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**Substituted 8'-pyridinyl-dihydrospiro-[cycloalkyl]-pyrimido [1,2-a] pyrimidin-6-one and 8'-pyrimidinyl-dihydrospiro-[cycloalkyl]-pyrimido (1,2-a) pyrimidin-6-one derivatives and their use against neurodegenerative diseases**

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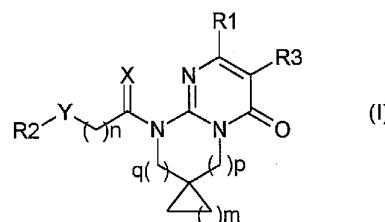
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(54) Title: SUBSTITUTED 8'-PYRIDINYL-DIHYDROSPIRO-[CYCLOALKYL]-PYRIMIDO [1,2-a] PYRIMIDIN-6-ONE AND 8'-PYRIMIDINYL-DIHYDROSPIRO-[CYCLOALKYL]-PYRIMIDO [1,2-a] PYRIMIDIN-6-ONE DERIVATIVES AND THEIR USE AGAINST NEURODEGENERATIVE DISEASES



(57) Abstract: The invention relates to a dihydrospiro-[cycloalkyl]-pyrimidone derivative represented by formula (I) or a salt thereof: wherein: X represents two hydrogen atoms, a sulfur atom, an oxygen atom or a C<sub>1-2</sub> alkyl group and a hydrogen atom; Y represents a bond, a carbonyl group, a methylene group optionally substituted; R1 represents a 2, 3 or 4-pyridine ring or a 2, 4 or 5-pyrimidine ring, the ring being optionally substituted; R2 represents a benzene ring or a naphthalene ring; the rings being optionally substituted; R3 represents a hydrogen atom, a C<sub>1-6</sub> alkyl group or a halogen atom; m represents 1 to 4 n represent 0 to 3 p represents 0 to 2 q represents 0 to 2, p+q being inferior to 4. The invention relates also to a medicament comprising the said derivative or a salt thereof as an active ingredient which is used for preventive and/or therapeutic treatment of a neurodegenerative disease caused by abnormal activity of GSK3 $\beta$ , such as Alzheimer disease.

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## SPECIFICATION

SUBSTITUTED 8'-PYRIDINYL-DIHYDROSPIRO-[CYCLOALKYL]-PYRIMIDO[1,2-A] PYRIMIDIN-6-ONE AND 8'-PYRIMIDINYL-DIHYDROSPIRO-[CYCLOALKYL]-PYRIMIDO[1,2-A] PYRIMIDIN-6-ONE DERIVATIVES AND THEIR USE AGAINST NEURODEGENERATIVE DISEASES

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## Technical Field

The present invention relates to compounds that are useful as an active ingredient of a medicament for preventive and/or therapeutic treatment of neurodegenerative diseases caused by abnormal activity of GSK3 $\beta$ .

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## Background Art

GSK3 $\beta$  (glycogen synthase kinase 3 $\beta$ ) is a proline directed serine, threonine kinase that plays an important role in the control of metabolism, 15 differentiation and survival. It was initially identified as an enzyme able to phosphorylate and hence inhibit glycogen synthase. It was later recognized that GSK3 $\beta$  was identical to tau protein kinase 1 (TPK1), an enzyme that phosphorylates tau protein in epitopes that are also found to be hyperphosphorylated in Alzheimer's disease and in several taupathies. 20 Interestingly, protein kinase B (AKT) phosphorylation of GSK3 $\beta$  results in a loss of its kinase activity, and it has been hypothesized that this inhibition may mediate some of the effects of neurotrophic factors. Moreover, phosphorylation by GSK3 $\beta$  of  $\beta$ -catenin, a protein involved in cell survival, results in its degradation by an ubiquitination dependent proteasome pathway. 25 Thus, it appears that inhibition of GSK3 $\beta$  activity may result in neurotrophic activity. Indeed there is evidence that lithium, an uncompetitive inhibitor of GSK3 $\beta$ , enhances neuritogenesis in some models and also increases neuronal survival, through the induction of survival factors such as Bcl-2 and the inhibition of the expression of proapoptotic factors such as P53 and Bax. 30 Recent studies have demonstrated that  $\beta$ -amyloid increases the GSK3 $\beta$  activity and tau protein phosphorylation. Moreover, this hyperphosphorylation as well as the neurotoxic effects of  $\beta$ -amyloid are blocked by lithium chloride and by a GSK3 $\beta$  antisense mRNA. These observations strongly suggest that GSK3 $\beta$  may be the link between the two major pathological processes in Alzheimer's disease: 35 abnormal APP (Amyloid Precursor Protein) processing and tau protein hyperphosphorylation.

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Although tau hyperphosphorylation results in a destabilization of the neuronal cytoskeleton, the pathological consequences of abnormal GSK3 $\beta$  activity are, most likely, not only due to a pathological phosphorylation of tau protein because, as mentioned above, an excessive activity of this kinase may affect survival

5 through the modulation of the expression of apoptotic and antiapoptotic factors. Moreover, it has been shown that  $\beta$ -amyloid-induced increase in GSK3 $\beta$  activity results in the phosphorylation and, hence the inhibition of pyruvate dehydrogenase, a pivotal enzyme in energy production and acetylcholine synthesis.

10

Altogether these experimental observations indicate that GSK3 $\beta$  may find application in the treatment of the neuropathological consequences and the cognitive and attention deficits associated with Alzheimer's disease, as well as other acute and chronic neurodegenerative diseases. These include, in a

15 non-limiting manner, Parkinson's disease, tauopathies (e.g. frontotemporoparietal dementia, corticobasal degeneration, Pick's disease, progressive supranuclear palsy) and other dementia including vascular dementia; acute stroke and others traumatic injuries; cerebrovascular accidents (e.g. age related macular degeneration); brain and spinal cord trauma; peripheral neuropathies;

20 retinopathies and glaucoma.

In addition GSK3 $\beta$  may find application in the treatment of other diseases such as: Non-insulin dependent diabetes (such as diabetes type II) and obesity; manic depressive illness; schizophrenia; alopecia; cancers such as breast cancer,

25 non-small cell lung carcinoma, thyroid cancer, T or B-cell leukemia and several virus-induced tumors.

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Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or 5 group of integers or steps.

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication 10 (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

#### Disclosure of the Invention

One aspect of the present invention is to provide compounds useful as an 15 active ingredient of a medicament for preventive and/or therapeutic treatment of a disease caused by abnormal GSK3 $\beta$  activity, more particularly of neurodegenerative diseases. A preferred aspect is to provide novel compounds useful as an active ingredient of a medicament that enables prevention and/or treatment of neurodegenerative diseases such as Alzheimer's disease.

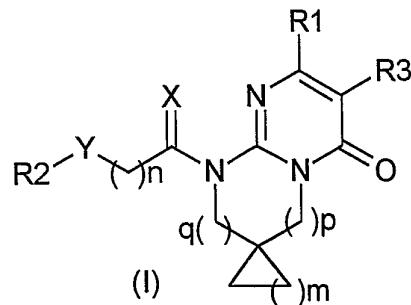
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Thus, the inventors of the present invention have identified compounds possessing inhibitory activity against GSK3 $\beta$ . As a result, they found that compounds represented by the following formula (I) had the desired activity and

were useful as an active ingredient of a medicament for preventive and/or therapeutic treatment of the aforementioned diseases.

