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TRAITEMENT DES TROUBLES D'IMMUNODÉFICIENCE

(54) Title: COMPOSITIONS COMPRISING IMMUNOMODULATORY COMPOUNDS AND THE USE THEREOF FOR THE
TREATMENT OF IMMUNODEFICIENCY DISORDERS

(57) **Abrégé/Abstract:**

Methods of treating, preventing and/or managing an immunodeficiency disease or disorder are disclosed. Specific methods encompass the administration of an immunomodulatory compound alone or in combination with a second active agent. Methods of boosting humoral immunity are also disclosed.



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(54) **Title:** COMPOSITIONS COMPRISING IMMUNOMODULATORY COMPOUNDS AND THE USE THEREOF FOR THE TREATMENT OF IMMUNODEFICIENCY DISORDERS

(57) **Abstract:** Methods of treating, preventing and/or managing an immunodeficiency disease or disorder are disclosed. Specific methods encompass the administration of an immunomodulatory compound alone or in combination with a second active agent. Methods of boosting humoral immunity are also disclosed.



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one of X and Y is C=O and the other of X and Y is C=O or CH₂;

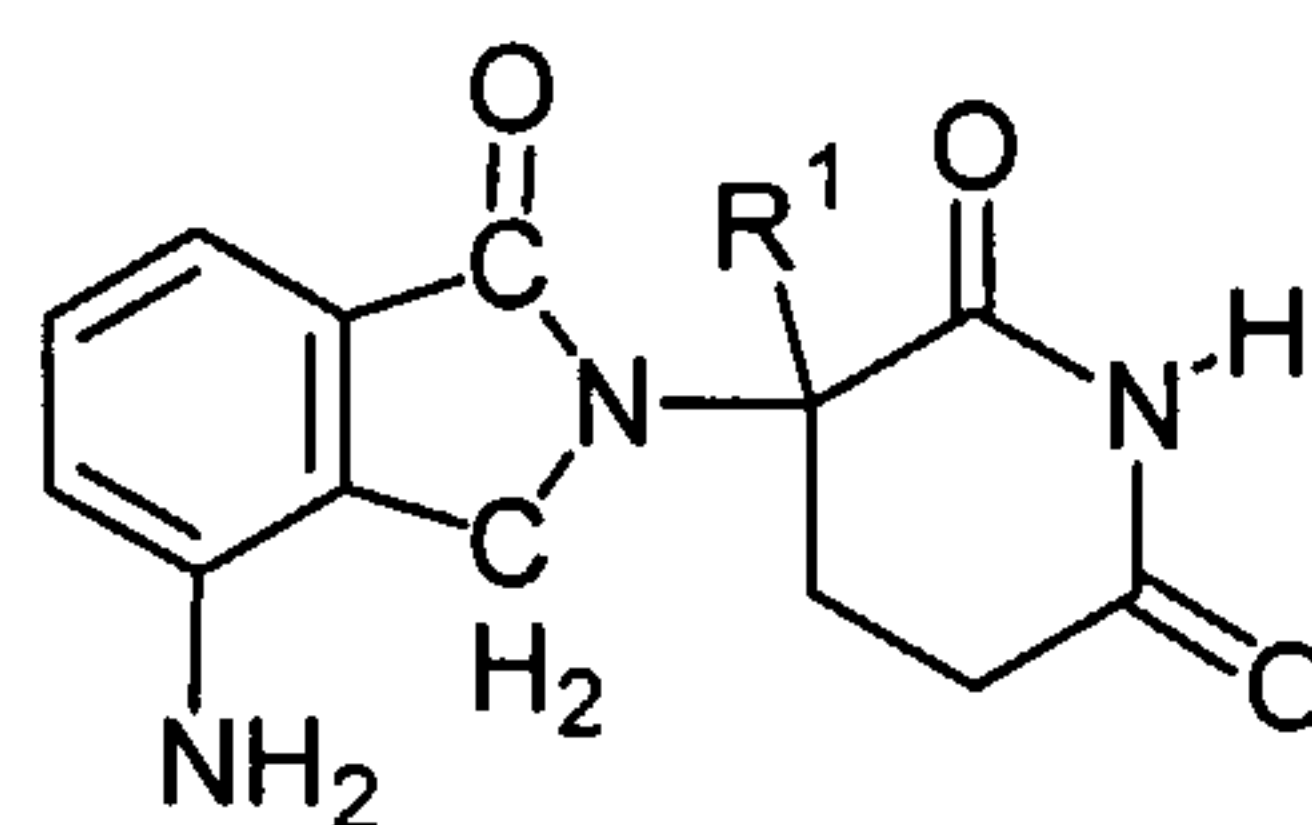
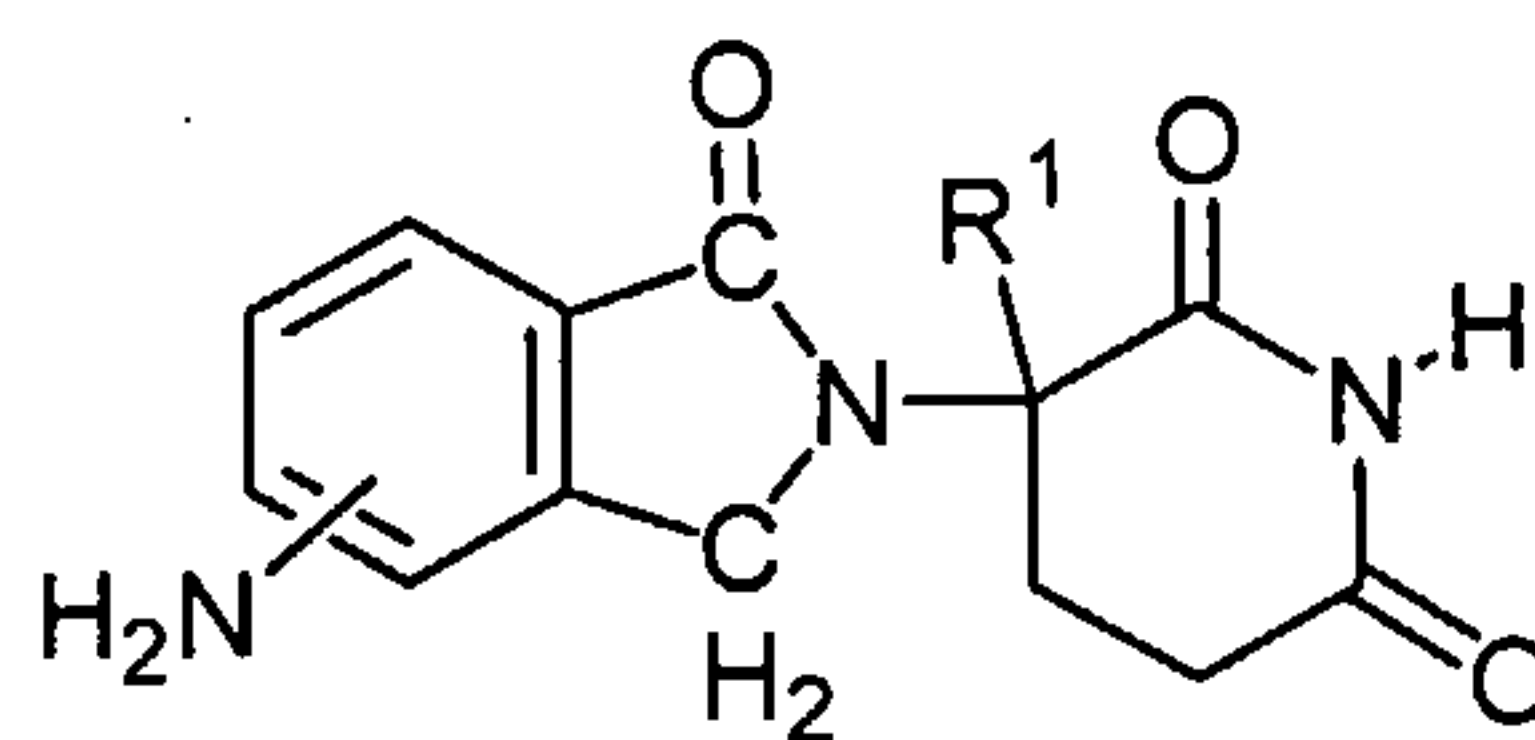
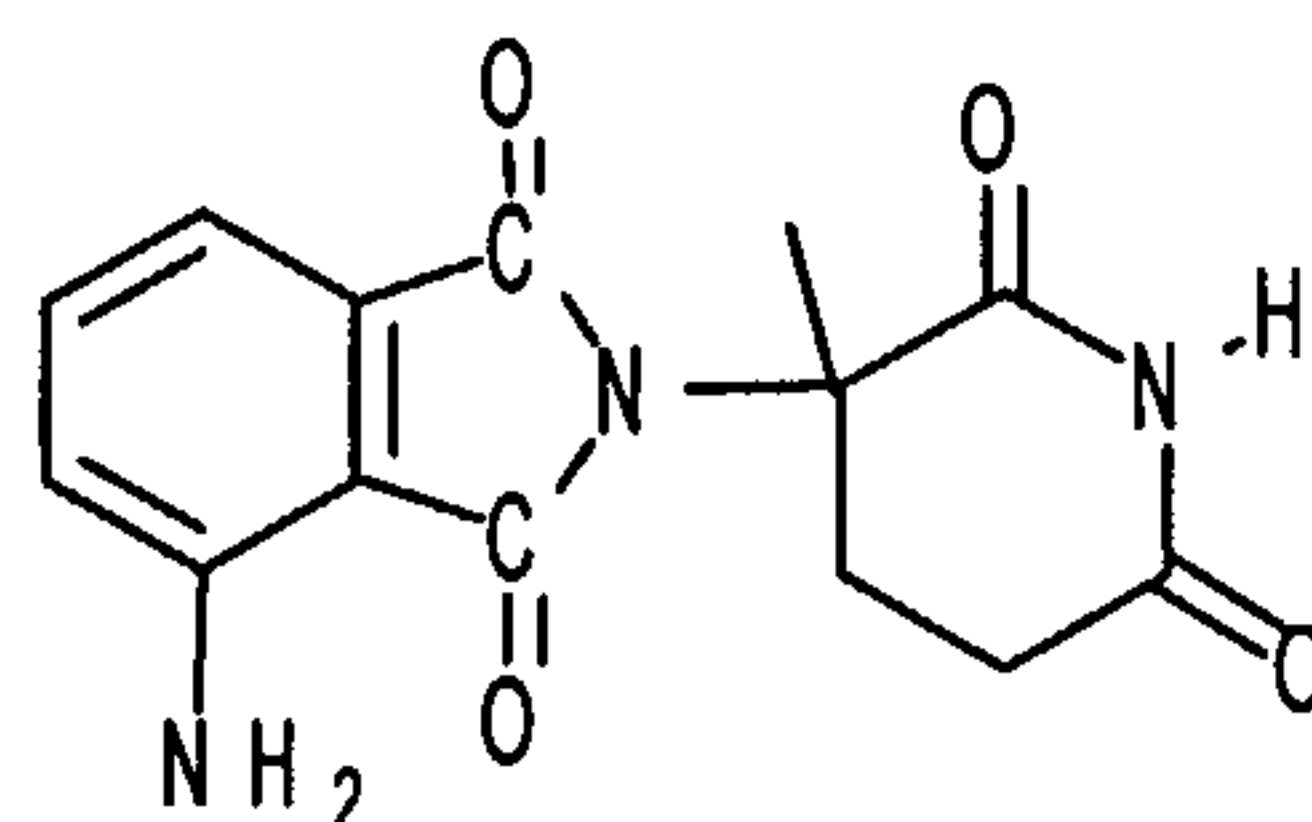
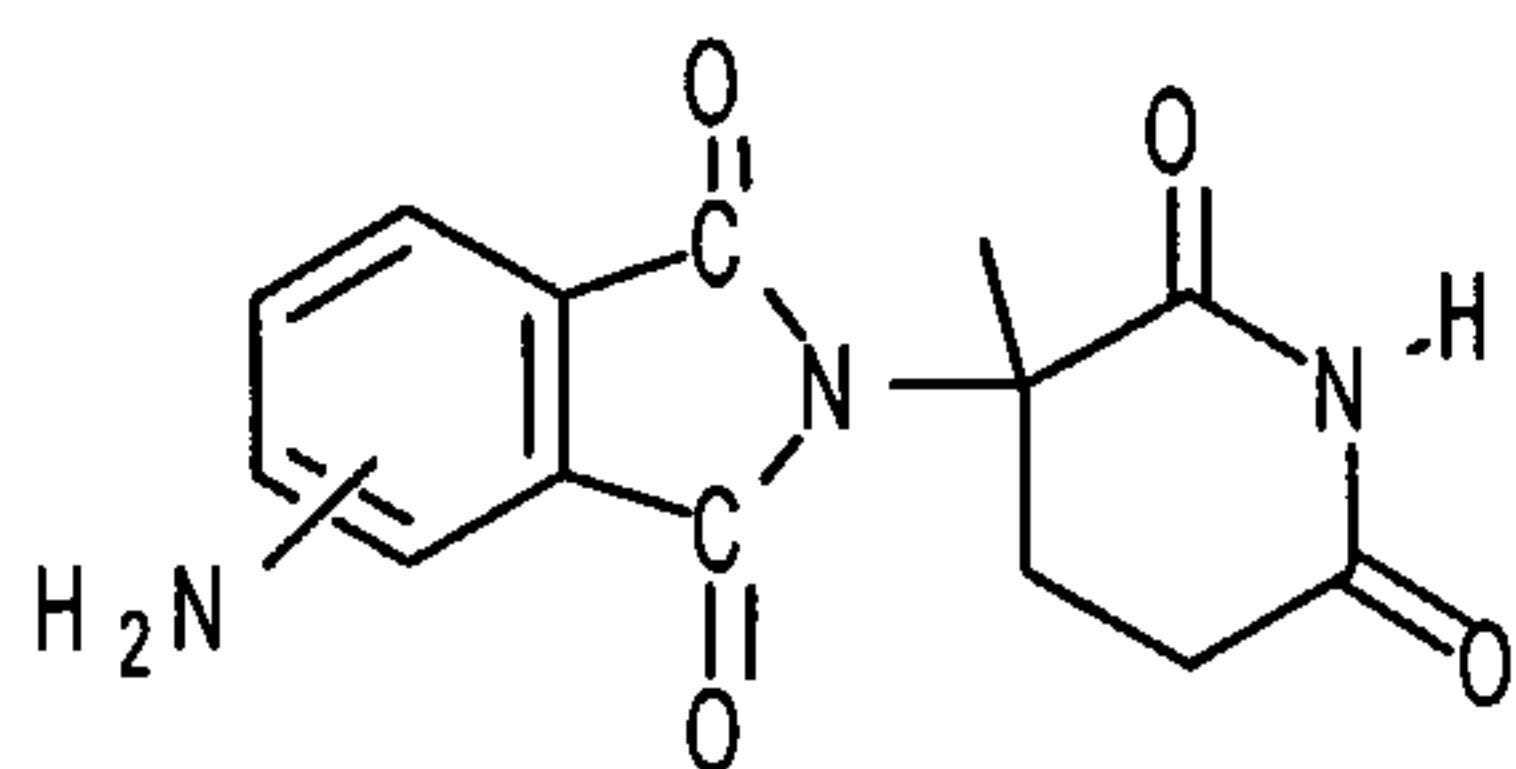
(i) each of R¹, R², R³, and R⁴, independently of the others, is halo, alkyl of 1 to 4 carbon atoms, or alkoxy of 1 to 4 carbon atoms or (ii) one of R¹, R², R³, and R⁴ is -NHR⁵ and the remaining of R¹, R², R³, and R⁴ are hydrogen;

5 R⁵ is hydrogen or alkyl of 1 to 8 carbon atoms;

R⁶ is hydrogen, alkyl of 1 to 8 carbon atoms, benzyl, or halo;

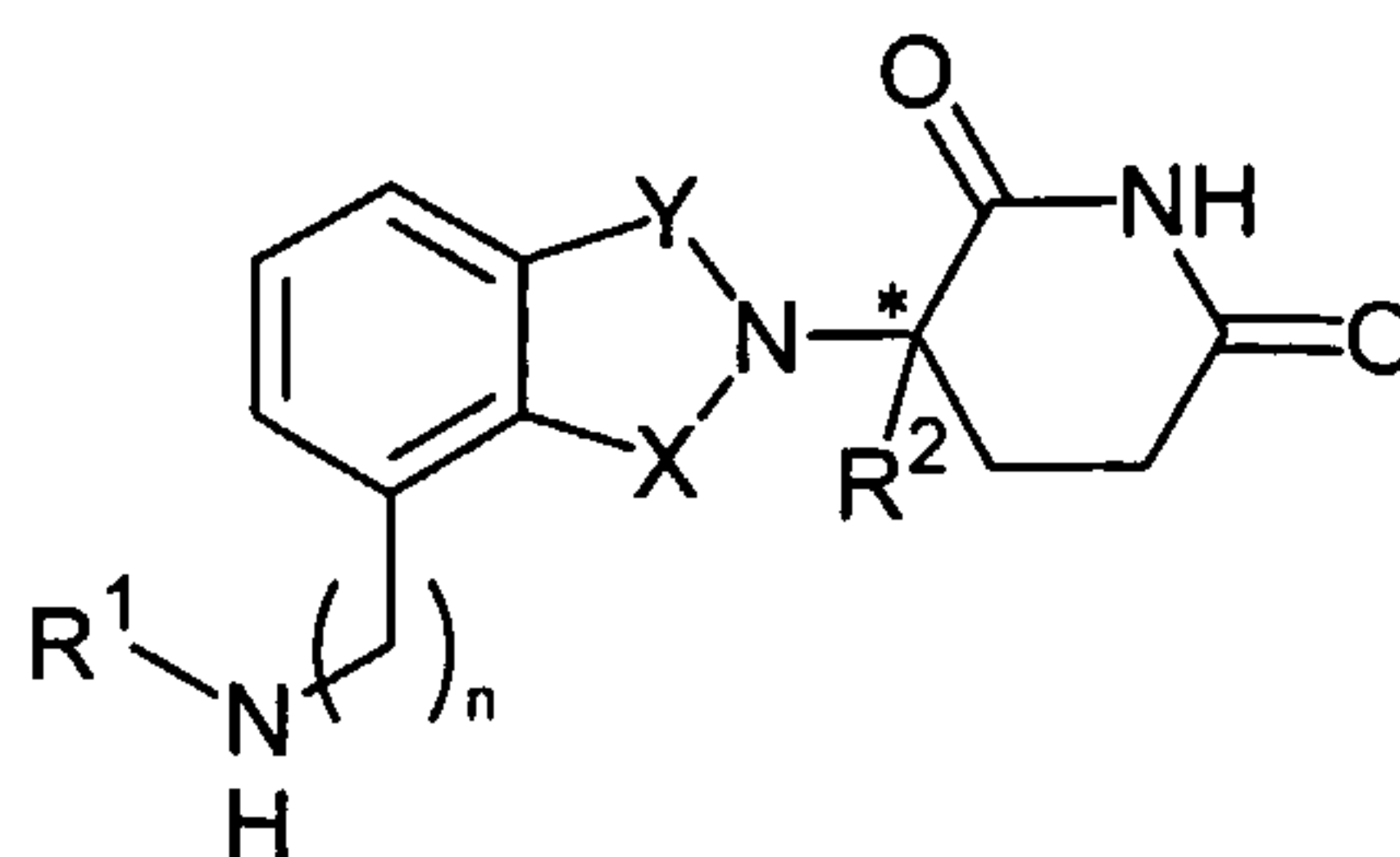
provided that R⁶ is other than hydrogen if X and Y are C=O and (i) each of R¹, R², R³, and R⁴ is fluoro or (ii) one of R¹, R², R³, or R⁴ is amino.

Compounds representative of this class are of the formulas:



10 wherein R¹ is hydrogen or methyl. In a separate embodiment, the invention encompasses the use of enantiomerically pure forms (*e.g.* optically pure (R) or (S) enantiomers) of these compounds.

Still other specific immunomodulatory compounds of the invention belong to a class of isoindole-imides disclosed in U.S. Patent Application Publication Nos. US 2003/0096841
 15 and US 2003/0045552, and International Application No. PCT/US01/50401 (International Publication No. WO 02/059106), each of which are incorporated herein by reference. Representative compounds are of formula II:



II

and pharmaceutically acceptable salts, hydrates, solvates, clathrates, enantiomers, diastereomers, racemates, and mixtures of stereoisomers thereof, wherein:

one of X and Y is C=O and the other is CH₂ or C=O;

5 R^1 is H, (C₁-C₈)alkyl, (C₃-C₇)cycloalkyl, (C₂-C₈)alkenyl, (C₂-C₈)alkynyl, benzyl, aryl, (C₀-C₄)alkyl-(C₁-C₆)heterocycloalkyl, (C₀-C₄)alkyl-(C₂-C₅)heteroaryl, C(O)R³, C(S)R³, C(O)OR⁴, (C₁-C₈)alkyl-N(R⁶)₂, (C₁-C₈)alkyl-OR⁵, (C₁-C₈)alkyl-C(O)OR⁵, C(O)NHR³, C(S)NHR³, C(O)NR³R^{3'}, C(S)NR³R^{3'} or (C₁-C₈)alkyl-O(CO)R⁵;

R^2 is H, F, benzyl, (C₁-C₈)alkyl, (C₂-C₈)alkenyl, or (C₂-C₈)alkynyl;

10 R^3 and $R^{3'}$ are independently (C₁-C₈)alkyl, (C₃-C₇)cycloalkyl, (C₂-C₈)alkenyl, (C₂-C₈)alkynyl, benzyl, aryl, (C₀-C₄)alkyl-(C₁-C₆)heterocycloalkyl, (C₀-C₄)alkyl-(C₂-C₅)heteroaryl, (C₀-C₈)alkyl-N(R⁶)₂, (C₁-C₈)alkyl-OR⁵, (C₁-C₈)alkyl-C(O)OR⁵, (C₁-C₈)alkyl-O(CO)R⁵, or C(O)OR⁵;

15 R^4 is (C₁-C₈)alkyl, (C₂-C₈)alkenyl, (C₂-C₈)alkynyl, (C₁-C₄)alkyl-OR⁵, benzyl, aryl, (C₀-C₄)alkyl-(C₁-C₆)heterocycloalkyl, or (C₀-C₄)alkyl-(C₂-C₅)heteroaryl;

R^5 is (C₁-C₈)alkyl, (C₂-C₈)alkenyl, (C₂-C₈)alkynyl, benzyl, aryl, or (C₂-C₅)heteroaryl;

20 each occurrence of R^6 is independently H, (C₁-C₈)alkyl, (C₂-C₈)alkenyl, (C₂-C₈)alkynyl, benzyl, aryl, (C₂-C₅)heteroaryl, or (C₀-C₈)alkyl-C(O)O-R⁵ or the R^6 groups can join to form a heterocycloalkyl group;

n is 0 or 1; and

* represents a chiral-carbon center.

25 In specific compounds of formula II, when n is 0 then R^1 is (C₃-C₇)cycloalkyl, (C₂-C₈)alkenyl, (C₂-C₈)alkynyl, benzyl, aryl, (C₀-C₄)alkyl-(C₁-C₆)heterocycloalkyl, (C₀-C₄)alkyl-(C₂-C₅)heteroaryl, C(O)R³, C(O)OR⁴, (C₁-C₈)alkyl-N(R⁶)₂, (C₁-C₈)alkyl-OR⁵, (C₁-C₈)alkyl-C(O)OR⁵, C(S)NHR³, or (C₁-C₈)alkyl-O(CO)R⁵;

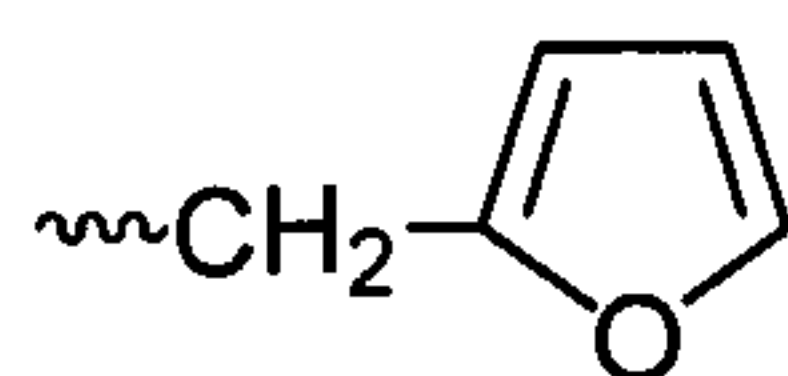
R^2 is H or (C₁-C₈)alkyl; and

30 R^3 is (C₁-C₈)alkyl, (C₃-C₇)cycloalkyl, (C₂-C₈)alkenyl, (C₂-C₈)alkynyl, benzyl, aryl, (C₀-C₄)alkyl-(C₁-C₆)heterocycloalkyl, (C₀-C₄)alkyl-(C₂-C₅)heteroaryl, (C₅-C₈)alkyl-N(R⁶)₂; (C₀-C₈)alkyl-NH-C(O)O-R⁵; (C₁-C₈)alkyl-OR⁵, (C₁-C₈)alkyl-C(O)OR⁵, (C₁-C₈)alkyl-O(CO)R⁵, or C(O)OR⁵; and the other variables have the same definitions.

