COMBINATION OF A SELECTIVE PDE4 INHIBITOR AND AN ADRENERGIC BETA-2 RECEPTOR AGONIST

The present invention relates to an inhaled combination of a selective PDE4 inhibitor and an adrenergic β2 receptor agonist, to pharmaceutical compositions, including devices for administering, and to the uses of such a combination.

A combination of a selective PDE4 inhibitor and an adrenergic β2 receptor agonist is useful in the treatment of obstructive airways and other inflammatory diseases, particularly the obstructive airways diseases asthma, chronic obstructive pulmonary disease (COPD) and other obstructive airways diseases exacerbated by heightened bronchial reflexes, inflammation, bronchial hyper-reactivity and bronchospasm. The combination is especially useful in the treatment of COPD.

Examples of particular diseases that may be treated with the present invention include the respiratory diseases asthma, acute respiratory distress syndrome, chronic pulmonary inflammatory disease, bronchitis, chronic bronchitis, chronic obstructive pulmonary (airway) disease and silicosis and diseases of the immune system such as allergic rhinitis and chronic sinusitis.

The 3',5'-cyclic nucleotide phosphodiesterases (PDEs) comprise a large class of enzymes divided into at least eleven different families which are structurally, biochemically and pharmacologically distinct from one another. The enzymes within each family are commonly referred to as isoenzymes, or isozymes. A total of more than fifteen gene products is included within this class, and further diversity results from differential splicing and post-translational processing of those gene products. The present invention is primarily concerned with the four gene products of the fourth family of PDEs, *i.e.*, PDE4A, PDE4B, PDE4C, and PDE4D. These enzymes are collectively referred to as being isoforms or subtypes of the PDE4 isoenzyme family (PDE4s).

PDE4s are characterized by selective, high affinity hydrolytic degradation of the second messenger cyclic nucleotide, adenosine 3',5'-cyclic monophosphate

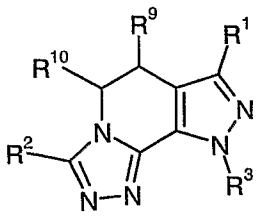
(cAMP), and by sensitivity to inhibition by rolipram. A number of selective inhibitors of the PDE4s have been discovered in recent years, and beneficial pharmacological effects resulting from that inhibition have been shown in a variety of disease models: see, *e.g.*, Torphy *et al.*, *Environ. Health Perspect.* **102** Suppl. 10, 79-84, 1994; Duplantier *et al.*, *J. Med. Chem.* **39** 120-125, 1996; Schneider *et al.*, *Pharmacol. Biochem. Behav.* **50** 211-217, 1995; Banner and Page, *Br. J. Pharmacol.* **114** 93-98, 1995; Barnette *et al.*, *J. Pharmacol. Exp. Ther.* **273** 674-679, 1995; Wright *et al.* "Differential *in vivo* and *in vitro* bronchorelaxant activities of CP-80633, a selective phosphodiesterase 4 inhibitor," *Can. J. Physiol. Pharmacol.* **75** 1001-1008, 1997; Manabe *et al.* "Anti-inflammatory and bronchodilator properties of KF19514, a phosphodiesterase 4 and 1 inhibitor," *Eur. J. Pharmacol.* **332** 97-107, 1997; and Ukita *et al.* "Novel, potent, and selective phosphodiesterase-4 inhibitors as antiasthmatic agents: synthesis and biological activities of a series of 1-pyridylnaphthalene derivatives," *J. Med. Chem.* **42** 1088-1099, 1999.

Adrenergic β receptors occur in the sympathetic nervous system. There are at least two types. Adrenergic β1 receptors are found in the heart and play a major role in regulating heart rate via the action of the agonists epinephrine and norepinephrine. Adrenergic β2 receptors are present on a number of cell types in the lung (e.g. airway smooth muscle cells, epithelial cells, and a variety of inflammatory cells) and adrenergic β2 receptor agonists are effective bronchodilators, causing the relaxation of airway smooth muscle. Sympathomimetic amines have a long history of use in the treatment of chronic airway diseases characterised by partially reversible airway narrowing such as COPD and asthma and were first used as bronchodilators in the form of intravenous epinephrine. Later, inhaled β-adrenergic agents such as isoprenaline were used which were relatively non-selective for β2 over β1 receptors and thus caused tachycardia at effective bronchodilator doses. More recently, inhaled β-adrenergic agents such as salbutamol have been used which are more selective for the β2 receptor but short-acting. Inhaled β-adrenergic agents formoterol, N-[2-hydroxy-5-(1-hydroxy-2-((2-(4-methoxyphenyl)-1-

methylethyl)amino)-ethyl)phenyl]formamide, and salmeterol are both selective for the β2 receptor and long-acting.

It has now been surprisingly found that a combinations of particular selective PDE4 inhibitors and adrenergic β2 receptor agonists offer significant benefits in the treatment of obstructive airways and other inflammatory diseases over treatment with either agent alone and over other known combinations. The advantage of the combination is to provide optimal control of airway calibre through the mechanism most appropriate to the disease pathology, namely adrenergic β2 receptor agonism, together with effective suppression of inappropriate inflammation. In this way, symptoms of the disease are controlled by correcting inappropriate airway neural reflexes which drive cough, mucus production and dyspnea. By administering a combination of an adrenergic β2 receptor agonist and a selective PDE4 inhibitor via the inhaled route, the benefits of each class are realised without the unwanted peripheral effects. Further, the particular combinations of the invention result in unexpected synergy, producing greater efficacy than maximally tolerated doses of either class of agent used alone.

The invention therefore provides an inhaled combination of (a) a selective PDE4 inhibitor of the formula (I)

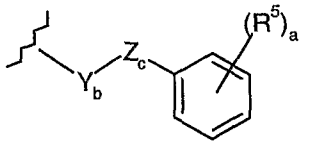


(I)

or a pharmaceutically acceptable salt or solvate thereof, wherein:

R^1 is H, (C_1-C_6) alkyl, (C_1-C_6) alkoxy, (C_2-C_4) alkenyl, phenyl, -$N(CH_3)_2$, (C_3-C_6) cycloalkyl, (C_3-C_6) cycloalkyl(C_1-C_3) alkyl or (C_1-C_6) acyl, wherein the alkyl, phenyl or alkenyl groups may be substituted with up to two -OH, (C_1-C_3) alkyl, or -CF_3 groups or up to three halogens;

R^2 and R^3 are each independently selected from the group consisting of H, (C_1-C_{14}) alkyl, (C_1-C_7) alkoxy(C_1-C_7) alkyl, (C_2-C_{14}) alkenyl, (C_3-C_7) cycloalkyl, (C_3-C_7) cycloalkyl(C_1-C_2) alkyl, a saturated or unsaturated (C_4-C_7) heterocyclic$(CH_2)_n$ group wherein n is 0, 1 or 2, containing as the heteroatom one or two of the group consisting of oxygen, sulfur, sulfonyl, nitrogen and NR^4 where R^4 is H or (C_1-C_4) alkyl; or a group of the Formula (II):



