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- (71) Applicant(s)  
**Wyeth**
- (72) Inventor(s)  
**Graziani, Edmund Idris;Pong, Kevin;Skotnicki, Jerauld**
- (74) Agent / Attorney  
**Phillips Ormonde Fitzpatrick, 367 Collins Street, Melbourne, VIC, 3000**
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**HOLT D. A. et al.: "Structure-Activity Studies of Synthetic FKBP Ligands As Peptidyl-Prolyl Isomerase Inhibitors", Bioorg. & Med. Chem. Letts., 1994, 4(2), 315-320.**  
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- (71) Applicant (for all designated States except US): **WYETH** [US/US]; Five Giralda Farms, Madison, New Jersey 07940 (US).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **GRAZIANI, Edmund, Idris** [CA/US]; 15 Samuel Road, Chestnut Ridge, New York 10977 (US). **PONG, Kevin** [US/US]; 61 Eldrige Drive, Robbinsville, New Jersey 08691 (US). **SKOT-NICKI, Jerauld** [US/US]; 148 Gallows Hill Road, Westfield, New Jersey 07090 (US).
- (74) Agent: **KODROFF, Cathy, A.**; Howson and Howson, 321 Norristown Road, Suite 200, Spring House Corporate Center, P.O. Box 457, Spring House, PA 19477 (US).

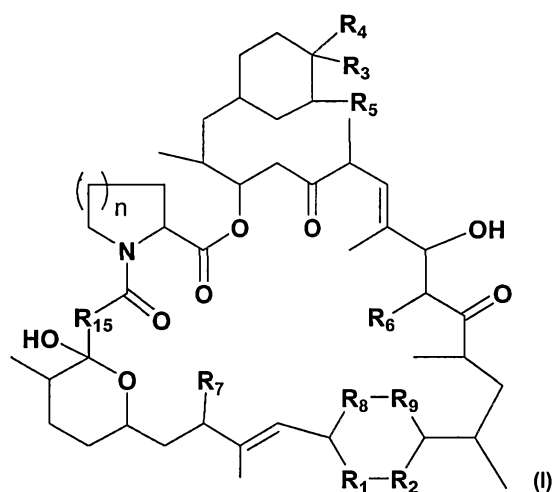
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(54) Title: RAPAMYCIN DERIVATIVES AND THE USES THEREOF IN THE TREATMENT OF NEUROLOGICAL DISORDERS



(57) Abstract: The present invention provides compounds of the following structure, wherein R<sub>1</sub>-R<sub>9</sub>, R<sub>15</sub>, and n are defined herein. These compounds are useful in treating neurological disorders or complications due to stroke or head injury, and as neuroprotective and neuroregenerative agents.

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## RAPAMYCIN DERIVATIVES AND THE USES THEREOF IN THE TREATMENT OF NEUROLOGICAL DISORDERS

### BACKGROUND OF THE INVENTION

5           The present invention provides rapamycin derivatives and their use in the treatment of neurological disorders.

          Ischemic stroke, which accounts for 83% of all stroke cases (the remaining 17% are of the hemorrhagic-type) occurs in approximately 700,000 Americans each year, which equates to roughly 1 stroke every 45 seconds. Ischemic strokes occur as a  
10       result of an obstruction within a blood vessel supplying blood to the brain. The underlying condition for this type of obstruction is the development of fatty deposits lining the vessel walls, called atherosclerosis. These fatty deposits can cause two types of obstruction: 1) cerebral thrombosis, which refers to a thrombus (blood clot) that develops at the clogged part of the vessel and 2) cerebral embolism, which refers  
15       generally to a blood clot that forms at another location in the circulatory system, usually the heart and large arteries of the upper chest and neck. A portion of the blood clot breaks loose, enters the bloodstream and travels through the brain's blood vessels until it reaches vessels too small to let it pass. Current therapies to treat ischemic stroke are limited. To date, the only approved drug for ischemic stroke is  
20       recombinant tissue plasminogen activator (rt-PA). rt-PA, which acts as a thrombolytic, has a limited therapeutic window of opportunity (3 hours), therefore allowing only 1-2% of all stroke patients to receive treatment. There are no marketed neuroprotectants agents for ischemic stroke.

          Parkinson's disease (PD) is a neurodegenerative disease that is  
25       neuropathologically characterized by the selective degeneration of dopaminergic (DAergic) neurons of the substantia nigra. PD is a progressive disease with a mean age at onset of 55, although 15% of patients are diagnosed before the age of 50. It is estimated that 1.5 million Americans have PD. Some of the classical signs of PD are resting tremor on one side of the body, generalized slowness of movement  
30       (bradykinesia), stiffness of limbs (rigidity), gait or balance problems (postural

dysfunction). Current PD medications treat symptoms, whereas none prevent or retard DAergic neuron degeneration.

Given their clinical importance, prototypical molecules that clearly exhibit both neuroprotective and/or neuroregenerative activities have been highly sought after.

5 Neurotrophins are a family of proteins that have extraordinary therapeutic properties in pre-clinical models of neurodegeneration. Although experimentally promising, clinical development of neurotrophins was met with severe obstacles and setbacks, such as the inability to deliver these large proteins to target population of neurons, instability of the proteins, and non-specific activity.

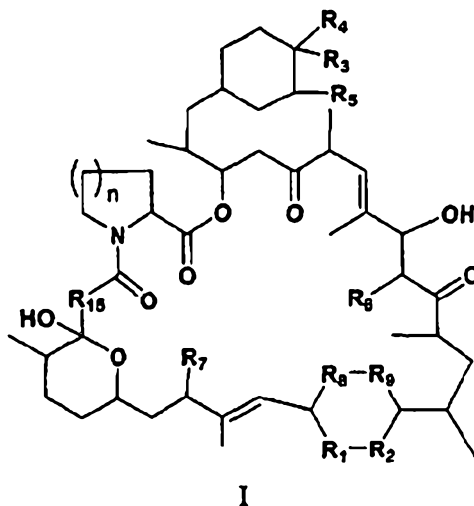
10 What is needed in the art are further compounds useful in treating neurological disorders.

Throughout the description and claims of this specification, the word "comprise" and variations of the word, such as "comprising" and "comprises", is not intended to exclude other additives, components, integers or steps.

15 A reference herein to a patent document or other matter which is given as prior art is not to be taken as an admission that that document or matter was known or that the information it contains was part of the common general knowledge as at the priority date of any of the claims.

20 SUMMARY OF THE INVENTION

In one aspect, the present invention provides a compound of the formula I:



wherein:

$R_1$  and  $R_2$  are the same or different and are selected from the group consisting of  $CR_{16}R_{17}$  and  $CR_{18}R_{19}$ ;

$R_3$  and  $R_4$  are:

(a) independently selected from the group consisting of H, OH, O( $C_1$  to  $C_6$  alkyl), O(substituted  $C_1$  to  $C_6$  alkyl), O(acyl), O(aryl), O(substituted aryl), and halogen; or

(b) taken together to form a double bond to O;

$R_5$ ,  $R_6$ , and  $R_7$  are independently selected from the group consisting of H, OH, and  $OCH_3$ ;

$R_8$  and  $R_9$  are connected through a (i) single bond and are  $CH_2$  or (ii) double bond and are CH;

$R_{10}$  is selected from the group consisting of  $C=O$ ,  $CHOH$ , and  $CH_2$ ;

$R_{11}$  and  $R_{12}$  are independently selected from the group consisting of H,  $C_1$  to  $C_6$  alkyl,  $C_1$  to  $C_6$  substituted alkyl, aryl, substituted aryl, acyl,  $CF_3$ , CN, and  $NO_2$ ;

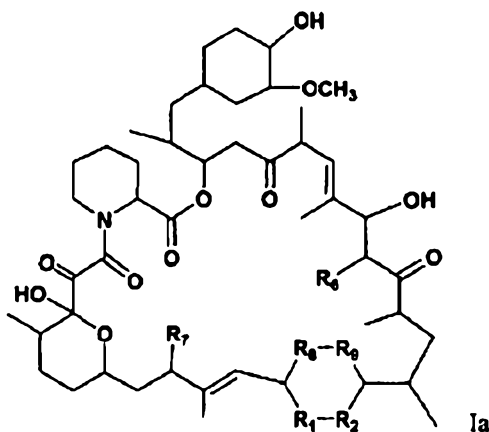
$R_{13}$  and  $R_{14}$  are independently selected from the group consisting of H,  $C_1$  to  $C_6$  alkyl,  $C_1$  to  $C_6$  substituted alkyl, aryl, substituted aryl, acyl,  $CF_3$ , CN, and  $NO_2$ ; or

$R_{15}$  and  $R_{16}$  are taken together to form a carbon-based or heterocyclic 5- to 7-membered ring;

$n$  is 1 or 2;

or a pharmaceutically acceptable salt thereof.