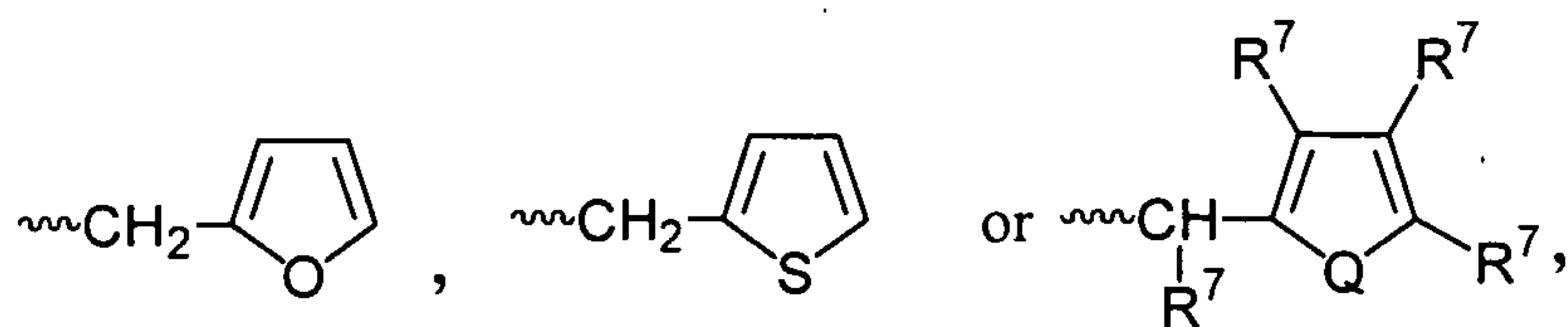
In other specific compounds of formula II, R^2 is H or (C_1-C_4) alkyl.

In other specific compounds of formula II, R^1 is (C_1-C_8) alkyl or benzyl.

In other specific compounds of formula II, R^1 is H, (C_1-C_8) alkyl, benzyl, CH_2OCH_3 , $CH_2CH_2OCH_3$, or



In another embodiment of the compounds of formula II, R^1 is



wherein Q is O or S, and each occurrence of R^7 is independently H, (C_1-C_8) alkyl, (C_3-C_7) cycloalkyl, (C_2-C_8) alkenyl, (C_2-C_8) alkynyl, benzyl, aryl, halogen, (C_0-C_4) alkyl- (C_1-C_6) heterocycloalkyl, (C_0-C_4) alkyl- (C_2-C_5) heteroaryl, (C_0-C_8) alkyl- $N(R^6)_2$, (C_1-C_8) alkyl- OR^5 , (C_1-C_8) alkyl- $C(O)OR^5$, (C_1-C_8) alkyl- $O(CO)R^5$, or $C(O)OR^5$, or adjacent occurrences of R^7 can be taken together to form a bicyclic alkyl or aryl ring.

In other specific compounds of formula II, R^1 is $C(O)R^3$.

In other specific compounds of formula II, R^3 is (C_0-C_4) alkyl- (C_2-C_5) heteroaryl, (C_1-C_8) alkyl, aryl, or (C_0-C_4) alkyl- OR^5 .

In other specific compounds of formula II, heteroaryl is pyridyl, furyl, or thienyl.

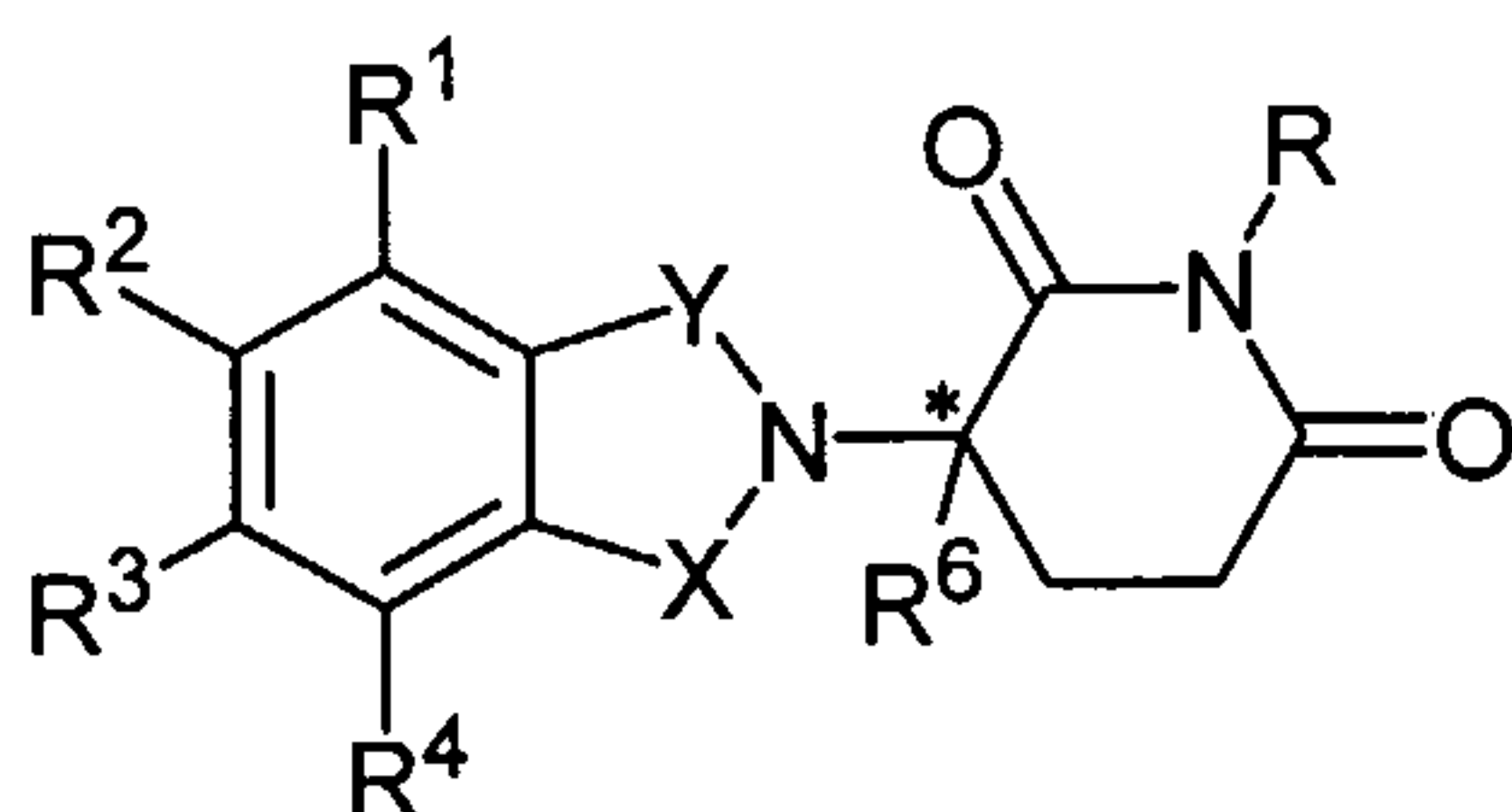
In other specific compounds of formula II, R^1 is $C(O)OR^4$.

In other specific compounds of formula II, the H of $C(O)NHC(O)$ can be replaced with (C_1-C_4) alkyl, aryl, or benzyl.

20 Further examples of the compounds in this class include, but are not limited to: [2-(2,6-dioxo-piperidin-3-yl)-1,3-dioxo-2,3-dihydro-1H-isoindol-4-ylmethyl]-amide; (2-(2,6-dioxo-piperidin-3-yl)-1,3-dioxo-2,3-dihydro-1H-isoindol-4-ylmethyl)-carbamic acid *tert*-butyl ester; 4-(aminomethyl)-2-(2,6-dioxo(3-piperidyl))-isoindoline-1,3-dione; *N*-(2-(2,6-dioxo-piperidin-3-yl)-1,3-dioxo-2,3-dihydro-1H-isoindol-4-ylmethyl)-acetamide; *N*-{(2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisoindolin-4-yl)methyl}cyclopropyl-carboxamide; 2-chloro-*N*-{(2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisoindolin-4-yl)methyl}acetamide; *N*-(2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisoindolin-4-yl)-3-pyridylcarboxamide; 3-{1-oxo-4-(benzylamino)isoindolin-2-yl}piperidine-2,6-dione; 2-(2,6-dioxo(3-piperidyl))-4-(benzylamino)isoindoline-1,3-dione; *N*-{(2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisoindolin-4-yl)methyl}propanamide; *N*-{(2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisoindolin-4-yl)methyl}-3-pyridylcarboxamide; *N*-{(2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisoindolin-4-yl)methyl}heptanamide; *N*-{(2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisoindolin-4-yl)methyl}-

2-furylcarboxamide; {N-(2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisindolin-4-yl)carbamoyl}methyl acetate; N-(2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisindolin-4-yl)pentanamide; N-(2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisindolin-4-yl)-2-thienylcarboxamide; N-{[2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisindolin-4-yl]methyl}(butylamino)carboxamide; N-{[2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisindolin-4-yl]methyl}(octylamino)carboxamide; and N-{[2-(2,6-dioxo(3-piperidyl))-1,3-dioxoisindolin-4-yl]methyl}(benzylamino)carboxamide.

Still other specific immunomodulatory compounds of the invention belong to a class of isoindole-imides disclosed in U.S. Patent Application Publication Nos. US 2002/0045643, International Publication No. WO 98/54170, and United States Patent No. 6,395,754, each of which is incorporated herein by reference. Representative compounds are of formula III:



III

and pharmaceutically acceptable salts, hydrates, solvates, clathrates, enantiomers, diastereomers, racemates, and mixtures of stereoisomers thereof, wherein:

one of X and Y is C=O and the other is CH₂ or C=O;

R is H or CH₂OCOR';

(i) each of R¹, R², R³, or R⁴, independently of the others, is halo, alkyl of 1 to 4 carbon atoms, or alkoxy of 1 to 4 carbon atoms or (ii) one of R¹, R², R³, or R⁴ is nitro or -NHR⁵ and the remaining of R¹, R², R³, or R⁴ are hydrogen;

R⁵ is hydrogen or alkyl of 1 to 8 carbons

R⁶ hydrogen, alkyl of 1 to 8 carbon atoms, benzo, chloro, or fluoro;

R' is R⁷-CHR¹⁰-N(R⁸R⁹);

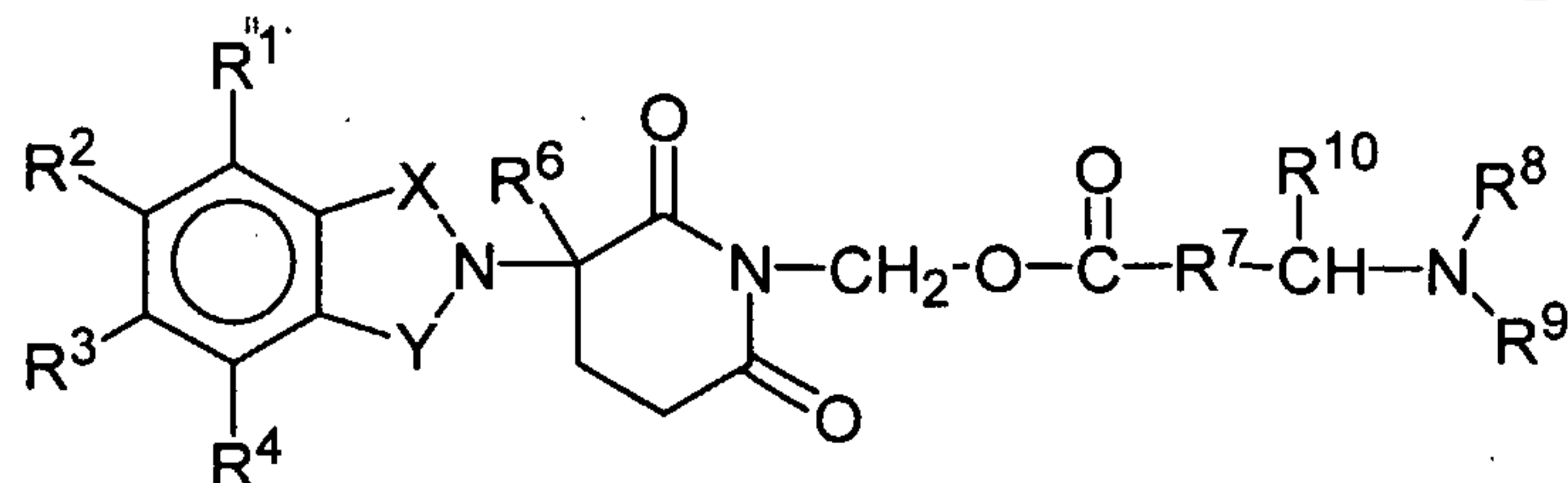
R⁷ is m-phenylene or p-phenylene or -(C_nH_{2n})- in which n has a value of 0 to 4;

each of R⁸ and R⁹ taken independently of the other is hydrogen or alkyl of 1 to 8 carbon atoms, or R⁸ and R⁹ taken together are tetramethylene, pentamethylene, hexamethylene, or -CH₂CH₂X₁CH₂CH₂- in which X₁ is -O-, -S-, or -NH-;

R¹⁰ is hydrogen, alkyl of to 8 carbon atoms, or phenyl; and

* represents a chiral-carbon center.

Other representative compounds are of formula:



wherein:

one of X and Y is C=O and the other of X and Y is C=O or CH₂;

(i) each of R¹, R², R³, or R⁴, independently of the others, is halo, alkyl of 1 to 4 carbon atoms, or alkoxy of 1 to 4 carbon atoms or (ii) one of R¹, R², R³, and R⁴ is -NHR⁵ and the remaining of R¹, R², R³, and R⁴ are hydrogen;

R⁵ is hydrogen or alkyl of 1 to 8 carbon atoms;

R⁶ is hydrogen, alkyl of 1 to 8 carbon atoms, benzo, chloro, or fluoro;

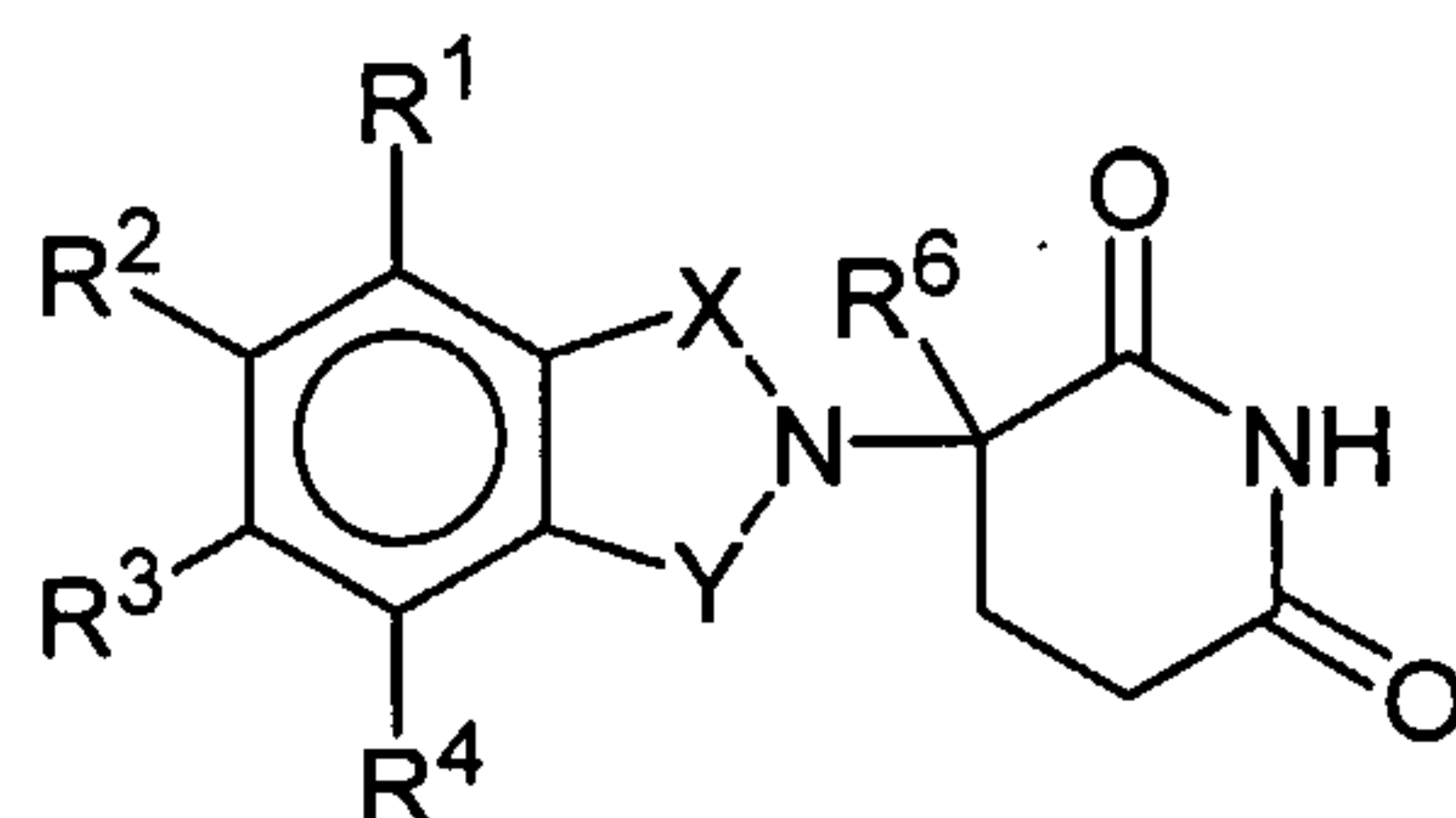
R⁷ is m-phenylene or p-phenylene or -(C_nH_{2n})- in which n has a value of 0 to 4;

each of R⁸ and R⁹ taken independently of the other is hydrogen or alkyl of 1 to 8 carbon atoms, or R⁸ and R⁹ taken together are tetramethylene, pentamethylene, hexamethylene, or -CH₂CH₂ X¹CH₂CH₂- in which X¹ is -O-, -S-, or -NH-;

R¹⁰ is hydrogen, alkyl of to 8 carbon atoms, or phenyl.

Other representative compounds are of formula:

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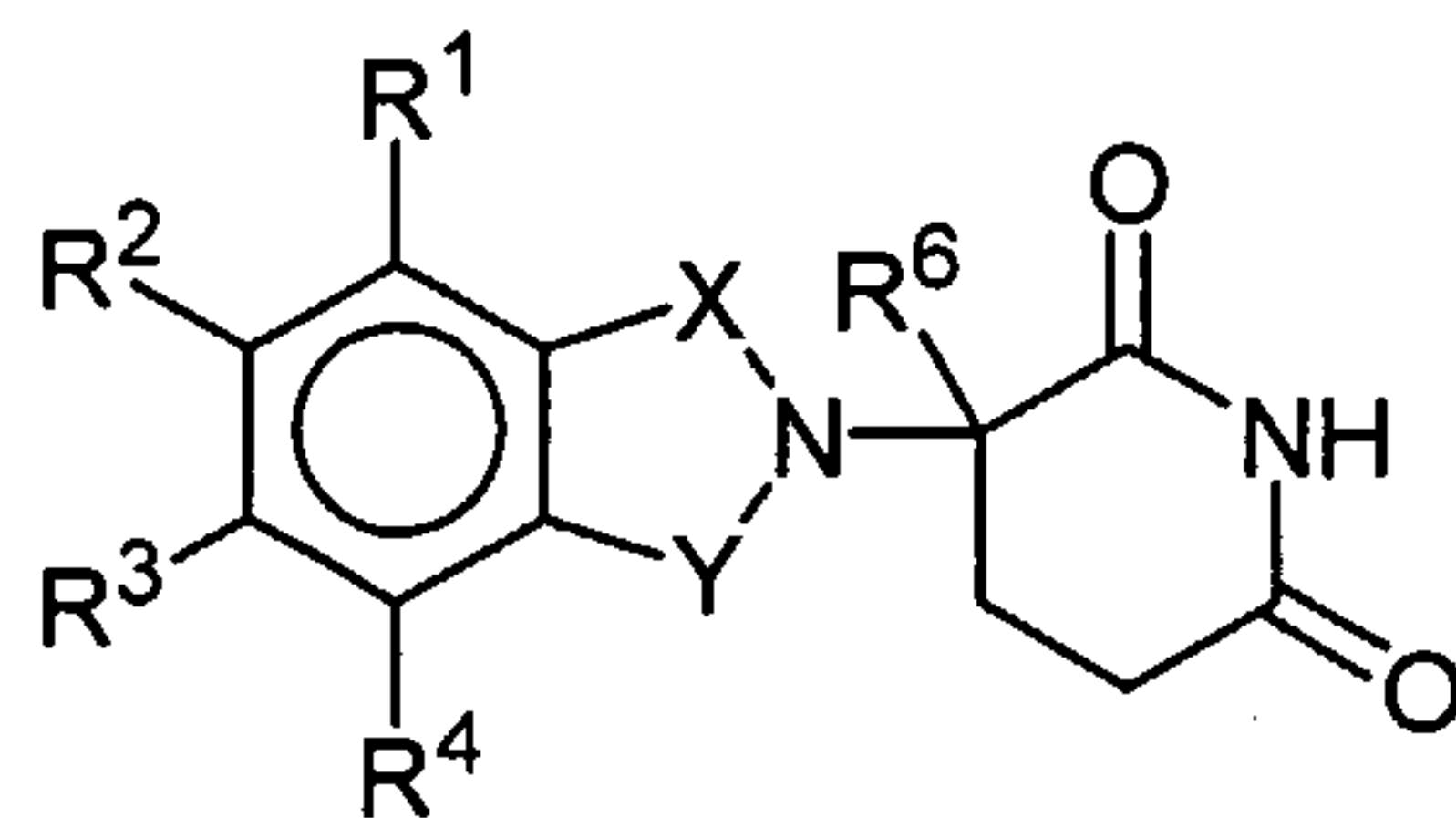
in which

one of X and Y is C=O and the other of X and Y is C=O or CH₂;

each of R¹, R², R³, and R⁴, independently of the others, is halo, alkyl of 1 to 4 carbon atoms, or alkoxy of 1 to 4 carbon atoms or (ii) one of R¹, R², R³, and R⁴ is nitro or protected amino and the remaining of R¹, R², R³, and R⁴ are hydrogen; and

R⁶ is hydrogen, alkyl of 1 to 8 carbon atoms, benzo, chloro, or fluoro.