The present invention thus provides dihydrospiro-[cycloalkyl]-pyrimidone

5 derivatives represented by formula (I) or salts thereof, solvates thereof or hydrates thereof:



wherein:

X represents two hydrogen atoms, a sulfur atom, an oxygen atom or a C<sub>1-2</sub> alkyl

10 group and a hydrogen atom;

Y represents a bond, a carbonyl group, a methylene group optionally substituted by one or two groups chosen from a C<sub>1-6</sub> alkyl group, a hydroxyl group, a C<sub>1-4</sub> alkoxy group, a C<sub>1-2</sub> perhalogenated alkyl group or an amino group;

15

R1 represents a 2, 3 or 4-pyridine ring or a 2, 4 or 5-pyrimidine ring, the ring being optionally substituted by a C<sub>1-4</sub> alkyl group, a C<sub>1-4</sub> alkoxy group, or a halogen atom;

20

R2 represents a benzene ring or a naphthalene ring; the rings being optionally substituted by 1 to 4 substituents selected from a C<sub>1-6</sub> alkyl group, a methylenedioxy group, a halogen atom, a C<sub>1-2</sub> perhalogenated alkyl group, a C<sub>1-3</sub> halogenated alkyl group, a hydroxyl group, a C<sub>1-4</sub> alkoxy group, a nitro, a cyano, an amino, a C<sub>1-5</sub> monoalkylamino group or a C<sub>2-10</sub> dialkylamino group;

25 R3 represents a hydrogen atom, a C<sub>1-6</sub> alkyl group or a halogen atom;

m represents 1 to 4;

n represent 0 to 3;

p represents 0 to 2; and

30 q represents 0 to 2, p+ q being inferior to 4.

According to another aspect of the present invention, there is provided a medicament comprising as an active ingredient a substance selected from the group consisting of the pyrimidone derivatives represented by formula (I) and the physiologically acceptable salts thereof, and the solvates thereof and the hydrates thereof. As preferred embodiments of the medicament, there are provided the aforementioned medicament which is used for preventive and/or therapeutic treatment of diseases caused by abnormal GSK3 $\beta$  activity, and the aforementioned medicament which is used for preventive and/or therapeutic treatment of neurodegenerative diseases and in addition other diseases such as:

5 10 Non-insulin dependent diabetes (such as diabetes type II) and obesity; manic depressive illness; schizophrenia; alopecia; cancers such as breast cancer, non-small cell lung carcinoma, thyroid cancer, T or B-cell leukemia and several virus-induced tumors.

15 As further preferred embodiments of the present invention, there are provided the aforementioned medicament wherein the diseases are neurodegenerative diseases and are selected from the group consisting of Alzheimer's disease, Parkinson's disease, tauopathies (e.g. frontotemporoparietal dementia, corticobasal degeneration, Pick's disease, progressive supranuclear 20 palsy) and other dementia including vascular dementia; acute stroke and others traumatic injuries; cerebrovascular accidents (e.g. age related macular degeneration); brain and spinal cord trauma; peripheral neuropathies; retinopathies and glaucoma, and the aforementioned medicament in the form of pharmaceutical composition containing the above substance as an active 25 ingredient together with one or more pharmaceutical additives.

The present invention further provides an inhibitor of GSK3 $\beta$  activity comprising as an active ingredient a substance selected from the group consisting of the dihydrospiro-[cycloalkyl]-pyrimidone derivatives of formula (I) and the salts thereof, and the solvates thereof and the hydrates thereof.

According to further aspects of the present invention, there is provided a method for preventive and/or therapeutic treatment of neurodegenerative diseases caused by abnormal GSK3 $\beta$  activity, which comprises the step of administering to 35 a patient a preventively and/or therapeutically effective amount of a substance selected from the group consisting of dihydrospiro-[cycloalkyl]-pyrimidone derivatives of formula (I) and the physiologically acceptable salts thereof, and the solvates thereof and the hydrates thereof; and a use of a substance selected from

the group consisting of the dihydrospiro-[cycloalkyl]-pyrimidone derivatives of formula (I) and the physiologically acceptable salts thereof, and the solvates thereof and the hydrates thereof for the manufacture of the aforementioned medicament.

5

As used herein, the C<sub>1-6</sub> alkyl group represents a straight or branched alkyl group having 1 to 6 carbon atoms, for example, methyl group, ethyl group, n-propyl group, isopropyl group, n-butyl group, isobutyl group, sec-butyl group, tert-butyl group, n-pentyl group, isopentyl group, neopentyl group, 1,1-dimethylpropyl group, n-hexyl group, isohexyl group, and the like;

10 The C<sub>1-4</sub> alkoxy group represents an alkyloxy group having 1 to 4 carbon atoms for example, methoxy group, ethoxy group, propoxy group, isopropoxy group, butoxy group, isobutoxy group, sec-butoxy group, tert-butoxy group, and the like;

15 The halogen atom represents a fluorine, chlorine, bromine or iodine atom;

The C<sub>1-2</sub> perhalogenated alkyl group represents an alkyl group wherein all the hydrogen have been substituted by a halogeno, for example a CF<sub>3</sub> or C<sub>2</sub>F<sub>5</sub>;

The C<sub>1-3</sub> halogenated alkyl group represents an alkyl group wherein at least one hydrogen has not been substituted by an halogen atom;

20 The C<sub>1-5</sub> monoalkylamino group represents an amino group substituted by one C<sub>1-6</sub> alkyl group, for example, methylamino group, ethylamino group, propylamino group, isopropylamino group, butylamino group, isobutylamino group, tert-butylamino group, pentylamino group and isopentylamino group;

25 The C<sub>2-10</sub> dialkylamino group represents an amino group substituted by two C<sub>1-5</sub> alkyl groups, for example, dimethylamino group, ethylmethylamino group, diethylamino group, methylpropylamino group and diisopropylamino group;

A leaving group L represents a group which could be easily cleaved and substituted, such a group may be for example a tosyl, a mesyl, a bromide and the like.

30

The compounds represented by the aforementioned formula (I) may form a salt. Examples of the salt include, when an acidic group exists, salts of alkali metals and alkaline earth metals such as lithium, sodium, potassium, magnesium, and calcium; salts of ammonia and amines such as methylamine, dimethylamine, trimethylamine, dicyclohexylamine, tris(hydroxymethyl)aminomethane, N,N-trimethylamine, dicyclohexylamine, tris(hydroxymethyl)aminomethane, N,N-bis(hydroxyethyl)piperazine, 2-amino-2-methyl-1-propanol, ethanolamine, N-methylglucamine, and L-glucamine; or salts with basic amino acids such as lysine,  $\delta$ -hydroxylysine, and arginine. The base-addition salts of acidic compounds are

prepared by standard procedures well known in the art.

When a basic group exists, examples include salts with mineral acids such as hydrochloric acid, hydrobromic acid, sulfuric acid, nitric acid, phosphoric acid; 5 salts with organic acids such as methanesulfonic acid, benzenesulfonic acid, p-toluenesulfonic acid, acetic acid, propionic acid, tartaric acid, fumaric acid, maleic acid, malic acid, oxalic acid, succinic acid, citric acid, benzoic acid, mandelic acid, cinnamic acid, lactic acid, glycolic acid, glucuronic acid, ascorbic acid, nicotinic acid, and salicylic acid; or salts with acidic amino acids such as aspartic acid, and 10 glutamic acid.

The acid-addition salts of the basic compounds are prepared by standard procedures well known in the art which include, but are not limited thereto, dissolving the free base in an aqueous alcohol solution containing the appropriate acid and isolating the salt by evaporating the solution, or by reacting the free base 15 and an acid in an organic solvent, in which case the salt separates directly, or is precipitated with a second organic solvent, or can be obtained by concentration of the solution. The acids which can be used to prepare the acid-addition salts include preferably those which produce, when combined with the free base, pharmaceutically-acceptable salts, that is, salts whose anions are relatively 20 innocuous to the animal organism in pharmaceutical doses of the salts, so that the beneficial properties inherent in the free base are not compromised by side effects ascribable to the anions. Although medicinally acceptable salts of the basic compounds are preferred, all acid-addition salts are within the scope of the present invention.

25

In addition to the dihydrospiro-[cycloalkyl]-pyrimidone derivatives represented by the aforementioned formula (I) and salts thereof, their solvates and hydrates also fall within the scope of the present invention.

30

The dihydrospiro-[cycloalkyl]-pyrimidone derivatives represented by the aforementioned formula (I) may have one or more asymmetric carbon atoms. As for the stereochemistry of such asymmetric carbon atoms, they may independently be in either (R) and (S) configuration, and the derivative may exist as stereoisomers such as optical isomers, or diastereoisomers. Any stereoisomers in 35 pure form, any mixtures of stereoisomers, racemates and the like fall within the scope of the present invention.

