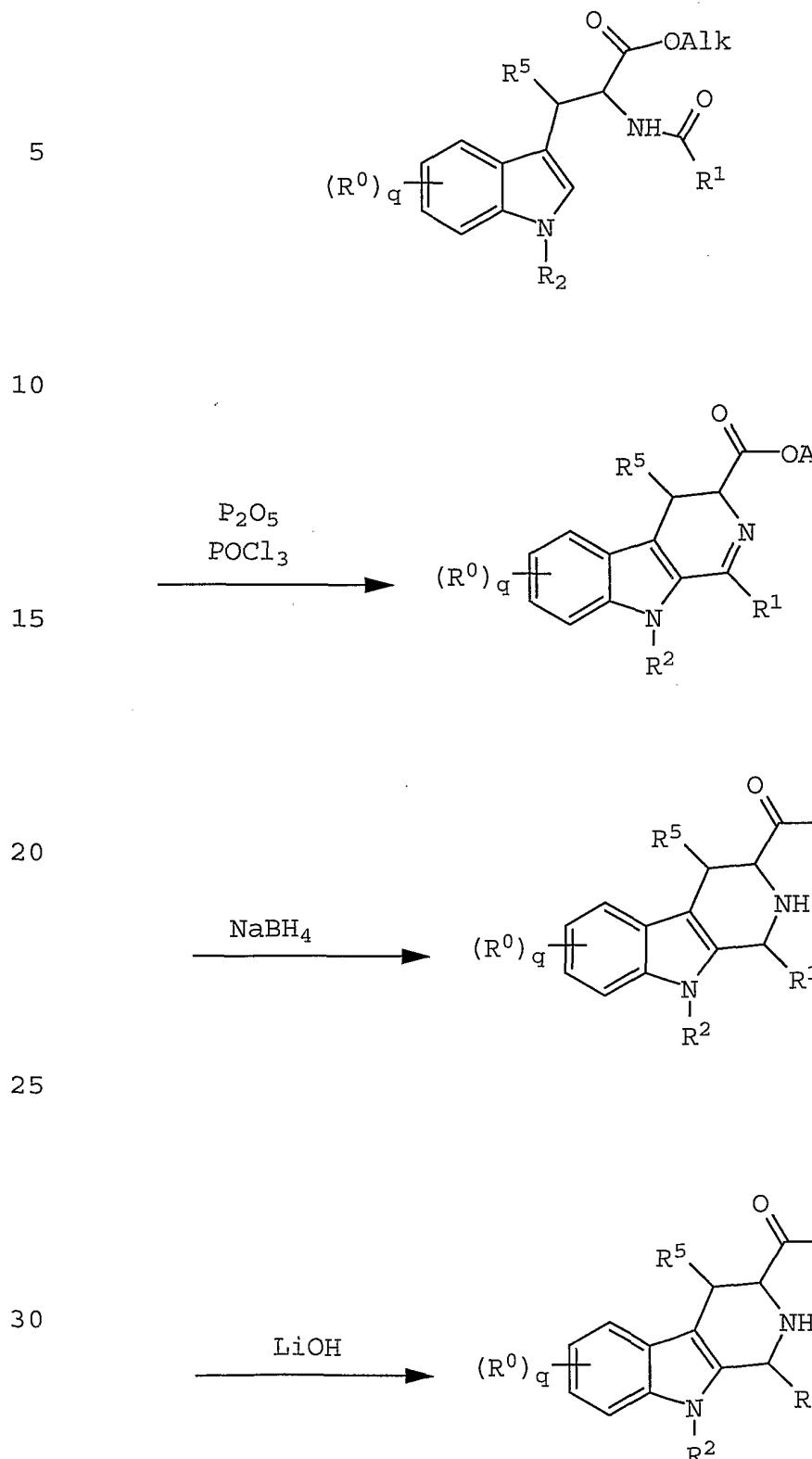
Method B

(R4=H)

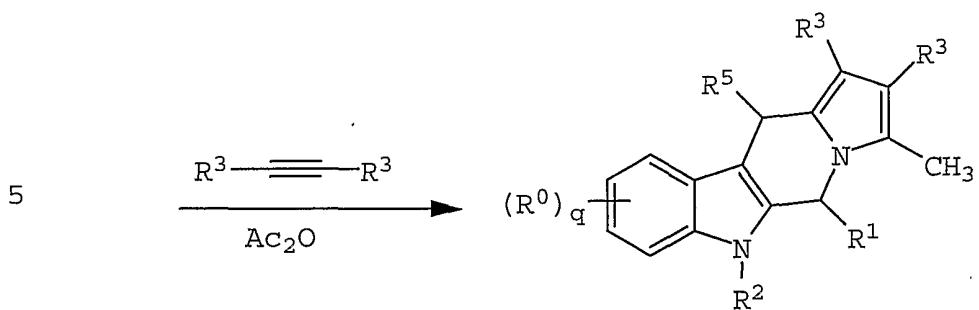
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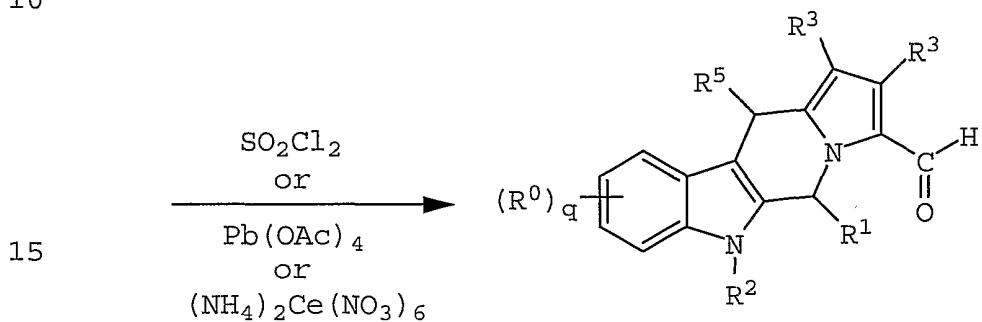
- 36 -



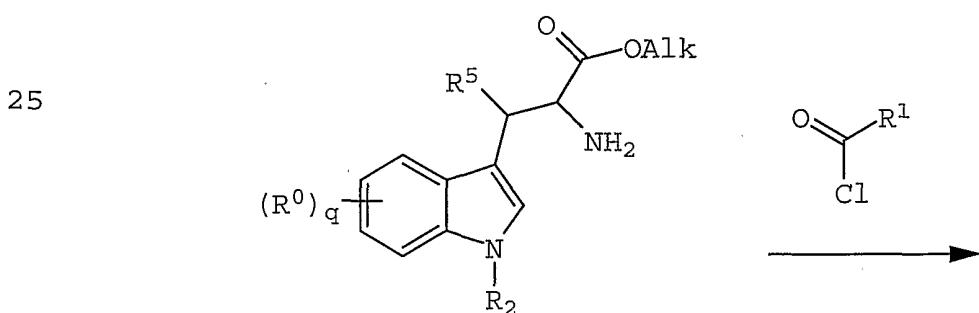
- 37 -



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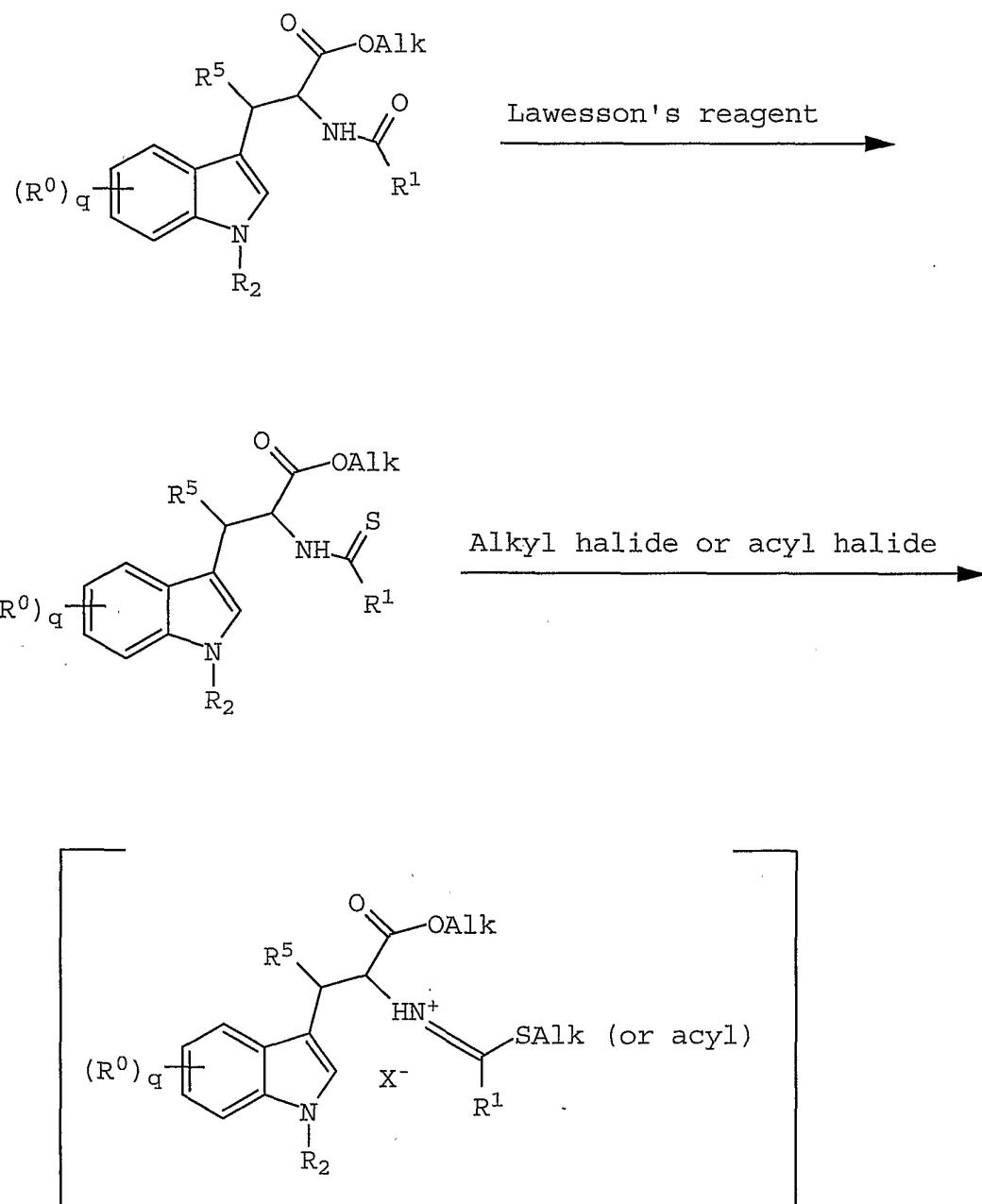