In another aspect, the present invention provides a compound of the formula Ia:



wherein:

$R_1$  and  $R_2$  are the same or different and are selected from the group consisting of  $CR_{16}R_{17}$  and  $CR_{18}R_{19}$ ;

R<sub>6</sub> and R<sub>7</sub> are independently selected from the group consisting of H, OH, and OCH<sub>3</sub>;  
R<sub>8</sub> and R<sub>9</sub> are connected through a (i) single bond and are CH<sub>2</sub> or (ii) double bond and  
are CH;

R<sub>16</sub> and R<sub>17</sub> are independently selected from the group consisting of H, C<sub>1</sub> to C<sub>6</sub> alkyl,  
C<sub>1</sub> to C<sub>6</sub> substituted alkyl, aryl, substituted aryl, acyl, CF<sub>3</sub>, CN, and NO<sub>2</sub>;

R<sub>18</sub> and R<sub>19</sub> are independently selected from the group consisting of H, C<sub>1</sub> to C<sub>6</sub> alkyl,  
C<sub>1</sub> to C<sub>6</sub> substituted alkyl, aryl, substituted aryl, acyl, CF<sub>3</sub>, CN, and NO<sub>2</sub>; or

R<sub>18</sub> and R<sub>19</sub> are taken together to form a 5- to 7-membered ring;  
or a pharmaceutically acceptable salt thereof.

In a further aspect, the present invention provides novel compounds useful in treating,  
and in the preparation of medicaments useful in the treatment of, neurological disorders.

In another aspect, the present invention provides novel neuroprotective agents.

In yet a further aspect, the present invention provides rapamycin derivatives, and  
pharmaceutically acceptable salts, prodrugs, and metabolites thereof.

In another aspect, the present invention provides methods of preparing rapamycin  
derivatives.

In a further aspect, the present invention provides methods of treating neurological  
disorders, and the use of a compound of the invention in the preparation of a medicament  
therefor.

In still another aspect, the present invention provides methods of treating  
complications due to stroke or head trauma, and the use of a compound of the invention in the  
preparation of a medicament therefor.

Other aspects and advantages of the present invention are described further in the  
following detailed description of the preferred embodiments thereof.

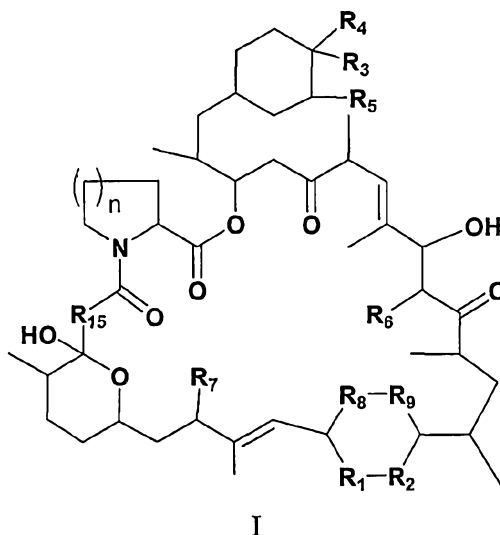
## DETAILED DESCRIPTION OF THE INVENTION

The present invention provides novel rapamycin derivatives which are useful as neuroprotective agents, particularly in compositions for use in treating neurological disorders. The neurological disorder, including, *e.g.*, a neurodegenerative or neuromuscular degenerative condition, can be a result of a genetic disorder present at birth, a disorder developed during the lifespan of an individual, *e.g.*, stroke, and/or the result of physical trauma, *e.g.*, head, spinal injury, or injury to the peripheral nervous system.

Thus, a compound of the invention may be useful in ameliorating the symptoms of a preexisting neurological disorder or preventing further neuro- and/or neuromuscular degeneration. In some embodiments, the neuroprotective agents of the invention can be used to delay the onset of symptoms associated with a neurological disorder.

### 1. Compounds of the Invention

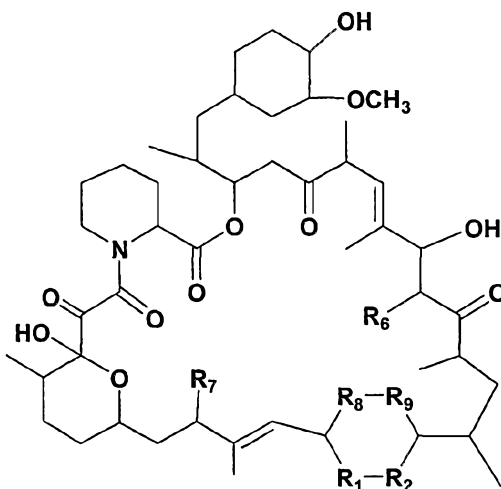
In one embodiment, the present invention provides rapamycin derivatives of the formula I:



$R_1$  and  $R_2$  are the same or different and are selected from among  $CR_{16}R_{17}$  and  $CR_{18}R_{19}$ .  $R_3$  and  $R_4$  are (a) independently selected from among H, OH,  $O(C_1$  to  $C_6$  alkyl),  $O(\text{substituted } C_1$  to  $C_6$  alkyl),  $O(\text{acyl})$ ,  $O(\text{aryl})$ ,  $O(\text{substituted aryl})$ , and halogen; or

(b) are taken together to form a double bond to O. R<sub>5</sub>, R<sub>6</sub>, and R<sub>7</sub> are independently selected among H, OH, and OCH<sub>3</sub>. R<sub>8</sub> and R<sub>9</sub> are connected through a (i) single bond and are CH<sub>2</sub> or (ii) double bond and are CH. R<sub>15</sub> is selected from among C=O, CHOH, and CH<sub>2</sub>. R<sub>16</sub> and R<sub>17</sub> are selected from among H, C<sub>1</sub> to C<sub>6</sub> alkyl, C<sub>1</sub> to C<sub>6</sub> substituted alkyl, aryl, substituted aryl, acyl, CF<sub>3</sub>, CN, and NO<sub>2</sub>. R<sub>18</sub> and R<sub>19</sub> are independently selected from among H, C<sub>1</sub> to C<sub>6</sub> alkyl, C<sub>1</sub> to C<sub>6</sub> substituted alkyl, aryl, substituted aryl, acyl, CF<sub>3</sub>, CN, and NO<sub>2</sub> or R<sub>17</sub> and R<sub>18</sub> are taken together to form a carbon-based or heterocyclic 5- to 7-membered ring. Further, n is 1 or 2.

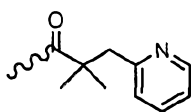
Additional compounds that can be prepared according to the present invention include compounds of the following structure:



where R<sub>1</sub>, R<sub>2</sub>, and R<sub>6</sub>-R<sub>9</sub> are defined as noted above.