Other representative compounds are of formula:



25

in which:

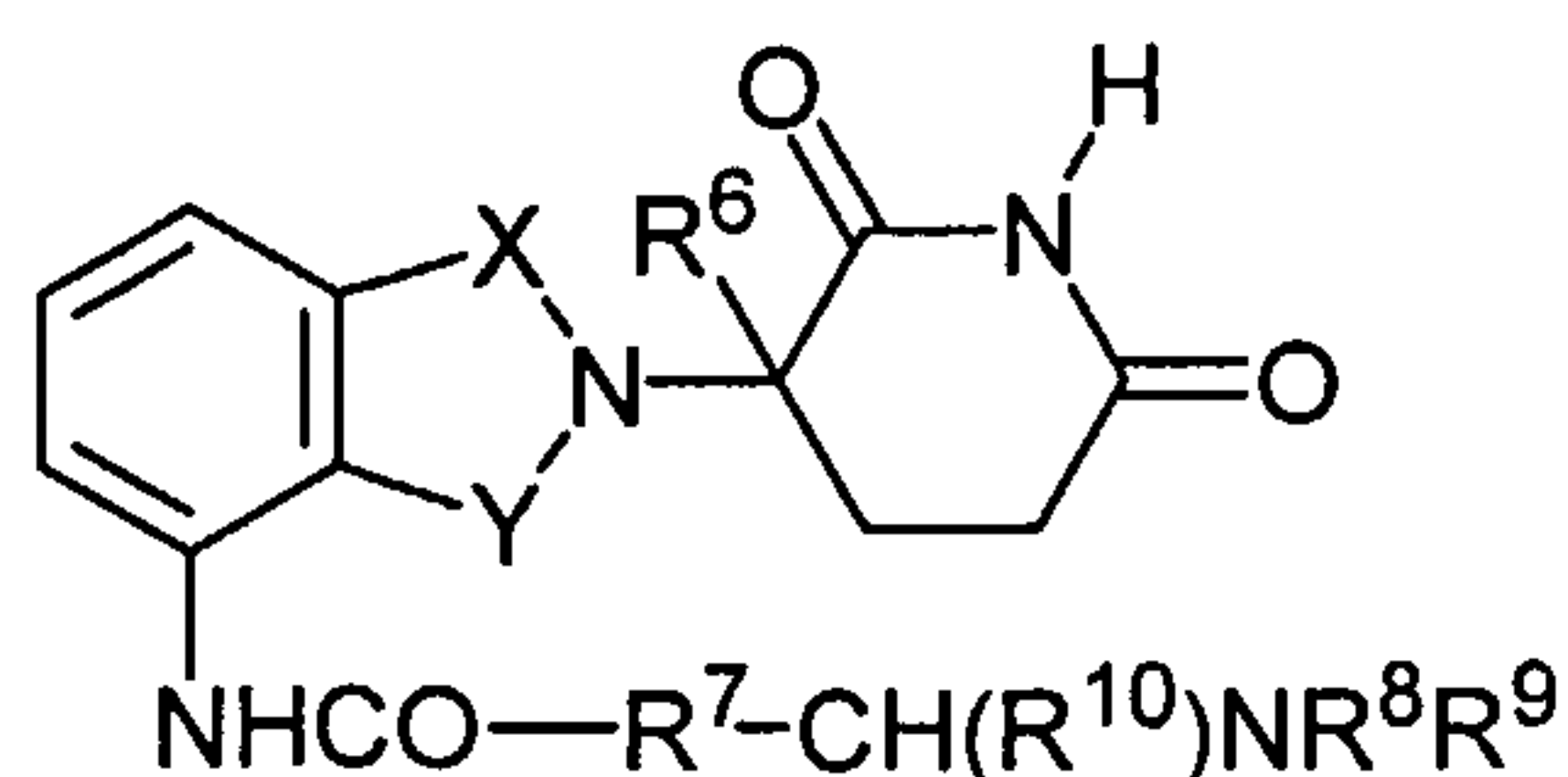
one of X and Y is C=O and the other of X and Y is C=O or CH₂;

(i) each of R^1 , R^2 , R^3 , and R^4 , independently of the others, is halo, alkyl of 1 to 4 carbon atoms, or alkoxy of 1 to 4 carbon atoms or (ii) one of R^1 , R^2 , R^3 , and R^4 is $-NHR^5$ and the remaining of R^1 , R^2 , R^3 , and R^4 are hydrogen;

R^5 is hydrogen, alkyl of 1 to 8 carbon atoms, or $CO-R^7-CH(R^{10})NR^8R^9$ in which
5 each of R^7 , R^8 , R^9 , and R^{10} is as herein defined; and

R^6 is alkyl of 1 to 8 carbon atoms, benzo, chloro, or fluoro.

Specific examples of the compounds are of formula:



in which:

10 one of X and Y is C=O and the other of X and Y is C=O or CH_2 ;

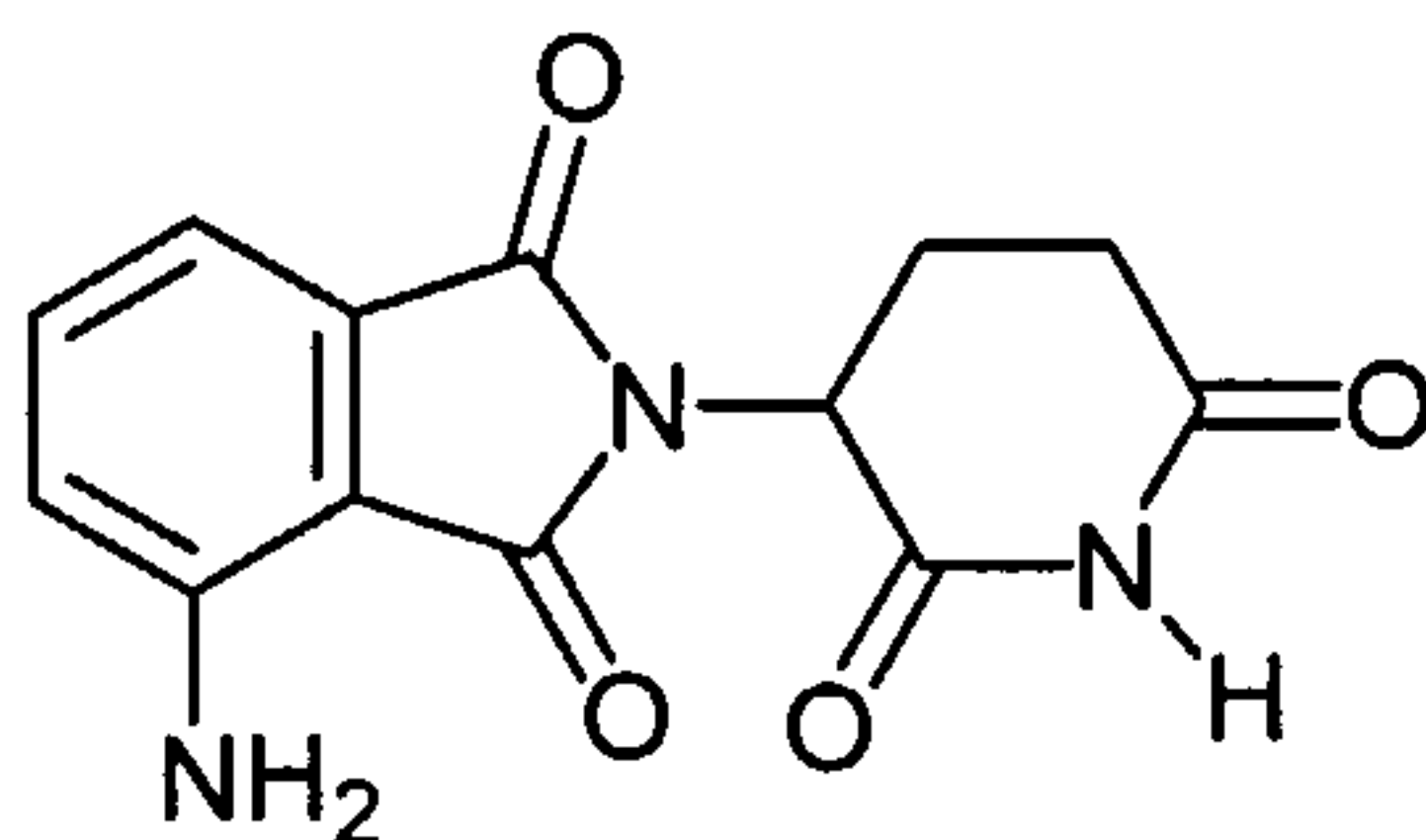
R^6 is hydrogen, alkyl of 1 to 8 carbon atoms, benzyl, chloro, or fluoro;

R^7 is m-phenylene, p-phenylene or $-(C_nH_{2n})-$ in which n has a value of 0 to 4;

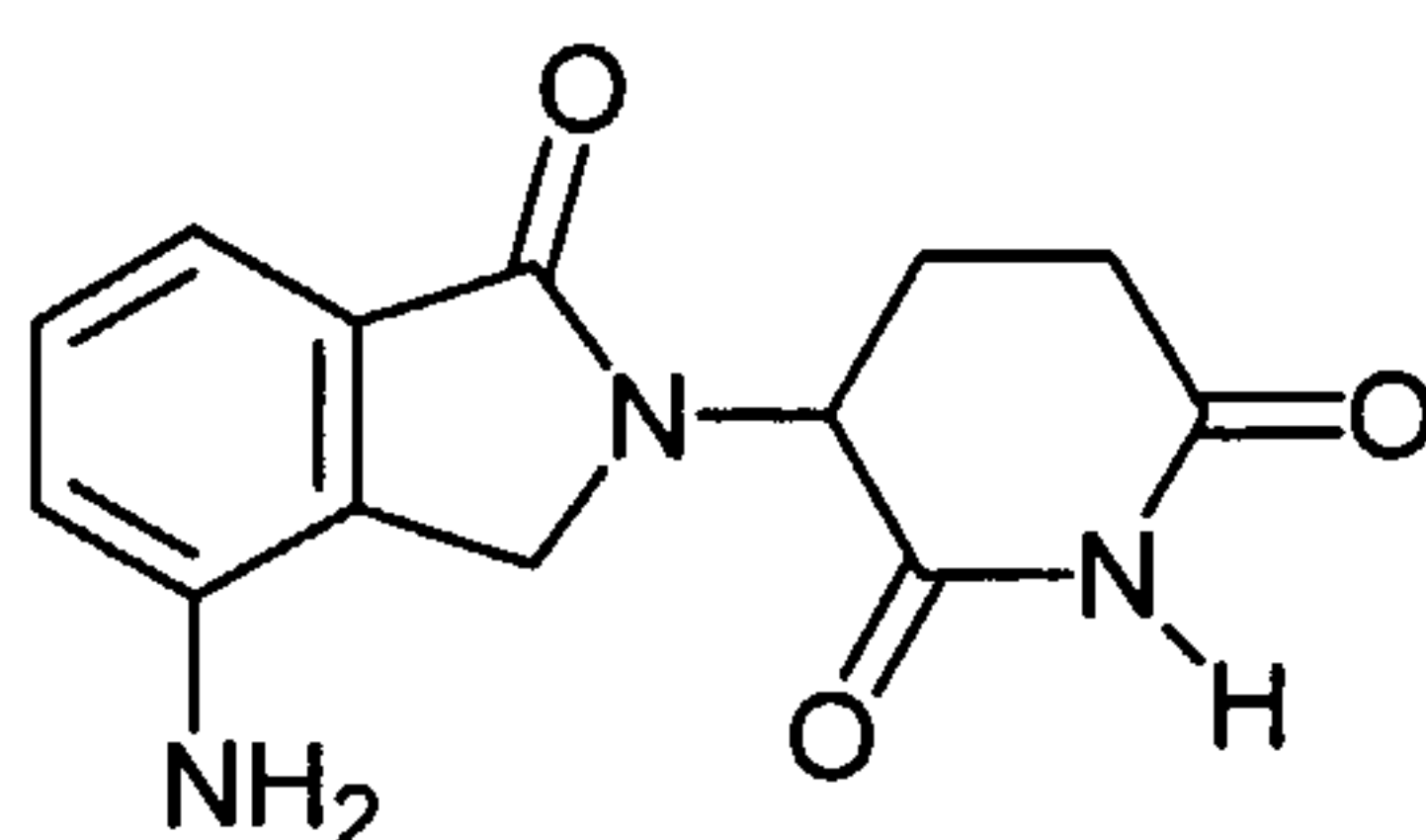
each of R^8 and R^9 taken independently of the other is hydrogen or alkyl of 1 to 8 carbon atoms, or R^8 and R^9 taken together are tetramethylene, pentamethylene,
15 hexamethylene, or $-CH_2CH_2X^1CH_2CH_2-$ in which X^1 is -O-, -S- or -NH-; and

R^{10} is hydrogen, alkyl of 1 to 8 carbon atoms, or phenyl.

The most preferred immunomodulatory compounds of the invention are 4-(amino)-2-(2,6-dioxo(3-piperidyl))-isoindoline-1,3-dione and 3-(4-amino-1-oxo-1,3-dihydro-isoindol-2-yl)-piperidine-2,6-dione. The compounds can be obtained via standard, synthetic
20 methods (*see e.g.*, United States Patent No. 5,635,517, incorporated herein by reference). The compounds are available from Celgene Corporation, Warren, NJ. 4-(Amino)-2-(2,6-dioxo(3-piperidyl))-isoindoline-1,3-dione has the following chemical structure:



The compound 3-(4-amino-1-oxo-1,3-dihydro-isoindol-2-yl)-piperidine-2,6-dione has the following chemical structure:



In another embodiment, specific immunomodulatory compounds of the invention encompass polymorphic forms of 3-(4-amino-1-oxo-1,3 dihydro-isoindol-2-yl)-piperidine-2,6-dione such as Form A, B, C, D, E, F, G and H, disclosed in U.S. provisional application no. 60/499,723 filed on September 4, 2003, and the corresponding U.S. non-provisional application, filed September 3, 2004, both of which are incorporated herein by reference. For example, Form A of 3-(4-amino-1-oxo-1,3 dihydro-isoindol-2-yl)-piperidine-2,6-dione is an unsolvated, crystalline material that can be obtained from non-aqueous solvent systems. Form A has an X-ray powder diffraction pattern comprising significant peaks at approximately 8, 14.5, 16, 17.5, 20.5, 24 and 26 degrees 2θ , and has a differential scanning calorimetry melting temperature maximum of about 270°C. Form A is weakly or not hygroscopic and appears to be the most thermodynamically stable anhydrous polymorph of 3-(4-amino-1-oxo-1,3 dihydro-isoindol-2-yl)-piperidine-2,6-dione discovered thus far.

Form B of 3-(4-amino-1-oxo-1,3 dihydro-isoindol-2-yl)-piperidine-2,6-dione is a hemihydrated, crystalline material that can be obtained from various solvent systems, including, but not limited to, hexane, toluene, and water. Form B has an X-ray powder diffraction pattern comprising significant peaks at approximately 16, 18, 22 and 27 degrees 2θ , and has endotherms from DSC curve of about 146 and 268°C, which are identified dehydration and melting by hot stage microscopy experiments. Interconversion studies show that Form B converts to Form E in aqueous solvent systems, and converts to other forms in acetone and other anhydrous systems.

Form C of 3-(4-amino-1-oxo-1,3 dihydro-isoindol-2-yl)-piperidine-2,6-dione is a hemisolvated crystalline material that can be obtained from solvents such as, but not limited to, acetone. Form C has an X-ray powder diffraction pattern comprising significant peaks at approximately 15.5 and 25 degrees 2θ , and has a differential scanning calorimetry melting temperature maximum of about 269°C. Form C is not hygroscopic below about 85% RH, but can convert to Form B at higher relative humidities.

Form D of 3-(4-amino-1-oxo-1,3 dihydro-isoindol-2-yl)-piperidine-2,6-dione is a crystalline, solvated polymorph prepared from a mixture of acetonitrile and water. Form D has an X-ray powder diffraction pattern comprising significant peaks at approximately 27 and 28 degrees 2θ , and has a differential scanning calorimetry melting temperature maximum of about 270°C. Form D is either weakly or not hygroscopic, but will typically convert to Form B when stressed at higher relative humidities.

Form E of 3-(4-amino-1-oxo-1,3 dihydro-isoindol-2-yl)-piperidine-2,6-dione is a dihydrated, crystalline material that can be obtained by slurring 3-(4-amino-1-oxo-1,3

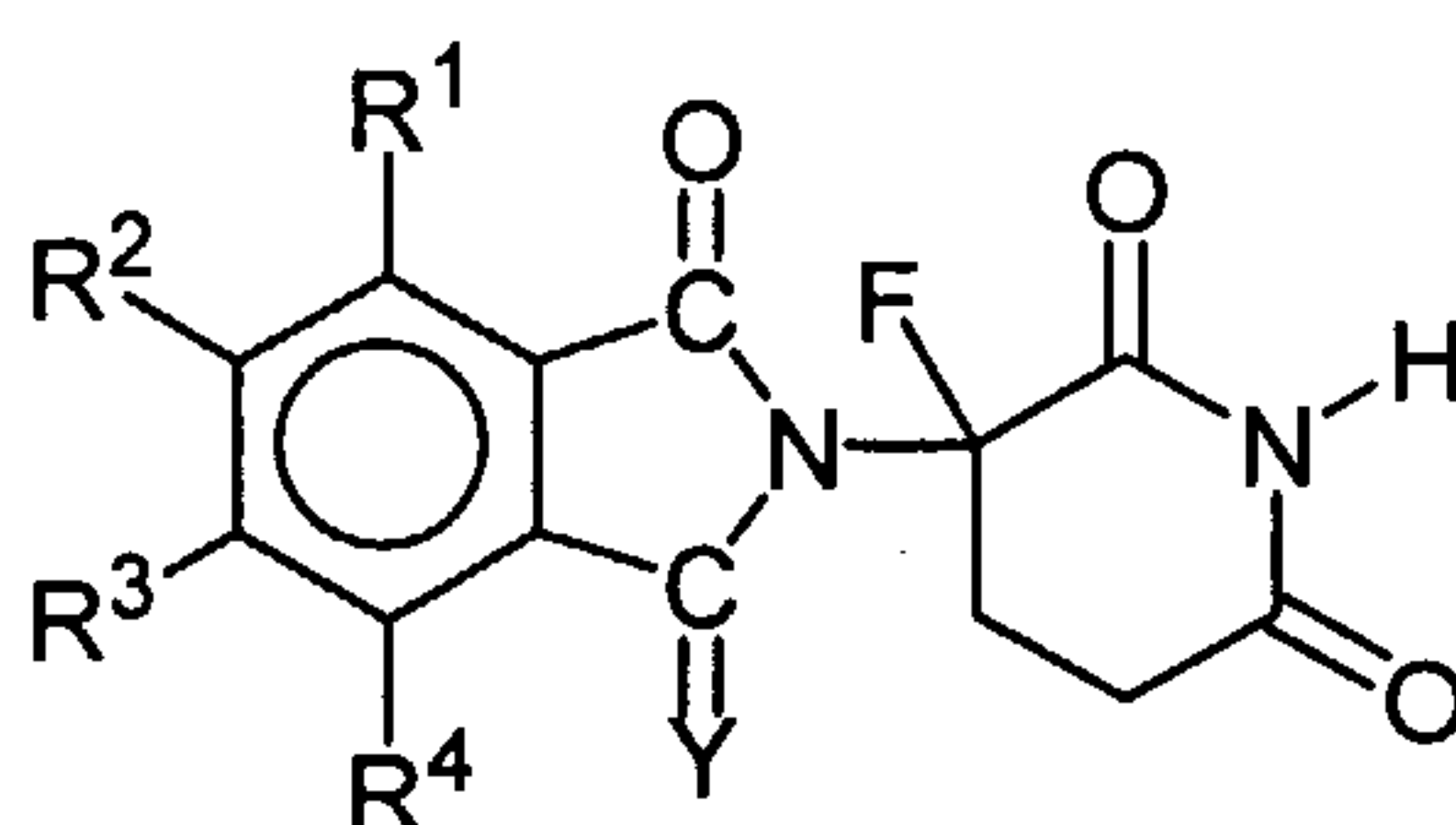
dihydro-isoindol-2-yl)-piperidene-2,6-dione in water and by a slow evaporation of 3-(4-amino-1-oxo-1,3 dihydro-isoindol-2-yl)-piperidene-2,6-dione in a solvent system with a ratio of about 9:1 acetone:water. Form E has an X-ray powder diffraction pattern comprising significant peaks at approximately 20, 24.5 and 29 degrees 2 θ , and has a differential scanning calorimetry melting temperature maximum of about 269°C. Form E can convert to Form C in an acetone solvent system and to Form G in a THF solvent system. In aqueous solvent systems, Form E appears to be the most stable form. Desolvation experiments performed on Form E show that upon heating at about 125°C for about five minutes, Form E can convert to Form B. Upon heating at 175°C for about five minutes, Form B can convert to Form F.

Form F of 3-(4-amino-1-oxo-1,3 dihydro-isoindol-2-yl)-piperidene-2,6-dione is an unsolvated, crystalline material that can be obtained from the dehydration of Form E. Form F has an X-ray powder diffraction pattern comprising significant peaks at approximately 19, 19.5 and 25 degrees 2 θ , and has a differential scanning calorimetry melting temperature maximum of about 269°C.

Form G of 3-(4-amino-1-oxo-1,3 dihydro-isoindol-2-yl)-piperidene-2,6-dione is an unsolvated, crystalline material that can be obtained from slurrying forms B and E in a solvent such as, but not limited to, tetrahydrofuran (THF). Form G has an X-ray powder diffraction pattern comprising significant peaks at approximately 21, 23 and 24.5 degrees 2 θ , and has a differential scanning calorimetry melting temperature maximum of about 267°C.

Form H of 3-(4-amino-1-oxo-1,3 dihydro-isoindol-2-yl)-piperidene-2,6-dione is a partially hydrated (about 0.25 moles) crystalline material that can be obtained by exposing Form E to 0 % relative humidity. Form H has an X-ray powder diffraction pattern comprising significant peaks at approximately 15, 26 and 31 degrees 2 θ , and has a differential scanning calorimetry melting temperature maximum of about 269°C.