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Modified Method B $\text{R}^4=\text{H}$ 

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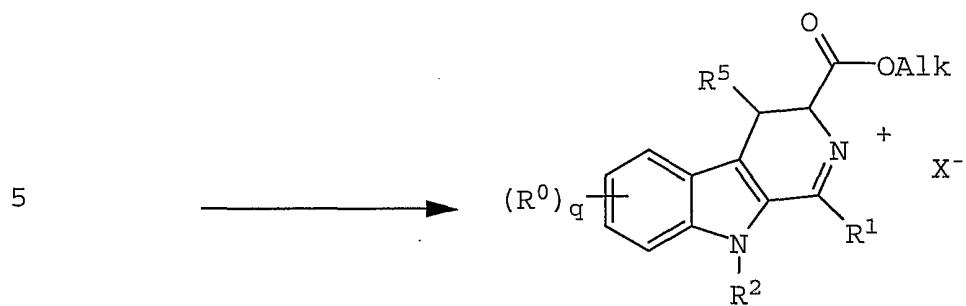


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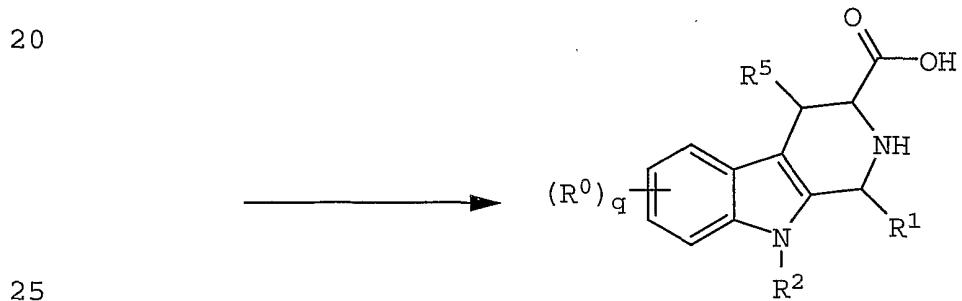
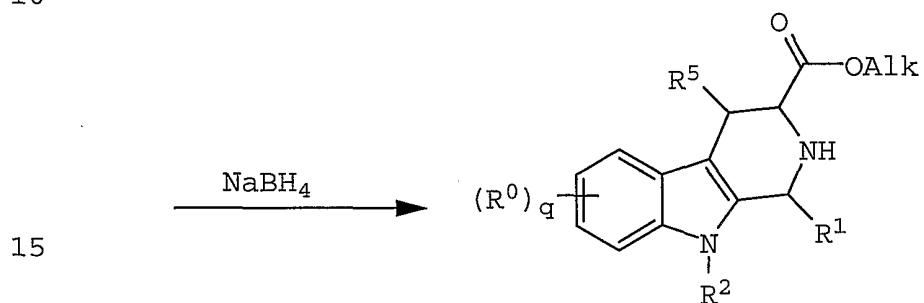
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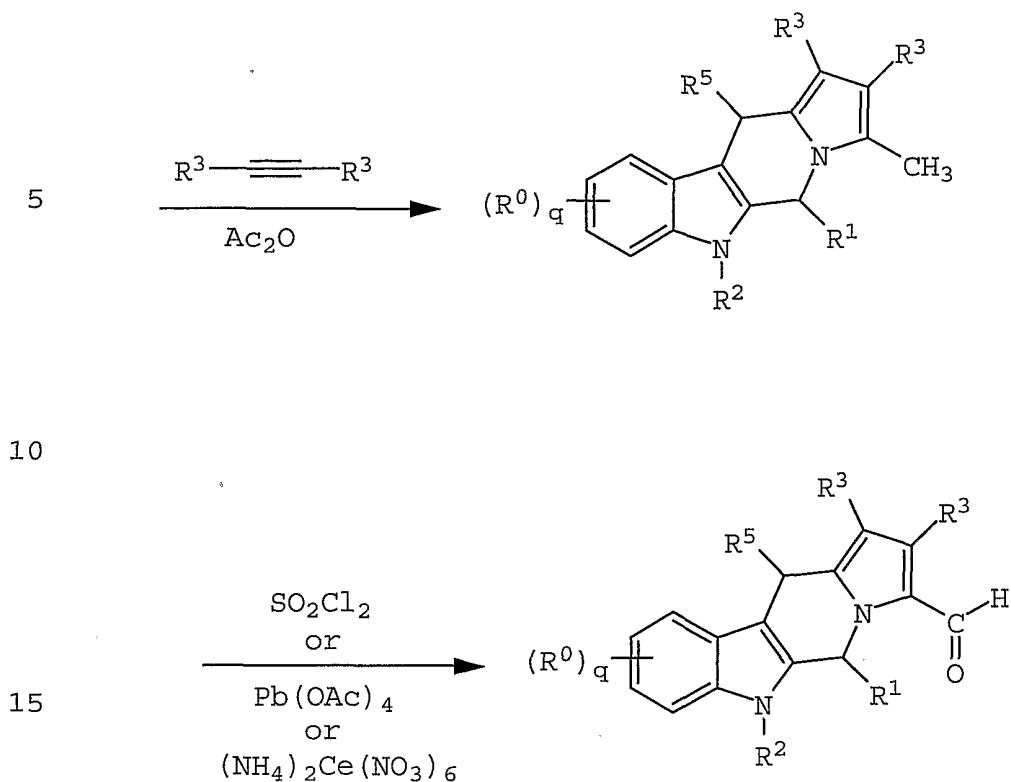


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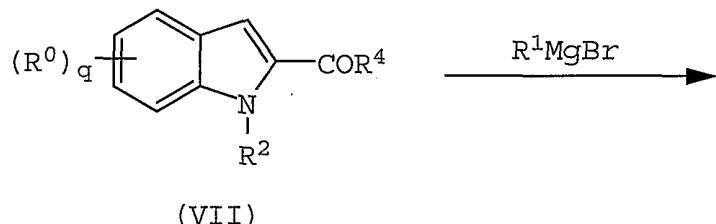


20 In the following Method C, treatment of an indole-2-carbaldehyde or a 1-(1H-indol-2-yl)ketone (VII) with a Grignard reagent provides an alcohol (VIII). Conversion of alcohol (VIII) to an azide (IX), followed by alkylation with an alkyne and a 25 cycloaddition provides a 4-[2-(1-azido)-1H-indol-3-yl]but-2-ynoic acid methyl ester (X).

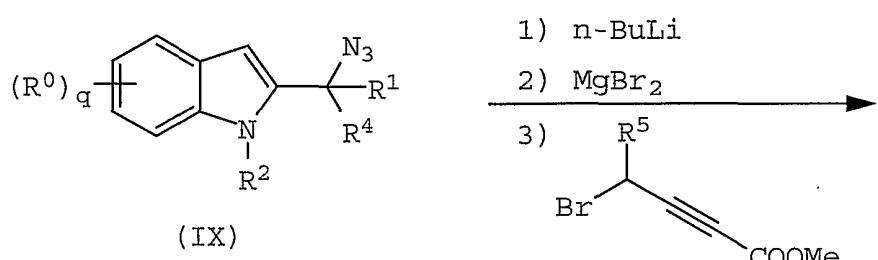
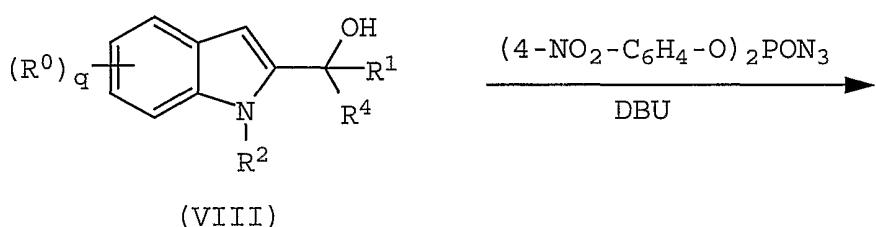
- 41 -

Method CX, Y=N, and R²=H

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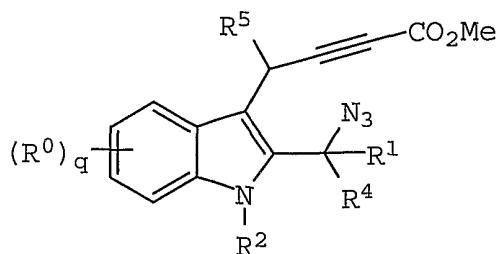


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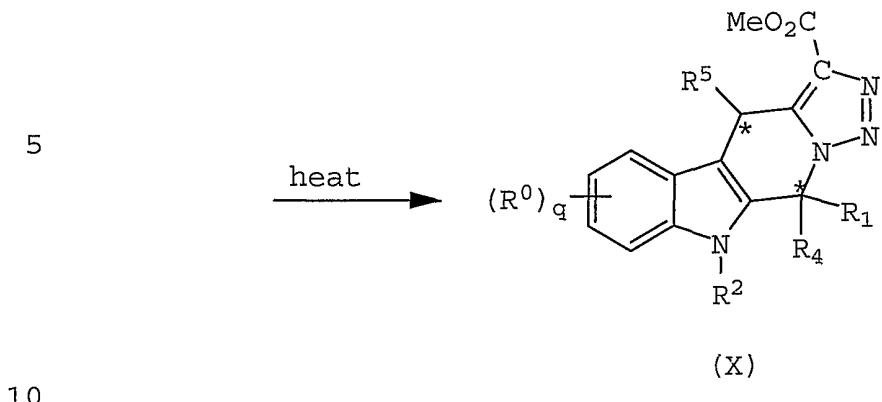


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It should be understood that protecting groups can be utilized in accordance with general principles of synthetic organic chemistry to provide compounds of structural formula (I). Protecting group-forming reagents, like benzyl chloroformate and trichloroethyl chloroformate, are well known to persons skilled in the art, for example, see T.W. Greene et al., "Protective Groups in Organic Synthesis, Third Edition," John Wiley and Sons, Inc., NY, NY (1999). These protecting groups are removed when necessary by appropriate basic, acidic, or hydrolytic conditions known to persons skilled in the art. Accordingly, compounds of structural formula (I) not specifically exemplified herein can be prepared by persons skilled in the art.

In addition, compounds of formula (I) can be converted to other compounds of formula (I). Thus, for example, a particular R substituent can be interconverted to prepare another suitably substituted compound of formula (I). Examples of appropriate interconversions include, but are not limited to, OR^a to hydroxy by suitable means (e.g., using an

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agent such as SnCl_2 , or a palladium catalyst, like palladium-on-carbon), or amino to substituted amino, such as acylamino or sulphonylamino, using standard acylating or sulfonylating conditions.