(II)

wherein a is an integer from 1 to 5; b and c are 0 or 1; R^5 is H, -OH, (C_1-C_5) alkyl, (C_2-C_5) alkenyl, (C_1-C_5) alkoxy, (C_3-C_6) cycloalkoxy, halogen, -CF_3, -CO_2R^6, -$CONR^6R^7$, -NR^6R^7, -NO_2, or -$SO_2NR^6R^7$ wherein R^6 and R^7 are each independently H, or (C_1-C_4) alkyl; Z is -O-, -S-, -SO_2-, -CO- or -$N(R^8)$- wherein R^8 is H or (C_1-C_4) alkyl; and Y is (C_1-C_5) alkylene or (C_2-C_6) alkenylene optionally substituted with up to two (C_1-C_7) alkyl or (C_3-C_7) cycloalkyl groups; wherein each of the alkyl, alkenyl, cycloalkyl, alkoxyalkyl or heterocyclic groups may be substituted with 1 to 14, preferably 1 to 5, (C_1-C_2) alkyl, CF_3, or halo groups; and

R^9 and R^{10} are each independently selected from the group consisting of H, (C_1-C_6) alkyl, (C_1-C_6) alkoxy, (C_6-C_{10}) aryl and (C_6-C_{10}) aryloxy;

and (b) an adrenergic β2 receptor agonist.

Further, the invention provides an inhaled combination of a selective PDE4 inhibitor of the formula (I), as defined above, and an adrenergic β2 receptor agonist for use as a medicament.

Further, the invention provides an inhaled combination of a selective PDE4 inhibitor of the formula (I), as defined above, and an adrenergic β2 receptor agonist for simultaneous, sequential or separate administration in the treatment of an obstructive airways or other inflammatory disease.

Further, the invention provides a pharmaceutical composition comprising a selective PDE4 inhibitor of the formula (I), as defined above, an adrenergic β2 receptor agonist and a pharmaceutically acceptable excipient, diluent or carrier, for administration by the inhaled route in the treatment of an obstructive airways or other inflammatory disease.

Further, the invention provides the use of a selective PDE4 inhibitor of the formula (I), as defined above, or an adrenergic β2 receptor agonist in the manufacture of a medicament for simultaneous, sequential or separate administration of both agents by the inhaled route in the treatment of an obstructive airways or other inflammatory disease.

Further, the invention provides a method of treating of an obstructive airways or other inflammatory disease comprising administering simultaneously, sequentially or separately, by the inhaled route, to a mammal in need of such treatment, an effective amount of a selective PDE4 inhibitor of the formula (I), as defined above, and an adrenergic β2 receptor agonist.

Further, the invention provides an inhalation device for simultaneous, sequential or separate administration of a selective PDE4 inhibitor of the formula (I), as defined above, and an adrenergic β2 receptor agonist in the treatment of an obstructive airways or other inflammatory disease.

A selective PDE4 inhibitor is one that has a greater affinity for the PDE4 isoenzyme than all other known PDE isoenzymes. Preferably, the affinity of a selective PDE4 inhibitor according to the invention is at least 100 fold greater for the PDE4 isoenzyme as compared with its affinity for the other PDE isoenzymes.

Preferred compounds of the formula (I) include those wherein R^1 is methyl, ethyl or isopropyl and those wherein R^3 is (C_1-C_6) alkyl, (C_2-C_6) alkenyl, (C_3-C_7) cycloalkyl, (C_3-C_7)cycloalkyl(C_1-C_6)alkyl or phenyl optionally susbtituted with 1 or 2 of the group consisting of H, -OH, (C_1-C_5) alkyl, (C_2-C_5) alkenyl, (C_1-C_5) alkoxy, halogen, trifluoromethyl, $-CO_2R^6$, $-CONR^6R^7$, $-NR^6R^7$, $-NO_2$ or $-SO_2NR^6R^7$ wherein R^6 and R^7 are each independently H or (C_1-C_4) alkyl.

Preferred individual compounds of the formula (I) include:

9-cyclopentyl-5,6-dihydro-7-ethyl-3-phenyl-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopenyl-5,6-dihydro-7-ethyl-3-(furan-2-yl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-pyridyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(4-pyridyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(3-thienyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

3-benzyl-9-cyclopentyl-5,6-dihydro-7-ethyl-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-propyl-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

3,9-dicyclopentyl-5,6-dihydro-7-ethyl-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(1-methylcyclohex-1-yl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

3-(*tert*-butyl)-9-cyclopentyl-5,6-dihydro-7-ethyl-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-methylphenyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-methoxyphenyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(thien-2-yl)-9*H*-pyrazolo[3,4-*c*]1,2,4-triazolo[4,3-α]pyridine;

3-(2-chlorophenyl)-9-cyclopentyl-5,6-dihydro-7-ethyl-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-iodophenyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-trifluoromethylphenyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine; and
5,6-dihydro-7-ethyl-9-(4-fluorophenyl)-3-(1-methylcyclohex-1-yl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

and the pharmaceutically acceptable salts and solvates thereof.

Particularly preferred compounds of the formula (I) include 9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-thienyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine and 9-cyclopentyl-5,6-dihydro-7-ethyl-3-(*tert*-butyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine and the pharmaceutically acceptable salts and solvates thereof.

The synthesis of compounds of the formula (I) is described in WO-A-96/39408.

Preferably, an adrenergic β2 receptor agonist used in a combination according to the invention is a selective adrenergic β2 receptor agonist, i.e. has a greater affinity for the adrenergic β2 receptor than all other known adrenergic β receptors. Preferably, the affinity of such a selective adrenergic β2 receptor agonist is at least 100 fold greater for the adrenergic β2 receptor as compared with its affinity for the other adrenergic β receptors.

Preferered adrenergic β2 receptor agonists for use in the invention include salmeterol, formoterol and the pharmaceutically acceptable salts and solvates thereof.

Particularly preferred combinations include:
9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-thienyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine, or a pharmaceutically acceptable salt or solvate thereof, and salmeterol, or a pharmaceutically acceptable salt or solvate thereof;
9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-thienyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine, or a pharmaceutically acceptable salt or solvate thereof, and formoterol, or a pharmaceutically acceptable salt or solvate thereof;
9-cyclopentyl-5,6-dihydro-7-ethyl-3-(*tert*-butyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine, or a pharmaceutically acceptable salt or solvate thereof, and salmeterol, or a pharmaceutically acceptable salt or solvate thereof; and
9-cyclopentyl-5,6-dihydro-7-ethyl-3-(*tert*-butyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine, or a pharmaceutically acceptable salt or solvate thereof, and formoterol, or a pharmaceutically acceptable salt or solvate thereof.