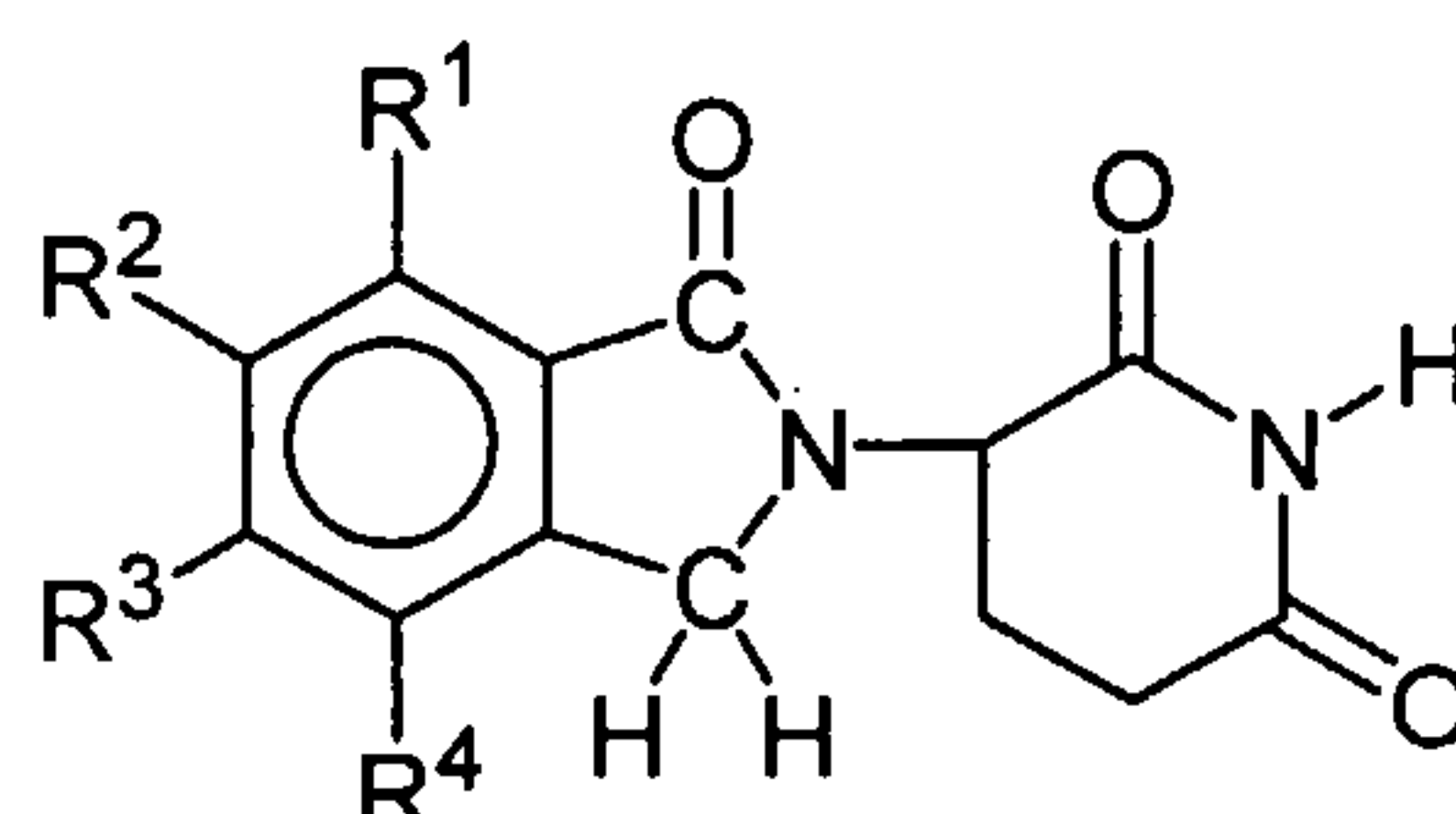
Other specific immunomodulatory compounds of the invention include, but are not limited to, 1-oxo-2-(2,6-dioxo-3-fluoropiperidin-3-yl) isoindolines and 1,3-dioxo-2-(2,6-dioxo-3-fluoropiperidine-3-yl) isoindolines such as those described in U.S. patent nos. 5,874,448 and 5,955,476, each of which is incorporated herein by reference. Representative compounds are of formula:



wherein Y is oxygen or H² and

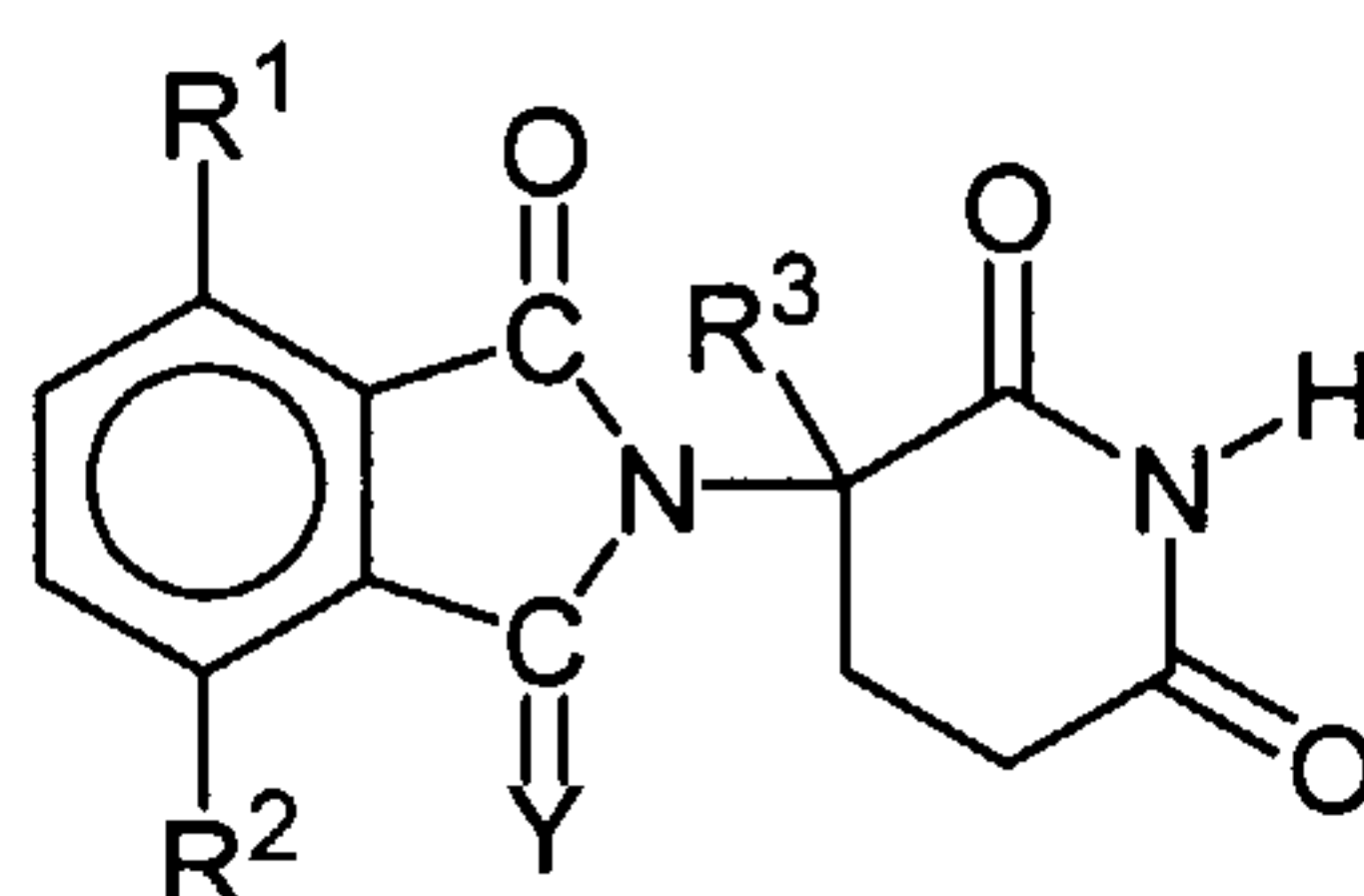
each of R¹, R², R³, and R⁴, independently of the others, is hydrogen, halo, alkyl of 1 to 4 carbon atoms, alkoxy of 1 to 4 carbon atoms, or amino.

Other specific immunomodulatory compounds of the invention include, but are not limited to, the tetra substituted 2-(2,6-dioxopiperidin-3-yl)-1-oxoisindolines described in U.S. patent no. 5,798,368, which is incorporated herein by reference. Representative compounds are of formula:



wherein each of R¹, R², R³, and R⁴, independently of the others, is halo, alkyl of 1 to 4 carbon atoms, or alkoxy of 1 to 4 carbon atoms.

Other specific immunomodulatory compounds of the invention include, but are not limited to, 1-oxo and 1,3-dioxo-2-(2,6-dioxopiperidin-3-yl) isoindolines disclosed in U.S. patent no. 6,403,613, which is incorporated herein by reference. Representative compounds are of formula:



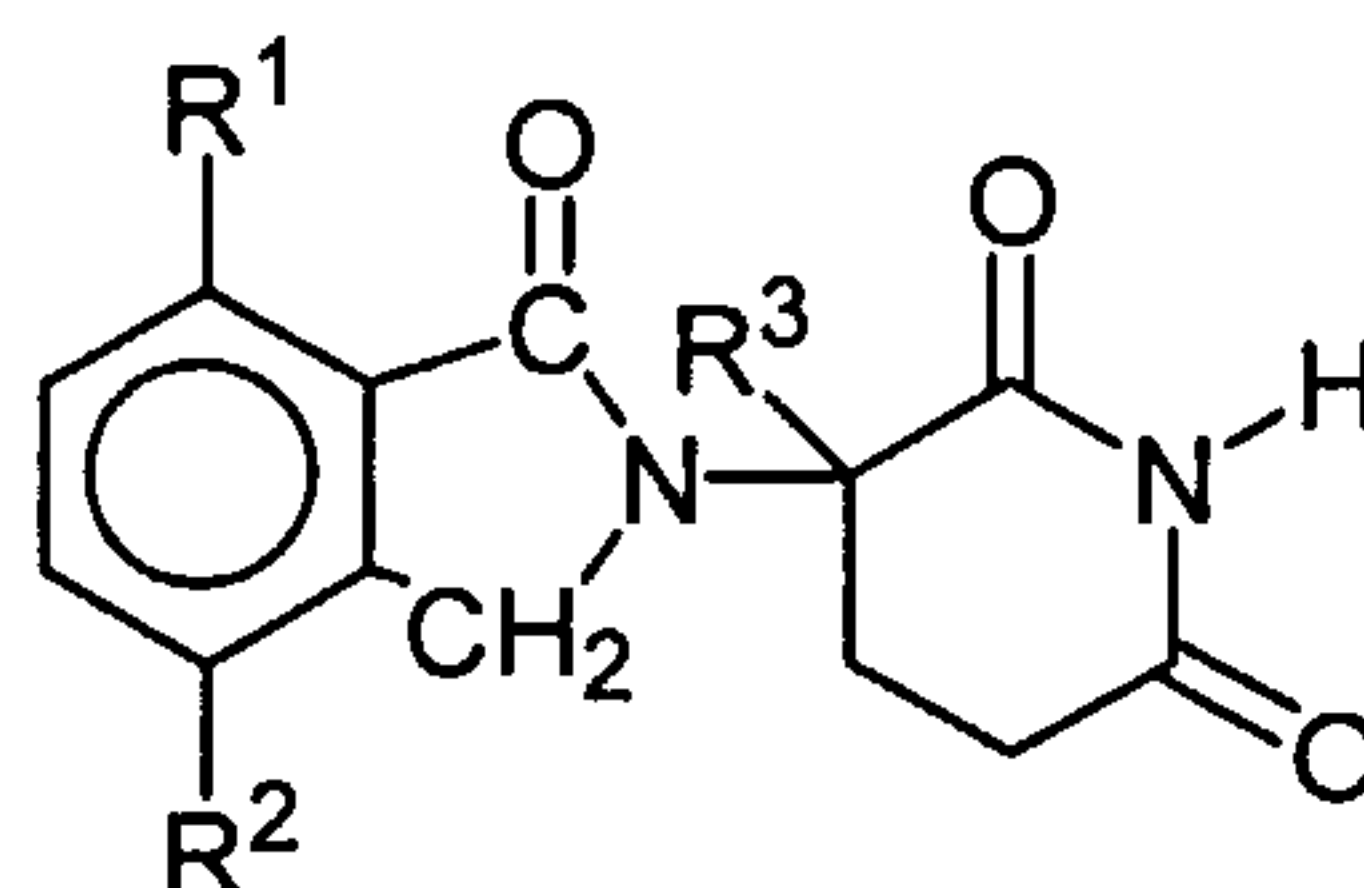
in which

Y is oxygen or H₂,

a first of R¹ and R² is halo, alkyl, alkoxy, alkylamino, dialkylamino, cyano, or carbamoyl, the second of R¹ and R², independently of the first, is hydrogen, halo, alkyl, alkoxy, alkylamino, dialkylamino, cyano, or carbamoyl, and

R³ is hydrogen, alkyl, or benzyl.

Specific examples of the compounds are of formula:

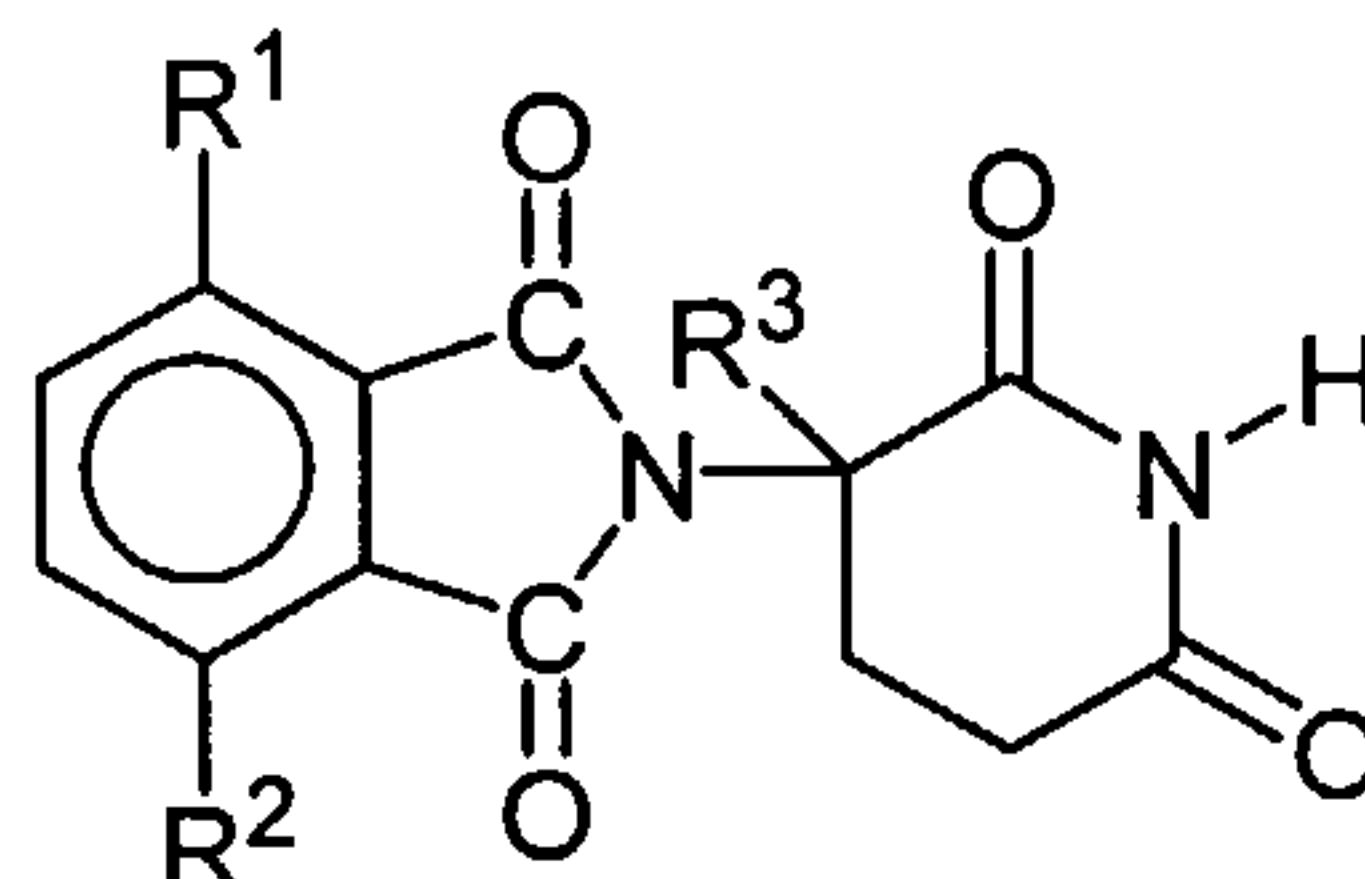


wherein a first of R^1 and R^2 is halo, alkyl of from 1 to 4 carbon atoms, alkoxy of from 1 to 4 carbon atoms, dialkylamino in which each alkyl is of from 1 to 4 carbon atoms, cyano, or carbamoyl,

the second of R^1 and R^2 , independently of the first, is hydrogen, halo, alkyl of from 1 to 4 carbon atoms, alkoxy of from 1 to 4 carbon atoms, alkylamino in which alkyl is of from 1 to 4 carbon atoms, dialkylamino in which each alkyl is of from 1 to 4 carbon atoms, cyano, or carbamoyl, and

R^3 is hydrogen, alkyl of from 1 to 4 carbon atoms, or benzyl. Specific examples include, but are not limited to, 1-oxo-2-(2,6-dioxopiperidin-3-yl)-4-methylisoindoline.

Other representative compounds are of formula:

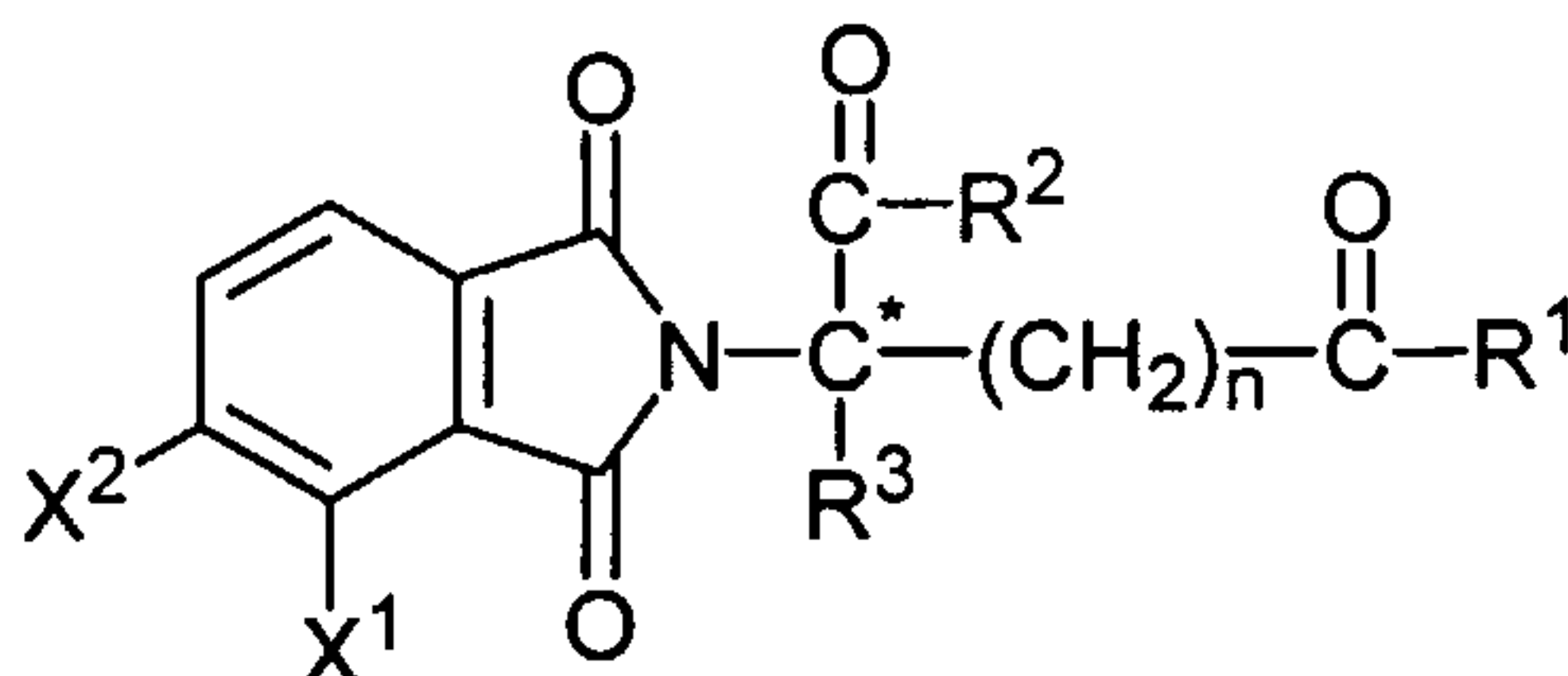


wherein a first of R^1 and R^2 is halo, alkyl of from 1 to 4 carbon atoms, alkoxy of from 1 to 4 carbon atoms, dialkylamino in which each alkyl is of from 1 to 4 carbon atoms, cyano, or carbamoyl,

the second of R^1 and R^2 , independently of the first, is hydrogen, halo, alkyl of from 1 to 4 carbon atoms, alkoxy of from 1 to 4 carbon atoms, alkylamino in which alkyl is of from 1 to 4 carbon atoms, dialkylamino in which each alkyl is of from 1 to 4 carbon atoms, cyano, or carbamoyl, and

R^3 is hydrogen, alkyl of from 1 to 4 carbon atoms, or benzyl.

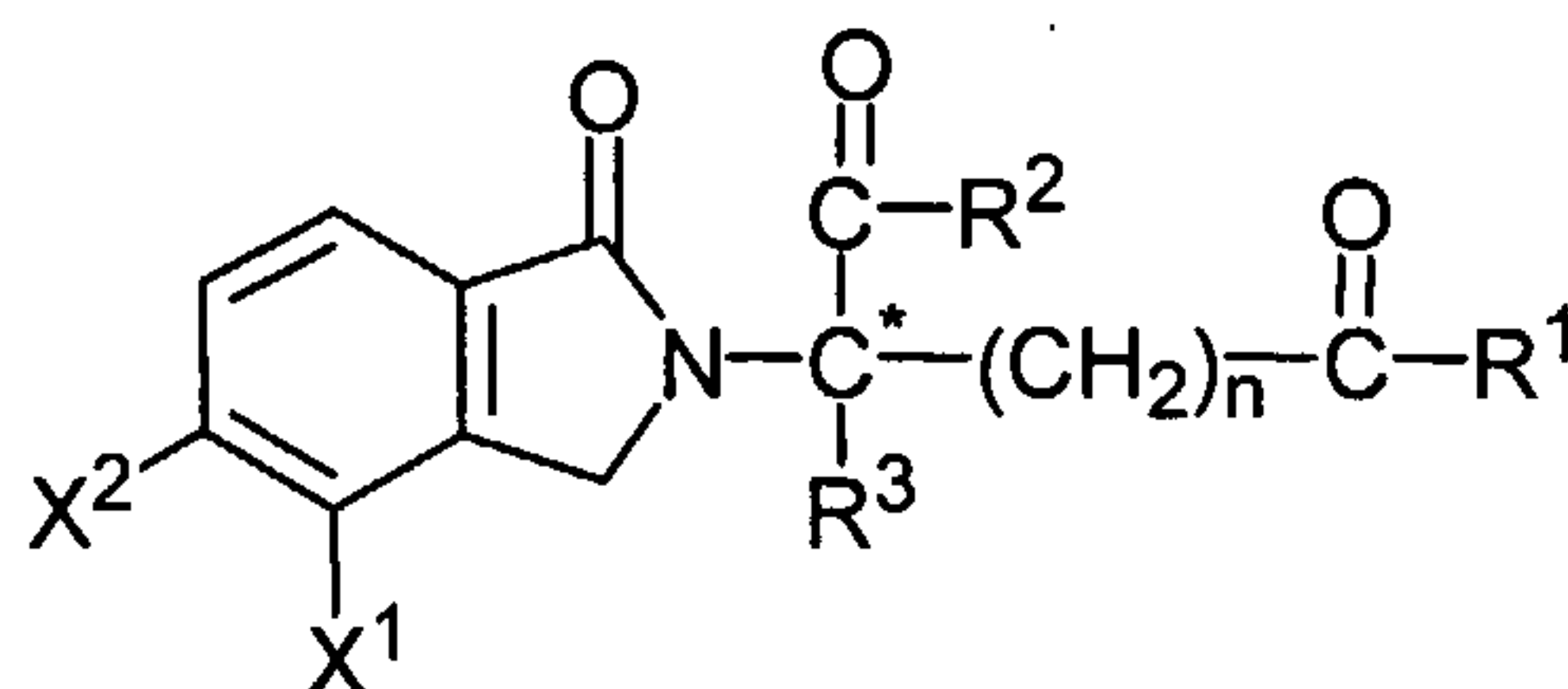
Other specific immunomodulatory compounds of the invention include, but are not limited to, 1-oxo and 1,3-dioxoisindolines substituted in the 4- or 5-position of the indoline ring described in U.S. patent no. 6,380,239 and co-pending U.S. application no. 10/900,270, filed July 28, 2004, which are incorporated herein by reference. Representative compounds are of formula:



in which the carbon atom designated C* constitutes a center of chirality (when n is not zero and R^1 is not the same as R^2); one of X^1 and X^2 is amino, nitro, alkyl of one to six carbons, or NH-Z, and the other of X^1 or X^2 is hydrogen; each of R^1 and R^2 independent of the other, is hydroxy or NH-Z; R^3 is hydrogen, alkyl of one to six carbons, halo, or

haloalkyl; Z is hydrogen, aryl, alkyl of one to six carbons, formyl, or acyl of one to six carbons; and n has a value of 0, 1, or 2; provided that if X¹ is amino, and n is 1 or 2, then R¹ and R² are not both hydroxy; and the salts thereof.

Further representative compounds are of formula:



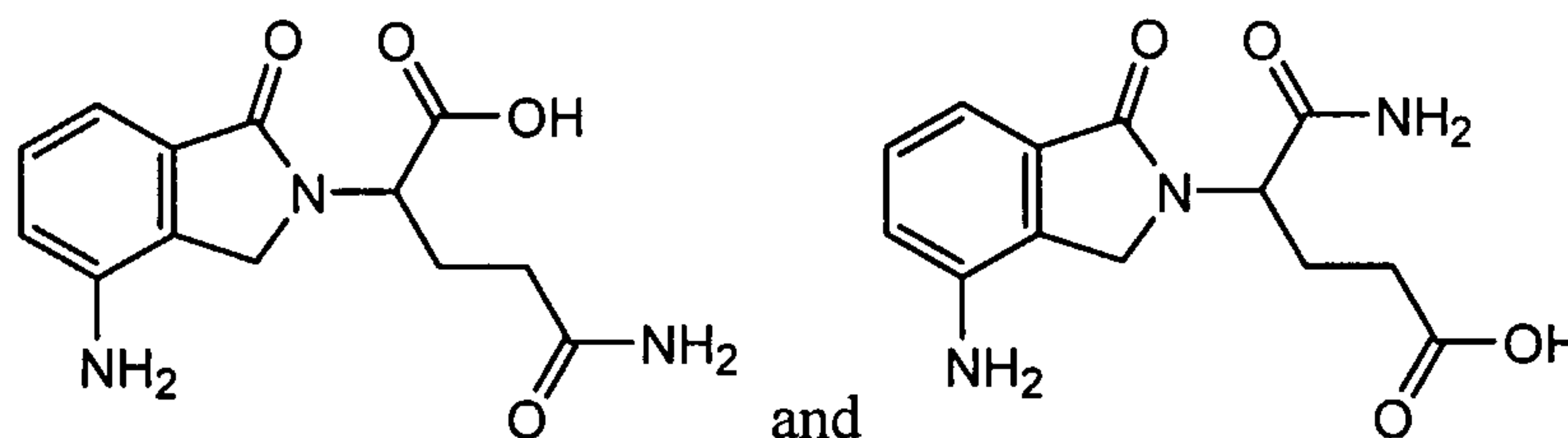
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in which the carbon atom designated C* constitutes a center of chirality when n is not zero and R¹ is not R²; one of X¹ and X² is amino, nitro, alkyl of one to six carbons, or NH-Z, and the other of X¹ or X² is hydrogen; each of R¹ and R² independent of the other, is hydroxy or NH-Z; R³ is alkyl of one to six carbons, halo, or hydrogen; Z is hydrogen, aryl or an alkyl or acyl of one to six carbons; and n has a value of 0, 1, or 2.

