

BENZOIC ACID (1-PHENYL-2-PYRIDIN-4-YL)ETHYL ESTERS AS PHOSPHODIESTERASE INHIBITORS

FIELD OF THE INVENTION

The present invention relates to inhibitors of the phosphodiesterase 4 (PDE4) enzyme. More particularly, the invention relates to 1-phenyl-2-pyridinyl alkyl alcohol derivatives, to processes for the preparation thereof, compositions comprising them, combinations and therapeutic uses thereof.

5 BACKGROUND OF THE INVENTION

Airway obstruction characterizes a number of severe respiratory diseases including asthma and chronic obstructive pulmonary disease (COPD). Events leading to airway obstruction include oedema of airway walls, increased mucous production and inflammation.

10 Drugs for treating respiratory diseases such as asthma and COPD are currently administered through inhalation. One of the advantages of the inhalatory route over the systemic one is the possibility of delivering the drug directly at site of action, avoiding any systemic side-effects, thus providing a more rapid clinical response and a higher therapeutic ratio.

15 Inhaled corticosteroids are the current maintenance therapy of choice for asthma and together with bronchodilator β_2 -agonists for acute symptom relief, they form the mainstay of current therapy for the disease. The current management of COPD is largely symptomatic by means of bronchodilating therapy with inhaled anticholinergics and inhaled β_2 -adrenoceptor agonists.
20 However, corticosteroids do not reduce the inflammatory response in COPD as they do in asthma.

Another class of therapeutic agents which are under investigation in view of its anti-inflammatory effects for the treatment of inflammatory respiratory diseases such as asthma and COPD is represented by the inhibitors

of the phosphodiesterase enzymes (PDEs), in particular of the phosphodiesterase type 4 (hereinafter referred to as PDE4).

Various compounds acting as PDE4 inhibitors have been disclosed. However, the usefulness of several PDE4 inhibitors of the first -generation
5 such as rolipram and piclamilast has been limited because of their undesirable side effects such as nausea, gastric acid secretion and emesis due to their action on PDE4 in the central nervous system and due to the action on PDE4 in parietal cells in the gut.

The cause of said side effects has been widely investigated.

10 It has been found that PDE4 exists in two distinct forms representing different conformations, that were designated as high affinity rolipram binding site or HPDE4, especially present in the central nervous system and in parietal cells, and low affinity rolipram binding site or LPDE4 (Jacobitz, S et al Mol. Pharmacol, 1996, 50, 891-899), which is found in the immune and
15 inflammatory cells. While both forms appear to exhibit catalytic activity, they differ with respect to their sensitivity to inhibitors. In particular, compounds with higher affinity for LPDE4 appear less prone to induce side-effects such as nausea, emesis and increased gastric secretion.

The effort of targeting LPDE4 has resulted in a slight improvement in
20 the selectivity for the second-generation PDE4 inhibitors such as cilomilast and roflumilast. However, even these compounds are not provided with a good selectivity towards LPDE4.

Compounds with selective LPDE4 inhibition activity are disclosed in WO2009/018909.

25 1-phenyl-2-pyridinyl alkylene alcohols and their use as PDE4 inhibitors are also described in WO 2008/006509.

The present invention provides a set of potent novel PDE4 inhibitors having excellent LPDE4 selectivity.

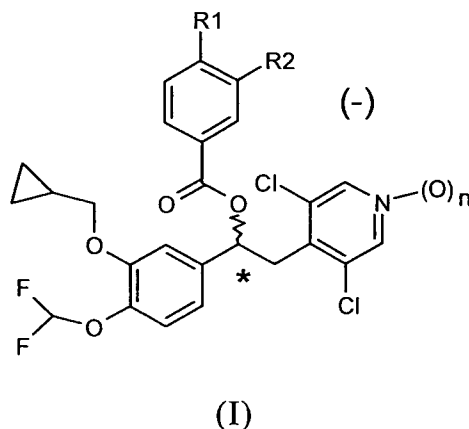
Surprisingly, it has been found that the presence of sulphonamido substituents on the benzoate residue markedly improves the potency.

Moreover, it has been surprisingly found that the sulphonylamido derivatives of the invention, which are (-) enantiomers (see the carbon atom marked with an asterisk below) are more potent than the corresponding (+) enantiomers and racemates.

It has now been found that an unexpectedly beneficial therapeutic effect, particularly a synergistic effect, is obtained in the treatment of inflammatory or obstructive diseases of the respiratory tract when the compounds of the invention are used in combination with a long-acting β_2 -agonist.

SUMMARY OF THE INVENTION

The invention is directed to compounds of general formula (I) as (-) enantiomers, acting as inhibitors of the phosphodiesterase 4 (PDE4) enzyme, to processes for the preparation thereof, compositions comprising them and therapeutic uses thereof



wherein:

n is 0 or 1;

R1 and R2 may be the same or different, and are selected from the group consisting of:

- linear or branched C₁-C₆ alkyl, optionally substituted by one or more halogen atoms;

- OR3 wherein R3 is a linear or branched C₁-C₆ alkyl optionally substituted with one or more halogen atoms or C₃-C₇ cycloalkyl groups; and
- HNSO₂R4 wherein R4 is a linear or branched C₁-C₄ alkyl optionally substituted with one or more halogen atoms,

wherein at least one of R1 and R2 is HNSO₂R4.

The invention also encompasses the pharmaceutically acceptable hydrates, solvates, addition complexes, inorganic or organic salts thereof, e.g. sodium, potassium and lysine salts.

The present invention is also directed to a process for the preparation of the compounds of formula (I) as reported in Scheme 1, which comprises reacting aldehyde (1) with methyldichloropyridine (2) to obtain racemic alcohol (3). This latter is then condensed with a chiral acid such as (S)-naproxen or (S)-acetylmandelic acid to obtain a diastereomeric mixture (10) or (5), respectively, as per routes 1 or 2 of scheme 1. Separation into the single diastereoisomers respectively (11) and (13) or (6) and (8) is carried out by chromatography, crystallization or other well known methods, giving after cleavage, respectively enantiomeric alcohols (-) (12) and (+) (14) or (+) (7) and (-) (9). Finally, by reaction with a suitable benzoic acid (15), enantiomers (+) (14) or (+) (7) give compounds of general formula (I).

The present invention is also directed to a process for the preparation of compounds of formula (I) wherein n is 0 as reported in Scheme 1, which comprises the reaction of any enantiomeric alcohol, for instance (+) (14), with a benzoic acid (15).

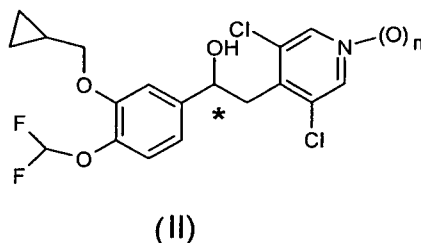
The present invention is also directed to a process for the preparation of compounds of formula (I) wherein n is 1 as reported in Scheme 1, which comprises the oxidization of enantiomeric alcohol (+) (14) by means of an oxidizing agent such as 3-chloroperbenzoic acid, peracetic acid or hydrogen

peroxide to obtain the alcohol (+) enantiomer (7), which by reaction with a benzoic acid of formula (15) gives compounds of formula (I) wherein n is 1.

The present invention is also directed to a process for the preparation of compounds of formula (I) wherein n is 1 as reported in Scheme 1, which
5 comprises the oxidization of esters of formula (I) wherein n is 0 by means of an oxidizing agent such as 3-chloroperbenzoic acid, peracetic acid or hydrogen peroxide.

The present invention is also directed to intermediate compounds of general formula (II)

10



wherein n is as defined above and the carbon atom represented with an asterisk below shows a (S) configuration.

The present invention also provides pharmaceutical compositions
15 comprising a compound of formula (I) and one or more pharmaceutically acceptable carriers and/or excipients.

The present invention in particular provides pharmaceutical preparations suitable for administration by inhalation.

The present invention also provides combinations of a compound of
20 formula (I) with a second component selected from the classes of long-acting β_2 agonists, M3 antagonists and corticosteroids.

The present invention also provides combinations of a compound of formula (I) with a long-acting β_2 agonist selected from the group consisting of carmoterol, GSK-642444, indacaterol, milveterol, arformoterol, formoterol,
25 salbutamol, formoterol, levalbuterol, terbutaline, AZD-3199, BI-1744-CL,

LAS-100977, bambuterol, isoproterenol, procaterol, clenbuterol, reproterol, fenoterol and ASF-1020.

The present invention also provides combinations of a compound of formula (I) with a M3 antagonist selected from the group consisting of acridinium, tiotropium, ipratropium and oxitropium.

The present invention also provides combinations of a compound of formula (I) with a corticosteroid selected from the group consisting of dexamethasone, fluticasone, fluticasone furoate, prednisolone, betamethasone, budesonide, mometasone, mometasone furoate, triamcinolone acetonide, ciclesonide, TPI-1020, beclomethasone, beclomethasone dipropionate, prednisone, deflazacort, hydrocortisone, QAE-397 and flunisolide.

In a preferred embodiment, the present invention provides combinations of a compound of formula (I) with formoterol or carmoterol.

The present invention also provides compounds of formula (I) for use as a medicament.

Also provided is the use of the compounds of formula (I) in the preparation of a medicament for the prevention or treatment of any disease wherein the activity of PDE4 receptors is implicated and inhibition of PDE4 receptor activity is desired.

The present invention also provides a method for the prevention or treatment of any disease wherein the activity of PDE4 receptors is implicated and inhibition of PDE4 receptor activity is desired, which methods comprises administering to a patient in need thereof a therapeutically effective amount of a compound of formula (I).

The above uses or methods comprise a compound of formula (I) either alone or combined with other active ingredients among those formerly reported.

The above diseases wherein the activity of PDE4 receptors and inhibition of PDE4 receptors are implicated, comprise diseases of the respiratory tract,

characterized by airway obstruction such as asthma and COPD.