Examples of compounds of the present invention are shown in table 1 hereinafter. However, the scope of the present invention is not limited by these compounds.

5 One of the embodiments of the present invention includes compounds of formula (I) wherein:

(1) R1 represents a 3- or 4-pyridine ring and more preferably a 4-pyridine ring; or a 4- or 5-pyrimidine ring and more preferably a 4-pyrimidine ring, the rings being optionally substituted by a C<sub>1-2</sub> alkyl group, a C<sub>1-2</sub> alkoxy group or a halogen atom;

10 and/or

(2) R2 represents a benzene ring or a naphthalene ring, the ring being optionally substituted 1 to 4 substituents selected from a C<sub>1-3</sub> alkyl group, a halogen atom, a hydroxyl group or a C<sub>1-2</sub> alkoxy group; and/or

(3) R3 represents a hydrogen atom, a C<sub>1-3</sub> alkyl group or a halogen atom; more

15 preferably a hydrogen atom; and/or

(4) Y represents a bond, a carbonyl group or a methylene group optionally substituted by one or two groups chosen from a C<sub>1-3</sub> alkyl group, a hydroxyl group, a C<sub>1-4</sub> alkoxy group, a C<sub>1-2</sub> perhalogenated alkyl group or an amino group;

(5) p + q equals 2 or 3, preferably 2; and more particularly wherein R1, R2, R3 and

20 Y are as defined here-above.

Another embodiment of the present invention include compounds of formula (I) wherein:

(1) R1 represents an unsubstituted 4-pyridine ring or 4-pyrimidine ring; and/or

25 (2) R2 represents a benzene ring, the ring being optionally substituted 1 to 4 substituents selected from a C<sub>1-3</sub> alkyl group, a halogen atom, a hydroxyl group or a C<sub>1-2</sub> alkoxy group; and/or

(3) R3 represents a hydrogen atom; and/or

(4) X represents two hydrogen atoms; and/or

30 (5) Y represents a bond, a carbonyl group or a methylene group optionally substituted by a hydroxyl group; and/or

(6) p represents 2 and q represents 0 ; and more particularly wherein R1, R2, R3, X, Y, p and q are as defined here-above.

Particularly compounds of the present invention represented by formula (I) include compounds of table 1 :

1. 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 5 2. 1'-(2-Oxo-2-phenylethyl)-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 10 3. 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 15 4. 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 5 5. 1'-(2R)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 20 6. 1'-(2-Oxo-2-phenylethyl)-8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 25 7. 1'-(2-Oxo-2-phenylethyl)-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
8. 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 30 9. 1'-(2-Oxo-2-phenylethyl)-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
10. 1'-(2-Oxo-2-phenylethyl)-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 35 11. 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
12. 1'-(2R)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

**13. 1'-(2R)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one**

5 **14. 1'-(phenylmethyl)- 8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one**

**15. 1'-(2R)-2-Hydroxy-2-phenylethyl]- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one**

10 **16. 1'-(phenylmethyl)- 8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one**

15 **17. 1'-(phenylmethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one**

**18. 1'-(phenylmethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one**

20 **19. 1'-(phenylmethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one**

**20. 1'-(phenylethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one**

25 **21. 1'-(phenylethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one**

30 **22. 1'-(phenylethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one**

**23. 1'-(phenylethyl)- 8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one**

35 **24. 1'-(phenylethyl)- 8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one**

**25. 1'-(2-Hydroxy-2-(3-bromo-phenylethyl))- 8'-pyrimidin-4-yl-3',4'-**

dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

**26.** 1'-(2-Oxo-2-(3-bromo-phenylethyl))- 8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one.

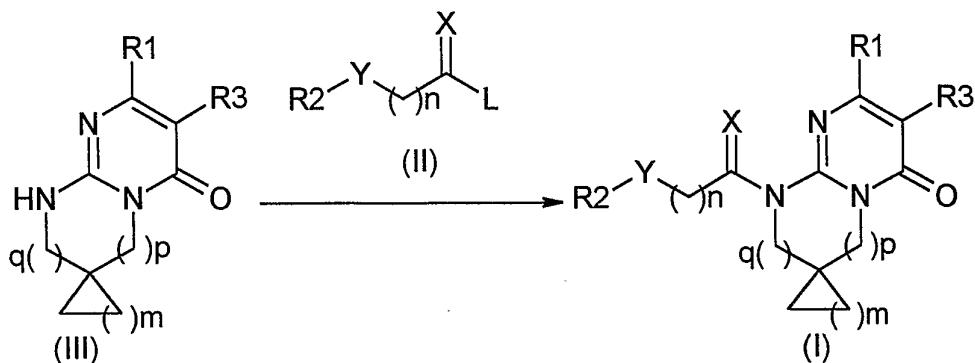
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As a further object, the present invention concerns also methods for preparing the dihydrospiro-[cycloalkyl]-pyrimidone compounds represented by the aforementioned formula (I).

10 These compounds can be prepared, for example, according to methods explained below.

### Preparation method

Dihydrospiro-[cycloalkyl]-pyrimidone compounds represented by the aforementioned formula (I), may be prepared according to the method described in 5 the scheme 1.



10

**Scheme 1**

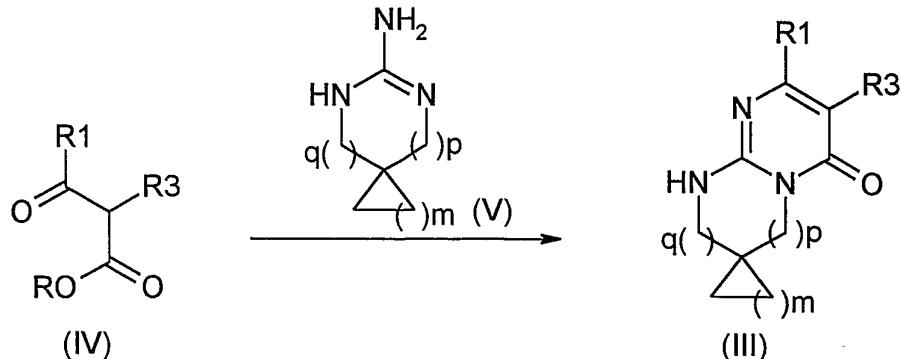
(In the above scheme the definition of R1, R2, R3, X, Y, m, n, p and q are the same as those already described for compound of formula (I)).

Following this method, the pyrimidinone derivative represented by the 15 above formula (III), wherein R1, R3, m, n, p and q are as defined for compound of formula (I), is allowed to react with a base such as sodium hydride, sodium carbonate or potassium carbonate in a solvent such as *N,N*-dimethylformamide, *N*-methylpyrrolidone, *N,N*-dimethylacetamide or chloroform at a suitable 20 temperature ranging from 0 to 130°C under ordinary air, then with a compound of formula (II), wherein R2, X, Y and n are as defined for compound of formula (I) and L represents a leaving group preferably bromide or mesyl group, to obtain the compound of the aforementioned formula (I).

Alternatively compounds of formula (I) wherein Y represents a carbonyl 25 group may be prepared by oxydation of a compound of formula (I) wherein Y represents a methylene group substituted by a hydroxyl group according to well known methods to one skilled in the art.

Compound of formula (II) is commercially available or may be synthesized 30 according to well-known methods to one skilled in the art.

Compound of formula (III) may be prepared according to the method defined in scheme 2.



**Scheme 2.**

5

(In the above scheme the definition of R1, R3, m, p and q are the same as already described.)

According to this method, the 3-ketoester of formula (IV), wherein R1 and R3 are as defined for compound of formula (I) and R is an alkyl group such as for example methyl or ethyl, is allowed to react with a compound of formula (V). The reaction may be carried out in the presence of a base such as potassium carbonate, in an alcoholic solvent such as methanol, ethanol and the like or without, at a suitable temperature ranging from 25° to 140°C under ordinary air.