5 Compounds of formula (I) can be prepared by the method above as individual stereoisomers or as a racemic mixture. Individual stereoisomers of the compounds of the invention can be prepared from racemates by resolution using methods known in the
10 art for the separation of racemic mixtures into their constituent stereoisomers, for example, using HPLC on a chiral column, such as Hypersil naphthyl urea, or using separation of salts of stereoisomers. Compounds of the invention can be isolated in
15 association with solvent molecules by crystallization from, or evaporation of, an appropriate solvent.

20 The pharmaceutically acceptable acid addition salts of the compounds of formula (I) that contain a basic center can be prepared in a conventional manner. For example, a solution of the free base can be treated with a suitable acid, either neat or in a suitable solution, and the resulting salt isolated either by filtration or by evaporation
25 under vacuum of the reaction solvent. Pharmaceutically acceptable base addition salts can be obtained in an analogous manner by treating a solution of a compound of formula (I) with a suitable base. Both types of salt can be formed or interconverted
30 using ion-exchange resin techniques. Thus, according to a further aspect of the invention, a method for preparing a compound of formula (I) or a salt or solvate (e.g., hydrate) is provided, followed by (i)

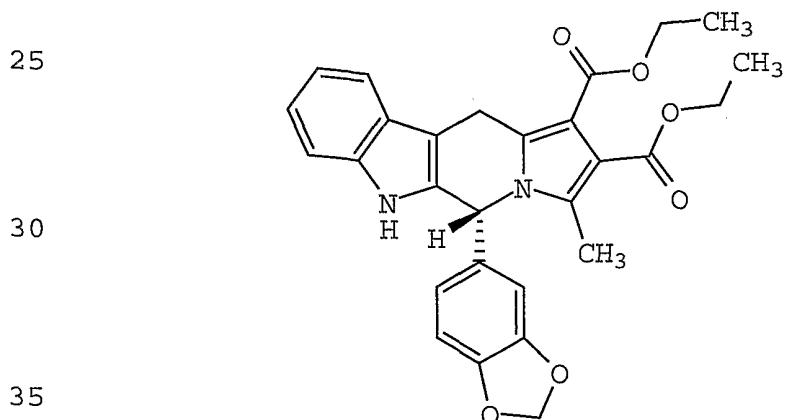
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salt formation, or (ii) solvate (e.g., hydrate) formation.

The following additional abbreviations are used hereafter in the accompanying examples: rt 5 (room temperature), min (minute), h (hour), g (gram), mmol (millimole), m.p. (melting point), LiOH (lithium hydroxide), eq (equivalents), L (liter), mL (milliliter), μ L (microliter), DMSO (dimethyl sulfoxide), CH_2Cl_2 (dichloromethane), IPA (isopropyl alcohol), TFA (trifluoroacetic acid), EtOH (ethanol), MeOH (methanol), DMF (dimethylformamide), Ac_2O (acetic anhydride), NaBH_4 (sodium borohydride), MgBr_2 (magnesium bromide), Et_3N (triethylamine), MeNH_2 (methylamine), AcOH (acetic acid), and THF (tetrahydrofuran). 10 15

Example 1

(R)-5-Benzo[1,3]dioxol-5-yl-3-methyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1,2-dicarboxylic acid diethyl ester

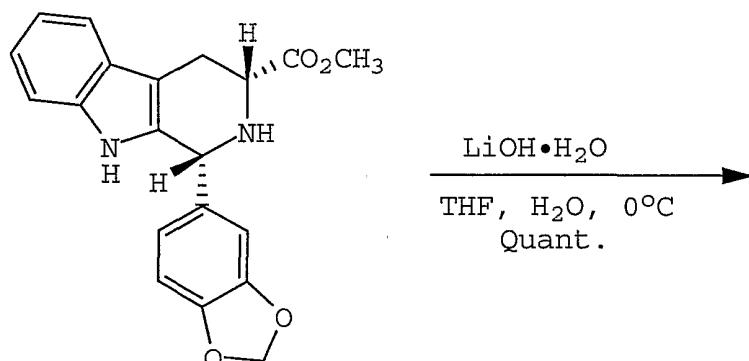


Example 1

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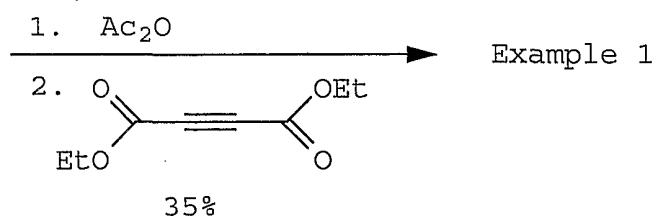
Example 1 was prepared from the (+)-carboline Intermediate 1 and diethyl acetylenediacarboxylate using the method described in F.M. Hershenson, *J. Org. Chem.*, 37, 3111 (1972) and depicted in the following synthetic scheme. Intermediate 1 can be prepared by the procedure disclosed in Daugan U.S. Patent No. 5,859,006.

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Intermediate 2

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Preparation of cis- β -Carboline Acid (Intermediate 2)

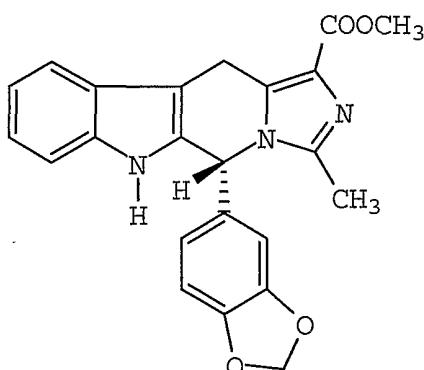
Preparation of Example 1

30 Diethyl acetylenedicarboxylate (0.35 mL, 2.2 mmol) was added to a stirred suspension of Intermediate 2 (0.49 g, 1.5 mmol) in acetic anhydride (10 mL) at room temperature. The resulting mixture was heated at 100°C for 1 hour. The cooled

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solution was concentrated under reduced pressure to provide a brown oil, which was purified by flash column chromatography, eluting with methylene chloride/ethyl acetate (7:1), to provide crude Example 1 as a bright yellow solid (245 mg, 35%). This solid was repurified by flash column chromatography, eluting with methylene chloride/ethyl acetate (98:2) to provide Example 1 [(-)-3] as a bright yellow solid (175 mg): mp 119-122°C (decomp.); TLC R_f (96:4 methylene chloride/ethyl acetate)=0.42; 1H NMR (300 MHz, DMSO- d_6): δ 11.05 (s, 1H), 7.52 (d, J =7.5 Hz, 1H), 7.33 (d, J =7.9 Hz, 1H), 7.10-7.00 (m, 2H), 6.86 (d, J =8.0 Hz, 1H), 6.72 (s, 1H), 6.66-6.60 (m, 2H), 5.96 (s, 2H), 4.43-4.11 (m, 6H), 2.16 (s, 3H), 1.29 (t, J =7.0 Hz, 3H), 1.22 (t, J =7.0, 3H); CI MS m/z 487 [$C_{28}H_{26}N_2O_6+H$] $^+$; $[\alpha]_D^{25^\circ C}=44.0^\circ$ ($c=0.1$, chloroform). Anal. Calcd. for $C_{28}H_{26}N_2O_6-0.5 H_2O$: C, 67.87; H, 5.49; N, 5.65. Found: C, 67.92; H, 5.58; N, 5.54.

Preparation of Examples 2 and 3

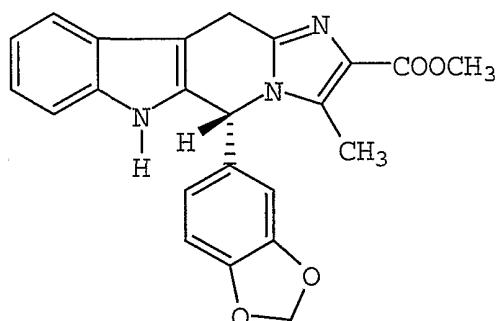


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Example 2

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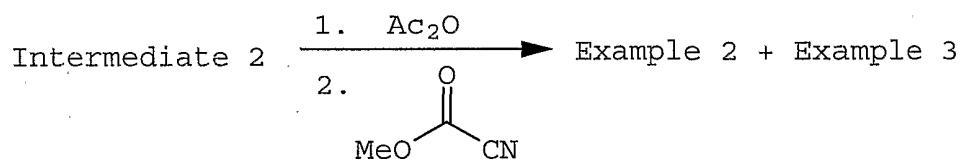
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Example 3

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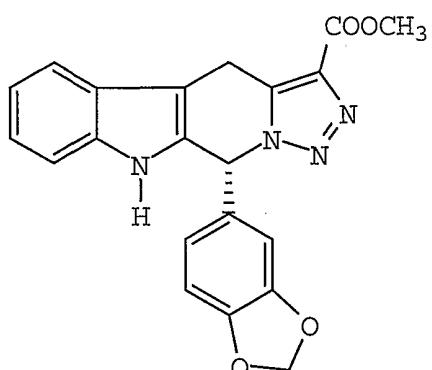
Examples 2 and 3 can be synthesized by the following synthetic scheme from Intermediate 2 described above in Example 1.



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Preparation of Example 4

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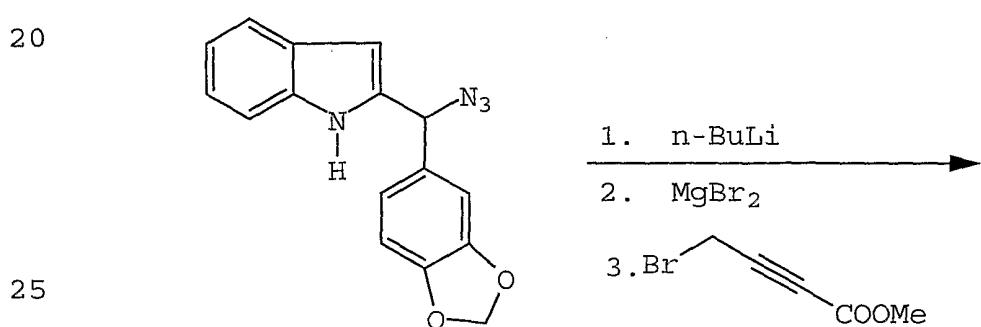
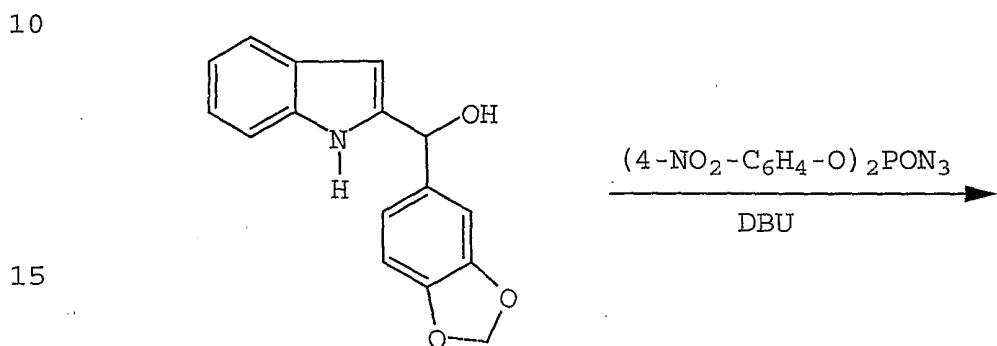
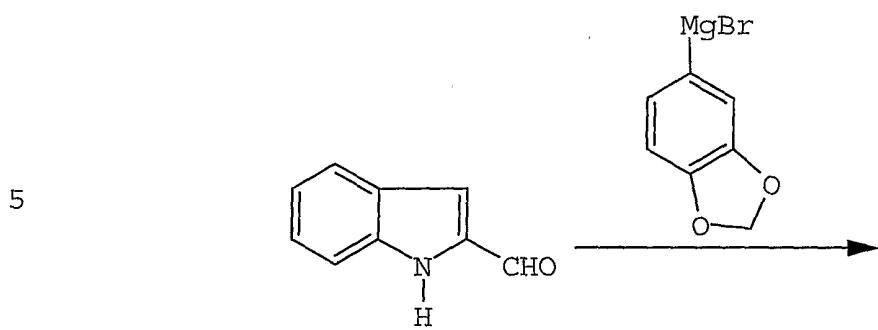