In one embodiment, the present invention provides compounds where R<sub>17</sub> and R<sub>18</sub> are taken together to form a carbon-based or heterocyclic 5- to 7-membered ring. Other examples of R<sub>17</sub> and R<sub>18</sub> include where each is an acyl substituted by alkoxy, e.g., -COOEt. R<sub>16</sub> and R<sub>19</sub> may each be CN. In another embodiment, the present invention provides compounds where R<sub>8</sub> and R<sub>9</sub> are bound through a single bond. In a further embodiment, the present invention provides compounds where R<sub>3</sub> or R<sub>4</sub> is OH. In yet another embodiment, the present invention provides compounds where R<sub>3</sub> or R<sub>4</sub> is -O(acyl), preferably where the substituted acyl is -C(O)-optionally substituted alkyl, in particular where alkyl can be straight or branched and optionally substituted, e.g., by heterocyclic such as aromatic heterocyclic such as pyridyl. An example is:





In still a further embodiment, the present invention provides compounds where  $R_5$ ,  $R_6$ , and  $R_7$  are  $OCH_3$ . In another embodiment, the present invention provides compounds where  $n$  is 2. In yet a further embodiment, the present invention provides compounds where  $R_{15}$  is  $C=O$ .

The compounds of the invention can contain one or more asymmetric carbon atoms and some of the compounds can contain one or more asymmetric (chiral) centers and can thus give rise to optical isomers and diastereomers. While shown without respect to stereochemistry, when the compounds can contain one or more chiral centers, preferably at least one of the chiral centers is of S-stereochemistry. Thus, the invention includes such optical isomers and diastereomers; as well as the racemic and resolved, enantiomerically pure stereoisomers; as well as other mixtures of the R and S stereoisomers, and pharmaceutically acceptable salts, hydrates, metabolites, and prodrugs thereof.

The term "alkyl" is used herein to refer to both straight- and branched-chain saturated aliphatic hydrocarbon groups having 1 to 10 carbon atoms, and desirably about 1 to 8 carbon atoms. The term "alkenyl" is used herein to refer to both straight- and branched-chain alkyl groups having one or more carbon-carbon double bonds and containing about 2 to 10 carbon atoms. In one embodiment, the term alkenyl refers to an alkyl group having 1 or 2 carbon-carbon double bonds and having 2 to about 6 carbon atoms. The term "alkynyl" group is used herein to refer to both straight- and branched-chain alkyl groups having one or more carbon-carbon triple bond and having 2 to 8 carbon atoms. In one embodiment, the term alkynyl refers to an alkyl group having 1 or 2 carbon-carbon triple bonds and having 2 to 6 carbon atoms.

The term "cycloalkyl" is used herein to refer to an alkyl group as previously described that is cyclic in structure and has about 4 to 10 carbon atoms, or about 5 to 8 carbon atoms.

The terms "substituted alkyl", "substituted alkenyl", and "substituted alkynyl" refer to alkyl, alkenyl, and alkynyl groups, respectively, having one or more substituents including, without limitation, halogen, CN, OH,  $NO_2$ , amino, aryl,

heterocyclic, alkoxy, aryloxy, alkylcarbonyl, alkylcarboxy, and arylthio, which groups can be optionally substituted. These substituents can be attached to any carbon of an alkyl, alkenyl, or alkynyl group provided that the attachment constitutes a stable chemical moiety.

5           The term "aryl" as used herein refers to an aromatic system, e.g., of 6-20 carbon atoms, which can include a single ring or multiple aromatic rings fused or linked together where at least one part of the fused or linked rings forms the conjugated aromatic system. The aryl groups can include, but are not limited to, phenyl, naphthyl, biphenyl, anthryl, tetrahydronaphthyl, phenanthryl, indene,  
10    benzonaphthyl, fluorenyl, and carbazolyl.

          The term "substituted aryl" refers to an aryl group which is substituted with one or more substituents including halogen, CN, OH, NO<sub>2</sub>, amino, alkyl, cycloalkyl, alkenyl, alkynyl, alkoxy, aryloxy, alkyloxy, alkylcarbonyl, alkylcarboxy, aminoalkyl, and arylthio, which groups can be optionally substituted. In one embodiment, a  
15    substituted aryl group is substituted with 1 to 4 substituents including halogen, CN, OH, NO<sub>2</sub>, amino, alkyl, cycloalkyl, alkenyl, alkynyl, alkoxy, aryloxy, alkyloxy, alkylcarbonyl, alkylcarboxy, aminoalkyl, and arylthio.

          The term "heterocyclic" as used herein refers to a stable 4- to 7-membered monocyclic or multicyclic heterocyclic ring which is saturated, partially unsaturated,  
20    or wholly unsaturated, including aromatic such as pyridyl. The heterocyclic ring has carbon atoms and one or more heteroatoms including nitrogen, oxygen, and sulfur atoms. In one embodiment, the heterocyclic ring has 1 to 4 heteroatoms in the backbone of the ring. When the heterocyclic ring contains nitrogen or sulfur atoms in the backbone of the ring, the nitrogen or sulfur atoms can be oxidized. The term  
25    "heterocyclic" also refers to multicyclic rings, e.g., of 9 to 20 ring members in which a heterocyclic ring is fused to an aryl ring. The heterocyclic ring can be attached to the aryl ring through a heteroatom or carbon atom, provided the resultant heterocyclic ring structure is chemically stable.

          A variety of heterocyclic groups are known in the art and include, without  
30    limitation, oxygen-containing rings, nitrogen-containing rings, sulfur-containing rings, mixed heteroatom-containing rings, fused heteroatom containing rings, and combinations thereof. Oxygen-containing rings include, but are not limited to, furyl,

tetrahydrofuranyl, pyranyl, pyronyl, and dioxinyl rings. Nitrogen-containing rings include, without limitation, pyrrolyl, pyrazolyl, imidazolyl, triazolyl, pyridyl, piperidiny, 2-oxopiperidiny, pyridazinyl, pyrimidinyl, pyrazinyl, piperazinyl, azepinyl, triazinyl, pyrrolidinyl, and azepinyl rings. Sulfur-containing rings include, without limitation, thienyl and dithiolyl rings. Mixed heteroatom containing rings include, but are not limited to, oxathioly, oxazolyl, thiazolyl, oxadiazolyl, oxatriazolyl, dioxazolyl, oxathiazolyl, oxathioly, oxazinyl, oxathiazinyl, morpholinyl, thiamorpholinyl, thiamorpholinyl sulfoxide, oxepinyl, thiepinyl, and diazepinyl rings. Fused heteroatom-containing rings include, but are not limited to, benzofuranyl, thionaphthene, indolyl, benzazolyl, purindinyl, pyranopyrrolyl, isoindazolyl, indoxazinyl, benzoxazolyl, anthranilyl, benzopyranyl, quinolinyl, isoquinolinyl, benzodiazonyl, naphthylridinyl, benzothienyl, pyridopyridinyl, benzoxazinyl, xanthenyl, acridinyl, and purinyl rings.

The term “substituted heterocyclic” as used herein refers to a heterocyclic group having one or more substituents including halogen, CN, OH, NO<sub>2</sub>, amino, alkyl, cycloalkyl, alkenyl, alkynyl, alkoxy, aryloxy, alkyloxy, alkylcarbonyl, alkylcarboxy, aminoalkyl, and arylthio, which groups can be optionally substituted. In one embodiment, a substituted heterocyclic group is substituted with 1 to 4 substituents.