Furthermore, the invention is also directed to the use of the compounds of formula (I) for the in vitro inhibition of PDE4.

The invention is also directed to a device which may be a single- or multi-dose dry powder inhaler, a metered dose inhaler or a soft mist nebulizer comprising a compound of formula (I).

The invention is also directed to a kit comprising the pharmaceutical compositions of compounds of formula (I), alone or in combination with an additional pharmaceutical ingredient, in admixture with one or more pharmaceutically acceptable carriers and/or excipients, and a device which may be a single- or multi-dose dry powder inhaler, a metered dose inhaler or a soft mist nebulizer.

DEFINITIONS

The term "halogen atoms" as used herein includes fluorine, chlorine, bromine and iodine.

As used herein, the expression "linear or branched C₁-C_x alkyl" where x is an integer greater than 1, such as C₁-C₆ or C₁-C₄ alkyl, refers to straight or branched chain alkyl groups wherein the number of carbon atoms is in the range 1 to x (e.g. 1 to 6 or 1 to 4). Examples of alkyl groups may thus include methyl, ethyl, n-propyl, isopropyl, t-butyl, pentyl, hexyl and the like.

Optionally in said groups one or more hydrogen atoms can be replaced by halogen atoms, preferably chlorine or fluorine.

As used herein, the expression "C₃-C₇ cycloalkyl" refers to cyclic non-aromatic hydrocarbon groups containing 3 to 7 ring carbon atoms. Examples of them may thus include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl and cycloheptyl.

Unless otherwise provided, when referring to chiral compounds, a degree of purity "substantially pure" here means at least greater than about 97% chirally

pure, preferably greater than 99% and most preferably greater than 99.9%.

FIGURE

Figure shows the existence of a synergic action for a preferred embodiment of the present invention.

5 OA=ovoalbumin

C1=3-Cyclopropylmethoxy-4-methanesulfonylamino-benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethyl ester

CARM=carmoterol

10 DETAILED DESCRIPTION OF THE INVENTION

The invention is directed to compounds acting as inhibitors of the phosphodiesterase 4 (PDE4) enzyme.

Said compounds inhibit the conversion of cyclic nucleotides, in particular cyclic adenosine monophosphate (cAMP), into their inactive
15 5'-mononucleotide forms.

In the airways, the physiological responses to elevated intracellular levels of cyclic nucleotides, in particular of cAMP, lead to the suppression of the activity of immune and pro-inflammatory cells such as mast cells, macrophages, T lymphocytes, eosinophils and neutrophils, resulting in a
20 decrease of the release of inflammatory mediators which include cytokines such as IL-1, IL-3 and tumor necrosis factor -alpha (TNF- α). It also leads to an airway smooth muscle relaxation and a decrease in oedema.

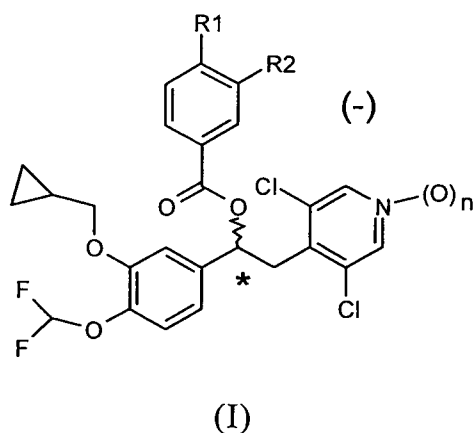
The catalytic site of PDE4 has been previously identified: it mainly comprises a hydrophobic region in which two sub-pockets are present, e.g. S₀ and
25 S₁, and a hydrophilic region containing the metal ions Zn²⁺ and Mg²⁺, that in turn comprises the sub-pocket S₂ spreading around the metal ions and a sub-pocket S₃ which branches approximately 90° from the middle of the hydrophobic pocket.

Most of the known compounds are provided with a moiety able of

interacting with the sub-pockets S_0 and S_1 of the hydrophobic region such as a substituted catechol group and with another moiety able of indirectly interacting with the metal ions of the S_2 sub-pocket, for example a heterocycle such as pyridine or pyrrolidone.

5 The present invention is directed to compounds that can maintain the interactions with the sub-pockets S_0 and S_1 by means of the substituted catechol moiety and the interaction with the metal ions region by means of the pyridine ring like other known PDE4 inhibitors, but differing from them, for the presence of a sulfonylamino-benzoic acid group, which enable them to
 10 establish an additional interaction with the sub-pocket S_3 .

In particular the present invention relates to compounds of general formula (I) as defined earlier, including the pharmaceutically acceptable inorganic and organic salts, hydrates, solvates or addition complexes thereof.



Preferred groups of compounds of formula (I) are those wherein:

- R1 is HNSO₂R₄, R2 is OR₃ and n is 0;
- R1 is HNSO₂R₄, R2 is OR₃ and n is 1;
- 20 - R1 is HNSO₂R₄, wherein R₄ is methyl, R2 is OR₃, wherein R₃ is cyclopropylmethyl and n is 0;
- R1 is HNSO₂R₄, wherein R₄ is methyl, R2 is OR₃, wherein R₃ is cyclopropylmethyl and n is 1;
- R1 is linear or branched C₁-C₆ alkyl, R2 is HNSO₂R₄ and n is 0;

- R1 is methyl, R2 is HNSO_2R_4 , wherein R4 is methyl and n is 0;
- R1 is linear or branched $\text{C}_1\text{-C}_6$ alkyl, R2 is HNSO_2R_4 and n is 1;
- R1 is methyl, R2 is HNSO_2R_4 , wherein R4 is methyl and n is 1;
- R2 is linear or branched $\text{C}_1\text{-C}_6$ alkyl, R1 is HNSO_2R_4 and n is 0;
- 5 - R2 is methyl, R1 is HNSO_2R_4 , wherein R4 is methyl and n is 0;
- R2 is linear or branched $\text{C}_1\text{-C}_6$ alkyl, R1 is HNSO_2R_4 and n is 1;
- R2 is methyl, R1 is HNSO_2R_4 , wherein R4 is methyl and n is 1;
- R1 is OR_3 , R2 is HNSO_2R_4 and n is 0;
- R1 is OR_3 , R2 is HNSO_2R_4 and n is 1;
- 10 - R1 is OR_3 wherein R3 is cyclopropylmethyl, R2 is HNSO_2R_4 and R4 is methyl and n is 1;
- R1 is OR_3 , R2 is HNSO_2R_4 and n is 1;
- both R1 and R2 are HNSO_2R_4 and n is 0;
- both R1 and R2 are HNSO_2R_4 , wherein R4 is methyl and n is 0;
- 15 - both R1 and R2 are HNSO_2R_4 and n is 1;
- both R1 and R2 are HNSO_2R_4 , wherein R4 is methyl and n is 1.

It will be apparent to those skilled in the art that compounds of general formula (I) at least contain one asymmetric center, presently represented by the carbon atom with an asterisk below, and therefore exist as optical stereoisomers.

20 The present invention is directed to the compounds of formula (I) which are (-) enantiomers with configuration (S) at the carbon atom represented with an asterisk below.

The present invention is also directed to the intermediate compounds of formula (II) wherein the carbon atom represented with an asterisk below
25 shows a (S) configuration.

The compounds of formula (I) show an in vitro inhibitory activity toward the PDE4 enzyme in the nM range and they are endowed with a remarkable activity in the lungs upon intra-tracheal administration in an

animal model of COPD.

They may also exhibit sustained pulmonary levels in the lungs, being undetectable in plasma, which is an index of a short systemic action.

According to preferred embodiments, the present invention provides the
5 compounds of formula (I) reported below:

Compound	Chemical name
C1	(-)-3-Cyclopropylmethoxy-4-methanesulfonylamino-benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethyl ester
C2	(-)-3-Cyclopropylmethoxy-4-methanesulfonylamino-benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester
C3	(-)-4-Cyclopropylmethoxy-3-methanesulfonylamino-benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester
C4	(-)-3,4-Bis-methanesulfonylamino-benzoic acid 1-(3-cyclopropyl-methoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester
C5	(-)-3-Methanesulfonylamino-4-methyl-benzoic acid 1-(3-cyclopropyl-methoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester
C6	(-)-4-Methanesulfonylamino-3-methyl-benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester

The above compounds have been conveniently identified as (-) enantiomers which, however, have (S) configuration at the carbon atom marked with an asterisk. As such, these same compounds can be also

identified as per the following table:

Compound	Chemical name
C1	3-Cyclopropylmethoxy-4-methanesulfonylamino-benzoic acid 1-(S)-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethyl ester
C2	3-Cyclopropylmethoxy-4-methanesulfonylamino-benzoic acid 1-(S)-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester
C3	4-Cyclopropylmethoxy-3-methanesulfonylamino-benzoic acid 1-(S)-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester
C4	3,4-Bis-methanesulfonylamino-benzoic acid 1-(S)-(3-cyclopropyl-methoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester
C5	3-Methanesulfonylamino-4-methyl-benzoic acid 1-(S)-(3-cyclopropyl-methoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester
C6	4-Methanesulfonylamino-3-methyl-benzoic acid 1-(S)-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester

Advantageously, the compounds of the invention are characterized by selectivity toward LPDE4 higher than that toward HPDE4, as obtained by the
5 determination of their IC₅₀ values.