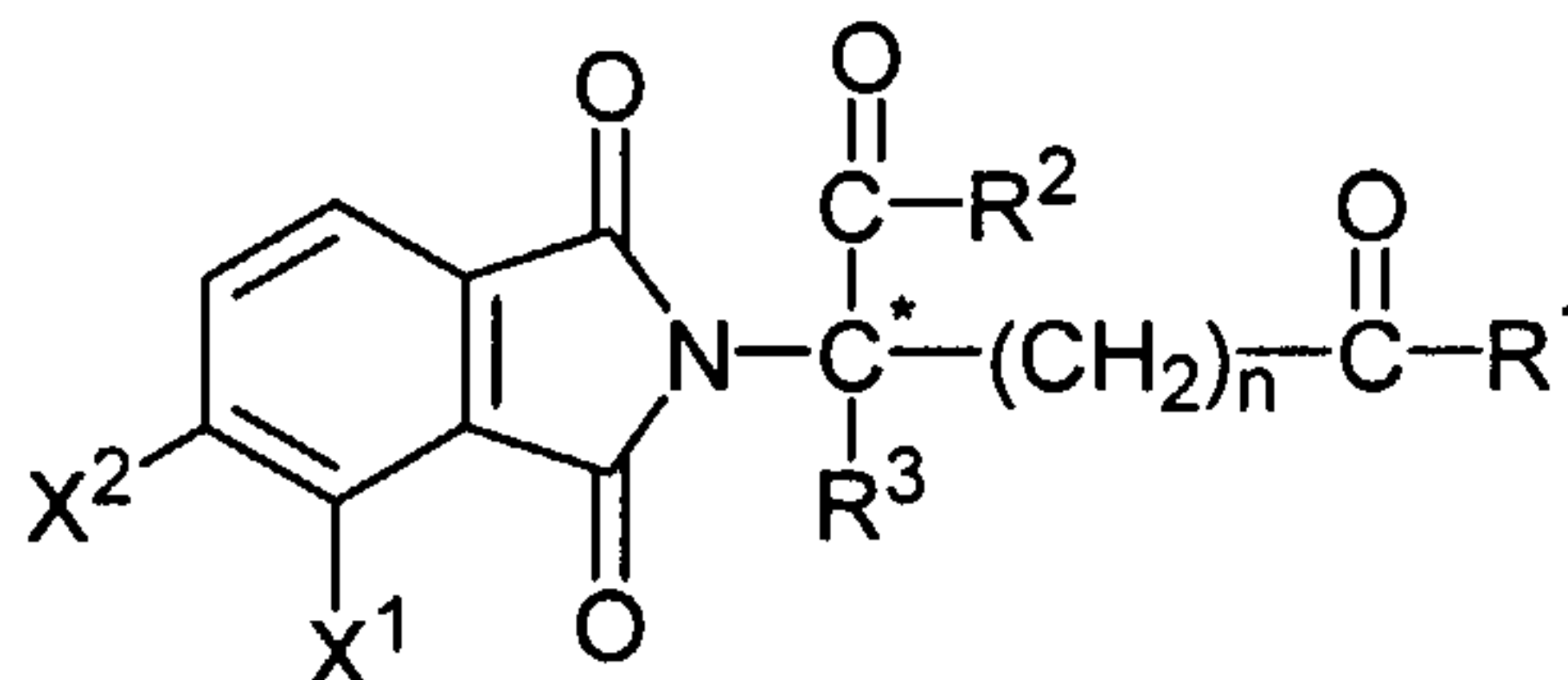
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Specific examples include, but are not limited to, 2-(4-amino-1-oxo-1,3-dihydro-isoindol-2-yl)-4-carbamoyl-butyric acid and 4-(4-amino-1-oxo-1,3-dihydro-isoindol-2-yl)-4-carbamoyl-butyric acid, which have the following structures, respectively, and pharmaceutically acceptable salts, solvates, prodrugs, and stereoisomers thereof:

15



Other representative compounds are of formula:



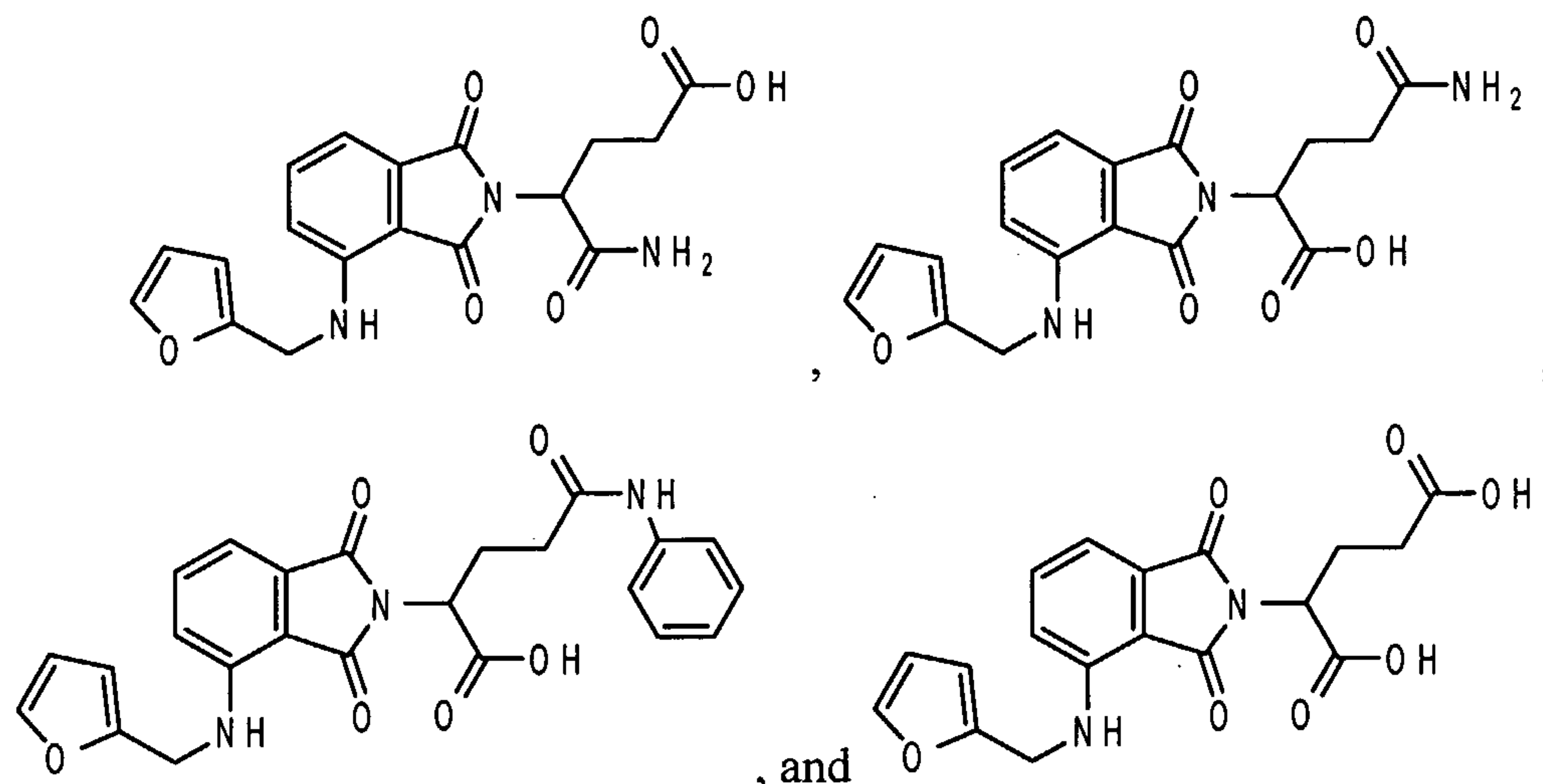
20

in which the carbon atom designated C* constitutes a center of chirality when n is not zero and R¹ is not R²; one of X¹ and X² is amino, nitro, alkyl of one to six carbons, or NH-Z, and the other of X¹ or X² is hydrogen; each of R¹ and R² independent of the other, is hydroxy or NH-Z; R³ is alkyl of one to six carbons, halo, or hydrogen; Z is hydrogen, aryl, or an alkyl or acyl of one to six carbons; and n has a value of 0, 1, or 2; and the salts thereof.

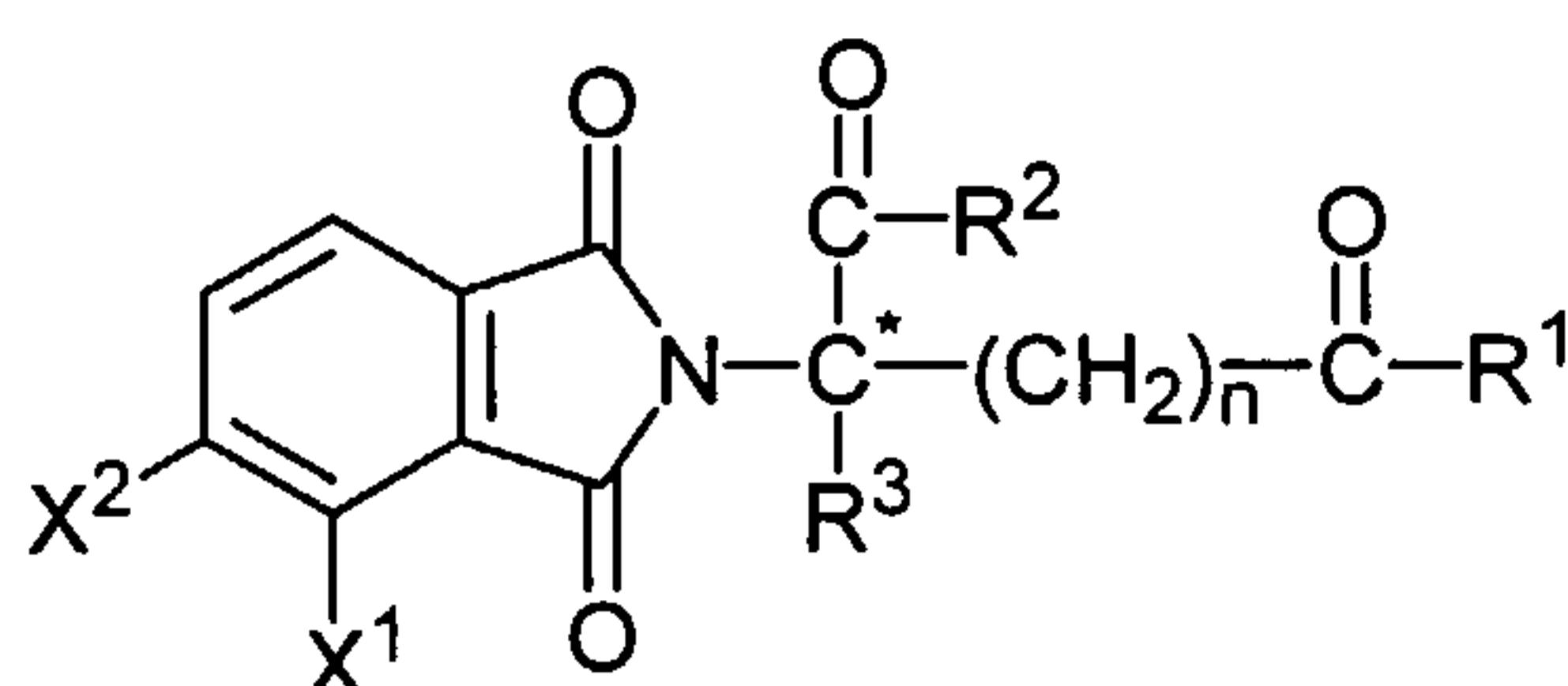
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Specific examples include, but are not limited to, 4-carbamoyl-4-{4-[(furan-2-yl-methyl)-amino]-1,3-dioxo-1,3-dihydro-isoindol-2-yl}-butyric acid, 4-carbamoyl-2-{4-

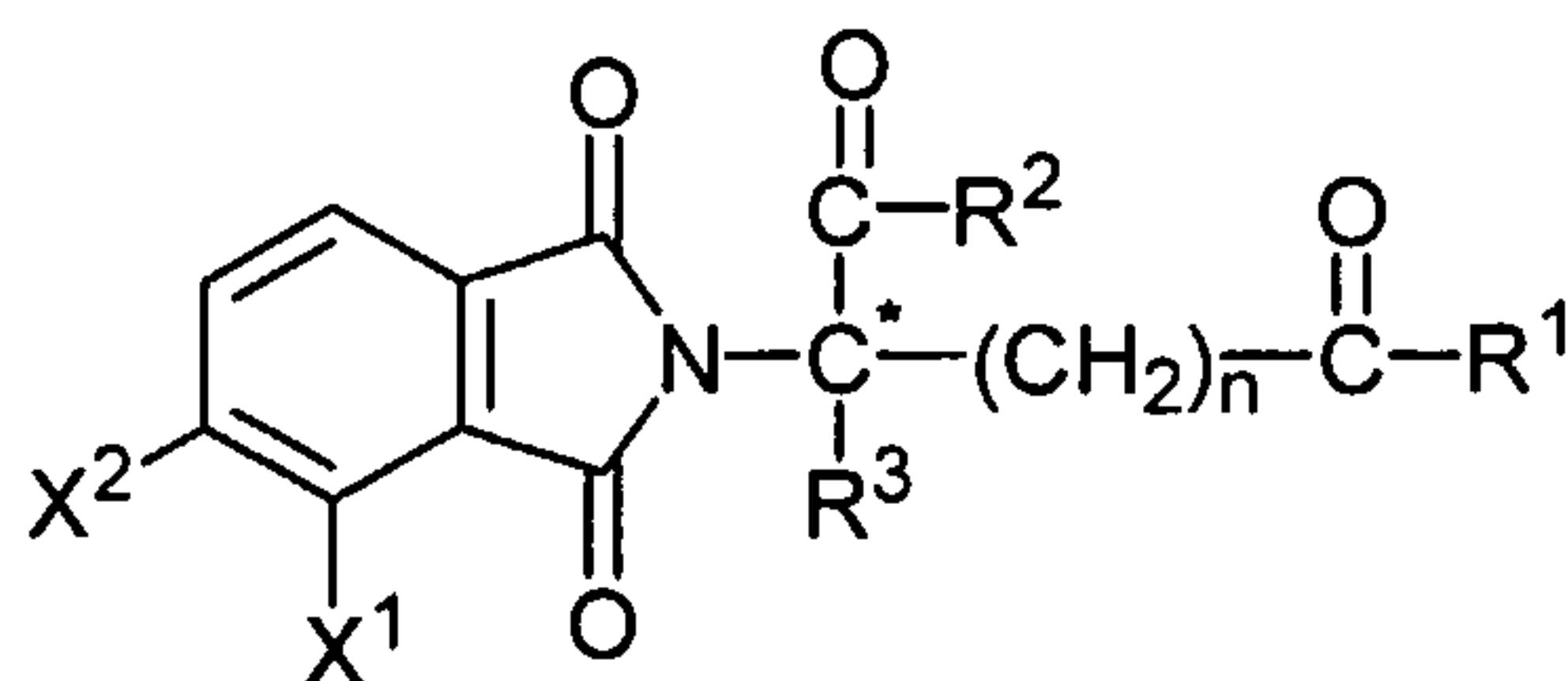
[(furan-2-yl-methyl)-amino]-1,3-dioxo-1,3-dihydro-isoindol-2-yl}-butyric acid, 2-{4-[(furan-2-yl-methyl)-amino]-1,3-dioxo-1,3-dihydro-isoindol-2-yl}-4-phenylcarbamoylebutyric acid, and 2-{4-[(furan-2-yl-methyl)-amino]-1,3-dioxo-1,3-dihydro-isoindol-2-yl}-pentanedioic acid, which have the following structures, respectively, and pharmaceutically acceptable salts, solvate, prodrugs, and stereoisomers thereof:



Other specific examples of the compounds are of formula:



- wherein one of X^1 and X^2 is nitro, or NH-Z, and the other of X^1 or X^2 is hydrogen; each of R^1 and R^2 , independent of the other, is hydroxy or NH-Z; R^3 is alkyl of one to six carbons, halo, or hydrogen; Z is hydrogen, phenyl, an acyl of one to six carbons, or an alkyl of one to six carbons; and
- n has a value of 0, 1, or 2;
- provided that if one of X^1 and X^2 is nitro, and n is 1 or 2, then R^1 and R^2 are other than hydroxy; and
- if $-COR^2$ and $-(CH_2)_nCOR^1$ are different, the carbon atom designated C^* constitutes a center of chirality. Other representative compounds are of formula:



- wherein one of X^1 and X^2 is alkyl of one to six carbons; each of R^1 and R^2 , independent of the other, is hydroxy or NH-Z;

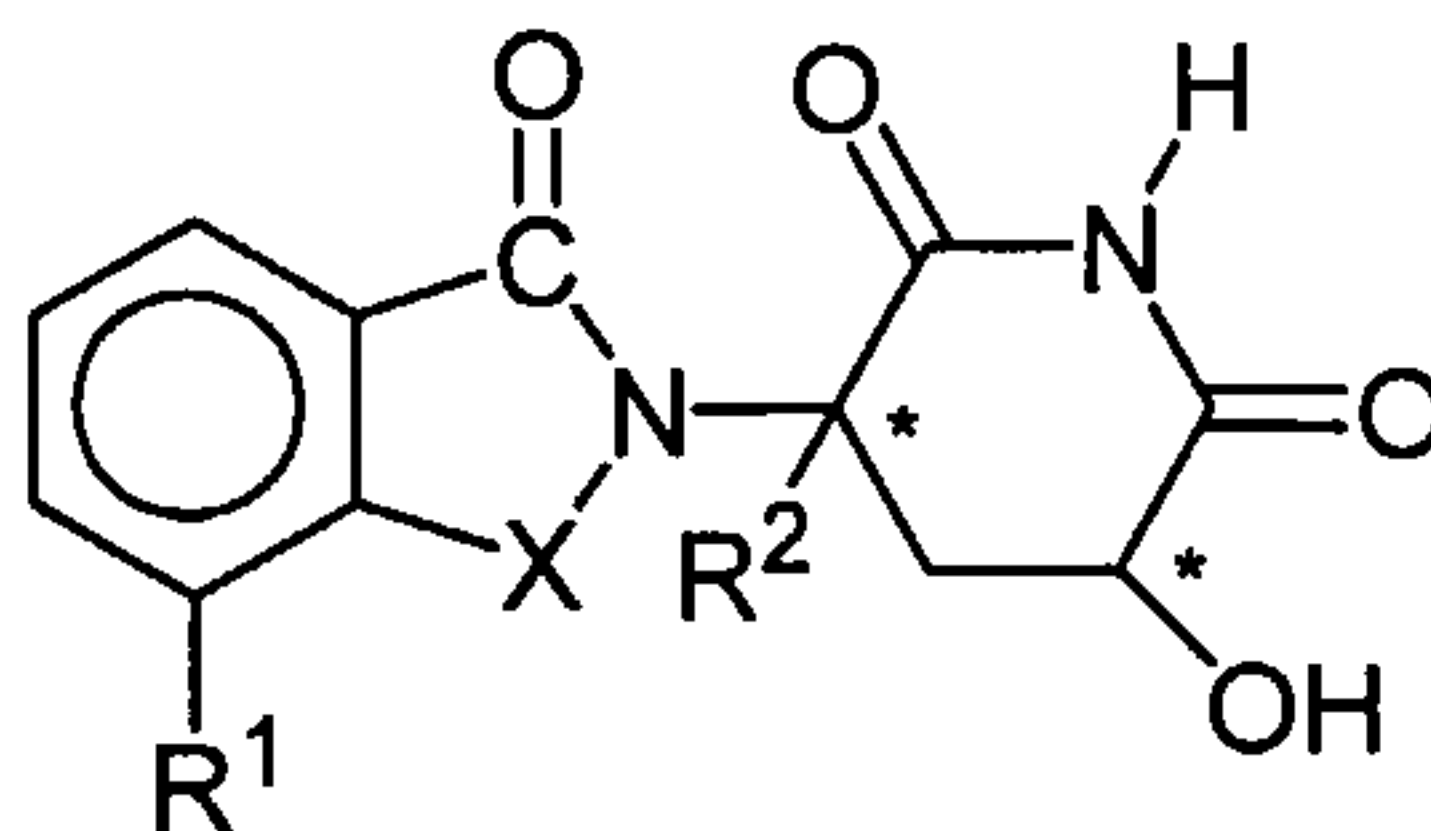
R^3 is alkyl of one to six carbons, halo, or hydrogen;

Z is hydrogen, phenyl, an acyl of one to six carbons, or an alkyl of one to six carbons; and

n has a value of 0, 1, or 2; and

5 if $-COR^2$ and $-(CH_2)_nCOR^1$ are different, the carbon atom designated C^* constitutes a center of chirality.

Still other specific immunomodulatory compounds of the invention include, but are not limited to, isoindoline-1-one and isoindoline-1,3-dione substituted in the 2-position with 2,6-dioxo-3-hydroxypiperidin-5-yl described in U.S. patent no. 6,458,810, which is
10 incorporated herein by reference. Representative compounds are of formula:



wherein:

the carbon atoms designated * constitute centers of chirality;

X is $-C(O)-$ or $-CH_2-$;

15 R^1 is alkyl of 1 to 8 carbon atoms or $-NHR^3$;

R^2 is hydrogen, alkyl of 1 to 8 carbon atoms, or halogen;

and

R^3 is hydrogen,

alkyl of 1 to 8 carbon atoms, unsubstituted or substituted with alkoxy of 1 to 8
20 carbon atoms, halo, amino, or alkylamino of 1 to 4 carbon atoms,
cycloalkyl of 3 to 18 carbon atoms,

phenyl, unsubstituted or substituted with alkyl of 1 to 8 carbon atoms, alkoxy of 1 to 8 carbon atoms, halo, amino, or alkylamino of 1 to 4 carbon atoms,

benzyl, unsubstituted or substituted with alkyl of 1 to 8 carbon atoms, alkoxy of 1 to
25 8 carbon atoms, halo, amino, or alkylamino of 1 to 4 carbon atoms, or $-COR^4$ in which

R^4 is hydrogen,

alkyl of 1 to 8 carbon atoms, unsubstituted or substituted with alkoxy of 1 to 8
carbon atoms, halo, amino, or alkylamino of 1 to 4 carbon atoms,

cycloalkyl of 3 to 18 carbon atoms,

30 phenyl, unsubstituted or substituted with alkyl of 1 to 8 carbon atoms, alkoxy of 1 to 8 carbon atoms, halo, amino, or alkylamino of 1 to 4 carbon atoms, or

benzyl, unsubstituted or substituted with alkyl of 1 to 8 carbon atoms, alkoxy of 1 to 8 carbon atoms, halo, amino, or alkylamino of 1 to 4 carbon atoms.

Compounds of the invention can either be commercially purchased or prepared according to the methods described in the patents or patent publications disclosed herein.

5 Further, optically pure compounds can be asymmetrically synthesized or resolved using known resolving agents or chiral columns as well as other standard synthetic organic chemistry techniques.

Various immunomodulatory compounds of the invention contain one or more chiral centers, and can exist as racemic mixtures of enantiomers or mixtures of diastereomers.