The term “acyl” refers to a -C(O)- group, which is substituted at the carbon atom. The acyl group can be substituted or a terminal acyl group such as an HC(O)-group. The substituents can include any substituents noted above for alkyl groups, viz. one or more substituents including, without limitation, halogen, CN, OH, NO<sub>2</sub>, amino, aryl, heterocyclic, alkoxy, aryloxy, alkylcarbonyl, alkylcarboxy, and arylthio, which groups can be optionally substituted. Examples include -C(O)-alkoxy (eg. -OMe or -OEt) or -C(O)-alkyl where alkyl can be straight or branched and optionally substituted e.g., by heterocyclic (such as pyridyl).

The term “alkoxy” as used herein refers to the O(alkyl) group, where the point of attachment is through the oxygen-atom and the alkyl group is optionally substituted.

The term “aryloxy” as used herein refers to the O(aryl) group, where the point of attachment is through the oxygen-atom and the aryl group is optionally substituted.

The term "alkyloxy" as used herein refers to the alkylOH group, where the point of attachment is through the alkyl group.

The term "arylthio" as used herein refers to the S(aryl) group, where the point of attachment is through the sulfur-atom and the aryl group can be optionally substituted.

The term "alkylcarbonyl" as used herein refers to the C(O)(alkyl) group, where the point of attachment is through the carbon-atom of the carbonyl moiety and the alkyl group is optionally substituted.

The term "alkylcarboxy" as used herein refers to the C(O)O(alkyl) group, where the point of attachment is through the carbon-atom of the carboxy moiety and the alkyl group is optionally substituted.

The term "aminoalkyl" as used herein refers to both secondary and tertiary amines where the point of attachment is through the nitrogen-atom and the alkyl groups are optionally substituted. The alkyl groups can be the same or different.

The term "halogen" as used herein refers to Cl, Br, F, or I groups.

## II. *Methods of Preparing the Compounds of the Invention*

The rapamycin derivatives of formula I of the present invention are prepared from a rapamycin starting material. In one embodiment, the rapamycin starting material includes, without limitation, rapamycin, norrapamycin, deoxorapamycin, desmethylrapamycins, or desmethoxyrapamycin, or pharmaceutically acceptable salts, prodrugs, or metabolites thereof. However, one of skill in the art would readily be able to select a suitable rapamycin starting material that can be utilized to prepare the novel rapamycin derivatives of the present invention.

The term "desmethylrapamycin" refers to the class of rapamycin compounds which lack one or more methyl groups. Examples of desmethylrapamycins that can be used according to the present invention include 3-desmethylrapamycin (US Patent No. 6,358,969), 7-O-desmethyl-rapamycin (US Patent No. 6,399,626), 17-desmethylrapamycin [US Patent No. 6,670,168], and 32-O-desmethylrapamycin, among others.

The term "desmethoxyrapamycin" refers to the class of rapamycin compounds which lack one or more methoxy groups and includes, without limitation, 32-desmethoxyrapamycin.

The rapamycin derivatives of formula I of the present invention are therefore prepared by combining a rapamycin starting material and an optionally substituted olefin. The term olefin refers to a molecule that contains a double bond. A variety of olefins can be utilized in the present invention and can readily be selected by one of skill in the art and include diethylfumarate, among others including any olefin sufficiently activated with electron-withdrawing substituents to undergo a [4+2] cycloaddition at temperatures up to 50 °C. One of skill in the art would readily be able to select the amount of olefin that would be effective in preparing the rapamycin derivatives of the present invention. In one embodiment, an excess of the olefin is utilized, *e.g.*, a 3:1 ratio of olefin to rapamycin starting material. However, even a 1:1 or 2:1 ratio of olefin to rapamycin starting material can be utilized as determined by one of skill in the art.

The olefin and rapamycin starting material is combined in a solvent. The solvent preferably dissolves the olefin and/or rapamycin on contact, or dissolves the olefin and rapamycin as the reaction proceeds. Solvents that can be utilized in the present invention include, without limitation, dimethylformamide, dioxane such as p-dioxane, chloroform, alcohols such as methanol and ethanol, ethyl acetate, water, acetonitrile, tetrahydrofuran, dichloromethane, and toluene, or combinations thereof. However, one of skill in the art would readily be able to select a suitable solvent based upon the solubility of the rapamycin starting material and olefin, as well as the reactivity of the solvent with the same. The amount of solvent utilized depends upon the scale of the reaction and specifically the amount of rapamycin starting material and olefin present in the reaction mixture. One of skill in the art would readily be able to determine the amount of solvent required.

Typically, the solution containing the olefin, rapamycin starting material, and solvent is maintained at elevated temperatures, and preferably a temperature that does not promote decomposition of the rapamycin and olefin. In one embodiment, the solution is maintained at a temperature of about 30 to about 80 °C, and preferably about 50 °C. The components are heated for a period of time sufficient to permit

reaction between the rapamycin starting material and olefin. One of skill in the art using known techniques would readily be able to monitor the progress of the reaction during heating and thereby determine the amount of time required to perform the reaction. In one embodiment, the rapamycin and olefin are combined with a solvent  
5 and maintained at a temperature of about 50 °C.

Isolation and purification of the rapamycin derivative is well within one of skill in the art and include chromatography including, without limitation, and recrystallization, high performance liquid chromatography (HPLC) such as reverse phase HPLC, and normal phase HPLC, and size-exclusion chromatography.

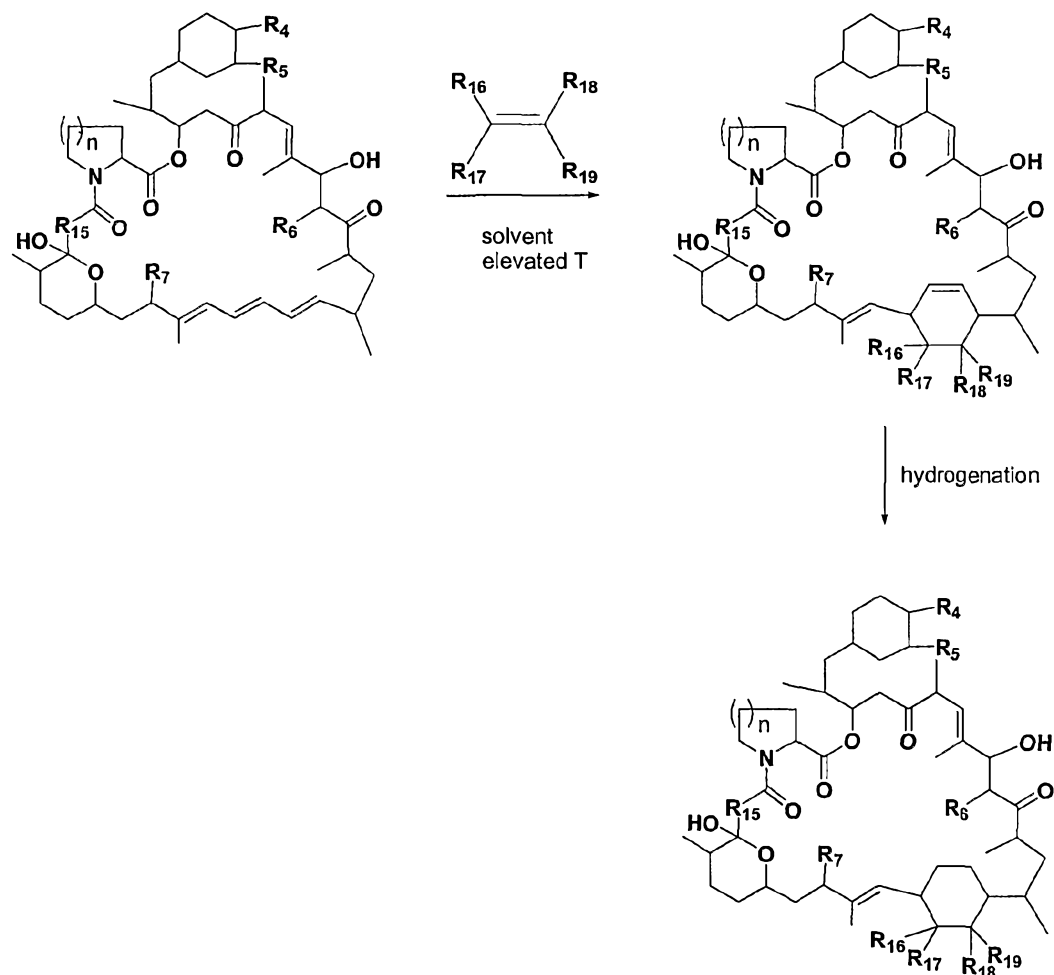
10 Once the rapamycin derivative is obtained, it can be reduced to form a more saturated rapamycin derivative. One of skill in the art would readily be able to select a suitable reducing agent for use in the present invention. In one embodiment, reduction of the rapamycin derivative can be effected using a hydrogenation agent. One of skill in the art would readily be able to select a suitable hydrogenation agent  
15 for use in the present invention. Typically, transition metal catalysts or transition metals on a support, preferably a carbon support, among others, in the presence hydrogen gas, are utilized to carry out the reduction. In another embodiment, the reduction is performed using palladium metal on carbon in the presence of hydrogen gas.