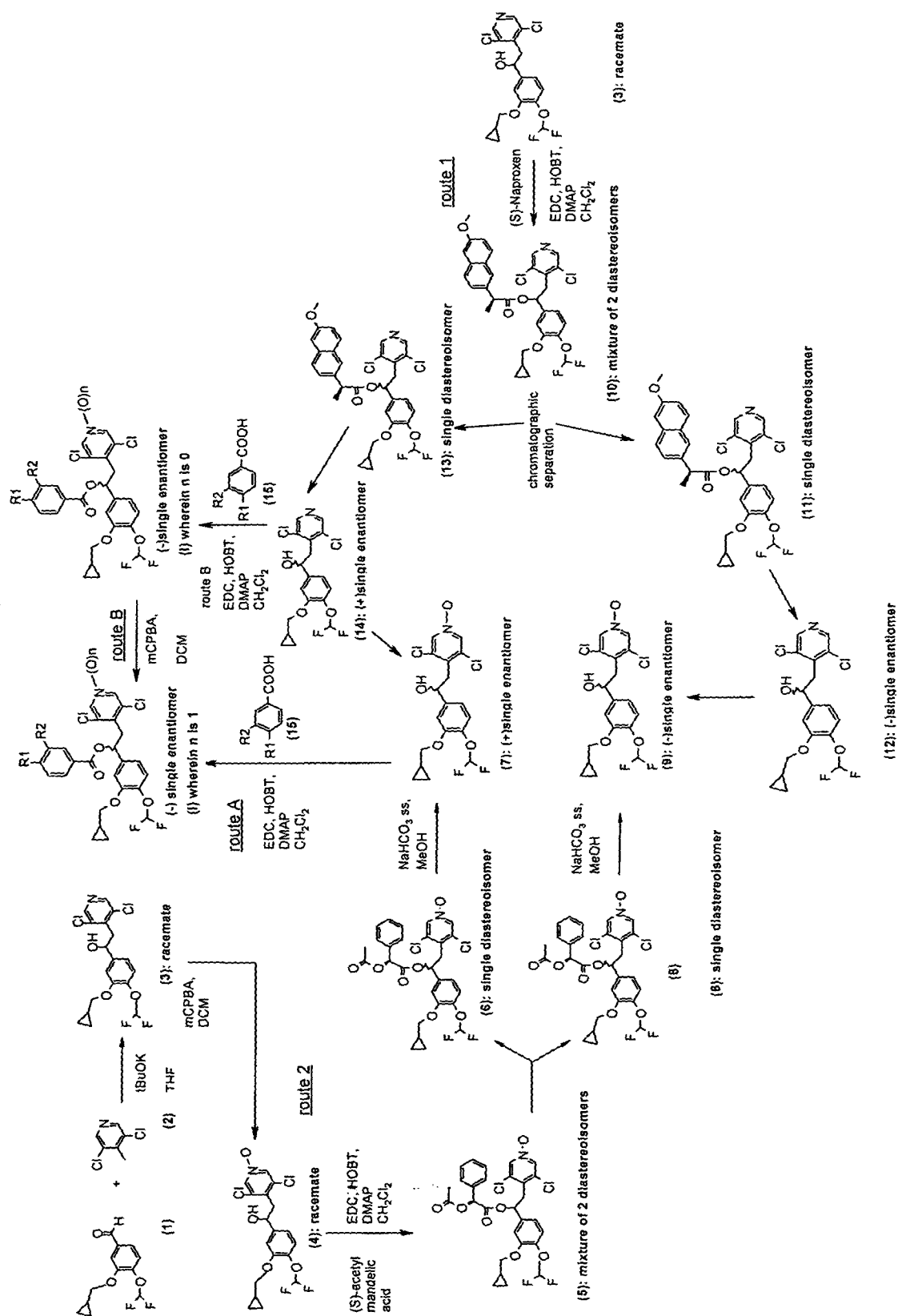
In the case of LPDE4, the IC₅₀ is the molar concentration of the test compound producing 50% inhibition of cAMP disappearance, assessed as described in Cortijo J et al *Br J Pharmacol* 1993, 108: 562-568. In the case of HPDE4 instead, the IC₅₀ is the molar concentration of the test compound

producing 50% inhibition of the binding of [H^3] rolipram, assessed as described in Duplantier AJ et al *J Med Chem* 1996; 39: 120-125.

Preferably, the HPDE4/LPDE4 IC_{50} ratio for the compounds of the invention is higher than 5, more preferably higher than 10, even more preferably higher than 20 and most preferably higher than 100.

The compounds of formula (I) may be prepared conventionally according to known methods. Some of the processes which can be used are described below and reported in Scheme 1.

Scheme 1



Procedure for the preparation of compounds of formula (I)

According to a particular embodiment of the present invention, the compounds of formula (I) may be prepared, for example, following the synthetic pathways described in Scheme 1.

5 Racemic alcohol (3) may be prepared by reacting aldehyde (1) with methyldichloropyridine (2).

Route 1 - Racemic alcohol (3) may be separated into (-) (12) and (+) (14) enantiomers by known methods, such as by reacting the racemic mixture with a suitable chiral auxiliary thus obtaining a mixture of diastereoisomers. Such diastereoisomers may be separated by crystallization or by chromatography or by means of enzymes according to known methods. Subsequently, the chiral auxiliary may be removed from diastereoisomers to give the desired chiral alcohol as a single enantiomer. Alternatively, the alcohol racemic mixture may be resolved by means of chromatography with a
10 chiral stationary phase, according to known methods (Ref: "Enantiomer Separation: Fundamentals and Practical Methods" F. Toda, Springer-Verlag 2004; "Drug Stereochemistry: Analytical Methods and Pharmacology", Irving W. Wainer, CRC Press, 1993).

In particular, racemic alcohol (3) may be condensed with a chiral acid
20 such as (S)-naproxen and the obtained diastereomeric mixture (10) may be separated into the two single diastereoisomers (11) and (13) by chromatography. After cleavage of the single diastereomeric esters by hydrolysis in an aqueous solvent or by alcoholysis in an alcoholic solvent, using acidic or basic conditions, enantiomeric pure alcohol intermediates (-)
25 (12) and (+) (14) may be obtained.

Route 2 - Racemate (4), obtained by oxidation of racemate (3) carried out according to conventional methods, may be reacted with a chiral acid such as (S)-acetylmandelic acid so obtaining a mixture of two diastereoisomers (5).

By trituration with diethyl ether and crystallization in a solvent such as isopropanol, ethanol or methanol, or by chromatographic separation, single diastereomeric esters (6) and (8) may be obtained.

After cleavage of single diastereomeric esters by hydrolysis in an aqueous solvent or by alcoholysis in an alcoholic solvent, using acidic or basic conditions, enantiomeric pure alcohol intermediates (+) (7) and (-) (9) may be obtained.

Compounds of general formula (I) wherein n is 0 may be prepared by reacting the proper enantiomeric alcohol (+)(14) with benzoic acid (15) in the presence of a suitable strong base such as lithium diisopropylamide (LDA), NaH or dimethylaminopyridine (DMAP) and in the presence of a condensing agent such as 1-Ethyl-3-[3-dimethylaminopropyl]carbodiimide hydrochloride (EDC) or N-hydroxybenzotriazole (HOBT) in a solvent such as dichloromethane. Other solvents may be used, such as dimethylformamide (DMF), tetrahydrofuran (THF), chloroform, dioxane or any other aprotic solvent known to those skilled in the art. In a particular embodiment, the reaction may also be carried out in the absence of solvents.

Compounds of formula (I) wherein n is 1 may be prepared by oxidizing corresponding compounds of formula (I) wherein n is 0 by means of an oxidizing agent such as 3-chloroperbenzoic acid, peracetic acid or hydrogen peroxide in solvents such as chloroform, dichloromethane or acetic acid (route B).

Alternatively, compounds of formula (I) wherein n is 1 may also be prepared by first oxidizing alcohol enantiomers (+) (14), by means of the aforementioned operative conditions, thus obtaining alcohol enantiomers (+) (7). Subsequent reaction between the given alcohol enantiomer with a benzoic acid of formula (15), thus provides the above compounds of formula (I) wherein n is 0 (route A).

Separation of (+) (7) and (-) (9) enantiomers from racemic alcohol (4),

in its turn be obtained by oxidation of racemic alcohol (3), may be carried out by known methods, as described above for separation of enantiomers of racemic alcohol (3).

The skilled person should be aware that optional variations to the synthetic steps reported in scheme 1 may be applied as well to the preparation of the compounds of the invention.

We refer, in particular, to the order of reactions that may be performed so as to get the desired compounds or intermediates thereof, as well as to the choice of operative conditions being adapted, including solvents, optional oxidizing agents, condensing agents, and the like.

As an example, in case chemically reactive substituents are present in any of the starting materials or intermediates thereof, that might give rise to unwanted side reactions, suitable protection of those same substituents may be carried out before the reaction takes place.

By analogy, subsequent deprotection may be then carried out, so as to obtain again the above chemically reactive substituent or group in the free form.

The protection and deprotection of functional groups is described in "Protective Groups in Organic Chemistry" 3rd edition, T.W. Greene and P.G.M. Wuts, Wiley-Interscience (1999) and "Protecting Groups", P.J. Kocienski, Georg Thieme Verlag (1994).

According to the present process for the preparation of the compounds of the invention, and variants thereof, the starting materials of formula (1) and (2) as well as any additional reactant [(e.g. of formula (15)], auxiliary of chirality, solvent or agent being employed, is known or may be easily prepared according to known methods.

The present invention also provides pharmaceutical compositions of compounds of formula (I) in admixture with one or more pharmaceutically

acceptable carriers, for example those described in Remington's Pharmaceutical Sciences Handbook, XVII Ed., Mack Pub., N.Y., U.S.A.

Examples include diluents (such as sucrose, mannitol, lactose, starches) and known excipients, including suspending agents, solubilizers, buffering
5 agents, binders, disintegrants, preservatives, colorants, flavours, lubricants and the like. Time release capsules, tablets and gels are also advantageous in administering the compounds of the present invention.

Administration of the compounds of the present invention may be accomplished according to patient needs, for example, orally, nasally,
10 parenterally, e.g. subcutaneously, intravenously, intramuscularly, intrasternally and by infusion, by inhalation, rectally, vaginally, topically, locally, transdermally, and by ocular administration. Various solid oral dosage forms may be used for administering compounds of the invention including such solid forms as tablets, gelcaps, capsules, caplets, granules, lozenges and
15 bulk powders.