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Example 4

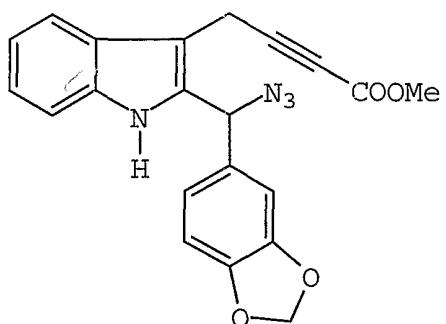
Example 4 can be prepared by the following synthetic scheme.

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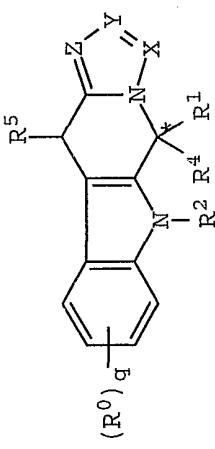
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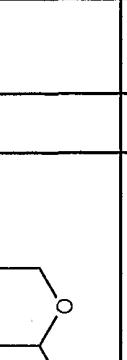
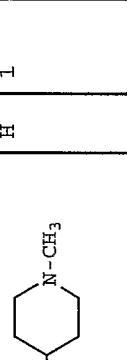
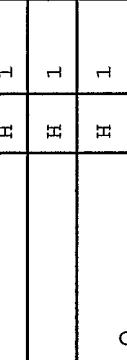
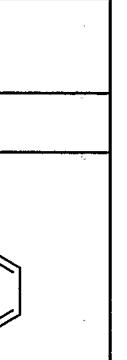
The following Examples 5-59 were prepared
by methods analogous to Examples 1-4.

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Example	X	Y	Z	R ⁰	R ^{1 (1)}	R ²	R ⁴	R ⁵
5	C-CH ₃	C- (CH ₂) ₄ CO ₂ H	C-CN	H	1	H	H	H
6	C-H	C-CH ₂ NHCH ₂ phenyl	C-CO ₂ C ₂ H ₅	H	1	H	H	H
7	C-H	C-H	C-CO ₂ H	H	2	H	H	H
8	C-CH ₂ NH ₂	C-H	C-CO ₂ C ₂ H ₅	H	2	H	H	H
9	C-CHO	C-H	C-CO ₂ C ₂ H ₅	H	3	H	H	H
10	C-H	C-H	C-H	H	1	H	H	H
11	C-H	C-H	C-CO ₂ C ₂ H ₅	H	4	H	H	H
12	C-C ₂ H ₅	C-CO ₂ C ₂ H ₅	C-CO ₂ C ₂ H ₅	H	1	H	H	H
13	C-C ₂ H ₅	C-CO ₂ H	C-CO ₂ C ₂ H ₅	H	1	H	H	H

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Example	X	Y	Z	R ⁰	R ^{1 (1)}	R ²	R ⁴	R ⁵
14	C-H	C-H		H	1	H	H	H
15	C-CH ₂ (CH ₃) ₂	C-CO ₂ C ₂ H ₅		H	1	H	H	H
16	C-H	C-H		H	1	H	H	H
17	C-H	C-H		H	1	H	H	H
18	C-CH ₂ OH	C-H		C-CO ₂ C ₂ H ₅	H	1	H	H
19	C-CH ₂ (CH ₃) ₂	C-H		C-CO ₂ C ₂ H ₅	H	1	H	H
20	C-H	C-H		O	H	1	H	H

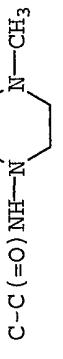
Example	X	Y	Z	R ⁰	R ^{1, 1)}	R ²	R ⁴	R ⁵
21	C-H	C-CO ₂ C ₂ H ₅	C-CO ₂ C ₂ H ₅	H	1	H	H	H
22	C-H	C-H	C-C(=O)-N(CO ₂ H)-Cyclohexyl	H	1	H	H	H
23	C-CHO	C-H	C-CO ₂ C ₂ H ₅	H	1	H	H	H
24	C-H	C-H	C-C(=O)NH(CH ₂) ₂ -Cyclohexyl	H	1	H	H	H
25	C-H	C-H	C-C(=O)NHCH ₂ -Cyclohexyl	H	1	H	H	H
26	C-H	C-H	C-C(=O)NH(CH ₂) ₂ -N(CH ₃) ₂	H	1	H	H	H
27	C-H	C-H	C-CN	H	1	H	H	H

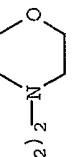
- 54 -

Example	X	Y	Z	R ⁰	R ^{1 (1)}	R ²	R ⁴	R ⁵
28	C-H	C-H		H	1	H	H	H
29	C-H	C-H		H	1	H	H	H
30	C-H	C-H		H	1	H	H	H
31	C-H	C-H			H	1	H	H
32	C-H	C-H			H	5	H	H
33	C-H	C-H			H	5	H	H

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Example	X	Y	Z	R ⁰	R ^{1, 1)}	R ²	R ⁴	R ⁵
34	C-H	C-H	C-C(=O)NH(CH ₂) ₂ -N(Cyclohexylmethyl)-	H	5	H	H	H
35	C-H	C-H	C-CO ₂ C ₂ H ₅	H	1	H	H	H
36	C-H	C-H	C-CO ₂ H	H	1	H	H	H
37	C-H	C-CO ₂ C ₂ H ₅	C-H	H	1	H	H	H
38	C-H	C-CO ₂ C ₂ H ₅	C-H	H	6	H	H	H
39	C-H	C-H	C-CO ₂ C ₂ H ₅	H	6	H	H	H
40	C-CH ₃	C-H	C-CO ₂ C ₂ H ₅	H	1	H	H	H
41	C-H	C-H	C-CO ₂ H	H	6	H	H	H
42	C-H	C-H	C-C(=O)NHCH ₂ -C ₆ H ₄ -OCH ₃	H	6	H	H	H
43	C-H	C-H	C-CO ₂ C ₂ H ₅	H	5	H	H	H
44	C-H	C-CO ₂ C ₂ H ₅	C-H	H	5	H	H	H
45	C-CH ₃	C-CO ₂ CH ₃	C-CO ₂ C ₂ H ₅	H	1	H	H	H

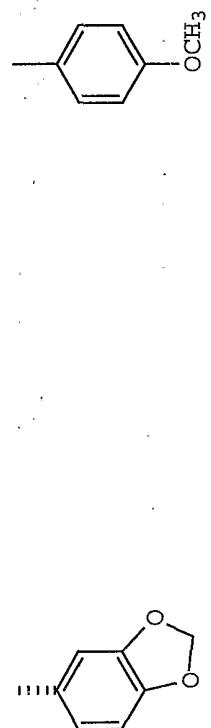
Example	X	Y	Z	R ⁰	R ^{1 (1)}	R ²	R ⁴	R ⁵
46	C-C ₂ H ₅	C-C(=O)NHCH ₂ - 	C-H	H	1	H	H	H
47	C-H	C-H	C-CO ₂ C ₂ H ₅	H	7	H	H	H
48	C-H	C-H	C-CO ₂ C ₂ H ₅	H	8	H	H	H
49	C-H	C-H	C-CO ₂ C ₂ H ₅	H	3	H	H	H
50	C-H	C-H	C-CO ₂ H	H	3	H	H	H
51	C-H	C-H	C-C(=O)NH-N- 	H	1	H	H	H
52	C-CH ₂ N(CH ₃) ₂	C-H	C-CO ₂ C ₂ H ₅	H	1	H	H	H
53	C-C ₂ H ₅	C-H		H	1	H	H	H

Example	X	Y	Z	R ⁰	R ^{1 (1)}	R ²	R ⁴	R ⁵
54	C-C ₂ H ₅	C-H	C-CO ₂ C ₂ H ₅	H	4	H	H	H
55	C-C ₂ H ₅	C-CO ₂ C ₂ H ₅	C-H	H	1	H	H	H
56	C-C ₂ H ₅	C-H	C-CO ₂ C ₂ H ₅	H	1	H	H	H
57	C-H	C-C ₂ H ₅	C-C(=O)NH ₂	H	1	H	H	H
58	C-CF ₃	C-C(=O)NH ₂	C-C(=O)NH ₂	H	1	H	H	H
59	C-H	N	C-C(=O)NH(CH ₂) ₂ -N 	H	1	H	H	H

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1) substituents R¹ are defined as follows:

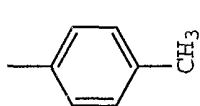
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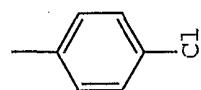
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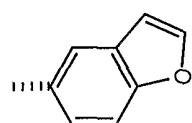
- 59 -



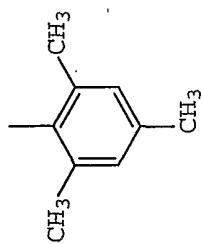
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3 =



4 =

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Compounds of the present invention can be formulated into tablets for oral administration.

For example, a compound of formula (I) can be formed into a dispersion with a polymeric carrier by the coprecipitation method set forth in WO 96/38131, incorporated herein by reference. The coprecipitated dispersion then can be blended with excipients, then pressed into tablets, which optionally are film-coated.

The compounds of structural formula (I) were tested for an ability to inhibit PDE5. The ability of a compound to inhibit PDE5 activity is related to the IC_{50} value for the compound, i.e., the concentration of inhibitor required for 50% inhibition of enzyme activity. The IC_{50} value for compounds of structural formula (I) were determined using recombinant human PDE5.