20 Reduction of the rapamycin derivative is typically carried out in a solvent. A variety of solvents can be utilized in the reduction and include, without limitation, alcohols such as methanol. However, one of skill in the art would readily be able to select a suitable solvent for use in the present invention and depending on the hydrogenation catalyst and rapamycin derivative being reduced. The amount of  
25 solvent depends on the scale of the reaction, and specifically the amount of rapamycin derivative being reduced.

The amount of hydrogenation agent utilized in the present invention can readily be determined by one of skill in the art. However, one of skill in the art would be able to determine and adjust the amount of hydrogenation agent necessary to  
30 perform the reduction and to form the more saturated rapamycin derivatives of the present invention. Further, a variety of apparatuses can be utilized to perform the hydrogenation of the present invention and include Parr apparatuses, among others.

The selection of the particular apparatus for the hydrogenation is well within one of skill in the art.

In one embodiment, the rapamycin derivatives of the present invention are prepared as summarized in Scheme 1 below:



5

where R<sub>4</sub>-R<sub>7</sub>, R<sub>15</sub>-R<sub>19</sub>, and n are defined above.

The rapamycin derivatives of the present invention can be utilized in the form of pharmaceutically acceptable salts, prodrugs, or metabolites thereof derived from pharmaceutically or physiologically acceptable acids or bases. These salts include, but are not limited to, the following salts with mineral or inorganic acids such as hydrochloric acid, sulfuric acid, nitric acid, phosphoric acid and organic acids such as acetic acid, oxalic acid, succinic acid, and maleic acid. Other salts include salts with alkali metals or alkaline earth metals, such as sodium, potassium, calcium or

10

magnesium in the form of esters, carbamates and other conventional "pro-drug" forms, which, when administered in such form, convert to the active moiety *in vivo*.

### III. Methods of Using the Compounds of the Present Invention

5           The rapamycin derivatives of formula I of the present invention, including the more and less saturated rapamycin derivatives, have use in a variety of applications and include those relating to neurological disorders. The compounds of the present invention are useful in treating neurological disorders including, but not limited to, Alzheimer's disease amyotrophic lateral sclerosis, epilepsy, Huntington's Disease,  
10    Parkinson's Disease, stroke, spinal cord injury, traumatic brain injury, Lewy body dementia, multiple sclerosis, Pick's disease, Niewmann-Pick disease, amyloid angiopathy, cerebral amyloid angiopathy, systemic amyloidosis, hereditary cerebral hemorrhage with amyloidosis of the Dutch type, inclusion body myositis, mild cognitive impairment and Down's syndrome, and in the preparation of medicaments  
15    therefor. The rapamycin derivatives are also useful in treating complications due to stroke, head trauma, or spinal injury, or other injuries to the brain, peripheral nervous, central nervous, or neuromuscular system, and in the preparation of medicaments therefor.

          The novel rapamycin derivatives are useful as neuroprotective agents. The  
20    rapamycin derivatives of the present invention may also be useful as neuroregenerative agents, *i.e.* restoring some neurological and/or neuromuscular or other function following onset of one of the above conditions and/or injury, stroke, or other trauma, and in the preparation of medicaments therefor.

          The dosage requirements of the rapamycin derivatives of the present invention  
25    can vary depending on the condition, severity of the symptoms presented and the particular subject being treated. One of skill in the art would readily be able to determine the amount of the rapamycin derivative required. In one embodiment, about 0.5 to 200 mg is administered. In a further embodiment, about 0.5 to 100 mg is administered. In another embodiment, about 0.5 to about 75 mg is administered. In  
30    yet a further embodiment, about 1 to about 25 mg is administered. In another embodiment, about 0.5 to about 10 mg is administered, particularly when used in



combination with another agent. In yet a further embodiment, about 2 to about 5 mg is administered. In yet another embodiment, about 5 to about 15 mg is administered.

Treatment can be initiated with dosages of the rapamycin derivative smaller than those required to produce a desired effect and generally less than the optimum  
5 dose of the rapamycin derivative. Thereafter, the dosage can be increased until the optimum effect under the circumstances is reached. Precise dosages will be determined by the administering physician based on experience with the individual subject being treated. In general, the compositions of this invention are most desirably administered at a concentration that will generally afford effective results  
10 without causing any harmful or deleterious side effects.

#### IV. Methods of Preparing Administrable Compositions Containing the Rapamycin Derivatives

In one aspect, the present invention includes methods of preparing a  
15 pharmaceutical composition containing one or more rapamycin derivatives of the present invention. The composition can be administered to a mammalian subject by several different routes and is desirably administered orally in solid or liquid form.

Solid forms, including tablets, capsules, and caplets, containing the rapamycin derivative can be formed by blending the rapamycin derivative with one or more of  
20 the components described above. In one embodiment, the components of the composition are dry or wet blended. In another embodiment, the components are dry granulated. In a further embodiment, the components are suspended or dissolved in a liquid and added to a form suitable for administration to a mammalian subject.

Liquid forms containing the rapamycin derivative can be formed by dissolving  
25 or suspending the rapamycin derivative in a liquid suitable for administration to a mammalian subject.

Compositions containing the rapamycin derivative of the present invention can be prepared according to the present invention by combining the rapamycin derivative and a pharmaceutically acceptable carrier.

30 The compositions described herein containing the rapamycin derivative can be formulated in any form suitable for the desired route of delivery using a pharmaceutically effective amount of the rapamycin derivative. For example, the

compositions of the invention can be delivered by a route such as oral, dermal, transdermal, intrabronchial, intranasal, intravenous, intramuscular, subcutaneous, parenteral, intraperitoneal, intranasal, vaginal, rectal, sublingual, intracranial, epidural, intratracheal, or by sustained release. In one embodiment, delivery is oral.

5           The oral dosage tablet composition of this invention can also be used to make oral dosage tablets containing analogs of the rapamycin derivative, including, but not limited to, esters, carbamates, sulfates, ethers, oximes, carbonates, and the like which are known to those of skill in the art.