Various liquid oral dosage forms may also be used for administering compounds of the invention, including aqueous and non-aqueous solutions, emulsions, suspensions, syrups, and elixirs. Such dosage forms can also contain known suitable inert diluents such as water and known suitable
20 excipients such as preservatives, wetting agents, sweeteners, flavours, as well as agents for emulsifying and/or suspending the compounds of the invention. The compounds of the invention may be injected, for example, intravenously, in the form of an isotonic sterile solution. Other known preparations are also possible.

25 Suppositories for rectal administration of the said compounds of the invention may be prepared by mixing the compound with a suitable excipient such as cocoa butter, salicylates and polyethylene glycols.

Formulations for vaginal administration may be in the form of cream,

gel, paste, foam, or spray formula containing, in addition to the active ingredient, conventional carriers.

For topical administration, the pharmaceutical compositions may be in the form of creams, ointments, liniments, lotions, emulsions, suspensions, gels, solutions, pastes, powders, sprays, and drops suitable for administration to the skin, eye, ear or nose. Topical administration may also involve transdermal administration, e.g. by means of transdermal patches.

For the treatment of the diseases of the respiratory tract, the compounds of the invention are preferably administered by inhalation.

Inhalable preparations include inhalable powders, propellant-containing metering aerosols or propellant-free inhalable formulations.

For administration as a dry powder, known single- or multi-dose inhalers may be utilized. In that case the powder may be filled in gelatine, plastic or other capsules, cartridges or blister packs or in a reservoir.

A diluent or carrier, generally chemically inert to the compounds of the invention, e.g. lactose or any other additive suitable for improving the respirable fraction may be added to the powdered compounds of the invention.

Inhalation aerosols containing propellant gas such as hydrofluoroalkanes may contain the compounds of the invention either in solution or in dispersed form. The propellant-driven formulations may also contain other ingredients such as co-solvents, stabilizers and optionally other excipients.

The propellant-free inhalable formulations comprising the compounds of the invention may be in form of solutions or suspensions in an aqueous, alcoholic or hydroalcoholic medium and they may be delivered by known jet or ultrasonic nebulizers or by soft-mist nebulizers such as Respimat®.

The compounds of the invention may be administered as the sole active agent or in combination with one or more other pharmaceutical active

ingredients including those currently used in the treatment of respiratory disorders, e. g. β_2 -agonists, corticosteroids and M3 antagonists.

The dosages of the compounds of the invention may depend upon a variety of factors including the particular disease to be treated, the severity of the symptoms, the route of administration, the frequency of the dosage interval, the particular compound utilized, the efficacy, toxicology profile, and pharmacokinetic profile of the compound.

Advantageously, the compounds of formula (I) may be administered for example, at a dosage comprised between 0.001 and 1000 mg/day, preferably between 0.1 and 500 mg/day.

When they are administered by inhalation route, the dosage of the compounds of formula (I) is advantageously comprised between 0.01 and 20 mg/day, preferably between 0.1 and 10 mg/day.

Preferably, the compounds of formula (I) alone or combined with other active ingredients may be administered for the prevention and/or treatment of any obstructive respiratory disease such as asthma, chronic bronchitis and chronic obstructive pulmonary disease (COPD).

However the compounds of formula (I) may be administered for the prevention and/or treatment of any disease wherein the activity of PDE4 receptors is implicated and inhibition of PDE4 receptor activity is desired, or a disease state which is mediated by PDE4 activity (for instance a disease state in which PDE4 is overexpressed or overactive). Examples of such diseases include: allergic disease states such as atopic dermatitis, urticaria, allergic rhinitis, allergic conjunctivitis, vernal conjunctivitis, eosinophilic granuloma, psoriasis, inflammatory arthritis, rheumatoid arthritis, septic shock, ulcerative colitis, Crohn's disease, reperfusion injury of the myocardium and brain, chronic glomerulonephritis, endotoxic shock, cystic fibrosis, arterial restenosis, atherosclerosis, keratosis, rheumatoid spondylitis, osteoarthritis,

pyresis, diabetes mellitus, pneumoconiosis, toxic and allergic contact eczema, atopic eczema, seborrheic eczema, lichen simplex, sunburn, itching in the anogenital area, alopecia areata, hypertrophic scars, discoid lupus erythematosus, systemic lupus erythematosus, follicular and wide-area
5 pyodermias, endogenous and exogenous acne, acne rosacea, Beghet's disease, anaphylactoid purpura nephritis, inflammatory bowel disease, leukemia, multiple sclerosis, gastrointestinal diseases, autoimmune diseases and the like.

They also include neurological and psychiatric disorders such as Alzheimer's disease, multiple sclerosis, amyolaterosclerosis (ALS), multiple
10 systems atrophy (MSA), schizophrenia, Parkinson's disease, Huntington's disease, Pick's disease, depression, stroke, and spinal cord injury.

The present invention will now be further described by way of the following examples.

EXAMPLE 1

15 **Preparation of 1-(3-Cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethanol (3)**

A solution of 3-cyclopropylmethoxy-4-difluoromethoxy-benzaldehyde (5.00 g) and 3,5-dichloro-4-methylpyridine (2.57 g) in 50 ml dry THF was cooled to -30°C.

20 Solid potassium t-butoxide (tBuOK, 1.96 g) was added portionwise maintaining the temperature between -30°C and -20°C, thus obtaining a dark red solution. After completion of the addition, the mixture was stirred at -30°C for 1h. A saturated aqueous solution of NH₄Cl (50 ml) was then added to the reaction mixture, maintaining the temperature between -5°C and -10°C. The
25 color of the reaction mixture turned to yellow.

The mixture was then extracted with EtOAc. The organic layer was dried over Na₂SO₄ and the solvent was evaporated off. The residue was treated with 30 ml of a mixture of petroleum ether/ EtOAc =8/2; the precipitate was

filtered and dried, obtaining 4.83 g of the title compound that was employed in the next step without further purification.

MS/ESI⁺ 404-406 [MH]⁺.

EXAMPLE 2

5 **Preparation of 1-(3-Cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethanol (4)**

Compound (3) (13.0 g) was dissolved in CH₂Cl₂ (250 ml) then m-chloro perbenzoic acid (16.5 g) was added and the resulting solution was stirred at room temperature for 2 hours. Na₂S₂O₃ (25.4 g) was added and the mixture
10 was vigorously stirred at r.t. for 1 hour. The solid residue was filtered off, the solution was washed with 1N NaOH (3x100 ml) then the organic phase was dried over Na₂SO₄ and the solvent was evaporated off to give 10.3 g of the desired product (4) as a white solid that was used in the next steps without further purification.

15 MS/ESI⁺ 420-422 [MH]⁺

EXAMPLE 3

Preparation of Acetoxy-phenyl-acetic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester (5, mixture of diastereoisomers)

20 Compound (4) (19.95 g), (S)-acetylmandelic acid (9.22g), 1-ethyl-3-[3-dimethylamino propyl]carbodiimide hydrochloride (18 g) and 4-dimethylaminopyridine (2.89 g) were dissolved, under N₂ atmosphere, in dry CH₂Cl₂ (300 ml). The reaction mixture was stirred at room temperature overnight. A 5% aqueous solution of NaHCO₃ (200 ml) was added and the
25 aqueous phase was extracted with CH₂Cl₂ (3 x 100 ml). The combined organic phases were dried over Na₂SO₄ and the solvent was evaporated under reduced pressure to give the title compound (5) as mixture of two diastereoisomers (32 g); separation of the two diastereoisomers is described in Examples 4 and 6.

EXAMPLE 4**Preparation of (+)-Acetoxy-phenyl-acetic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester (6)**

5 The crude diastereomeric mixture (5) (32g) was triturated with Et₂O (100 ml), sonicated and filtered. The procedure was repeated four times in order to obtain a solid mixture enriched in diastereoisomer (6). This solid was crystallized from iPrOH (80 ml) and filtered to give 9.65 g of compound (6) with diastereomeric purity >95%. The diastereomeric purity was determined
10 by HPLC analysis and by analytical chiral HPLC performed on Chiracel OD column (isocratic elution with hexane:isopropanol 40:60, flow 0.45 ml/min, retention time = 27.2 min).

MS/ESI⁺ 596, 598 [MH]⁺

¹H NMR (300 MHz, DMSO-d₆) ppm 8.57 (s, 2 H), 7.27 - 7.44 (m, 5
15 H), 6.91 - 7.18 (m, 1 H), 7.03 (t, 1 H), 6.71 - 6.79 (m, 2 H), 5.95 (dd, 1 H), 5.85 (s, 1 H), 3.72 (dd, 1 H), 3.60 (dd, 1 H), 3.41 (dd, 1 H), 3.23 (dd, 1 H), 2.13 (s, 3 H), 1.07 - 1.31 (m, 1 H), 0.48 - 0.72 (m, 2 H), 0.21 - 0.44 (m, 2 H)

[α]_D = +14° (c=0.54, MeOH)

EXAMPLE 5**Preparation of (+)-1-(3-Cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethanol (7)**

20 Compound (6) (6.42 g) was suspended in methanol (350 ml) then a saturated solution of NaHCO₃ (175 ml) was added. The white suspension was vigorously stirred at room temperature overnight. The reaction mixture was
25 diluted with CH₂Cl₂ (700 ml) and washed with a 5% aqueous solution of NaHCO₃ (300 ml); the aqueous phase was extracted with CH₂Cl₂ (2 x 300 ml), the combined organic layers were dried over Na₂SO₄ and the solvent was evaporated off under vacuum. The crude white solid obtained was triturated

with Et₂O (2x100 ml) and filtered to give 3.88 g of compound (7) with enantiomeric purity >99%. The enantiomeric purity was determined by analytical chiral HPLC performed on Chiracel OD column (isocratic elution with hexane:isopropanol 30:70, flow 0.35 ml/min, retention time = 22.3 min).