15 Alternatively, compound of formula (III) wherein R3 represents a hydrogen atom may be halogenated in order to give compounds of formula (III) wherein R3 is a halogen atom such as a bromine atom or a chlorine atom. The reaction may be carried out in an acidic medium such as acetic acid or propionic acid, in presence of bromosuccinimide or chlorosuccinimide, or bromine.

20

In addition, compounds of formula (III) wherein R3 represents a fluorine atom may be obtained by analogy to the method described in *Tetrahedron Letters*, Vol. 30, N° 45, pp 6113-6116, 1989.

25 As a further object, the present invention concerns also the compound of formula (III) as intermediate for preparing compound of formula (I).

Compound of formula (IV) is commercially available or may be synthesized according to well-known methods to one skilled in the art.

30

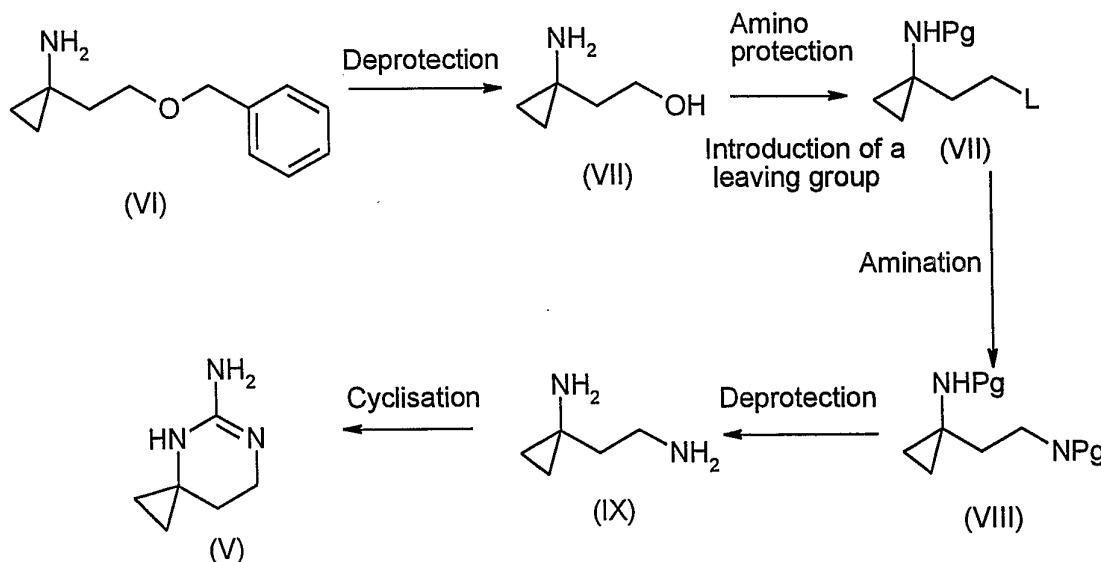
For example compounds of formula (IV), wherein R1 represent a pyridine

ring or a pyrimidine ring, optionally substituted by a C<sub>1-4</sub> alkyl group, C<sub>1-4</sub> alkoxy group or a halogen atom, can be prepared by reacting respectively an isonicotinic acid or a pyrimidine-carboxylic acid, optionally substituted by a C<sub>1-4</sub> alkyl group, C<sub>1-4</sub> alkoxy group or a halogen, with the corresponding malonic acid monoester.

5 The reaction can be carried out using methods well known to one skilled in the art, such as for example in presence of a coupling agent such as 1,1'-carbonylbis-1*H*-imidazole in a solvent such as tetrahydrofuran at a temperature ranging from 20 to 70°C.

10 Compound of formula (V) is commercially available or may be synthesized according to well-known methods of one skilled in the art.

15 For example compound of formula (V), when *m* represents 1, *p* represents 2 and *q* represents 0, may be prepared according to the method defined in scheme 3 and according to the method described by Smith and Christensen (J. Org. Chem. 1955, 20, 829) for the last step. The conditions which may be used are given in the chemical examples.



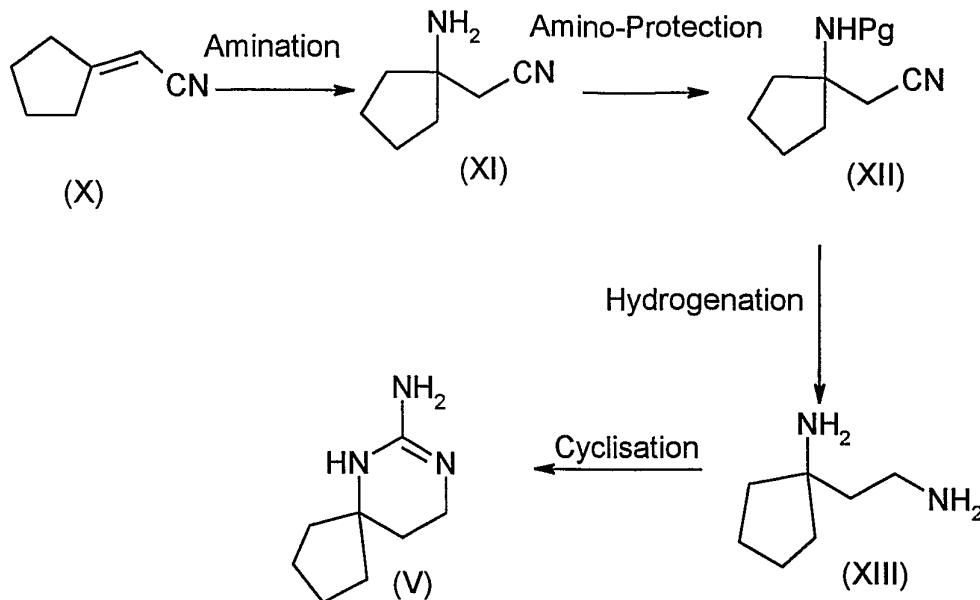
20

**Scheme 3**

(In the above scheme Pg represents an amino-protecting group and L a leaving group)

25 As another example compound of formula (V), when *m* equals 3, *p* represents 2 and *q* represents 0, may be prepared according to the method defined in scheme 4 and according to the method described by Smith and Christensen (J. Org. Chem. 1955, 20, 829) for the last step. The conditions which

may be used are given in the chemical examples.



**Scheme 4**

5

(In the above scheme Pg represents a protecting group)

Compound of formula (VI) may be synthesized according to the method described by Bertus and Szymoniak (Chem. Commun. 2001, 1792).

10

Compound of formula (X) may be synthesized according to the method described by Suzuki et al. (Synthetic Communication 1998, 28(4), 701).

15

In the above reactions protection or deprotection of a functional group may sometimes be necessary. A suitable protecting group Pg can be chosen depending on the type of the functional group, and a method described in the literature may be applied. Examples of protecting groups, of protection and deprotection methods are given for example in Protective groups in Organic Synthesis Greene et al., 2nd Ed. (John Wiley & Sons, Inc., New York).

20

The compounds of the present invention have inhibitory activity against GSK3 $\beta$ . Accordingly, the compounds of the present invention are useful as an active ingredient for the preparation of a medicament, which enables preventive and/or therapeutic treatment of a disease caused by abnormal GSK3 $\beta$  activity and more particularly of neurodegenerative diseases such as Alzheimer's disease. In addition, the compounds of the present invention are also useful as an active

25

ingredient for the preparation of a medicament for preventive and/or therapeutic treatment of neurodegenerative diseases such as Parkinson's disease, tauopathies (e.g. frontotemporoparietal dementia, corticobasal degeneration, Pick's disease, progressive supranuclear palsy) and other dementia including 5 vascular dementia; acute stroke and others traumatic injuries; cerebrovascular accidents (e.g. age related macular degeneration); brain and spinal cord trauma; peripheral neuropathies; retinopathies and glaucoma; and other diseases such as non-insulin dependent diabetes (such as diabetes type II) and obesity; manic depressive illness; schizophrenia; alopecia; cancers such as breast cancer, non-10 small cell lung carcinoma, thyroid cancer, T or B-cell leukemia and several virus-induced tumors.