A selective PDE4 inhibitor or an adrenergic β2 receptor agonist used in accordance with the invention may optionally be utilised in the form of a pharmaceutically acceptable salt or solvate. Such a salt may be an acid addition or a base salt.

Suitable acid addition salts are formed from acids which form non-toxic salts and examples are the hydrochloride, hydrobromide, hydroiodide, sulphate, bisulphate, nitrate, phosphate, hydrogen phosphate, acetate, maleate, fumarate, lactate, tartrate, citrate, gluconate, succinate, saccharate, benzoate, methanesulphonate, ethanesulphonate, benzenesulphonate, p-toluenesulphonate and pamoate salts.

Suitable base salts are formed from bases which form non-toxic salts and examples are the sodium, potassium, aluminium, calcium, magnesium, zinc and diethanolamine salts.

For a review on suitable salts see Berge et al, J. Pharm. Sci., 66, 1-19, 1977.

The pharmaceutically acceptable solvates of the selective PDE4 inhibitors and adrenergic β2 receptor agonists used in accordance with the invention, or salts thereof, include the hydrates thereof.

The selective PDE4 inhibitors and adrenergic β2 receptor agonists of the invention may exist in one or more polymorphic forms.

The selective PDE4 inhibitors and adrenergic β2 receptor agonists of the invention (henceforth, 'compounds of the invention') may contain one or more asymmetric carbon atoms and therefore exists in two or more stereoisomeric forms (e.g. R,R' formoterol is a preferred embodiment). Where such a compound contains an alkenyl or alkenylene group, cis/trans (or Z/E) isomerism may also occur. The present invention includes these individual stereoisomers of the compounds of the invention and, where appropriate, the individual tautomeric forms thereof, together with mixtures thereof.

Separation of diastereoisomers or cis and trans isomers may be achieved by conventional techniques, e.g. by fractional crystallisation, chromatography or H.P.L.C. of a stereoisomeric mixture of a compound of the invention or a suitable salt or derivative thereof. An individual enantiomer of a compound of the invention may also be prepared from a corresponding optically pure intermediate or by resolution, such as by H.P.L.C. of the corresponding racemate using a suitable chiral support or by fractional crystallisation of the diastereoisomeric salts formed by reaction of the corresponding racemate with a suitable optically active acid or base, as appropriate.

The present invention also includes all suitable isotopic variations of a compound of the invention or a pharmaceutically acceptable salt thereof. An isotopic variation of a compound of the invention or a pharmaceutically acceptable salt thereof is defined as one in which at least one atom is replaced

by an atom having the same atomic number but an atomic mass different from the atomic mass usually found in nature. Examples of isotopes that can be incorporated into compounds of the invention and pharmaceutically acceptable salts thereof include isotopes of hydrogen, carbon, nitrogen, oxygen, phosphorus, sulphur, fluorine and chlorine such as ^{2}H, ^{3}H, ^{13}C, ^{14}C, ^{15}N, ^{17}O, ^{18}O, ^{31}P, ^{32}P, ^{35}S, ^{18}F and ^{36}Cl, respectively. Certain isotopic variations of the compounds of the invention and pharmaceutically acceptable salts thereof, for example, those in which a radioactive isotope such as ^{3}H or ^{14}C is incorporated, are useful in drug and/or substrate tissue distribution studies. Tritiated, i.e., ^{3}H, and carbon-14, i.e., ^{14}C, isotopes are particularly preferred for their ease of preparation and detectability. Further, substitution with isotopes such as deuterium, i.e., ^{2}H, may afford certain therapeutic advantages resulting from greater metabolic stability, for example, increased *in vivo* half-life or reduced dosage requirements and hence may be preferred in some circumstances.

The types of diseases that may be treated using the combinations of the present invention include, but are not limited to, asthma, chronic or acute bronchoconstriction, chronic bronchitis, small airways obstruction, emphysema, chronic obstructive pulmonary disease (COPD), COPD that has chronic bronchitis, pulmonary emphysema or dyspnea associated therewith and COPD that is characterised by irreversible, progressive airways obstruction.

Asthma

One of the most important respiratory diseases treatable with the combinations of therapeutic agents of the present invention is asthma, a chronic, increasingly common disorder encountered worldwide and characterized by intermittent reversible airway obstruction, airway hyper-responsiveness and inflammation. The cause of asthma has yet to be determined, but the most common pathological expression of asthma is inflammation of the airways, which may be significant even in the airways of patients with mild asthma. This inflammation drives reflex airway events resulting in plasma protein extravasation, dyspnea and bronchoconstriction. Based on bronchial biopsy and lavage studies it has been clearly shown that asthma involves infiltration by mast cells, eosinophils,

and T-lymphocytes into a patient's airways. Bronchoalveolar lavage (BAL) in atopic asthmatics shows activation of interleukin (IL)-3, IL-4, IL-5 and granulocyte/macrophage-colony stimulating factor (GM-CSF) that suggests the presence of a T-helper 2 (Th-2)-like T-cell population.

The combinations of therapeutic agents of the present invention are useful in the treatment of atopic and non-atopic asthma. The term "atopy" refers to a genetic predisposition toward the development of type I (immediate) hypersensitivity reactions against common environmental antigens. The most common clinical manifestation is allergic rhinitis, while bronchial asthma, atopic dermatitis, and food allergy occur less frequently. Accordingly, the expression "atopic asthma" as used herein is intended to be synonymous with "allergic asthma", *i.e.*, bronchial asthma which is an allergic manifestation in a sensitized person. The term "non-atopic asthma" as used herein is intended to refer to all other asthmas, especially essential or "true" asthma, which is provoked by a variety of factors, including vigorous exercise, irritant particles, psychologic stresses, *etc.*

Chronic Obstructive Pulmonary Disease (COPD)

The combinations of therapeutic agents of the present invention are still further useful in the treatment of COPD or COAD including chronic bronchitis, pulmonary emphysema or dyspnea associated therewith. COPD is characterized by poorly reversible, progressive airways obstruction. Chronic bronchitis is associated with hyperplasia and hypertrophy of the mucus secreting glands of the submucosa in the large cartilaginous airways. Goblet cell hyperplasia, mucosal and submucosal inflammatory cell infiltration, edema, fibrosis, mucus plugs and increased smooth muscle are all found in the terminal and respiratory bronchioles. The small airways are known to be a major site of airway obstruction. Emphysema is characterized by destruction of the alveolar wall and loss of lung elasticity. A number of risk factors have also been identified as linked to the incidence of COPD. The link between tobacco smoking and COPD is well established. Other risk factors include exposure to coal dust and various genetic factors. See Sandford *et al.*, "Genetic risk factors for chronic obstructive pulmonary disease," *Eur. Respir. J.* **10** 1380-1391, 1997.