5 MS/ESI⁺ 420-422 [MH]⁺

¹H NMR (300 MHz, DMSO-d₆) ppm 8.51 (s, 2 H), 7.11 (d, 1 H), 7.05 (d, 1 H), 6.88 (dd, 1 H), 7.01 (t, 1 H), 5.59 (d, 1 H), 4.84 (dd, 1 H), 3.89 (dd, 1 H), 3.84 (dd, 1 H), 3.18 (dd, 1 H), 3.02 (dd, 1 H), 1.03 - 1.35 (m, 1 H), 0.46 - 0.67 (m, 2 H), 0.24 - 0.46 (m, 2 H)

10 [α]_D = +68° (c=0.5, MeOH)

EXAMPLE 6

Preparation of (+)-Acetoxy-phenyl-acetic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester (8)

15 The crude diastereomeric mixture (5) was triturated with Et₂O (100 ml), sonicated and filtered. The procedure was repeated four times, and the filtrates were collected and evaporated under reduced pressure to give a solid mixture enriched in diastereoisomer (8) that was crystallized from iPrOH (100 ml) to give 6.4g of compound (8) as a white solid with diastereomeric purity >99%.
20 The diastereomeric purity was determined by HPLC analysis and by analytical chiral HPLC performed on Chiracel OD column (isocratic elution with hexane:isopropanol 40:60, flow 0.45 ml/min, retention time = 21.6min).

MS/ESI⁺ 596, 598 [MH]⁺

¹H NMR (300 MHz, DMSO-d₆) ppm 8.27 (s, 2 H), 7.27 - 7.45 (m, 5 H),
25 7.20 (d, 1 H), 7.08 (d, 1 H), 7.00 (dd, 1 H), 7.08 (t, 1 H), 5.97 (dd, 1 H), 5.85 (s, 1 H), 3.93 (dd, 1 H), 3.89 (dd, 1 H), 3.33 (dd, 1 H), 3.17 (dd, 1 H), 2.07 (s, 3 H), 1.14 - 1.38 (m, 1 H), 0.50 - 0.71 (m, 2 H), 0.21 - 0.47 (m, 2 H)

[α]_D = +26° (c=0.55, MeOH)

EXAMPLE 7**Preparation of (-)-1-(3-Cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethanol (9)**

Compound (8) (1.18 g) was suspended in methanol (50 ml) then a
5 saturated solution of NaHCO₃ (25 ml) was added. The white suspension was
vigorously stirred at room temperature for 24 hours. The reaction mixture was
diluted with CH₂Cl₂ (700 ml) then a 5% aqueous solution of NaHCO₃
(300 ml) was added and the phases are separated. The aqueous phase was
extracted with CH₂Cl₂ (2 x 100 ml), the combined organic layers were dried
10 over Na₂SO₄ and the solvent was evaporated off under vacuum. The crude
white solid obtained was triturated twice with Et₂O (50 ml) and once with
CH₂Cl₂ (20 ml), then was filtered to give 0.74 g of compound (7) with
enantiomeric purity >99%. The enantiomeric purity was determined by
analytical chiral HPLC performed on Chiracel OD column (isocratic elution
15 with hexane:isopropanol 30:70, flow 0.35 ml/min, retention time = 24.0 min).

MS/ESI⁺ 420-422 [MH]⁺

¹H NMR (300 MHz, DMSO-d₆) ppm 8.51 (s, 2 H), 7.11 (d, 1 H), 7.05
(d, 1 H), 6.88 (dd, 1 H), 7.01 (t, 1 H), 5.59 (d, 1 H), 4.84 (dt, 1 H), 3.89 (dd, 1
H), 3.84 (dd, 1 H), 3.18 (dd, 1 H), 3.02 (dd, 1 H), 1.08 - 1.32 (m, 1 H),
20 0.47 - 0.66 (m, 2 H), 0.26 - 0.45 (m, 2 H)

[α]_D = -61° (c=0.5, MeOH)

EXAMPLE 8

**2-(6-Methoxy-naphthalen-2-yl)-propionic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-
25 4-yl)-ethyl ester (10, mixture of diastereoisomers 11 and 13)**

Compound (3) (12.0 g) was dissolved in DMF (100 ml) then (S)-2-(6-methoxy-naphthalen-2-yl)-propionic acid (7.5 g), 4-dimethylaminopyridine (3.6 g) and 1-ethyl-3-[3-dimethylaminopropyl]carbodiimide hydrochloride

(5.7 g) were added. After stirring at rt for 4 hours, water (1000 ml) is added. The mixture was extracted with EtOAc (500 ml x 2), the combined organic layers are dried over sodium sulphate and the solvent was evaporated off under reduced pressure to afford 17.0 g of an oil which is crystallized from EtOH thus obtaining
5 11.5 g of the title compound as mixture of diastereomers (11) and (13).

^1H NMR (200 MHz, CDCl_3) ppm 8.43 and 8.60 (2s, 1H each, 2H), 7.51-7.68 (m, 3H), 7.10-7.23 (m, 3H), 6.85-6.97 (m, 2H), 6.51-6.68 (m, 1H), 6.22-6.97 (t, 1H, CHF_2), 6.00-6.13 (m, 1H), 3.93-3.95 (s, 3H, OCH_3), 3.72-3.84 (m, 2H), 3.07-3.57 (m, 3H), 1.42-1.45 (d, 3H, CH_3), 0.94-1.25 (m,
10 1H), 0.51-0.67 (m, 2H), 0.12-0.36 (m, 2H).

MS/ESI⁺ 616, 618 [MH]⁺

EXAMPLE 9

**(+)-2-(6-Methoxy-naphthalen-2-yl)-propionic acid 1-(3-cyclopropyl methoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethyl
15 ester (second eluted diastereoisomer) (13)**

The compound was isolated from the diastereomeric mixture of example 8 by HPLC separation using a Daisogel 10 μm , 50x300 mm column; eluent: n-hexane/methyl-*tert*-butyl-ether/isopropyl alcohol: 90/9.9/0.1; flow: 80 ml/min.; loading: 300 mg per injection; elution time: from 11 to 20 min.
20 The collected fractions were evaporated and the residue was crystallized from n-hexane/isopropyl-alcohol.

^1H NMR (200 MHz, CDCl_3) ppm 8.60 (s, 2H), 7.68-7.75 (m, 2H), 7.58-7.59 (m, 1H), 7.27-7.29 (d, 1H), 7.12-7.24 (m, 2H), 6.98-7.04 (m, 1H), 6.73-6.78 (dd, 1H), 6.67-6.68 (d, 1H), 6.60-7.35 (t, 1H, CHF_2), 5.99-6.06 (m, 1H),
25 3.84-3.87 (m, 4H), 3.47-3.55 (m, 2H), 3.32-3.41 (dd, 1H), 3.22-3.29 (m, 1H), 1.33-1.37 (d, 3H, CH_3), 0.96-1.03 (m, 1H), 0.43-0.52 (m, 2H), 0.13-0.21 (m, 2H).

MS/ESI⁺ 616, 618 [MH]⁺

$[\alpha]_{\text{D}} = +52.8^\circ$ (c=0.5, MeOH)

EXAMPLE 10

(+)-2-(6-Methoxy-naphthalen-2-yl)-propionic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethyl ester (first eluted diastereoisomer) (11)

5 The compound was isolated from the diastereomeric mixture of example 8 by HPLC separation using a Daisogel 10 μ m, 50x300 mm column; eluent: n-hexane/methyl-*tert*-butyl-ether/isopropyl-alcohol: 90/9.9/0.1; flow: 80 ml/min.; loading: 300 mg per injection; elution time: from 7 to 10 min. The collected fractions were evaporated and the residue was crystallized from
10 n-hexane/isopropyl-alcohol.

^1H NMR (200 MHz, CDCl_3) ppm 8.27 (s, 2H), 7.64-7.80 (m, 2H), 7.56-7.57 (m, 1H), 7.28-7.29 (d, 1H), 7.14-7.20 (m, 3H), 6.68-7.42 (t, 1H, CHF_2), 6.93-6.98 (m, 2H), 6.00-6.07 (m, 1H), 3.88-3.92 (m, 4H), 3.71-3.84 (m, 2H), 3.39-3.51 (dd, 1H), 3.16-3.25 (dd, 1H), 1.33-1.37 (d, 3H, CH_3),
15 1.08-1.23 (m, 1H), 0.50-0.59 (m, 2H), 0.34-0.26 (m, 2H).

MS/ESI⁺ 616, 618 [MH]⁺

$[\alpha]_{\text{D}} = +45^\circ$ (c=0.5, MeOH)

EXAMPLE 11

(+)-1-(3-Cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethanol (14)

20

To a suspension of (+)-2-(6-methoxy-naphthalen-2-yl)-propionic acid-1-(3-cyclopropyl methoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethyl ester (13) (14.0 g) in methanol (110 ml), potassium *tert*-butoxide (5.1 g) was added. The resulting mixture was stirred at rt for 2 hrs, obtaining a clear solution.
25 Water was slowly added under stirring to incipient precipitation (turbid solution).

After stirring for further 60 min. the precipitated solid was filtered, washed with water and dissolved in chloroform (100 ml). The solution was dried over sodium sulphate and the solvent removed under vacuum. The residue

was crystallized in chloroform/ hexane=1/2.5 to obtain 8.1 g of white solid.

^1H NMR (200 MHz, CDCl_3) ppm δ 8.45 (s, 2H), 7.19-7.08 (d, 1H), 7.06-7.00 (d, 1H), 6.95-6.85 (dd, 1H), 6.99-6.24 (t, 1H, CHF_2), 5.18-5.00 (m, 1H), 3.98-3.78 (m, 2H), 3.54-3.35 (m, 1H), 3.31-3.15 (m, 1H), 2.04-1.94
5 (d, 1H, OH), 1.40-1.14 (m, 1H), 0.75-0.53 (m, 2H), 0.50-0.29 (m, 2H).

MS/ESI⁺ 404, 406 [MH]⁺.

$[\alpha]_{\text{D}} = +9.35^\circ$ (c=1, CHCl_3).