10 This invention encompasses the use of stereomerically pure forms of such compounds, as well as the use of mixtures of those forms. For example, mixtures comprising equal or unequal amounts of the enantiomers of a particular immunomodulatory compounds of the invention may be used in methods and compositions of the invention. These isomers may be asymmetrically synthesized or resolved using standard techniques such as chiral columns
15 or chiral resolving agents. *See, e.g., Jacques, J., et al., Enantiomers, Racemates and Resolutions* (Wiley-Interscience, New York, 1981); Wilen, S. H., *et al., Tetrahedron* 33:2725 (1977); Eliel, E. L., *Stereochemistry of Carbon Compounds* (McGraw-Hill, NY, 1962); and Wilen, S. H., *Tables of Resolving Agents and Optical Resolutions* p. 268 (E.L. Eliel, Ed., Univ. of Notre Dame Press, Notre Dame, IN, 1972).

20 It should be noted that if there is a discrepancy between a depicted structure and a name given that structure, the depicted structure is to be accorded more weight. In addition, if the stereochemistry of a structure or a portion of a structure is not indicated with, for example, bold or dashed lines, the structure or portion of the structure is to be interpreted as encompassing all stereoisomers of it.

25 5.3 SECOND ACTIVE AGENTS

Immunomodulatory compounds can be combined with other pharmacologically active compounds ("second active agents") in methods of the invention. It is believed that certain combinations work synergistically in the treatment, prevention and/or management of immunodeficiency disorders. Immunomodulatory compounds can also work to alleviate
30 adverse effects associated with certain second active agents, and some second active agents can be used to alleviate adverse effects associated with immunomodulatory compounds.

One or more second active ingredients or agents can be used in the methods of the invention together with an immunomodulatory compound. Second active agents can be

large molecules (*e.g.*, proteins) or small molecules (*e.g.*, synthetic inorganic, organometallic, or organic molecules).

This invention also encompasses the use of native, naturally occurring, and recombinant proteins.

5 The invention further encompasses mutants and derivatives (*e.g.*, modified forms) of naturally occurring proteins that exhibit, *in vivo*, at least some of the pharmacological activity of the proteins upon which they are based. Examples of mutants include, but are not limited to, proteins that have one or more amino acid residues that differ from the corresponding residues in the naturally occurring forms of the proteins. Also encompassed
10 by the term “mutants” are proteins that lack carbohydrate moieties normally present in their naturally occurring forms (*e.g.*, nonglycosylated forms). Examples of derivatives include, but are not limited to, pegylated derivatives and fusion proteins, such as proteins formed by fusing IgG1 or IgG3 to the protein or active portion of the protein of interest. *See, e.g.*, Penichet, M.L. and Morrison, S.L., *J. Immunol. Methods* 248:91-101 (2001).

15 In one embodiment of the invention, the large molecule active agent reduces, eliminates, or prevents an adverse effect associated with the administration of an immunomodulatory compound. Depending on the particular immunomodulatory compound and the disease or disorder being treated, adverse effects can include, but are not limited to, drowsiness and somnolence, dizziness and orthostatic hypotension, neutropenia,
20 infections that result from neutropenia, increased HIV-viral load, bradycardia, Stevens-Johnson Syndrome and toxic epidermal necrolysis, and seizures (*e.g.*, grand mal convulsions).

 Second active agents that are small molecules can also be used to alleviate adverse effects associated with the administration of an immunomodulatory compound. However,
25 like some large molecules, many are believed to be capable of providing a synergistic effect when administered with (*e.g.*, before, after or simultaneously) an immunomodulatory compound.

 Specific second active agents include, but are not limited to: antibiotics (therapeutic or prophylactic) such as, but not limited to, ampicillin, tetracycline, penicillin,
30 cephalosporins, streptomycin, kanamycin, and erythromycin; antivirals such as, but not limited to, amantadine, rimantadine, acyclovir, and ribavirin; immunoglobulin; plasma; immunologic enhancing drugs such as, but not limited to, levamisole and isoprinosine; biologics such as, but not limited to, gammaglobulin, transfer factor, interleukins, and interferons; hormones such as, but not limited to, thymic; and other immunologic agents

such as, but not limited to, B cell stimulators (*e.g.*, BAFF/BlyS), cytokines (*e.g.*, IL-2, IL-4, and IL-5), growth factors (*e.g.*, TGF- β), antibodies (*e.g.*, anti-CD40 and IgM), oligonucleotides containing unmethylated CpG motifs (*e.g.*, TCGTCGTTTTGTCGTTTTGTCGTT), and vaccines (*e.g.*, viral and tumor peptide vaccines).

In another embodiment, methods of this invention can be used in combination with other methods used for the treatment, prevention, and/or management of an immunodeficiency disease or disorder. Examples of other methods include, but not limited to, stem cell transplantation, enzyme replacement therapy using, for example, bovine adenosine deaminase conjugated to polyethylene glycol (PEG-ADA), fetal thymus transplant, cultured neonatal thymus transplant, thymic epithelial cell transplant, and fetal liver transplant.

5.4 METHODS OF TREATMENTS AND PREVENTION

Methods of this invention encompass methods of treating, preventing and/or managing various immunodeficiency diseases or disorders. Examples of such diseases or disorders include, but are not limited to, adenosine deaminase deficiency, antibody deficiency with normal or elevated Igs, ataxia-telangiectasia, bare lymphocyte syndrome, common variable immunodeficiency, DiGeorge syndrome, Ig deficiency with hyper-IgM, Ig heavy chain deletions, IgA deficiency, immunodeficiency with thymoma, reticular dysgenesis, Nezelof syndrome, selective IgG subclass deficiency, transient hypogammaglobulinemia of infancy, Wiscott-Aldrich syndrome, X-linked agammaglobulinemia, and X-linked severe combined immunodeficiency.

Methods encompassed by this invention comprise administering one or more immunomodulatory compound of the invention, or a pharmaceutically acceptable salt, solvate, stereoisomer, or prodrug thereof, to a patient (*e.g.*, a human) suffering, or likely to suffer, from an immunodeficiency disease or disorder.

In one embodiment of the invention, an immunomodulatory compound of the invention can be administered orally and in single or divided daily doses in an amount of from about 0.10 to about 150 mg/day. In a particular embodiment, 4-(amino)-2-(2,6-dioxo(3-piperidyl))-isoindoline-1,3-dione may be administered in an amount of from about 0.1 to about 1 mg per day, or alternatively from about 0.1 to about 5 mg every other day. In a particular embodiment, 3-(4-amino-1-oxo-1,3-dihydro-isoindol-2-yl)-piperidine-2,6-dione may be administered in an amount of from about 1 to about 25 mg per day, or alternatively from about 10 to about 50 mg every other day. In another embodiment,

3-(4-amino-1-oxo-1,3-dihydro-isoindol-2-yl)-piperidine-2,6-dione may be administered in an amount of about 50 mg per day. In another embodiment,

3-(4-amino-1-oxo-1,3-dihydro-isoindol-2-yl)-piperidine-2,6-dione may be administered in an amount of about 25 mg per day. In another embodiment,

5 3-(4-amino-1-oxo-1,3-dihydro-isoindol-2-yl)-piperidine-2,6-dione may be administered in an amount of about 10 mg per day.

It is believed that the immunomodulatory compounds of this invention are effective in boosting humoral immunity in a patient. Therefore, in another embodiment, this invention encompasses methods of enhancing an immune response to an immunogen,
10 comprising administering a therapeutically or prophylactically effective amount of an immunomodulatory compound of the invention, or a pharmaceutically acceptable salt, solvate, stereoisomer, or prodrug thereof, to a patient in need of such enhancement. The immunomodulatory compound may be administered prior to, during, or subsequent to the patient's exposure to the immunogen.

15 In a particular embodiment, the immunomodulatory compounds of this invention may be used to enhance the effect of vaccines such as, but not limited to, vaccines for pathogenic disorders, cancer, and autoimmune diseases. One of the goals of vaccines is to mount an immune response to an immunogen, and thereby forming a population of memory B-cells (and T-cells) that have affinity for the particular immunogen. Without being limited
20 by a particular theory, it is believed that since immunomodulatory compounds used in the invention are shown to enhance the level, proliferation, and activation of B-cell TLR 9, the formation of memory cells may be enhanced, and immunologic protection against the immunogen can be improved. Therefore, this invention also encompasses a method of enhancing the immune response to an immunogen in a patient, comprising administering to
25 a patient in need of such enhancement an immunomodulatory compound and a vaccine comprising the immunogen. The immunomodulatory compound can be administered prior to, simultaneously with, and subsequent to the administration of the vaccine.

Suitable vaccines that can be used with immunomodulatory compounds include, but are not limited to, those comprising antigens from an animal, a plant, a bacteria, a
30 protozoan, a parasite, a virus or a combination thereof. The antigenic or immunogenic agent may be any viral peptide, protein, polypeptide, or a fragment thereof derived from a virus including, but not limited to, RSV-viral proteins, *e.g.*, RSV F glycoprotein, RSV G glycoprotein, influenza viral proteins, *e.g.*, influenza virus neuraminidase, influenza virus hemagglutinin, herpes simplex viral protein, *e.g.*, herpes simplex virus glycoprotein

including for example, gB, gC, gD, and gE. The antigenic or immunogenic agent for use in the compositions of the invention may be an antigen of a pathogenic virus such as, an antigen of adenoviridae (*e.g.*, mastadenovirus and aviadenovirus), herpesviridae (*e.g.*, herpes simplex virus 1, herpes simplex virus 2, herpes simplex virus 5, and herpes simplex virus 6), leviviridae (*e.g.*, levivirus, enterobacteria phase MS2, allovirus), poxviridae (*e.g.*, chordopoxvirinae, parapoxvirus, avipoxvirus, capripoxvirus, leporipoxvirus, suipoxvirus, molluscipoxvirus, and entomopoxvirinae), papovaviridae (*e.g.*, polyomavirus and papillomavirus), paramyxoviridae (*e.g.*, paramyxovirus, parainfluenza virus 1, morbillivirus (*e.g.*, measles virus), rubulavirus (*e.g.*, mumps virus), pneumonovirinae (*e.g.*, pneumovirus, human respiratory syncytial virus), metapneumovirus (*e.g.*, avian pneumovirus and human metapneumovirus), picornaviridae (*e.g.*, enterovirus, rhinovirus, hepatovirus (*e.g.*, human hepatitis A virus), cardiovirus, and aphovirus), reoviridae (*e.g.*, orthoreovirus, orbivirus, rotavirus, cypovirus, fijivirus, phytoreovirus, and oryzavirus), retroviridae (*e.g.*, mammalian type B retroviruses, mammalian type C retroviruses, avian type C retroviruses, type D retrovirus group, BLV-HTLV retroviruses), lentivirus (*e.g.* human immunodeficiency virus 1 and human immunodeficiency virus 2), spumavirus, flaviviridae (*e.g.*, hepatitis C virus), hepadnaviridae (*e.g.*, hepatitis B virus), togaviridae (*e.g.*, alphavirus (*e.g.*, sindbis virus) and rubivirus (*e.g.*, rubella virus), rhabdoviridae (*e.g.*, vesiculovirus, lyssavirus, ephemerovirus, cytorhabdovirus, and nucleorhabdovirus), arenaviridae (*e.g.*, arenavirus, lymphocytic choriomeningitis virus, Lassa virus, and Lassa virus), and coronaviridae (*e.g.*, coronavirus and torovirus).

In one embodiment, the vaccines may be those comprising a cancer or tumor antigen including but not limited to, KS 1/4 pan-carcinoma antigen, ovarian carcinoma antigen (CA125), prostatic acid phosphatase, prostate specific antigen, melanoma-associated antigen p97, melanoma antigen gp75, high molecular weight melanoma antigen (HMW-MAA), prostate specific membrane antigen, carcinoembryonic antigen (CEA), polymorphic epithelial mucin antigen, human milk fat globule antigen, colorectal tumor-associated antigens such as: CEA, TAG-72, CO17-1A; GICA 19-9, CTA-1 and LEA, Burkitt's lymphoma antigen-38.13, CD19, human B-lymphoma antigen-CD20, CD33, melanoma specific antigens such as ganglioside GD2, ganglioside GD3, ganglioside GM2, ganglioside GM3, tumor-specific transplantation type of cell-surface antigen (TSTA) such as virally-induced tumor antigens including T-antigen DNA tumor viruses and Envelope antigens of RNA tumor viruses, oncofetal antigen-alpha-fetoprotein such as CEA of colon, bladder tumor oncofetal antigen, differentiation antigen such as human lung carcinoma antigen L6,

L20, antigens of fibrosarcoma, human leukemia T cell antigen-Gp37, neoglycoprotein, sphingolipids, breast cancer antigen such as EGFR (Epidermal growth factor receptor), HER2 antigen (p185^{HER2}), polymorphic epithelial mucin (PEM), malignant human lymphocyte antigen-APO-1, differentiation antigen such as I antigen found in fetal erythrocytes, primary endoderm, I antigen found in adult erythrocytes, preimplantation embryos, I(Ma) found in gastric adenocarcinomas, M18, M39 found in breast epithelium, SSEA-1 found in myeloid cells, VEP8, VEP9, Myl, VIM-D5, D₁56-22 found in colorectal cancer, TRA-1-85 (blood group H), C14 found in colonic adenocarcinoma, F3 found in lung adenocarcinoma, AH6 found in gastric cancer, Y hapten, Le^y found in embryonal carcinoma cells, TL5 (blood group A), EGF receptor found in A431 cells, E₁ series (blood group B) found in pancreatic cancer, FC10.2 found in embryonal carcinoma cells, gastric adenocarcinoma antigen, CO-514 (blood group Le^a) found in Adenocarcinoma, NS-10 found in adenocarcinomas, CO-43 (blood group Le^b), G49 found in EGF receptor of A431 cells, MH2 (blood group ALe^b/Le^y) found in colonic adenocarcinoma, 19.9 found in colon cancer, gastric cancer mucins, T₅A₇ found in myeloid cells, R₂₄ found in melanoma, 4.2, G_{D3}, D1.1, OFA-1, G_{M2}, OFA-2, G_{D2}, and M1:22:25:8 found in embryonal carcinoma cells, and SSEA-3 and SSEA-4 found in 4 to 8-cell stage embryos, and T cell receptor derived peptide from a Cutaneous T cell Lymphoma.

The immunogen for use in the vaccine may be any substance that under appropriate conditions results in an immune response in a subject, including, but not limited to, polypeptides, peptides, proteins, glycoproteins, lipids, nucleic acids, and polysaccharides. The concentration of immunogen in the vaccine may be determined using standard methods known to one skilled in the art and depends on the potency and nature of the immunogen.

Patients in need of humoral immunity boost can be determined based on variety of factors, including, but not limited to, demographics, genetic factors, and work environment. Persons who dwell in or travel to an area where high level exposure to pathogens is likely are one example of such patients. Persons who have family history of genetically descended immune disorder are another example. Furthermore, persons who are typically exposed to high level of pathogens (*e.g.*, health workers) are yet another example of such patients.

As used herein, and unless otherwise specified, the term “enhancing” or “enhance,” when used in connection with immune response, means that when an antigenic or immunogenic agent is administered to a subject who has been or is being treated with an immunomodulatory compound, there is an increased antibody formation, as compared to a

subject to which same amount of the antigenic or immunogenic agent alone is administered, as determined by any conventional methods of antibody level determination known in the art, for example, nephelometry, immunoelectrophoresis, radioimmunoassay, and ELISA. In some embodiments, when methods of this invention are used, antibody formation is

5 increased by about 5%, 10%, 20%, 50%, or 100% or more, as compared to the antibody formation obtained when such methods are not used.

As used herein, and unless otherwise specified, the term "immunogen" means any foreign objects that can trigger an immune response, *i.e.*, formation of antibodies, in a subject. Immunogens include, but are not limited to, antigens from an animal, a plant, a

10 bacteria, a protozoan, a parasite, a virus or a combination thereof. Immunogens may be any substance that results in an immune response in a subject, including, but not limited to, polypeptides, peptides, proteins, glycoproteins, and polysaccharides.

5.4.1 COMBINATION THERAPY WITH A SECOND ACTIVE AGENT OR THERAPY

15 Specific methods of the invention comprise administering an immunomodulatory compound of the invention, or a pharmaceutically acceptable salt, solvate, stereoisomer, or prodrug thereof, in combination with one or more second active agents or other therapies. Examples of immunomodulatory compounds of the invention are disclosed herein (*see, e.g.*, section 5.2). Examples of second active agents and other therapies are also disclosed herein

20 (*see, e.g.*, section 5.3).

Administration of the immunomodulatory compounds and the second active agents to a patient can occur simultaneously or sequentially by the same or different routes of administration. The suitability of a particular route of administration employed for a particular active agent will depend on the active agent itself (*e.g.*, whether it can be

25 administered orally without decomposing prior to entering the blood stream) and the disease being treated. A particular route of administration for an immunomodulatory compound of the invention is oral. Particular routes of administration for the second active agents or ingredients of the invention are known to those of ordinary skill in the art. *See, e.g., The Merck Manual*, 1023-1041 (17th ed., 1999).

30 The amount of second active agent administered can be determined based on the specific agent used, the type of disease being treated or managed, the severity and stage of disease, and the amount(s) of immunomodulatory compounds of the invention and any optional additional active agents concurrently administered to the patient. Those of ordinary skill in the art can determine the specific amounts according to conventional

procedures known in the art. In the beginning, one can start from the amount of the second active agent that is conventionally used in the therapies, and adjust the amount according to the factors described above. *See, e.g., Physician's Desk Reference* (56th Ed., 2004).

In one embodiment of the invention, the second active agent is administered
5 intravenously or subcutaneously and once or twice daily in an amount of from about 1 to about 1000 mg, from about 5 to about 500 mg, from about 10 to about 350 mg, or from about 50 to about 200 mg. The specific amount of the second active agent will depend on the specific agent used, the type of disease being treated or managed, the severity and stage of disease, and the amount(s) of immunomodulatory compounds of the invention and any
10 optional additional active agents concurrently administered to the patient.

In one embodiment, an immunomodulatory compound can be administered in an amount of from about 0.1 to about 150 mg, and preferably from about 1 to about 25 mg, more preferably from about 2 to about 10 mg orally and daily alone, or in combination with a second active agent disclosed herein (*see, e.g.,* section 5.3), prior to, during, or after the
15 use of conventional therapy.

5.4.2 CYCLING THERAPY

In certain embodiments, the prophylactic or therapeutic agents of the invention are cyclically administered to a patient. Cycling therapy involves the administration of an active agent for a period of time, followed by a rest for a period of time, and repeating this
20 sequential administration. Cycling therapy can reduce the development of resistance to one or more of the therapies, avoid or reduce the side effects of one of the therapies, and/or improves the efficacy of the treatment.

Consequently, in one specific embodiment of the invention, an immunomodulatory compound of the invention is administered daily in a single or divided doses in a four to six
25 week cycle with a rest period of about a week or two weeks. The invention further allows the frequency, number, and length of dosing cycles to be increased. Thus, another specific embodiment of the invention encompasses the administration of an immunomodulatory compound of the invention for more cycles than are typical when it is administered alone. In yet another specific embodiment of the invention, an immunomodulatory compound of
30 the invention is administered for a greater number of cycles that would typically cause dose-limiting toxicity in a patient to whom a second active ingredient is not also being administered.

In one embodiment, an immunomodulatory compound of the invention is administered daily and continuously for three or four weeks at a dose of from about 0.1 to

about 150 mg/d followed by a break of one or two weeks. 4-(Amino)-2-(2,6-dioxo(3-piperidyl))-isoindoline-1,3-dione is preferably administered daily and continuously at an initial dose of 0.1 to 5 mg/d with dose escalation (every week) by 1 to 10 mg/d to a maximum dose of 50 mg/d for as long as therapy is tolerated. In a particular embodiment, 3-(4-amino-1-oxo-1,3-dihydro-isoindol-2-yl)-piperidine-2,6-dione is administered in an amount of about 1, 5, 10, or 25mg/day, preferably in an amount of about 10 mg/day for three to four weeks, followed by one week or two weeks of rest in a four or six week cycle.

In one embodiment of the invention, an immunomodulatory compound of the invention and a second active ingredient are administered orally, with administration of an immunomodulatory compound of the invention occurring 30 to 60 minutes prior to a second active ingredient, during a cycle of four to six weeks. In another embodiment of the invention, the combination of an immunomodulatory compound of the invention and a second active ingredient is administered by intravenous infusion over about 90 minutes every cycle. In a specific embodiment, one cycle comprises the administration of from about 1 to about 25 mg/day of 3-(4-amino-1-oxo-1,3-dihydro-isoindol-2-yl)-piperidine-2,6-dione and from about 50 to about 200 mg/m²/day of a second active ingredient daily for three to four weeks and then one or two weeks of rest. In another specific embodiment, each cycle comprises the administration of from about 5 to about 10 mg/day of 4-(amino)-2-(2,6-dioxo(3-piperidyl))-isoindoline-1,3-dione and from about 50 to about 200 mg/m²/day of a second active ingredient for 3 to 4 weeks followed by one or two weeks of rest. Typically, the number of cycles during which the combinatorial treatment is administered to a patient will be from about one to about 24 cycles, more typically from about two to about 16 cycles, and even more typically from about four to about three cycles.

5.5 PHARMACEUTICAL COMPOSITIONS AND DOSAGE FORMS

Pharmaceutical compositions can be used in the preparation of individual, single unit dosage forms. Pharmaceutical compositions and dosage forms of the invention comprise an immunomodulatory compound of the invention, or a pharmaceutically acceptable salt, solvate, stereoisomer, or prodrug thereof, and a second active agent. Pharmaceutical compositions and dosage forms of the invention can further comprise one or more excipients.

Pharmaceutical compositions and dosage forms of the invention can also comprise one or more additional active ingredients. Consequently, pharmaceutical compositions and dosage forms of the invention comprise the active ingredients disclosed herein (*e.g.*, an

immunomodulatory compound and a second active agent). Examples of optional second, or additional, active ingredients are disclosed herein (*see, e.g.,* section 5.3).

Single unit dosage forms of the invention are suitable for oral, mucosal (*e.g.,* nasal, sublingual, vaginal, buccal, or rectal), parenteral (*e.g.,* subcutaneous, intravenous, bolus injection, intramuscular, or intraarterial), topical (*e.g.,* eye drops or other ophthalmic preparations), transdermal or transcutaneous administration to a patient. Examples of dosage forms include, but are not limited to: tablets; caplets; capsules, such as soft elastic gelatin capsules; cachets; troches; lozenges; dispersions; suppositories; powders; aerosols (*e.g.,* nasal sprays or inhalers); gels; liquid dosage forms suitable for oral or mucosal administration to a patient, including suspensions (*e.g.,* aqueous or non-aqueous liquid suspensions, oil-in-water emulsions, or a water-in-oil liquid emulsions), solutions, and elixirs; liquid dosage forms suitable for parenteral administration to a patient; eye drops or other ophthalmic preparations suitable for topical administration; and sterile solids (*e.g.,* crystalline or amorphous solids) that can be reconstituted to provide liquid dosage forms suitable for parenteral administration to a patient.

The composition, shape, and type of dosage forms of the invention will typically vary depending on their use. For example, a dosage form used in the acute treatment of a disease may contain larger amounts of one or more of the active ingredients it comprises than a dosage form used in the chronic treatment of the same disease. Similarly, a parenteral dosage form may contain smaller amounts of one or more of the active ingredients it comprises than an oral dosage form used to treat the same disease. These and other ways in which specific dosage forms encompassed by this invention will vary from one another will be readily apparent to those skilled in the art. *See, e.g., Remington's Pharmaceutical Sciences*, 18th ed., Mack Publishing, Easton PA (1990).

Typical pharmaceutical compositions and dosage forms comprise one or more excipients. Suitable excipients are well known to those skilled in the art of pharmacy, and non-limiting examples of suitable excipients are provided herein. Whether a particular excipient is suitable for incorporation into a pharmaceutical composition or dosage form depends on a variety of factors well known in the art including, but not limited to, the way in which the dosage form will be administered to a patient. For example, oral dosage forms such as tablets may contain excipients not suited for use in parenteral dosage forms. The suitability of a particular excipient may also depend on the specific active ingredients in the dosage form. For example, the decomposition of some active ingredients may be accelerated by some excipients such as lactose, or when exposed to water. Active

ingredients that comprise primary or secondary amines are particularly susceptible to such accelerated decomposition. Consequently, this invention encompasses pharmaceutical compositions and dosage forms that contain little, if any, lactose other mono- or di-saccharides. As used herein, the term "lactose-free" means that the amount of lactose present, if any, is insufficient to substantially increase the degradation rate of an active ingredient.