The incidence of COPD is increasing and it represents a significant economic burden on the populations of the industrialized nations. COPD also presents itself clinically with a wide range of variation from simple chronic bronchitis without disability to patients in a severely disabled state with chronic respiratory failure.

COPD is characterized by inflammation of the airways, as is the case with asthma, but the inflammatory cells that have been found in the bronchoalveolar lavage fluid and sputum of patients are neutrophils and macrophages rather than eosinophils. Elevated levels of inflammatory mediators are also found in COPD patients, including IL-8, LTB_4, and TNF-α, and the surface epithelium and sub-epithelium of the bronchi of such patients has been found to be infiltrated by T-lymphocytes and macrophages. Symptomatic relief for COPD patients can be provided by the use of β-agonist and anticholinergic bronchodilators, but the progress of the disease remains unaltered. COPD has been treated using theophylline, but without much success, due in part to its propensity to produce unwanted effects. Steroids have also failed to hold out much promise as satisfactory treatment agents in COPD as they are relatively ineffective as anti-inflammatory agents.

Accordingly, the use of the combinations of therapeutic agents of the present invention to treat COPD and its related and included obstructed airways diseases, represents a significant advance in the art. The present invention is not limited to any particular mode of action or any hypothesis as to the way in which the desired therapeutic objectives have been obtained by utilizing the combinations of therapeutic agents of the present invention.

Bronchitis and Bronchiectasis

In accordance with the particular and diverse inhibitory activities described above that are possessed by the combinations of therapeutic agents of the present invention, they are useful in the treatment of bronchitis of whatever type, etiology, or pathogenesis, including, *e.g.*, acute bronchitis which has a short but severe course and is caused by exposure to cold, breathing of irritant

substances, or an acute infection; catarrhal bronchitis which is a form of acute bronchitis with a profuse mucopurulent discharge; chronic bronchitis which is a long-continued form of bronchitis with a more or less marked tendency to recurrence after stages of quiescence, due to repeated attacks of acute bronchitis or chronic general diseases, characterized by attacks of coughing, by expectoration either scanty or profuse, and by secondary changes in the lung tissue; dry bronchitis which is characterized by a scanty secretion of tough sputum; infectious asthmatic bronchitis which is a syndrome marked by the development of symptoms of bronchospasm following respiratory tract infections in persons with asthma; productive bronchitis which is bronchitis associated with a productive cough.

The effectiveness of the combinations of therapeutic agents of the present invention to treat atopic asthma or non-atopic asthma, COPD or other chronic inflammatory airways diseases may be demonstrated by the use of a number of different models known in the art including the models described below.

Bronchodilator Activity - cAMP is involved not only in smooth muscle relaxation, but also exerts an overall inhibitory influence on airway smooth muscle proliferation, both of which may result from elevation of cAMP by the PDE4 component of the invention. Airway smooth muscle hypertrophy and hyperplasia can be modulated by cAMP, and these conditions are common morphological features of chronic asthma.

Bronchospasmolytic Activity *In Vitro* - The ability of the combinations of therapeutic agents of the present invention to cause relaxation of guinea-pig tracheal smooth muscle is demonstrated in the following test procedure. Guinea-pigs (350-500 g) are killed with sodium pentothal (100 mg/kg i.p.). The trachea is dissected and a section 2-3 cm in length is excised. The trachea is transected in the transverse plane at alternate cartilage plates so as to give rings of tissue 3-5 mm in depth. The proximal and distal rings are discarded. Individual rings are mounted vertically on stainless steel supports, one of which is fixed at the base of an organ bath, while the other is attached to an isometric transducer.

The rings are bathed in Krebs solution (composition μM: $NaHCO_3$ 25; NaCl 113; KCl 4.7; $MgSO_4 \cdot 7H_2O$ 1.2; KH_2PO_4 1.2; $CaCl_2$ 2.5; glucose 11.7) at 37°C and gassed with O_2/CO_2 (95:5, v/v). Rings prepared in this manner are contracted by field stimulation. To ascertain spasmolytic activity, test combinations of therapeutic agents of the present invention are dissolved in physiological saline and added in increasing quantities to the organ bath at 5m intervals to provide a cumulative concentration-effect curve.

In the above test model, combinations of therapeutic agents of the present invention generally inhibit field stimulated contraction of guinea-pig tracheal ring preparations at concentrations in the range of from 0.001 to 1.0 μM.

Ozone-induced bronchial hyperreactivity model The ability of combinations of therapeutic agents of the present invention to prevent increased responsiveness of the airways to noxious stimuli, also known as bronchial hyperreactivity, is demonstrated in the determination of the effects of these agents on activity of lung responsiveness in guinea-pigs. Adult guinea-pigs (300-600g) are pretreated and prepared according to the method Yeadon et al, 1992, Pulm. Pharmacology, 5, 101-112. Responsiveness of the airways to a variety of stimuli are monitored at basal state and after various interventions which result in changes in pulmonary mechanics. Test articles were administered i.t. or by aerosol at various times prior to challenge. Ozone pretreatment in control animals resulted in a 3-100x increase in lung responsiveness which was dose-relatedly blocked by combinations of the therapeutic agents of the invention.

In the above test model the combinations of therapeutic agents of the present invention generally exhibit anti-inflammatory activity at dosages in the range of from 0.001 to 0.3 mg/kg i.t..

Relaxation of Human Bronchus - Samples of human lungs dissected during surgery for cancer are obtained within 3 days after removal. Small bronchi (inner diameter ≈ 2 to 5 mm) are excised, cut into segments and placed in 2 ml liquid nitrogen storage ampoules filled with fetal calf serum (FCS) containing 1.8M

dimethylsulfoxide (DMSO) and 0.1M sucrose as cryoprotecting agents. The ampoules are placed in a polystyrol box (11 x 11 x 22 cm) and slowly frozen at a mean cooling rate of about 0.6°C/m in a freezer maintained at -70°C. After 3-15h the ampoules are transferred into liquid nitrogen (-196°C) where they are stored until use. Before use the tissues are exposed for 30-60m to -70°C before being thawed within 2.5m by placing the ampoules in a 37°C water bath. Thereafter the bronchial segments are rinsed by placing them in a dish containing Krebs-Henseleit solution (μM: NaCl 118, KCl 4.7. $MgSO_4$ 1.2, $CaCl_2$ 1.2, KH_2P0_4 1.2, $NaHCO_3$ 25, glucose 11, EDTA 0.03) at 37°C, cut into rings and suspended in 10 ml organ baths for isometric tension recording under a preload of about 1g. Further increases in tension are induced *via* the application of field stimulation, which is known to induce activation of nerves in the airway sample and generate tension *via* release of acetylcholine and other neurally derived mediators. Concentration-response curves are produced by cumulative additions, each concentration being added when the maximum effect has been produced by the previous concentration. Papaverine (300 μM) is added at the end of the concentration response curve to induce complete relaxation of the bronchial rings. This effect is taken as 100% relaxation.