The present invention further relates to a method for treating neurodegenerative diseases caused by abnormal activity of GSK3 $\beta$  and of the 15 aforementioned diseases which comprises administering to a mammalian organism in need thereof an effective amount of a compound of the formula (I).

As the active ingredient of the medicament of the present invention, a substance may be used which is selected from the group consisting of the 20 compound represented by the aforementioned formula (I) and pharmacologically acceptable salts thereof, and solvates thereof and hydrates thereof. The substance, *per se*, may be administered as the medicament of the present invention, however, it is desirable to administer the medicament in a form of a pharmaceutical composition which comprises the aforementioned substance as an 25 active ingredient and one or more pharmaceutical additives. As the active ingredient of the medicament of the present invention, two or more of the aforementioned substances may be used in combination. The above pharmaceutical composition may be supplemented with an active ingredient of another medicament for the treatment of the above mentioned diseases. The type 30 of pharmaceutical composition is not particularly limited, and the composition may be provided as any formulation for oral or parenteral administration. For example, the pharmaceutical composition may be formulated, for example, in the form of pharmaceutical compositions for oral administration such as granules, fine granules, powders, hard capsules, soft capsules, syrups, emulsions, suspensions, 35 solutions and the like, or in the form of pharmaceutical compositions for parenteral administration such as injections for intravenous, intramuscular, or subcutaneous administration, drip infusions, transdermal preparations, transmucosal preparations, nasal drops, inhalants, suppositories and the like. Injections or drip

infusions may be prepared as powdery preparations such as in the form of lyophilized preparations, and may be used by dissolving just before use in an appropriate aqueous medium such as physiological saline. Sustained-release preparations such as those coated with a polymer may be directly administered 5 intracerebrally.

Types of pharmaceutical additives used for the manufacture of the pharmaceutical composition, content ratios of the pharmaceutical additives relative to the active ingredient, and methods for preparing the pharmaceutical 10 composition may be appropriately chosen by those skilled in the art. Inorganic or organic substances, or solid or liquid substances may be used as pharmaceutical additives. Generally, the pharmaceutical additives may be incorporated in a ratio ranging from 1% by weight to 90% by weight based on the weight of an active ingredient.

15 Examples of excipients used for the preparation of solid pharmaceutical compositions include, for example, lactose, sucrose, starch, talc, cellulose, dextrin, kaolin, calcium carbonate and the like. For the preparation of liquid compositions for oral administration, a conventional inert diluent such as water or a vegetable oil may be used. The liquid composition may contain, in addition to the inert diluent, 20 auxiliaries such as moistening agents, suspension aids, sweeteners, aromatics, colorants, and preservatives. The liquid composition may be filled in capsules made of an absorbable material such as gelatin. Examples of solvents or suspension mediums used for the preparation of compositions for parenteral administration, e.g. injections, suppositories, include water, propylene glycol, 25 polyethylene glycol, benzyl alcohol, ethyl oleate, lecithin and the like. Examples of base materials used for suppositories include, for example, cacao butter, emulsified cacao butter, lauric lipid, witepsol.

The dose and frequency of administration of the medicament of the 30 present invention are not particularly limited, and they may be appropriately chosen depending on conditions such as a purpose of preventive and/or therapeutic treatment, a type of a disease, the body weight or age of a patient, severity of a disease and the like. Generally, a daily dose for oral administration to an adult may be 0.01 to 1,000 mg (the weight of an active ingredient), and the 35 dose may be administered once a day or several times a day as divided portions, or once in several days. When the medicament is used as an injection, administrations may preferably be performed continuously or intermittently in a daily dose of 0.001 to 100 mg (the weight of an active ingredient) to an adult.

## Chemical Examples

The present invention will be explained more specifically with reference to the following general examples, however, the scope of the present invention is not limited to these examples.

### Example 1 (Compound N° 1 of table 1)

10 1'-[*(2S)*-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-*a*]pyrimidin]-6'(*1'H*)-one. (1:1) (hydrochloride)

#### 1.1 2-(1-Amino-cyclopropyl)-ethanol hydrochloride (1:1)

15 To a solution of 8.63g (45.11 mmol) of 1-(2-benzyloxy-ethyl)-cyclopropylamine and 3g of palladium 10 wt. % on activated carbon in 100 ml of isopropanol was added 100 ml of a solution of hydrochloric acid in isopropanol (5-6 N). The mixture was shaken at 40°C under hydrogen pressure of 4 atmospheres until hydrogen uptake ceased.

20 The catalyst was removed by filtration and washed with isopropanol. The filtrate was evaporated to dryness to afford 6.22g of pure product as a viscous oil.

#### 1.2 *Tert*-Butyl 1-(2-hydroxyethyl)cyclopropylcarbamate

25 To a solution of 6.21g (45.11 mmol) of 2-(1-amino-cyclopropyl)-ethanol hydrochloride (1:1) in 63 ml of tetrahydrofuran was added 1 ml of water, 12.68 ml (90.22 mmol) of triethylamine and 9.84g (45.11 mmol) of di-*tert*-butyl dicarbonate in 21 ml of tetrahydrofuran. The resulting mixture was stirred at room temperature for 16h.

30 The mixture was evaporated, dissolved in 100 ml of diethyl ether and was treated with an aqueous hydrochloric acid solution (0.1 N). The combined extracts were washed with saturated aqueous sodium chloride and evaporated. The crude product was triturated with water and filtered to afford 6.68g of pure product as a white solid.

35 Mp : 93-95°C.

1.3 2-{1-[(*tert*-butoxycarbonyl)amino]cyclopropyl}ethyl methanesulfonate

To a solution of 6.472g (32.16 mmol) of *tert*-butyl 1-(2-hydroxyethyl)cyclopropylcarbamate in 61 ml of anhydrous dichloromethane was

5 added 12.79 ml (91 mmol) of anhydrous triethylamine. The resulting mixture is cooled at -20°C. Then 3.54 ml (45.66 mmol) of mesyl chloride in 11 ml of anhydrous dichloromethane was added. The resulting mixture was stirred at room temperature for 2h. The mixture was poured into ice-water and the organic layer was washed with saturated aqueous sodium chloride, dried over sodium sulfate  
10 and evaporated. The crude product was triturated with petroleum ether and filtered to give 7.82g of pure product as an orange solid.

Mp : 88-89°C

1.4 *tert*-butyl 1-[2-(1,3-dioxo-1,3-dihydro-2*H*-isoindol-2-yl)ethyl]-

15 cyclopropylcarbamate

To a solution of 7.82g (28 mmol) of 2-{1-[(*tert*-butoxycarbonyl)amino]-cyclopropyl}ethyl methanesulfonate in 35 ml of anhydrous dimethylformamide was added 5.45g (29.4 mmol) of potassium phthalimide. The resulting mixture was  
20 stirred at 150°C for 18h. The mixture was then filtered and washed with diethyl ether. The filtrate was evaporated to dryness, the crude product was heated in water and the precipitate was filtered. The product was dried to give 4.63g of pure compound as an orange solid.

Mp : 125-127°C.

25

1.5 *tert*-butyl 1-(2-aminoethyl)cyclopropylcarbamate

To a solution of 4.57g (13.83 mmol) of *tert*-butyl 1-[2-(1,3-dioxo-1,3-dihydro-2*H*-isoindol-2-yl)ethyl]cyclopropylcarbamate in 80 ml of ethanol was added 3.36ml (69.16 mmol) of hydrazine hydrate and the resulting mixture was heated under reflux for 16h. The mixture was filtered and washed with diethyl ether. The filtrate was evaporated to dryness to give 2.3g of pure compound as an orange oil.

## 1.6 1-(2-Aminoethyl)cyclopropanamine hydrobromide (1:2)

35

To a solution of 20 ml of hydrobromide (33%) in acetic acid was added 2.29g (11.46 mmol) of *tert*-butyl 1-(2-aminoethyl)cyclopropylcarbamate and the resulting solution was stirred at 60°C for 1h.

The mixture was cooled and diethyl ether was added. The resulting precipitate was filtered. The product was dried to give 2.69g of pure compound as a brown solid.