The compounds of the present invention typically exhibit an IC_{50} value against recombinant human PDE5 of less than about 50 μM , and preferably less than about 25 μM , and more preferably less than about 15 μM . The compounds of the present invention typically exhibit an IC_{50} value against recombinant human PDE5 of less than about 1 μM , and often less than about 0.05 μM . To achieve the full advantage of the present invention, a present PDE5 inhibitor has an IC_{50} of about 0.1 nM to about 15 μM .

The production of recombinant human PDEs and the IC_{50} determinations can be accomplished by well-known methods in the art. Exemplary methods are described as follows:

EXPRESSION OF HUMAN PDES

Expression in *Saccharomyces cerevisiae* (Yeast)

25 HUMAN PHOSPHODIESTERASE PREPARATIONS

Phosphodiesterase Activity Determinations

30 Phosphodiesterase activity of the preparations was determined as follows. PDE assays utilizing a charcoal separation technique were performed essentially as described in Loughney et al. (1996). In this assay, PDE activity converts [³²P]cAMP or

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[³²P]cGMP to the corresponding [³²P]5'-AMP or [³²P]5'-GMP in proportion to the amount of PDE activity present. The [³²P]5'-AMP or [³²P]5'-GMP then was quantitatively converted to free [³²P]phosphate and unlabeled adenosine or guanosine by the action of snake venom 5'-nucleotidase. Hence, the amount of [³²P]phosphate liberated is proportional to enzyme activity. The assay was performed at 30°C in a 100 μ L reaction mixture containing (final concentrations) 40 mM Tris HCl (pH 8.0), 1 μ M ZnSO₄, 5 mM MgCl₂, and 0.1 mg/mL bovine serum albumin (BSA). PDE enzyme was present in quantities that yield <30% total hydrolysis of substrate (linear assay conditions). The assay was initiated by addition of substrate (1 mM [³²P]cAMP or cGMP), and the mixture was incubated for 12 minutes. Seventy-five (75) μ g of *Crotalus atrox* venom then was added, and the incubation was continued for 3 minutes (15 minutes total). The reaction was stopped by addition of 200 μ L of activated charcoal (25 mg/mL suspension in 0.1 M NaH₂PO₄, pH 4). After centrifugation (750 X g for 3 minutes) to sediment the charcoal, a sample of the supernatant was taken for radioactivity determination in a scintillation counter and the PDE activity was calculated.

Purification of PDE5 from *S. cerevisiae*

Cell pellets (29 g) were thawed on ice with an equal volume of Lysis Buffer (25 mM Tris HCl, pH 8, 5 mM MgCl₂, 0.25 mM DTT, 1 mM benzamidine, and 10 μ M ZnSO₄). Cells were lysed in a Microfluidizer[®] (Microfluidics Corp.) using nitrogen at 20,000

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psi. The lysate was centrifuged and filtered through 0.45 μ m disposable filters. The filtrate was applied to a 150 mL column of Q SEPHAROSE[®] Fast-Flow (Pharmacia). The column was washed with 1.5 volumes of Buffer A (20 mM Bis-Tris Propane, pH 6.8, 1 mM MgCl₂, 0.25 mM DTT, 10 μ M ZnSO₄) and eluted with a step gradient of 125 mM NaCl in Buffer A followed by a linear gradient of 125-1000 mM NaCl in Buffer A. Active fractions from the linear gradient were applied to a 180 mL hydroxyapatite column in Buffer B (20 mM Bis-Tris Propane (pH 6.8), 1 mM MgCl₂, 0.25 mM DTT, 10 μ M ZnSO₄, and 250 mM KCl). After loading, the column was washed with 2 volumes of Buffer B and eluted with a linear gradient of 0-125 mM potassium phosphate in Buffer B. Active fractions were pooled, precipitated with 60% ammonium sulfate, and resuspended in Buffer C (20 mM Bis-Tris Propane, pH 6.8, 125 mM NaCl, 0.5 mM DTT, and 10 μ M ZnSO₄). The pool was applied to a 140 mL column of SEPHACRYL[®] S-300 HR and eluted with Buffer C. Active fractions were diluted to 50% glycerol and stored at -20°C.

The resultant preparations were about 85% pure by SDS-PAGE. These preparations had specific activities of about 3 μ mol cGMP hydrolyzed per minute per milligram protein.

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Inhibitory Effect on cGMP-PDE

cGMP-PDE activity of compounds of the present invention was measured using a one-step assay adapted from Wells et al., *Biochim. Biophys. Acta*, 384, 430 (1975). The reaction medium contained 50 mM Tris-HCl, pH 7.5, 5 mM magnesium acetate, 250 µg/ml 5'-Nucleotidase, 1 mM EGTA, and 0.15 µM 8-[H³]-cGMP. Unless otherwise indicated, the enzyme used was a human recombinant PDE5 (ICOS Corp., Bothell, Washington).

Compounds of the invention were dissolved in DMSO finally present at 2% in the assay. The incubation time was 30 minutes during which the total substrate conversion did not exceed 30%.

The IC₅₀ values for the compounds examined were determined from concentration-response curves typically using concentrations ranging from 10 nM to 10 µM. Tests against other PDE enzymes using standard methodology showed that compounds of the invention are selective for the cGMP-specific PDE enzyme.

Biological Data

The compounds according to the present invention were typically found to exhibit an IC₅₀ value of less than 500 nM (i.e., 0.5 µM). *In vitro* test data for representative compounds of the invention is given in the following table:

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Table 1: *In vitro* Results

Example	PDE5 IC ₅₀ (μM)
1	0.0056
6	0.01
5 7	0.004
8	0.04
9	0.0062
10 11	0.14
12	0.15
10 13	0.01
14	0.0059
15 16	0.0058
17	0.19
18	0.33
15 19	0.008
20 21	0.01
19 22	0.46
20 23	0.0015
21 24	0.0012
20 25	0.003
22 26	0.0039
24 27	0.0021
25 28	0.0059
26 29	0.11
25 30	0.0036
28 31	0.0037
29 30	0.0038
30	0.01
31	0.02

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Table 1: *In vitro* Results

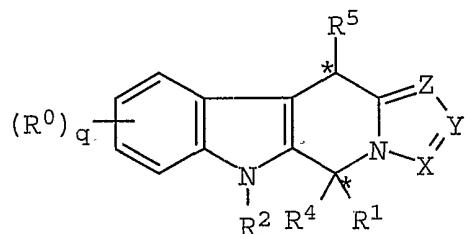
Example	PDE5 IC ₅₀ (μM)
32	0.01
33	0.11
34	0.03
35	0.0055
5 36	0.01
37	0.04
38	0.59
39	0.08
40	0.02
10 41	0.12
42	0.2
43	0.0021
44	0.06
45	0.0075
15 46	0.28
47	0.01
48	0.03
49	0.0071
50	0.01
20 51	0.04
52	0.15
53	0.05
54	0.16
55	0.46
25 56	0.01

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Obviously, many modifications and variations of the invention as hereinbefore set forth can be made without departing from the spirit and scope thereof, and, therefore, only such limitations 5 should be imposed as are indicated by the appended claims.

WHAT IS CLAIMED IS:

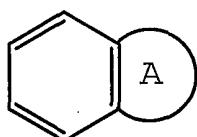
1. A compound having a formula



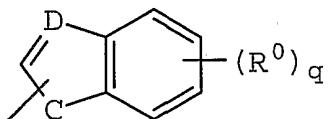
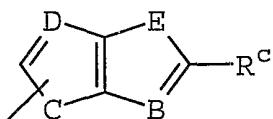
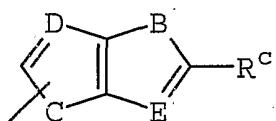
wherein R⁰, independently, is selected from the group consisting of halo, C₁₋₆alkyl, aryl, heteroaryl, C₃₋₈cycloalkyl, C₃₋₈heterocycloalkyl, C₃₋₈cycloalkylQ, C(=O)R^a, OC(=O)R^a, C(=O)OR^a, C₁₋₄alkyl-eneNR^aR^b, C₁₋₄alkyleneHet, C₁₋₄alkyleneC(=O)OR^a, C(=O)-NR^aSO₂R^c, C(=O)C₁₋₄alkyleneHet, C(=O)NR^aR^b, C(=O)NR^aR^c, C(=O)NR^aC₁₋₄alkyleneOR^b, C(=O)NR^aC₁₋₄alkyleneHet, OR^a, OC₁₋₄alkyleneC(=O)OR^a, OC₁₋₄alkyleneNR^aR^b, OC₁₋₄alkylene-Het, OC₁₋₄alkyleneOR^a, OC₁₋₄alkyleneNR^aC(=O)OR^b, NR^aR^b, NR^aC₁₋₄alkyleneNR^aR^b, NR^aC(=O)R^b, NR^aC(=O)NR^aR^b, N(SO₂C₁₋₄alkyl)₂, NR^a(SO₂C₁₋₄alkyl), nitro, trifluoromethyl, trifluoromethoxy, cyano, SO₂NR^aR^b, SO₂R^c, SOR^a, SR^a, and OSO₂CF₃;

R¹ is selected from the group consisting of optionally substituted aryl, optionally substituted heteroaryl, an optionally substituted C₃₋₈cycloalkyl ring, an optionally substituted C₃₋₈heterocycloalkyl ring, an optionally substituted bicyclic ring

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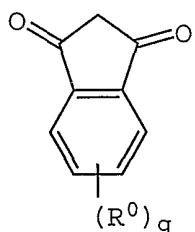


wherein the fused ring A is a 5- or 6-membered ring, saturated or partially or fully unsaturated, and comprises carbon atoms and optionally one to three heteroatoms selected from oxygen, sulfur, and nitrogen, hydrogen, C_{1-6} alkyl, aryl C_{1-3} alkyl, C_{1-3} -alkylenearyl, halo C_{1-6} alkyl, C_{1-4} alkyleneC(=O)OR^a, C_{1-4} alkyleneC(=O)NR^aR^b, C_{3-8} cycloalkyl, C_{3-8} cycloalkenyl, C_{3-8} heterocycloalkenyl, C_{1-4} alkyleneHet, C_{1-4} alkylene-QR^a, C_{2-6} alkenyleneQR^a, C_{1-4} alkyleneQC₁₋₄alkyleneQR^a,



and a spiro substituent having the structure

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R^2 is selected from the group consisting of hydrogen, C_{1-6} alkyl, C_{3-8} cycloalkyl, C_{3-8} heterocycloalkyl, C_{2-6} alkenyl, C_{1-3} alkylenearyl, aryl C_{1-3} alkyl, $C(=O)R^a$, aryl, heteroaryl, $C(=O)R^a$, $C(=O)NR^aR^b$, $C(=O)-NR^aR^c$, $C(=S)NR^aR^b$, $C(=S)NR^aR^c$, SO_2R^a , $SO_2NR^aR^b$, $S(=O)R^a$, $S(=O)NR^aR^b$, $C(=O)NR^aC_{1-4}$ alkyleneOR a , $C(=O)NR^aC_{1-4}$ alkyleneHet, $C(=O)C_{1-4}$ alkylenearyl, $C(=O)C_{1-4}$ alkyleneheteroaryl, C_{1-4} alkylenearyl substituted with one or more of $SO_2NR^aR^b$, NR^aR^b , $C(=O)OR^a$, $NR^aSO_2CF_3$, CN , NO_2 , $(C(=O)R^a, OR^a, C_{1-4}$ alkyleneNR $^aR^b$, and OC_{1-4} alkyleneNR $^aR^b$, C_{1-4} alkyleneheteroaryl, C_{1-4} alkyleneHet, C_{1-4} alkylene- $C(=O)C_{1-4}$ alkylenearyl, C_{1-4} alkylene $C(=O)C_{1-4}$ alkylene-heteroaryl, C_{1-4} alkylene $C(=O)Het$, C_{1-4} alkylene- $C(=O)NR^aR^b$, C_{1-4} alkyleneOR a , C_{1-4} alkyleneNR $^aC(=O)R^a$, C_{1-4} alkyleneOC $_{1-4}$ alkyleneOR a , C_{1-4} alkyleneNR $^aR^b$, C_{1-4} alkyleneC $(=O)OR^a$, and C_{1-4} alkyleneOC $_{1-4}$ alkylene- $C(=O)OR^a$;