          A pharmaceutically effective amount of the rapamycin derivative can vary  
10 depending on the specific compound(s), mode of delivery, severity of the condition being treated, and any other active ingredients used in the composition. The dosing regimen can also be adjusted to provide the optimal therapeutic response. Several divided doses can be delivered daily, *e.g.*, in divided doses 2 to 4 times a day, or a single dose can be delivered. The dose can however be proportionally reduced or  
15 increased as indicated by the exigencies of the therapeutic situation. In one embodiment, the delivery is on a daily, weekly, or monthly basis. In another embodiment, the delivery is on a daily delivery. However, daily dosages can be lowered or raised based on the periodic delivery.

          The rapamycin derivatives of the present invention can be combined with one  
20 or more pharmaceutically acceptable carriers or excipients including, without limitation, solid and liquid carriers which are compatible with the compositions of the present invention. Such carriers include adjuvants, syrups, elixirs, diluents, binders, lubricants, surfactants, granulating agents, disintegrating agents, emollients, metal chelators, pH adjustors, surfactants, fillers, disintegrants, and combinations thereof,  
25 among others. In one embodiment, the rapamycin derivative is combined with metal chelators, pH adjustors, surfactants, fillers, disintegrants, lubricants, and binders.

          Adjuvants can include, without limitation, flavoring agents, coloring agents, preservatives, and supplemental antioxidants, which can include vitamin E, ascorbic acid, butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA).

30           Binders can include, without limitation, cellulose, methylcellulose, hydroxymethylcellulose, carboxymethylcellulose calcium, carboxymethylcellulose sodium, hydroxypropylcellulose, hydroxypropylmethylcellulose phthalate,

microcrystalline cellulose, noncrystalline cellulose, polypropylpyrrolidone, polyvinylpyrrolidone (povidone, PVP), gelatin, gum arabic and acacia, polyethylene glycols, starch, sugars such as sucrose, kaolin, dextrose, and lactose, cholesterol, tragacanth, stearic acid, gelatin, casein, lecithin (phosphatides), cetostearyl alcohol, cetyl alcohol, cetyl esters wax, dextrans, dextrin, glyceryl monooleate, glyceryl monostearate, glyceryl palmitostearate, polyoxyethylene alkyl ethers, polyoxyethylene castor oil derivatives, polyoxyethylene stearates, polyvinyl alcohol, and gelatin, among others. In one embodiment, the binder is povidone, hydroxypropylmethylcellulose, carboxymethylcellulose, or gelatin. In another embodiment, the binder is povidone.

Lubricants can include magnesium stearate, light anhydrous silicic acid, talc, stearic acid, sodium lauryl sulfate, and sodium stearyl fumarate, among others. In one embodiment, the lubricant is magnesium stearate, stearic acid, or sodium stearyl fumarate. In another embodiment, the lubricant is magnesium stearate.

Granulating agents can include, without limitation, silicon dioxide, microcrystalline cellulose, starch, calcium carbonate, pectin, crospovidone, and polyplasdone, among others.

Disintegrating agents or disintegrants can include croscarmellose sodium, starch, carboxymethylcellulose, substituted hydroxypropylcellulose, sodium bicarbonate, calcium phosphate, calcium citrate, sodium starch glycolate, pregelatinized starch or crospovidone, among others. In one embodiment, the disintegrant is croscarmellose sodium.

Emollients can include, without limitation, stearyl alcohol, mink oil, cetyl alcohol, oleyl alcohol, isopropyl laurate, polyethylene glycol, olive oil, petroleum jelly, palmitic acid, oleic acid, and myristyl myristate.

Surfactants can include polysorbates, sorbitan esters, poloxamer, or sodium lauryl sulfate. In one embodiment, the surfactant is sodium lauryl sulfate.

Metal chelators can include physiologically acceptable chelating agents including edetic acid, malic acid, or fumaric acid. In one embodiment, the metal chelator is edetic acid.

pH adjusters can also be utilized to adjust the pH of a solution containing the rapamycin derivative to about 4 to about 6. In one embodiment, the pH of a solution

containing the rapamycin derivative is adjusted to a pH of about 4.6. pH adjustors can include physiologically acceptable agents including citric acid, ascorbic acid, fumaric acid, or malic acid, and salts thereof. In one embodiment, the pH adjuster is citric acid.

5            Fillers that can be used according to the present invention include anhydrous lactose, microcrystalline cellulose, mannitol, calcium phosphate, pregelatinized starch, or sucrose. In one embodiment, the filler is anhydrous lactose. In another embodiment, the filler is microcrystalline cellulose.

10            In one embodiment, compositions containing the rapamycin derivative of the invention are delivered orally by tablet, caplet or capsule, microcapsules, dispersible powder, granule, suspension, syrup, elixir, and aerosol. In a further embodiment, when compositions containing the rapamycin derivative are delivered orally, delivery is by tablets and hard- or liquid-filled capsules.

15            In another embodiment, the compositions containing the rapamycin derivative can be delivered intravenously, intramuscularly, subcutaneously, parenterally and intraperitoneally in the form of sterile injectable solutions, suspensions, dispersions, and powders which are fluid to the extent that easy syringe ability exists. Such injectable compositions are sterile and stable under conditions of manufacture and storage, and free of the contaminating action of microorganisms such as bacteria and  
20            fungi.

              In a further embodiment, compositions containing the rapamycin derivative can be delivered rectally in the form of a conventional suppository.

              In another embodiment, compositions containing the rapamycin derivative can be delivered vaginally in the form of a conventional suppository, cream, gel, ring, or  
25            coated intrauterine device (IUD).

              In yet another embodiment, compositions containing the rapamycin derivative can be delivered intranasally or intrabronchially in the form of an aerosol.

              The rapamycin derivatives are administered orally as well as by intravenous, intramuscular, or subcutaneous routes. Solid carriers include starch, lactose,  
30            dicalcium phosphate, microcrystalline cellulose, sucrose and kaolin, while liquid carriers include sterile water, polyethylene glycols, non-ionic surfactants and edible oils such as corn, peanut and sesame oils, as are appropriate to the nature of the active

ingredient and the particular form of administration desired. Adjuvants customarily employed in the preparation of pharmaceutical compositions are advantageously included, such as flavoring agents, coloring agents, preserving agents, and antioxidants, for example, vitamin E, ascorbic acid, BHT and BHA.

5           The preferred pharmaceutical compositions from the standpoint of ease of preparation and administration are solid compositions, particularly tablets and hard-filled or liquid-filled capsules. Similarly, oral administration of the compounds is preferred.

          The rapamycin derivatives are also administered parenterally or  
10 intraperitoneally. Solutions or suspensions of these active compounds as a free base or pharmacologically acceptable salt are prepared in water suitably mixed with a surfactant such as hydroxypropylcellulose. Dispersions are also prepared in glycerol, liquid, polyethylene glycols and mixtures thereof in oils. Under ordinary conditions of storage and use, these preparations contain a preservative to prevent the growth of  
15 microorganisms.

          The pharmaceutical forms suitable for injectable use include sterile aqueous solutions or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersions. In all cases, the form is sterile and fluid to the extent that easy syringe ability exists. It is stable under conditions of manufacture  
20 and storage and is preserved against the contaminating action of microorganisms such as bacterial and fungi. The carrier is a solvent or dispersion medium containing, for example, water, ethanol (*e.g.*, glycerol, propylene glycol and liquid polyethylene glycol), suitable mixtures thereof, and vegetable oil.

## 25 V. Kits of the Invention

          The present invention also provides kits or packages containing the rapamycin derivatives. Kits of the present invention can include the rapamycin derivative of the present invention and a carrier suitable for administration to a mammalian subject as discussed above. The kits can also contain the reagents required to prepare the  
30 rapamycin derivatives of the present invention and include a rapamycin, an optionally substituted olefin, and a solvent.