EXAMPLE 12

(-)-1-(3-Cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethanol (12) 10

Starting from diastereoisomer (11), following the procedure of Example 10, alcohol (12) was obtained.

MS/ESI⁺ 404, 406 [MH]⁺.

$[\alpha]_{\text{D}} = -9.15^\circ$ (c=1, CHCl_3).

EXAMPLE 13 15

Preparation of alcohol (7) by oxidation of alcohol (14)

Compound (14) (3.0 g) was dissolved in CH_2Cl_2 (100 ml). 70% m-Chloro perbenzoic acid (5.4 g) was added and the resulting solution was stirred at room temperature for 18 hours. Solid $\text{Na}_2\text{S}_2\text{O}_3$ (5 g) was then added
20 and the mixture was vigorously stirred at r.t. for 30 min. The solid residue was filtered off; the organic solution was diluted with additional 100 ml of CH_2Cl_2 and washed with aqueous saturated NaHCO_3 solution (3x100 ml). The organic phase was dried over Na_2SO_4 and the solvent was evaporated off. The residue was triturated in EtOAc (20 ml) to give 1.9 g of the desired product 7 as a
25 white solid, which was used in the next step without further purification.

^1H NMR (200 MHz, CDCl_3) ppm δ 8.14 (s, 2H), 7.18-7.09 (d, 1H), 7.07-7.02 (d, 1H), 6.92-6.83 (dd, 1H), 7.01-6.22 (t, 1H, CHF_2), 5.10-4.96 (m, 1H), 3.96-3.84 (d, 2H), 3.45-3.29 (m, 1H), 3.23-3.07 (m, 1H), 3.24-3.17 (d,

1H, OH), 1.41-1.67 (m, 1H), 0.75-0.53 (m, 2H), 0.50-0.29 (m, 2H).

MS/ESI⁺ 420, 422 [MH]⁺

[α]_D = + 65.0° (c=0.5, MeOH)

EXAMPLE 14

5 **Preparation of alcohol (9) by oxidation of alcohol (12)**

Alcohol (9) may be obtained following the procedure described in Example 13, using alcohol (12) in place of alcohol (14) as starting material.

MS/ESI⁺ 420, 422 [MH]⁺

[α]_D = -60.6° (c=0.5, MeOH)

10 EXAMPLE 15

Preparation of (-)-3-Cyclopropylmethoxy-4-methanesulfonylamino-benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-pyridin-4-yl)-ethyl ester (C1)

Step 1: 3-Cyclopropylmethoxy-4-(N-tert-butoxycarbonyl-N-methanesulfonyl)-amino benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethyl ester

1-Ethyl-3-[3-dimethylamino propyl]carbodiimide hydrochloride (2.85 g) was added to a solution of alcohol (14) (2.0 g), 4-dimethylaminopyridine (0.3 g), 3-cyclopropylmethoxy-4-(N-tert-butoxycarbonyl-N-methanesulfonyl)-amino-benzoic acid (2.0 g) in dry CH₂Cl₂ (180 ml) at r.t. under nitrogen atmosphere.

After stirring at r.t. overnight, the mixture was washed with 5% aqueous HCl (2 x 100 ml); the organic phase was separated and washed with a saturated aqueous solution of NaHCO₃ (2 x 100 ml), dried over Na₂SO₄ and evaporated to dryness. The crude was purified by flash chromatography on silica gel in gradient elution (hexane/EtOAc 10/1 to 6/4) to afford 1.4 g of the title compound.

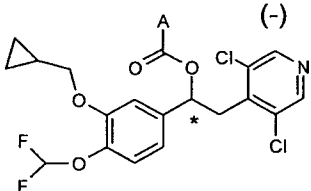
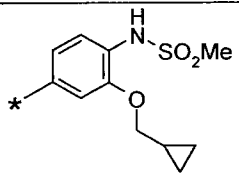
25 Step 2: Preparation of C1

3-Cyclopropylmethoxy-4-(N-tert-butoxycarbonyl-N-methanesulfonyl)-

amino-benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethyl ester (1.4 g) was dissolved in CH₂Cl₂ (140 ml). A 4M solution of HCl in dioxane (40 ml) was added and the resulting mixture was stirred at r.t. for 24 hours. The reaction mixture was then evaporated to dryness and the residue was triturated in iPrOH (50 ml) and subsequently in EtOH (50 ml) followed by Et₂O (70 ml) to afford 0.880 g of compound (C1).

Analytical characterisation of C1 is reported in Table 1.

Table 1

		
Compound	A	analytical
C1		MS/ESI⁺ 671, 673 [MH]⁺; ¹H NMR (300 MHz, DMSO-d₆) ppm 9.13 (br. s., 1 H) 8.60 (s, 2 H) 7.55 (dd, 1 H) 7.44 - 7.49 (m, 1 H) 7.39 (d, 1 H) 7.06 (t, 1 H) 6.78 - 7.33 (m, 3 H) 6.20 - 6.30 (m, 1 H) 3.87 - 3.98 (m, 4 H) 3.63 - 3.78 (m, 1 H) 3.38 - 3.50 (m, 1 H) 3.10 (s, 3 H) 1.09 - 1.40 (m, 2 H) 0.48 - 0.67 (m, 4 H) 0.28 - 0.44 (m, 4 H) [α]_D = -22° (c=0.4, MeOH)

10 Analogously, the following compounds may be prepared:

- (-)-4-Cyclopropylmethoxy-3-methanesulfonylamino-benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethyl ester,
- (-)-3,4-Bis-methanesulfonylamino-benzoic acid 1-(3-

cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethyl ester,

- (-)-3-Methanesulfonylamino-4-methyl-benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-pyridin-4-yl)-ethyl ester and
- (-)-4-Methanesulfonylamino-3-methyl-benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester.

EXAMPLE 16

10 **Preparation of (-)-3-Cyclopropylmethoxy-4-methanesulfonylamino-benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester (C2)**

Compound (C2) was prepared according to the same synthetic procedure of Example 15, starting from alcohol intermediate (7).

15 Alternatively, compound (C2) can be prepared starting from compound (C1) as described in the following Example 17.

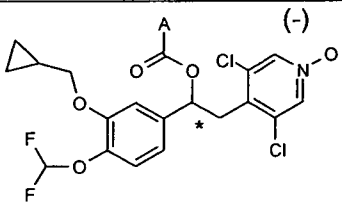
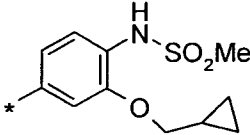
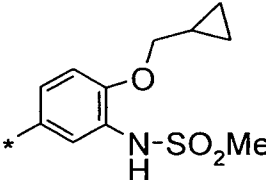
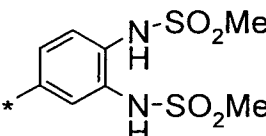
EXAMPLE 17

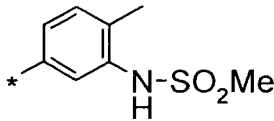
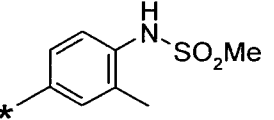
20 **Preparation of (-)-3-Cyclopropylmethoxy-4-methanesulfonylamino-benzoic acid 1-(3-cyclopropylmethoxy-4-difluoromethoxy-phenyl)-2-(3,5-dichloro-1-oxy-pyridin-4-yl)-ethyl ester (C2) starting from compound (C1)**

Compound (C1) (0.69 g) was dissolved in CH₂Cl₂ (20 ml). 70% m-Chloro perbenzoic acid (0.355 g) was added and the resulting solution was stirred at room temperature for 18 hours. Solid Na₂S₂O₃ (0.244 g) was then added and the mixture was vigorously stirred at r.t. for 30min. The solid residue was filtered off; the organic solution was diluted with additional 20 ml of CH₂Cl₂ and washed with aqueous saturated NaHCO₃ solution (3x20 ml). The organic phase was dried over Na₂SO₄ and the solvent was evaporated off. The residue was triturated in EtOH (20 ml) to give 0.710 g of the desired compound (C2) as a white solid.

The following compounds were prepared following the same route using suitable reagents:

Table 2

		
Compound	A	Analytical
C2		MS/ESI ⁺ 687, 689 [MH] ⁺ ; ¹ H NMR (300 MHz, DMSO-d ₆) ppm 9.14 (br. s., 1 H), 8.56 (s, 2 H), 7.59 (dd, 1 H), 7.49 (d, 1 H), 7.41 (d, 1 H), 7.14 - 7.27 (m, 2 H), 7.07 (dd, 1 H), 7.06 (t, 1 H), 6.18 (dd, 1 H), 3.84 - 4.04 (m, 4 H), 3.61 (dd, 1 H), 3.34 (dd, 1 H), 3.11 (s, 3 H), 1.25 - 1.43 (m, 1 H), 1.13 - 1.26 (m, 1 H), 0.49 - 0.67 (m, 4 H), 0.27 - 0.47 (m, 4 H) [α] _D = -47° (c=0.4, MeOH)
C3		¹ H NMR (200 MHz, CD ₃ OD-d ₄ calibrated at 3.31 ppm) δ ppm 8.42 (s, 2 H), 8.13 (d, J=2.44 Hz, 1 H), 7.85 (dd, J=8.79, 2.44 Hz, 1 H), 7.12 - 6.37 (t, 1H, CHF ₂), 7.00 - 7.24 (m, 4 H), 6.26 - 6.40 (m, 1 H), 3.97 (dd, J=14.89, 7.08 Hz, 4 H), 3.75 (dd, J=13.92, 9.52 Hz, 1 H), 3.45 (dd, J=14.16, 4.39 Hz, 1 H), 2.98 (s, 3 H), 1.17 - 1.45 (m, 2 H), 0.54 - 0.75 (m, 4 H), 0.29 - 0.47 (m, 4 H) [α] _D = -36 (c=0.1, CHCl ₃)
C4		¹ H NMR (200 MHz, CDCl ₃ calibrated at 7.26 ppm) δ ppm 8.23 (s, 2 H), 7.85 - 8.01 (m, 2 H), 7.69 (d, J=8.30 Hz, 1 H), 7.20 (m, 1 H), 7.00 - 6.25 (t, 1H, CHF ₂), 6.97 - 7.11 (m, 2 H), 6.21 - 6.32 (m, 1 H), 3.91 (d, J=6.84 Hz, 2 H), 3.72 (dd, J=13.67, 10.74 Hz, 1 H), 3.32 (dd, J=13.92, 3.66 Hz, 1 H), 3.04 (d, J=17.58 Hz, 6 H), 1.16 - 1.35 (m, 1 H), 0.55 - 0.74 (m, 2 H), 0.30 - 0.45 (m, 2 H) [α] _D = -27 (c=0.1, CHCl ₃)