X , Y , and Z , independently, are selected from N and CR^3 ;

R^3 , independently, is selected from the group consisting of hydrogen, C_{1-10} alkyl, C_{2-10} alkenyl, C_{2-10} alkynyl, aryl, heteroaryl, aryl C_{1-3} alkyl, C_{1-3} alkylenearyl, $C(=O)OR^a$, $C(=O)NR^aR^c$, aryl, C_{1-4} alkyleneNR $^aR^b$, halo, NO_2 , CF_3 , CF_3O , OR^a , $OC(=O)R^a$, OC_{1-4} alkyleneC $(=O)OR^a$, C_{1-4} alkyleneOC $_{1-4}$ alkyleneC $(=O)OR^a$, $C(=O)NR^aSO_2R^c$, $C(=O)C_{1-4}$ alkyleneHet, C_{2-6} alkenyleneNR $^aR^b$,

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$C(=O)NR^aC_{1-4}alkyleneOR^b$, $C(=O)NR^aC_{1-4}alkyleneHet$, $OC_{2-4}alkyleneNR^aR^b$, $OC_{1-4}alkyleneCH(OR^a)CH_2NR^aR^b$, $OC_{2-4}alkyleneOR^a$, $OC_{2-4}alkyleneNR^aC(=O)OR^b$, NR^aR^b , $NR^aC_{1-4}alkylene-NR^aR^b$, $NR^aC(=O)R^b$, $NR^aC(=O)NR^aR^b$, $N(SO_2C_{1-4}alkyl)_2$, $NR^a(SO_2C_{1-4}alkyl)$, $SO_2NR^aR^b$, $OSO_2trifluoromethyl$, $C(=O)R^a$, $C_{1-3}alkyleneOR^a$, CN , and $C_{1-6}alkyleneC(=O)OR^a$;

R^4 and R^5 , independently, are selected from the group consisting of hydrogen, $C_{1-6}alkyl$, aryl, heteroaryl, $arylC_{1-3}alkyl$, $C_{1-3}alkylenearyl$, $C_{1-3}alkyleneHet$, $C_{3-8}cycloalkyl$, and $C_{3-8}heterocycloalkyl$;

R^a is selected from the group consisting of hydrogen, $C_{1-6}alkyl$, aryl, $arylC_{1-3}alkyl$, $C_{1-3}alkylenearyl$, heteroaryl, $heteroarylC_{1-3}alkyl$, and $C_{1-3}alkylenehet$ eroaryl;

R^b is selected from the group consisting of hydrogen, $C_{1-6}alkyl$, $C_{3-8}cycloalkyl$, $C_{1-3}alkyleneN(R^a)_2$, aryl, $arylC_{1-3}alkyl$, $C_{1-3}alkylenearyl$, and heteroaryl;

R^c is selected from the group consisting of hydrogen, $C_{1-6}alkyl$, aryl, heteroaryl, $arylC_{1-3}alkyl$, heteroaryl $C_{1-3}alkyl$, $C_{1-3}alkyleneN(R^a)_2$, $C_{1-6}alkylenearyl$, $C_{1-6}alkyleneHet$, halo $C_{1-6}alkyl$, $C_{3-8}cycloalkyl$, $C_{3-8}heterocycloalkyl$, Het, $C_{1-3}alkylenehet$ eroaryl, $C_{1-6}alkyleneC(=O)OR^a$, and $C_{1-3}alkyleneC_{3-8}heterocycloalkyl$;

or R^a and R^c are taken together to form a 5- or 6-membered ring, optionally containing at least one heteroatom;

R^d is null or is selected from the group consisting of hydrogen, $C_{1-6}alkyl$, aryl, heteroaryl, $arylC_{1-3}alkyl$, heteroaryl $C_{1-3}alkyl$, $C_{1-3}alkylenearyl$, and $C_{1-3}alkylenehet$ eroaryl;

Q is O , S , or NR^a ;

B is O , S , or NR^d ;

C is O , S , or NR^a ;

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D is CR^a or N;

E is CR^a, C(R^a)₂, or NR^d; and

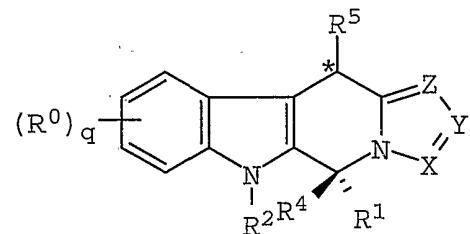
Het represents a 5- or 6-membered heterocyclic ring, saturated or partially or fully unsaturated, containing at least one heteroatom selected from the group consisting of oxygen, nitrogen, and sulfur, and optionally substituted with C₁₋₄alkyl or C(=O)OR^a;

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

pharmaceutically acceptable salts and
hydrates thereof.

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2. The compound of claim 1 represented by the formula

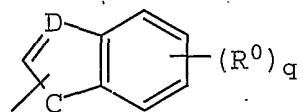
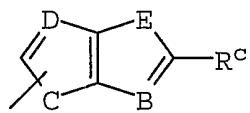
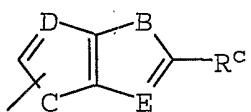


and pharmaceutically acceptable salts and hydrates thereof.

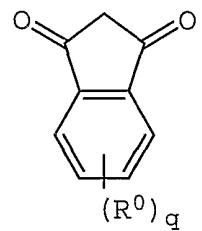
3. The compound of claim 1 wherein q is 0, or R⁰ is selected from the group consisting of aryl, Het, OR^a, C(=O)OR^a, C₁₋₄alkyleneNR^aR^b, OC(=O)R^a, C(=O)R^a, NR^aR^b, C₃₋₈cycloalkyl, C₃₋₈cycloalkylQ, C(=O)NR^aR^b, and C(=O)NR^aR^c, or two R⁰ groups are taken together with the carbon atoms to which they are attached to form a 5- or 6-membered ring, saturated or partially or fully saturated, optionally substituted and optionally containing one or two heteroatoms selected from oxygen, nitrogen, and sulfur.

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4. The compound of claim 1 wherein R¹ is selected from the group consisting of C₁₋₄alkyleneQR^a, C₁₋₄alkyleneQC₁₋₄alkyleneQR^a, C₃₋₈cycloalkyl, C₃₋₈cycloalkenyl, C₁₋₆alkyl,

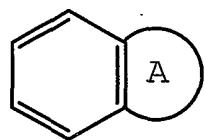


, and

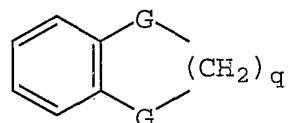


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5. The compound of claim 1 wherein R¹ is the optionally substituted bicyclic ring system



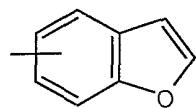
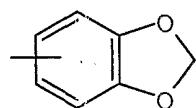
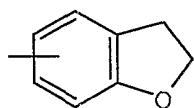
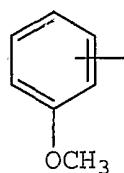
6. The compound of claim 5 wherein R¹ is



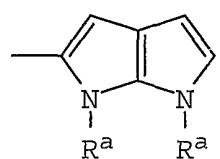
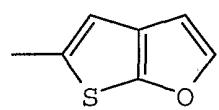
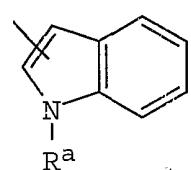
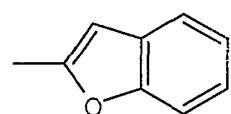
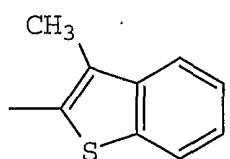
and wherein q is an integer 1 or 2, and G, independently, are C(R^a)₂, O, S, or NR^a.

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7. The compound of claim 1 wherein R¹ is selected from the group consisting of

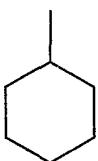


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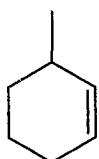


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-CH₂OR^a, -CH₂OCH₂OR^a,



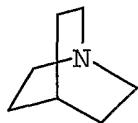
, and



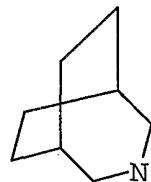
8. The compound of claim 1 wherein the R² group is selected from the group consisting of aryl, heteroaryl, OR^a, NR^aR^b, NR^aR^c, C₁₋₄alkyleneHet, C₁₋₄-alkyleneheteroaryl, C₁₋₄alkylenearyl, C₁₋₄alkyleneC-(=O)C₁₋₄alkylenearyl, C₁₋₄alkyleneC(=O)OR^a, C₁₋₄alkyleneC(=O)NR^aR^b, C₁₋₄alkyleneC(=O)NR^aR^c, C₁₋₄alkyleneC(=O)Het, C₁₋₄alkyleneNR^aR^b, C₁₋₄alkyleneNR^aR^c, C₁₋₄alkyleneNR^aC(=O)R^a, and C₁₋₄alkyleneOC₁₋₄alkyleneOR^a.