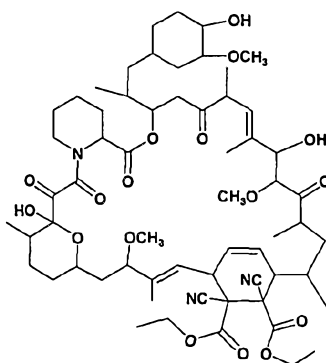
The kits can optionally include other reagents to form other rapamycin derivatives and include hydrogenation agents.

The kit can further contain instructions for performing the reactions of the present invention. Also provided in a kit can be other suitable chemicals, disposable gloves, decontamination instructions, applicator sticks or containers, and sample preparator cups.

The following examples are provided to illustrate the invention and do not limit the scope thereof. One skilled in the art will appreciate that although specific reagents and conditions are outlined in the following examples, modifications can be made which are meant to be encompassed by the spirit and scope of the invention.

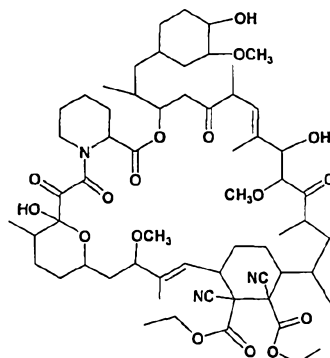
## EXAMPLES

### 15 Example 1



Rapamycin (0.25 g, 0.274 mmol) is dissolved in 5 mL solvent with gentle heating. To this solution is added, dropwise, a solution of diethyl dicyanofumarate (0.183 g, 3 eq) in 7 mL solvent. The reaction mixture is stirred at 50 to 80 °C for 12 to 36 hours, and then the reaction mixture is chromatographed via reversed-phase HPLC to yield the product.

## Example 2



The compound prepared according to Example 1 is dissolved in methanol in an 18 mm test-tube, and a spatula tip of Pd/C catalyst (Aldrich) is added. The mixture is hydrogenated on a Parr apparatus for 15 minutes at 2.0 atmosphere H<sub>2</sub>. The products are chromatographed via reversed-phase HPLC to yield give the product.

## Example 3

Mesencephalic dopaminergic neuron cultures are prepared as described in Pong et al., J. Neurochem. 69: 986-994, 1997, which is incorporated herein by reference in its entirety. Embryonic day 15 (E15) rat fetuses are collected and dissected in ice-cold phosphate-buffered saline (PBS). The ventral piece of tissue compromising the mesencephalic dopaminergic region is dissected out. Dissected pieces of tissue are pooled together and transferred to an enzymatic dissociation medium containing 20 IU/mL papain in Earle's balanced salt solution (Worthington Biochemical, Freehold, NJ, USA) and incubated for 60 minutes at 37°C. After enzymatic dissociation, the papain solution is aspirated and the tissue mechanically triturated with a fire-polished glass Pasteur pipette in complete medium (equal volumes of minimum essential medium (MEM) and F-12 nutrient mixture (GibcoBRL) supplemented with 0.1 mg/mL apotransferrin and 2.5 µg/mL insulin) containing 2,000 IU/mL DNase and 10 mg/mL ovomucoid protease inhibitor.

For dopamine uptake experiments, single-cell suspensions in complete media are seeded on poly-L-ornithine and laminin coated 24-well plates. The cultures are maintained for seven days prior to experimentation. Cultures are pretreated with various concentrations of the compound for 24 hours, then exposed to 10 mM MPP+

for 1 hour. Following the 1 hour incubation, media is exchanged three times and fresh compound is added for an additional 48 hours.

After 48 hours growth of mesencephalic dopaminergic neuron cultures following MPP<sup>+</sup> exposure, high-affinity 3H-dopamine uptake is performed using a modified method described by Prochiantz et al., Nature 293: 570-572, 1981, which is  
5 incorporated herein by reference. Cultures are washed with pre-warmed PBS containing 5.6 mM glucose and 1 mM ascorbic acid. Cultures are then incubated for 15 minutes at 37°C with 50 nM 3H-dopamine (31 Ci/mmol, DuPont-NEN, Wilmington, DE, USA). The cultures are washed twice with buffer and lysed with  
10 0.5 N NaOH. The lysate is transferred to a scintillation vial containing Ultima Gold™ scintillation cocktail and radioactivity is determined with a liquid scintillation counter. Alternatively, culture lysates are washed twice with buffer, incubated for 2 hours at room temperature with Optiphase Supermix™ scintillation cocktail (Wallac Scintillation Products, Gaithersburg, MD, USA), and radioactivity measured with a  
15 liquid scintillation counter.

Dissociated cortical neuron cultures are prepared as previously described (Pong et al., 2001). Briefly, embryonic day 15 rat fetuses are collected and dissected in ice-cold PBS. Dissected cortices are pooled together and transferred to an enzymatic dissociation medium containing papain. After 30 minutes, the tissue is  
20 mechanically triturated with a fire-polished glass Pasteur pipette. Single-cell suspensions in complete media are seeded on poly-L-ornithine and laminin coated 96-well plates. After 24 hours, cultures are treated with various concentrations of compound for 72 hours. The cultures are then fixed and stained with an anti-tubulin primary antibody (TUJ-1) and a fluorescent-tagged secondary antibody. Neurite  
25 outgrowth is determined by using the Enhanced Neurite Outgrowth (ENO) algorithm with the Cellomics ArrayScan and expressed as average neurite length or total neurite length per cell.

The compounds of Example 1 and 2 are anticipated to be active in cortical neuron assays with an EC<sub>50</sub> less than 1 μM and active in dopaminergic uptake assays  
30 with an EC<sub>50</sub> less than 1 μM.



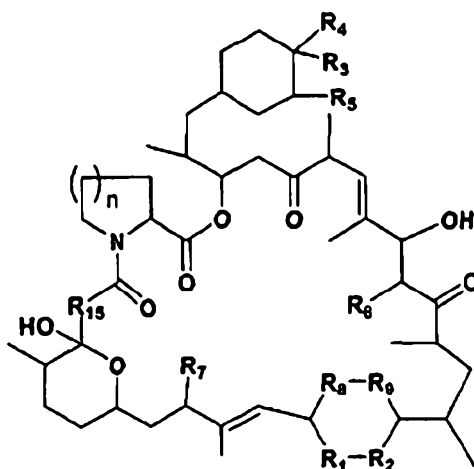
While the invention has been described with reference to a particularly preferred embodiment, it will be appreciated that modifications can be made without departing from the spirit of the invention. Such modifications are intended to fall within the scope of the appended claims.

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The claims defining the invention are as follows:

1. A compound of the formula I:



I

wherein:

$R_1$  and  $R_2$  are the same or different and are selected from the group consisting of  $CR_{16}R_{17}$  and  $CR_{18}R_{19}$ ;

$R_3$  and  $R_4$  are:

- (a) independently selected from the group consisting of H, OH,  $O(C_1$  to  $C_6$  alkyl),  $O(\text{substituted } C_1$  to  $C_6$  alkyl),  $O(\text{acyl})$ ,  $O(\text{aryl})$ ,  $O(\text{substituted aryl})$ , and halogen; or  
 (b) taken together to form a double bond to O;

$R_5$ ,  $R_6$ , and  $R_7$  are independently selected from the group consisting of H, OH, and  $OCH_3$ ;

$R_8$  and  $R_9$  are connected through a (i) single bond and are  $CH_2$  or (ii) double bond and are CH;

$R_{10}$  is selected from the group consisting of  $C=O$ ,  $CHOH$ , and  $CH_2$ ;

$R_{11}$  and  $R_{12}$  are independently selected from the group consisting of H,  $C_1$  to  $C_6$  alkyl,  $C_1$  to  $C_6$  substituted alkyl, aryl, substituted aryl, acyl,  $CF_3$ , CN, and  $NO_2$ ;

$R_{13}$  and  $R_{14}$  are independently selected from the group consisting of H,  $C_1$  to  $C_6$  alkyl,  $C_1$  to  $C_6$  substituted alkyl, aryl, substituted aryl, acyl,  $CF_3$ , CN, and  $NO_2$ ; or

$R_{15}$  and  $R_{16}$  are taken together to form a carbon-based or heterocyclic 5- to 7-membered ring;

n is 1 or 2;

or a pharmaceutically acceptable salt thereof.