Mp : 233-235°C

5

1.7 4,6-Diazaspiro[2.5]oct-5-en-5-amine hydrobromide (1:1)

To a solution of 2.65g (10.11 mmol) of 1-(2-aminoethyl)cyclopropanamine hydrobromide in 21ml of methanol was added 3.83 ml (21.24 mmol) of a solution 10 of sodium methoxide in methanol (5.55 N). The mixture was stirred at room temperature for 2h. The precipitate was filtered and the filtrate was evaporated. The crude was dissolved in 9 ml of water and 1.07g (10.11 mmol) of cyanogen bromide was added portion wise. The resulting mixture was stirred at room 15 temperature for 2h and evaporated to dryness to give 2.08g of pure compound as an orange oil.

1.8 8'-Pyridinyl-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

20 A mixture of 1.77g (9.19 mmol) of ethyl 3-(pyridin-4-yl)-3-oxopropionate, 2.084g (10.11 mmol) of 4,6-diazaspiro[2.5]oct-5-en-5-amine hydrobromide and 2.79g (20.22 mmol) of potassium carbonate in 17ml of ethanol was heated at reflux temperature during 12 h.

25 The cooled solution was evaporated to removed solvent, the residue was treated with water and the precipitate was filtered to give 0.88g of product as a yellow powder.

Mp : 277-278°C.

1.9 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[30 cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one (1:1) (hydrochloride)

To a solution of 0.5g (1.97 mmol) of 8'-pyridinyl-4-yl-3',4'-dihydrospiro-[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one in 10ml of anhydrous 35 dimethylformamide was added 0.173g (4.33 mmol) of sodium hydride (60% suspension in mineral oil). The mixture was allowed to stir at 50°C for 1h. Then 0.4g (2.56 mmol) of (1-S)-2-chloro-1-phenyl ethanol was added and the mixture allowed to stir at 120°C for 16h.

Water was added and the mixture extracted with ethyl acetate. The extracts were

washed with a saturated aqueous solution of sodium chloride, dried and evaporated to give crude product. Purification by chromatography on silica gel eluting with a mixture of ethyl dichloromethane/methanol in the proportions 100/0 to 95/5 led to compound in the form of free base. The base was transformed into 5 its hydrochloride salt to give 0.443g of pure product.

Mp : 219-221 °C,  $[\alpha]_D = -9.5$  (c=0.4, CH<sub>3</sub>OH).

RMN (200 MHz ; DMSO-d<sup>6</sup>) :  $\delta$  8.90 (d, 2H) ; 8.35 (d, 2H) ; 7.12-7.46 (m, 5H) ; 6.61 (s, 1H) ; 4.88 (t, 1H) ; 3.4-4.05 (m, 4H) ; 1.83 (t, 2H) ; 1.03-1.33 (m, 2H) ; 0.58-0.85 (m, 2H).

10

Example 2 (Compound N° 2 of table 1)

1'-{(2-Oxo-2-phenylethyl)-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one (1:1) (hydrochloride)

15

0.31g (0.83 mmol) of 1'-(2S)-2-hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one was dissolved in 8ml of anhydrous dichloromethane and mixed with 0.145g (1.24 mmol) of N-methylmorpholine N-oxide, 0.003g (0.0083 mmol) of tetra-n-propylammonium perruthenate and 1g of powdered molecular sieves (4A). The mixture was stirred 20 at 20°C under nitrogen atmosphere for 12h.

The mixture was filtered. The filtrate was washed with a saturated aqueous solution of ammonium chloride, dried and evaporated to give crude product. Purification by chromatography on silica gel eluting with a mixture of

25 dichloromethane/methanol in the proportions 100/0 to 95/5 gave the compound in the form of free base which was transformed into its hydrochloride salt to give 0.078g of pure product.

Mp : 232-234 °C.

30 RMN (200 MHz ; DMSO-d<sup>6</sup>) :  $\delta$  8.62 (d, 2H) ; 8.03 (d, 2H) ; 8.00 (d, 2H) ; 7.51-7.78 (m, 3H) ; 6.61 (s, 1H) ; 5.15 (s, 2H) ; 4.01 (t, 2H) ; 2.04 (t, 2H) ; 1.17 (t, 2H) ; 0.78 (t, 2H).

Example 3 (Compound N° 3 of table 1)

35 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one.(1:1) (hydrochloride)

3.1 (1-Aminocyclopentyl)acetonitrile

A solution of 15.91g (0.15 mol) of cyclopentylideneacetonitrile in 170 ml of an aqueous ammonia solution (29%) and 57 ml of methanol was heated at 100°C in a sealed tube for 24h. The reaction mixture was concentrated, and the residue was 5 chromatographed on silica gel eluting with a mixture of dichloromethane/methanol in the proportions 90/10 to afford 12.15g of the product as a colorless oil.

### 3.2 *Tert*-butyl 1-(cyanomethyl)cyclopentylcarbamate

10 The product was obtained by analogy with the method described in step 1.2 and using (1-aminocyclopentyl)acetonitrile. The compound was used as such in the next step.

### 3.3 *Tert*-butyl 1-(2-aminoethyl)cyclopentylcarbamate

15 To a suspension of 8.48g (223.63 mmol) of lithium aluminium hydride in 687 ml of diethyl ether at 0°C was added dropwise 16.7g (74.54 mmol) of *tert*-butyl 1-(cyanomethyl)cyclopentylcarbamate dissolved in 344 ml of diethyl ether. The resulting mixture was stirred at 0°C under nitrogen atmosphere for 1h.

20 The reaction mixture was diluted with 100 ml of diethyl ether at 0°C and treated with excess of a saturated aqueous solution of sodium sulfate. Further solid sodium sulfate was added and the organic phase was filtered to remove salts. The solvent was evaporated to dryness to give 13.83g of product as an oil.

### 25 3.4 1-(2-Aminoethyl)cyclopentanamine hydrobromide (1:2)

The product was obtained by analogy with the method described in step 1.6 and using *tert*-butyl 1-(2-aminoethyl)cyclopentylcarbamate. The compound was used as such in the next step.

30 Mp : 194-196 °C.

### 3.5 6,8-Diazaspiro[4.5]dec-7-en-7amine hydrobromide (1 : 1)

35 The product was obtained by analogy with the method described in step 1.7 and using 1-(2-aminoethyl)cyclopentanamine hydrobromide (1:2). The compound was used as such in the next step.

### 3.6 8'-Pyridinyl-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]

pyrimidin]-6'(1'H)-one

The product was obtained by analogy with the method described in step 1.8 and using 6,8-diazaspiro[4.5]dec-7-en-7amine hydrobromide (1 : 1). The compound

5 was used as such in the next step.

Mp : 241-243 °C.

3.7 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro [cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one.(1:1) (hydrochloride)

10 The product was obtained by analogy with the method described in step 1.9 and using 8'-pyridinyl-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]-pyrimidin]-6'(1'H)-one.

Mp : 221-223 °C,  $[\alpha]_D = -32.8$  (c=1.036, CH<sub>3</sub>OH).

15 RMN (200 MHz ; DMSO-d<sup>6</sup>) :  $\delta$  8.91 (d, 2H) ; 8.41 (d, 2H) ; 7.13-7.47 (m, 5H) ; 6.67 (s, 1H) ; 5.22 (dd, 1H) ; 3.71-4.04 (m, 3H) ; 3.38-3.59 (m, 1H) ; 2.26-2.62 (m, 2H) ; 1.76-2.15 (dm, 2H) ; 1.30-1.76 (m, 6H).

Example 4 (Compound N° 4 of table 1)

20 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro [cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

4.1 8'-Pyrimidinyl-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

25 The product was obtained by analogy with the method described in step 1.8, using ethyl 3-(4-pyrimidinyl)-3-oxopropionate, (prepared by analogy to the method described in patent DE 2705582) and 6,8-Diazaspiro[4.5]dec-7-en-7amine hydrobromide (1 : 1) (prepared according to example 3.5). The compound obtained was treated with water and the precipitate recovered by filtration to give 2.92g of product.