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9. The compound of claim 8 wherein R^2 is selected from the group consisting of C_{1-4} alkyleneheteroaryl, wherein the heteroaryl group is selected from the group consisting of benzimidazole, a triazole, and imidazole; C_{1-4} alkyleneHet, wherein Het is selected from the group consisting of piperazine, morpholine, pyrrolidine, pyrrolidone, tetrahydrofuran, piperidine,



, and



C_{1-4} alkylene C_6H_5 , optionally substituted with one to three groups selected from the group consisting of $C(=O)OR^a$, NR^aR^b , $NR^aSO_2CF_3$, $SO_2NR^aR^b$, CN , OR^a , $C(=O)R^a$, C_{1-4} alkylene NR^aR^b , nitro, OC_{1-4} alkylenearyl, and OC_{1-4} alkylene NR^aR^b ; C_{1-4} alkylene $C(=O)benzyl$; C_{1-4} alkylene $C(=O)OR^a$; C_{1-4} alkylene $C(=O)NR^aR^b$; C_{1-4} alkylene $C(=O)-NR^aR^c$; NR^aR^b ; OH ; OC_{1-4} alkyl; C_6H_5 ; C_{1-4} alkylene NR^aR^b ; C_{1-4} alkylene OR^a ; C_{1-4} alkylene $NHC(=O)R^a$; and C_{1-4} alkylene OC_{1-4} alkylene OR^a .

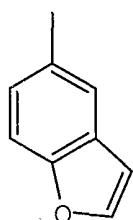
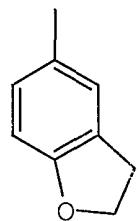
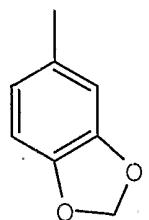
- 80 -

10. The compound of claim 8 wherein R² is selected from the group consisting of C₁₋₆alkyl, C(=O)OR^a, C₁₋₄alkyleneC(=O)OR^a, CN, C₁₋₄alkyleneNR^aR^b, C(=O)R^a, hydrogen, C(=O)NR^aC₁₋₄alkyleneHet, C₁₋₄alkyleneOR^a, CF₃, C(=O)NR^aR^c, aryl, and heteroaryl.

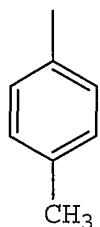
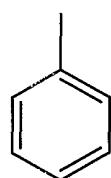
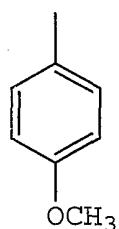
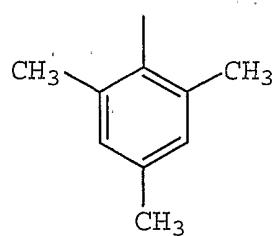
11. The compound of claim 1 wherein R⁴ and R⁵, independently, are selected from the group consisting of hydrogen, C₁₋₆alkyl, aryl, and heteroaryl.

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12. The compound of claim 1 wherein R⁰ is selected from the group consisting of halo, methyl, trifluoromethyl, and trifluoromethoxy; R¹ is selected from the group consisting of



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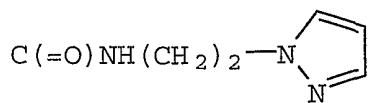
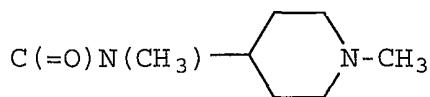
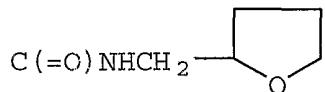
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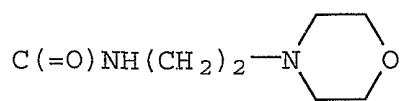
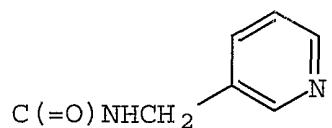
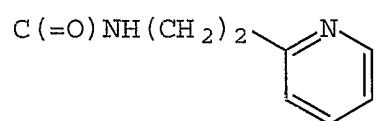
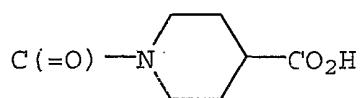
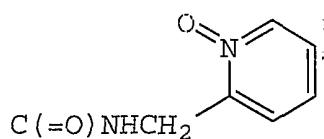


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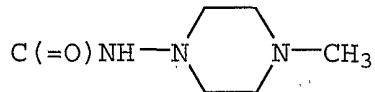
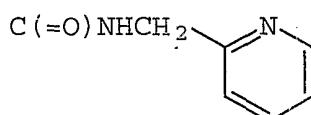
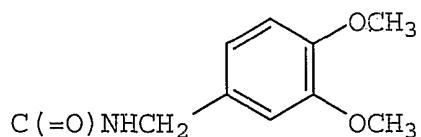
R^2 is selected from the group consisting of hydrogen, C_{1-6} alkyl, $C(=O)NR^aR^c$, and C_{1-4} alkyleneHet; R^3 is selected from the group consisting of $C(=O)OC_2H_5$, CO_2H , CH_3 , $CN(CH_2)_4C(=O)OH$, $C(=O)OCH_3$, $CH_2NHCH_2C_6H_5$, CH_2NH_2 , CHO , H , C_2H_5 , $CH(CH_3)_2$, CH_2OH , $C(=O)NH(CH_2)_2-N(CH_3)_2$, $C(=O)N(CH_3)CH_2CO_2H$,



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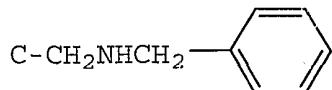


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$\text{C}(\text{=O})\text{NH}(\text{CH}_2)_2\text{NH}_2$, $\text{CH}_2\text{N}(\text{CH}_3)_2$, and $\text{C}(\text{=O})\text{NH}_2$; R^4 and R^5 are selected from the group consisting of hydrogen and C_{1-6} alkyl; and $=\text{Z}-\text{Y}=\text{X}-$ is selected from the group consisting of $=\text{C}(\text{R}^3)-\text{C}(\text{R}^3)=\text{CR}^3-$, $=\text{C}(\text{R}^3)-\text{N}=\text{CR}^3$, $=\text{C}(\text{R}^3)-\text{N}=\text{N}-$, and $=\text{N}-\text{C}(\text{R}^3)=\text{C}(\text{R}^3)-$.

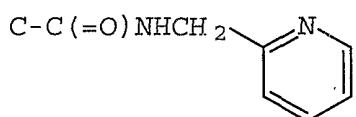
13. The compound of claim 1 wherein X is selected from the group consisting of N, $\text{C}-\text{CH}_3$, $\text{C}-\text{H}$,



$\text{C}-\text{CH}_2\text{NH}_2$, $\text{C}-\text{CHO}$, $\text{C}-\text{C}_2\text{H}_5$, $\text{C}-\text{CH}(\text{CH}_3)_2$, $\text{C}-\text{CH}_2\text{OH}$, $\text{C}-\text{CH}_2\text{N}-(\text{CH}_3)_2$, and $\text{C}-\text{CF}_3$.

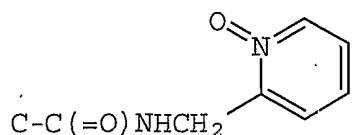
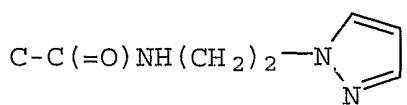
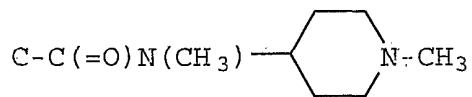
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14. The compound of claim 13 wherein Y is selected from the group consisting of C-H, C-CO₂C₂H₅, N, C-(CH₂)₄CO₂H, C-CO₂H,

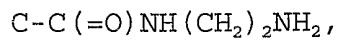
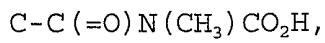
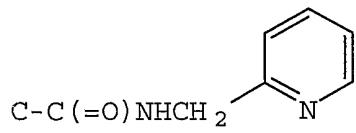
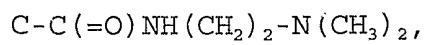
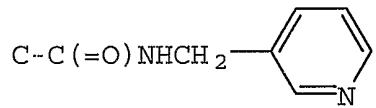
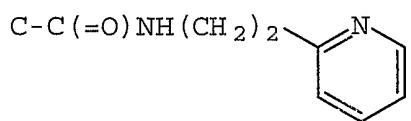
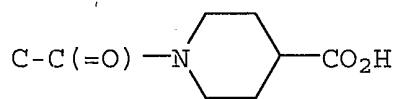
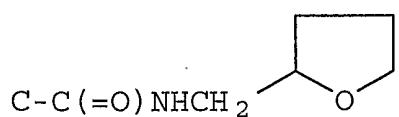


$\text{C}-\text{C}_2\text{H}_5$, and $\text{C}-\text{C}(\text{=O})\text{NH}_2$.

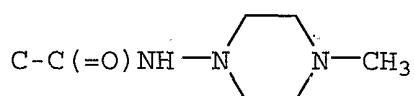
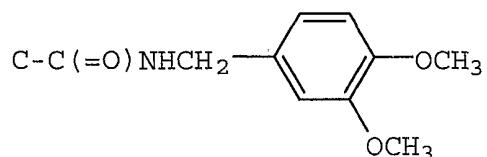
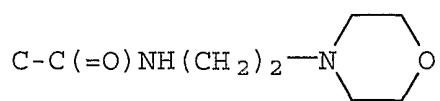
15. The compound of claim 14 wherein Z is selected from the group consisting of C-H, C-CO₂C₂H₅, C-CO₂CH₃, C-CN, C-CO₂H,



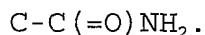
- 87 -



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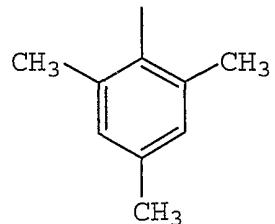
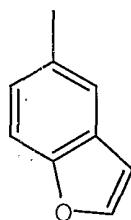
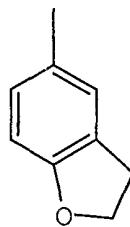
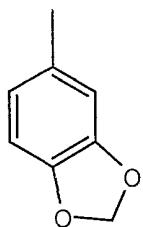
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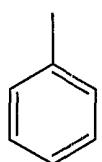
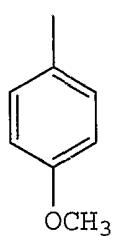
16. The compound of claim 15 wherein R^2 is hydrogen, R^4 is hydrogen, and R^5 is hydrogen.