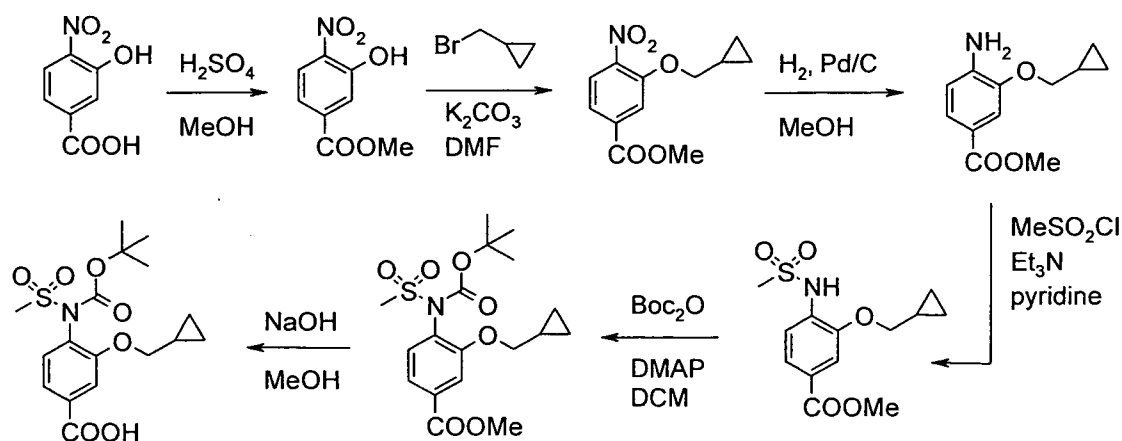
C5		¹ H NMR (200 MHz, DMSO-d ₆ calibrated at 2.50 ppm) δ ppm 9.25 (s, 1 H), 8.53 (s, 2 H), 7.91 (m, 1 H), 7.76 (d, J=8.30 Hz, 1 H), 7.43 - 6.69 (t, 1H, CHF ₂), 7.40 (d, J=8.30 Hz, 1 H), 7.19 (d, J=4.39 Hz, 2 H), 7.00 - 7.12 (m, 1 H), 6.21 (dd, J=9.52, 4.15 Hz, 1 H), 3.92 (d, J=6.84 Hz, 2 H), 3.63 - 3.55 (m, 1 H), 3.37 (d, J=4.39 Hz, 1 H), 2.99 (s, 3 H), 2.37 (s, 3 H), 1.11 - 1.28 (m, 1 H), 0.48 - 0.65 (m, 2 H), 0.26 - 0.41 (m, 2 H) [α] _D = - 38.67°
C6		¹ H NMR (200 MHz, DMSO-d ₆ calibrated at 2.50 ppm) δ ppm 8.55 (s, 2 H), 7.93-7.83 (m, 2 H), 7.49 (d, J=8.30 Hz, 1 H), 7.43 - 6.69 (t, 1H, CHF ₂), 7.03 - 7.27 (m, 3 H), 6.11 - 6.24 (m, 1 H), 3.93 (d, J=6.84 Hz, 2 H), 3.60 (s, 3 H), 2.28 (s, 3 H), 1.11 - 1.29 (m, 1 H), 0.57 (m, 2 H), 0.34 (m, 2 H) [α] _D = - 58.0°

The carboxylic acid intermediates employed in the synthesis of the described final compounds are commercially available or are already known or are synthesized according to known methods.

EXAMPLE 18

5 Synthesis of 3-Cyclopropylmethoxy-4-(N-tert-butoxycarbonyl-N-methane-sulfonyl)-amino-benzoic acid

Scheme 2



Step 1: 3-Hydroxy-4-nitro-benzoic acid methyl ester

3-Hydroxy-4-nitro-benzoic acid (10 g) was dissolved in MeOH (500 ml). 96% H₂SO₄ (2 ml) was added and the mixture was heated to 60°C for 18 hours. The reaction mixture was concentrated to approx. 200 ml, diluted with EtOAc (200 ml) and washed with an aqueous saturated solution of NaHCO₃ (2 x 20 ml). The organic layer was dried over Na₂SO₄ and the solvent was evaporated off to yield 10.5 g of the desired intermediate.

Step 2: 3-Cyclopropylmethoxy-4-nitro-benzoic acid methyl ester

3-Hydroxy-4-nitro-benzoic acid methyl ester (10.5 g) was dissolved in dry DMF (150 ml) under N₂ atmosphere. K₂CO₃ (24.3 g), KI (2.6 g) and cyclopropylmethylbromide (10.3 ml) were added and the mixture was stirred at 50°C for 6 hours. The reaction mixture was diluted with water (300 ml) and extracted with Et₂O (2 x 200 ml); the combined organic layers were dried over Na₂SO₄ and the solvent was evaporated off to yield 12.7 g of the desired intermediate.

Step 3: 4-Amino-3-cyclopropylmethoxy-benzoic acid methyl ester

3-Cyclopropylmethoxy-4-nitro-benzoic acid methyl ester (12.7 g) was dissolved in MeOH (100 ml) and EtOAc (100 ml); 10% Pd/C (1.0 g, suspended in 20 ml of water) was added and the mixture is hydrogenated in a Parr apparatus (H₂: 20 psi) for 5 hours. 37%HCl was added (10 ml) and hydrogenation was continued for additional 2 hours to obtain complete conversion. The catalyst was filtered over a celite pad, the mixture was diluted with EtOAc (200 ml) and washed with an aqueous saturated solution of NaHCO₃ (2 x 100 ml). The organic layer was dried over Na₂SO₄ and the solvent was evaporated off to yield 10.7 g of the desired intermediate.

Step 4: 3-Cyclopropylmethoxy-4-methanesulfonylamino-benzoic acid methyl ester

Methyl 3-(cyclopropylmethoxy)-4-aminobenzoate (8.86 g) was

dissolved in pyridine (80 mL) at room temperature under N₂ atmosphere. Methanesulfonyl chloride (4.04 mL) was added and the mixture was stirred at r.t. for 18 hours. The reaction mixture was evaporated to dryness, the crude

- 5 The organic layer was dried over Na₂SO₄ and the solvent was evaporated off to yield 11.7 g of the desired intermediate.

MS/ESI⁺ 300 [MH]⁺

Step 5: 3-Cyclopropylmethoxy-4-(N-tert-butoxycarbonyl-N-methanesulfonyl)-amino-benzoic acid methyl ester

- 10 3-Cyclopropylmethoxy-4-methanesulfonylamino-benzoic acid methyl ester (3.0g) was dissolved in CH₂Cl₂ (150 ml). Dimethylaminopyridine (DMAP, 1.22 g) and Boc₂O (2.18 g) were added and the mixture was stirred at r.t. for 1 hour. The reaction mixture was washed with 5% aqueous HCl (2 x 50 ml), the organic layer was dried over Na₂SO₄ and the solvent was evaporated off. The
- 15 residue was triturated in Et₂O and filtered to afford 4.0 g of the desired intermediate that was used in the next steps without further purification.

Step 6: 3-Cyclopropylmethoxy-4-(N-tert-butoxycarbonyl-N-methanesulfonyl)-amino-benzoic acid

- 20 Cyclopropylmethoxy-4-(N-tert-butoxycarbonyl-N-methanesulfonyl)-amino-benzoic acid methyl ester (4.0 g) was dissolved in MeOH (100 ml). 1N NaOH (15 ml) was added and the resulting mixture was stirred at r.t. for 1 hour, then was heated to 50°C for 2 hours. The reaction mixture was then diluted with EtOAc (250 ml) and washed with 1N HCl (2 x 100 ml). The organic layer was dried over Na₂SO₄ and the solvent was evaporated off to
- 25 give 3.5 g of the desired acid derivative.

MS/ESI⁺ 386 [MH]⁺.

Legend

* NMR

s = singlet

d = doublet

t = triplet

q = quartet

5 dd = doublet of doublets

m = multiplet

br = broad

ESI = electrospray

PHARMACOLOGICAL ACTIVITY OF THE COMPOUNDS OF

10 THE INVENTION

EXAMPLE 19

In vitro determination of PDE4 inhibitory activity in the peripheral blood mononuclear cells (PBMCs) assay

The assay, which is based on the known inhibitory activity exerted by
15 PDE4 inhibitors on the lipopolysaccharides (LPS)-induced tumour necrosis factor-alpha (TNF- α) release in peripheral blood mononuclear cells (PBMCs), is performed according to a method previously described (Hatzelmann A et al *J. Pharmacol. Exp. Ther.* 2001; 297:267-279; Draheim R et al *J. Pharmacol. Exp. Ther.* 2004; 308:555-563.

20 Cryopreserved human PBMCs, (100 μ l/well) are incubated in 96-well plates (10^5 cells/well), for 30 min, in the presence or absence (50 microl) of the test compounds whose concentrations range from 10^{-12} M to 10^{-6} M. Subsequently, LPS (3 ng/ml) is added.

After 18 h incubation at 37°C in a humidified incubator under an
25 atmosphere of 95% air and 5% CO₂, culture medium is collected and TNF- α measured by ELISA.