In the above test model the combinations of therapeutic agents of the present invention generally produce concentration-related relaxation of human bronchus ring preparations at concentrations in the range of from 0.001 to 1.0 μM with preferred embodiments being active at concentrations in the range of from 5.0 nM to 500 nM.

Suppression of Capsaicin-induced Bronchoconstriction - Male Dunkin-Hartley guinea-pigs (400-800g) having free access to food and water prior to the experiment, are anaesthetized with sodium phenobarbital (100 mg/kg i.p. [intra peritoneal]). Animals, maintained at 37°C with a heated pad, controlled by a rectal thermometer, are ventilated via a tracheal cannula (about 8 ml/kg, 1 Hz) with a mixture of air and oxygen (45:55 v/v). Ventilation is monitored at the trachea by a pneumotachograph connected to a differential pressure transducer in line with the respiratory pump. Pressure changes within the thorax are

monitored directly *via* an intrathoracic cannula, using a differential pressure transducer so that the pressure difference between the trachea and thorax can be measured and displayed. From these measurements of air-flow and transpulmonary pressure, both airway resistance (R_1 $cmH_20/l/s$) and compliance (Cd_{dyn}) are calculated with a digital electronic respiratory analyzer for each respiratory cycle. Blood pressure and heart rate are recorded from the carotid artery using a pressure transducer.

When values for basal resistance and compliance are stable, an acute episode of bronchoconstriction is induced by an intravenous bolus of capsaicin. Capsaicin is dissolved in 100% ethanol and diluted with phosphate buffered saline. Test combinations of therapeutic agents of the present invention are administered when the response to capsaicin is stable, which is calculated to be after 2-3 such administrations at 10 min intervals. Reversal of bronchoconstriction is assessed over 1-8 h following either intratracheal or intraduodenal instillation or intravenous bolus injection. Bronchospasmolytic activity is expressed as a % inhibition of the initial, maximal resistance (R_D) following the infusion of capsaicin. ED_{50} values represent the dose which causes a 50% reduction of the increase in resistance induced by capsaicin. Duration of action is defined as the time in minutes where bronchoconstriction is reduced by 50% or more. Effects on blood pressure (BP) and heart rate (HR) are characterized by ED_{20} values; *i.e.*, the doses which reduce BP or HR by 20% measured 5m after administration.

In the above test model the combinations of therapeutic agents of the present invention generally exhibit bronchodilator activity at dosages in the range of from 0.001 to 0.1 mg/kg *i.t.* [intra tracheal]. Further, the combination delivered *i.t.* exhibits an at least additive inhibitory effect on bronchospasm, with each component alone being able to inhibit more than 50% of the observed control response.

LPS-Induced Lung Neutrophilia - The recruitment to and activation of neutrophils in the lungs is considered an important pathological feature in COPD and in

severe asthma. Consequently, inhibition of either or both of these endpoints in animals provides supportive evidence of the utility of the present invention.

Male Wistar-Albino rats (150-250g) or male Dunkin-Hartley guinea-pigs (400-600g) are pretreated with the test articles alone or in combination by inhalation or intratracheal (i.t.) instillation under brief general anaesthesia. After 1-24h after compound administration, animals are challenged with an inhalation aerosol of bacterial liopolysaccharide (LPS) sufficient to induce over the subsequent 1-24h of a pronounced lung neutrophilia. The neutrophilia is assessed by cell counting in bronchial washings or by determination of neutrophil products in lung washings or tissue. In this test system, the therapeutic agents of the present invention generally exhibit anti-inflammatory activity at doses ranging from 0.0001 to 0.1 mg/kg i.t. Unexpectedly, the combination delivered i.t. exerts at least an additive effect on inflammation, despite the fact that one of the components does not on its own exert a significant anti-inflammatory effect. Further, equivalent anti-inflammatory effects of a high dose of one of the components can be observed with lower doses when used in combination as in this invention, thus minimising systemic unwanted effects.

Allergic guinea-pig Assay - A test for evaluating the therapeutic impact of the combinations of therapeutic agents of the present invention on the symptom of dyspnea and bronchspasm *i.e.*, difficult or labored breathing and increased lung resistance, and on the symptom of inflammation, *i.e.* lung neutrophilia and eosinophilia, utilizes Dunkin-Hartley guinea-pigs (400-600 g body weight).

The egg albumin (EA), grade V, crystallized and lyophilized, aluminum hydroxide, and mepyramine maleate used in this test are commercially available. The challenge and subsequent respiratory readings are carried out in a clear plastic box with internal dimensions of 10x6x4 inches. The head and body sections of the box are separable. In use the two are held firmly together by clamps, and an airtight seal between the chambers is maintained by a soft rubber gasket. Through the centre of the head end of the chamber a nebulizer is inserted *via* an airtight seal and each end of the box also has an outlet. A

pneumotachograph is inserted into one end of the box and is coupled to a volumetric pressure transducer which is then connected to a dynograph through appropriate couplers. While aerosolizing the antigen, the outlets are open and the pneumotachograph is isolated from the chamber. The outlets are then closed and the pneumotachograph and the chamber are connected during the recording of the respiratory patterns. For challenge, 2 ml of a 3% solution of antigen in saline is placed in each nebulizer and the aerosol is generated with air from a small diaphragm pump operating at 10 psi and a flow rate of 8 l/m.

Guinea-pigs are sensitized by injecting subcutaneously and i.p. 1 ml of a suspension containing 1 mg EA and 200 mg aluminum hydroxide in saline. They are used between days 12 and 24 post-sensitization. In order to eliminate the histamine component of the response, guinea-pigs are pretreated i.p. 30min prior to aerosol challenge with 2mg/kg of mepyarmine. Guinea-pigs are then exposed to an aerosol of 3% EA in saline for exactly 1m, then respiratory profiles are recorded for a further 30m. Subsequently, lung inflammation is determined post mortem over a period of 1-48h. The duration of continuous dyspnea is measured from the respiratory recordings.

Test combinations of therapeutic agents of the present invention are generally administered i.t. or by aerosol 0.5-4h prior to challenge. The combinations of compounds are either dissolved in saline or biocompatible solvents. The activity of the compounds is determined on the basis of their ability to decrease the magnitude and duration of symptoms of dyspnea and broncospasm and/or magnitude of lung inflammation in comparison to a group of vehicle-treated controls. Tests of the combinations of therapeutic agents of the present invention are evaluated over a series of doses and an ED_{50} is derived that is defined as the dose (mg/kg) which will inhibit the duration of symptoms by 50%.