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17. The compound of claim 16 wherein R¹ is selected from the group consisting of



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, and



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18. A compound selected from the group consisting of

(++)-5-benzo[1,3]dioxol-5-yl-3-(benzylamino-methyl)-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-(2,3-dihydrobenzofuran-5-yl)-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid;

(++)-3-aminomethyl-5-(2,3-dihydrobenzofuran-5-yl)-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-benzofuran-5-yl-3-formyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole;

(++)-5-methoxy-2,6-dimethylphenyl)-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-benzo[1,3]dioxol-5-yl-3-ethyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1,2-dicarboxylic acid diethyl ester;

(++)-5-benzo[1,3]dioxol-5-yl-3-ethyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1,2-dicarboxylic acid;

(++)-(++)-5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid (tetrahydrofuran-2-yl-methyl) amide;

(++)-5-benzo[1,3]dioxol-5-yl-3-isopropyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1,2-dicarboxylic acid diethyl ester;

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(++)-5-benzo[1,3]dioxol-5-yl-3-isopropyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid methyl-(1-methylpiperidin-4-yl)amide;

(++)-5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid (2-pyrazol-1-yl-ethyl)amide;

(++)-5-benzo[1,3]dioxol-5-yl-3-hydroxymethyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-benzo[1,3]dioxol-5-yl-3-isopropyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid (1-oxy-pyridin-2-ylmethyl)amide;

(++)-5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-1,2-dicarboxylic acid diethyl ester;

(++)-1-[1-(5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indol-1-yl)methanoyl]piperidine-4-carboxylic acid;

(++)-5-benzo[1,3]dioxol-5-yl-3-formyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid (2-pyridin-2-yl-ethyl)amide;

(++)-5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid (pyridin-3-ylmethyl)amide;

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(++)-5-benzo-[1,3]dioxol-5-yl-6,11-5H-indolizino-[6,7-b]indole-1-carboxylic acid (2-dimethylamine-ethyl)amide;

(++)-5-benzo[1,3]dioxol-5-yl-3-methyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carbonitrile;

(++)-5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid (pyridin-2-ylmethyl)amide;

(++)-{[1-(5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-yl)methanoyl]methyl-amino}acetic acid;

(++)-5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid (2-aminoethyl)amide;

(++)-5-benzo[1,3]dioxol-5-yl-3-methyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid (2-morpholin-4-yl-ethyl)amide;

(++)-5-(4-methoxyphenyl)-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid;

(++)-5-(4-methoxyphenyl)-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid 3,4-dimethoxybenzylamide;

(++)-5-(4-methoxyphenyl)-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid (2-morpholin-4-yl-ethyl)amide;

(++)-5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-benzo[1,3]dioxol-5-yl,6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid;

(++)-5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-2-carboxylic acid ethyl ester;

(++)-5-phenyl-6,11-dihydro-5H-indolizino[6,7-b]indole-2-carboxylic acid ethyl ester;

(++)-5-phenyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-benzo[1,3]dioxol-5-yl-3-methyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-phenyl-6,11-dihydro-5H-indolizino[6,7-b]indole-2-carboxylic acid;

(++)-5-phenyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid 3,4-dimethoxybenzyl amide;

(++)-5-(4-methoxyphenyl)-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-(4-methoxyphenyl)-6,11-dihydro-5H-indolizino[6,7-b]indole-2-carboxylic acid ethyl ester;

(++)-5-benzo[1,3]dioxo-5-yl-3-methyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1,2-dicarboxylic acid dimethyl ester;

(++)-5-benzo[1,3]dioxol-5-yl-3-ethyl-6,11-dihydro-5H-indolizino[6,7-b]indole-2-carboxylic acid (pyridin-2-ylmethyl) amide;

(++)-5-p-tolyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-(4-chlorophenyl)-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-benzofuran-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

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(++)-5-benzofuran-5-yl-6,11-dihydro-5H-indolizino-[6,7-b]indole-1-carboxylic acid;

(++)-5-benzo[1,3]dioxol-5-yl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid(4-methyl-piperazin-1-yl)amide;

(++)-5-benzo[1,3]dioxol-5-yl-3-dimethylamino-methyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

(++)-5-benzo[1,3]dioxol-5-yl-3-ethyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid (pyridin-2-ylmethyl)amide;

(++)-3-ethyl-5-(4-methoxy-2,6-dimethylphenyl)-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

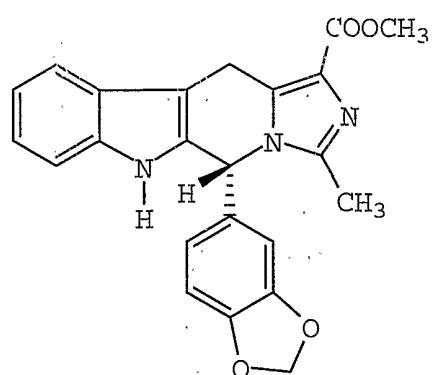
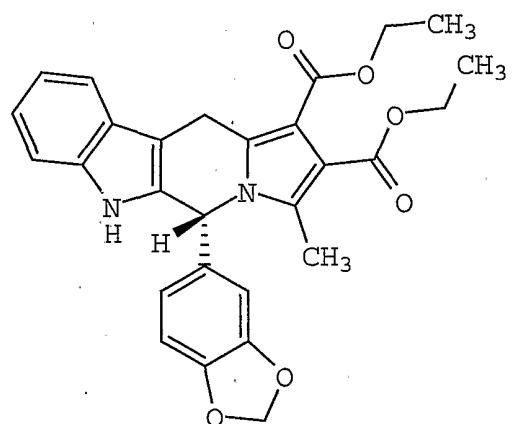
(++)-5-benzo[1,3]dioxol-5-yl-3-ethyl-6,11-dihydro-5H-indolizino[6,7-b]indole-2-carboxylic acid ethyl ester;

(++)-5-benzo[1,3]dioxol-5-yl-3-ethyl-6,11-dihydro-5H-indolizino[6,7-b]indole-1-carboxylic acid ethyl ester;

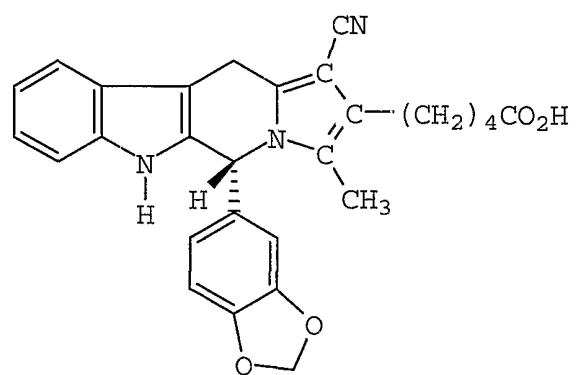
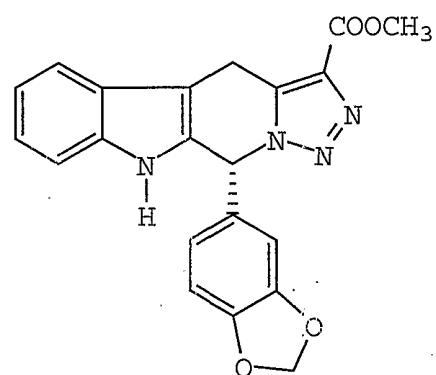
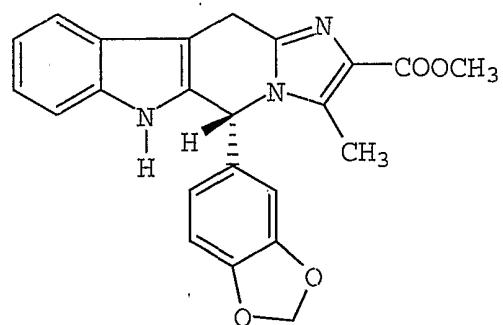
and pharmaceutically acceptable salts and solvates thereof.

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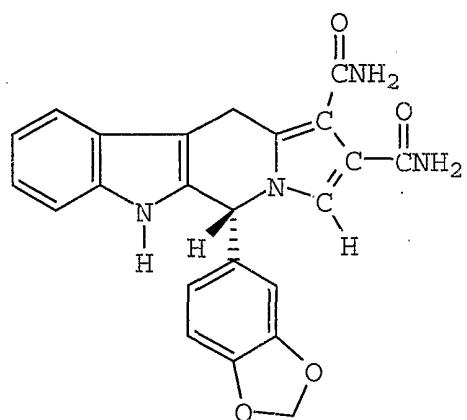
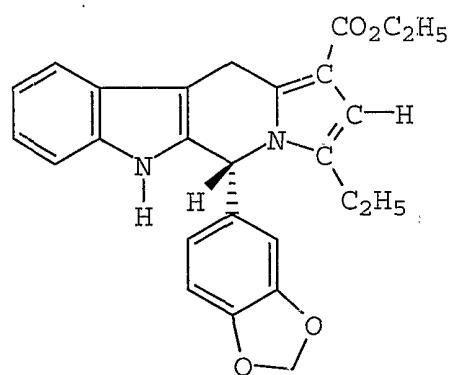
19. A compound having the formula:



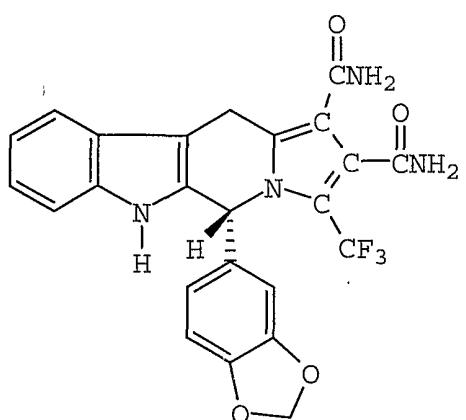
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, and



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20. A pharmaceutical composition comprising a compound of claim 1, together with a pharmaceutically acceptable diluent or carrier.

21. A method of treating a male or female animal having a condition where inhibition of a cGMP-specific PDE is of a therapeutic benefit comprising treating said animal with an effective amount of a pharmaceutical composition comprising a compound of claim 1, together with a pharmaceutically acceptable diluent or carrier.

22. The method of claim 21 wherein the condition is male erectile dysfunction.

23. The method of claim 22 wherein the treatment is an oral treatment.

24. The method of claim 21 wherein the condition is female arousal disorder.

25. The method of claim 24 wherein the treatment is an oral treatment.

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26. The method of claim 21 wherein the condition is selected from the group consisting of stable angina, unstable angina, variant angina, hypertension, pulmonary hypertension, chronic obstructive pulmonary disease, malignant hypertension, pheochromocytoma, acute respiratory distress syndrome, congestive heart failure, acute renal failure, chronic renal failure, atherosclerosis, a condition of reduced blood vessel patency, a peripheral vascular disease, a vascular disorder, thrombocytopenia, an inflammatory disease, myocardial infarction, stroke, bronchitis, chronic asthma, allergic asthma, allergic rhinitis, glaucoma, peptic ulcer, a gut motility disorder, postpercutaneous transluminal coronary angioplasty, carotid angioplasty, post-bypass surgery graft stenosis, osteoporosis, preterm labor, benign prostatic hypertrophy, and irritable bowel syndrome.

27. A method of treating a condition where inhibition of a cGMP-specific PDE is of therapeutic benefit, in a human or a nonhuman animal body, comprising administering to said body a therapeutically effective amount of a compound of claim 1.

28. A method for the curative or prophylactic treatment of male erectile dysfunction or female arousal disorder, comprising administration of an effective dose of a compound of claim 1, and pharmaceutically acceptable salts and solvates thereof, to an animal.

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29. Use of a compound of claim 1 for the manufacture of a medicament for the curative or prophylactic treatment of a condition where inhibition of a cGMP-specific PDE is of a therapeutic benefit.