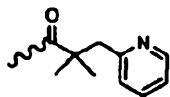
2. The compound according to claim 1, wherein  $R_{17}$  and  $R_{18}$  are taken together to form a carbon-based or heterocyclic 5- to 7-membered ring.

3. The compound according to claim 1 or claim 2, wherein  $R_8$  and  $R_9$  are bound through a single bond.

4. The compound according to any one of claims 1 to 3, wherein  $R_3$  or  $R_4$  is OH.

5. The compound according to any one of claims 1 to 3, wherein  $R_3$  or  $R_4$  is O(acyl).

6. The compound according to claim 5, wherein said acyl is:

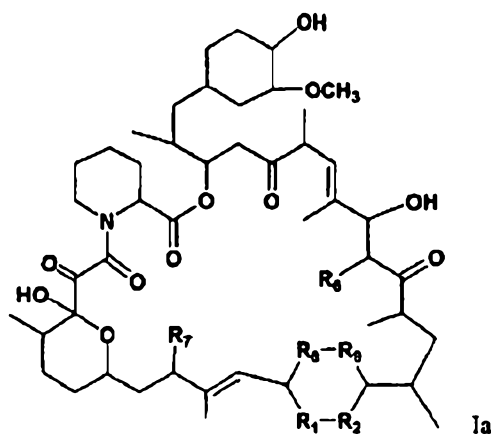


7. The compound according to any one of claims 1 to 6, wherein  $R_5$ ,  $R_6$ , and  $R_7$  are  $OCH_3$ .

8. The compound according to any one of claims 1 to 7, wherein  $n$  is 2.

9. The compound according to any one of claims 1 to 8, wherein  $R_{15}$  is  $C=O$ .

10. A compound of the formula Ia:



Ia

wherein:

$R_1$  and  $R_2$  are the same or different and are selected from the group consisting of  $CR_{16}R_{17}$  and  $CR_{18}R_{19}$ ;

$R_6$  and  $R_7$  are independently selected from the group consisting of H, OH, and  $OCH_3$ ;

$R_8$  and  $R_9$  are connected through a (i) single bond and are  $CH_2$  or (ii) double bond and are CH;

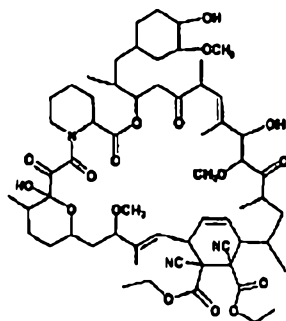
$R_{16}$  and  $R_{17}$  are independently selected from the group consisting of H,  $C_1$  to  $C_6$  alkyl,  $C_1$  to  $C_6$  substituted alkyl, aryl, substituted aryl, acyl,  $CF_3$ , CN, and  $NO_2$ ;

$R_{18}$  and  $R_{19}$  are independently selected from the group consisting of H,  $C_1$  to  $C_6$  alkyl,  $C_1$  to  $C_6$  substituted alkyl, aryl, substituted aryl, acyl,  $CF_3$ , CN, and  $NO_2$ ; or

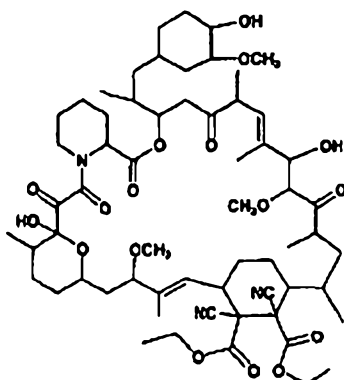
$R_{18}$  and  $R_{19}$  are taken together to form a 5- to 7-membered ring;

or a pharmaceutically acceptable salt thereof.

11. The compound according to claims 1 or 10 having the structure



12. The compound according to claims 1 or 10 having the structure



13. The compound according to any of claims 1 to 12 which is a neuroprotective or neuroregenerative agent.

14. A method of treating neurodegenerative disorders comprising administering to a subject in need thereof (i) a compound as defined in any one of claims 1 to 12, or a pharmaceutically acceptable salt thereof; and (ii) a pharmaceutically acceptable carrier.

15. The method according to claim 14, wherein said neurodegenerative disorder is selected from the group consisting of Alzheimer's disease, amyotrophic lateral sclerosis, epilepsy, Huntington's Disease, Parkinson's Disease, stroke, spinal cord injury, traumatic brain injury, Lewy body dementia, multiple sclerosis, Pick's disease, Niewmann-Pick disease, amyloid angiopathy, cerebral amyloid angiopathy, systemic amyloidosis, hereditary cerebral hemorrhage with amyloidosis of the Dutch type, inclusion body myositis, mild cognitive impairment and Down's syndrome.

16. A method of treating complications due to stroke or head trauma comprising administering to a subject in need thereof (i) a compound as defined in any one of claims 1 to 12, or a pharmaceutically acceptable salt thereof; and (ii) a pharmaceutically acceptable carrier.

17. A method of preparing a compound as defined in claim 1 or claim 10, or a pharmaceutically acceptable salt thereof, comprising reacting rapamycin or an analog thereof with an olefin of formula  $R_{16}R_{17}C=CR_{18}R_{19}$  to give a compound as defined in claim 1 or claim 10 wherein  $R_8$  and  $R_9$  are connected through a double bond and are CH, and if desired, hydrogenating to give a compound as defined in claim 1 or claim 10 wherein  $R_8$  and  $R_9$  are connected through a single bond and are  $CH_2$ , and further if desired, isolating as a pharmaceutically acceptable salt thereof.

18. The method according to claim 17, wherein said rapamycin analog is norrapamycin, deoxorapamycin, or desmethylrapamycin.

19. The method according to claim 17 or claim 18, wherein the reaction is performed at elevated temperatures.

20. The method according to any one of claims 17 to 19, wherein the product is isolated using chromatography.

21. The method according to any one of claims 17 to 20, wherein the hydrogenation is carried out using a Pd/C catalyst and hydrogen gas.

22. The method according to any one of claims 17 to 21, wherein the product has formula I wherein R<sub>8</sub> and R<sub>9</sub> are connected through a single bond and are CH<sub>2</sub>, or a pharmaceutically acceptable salt thereof.

23. Use of a compound as defined in any one of claims 1 to 12, or a pharmaceutically acceptable salt thereof, in the preparation of a medicament for treating neurodegenerative disorders in a subject in need thereof.

24. The use according to claim 23, wherein said neurodegenerative disorder is selected from the group consisting of Alzheimer's disease, amyotrophic lateral sclerosis, epilepsy, Huntington's Disease, Parkinson's Disease, stroke, spinal cord injury, traumatic brain injury, Lewy body dementia, multiple sclerosis, Pick's disease, Niewmann-Pick disease, amyloid angiopathy, cerebral amyloid angiopathy, systemic amyloidosis, hereditary cerebral hemorrhage with amyloidosis of the Dutch type, inclusion body myositis, mild cognitive impairment and Down's syndrome.

25. Use of a compound as defined in any one of claims 1 to 12, or a pharmaceutically acceptable salt thereof, in the preparation of a medicament for treating complications due to stroke or head trauma in a subject in need thereof.

26. A compound prepared by the method of any one of claims 17 to 22.

27. A compound according to claim 1 or claim 10, substantially as hereinbefore described with reference to any one of the Examples.