Anti-inflammatory Activity The anti-inflammatory activity of the combinations of therapeutic agents of the present invention is demonstrated by the inhibition of eosinophil or neutrophil activation. In this assay blood samples (50ml) are collected from non-atopic volunteers with eosinophil numbers ranging between

0.06 and 0.47 x 10^9 L^{-1}. Venous blood is collected into centrifuge tubes containing 5 ml trisodium citrate (3.8%, pH 7.4).

The anticoagulated blood is diluted (1:1, v:v) with phosphate-buffered saline (PBS, containing neither calcium nor magnesium) and is layered onto 15 ml isotonic Percoll (density 1.082 - 1.085 g/ml, pH 7.4), in a 50 ml centrifuge tube. Following centrifugation (30 minutes, 1000 x g, 20°C), mononuclear cells at the plasma/Percoll interface are aspirated carefully and discarded.

The neutrophil/eosinophil/erythrocyte pellet (*ca.* 5 ml by volume) is gently resuspended in 35 ml of isotonic ammonium chloride solution (NH_4Cl, 155mM; $KHCO_3$, 10mM; EDTA. 0.1mM; 0-4°C). After 15 min, cells are washed twice (10 min, 400 x g, 4°C) in PBS containing fetal calf serum (2%, FCS).

A magnetic cell separation system is used to separate eosinophils and neutrophils. This system is able to separate cells in suspension according to surface markers, and comprises a permanent magnet, into which is placed a column that includes a magnetizable steel matrix. Prior to use, the column is equilibrated with PBS/FCS for 1 hour and then flushed with ice-cold PBS/FCS on a retrograde basis *via* a 20 ml syringe. A 21G hypodermic needle is attached to the base of the column and 1-2 ml of ice cold buffer are allowed to efflux through the needle.

Following centrifugation of granulocytes, supernatant is aspirated and cells are gently resuspended with 100µl magnetic particles (anti-CD16 monoclonal antibody, conjugated to superparamagnetic particles). The eosinophil/neutrophil/anti-CD16 magnetic particle mixture is incubated on ice for 40 minutes and then diluted to 5 ml with ice-cold PBS/FCS. The cell suspension is slowly introduced into the top of the column and the tap is opened to allow the cells to move slowly into the steel matrix. The column is then washed with PBS/FCS (35ml) which is carefully added to the top of the column so as not to disturb the magnetically labeled neutrophils already trapped in the steel matrix. Non-labeled eosinophils are collected in a 50ml centrifuge tube and washed (10

minutes, 400 x g, 4°C). The resulting pellet is resuspended in 5 ml Hank's balanced salt solution (HBSS) so that cell numbers and purity can be assessed prior to use. The separation column is removed from the magnet and the neutrophil fraction is eluted. The column is then washed with PBS (50ml) and ethanol (absolute) and stored at 4°C.

Total cells are counted with a micro cell counter. One drop of lysogenic solution is added to the sample, which after 30s is recounted to assess contamination with erythrocytes. Cytospin smears are prepared on a Shandon Cytospin 2 cytospinner (100 µl samples, 3 minutes, 500 rpm). These preparations are stained and differential cell counts are determined by light microscopy, examining at least 500 cells. Cell viability is assessed by exclusion of trypan blue.

Eosinophils or neutrophils are diluted in HBSS and pipetted into 96 well microtiter plates (MTP) at 1-10 x 10^3 cells/well. Each well contains a 200 µl sample comprising: 100 µl cell suspension; 50 µl HBSS; 10 µl lucigenin; 20 µl activation stimulus; and 20 µl test compound.

The samples are incubated with test compound or vehicle for 10m prior to addition of an activation stimulus fMLP (1-10 µM) or C5a (1-100nM) dissolved in dimethylsulfoxide and thereafter diluted in buffer, such that the highest solvent concentration used is 1% (at 100 µM test compound). MTPs are agitated to facilitate mixing of the cells and medium, and the MTP is placed into a luminometer. Total chemiluminescence and the temporal profile of each well is measured simultaneously over 20m and the results expressed as arbitrary units, or as a percentage of fMLP-induced chemiluminescence in the absence of test compound. Results are fitted to the Hill equation and IC_{50} values are calculated automatically.

The combinations of therapeutic agents of the present invention are generally active in the above test method at concentrations in the range of from 0.0001µM

to 0.5 μM, with preferred embodiments being active at concentrations in the range of from 0.1 nM to 100 nM.

The anti-inflammatory activity of the combinations of therapeutic agents of the present invention is additionally demonstrated by the inhibition of plasma extravasation into rat airways. In this assay tracheal tissue is taken and the extent of plasma leakage determined. This assay relates equally to other chronic inflammatory diseases of the airways including but not limited to COPD and accordingly is not recapitulated in that section.

Wistar albino rats (150-200g) or Dunkin-Hartley guinea-pigs (450-600g) are anaesthetised with sodium pentobarbitone and venous and arterial cannulae installed. Evans Blue dye to bind plasma proteins is administered i.v. (30mg/kg). After 10mins the test agents are administered i.t. and 10mins later capsaicin administered i.v. (3ug/kg). 30mins later, tracheal tissue is removed, extracted overnight into formamide and absorbance read at 620nm. In some experiments the order of dosing was reversed such that the compounds were administered before the Evans Blue and inflammatory stimulus.

In the above test model In the above test model the combinations of therapeutic agents of the present invention generally exhibit anti-inflammatory activity at dosages in the range of from 0.001 to 0.1 mg/kg *i.t.*

From the above it may be seen that the combinations of therapeutic agents of the present invention are useful for the treatment of inflammatory or obstructive airways diseases or other conditions involving airways obstruction. In particular they are useful for the treatment of bronchial asthma.

In view of their anti-inflammatory activity and their influence on airways hyper-reactivity, the combinations of therapeutic agents of the present invention are useful for the treatment, in particular prophylactic treatment, of obstructive or

inflammatory airways diseases. Thus, by continued and regular administration over prolonged periods of time the combinations of compounds of the present invention are useful in providing advance protection against the recurrence of bronchoconstriction or other symptomatic attack consequential to obstructive or inflammatory airways diseases. The combinations of compounds of the present invention are also useful for the control, amelioration or reversal of the basal status of such diseases.

Having regard to their bronchodilator activity the combinations of therapeutic agents of the present invention are useful as bronchodilators, *e.g.*, in the treatment of chronic or acute bronchoconstriction, and for the symptomatic treatment of obstructive or inflammatory airways diseases.