The results regarding compounds C1 to C6, expressed as mean $\pm$ 95% confidence limits of the molar concentration of the test compound producing

50% inhibition of LPS-induced TNF- α release (IC_{50}), are comprised between 0.06 and 4.4 nM. The effects of the tested compounds are calculated as percentage of inhibition of TNF- α release, assuming LPS-induced TNF- α production in the absence of inhibitor compound as 100% and basal TNF- α production of PBMCs in the absence of LPS as 0%.

EXAMPLE 20

Evaluation of the ability to inhibit the low affinity LPDE4 versus the ability to compete for the high affinity HPDE4

The affinity toward LPDE4 and HPDE4 is assessed as previously described respectively in Cortijo J et al *Br J Pharmacol* 1993, 108: 562-568 and Duplantier AJ et al *J Med Chem* 1996; 39: 120-125.

The concentration of the test compound ranges between 10^{-12} M and 10^{-5} M. The values of affinity toward LPDE4 and HPDE4 tested on compounds C1 to C6 are comprised between 82 and 477.

15 In the case of LPDE4, the IC_{50} is the molar concentration of the test compound producing 50% inhibition of cAMP disappearance, while in the case of HPDE4, the IC_{50} is the molar concentration of the test compound producing 50% inhibition of the binding of [H^3] rolipram.

The results indicate that the compounds of the invention inhibit LPDE4 with subnanomolar affinity and are considerably more selective toward LPDE4 versus HPDE4.

EXAMPLE 21

Synergistic activity of fixed dose combination of Carmoterol/C1 on carbachol-induced contraction in guinea-pigs trachea.

25 Zig-zag tracheal segments are obtained from male Ovoalbumin(OA)-sensitised guinea pigs and two preparations are obtained from a trachea. Each preparation is placed in 20-ml organ bath filled with oxygenated (O_2 95% and CO_2 5%) normal Krebs-Henseleit solution and maintained at 37°C. Tracheal

preparations are connected to isometric force transducers under a resting tone of 1 g. After an equilibration period of 60 min, tracheal preparations are pretreated for 30 min with C1 (10^{-7} M), Carmoterol ($3 \cdot 10^{-10}$ M), the association C1 and Carmoterol or vehicle, respectively, followed by
5 cumulative administration of OA (10^{-10} - 10^{-5} g/ml). At the end of the OA administration a maximal concentration of carbachol (10^{-5} M) is added to obtain the maximal contraction of each preparation. The effects are expressed as percent values of the carbachol-induced maximal response (100%).

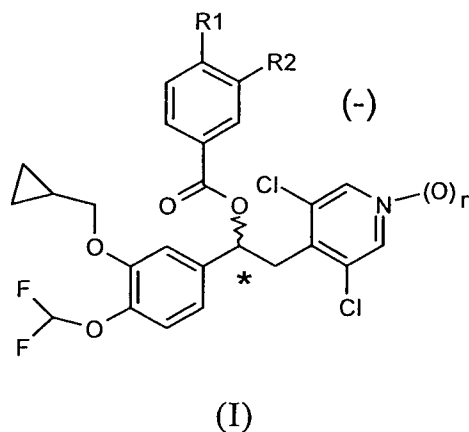
30-min pre-treatment of the preparation with C1 (10^{-7} M) caused an
10 inhibition of the OA-induced contraction of 23%. Similarly the inhibition produced by Carmoterol ($3 \cdot 10^{-10}$ M) is 18%.

C1 (10^{-7} M) and Carmoterol ($3 \cdot 10^{-10}$ M)-combination caused a reduction of the OA-induced contraction of the 93%.

This study shows that both carmoterol and C1 are potent in
15 antagonizing carbachol-induced contraction in guinea-pig airways. Moreover, in line with their complementary molecular mechanism of action, in the frame of a functional agonism-antagonism, fixed combinations display synergistic effect in the control of cholinergic contraction in guinea-pig trachealis.

CLAIMS

1. A compound of general formula (I) as (-) enantiomer



wherein:

n is 0 or 1;

R1 and R2 may be the same or different, and are selected from the group consisting of:

- linear or branched C₁-C₆ alkyl, optionally substituted by one or more halogen atoms;
- OR3 wherein R3 is a linear or branched C₁-C₆ alkyl optionally substituted with one or more halogen atoms or C₃-C₇ cycloalkyl groups; and
- HNSO₂R4 wherein R4 is a linear or branched C₁-C₄ alkyl optionally substituted with one or more halogen atoms,

wherein at least one of R1 and R2 is HNSO₂R4, the pharmaceutically acceptable inorganic or organic salts, hydrates, solvates or addition complexes thereof.

2. A compound according to claim 1, wherein R1 is HNSO₂R4, wherein R4 is methyl, R2 is OR3, wherein R3 is cyclopropylmethyl and n is 0.
3. A compound according to claim 1, wherein R1 is HNSO₂R4, wherein R4 is methyl, R2 is OR3, wherein R3 is cyclopropylmethyl and n is 1.

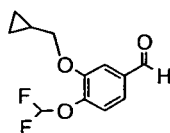
4. A compound according to claim 1, wherein R1 is OR3, R2 is HNSO₂R4 wherein R4 is methyl and n is 1.

5. A compound according to claim 1, wherein R1 is methyl, R2 is HNSO₂R4 wherein R4 is methyl and n is 1.

5 6. A compound according to claim 1, wherein both R1 and R2 are HNSO₂R4, wherein R4 is methyl and n is 0.

7. A compound according to claim 1, wherein both R1 and R2 are HNSO₂R4, wherein R4 is methyl and n is 1.

8. A process for the preparation of compounds as defined in claims 1 to 7,
10 comprising the step of reacting aldehyde (1)



(1)

with methyldichloropyridine (2)

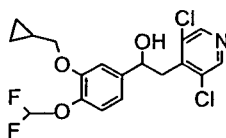
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(2)

to obtain racemic alcohol (3) which is optionally oxidized to the
corresponding N-oxide derivative (4)

20

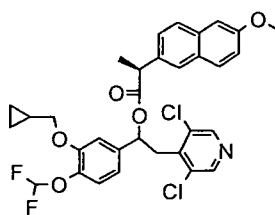


(3)

condensing (3) or (4) with a chiral acid such as (S)-naproxen or
(S)-acetylmandelic acid to obtain, respectively, a diastereomeric mixture (10)

25

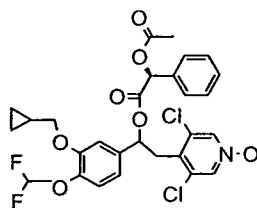
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(10)

or (5),

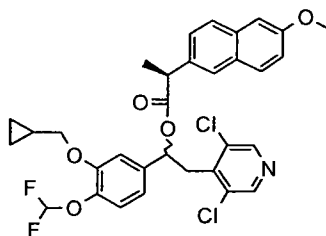
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(5)

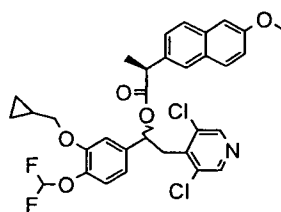
separating the diastereoisomeric mixture (10) or (5) into two single diastereoisomers respectively (11)

10



(11)

and (13)

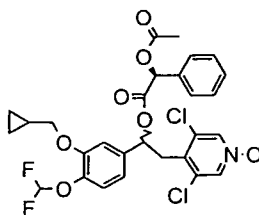


(13)

15

or (6)

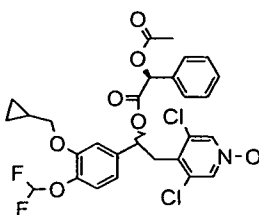
42



(6)

and (8)

5

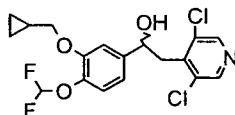


(8)

by chromatography, or crystallization, giving after cleavage, alcohol

(14)

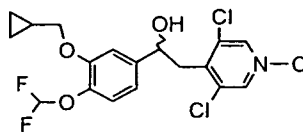
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(14)

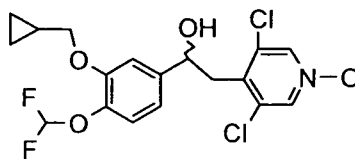
or (+) (7)

15



(7)

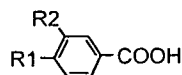
and (-) (9)



(9)

20

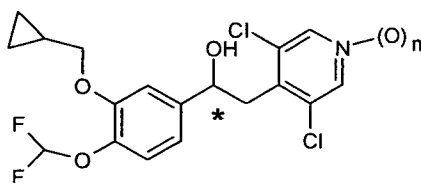
and then reacting compound (+) (14) or (+) (7) with the suitable benzoic acid (15)



(15)

to give compounds of general formula (I), wherein R1 and R2 are as defined in claim 1.

9. A compound of general formula (II)



(II)

wherein n is as defined in claim 1 and the carbon atom represented with an asterisk below show a (S) configuration.

10. A combination of a compound of formula (I) as defined in claims 1 to 7 with a second pharmaceutical active component selected from the classes of β_2 agonists, M3 antagonists and corticosteroids.

11. A combination according to claim 9, wherein the second active component is formoterol or carmoterol.

12. A pharmaceutical composition comprising a compound of formula (I) as defined in claims 1 to 7, or a combination according to claims 9 or 10, and one or more pharmaceutically acceptable carriers and/or excipients.

13. A compound of formula (I) as defined in claims 1 to 7, as a medicament.

14. A compound of formula (I) as defined in claims 1 to 7, for the prevention and/or treatment of a disease of the respiratory tract characterized by airway obstruction such as asthma and COPD.

15. A device comprising a pharmaceutical composition according to claim 11.
16. A kit comprising the pharmaceutical compositions of claim 11 and a device which may be a single- or multi-dose dry powder inhaler, a metered dose inhaler or a soft mist nebulizer.
- 5 17. The use of a compound of formula (I) as defined in claims 1 to 7, for the prevention and/or treatment of allergic rhinitis.
18. The use of a compound of formula (I) as defined in claims 1 to 7, for the prevention and/or treatment of atopic dermatitis.