Lactose-free compositions of the invention can comprise excipients that are well known in the art and are listed, for example, in the *U.S. Pharmacopeia* (USP) 25-NF20 (2002). In general, lactose-free compositions comprise active ingredients, a binder/filler, and a lubricant in pharmaceutically compatible and pharmaceutically acceptable amounts. Particular lactose-free dosage forms comprise active ingredients, microcrystalline cellulose, pre-gelatinized starch, and magnesium stearate.

This invention further encompasses anhydrous pharmaceutical compositions and dosage forms comprising active ingredients, since water can facilitate the degradation of some compounds. For example, the addition of water (*e.g.*, 5%) is widely accepted in the pharmaceutical arts as a means of simulating long-term storage in order to determine characteristics such as shelf-life or the stability of formulations over time. *See, e.g.*, Jens T. Carstensen, *Drug Stability: Principles & Practice*, 2d. Ed., Marcel Dekker, NY, NY, 1995, pp. 379-80. In effect, water and heat accelerate the decomposition of some compounds. Thus, the effect of water on a formulation can be of great significance since moisture and/or humidity are commonly encountered during manufacture, handling, packaging, storage, shipment, and use of formulations.

Anhydrous pharmaceutical compositions and dosage forms of the invention can be prepared using anhydrous or low moisture containing ingredients and low moisture or low humidity conditions. Pharmaceutical compositions and dosage forms that comprise lactose and at least one active ingredient that comprises a primary or secondary amine are preferably anhydrous if substantial contact with moisture and/or humidity during manufacturing, packaging, and/or storage is expected.

An anhydrous pharmaceutical composition should be prepared and stored such that its anhydrous nature is maintained. Accordingly, anhydrous compositions are preferably packaged using materials known to prevent exposure to water such that they can be included in suitable formulary kits. Examples of suitable packaging include, but are not limited to, hermetically sealed foils, plastics, unit dose containers (*e.g.*, vials), blister packs, and strip packs.

The invention further encompasses pharmaceutical compositions and dosage forms that comprise one or more compounds that reduce the rate by which an active ingredient will decompose. Such compounds, which are referred to herein as "stabilizers," include, but are not limited to, antioxidants such as ascorbic acid, pH buffers, or salt buffers.

5 Like the amounts and types of excipients, the amounts and specific types of active ingredients in a dosage form may differ depending on factors such as, but not limited to, the route by which it is to be administered to patients. However, typical dosage forms of the invention comprise an immunomodulatory compound of the invention or a pharmaceutically acceptable salt, solvate, stereoisomer, or prodrug thereof in an amount of
10 from about 0.10 to about 150 mg. Typical dosage forms comprise an immunomodulatory compound of the invention or a pharmaceutically acceptable salt, solvate, stereoisomer, or prodrug thereof in an amount of about 0.1, 1, 2, 5, 7.5, 10, 12.5, 15, 17.5, 20, 25, 50, 100, 150 or 200 mg. In a particular embodiment, a dosage form comprises 4-(amino)-2-(2,6-dioxo(3-piperidyl))-isoindoline-1,3-dione in an amount of about 1, 2, 5, 10, 25 or 50 mg. In
15 a specific embodiment, a dosage form comprises 3-(4-amino-1-oxo-1,3-dihydro-isoindol-2-yl)-piperidine-2,6-dione in an amount of about 5, 10, 25 or 50 mg. Typical dosage forms comprise the second active ingredient in an amount of 1 to about 1000 mg, from about 5 to about 500 mg, from about 10 to about 350 mg, or from about 50 to about 200 mg. Of course, the specific amount of the agent will depend on the specific agent used, the type of
20 disease or disorder being treated or managed, and the amount(s) of an immunomodulatory compound of the invention and any optional additional active agents concurrently administered to the patient.

5.5.1 ORAL DOSAGE FORMS

Pharmaceutical compositions of the invention that are suitable for oral
25 administration can be presented as discrete dosage forms, such as, but are not limited to, tablets (*e.g.*, chewable tablets), caplets, capsules, and liquids (*e.g.*, flavored syrups). Such dosage forms contain predetermined amounts of active ingredients, and may be prepared by methods of pharmacy well known to those skilled in the art. *See generally, Remington's Pharmaceutical Sciences*, 18th ed., Mack Publishing, Easton PA (1990).

30 Typical oral dosage forms of the invention are prepared by combining the active ingredients in an intimate admixture with at least one excipient according to conventional pharmaceutical compounding techniques. Excipients can take a wide variety of forms depending on the form of preparation desired for administration. For example, excipients suitable for use in oral liquid or aerosol dosage forms include, but are not limited to, water,

glycols, oils, alcohols, flavoring agents, preservatives, and coloring agents. Examples of excipients suitable for use in solid oral dosage forms (*e.g.*, powders, tablets, capsules, and caplets) include, but are not limited to, starches, sugars, micro-crystalline cellulose, diluents, granulating agents, lubricants, binders, and disintegrating agents.

5 Because of their ease of administration, tablets and capsules represent the most advantageous oral dosage unit forms, in which case solid excipients are employed. If desired, tablets can be coated by standard aqueous or nonaqueous techniques. Such dosage forms can be prepared by any of the methods of pharmacy. In general, pharmaceutical compositions and dosage forms are prepared by uniformly and intimately admixing the
10 active ingredients with liquid carriers, finely divided solid carriers, or both, and then shaping the product into the desired presentation if necessary.

 For example, a tablet can be prepared by compression or molding. Compressed tablets can be prepared by compressing in a suitable machine the active ingredients in a free-flowing form such as powder or granules, optionally mixed with an excipient. Molded
15 tablets can be made by molding in a suitable machine a mixture of the powdered compound moistened with an inert liquid diluent.

 Examples of excipients that can be used in oral dosage forms of the invention include, but are not limited to, binders, fillers, disintegrants, and lubricants. Binders suitable for use in pharmaceutical compositions and dosage forms include, but are not
20 limited to, corn starch, potato starch, or other starches, gelatin, natural and synthetic gums such as acacia, sodium alginate, alginic acid, other alginates, powdered tragacanth, guar gum, cellulose and its derivatives (*e.g.*, ethyl cellulose, cellulose acetate, carboxymethyl cellulose calcium, sodium carboxymethyl cellulose), polyvinyl pyrrolidone, methyl
cellulose, pre-gelatinized starch, hydroxypropyl methyl cellulose, (*e.g.*, Nos. 2208, 2906,
25 2910), microcrystalline cellulose, and mixtures thereof.

 Suitable forms of microcrystalline cellulose include, but are not limited to, the materials sold as AVICEL-PH-101, AVICEL-PH-103 AVICEL RC-581, AVICEL-PH-105 (available from FMC Corporation, American Viscose Division, Avicel Sales, Marcus Hook, PA), and mixtures thereof. An specific binder is a mixture of microcrystalline cellulose
30 and sodium carboxymethyl cellulose sold as AVICEL RC-581. Suitable anhydrous or low moisture excipients or additives include AVICEL-PH-103™ and Starch 1500 LM.

 Examples of fillers suitable for use in the pharmaceutical compositions and dosage forms disclosed herein include, but are not limited to, talc, calcium carbonate (*e.g.*, granules or powder), microcrystalline cellulose, powdered cellulose, dextrates, kaolin, mannitol,

silicic acid, sorbitol, starch, pre-gelatinized starch, and mixtures thereof. The binder or filler in pharmaceutical compositions of the invention is typically present in from about 50 to about 99 weight percent of the pharmaceutical composition or dosage form.

Disintegrants are used in the compositions of the invention to provide tablets that
5 disintegrate when exposed to an aqueous environment. Tablets that contain too much disintegrant may disintegrate in storage, while those that contain too little may not disintegrate at a desired rate or under the desired conditions. Thus, a sufficient amount of disintegrant that is neither too much nor too little to detrimentally alter the release of the active ingredients should be used to form solid oral dosage forms of the invention. The
10 amount of disintegrant used varies based upon the type of formulation, and is readily discernible to those of ordinary skill in the art. Typical pharmaceutical compositions comprise from about 0.5 to about 15 weight percent of disintegrant, preferably from about 1 to about 5 weight percent of disintegrant.

Disintegrants that can be used in pharmaceutical compositions and dosage forms of
15 the invention include, but are not limited to, agar-agar, alginic acid, calcium carbonate, microcrystalline cellulose, croscarmellose sodium, crospovidone, polacrillin potassium, sodium starch glycolate, potato or tapioca starch, other starches, pre-gelatinized starch, other starches, clays, other alginates, other celluloses, gums, and mixtures thereof.

Lubricants that can be used in pharmaceutical compositions and dosage forms of the
20 invention include, but are not limited to, calcium stearate, magnesium stearate, mineral oil, light mineral oil, glycerin, sorbitol, mannitol, polyethylene glycol, other glycols, stearic acid, sodium lauryl sulfate, talc, hydrogenated vegetable oil (*e.g.*, peanut oil, cottonseed oil, sunflower oil, sesame oil, olive oil, corn oil, and soybean oil), zinc stearate, ethyl oleate, ethyl laureate, agar, and mixtures thereof. Additional lubricants include, for example, a
25 syloid silica gel (AEROSIL200, manufactured by W.R. Grace Co. of Baltimore, MD), a coagulated aerosol of synthetic silica (marketed by Degussa Co. of Plano, TX), CAB-O-SIL (a pyrogenic silicon dioxide product sold by Cabot Co. of Boston, MA), and mixtures thereof. If used at all, lubricants are typically used in an amount of less than about 1 weight percent of the pharmaceutical compositions or dosage forms into which they are
30 incorporated.

A particular solid oral dosage form of the invention comprises an immunomodulatory compound of the invention, anhydrous lactose, microcrystalline cellulose, polyvinylpyrrolidone, stearic acid, colloidal anhydrous silica, and gelatin.

5.5.2 DELAYED RELEASE DOSAGE FORMS

Active ingredients of the invention can be administered by controlled release means or by delivery devices that are well known to those of ordinary skill in the art. Examples include, but are not limited to, those described in U.S. Patent Nos.: 3,845,770; 3,916,899; 5 3,536,809; 3,598,123; and 4,008,719, 5,674,533, 5,059,595, 5,591,767, 5,120,548, 5,073,543, 5,639,476, 5,354,556, and 5,733,566, each of which is incorporated herein by reference. Such dosage forms can be used to provide slow or controlled-release of one or more active ingredients using, for example, hydropropylmethyl cellulose, other polymer matrices, gels, permeable membranes, osmotic systems, multilayer coatings, microparticles, 10 liposomes, microspheres, or a combination thereof to provide the desired release profile in varying proportions. Suitable controlled-release formulations known to those of ordinary skill in the art, including those described herein, can be readily selected for use with the active ingredients of the invention. The invention thus encompasses single unit dosage forms suitable for oral administration such as, but not limited to, tablets, capsules, gelcaps, 15 and caplets that are adapted for controlled-release.

All controlled-release pharmaceutical products have a common goal of improving drug therapy over that achieved by their non-controlled counterparts. Ideally, the use of an optimally designed controlled-release preparation in medical treatment is characterized by a minimum of drug substance being employed to cure or control the condition in a minimum 20 amount of time. Advantages of controlled-release formulations include extended activity of the drug, reduced dosage frequency, and increased patient compliance. In addition, controlled-release formulations can be used to affect the time of onset of action or other characteristics, such as blood levels of the drug, and can thus affect the occurrence of side (*e.g.*, adverse) effects.

25 Most controlled-release formulations are designed to initially release an amount of drug (active ingredient) that promptly produces the desired therapeutic effect, and gradually and continually release of other amounts of drug to maintain this level of therapeutic or prophylactic effect over an extended period of time. In order to maintain this constant level of drug in the body, the drug must be released from the dosage form at a rate that will 30 replace the amount of drug being metabolized and excreted from the body. Controlled-release of an active ingredient can be stimulated by various conditions including, but not limited to, pH, temperature, enzymes, water, or other physiological conditions or compounds.

5.5.3 PARENTERAL DOSAGE FORMS

Parenteral dosage forms can be administered to patients by various routes including, but not limited to, subcutaneous, intravenous (including bolus injection), intramuscular, and intraarterial. Because their administration typically bypasses patients' natural defenses
5 against contaminants, parenteral dosage forms are preferably sterile or capable of being sterilized prior to administration to a patient. Examples of parenteral dosage forms include, but are not limited to, solutions ready for injection, dry products ready to be dissolved or suspended in a pharmaceutically acceptable vehicle for injection, suspensions ready for injection, and emulsions.

10 Suitable vehicles that can be used to provide parenteral dosage forms of the invention are well known to those skilled in the art. Examples include, but are not limited to: Water for Injection USP; aqueous vehicles such as, but not limited to, Sodium Chloride Injection, Ringer's Injection, Dextrose Injection, Dextrose and Sodium Chloride Injection, and Lactated Ringer's Injection; water-miscible vehicles such as, but not limited to, ethyl
15 alcohol, polyethylene glycol, and polypropylene glycol; and non-aqueous vehicles such as, but not limited to, corn oil, cottonseed oil, peanut oil, sesame oil, ethyl oleate, isopropyl myristate, and benzyl benzoate.

Compounds that increase the solubility of one or more of the active ingredients disclosed herein can also be incorporated into the parenteral dosage forms of the invention.

20 For example, cyclodextrin and its derivatives can be used to increase the solubility of an immunomodulatory compound of the invention and its derivatives. *See, e.g.*, U.S. Patent No. 5,134,127, which is incorporated herein by reference.

5.5.4 TOPICAL AND MUCOSAL DOSAGE FORMS

Topical and mucosal dosage forms of the invention include, but are not limited to,
25 sprays, aerosols, solutions, emulsions, suspensions, eye drops or other ophthalmic preparations, or other forms known to one of skill in the art. *See, e.g.*, *Remington's Pharmaceutical Sciences*, 16th and 18th eds., Mack Publishing, Easton PA (1980 & 1990); and *Introduction to Pharmaceutical Dosage Forms*, 4th ed., Lea & Febiger, Philadelphia (1985). Dosage forms suitable for treating mucosal tissues within the oral cavity can be
30 formulated as mouthwashes or as oral gels.

Suitable excipients (*e.g.*, carriers and diluents) and other materials that can be used to provide topical and mucosal dosage forms encompassed by this invention are well known to those skilled in the pharmaceutical arts, and depend on the particular tissue to which a given pharmaceutical composition or dosage form will be applied. With that fact in mind,

typical excipients include, but are not limited to, water, acetone, ethanol, ethylene glycol, propylene glycol, butane-1,3-diol, isopropyl myristate, isopropyl palmitate, mineral oil, and mixtures thereof to form solutions, emulsions or gels, which are non-toxic and pharmaceutically acceptable. Moisturizers or humectants can also be added to pharmaceutical compositions and dosage forms if desired. Examples of such additional ingredients are well known in the art. *See, e.g., Remington's Pharmaceutical Sciences*, 16th and 18th eds., Mack Publishing, Easton PA (1980 & 1990).

The pH of a pharmaceutical composition or dosage form may also be adjusted to improve delivery of one or more active ingredients. Similarly, the polarity of a solvent carrier, its ionic strength, or tonicity can be adjusted to improve delivery. Compounds such as stearates can also be added to pharmaceutical compositions or dosage forms to advantageously alter the hydrophilicity or lipophilicity of one or more active ingredients so as to improve delivery. In this regard, stearates can serve as a lipid vehicle for the formulation, as an emulsifying agent or surfactant, and as a delivery-enhancing or penetration-enhancing agent. Different salts, hydrates or solvates of the active ingredients can be used to further adjust the properties of the resulting composition.

5.5.5 KITS

Typically, active ingredients of the invention are preferably not administered to a patient at the same time or by the same route of administration. This invention therefore encompasses kits which, when used by the medical practitioner, can simplify the administration of appropriate amounts of active ingredients to a patient.

A typical kit of the invention comprises a dosage form of an immunomodulatory compound of the invention, or a pharmaceutically acceptable salt, solvate, stereoisomer, or prodrug thereof. Kits encompassed by this invention can further comprise additional active ingredients. Examples of the additional active ingredients include, but are not limited to, those disclosed herein (*see, e.g.,* section 5.3).

Kits of the invention can further comprise devices that are used to administer the active ingredients. Examples of such devices include, but are not limited to, syringes, drip bags, patches, and inhalers.

Kits of the invention can further comprise cells or blood for transplantation as well as pharmaceutically acceptable vehicles that can be used to administer one or more active ingredients. For example, if an active ingredient is provided in a solid form that must be reconstituted for parenteral administration, the kit can comprise a sealed container of a suitable vehicle in which the active ingredient can be dissolved to form a particulate-free

sterile solution that is suitable for parenteral administration. Examples of pharmaceutically acceptable vehicles include, but are not limited to: Water for Injection USP; aqueous vehicles such as, but not limited to, Sodium Chloride Injection, Ringer's Injection, Dextrose Injection, Dextrose and Sodium Chloride Injection, and Lactated Ringer's Injection; water-miscible vehicles such as, but not limited to, ethyl alcohol, polyethylene glycol, and polypropylene glycol; and non-aqueous vehicles such as, but not limited to, corn oil, cottonseed oil, peanut oil, sesame oil, ethyl oleate, isopropyl myristate, and benzyl benzoate.

6. EXAMPLES

Certain embodiments of the invention are illustrated by the following non-limiting examples.

6.1 MATERIALS AND METHODS

6.1.1 MATERIALS

Buffy coat (50 ml) from healthy donor was obtained from *San Diego Blood Bank*. Anti-CD40 (#5555587), FITC conjugated anti human CD69 (#5555530), FITC conjugated anti human CD40 (#5555588), PE conjugated anti human CD80 (#557227), PerCP-Cy5.5 conjugated anti human HLA-DR (#552764) CD40 ligand (CD154, #555698) were purchased from *BD Pharmingen*. LPS from *E.coli* (#L6529,) was purchased from *Sigma*. Recombinant human IL-4 (#200-04) was purchased from *Pepro Tech*. Goat anti-human IgM (Fc5u fragment, #109-006-129) was purchased from *Jackson Immuno Research, Lab Inc*. Cell proliferation ELISA (BrdU, #1-647-229) was purchased from *Roche Applied Science*. PE anti human TLR 9 (#12-9099, clone # eB72-1665) was purchased from *eBioscience*. Phospho-STAT 6 (#9361) was purchased from *Cell Signaling*.

6.1.2 PURIFICATION OF HPBMCS AND ISOLATION OF CD19⁺ CELLS

Human buffy coat (50 ml) was diluted with 50 ml sterile PBS (Ca⁺⁺, Mg⁺⁺ free), and mixed gently. A 25 ml aliquot of diluted buffy coat was transferred to each 50 ml centrifuge tube, and Histopaque-1077 (14 ml, #1077-1, Sigma) was gently layered into the bottom of the tube. The sample was centrifuged at 2,000 rpm for 30 min at room temperature. The interface containing mononuclear cells was transferred into 50 ml centrifuge tube, and washed once with PBS (1200 rpm, 5 min). The supernatant was discarded. Cell pellet was resuspended in Miltenyi buffer. Anti-CD19⁺ microbeads were added to the suspension (10⁷ cells in 80 µl of buffer, 20 µl antibody beads for 10⁷ cells) and

incubated for 15 min at 4°C. Cell pellet was washed once and resuspended in 1 ml Miltenyi buffer. The cell suspension was added to the magnetic column, washed with 10 ml Miltenyi buffer in the column. CD19⁺ cells are released by 1 ml Miltenyi Buffer without magnetic field. CD19⁺ cells were washed twice with RPMI complete medium. B cells (2x10⁵) were
5 plated in 96 well plate.

6.1.3 B CELL STIMULATION WITH ANTI-IGM, ANTI CD40, LPS, BAFF, AND IL-4

B cells were pretreated with 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline or 1-oxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline at the concentrations of 60 μM, 6
10 μM, 0.6 μM, 0.06 μM, 0.006 μM, and 0.0006 μM for 30 min, then were added 2 μg/ml of anti-IgM, 2 μg/ml of anti CD40, 40 ng/ml IL-4, 100 ng/ml of recombinant BAFF, and/or 0.5 μg/ml of LPS. B cells were typically treated with the immunomodulatory compound alone or in presence of one or more of above stimuli for 3 days. Stimulated B cells with or without the treatment with immunomodulatory compound were used for cell proliferation
15 assay and cytokines analysis.

6.1.4 IgE ELISA

Human PBMCs (1 x 10⁶/ml) were treated with immunomodulatory compounds in presence of anti-CD40 (2 ug/ml) and IL-4 (40 ng/ml) for three weeks. Fifty microliter of supernatant was used for IgE ELISA, following the manufacturer's instruction. The
20 absorbance was read by ELISA reader at OD=450 nm.

6.1.5 WESTERN BLOTTING

CD-19 B cells (2 x 10⁶/ml) were pretreated with 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline at 10 μM and 1 μM for 30 minutes. IL-4 (100 ng/ml) was added to cell suspension for 30 minutes, and the cell pellet was washed once by PBS and lysed with 50 μl
25 of the sample buffer. Cell lysates were heated at 100°C for 5 minutes, and 20 μl of cell lysates were loaded to 4-20% Tris-glycine SDS-PAGE (Invitrogen). The transferred membrane was blotted with 1:1000 anti-phospho STAT6 antibody (Cell signaling) for overnight at 4°C prior to secondary HRP conjugated anti rabbit antibody. The signal of the membrane was developed by ECL kit, following the manufacturer's instructions.

30 6.2 FACS ANALYSIS OF CD80, CD40 AND HLA-DR EXPRESSION

B cells were treated with 1 μM 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline in presence of LPS; CD40 ligand and IL-4; or BAFF for 3 days. The suspension of B cells was washed by PBS once, and incubated with FITC conjugated anti

human CD40, PE conjugated anti human CD80, or PerCP-Cy5.5 conjugated anti human HLA-DR for 30 min in the dark. B cells were subject to FACS analysis using *BD FACS Aria* (*BD biosciences*).

CD80, CD40 and HLA-DR are molecular markers of B cell activation. As shown in Figure 1A, normal B cells treated with 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline in the presence of CD40 ligand and IL-4 exhibited an increased CD80 expression. Moreover, as shown in Figure 1B, the number of B cells expressing CD80 were also increased when the cells were treated with 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline. CD40 (Figure 2A) and HLA-DR expressions were also upregulated by 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline in B cells treated with BAFF or LPS. These results show that immunomodulatory compound of the invention can stimulate B cell activation.

6.3 FACS ANALYSIS OF CD69 EXPRESSION

B cells were treated with 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline (Figure 3A) or 1-oxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline (Figure 3B) in presence of anti IgM, anti CD40 and IL-4 for 3 days. The suspension of B cells was washed by PBS once, and incubated with FITC conjugated anti human CD69 for 30 min in the dark. B cells were subject to FACS analysis using flow cytometer (*EPICS XL-MCL, Beckman Coulter Company*).

CD69 is another molecular marker for B cell activation. As shown in Figures 3A and 3B, both 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline and 1-oxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline dose-dependently enhanced CD69 expression in CD19⁺ B cells treated with anti human IgM, anti human CD40, and recombinant human IL-4. These results show that immunomodulatory compounds of the invention can enhance B cell activation.

6.4 EFFECTS OF IMiDs ON TNF α EXPRESSION

TNF α levels in 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline or 1-oxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline treated B cells were determined using TNF α ELISA. As shown in Figure 4, both 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline and 1-oxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline dose dependently enhance TNF α production in B cells.

6.5 MEASUREMENT OF CYTOKINE IL-6 BY LUMINEX

B cells were treated with 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline at 60 μ M, 6 μ M, 0.6 μ M, 0.06 μ M, 0.006 μ M and 0.0006 μ M in presence of anti IgM, anti CD40 and IL-4 for 3 days. Supernatant (25 μ l) was collected and incubated with 25 μ l anti IL-6 beads for about 1 hour. The beads were washed three times, then incubated with 25 μ l anti detection antibody and subsequent streptavidin-phycoerthrin for 1 hour. The beads were washed three times prior to resuspending in 100 μ l Sheath Fluid. The plate was read on Bio-Plex instrument (Bio-Rad). As shown in Figure 5, 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline, in combination with anti IgM, anti CD40 and IL-4, enhanced IL-6 expression by immunomodulatory compound in a dose dependent manner (Figure 5B), but alone, did not enhance the expression of IL-6 (Figure 5A).

6.6 MORPHOLOGICAL CHANGES OF ACTIVATED B CELLS

B cells were treated with 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline (Figure 6) in presence of anti IgM, anti CD40 and IL-4 for 3 days. The images were captured using phase contrast microscopy with MetaMorph software.