Obstructive or inflammatory airways diseases to which the present invention applies include asthma; pneumoconiosis; chronic eosinophilic pneumonia; chronic obstructive airways or pulmonary disease (COAD or COPD); and adult respiratory distress syndrome (ARDS), as well as exacerbation of airways hyper-reactivity consequent to other drug therapy, *e.g.*, aspirin or β-agonist therapy.

The selective PDE4 inhibitors and adrenergic β2 receptor agonists of the present invention can be administered alone or in combination but will generally be administered in admixture with a suitable pharmaceutical excipient, diluent or carrier.

The selective PDE4 inhibitors and adrenergic β2 receptor agonists of the present invention are preferably administered by inhalation and are conveniently delivered in the form of a dry powder (either alone or as a mixture, for example a mixture with lactose) from a dry powder inhaler or an aerosol spray presentation from a pressurised container, pump, spray, atomiser (preferably an atomiser using electrohydrodynamics to produce a fine mist) or nebuliser, with or without the use of a suitable propellant, e.g. dichlorodifluoromethane, trichlorofluoromethane, dichlorotetrafluoroethane, a hydrofluoroalkane such as 1,1,1,2-tetrafluoroethane (HFA 134A [trade mark]) or 1,1,1,2,3,3,3-

heptafluoropropane (HFA 227EA [trade mark]), carbon dioxide, a further perfluorinated hydrocarbon such as Perflubron (trade mark) or other suitable gas. In the case of a pressurised aerosol, the dosage unit may be determined by providing a valve to deliver a metered amount. The pressurised container, pump, spray, atomiser or nebuliser may contain a solution or suspension of the active compound, e.g. using a mixture of ethanol (optionally, aqueous ethanol) or a suitable agent for dispersing, solubilising or extending release and the propellant as the solvent, which may additionally contain a lubricant, e.g. sorbitan trioleate. Capsules, blisters and cartridges (made, for example, from gelatin or HPMC) for use in an inhaler or insufflator may be formulated to contain a powder mix of the compound of the invention, a suitable powder base such as lactose or starch and a performance modifier such as l-leucine, mannitol or magnesium stearate.

Prior to use in a dry powder formulation or suspension formulation for inhalation the compound of the invention will be micronised to a size suitable for delivery by inhalation (typically considered as less than 5 microns). Micronisation could be achieved by a range of methods, for example spiral jet milling, fluid bed jet milling or use of supercritical fluid crystallisation.

A suitable solution formulation for use in an atomiser using electrohydrodynamics to produce a fine mist may contain from 1μg to 10mg of the compound of the invention per actuation and the actuation volume may vary from 1 to 100μl. A typical formulation may comprise a compound of the invention, propylene glycol, sterile water, ethanol and sodium chloride. Alternative solvents may be used in place of propylene glycol, for example glycerol or polyethylene glycol.

Aerosol or dry powder formulations are preferably arranged so that each metered dose or "puff" contains from 1 to 4000 μg of a compound of the invention for delivery to the patient. The overall daily dose with an aerosol will be in the range of from 1μg to 20mg which may be administered in a single dose or, more usually, in divided doses throughout the day.

The preferred ratio, by weight (w/w), of selective PDE4 inhibitor:adrenergic β2 receptor agonist used will depend on the particular combination being examined. This is due to differences in the potency of individual compounds. The physician in any event will determine the actual dosage of each compound which will be most suitable for any individual patient and it will vary with the age, weight and response of the particular patient.

It is to be appreciated that all references herein to treatment include curative, palliative and prophylactic treatment.

Test data - Inhibition of elastase release from isolated human neutrophils

Venous blood (90 ml) from healthy human volunteers of either sex was collected into 10ml 3.8% (w/v) sodium citrate, and 8ml aliquots were dispensed into 15ml polypropylene centrifuge tubes each containing 4ml of 6% dextran (average Molecular Weight 148,000) in Hanks Balanced Salt Solution (HBSS). The dextran/blood was mixed gently by inversion and left to stand at room temperature for 45 minutes to allow erythrocyte sedimentation. Aliquots of 16ml from the leukocyte-rich supernatant were overlaid on 10ml Ficoll-Hypaque cushions in 50ml polypropylene centrifuge tubes and the tubes centrifuged at 400g for 35mins at 21°C. The plasma, mononuclear cell layer and Ficoll were removed leaving the granulocyte-rich pellet. The pellets were initially re-suspended in 10ml ice-cold distilled water for 45 seconds to lyse contaminating red blood cells, followed by the addition of 10ml of ice-cold double concentrated phosphate buffered saline (PBS) solution to each tube to restore osmolarity. The suspensions were re-centrifuged at 200g for 10min at 4°C to generate neutrophil pellets. The supernatants were removed and the pellets gently resuspended in a total volume of 10ml ice-cold HBSS using a Pasteur pipette. A differential white cell count was performed on the resulting neutrophil suspension using a Beckman Coulter Ac. T5 haematology analyser and the cells stored on ice until assay. Immediately prior to assay, aliquots of the neutrophil suspension were removed and diluted to a count of $4x10^6$ neutrophils/ml ice-cold HBSS containing 2U/ml adenosine deaminase.

Inhibition of fMLP induced elastase release was performed using a 160µl assay volume in 96-well polystyrene microtiter plates. Elastase release was assayed by measuring the rate of cleavage of the synthetic substrate MeOSuc-Ala-Ala-Pro-Val-*p*NA. For measurement of elastase release, assay wells contained 8µl of 100µg/ml cytochalasin B (in 10% DMSO/90% HBSS), 8µl test compound (diluted in HBSS), 40µl neutrophil suspension and 96µl of 156µM MeOSuc-Ala-Ala-Pro-Val-*p*NA (in HBSS). Assay plates were incubated at 37°C for 10 minutes before addition of 8µl of 2µM fMLP (in HBSS) and measurement of rate of substrate cleavage was measured at λ=405nm for 3 minutes at 37°C. Basal elastase

release was determined by the addition of 8µl HBSS in place of fMLP. The data reproduced below in Table 1 are IC50 values, i.e. the concentration (in nM) of active agent required to achieve 50% inhibition of fMLP-induced elastase release. In the case of the combination experiments, 1000nM of 9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-thienyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine (C) was added to the assay and a concentration response curve was then generated for formoterol (F) or salmeterol (S).

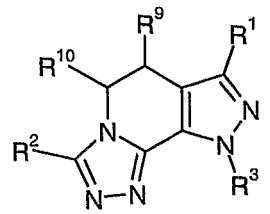
Table 1 - Inhibition of elastase release (IC50 values in nM)

F	S	C	F+C	S+C
>1000	>1000	>1000	0.4	1.0

Combined application of a β2 agonist (formoterol or salmeterol) with a PDE4 inhibitor (9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-thienyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine) is demonstrated to produce synergistic inhibition of pro-inflammatory neutrophil function. Weak (µM) inhibition of fMLP-induced elastase release from the isolated human neutrophil was achieved by individual treatment with these pharmacological agents, and this was dramatically enhanced to highly potent (nM) inhibition by their combined application.