30 Mp. : 243-244°C.

4.2 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro [cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

35 The product was obtained by analogy with the method described in step 1.9 and using 8'-pyrimidinyl-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]

pyrimidin]-6'(1'H)-one.

Mp : 157-158 °C,  $[\alpha]_D = -28.9$  (c=1.018, CH<sub>3</sub>OH).

RMN (200 MHz ; DMSO-d<sup>6</sup>) :  $\delta$  9.28 (s, 1H) ; 9.01 (d, 1H) ; 8.14 (d, 1H) ; 7.15-7.50 (m, 5H) ; 6.72 (s, 1H) ; 5.19 (t, 1H) ; 3.70-4.04 (m, 3H) ; 3.38-3.58 (m, 1H) ; 2.26-

5 2.55 (m, 2H) ; 1.74-2.12 (dm, 2H) ; 1.25-1.74 (m, 6H).

A list of chemical structures and physical data for compounds of the aforementioned formula (I), illustrating the present invention, is given in table 1. The compounds have been prepared according to the methods of the examples.

10

In the table, R1 is an unsubstituted pyrimidin-4-yl group or an unsubstituted pyridin-4-yl group, p represents 2, q represents 0, Ph represents a phenyl group, (S), (R) or (Rac.) indicates in the column "Y" the stereochemistry of the carbon atom:

15 (rac.) means racemic mixture

(R) means absolute R configuration

(S) means absolute S configuration

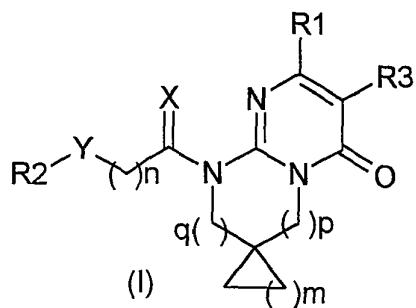
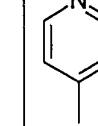
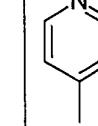
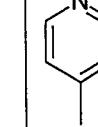
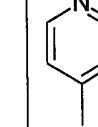
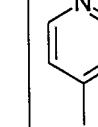
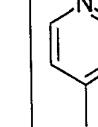
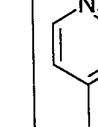
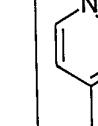
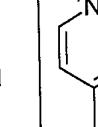
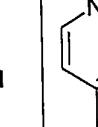
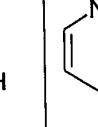
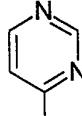
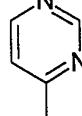
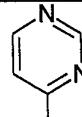
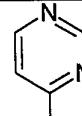


Table 1

Nº	R2	Y	X	R1	R3	m	n	Mp °C	salt
1	Ph	CH(OH) (S)	H,H		H	1	0	219-221	(1:1) (hydrochloride)
2	Ph	CO	H,H		H	1	0	232-234	(1:1) (hydrochloride)
3	Ph	CH(OH) (S)	H,H		H	3	0	221-223	(1:1) (hydrochloride)
4	Ph	CH(OH) (S)	H,H		H	3	0	157-158	Free base
5	Ph	CH(OH) (R)	H,H		H	3	0	155-156	Free base
6	Ph	CO	H,H		H	3	0	194-196	Free base
7	Ph	CO	H,H		H	3	0	161-162	(1:1) (hydrochloride)
8	Ph	CH(OH) (S)	H,H		H	2	0	214-216	(1:1) (hydrochloride)

N°	R2	Y	X	R1	R3	m	n	Mp °C	salt
9	Ph	CO	H,H		H	2	0	242-244	(1:1) (hydrochloride)
10	Ph	CO	H,H		H	2	0	207-208	Free base
11	Ph	CH(OH) (S)	H,H		H	2	0	186-187	Free base
12	Ph	CH(OH) (R)	H,H		H	2	0	182-184	Free base
13	Ph	CH(OH) (R)	H,H		H	2	0	218-220	(1:1) (hydrochloride)
14	Ph	bond	H,H		H	2	0	149-150	Free base
15	Ph	CH(OH) (R)	H,H		H	3	0	221-222	(1:1) (hydrochloride)
16	Ph	bond	H,H		H	3	0	191-193	Free base
17	Ph	bond	H,H		H	1	0	233-235	(1:1) (hydrochloride)
18	Ph	bond	H,H		H	2	0	213-215	(1:1) (hydrochloride)
19	Ph	bond	H,H		H	3	0	227-228	(1:1) (hydrochloride)

N°	R2	Y	X	R1	R3	m	n	Mp °C	salt
20	Ph	bond	H,H		H	3	1	208-210	(1:1) (hydrochloride)
21	Ph	bond	H,H		H	2	1	210-211	(1:1) (hydrochloride)
22	Ph	bond	H,H		H	1	1	224-225	(1:1) (hydrochloride)
23	Ph	bond	H,H		H	2	1	166-167	Free base
24	Ph	bond	H,H		H	3	1	190-191	Free base
25	3-Br-Ph	C(H)(OH) (Rac.)	H,H		H	2	1	177-178	Free Base
26	3-Br-Ph	CO	H,H		H	2	1	169-171	Free Base

**Test Example: Inhibitory activity of the medicament of the present invention against GSK3 $\beta$ :**

Two different protocols can be used.

5

In a first protocol : 7.5  $\mu$ M of prephosphorylated GS1 peptide and 10  $\mu$ M ATP (containing 300,000 cpm of 33P-ATP) were incubated in 25 mM Tris-HCl, pH 7.5, 0.6 mM DTT, 6 mM MgCl<sub>2</sub>, 0.6 mM EGTA, 0.05 mg/ml BSA buffer for 1 hour at room temperature in the presence of GSK3beta (total reaction volume : 100

10 microliters).

In a second protocol : 4.1  $\mu$ M of prephosphorylated GS1 peptide and 42  $\mu$ M ATP (containing 260,000 cpm 33P-ATP) were incubated in 80 mM Mes-NaOH, pH 6.5, 1 mM Mg acetate, 0.5 mM EGTA, 5 mM 2-mercaptoethanol, 0.02% Tween 20,

15 10% glycerol buffer for 2 hours at room temperature in the presence of GSK3beta. Inhibitors were solubilised in DMSO (final solvent concentration in the reaction medium, 1%).

20 The reaction was stopped with 100 microliters of a solution made of 25 g polyphosphoric acid (85% P<sub>2</sub>O<sub>5</sub>), 126 ml 85% H<sub>3</sub>PO<sub>4</sub>, H<sub>2</sub>O to 500 ml and then diluted to 1:100 before use. An aliquot of the reaction mixture was then transferred to Whatman P81 cation exchange filters and rinsed with the solution described above. Incorporated 33P radioactivity was determined by liquid scintillation spectrometry.

25 The phosphorylated GS-1 peptide had the following sequence :

NH<sub>2</sub>-YRRAAVPPSPSLSRHSSPHQS(P)EDEE-COOH.

30 The GSK3 $\beta$  inhibitory activity of the compounds of the present invention are expressed in IC<sub>50</sub>, and as an illustration the range of IC<sub>50</sub>'s of the compounds in table 1 is between 1 nanomolar to 1 micromolar concentrations.

For example compound No. 10 of table 1 shows an IC<sub>50</sub> of 0.0006  $\mu$ M.