6.7 CELL PROLIFERATION BY BrdU ELISA

The crosslinking of B cell receptor antigen ("BCR") is the primary signal for B cell activation in response to antigen, and is critical in initializing subsequent B cell activation, proliferation, and differentiation. To assess B cell activation, B cells were treated with 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline or 1-oxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline in presence of stimuli for 3 days. 25 μ l BrdU was added to 250 μ l cell culture 24 hours before harvesting cells. B cells were dried at 60°C after removal of labeling supernatant. 100 μ l FixDenat solution was added to fix cells for 30 min at room temperature. FixDenat solution was removed by tapping plate, then 100 μ l anti-BrdU-POD was added each well for 90 min, at room temperature, and the plate was washed three times. 100 μ l of substrate was added to plate for 10 min, then 100 μ l stop solution was added. Absorbance was measured by using an ELISA microplate reader (*Molecular Devices*) at OD 450 nm. As shown in Figure 7A, both immunomodulatory compounds, while having minimal effect on B cell activation alone, enhance B cell proliferation when combined with IgM that functions as cross-linking of the BCR on B cell surface, resulting in the activation of B cells.

Morphological changes also support IMiDs' costimulation of B cells to drive their proliferation. As shown in Figure 7B, when treated by 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-

4-aminoisoindoline and anti-IgM, B cells formed large aggregates which were significantly different from unstimulated B cells or B cells treated with 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline alone, or 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline with anti-CD40 plus IL-4. Clearly, IMiDs are acting as a co-stimulus for BCR to promote B cell proliferation.

Other factors may also result in B-cell activation and proliferation. In this regard, B cell proliferation mediated by LPS and BAFF signaling was also examined. As shown in Figure 7C, 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline showed a similar effect to anti-IgM. LPS binds to BCR to activate B cells while BAFF triggers a unique B cell response through BAFF receptors. The modulation of BCR and BAFF cell signaling by 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline suggests that IMiDs could potentially promote humoral immune responses, especially thymus-independent responses.

6.8 TLR 9 EXPRESSION BY FACSARRAY

B cells were plated in 96 well plate and treated with 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline at concentrations of 60 μ M, 6 μ M, 0.6 μ M, 0.06 μ M, 0.006 μ M and 0.0006 μ M in presence of stimuli for 3 days. B cells were fixed by 1% paraformaldehyde for 30 minutes, followed by permeablizing cells with 1% Triton X-100 for 30 minutes. B cells were incubated with anti human TLR 9 antibody R-PHYCOERYTHIN (PE)-conjugated anti human TLR 9 antibody for 1 hour in dark (0.5 μ g/ 10^6 cells). B cells were then washed with PBS once. B cells were resuspended in 150 μ l PBS containing 1% BSA and read in FACS array instrument (*BD Bioscience*). Figures 8A-8D show that an immunomodulatory compound can increase TLR expression in combination with other stimuli, particularly with IgM.

6.9 EFFECTS ON CYTOKINE SIGNALING

Effects of immunomodulatory compounds on cytokine signaling, which impact on B cell proliferation have been examined using procedures described in section 6.1.3, above. As shown in Figures 9A-9C, immunomodulatory compounds showed inhibitory effects on IL-4 induced cell proliferation, whereas promotional effects were seen for IL-2, IL-5, and IFN-gamma induced cell proliferation. The results are summarized in Figure 9D.

6.9.1 EFFECTS ON IL-4 MEDIATED B CELL ACTIVATION

To assess whether the effects of immunomodulatory compounds on IL-4 signaling impact on IL-4 mediated B cell activation, FACS array of immediate early expression marker CD69 expression at triplicates and six doses was examined using 1,3-dioxo-(2,6-

dioxopiperidin-3-yl)-4-aminoisoindoline or 1-oxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline. As shown in Figures 10A and B, neither immunomodulatory compound inhibited CD69 expression in IL-4 stimulated CD19⁺ B cells. Thus, it is clear that immunomodulatory compounds have no impact on this process.

5 6.9.2 IMiDs INHIBIT IgE SYNTHESIS VIA STAT6 SIGNALING

IL-4 is a unique signal for B cells to produce IgE during the immunoglobulin class switch. To assess whether immunomodulatory compounds can regulated IgE synthesis, 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline or 1-oxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline was incubated with human PBMCs in presence of CD40+IL-4 for three
10 weeks. The data showed these compounds indeed inhibited IgE synthesis in a dose dependent manner with IC₅₀ around 0.1 μ M –0.3 μ M. (Figures 11A and B).

Immunomodulatory compounds also inhibited IgG1 synthesis, which is mediated by IL-4 signaling as well (Figure 11C). IL-4 has been shown to bind the receptor to trigger STAT6 signaling to promote IgE gene transcription. Because activation of STAT6 is
15 important in IL-4 induced IgE and IgG₁ class switching, whether immunomodulatory compounds could inhibit phosphorylation of STAT6 was investigated. B cells were pretreated with 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline for 30 minutes, then stimulated with 100 ng/ml of IL-4 for 30 minutes. The activation of STAT6 was assessed by anti-phospho-STAT6 (Tyr 641). The data showed that immunomodulatory compounds
20 can block phosphorylation of STAT6 (Figure 11D).

In addition to the suppression of IL-4 induced proliferation, CD40+IL-4 induced HLA-DR expression was also examined. B cells were treated by 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline with CD40L+IL-4 for 72 hours, and the cell surface expression markers CD40 and HLA-DR were measured by FACS. The data
25 showed that B cells could be activated in response to stimulation alone, but no enhancement with immunomodulatory compound was observed (Figure 11E). In contrast, for the B cells that were treated with BAFF, 1,3-dioxo-(2,6-dioxopiperidin-3-yl)-4-aminoisoindoline increased CD40 expression by 60% and HLA-DR expression by 86% (Figure 11F). The data are consistent with the previous observation that immunomodulatory compounds have
30 no effect on CD40+IL-4 signaling. Therefore, immunomodulatory compounds were shown to block CD40/IL-4/IgE signaling associated with inhibition of B cell proliferation.

6.10 INHIBITION OF IgE PRODUCTION BY VARIOUS IMiDs

6.10.1 PROCEDURES

Treatment of PBMC: 200 μ l of 1×10^6 /ml human PBMC were plated in 96 well plate, and the cells were pretreated with IMiDs at indicated concentrations (60, 6, 0.6, 0.06, 0.006, 0.0006 μ M) for 30 minutes. Anti CD40 (#AHS4002, Biosource, 2 μ g/ml) and IL-4 (#200-04, Pepro Tech, 40 ng/ml) were added to each well. Human PBMC in presence of IMiDs, anti CD40 and IL-4 were incubated for three weeks. Fifty microliters of supernatant was subjected to IgE ELISA.

IgE ELISA: The IgE ELISA Quantitation Kit was purchased from Bethyl Laboratories, Inc. (#E80-108). The Nunc-Immuno ELISA plate (Nalge Nunc International) was coated with 1:1000 goat anti human IgE at room temperature for 1 hour, and the plate was blocked with 1% BSA for 30 minutes. Fifty microliters of supernatant and 100 μ l IgE standard were added to each well and incubated at room temperature for 2 hours. Then the plate was washed with PBS 3 times. One hundred microliters of goat anti human IgE-HRP conjugated antibody was added to each well and incubated for 60 minutes. The ELISA plate was read at OD=450 nm in ELISA plate reader.

6.10.2 RESULTS

As shown in Table 1, below, out of 12 IMiDs tested, five showed particularly potent characteristics in inhibiting IgE synthesis. The inhibition of IgE was correlated with anti-inflammatory property of IMiDs. Table 2 shows the correlation between IgE inhibition and EC50 of IMiDs for IFN-gamma and IL-2. Since IFN-gamma is a strong antagonist of IL-4/IgE signaling, the results suggest that potential stimulation of IFN-gamma in this system might be involved in the mechanism of IgE inhibition. These results are indicative of therapeutic efficacy of IMiDs in allergic disorders.

Table 1. Correlation Between Inhibition of IgE and Pro-inflammatory Cytokines

IMiD	IC ₅₀ Ig E	IC ₅₀ TNF α	IC ₅₀ IL-1 β	IC ₅₀ IL-6	IC ₅₀ IL-12	IC ₅₀ MCP-1	IC ₅₀ MIP-1 α	% IL-10 (+LPS)	% Rantes (+LPS)
1	+	++	+	+	+++	+	+	++	+
2	+++	+++	+++	+++	+++	+++	+++	+++	++
3	+++	+++	+++	+++	+++	++	++	+++	++
4	NT	+++	+++	+++	+++	++	+++	+++	++
5	+++	+++	+++	+++	+++	+++	+++	+++	++

6	++	+	+	+	++	+	+	+	+
7	+++	+++	+++	+++	+++	+++	+++	+++	++
8	++	+++	+++	++	+++	+	+	+++	++
9	+++	+++	+++	+++	+++	+++	+++	+++	++
10	+	+	+	+	+	+	+	+	+
11	+	++	++	+	++	+	+	++	++
12	++	++	+	+	+++	+	+	++	++

Table 2. Correlation Between IgE Inhibition and IFN- γ /IL-2 Stimulation

IMiD	IC ₅₀ Ig E	EC ₅₀ IFN- γ	EC ₅₀ IL-2
1	+	+	+
2	+++	+++	+++
3	+++	+++	+++
4	NT	+++	+++
5	+++	+++	+++
6	++	++	+
7	+++	+	++
8	++	+++	++
9	+++	+++	+++
10	+	+	+
11	+	+	++
12	++	++	+

All of the references cited herein are incorporated by reference in their entirety.

- 5 While the invention has been described with respect to the particular embodiments, it will be apparent to those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the invention as recited by the appended claims.

- 10 The embodiments of the invention described above are intended to be merely exemplary, and those skilled in the art will recognize, or will be able to ascertain using no more than routine experimentation, numerous equivalents of specific compounds, materials, and procedures. All such equivalents are considered to be within the scope of the invention and are encompassed by the appended claims.

CLAIMS

What is claimed is:

1. A method of treating, managing or preventing an immunodeficiency disease or disorder, which comprises administering to a patient in need of such treatment,
5 management or prevention a therapeutically or prophylactically effective amount of an immunomodulatory compound, or a pharmaceutically acceptable salt, solvate, or stereoisomer thereof.
2. A method of treating, managing or preventing an immunodeficiency disease or disorder, which comprises administering to a patient in need of such treatment,
10 management or prevention a therapeutically or prophylactically effective amount of an immunomodulatory compound, or a pharmaceutically acceptable salt, solvate, or stereoisomer thereof, and a therapeutically or prophylactically effective amount of a second active agent.
3. The method of claim 1 or 2, wherein the immunodeficiency disease
15 or disorder is primary immunodeficiency or secondary immunodeficiency.
4. The method of claim 3, wherein the immunodeficiency disease or disorder is primary immunodeficiency.
5. The method of claim 1 or 2, wherein the immunodeficiency disease
or disorder is adenosine deaminase deficiency, antibody deficiency with normal or elevated
20 Igs, ataxia-telangiectasia, bare lymphocyte syndrome, common variable immunodeficiency, DiGeorge syndrome, Ig deficiency with hyper-IgM, Ig heavy chain deletions, IgA deficiency, immunodeficiency with thymoma, reticular dysgenesis, Nezelof syndrome, selective IgG subclass deficiency, transient hypogammaglobulinemia of infancy, Wiscott-Aldrich syndrome, X-linked agammaglobulinemia, or X-linked severe combined
25 immunodeficiency.
6. The method of claim 5, wherein the immunodeficiency disease or disorder is X-linked agammaglobulinemia.
7. The method of claim 2, wherein the second active agent is an
antibiotic, an antiviral, an immunoglobulin, plasma, an immunologic-enhancing drug, a
30 biologic, or a hormone.
8. The method of claim 7, wherein the antibiotic is ampicillin, tetracycline, penicillin, cephalosporins, streptomycin, kanamycin, or erythromycin

9. The method of claim 7, wherein the antiviral is amantadine, rimantadine, acyclovir, or ribavirin.

10. The method of claim 7, wherein the immunologic-enhancing drug is levamisole or isoprinosine.

5 11. The method of claim 7, wherein the biologic is a transfer factor, an interleukin, or an interferon.

12. The method of claim 7, wherein the hormone is thymic hormone.

13. A method of enhancing an immune response to an immunogen, comprising administering to a subject in need thereof a therapeutically or prophylactically effective amount of an immunomodulatory compound, or a pharmaceutically acceptable salt, solvate, or stereoisomer thereof.

14. The method of claim 13, wherein the immunomodulatory compound is administered prior to the subject's exposure to the immunogen.

15 15. The method of claim 13, wherein the immunomodulatory compound is administered during the subject's exposure to the immunogen.

16. The method of claim 13, wherein the immunomodulatory compound is administered subsequent to the subject's exposure to the immunogen.

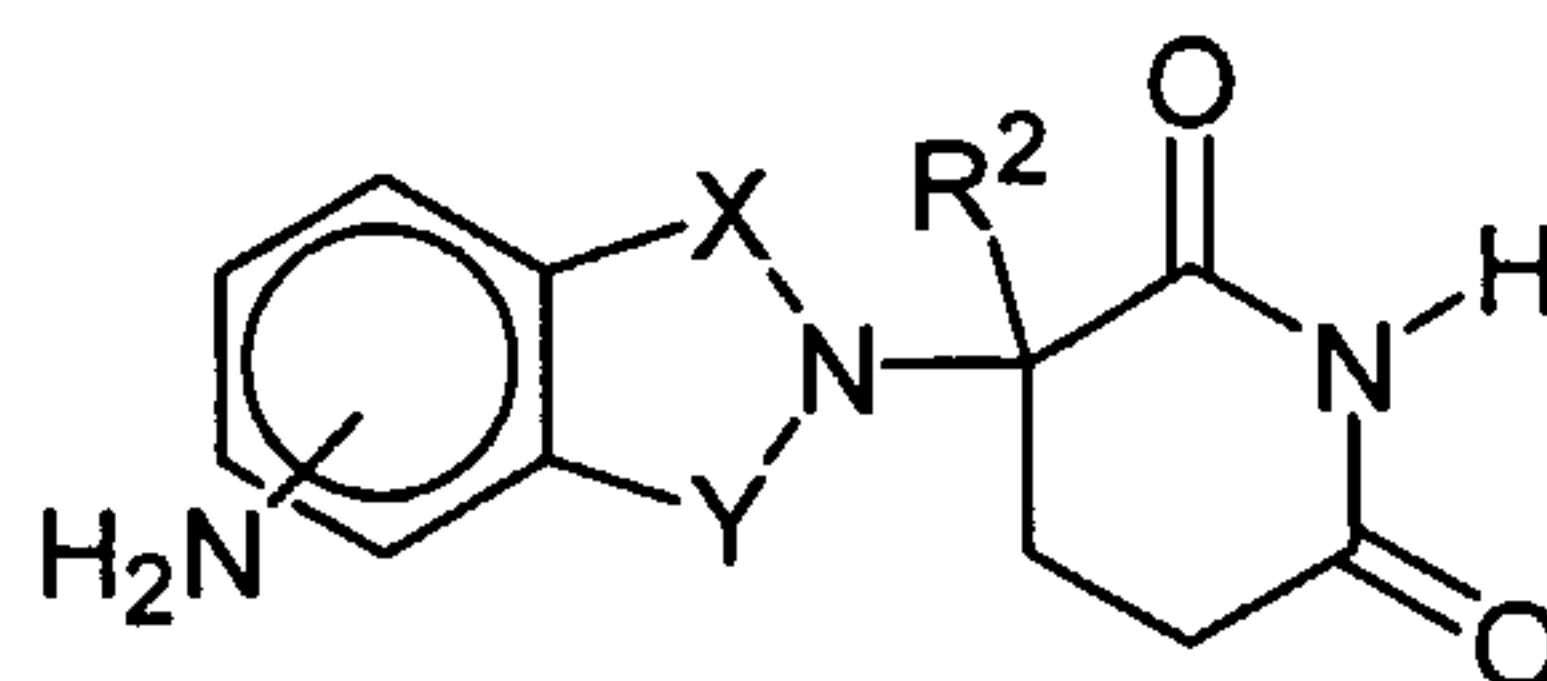
17. The method of claim 1, 2, or 13, wherein the immunomodulatory compound is 4-(amino)-2-(2,6-dioxo(3-piperidyl))-isoindoline-1,3-dione.

20 18. The method of claim 17, wherein the immunomodulatory compound is enantiomerically pure.

19. The method of claims 1, 2, or 13, wherein the immunomodulatory compound is 3-(4-amino-1-oxo-1,3-dihydro-isoindol-2-yl)-piperidine-2,6-dione.

25 20. The method of claim 19, wherein the immunomodulatory compound is enantiomerically pure.

21. The method of any one of claims 1, 2, or 13, wherein the immunomodulatory compound is of formula (I):

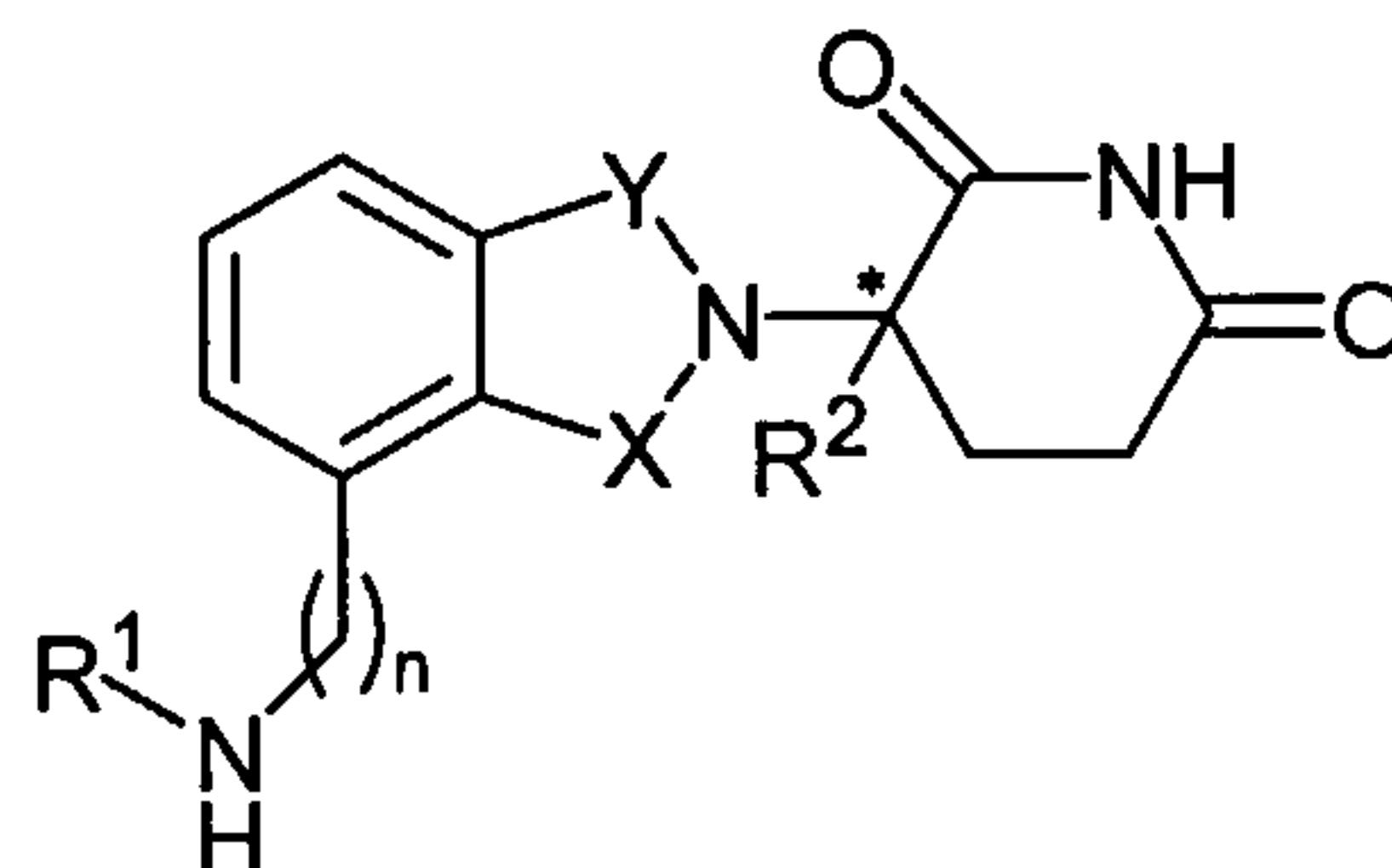


(I)

wherein one of X and Y is C=O, the other of X and Y is C=O or CH₂, and R² is hydrogen or lower alkyl.

22. The method of claim 21, wherein the immunomodulatory compound is enantiomerically pure.

23. The method of any one of claims 1, 2, or 13, wherein the immunomodulatory compound is of formula (II):



(II)

wherein

one of X and Y is C=O and the other is CH₂ or C=O;

R¹ is H, (C₁-C₈)alkyl, (C₃-C₇)cycloalkyl, (C₂-C₈)alkenyl, (C₂-C₈)alkynyl, benzyl, aryl, (C₀-C₄)alkyl-(C₁-C₆)heterocycloalkyl, (C₀-C₄)alkyl-(C₂-C₅)heteroaryl, C(O)R³, C(S)R³, C(O)OR⁴, (C₁-C₈)alkyl-N(R⁶)₂, (C₁-C₈)alkyl-OR⁵, (C₁-C₈)alkyl-C(O)OR⁵, C(O)NHR³, C(S)NHR³, C(O)NR³R^{3'}, C(S)NR³R^{3'} or (C₁-C₈)alkyl-O(CO)R⁵;

R² is H, F, benzyl, (C₁-C₈)alkyl, (C₂-C₈)alkenyl, or (C₂-C₈)alkynyl;

R³ and R^{3'} are independently (C₁-C₈)alkyl, (C₃-C₇)cycloalkyl, (C₂-C₈)alkenyl, (C₂-C₈)alkynyl, benzyl, aryl, (C₀-C₄)alkyl-(C₁-C₆)heterocycloalkyl, (C₀-C₄)alkyl-(C₂-C₅)heteroaryl, (C₀-C₈)alkyl-N(R⁶)₂, (C₁-C₈)alkyl-OR⁵, (C₁-C₈)alkyl-C(O)OR⁵, (C₁-C₈)alkyl-O(CO)R⁵, or C(O)OR⁵;

R⁴ is (C₁-C₈)alkyl, (C₂-C₈)alkenyl, (C₂-C₈)alkynyl, (C₁-C₄)alkyl-OR⁵, benzyl, aryl, (C₀-C₄)alkyl-(C₁-C₆)heterocycloalkyl, or (C₀-C₄)alkyl-(C₂-C₅)heteroaryl;

R⁵ is (C₁-C₈)alkyl, (C₂-C₈)alkenyl, (C₂-C₈)alkynyl, benzyl, aryl, or (C₂-C₅)heteroaryl;

each occurrence of R¹ is independently H, (C₁–C₈)alkyl, (C₂–C₈)alkenyl, (C₂–C₈)alkynyl, benzyl, aryl, (C₂–C₅)heteroaryl, or (C₀–C₈)alkyl–C(O)O–R⁵ or the R⁶ groups join to form a heterocycloalkyl group;

n is 0 or 1; and

5 * represents a chiral-carbon center.

24. The method of claim 23, wherein the immunomodulatory compound is enantiomerically pure.

25. A pharmaceutical composition comprising an immunomodulatory compound, or a pharmaceutically acceptable salt, solvate, or stereoisomer thereof, and a
10 second active ingredient, wherein the second active ingredient is an antibiotic, an antiviral, an immunoglobulin, plasma, an immunologic-enhancing drug, a biologic, or a hormone.

26. The pharmaceutical composition of claim 25, wherein the antibiotic is ampicillin, tetracycline, penicillin, cephalosporins, streptomycin, kanamycin, or erythromycin.

15 27. The pharmaceutical composition of claim 25, wherein the antiviral is amantadine, rimantadine, acyclovir, or ribavirin.

28. The pharmaceutical composition of claim 25, wherein the immunologic-enhancing drug is levamisole or isoprinosine.

29. The pharmaceutical composition of claim 25, wherein the biologic is
20 a transfer factor, an interleukin, or an interferon.

30. The pharmaceutical composition of claim 25, wherein the hormone is thymic hormone.