## Formulation Example

## (1) Tablets

5 The ingredients below were mixed by an ordinary method and compressed by using a conventional apparatus.

Compound of Example 1	30 mg
Crystalline cellulose	60 mg
Corn starch	100 mg
Lactose	200 mg
10 Magnesium stearate	4 mg

## (2) Soft capsules

15 The ingredients below were mixed by an ordinary method and filled in soft capsules.

Compound of Example 1	30 mg
Olive oil	300 mg
Lecithin	20 mg

## (1) Parenteral preparations

20 The ingredients below were mixed by an ordinary method to prepare injections contained in a 1 ml ampoule.

Compound of Example 1	3 mg
Sodium chloride	4 mg
25 Distilled water for injection	1 ml

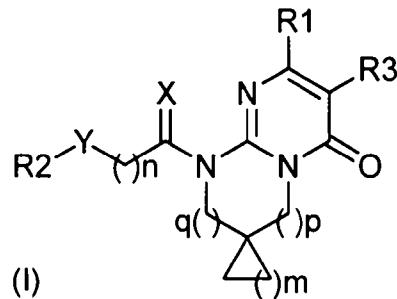
## Industrial Applicability

30 The compounds of the present invention have GSK3 $\beta$  inhibitory activity and are useful as an active ingredient of a medicament for preventive and/or therapeutic treatment of diseases caused by abnormal activity of GSK3 $\beta$  and more particularly of neurodegenerative diseases.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A dihydrospiro-[cycloalkyl]-pyrimidone derivative represented by formula (I) or a salt thereof, or a solvate thereof or a hydrate thereof:



5 wherein:

X represents two hydrogen atoms, a sulfur atom, an oxygen atom or a C<sub>1-2</sub> alkyl group and a hydrogen atom;

10 Y represents a bond, a carbonyl group, a methylene group optionally substituted by one or two groups chosen from a C<sub>1-6</sub> alkyl group, a hydroxyl group, a C<sub>1-4</sub> alkoxy group, a C<sub>1-2</sub> perhalogenated alkyl group or an amino group;

15 R1 represents a 2, 3 or 4-pyridine ring or a 2, 4 or 5-pyrimidine ring, the ring being optionally substituted by a C<sub>1-4</sub> alkyl group, a C<sub>1-4</sub> alkoxy group, or a halogen atom;

20 R2 represents a benzene ring or a naphthalene ring; the rings being optionally substituted by 1 to 4 substituents selected from a C<sub>1-6</sub> alkyl group, a methylenedioxy group, a halogen atom, a C<sub>1-2</sub> perhalogenated alkyl group, a C<sub>1-3</sub> halogenated alkyl group, a hydroxyl group, a C<sub>1-4</sub> alkoxy group, a nitro, a cyano, an amino, a C<sub>1-5</sub> monoalkylamino group or a C<sub>2-10</sub> dialkylamino group;

R3 represents a hydrogen atom, a C<sub>1-6</sub> alkyl group or a halogen atom;

25 m represents 1 to 4;

n represents 0 to 3;

p represents 0 to 2; and

q represents 0 to 2, p+q being inferior to 4.

2. A dihydrospiro-[cycloalkyl]-pyrimidone derivative or a salt thereof, or a solvate thereof or a hydrate thereof according to claim 1, wherein R1 represents an unsubstituted 4-pyridinyl group or unsubstituted 4-pyrimidinyl group.

5 3. A dihydrospiro-[cycloalkyl]-pyrimidone derivative or a salt thereof, or a solvate thereof or a hydrate thereof according to claim 1 or 2, wherein

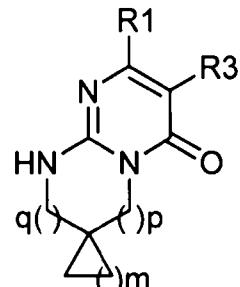
- R1 represents an unsubstituted 4-pyridine ring or a 4-pyrimidine ring; and
- R2 represents a benzene ring, the ring being optionally substituted 1 to 4 substituents selected from a C<sub>1-3</sub> alkyl group, a halogen atom, a hydroxyl group or a C<sub>1-2</sub> alkoxy group; and
- R3 represents a hydrogen atom; and
- X represents two hydrogen atoms; and
- Y represents a bond, a carbonyl group or a methylene group optionally substituted by a hydroxyl group; and
- 15 • p represents 2 and q represents 0.

4. A dihydrospiro-[cycloalkyl]-pyrimidone derivative which is selected from the group consisting of:

- 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2-Oxo-2-phenylethyl)-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 25 • 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2R)-2-Hydroxy-2-phenylethyl]-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 30 • 1'-(2-Oxo-2-phenylethyl)-8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2-Oxo-2-phenylethyl)-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one,
- 1'-(2S)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 35 • 1'-(2-Oxo-2-phenylethyl)-8'-pyridin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2-Oxo-2-phenylethyl)-8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one

- 1'-(2S)-2-Hydroxy-2-phenylethyl]- 8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2R)-2-Hydroxy-2-phenylethyl]- 8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 5 • 1'-(2R)-2-Hydroxy-2-phenylethyl]-8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylmethyl)- 8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 10 • 1'-(2R)-2-Hydroxy-2-phenylethyl]- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylmethyl)- 8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylmethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 15 • 1'-(phenylmethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylmethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 20 • 1'-(phenylethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(phenylethyl)- 8'-pyridin-4-yl-3',4'-dihydrospiro-[cyclopropane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 25 • 1'-(phenylethyl)- 8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one and
- 1'-(phenylethyl)- 8'-pyrimidin-4-yl-3',4'-dihydrospiro-[cyclopentane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 1'-(2-Hydroxy-2-(3-bromo-phenylethyl))- 8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- 30 • 1'-(2-Oxo-2-(3-bromo-phenylethyl))- 8'-pyrimidin-4-yl-3',4'-dihydrospiro[cyclobutane-1,2'-pyrimido[1,2-a]pyrimidin]-6'(1'H)-one
- or a salt thereof, or a solvate thereof or a hydrate thereof.

## 5. A compound of formula (III)



(III)

wherein R1, R3, m, p and q are as defined for compound of formula (I) according to claim 1.

5

6. A medicament comprising as an active ingredient a substance selected from the group consisting of a dihydrospiro-[cycloalkyl]-pyrimidone derivative represented by formula (I) or salts thereof, or a solvate thereof or a hydrate thereof according to claim 1, and one or more pharmaceutical additives.

10

7. A GSK3 $\beta$  inhibitor selected from the group of a dihydrospiro-[cycloalkyl]-pyrimidone derivative represented by formula (I) or salts thereof, or a solvate thereof or a hydrate thereof according to claim 1.

15

8. Use of a compound according to claims 1 to 4 for the preparation of a medicament for preventive and/or therapeutic treatment of a disease caused by abnormal GSK3 $\beta$  activity.

20

9. Use of a compound according to claims 1 to 4 for the preparation of a medicament for preventive and/or therapeutic treatment of a neurodegenerative disease.

10. Use of a compound according to claim 9, wherein the neurodegenerative disease is selected from the group consisting of Alzheimer's disease, Parkinson's disease, tauopathies, vascular dementia; acute stroke, traumatic injuries; cerebrovascular accidents, brain cord trauma, spinal cord 5 trauma; peripheral neuropathies; retinopathies or glaucoma.

11. Use of a compound according to claims 1 to 4 for the preparation of a medicament for preventive and/or therapeutic treatment of non-insulin dependent diabetes; obesity; manic depressive illness; schizophrenia; alopecia; or cancers.

10

12. Use according to claim 11 wherein cancer is breast cancer, non-small cell lung carcinoma, thyroid cancer, T or B-cell leukemia or virus-induced tumors.

13. A method of treatment or prevention of a disease caused by abnormal 15 GSK3 $\beta$  activity in a patient which comprises administering to the patient an effective amount of a compound according to any one of claims 1 to 4.

14. The method according to claim 13 wherein the disease is a neurodegenerative disease.

20

15. The method according to claim 14 wherein the neurodegenerative disease is selected from the group consisting of Alzheimer's disease, Parkinson's disease, tauopathies, vascular dementia; acute stroke, traumatic injuries; cerebrovascular accidents, brain cord trauma, spinal cord trauma; peripheral 25 neuropathies; retinopathies or glaucoma.

16. The method according to claim 13 wherein the disease is non-insulin dependent diabetes; obesity; manic depressive illness; schizophrenia; alopecia; or cancers.

30

17. The method according to claim 16 wherein the cancer is breast cancer, non-small cell lung carcinoma, thyroid cancer, T or B-cell leukemia or virus-induced tumors.

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18. A compound of any one of claims 1, 4 and 5, substantially as hereinbefore described.