Claims

1. An inhaled combination of (a) a selective PDE4 inhibitor of the formula (I)

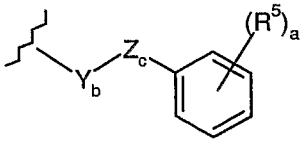


(I)

or a pharmaceutically acceptable salt or solvate thereof, wherein:

R^1 is H, (C_1-C_6) alkyl, (C_1-C_6) alkoxy, (C_2-C_4) alkenyl, phenyl, -$N(CH_3)_2$, (C_3-C_6) cycloalkyl, (C_3-C_6) cycloalkyl(C_1-C_3) alkyl or (C_1-C_6) acyl, wherein the alkyl, phenyl or alkenyl groups may be substituted with up to two -OH, (C_1-C_3) alkyl, or -CF_3 groups or up to three halogens;

R^2 and R^3 are each independently selected from the group consisting of H, (C_1-C_{14}) alkyl, (C_1-C_7) alkoxy(C_1-C_7) alkyl, (C_2-C_{14}) alkenyl, (C_3-C_7) cycloalkyl, (C_3-C_7) cycloalkyl(C_1-C_2) alkyl, a saturated or unsaturated (C_4-C_7) heterocyclic$(CH_2)_n$ group wherein n is 0, 1 or 2, containing as the heteroatom one or two of the group consisting of oxygen, sulfur, sulfonyl, nitrogen and NR^4 where R^4 is H or (C_1-C_4) alkyl; or a group of the Formula (II):



(II)

wherein a is an integer from 1 to 5; b and c are 0 or 1; R^5 is H, -OH, (C_1-C_5) alkyl, (C_2-C_5) alkenyl, (C_1-C_5) alkoxy, (C_3-C_6) cycloalkoxy, halogen, -CF_3, -CO_2R^6, -$CONR^6R^7$, -NR^6R^7, -NO_2, or -$SO_2NR^6R^7$ wherein R^6 and R^7 are each independently H, or (C_1-C_4) alkyl; Z is -O-, -S-, -SO_2-, -CO- or -$N(R^8)$- wherein R^8 is H or (C_1-C_4) alkyl; and Y is (C_1-C_5) alkylene or (C_2-C_6) alkenylene optionally substituted with up to two (C_1-C_7) alkyl or (C_3-C_7) cycloalkyl groups; wherein each

of the alkyl, alkenyl, cycloalkyl, alkoxyalkyl or heterocyclic groups may be substituted with 1 to 14, preferably 1 to 5, (C_1-C_2) alkyl, CF_3, or halo groups; and

R^9 and R^{10} are each independently selected from the group consisting of H, (C_1-C_6) alkyl, (C_1-C_6) alkoxy, (C_6-C_{10}) aryl and (C_6-C_{10}) aryloxy;

and (b) an adrenergic β2 receptor agonist.

2. A combination as claimed in claim 1 wherein R^1 is methyl, ethyl or isopropyl.

3. A combination as claimed in claim 1 or claim 2 wherein R^3 is (C_1-C_6) alkyl, (C_2-C_6) alkenyl, (C_3-C_7) cycloalkyl, (C_3-C_7)cycloalkyl(C_1-C_6)alkyl or phenyl optionally susbtituted with 1 or 2 of the group consisting of H, -OH, (C_1-C_5) alkyl, (C_2-C_5) alkenyl, (C_1-C_5) alkoxy, halogen, trifluoromethyl, $-CO_2R^6$, $-CONR^6R^7$, $-NR^6R^7$, $-NO_2$ or $-SO_2NR^6R^7$ wherein R^6 and R^7 are each independently H or (C_1-C_4) alkyl.

4. A combination as claimed in any one of the preceding claims wherein the selective PDE4 inhibitor of the formula (I) is selected from:

9-cyclopentyl-5,6-dihydro-7-ethyl-3-phenyl-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopenyl-5,6-dihydro-7-ethyl-3-(furan-2-yl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-pyridyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(4-pyridyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(3-thienyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

3-benzyl-9-cyclopentyl-5,6-dihydro-7-ethyl-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-propyl-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

3,9-dicyclopentyl-5,6-dihydro-7-ethyl-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(1-methylcyclohex-1-yl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

3-(*tert*-butyl)-9-cyclopentyl-5,6-dihydro-7-ethyl-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-methylphenyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-methoxyphenyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(thien-2-yl)-9*H*-pyrazolo[3,4-*c*]1,2,4-triazolo[4,3-α]pyridine;

3-(2-chlorophenyl)-9-cyclopentyl-5,6-dihydro-7-ethyl-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-iodophenyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-trifluoromethylphenyl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine; and

5,6-dihydro-7-ethyl-9-(4-fluorophenyl)-3-(1-methylcyclohex-1-yl)-9*H*-pyrazolo[3,4-*c*]-1,2,4-triazolo[4,3-α]pyridine;

and the pharmaceutically acceptable salts and solvates thereof.

5. A combination as claimed in claim 4 wherein the selective PDE4 inhibitor of the formula (I) is selected from 9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-thienyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine and 9-cyclopentyl-5,6-dihydro-7-ethyl-3-(*tert*-butyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine and the pharmaceutically acceptable salts and solvates thereof.

6. A combination as claimed in any one of the preceding claims wherein the adrenergic β2 receptor agonist is selected from salmeterol, formoterol and the pharmaceutically acceptable salts and solvates thereof.

7. A combination as claimed in claim 1 wherein:

the selective PDE4 inhibitor of the formula (I) is 9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-thienyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine, or a pharmaceutically acceptable salt or solvate thereof, and the adrenergic β2 receptor agonist is salmeterol, or a pharmaceutically acceptable salt or solvate thereof;

the selective PDE4 inhibitor of the formula (I) is 9-cyclopentyl-5,6-dihydro-7-ethyl-3-(2-thienyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine, or a pharmaceutically acceptable salt or solvate thereof, and the adrenergic β2 receptor agonist is formoterol, or a pharmaceutically acceptable salt or solvate thereof;

the selective PDE4 inhibitor of the formula (I) is 9-cyclopentyl-5,6-dihydro-7-ethyl-3-(*tert*-butyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine, or a pharmaceutically acceptable salt or solvate thereof, and the adrenergic β2 receptor agonist is salmeterol, or a pharmaceutically acceptable salt or solvate thereof; or

the selective PDE4 inhibitor of the formula (I) is 9-cyclopentyl-5,6-dihydro-7-ethyl-3-(*tert*-butyl)-9*H*-pyrazolo[3,4-c]-1,2,4-triazolo[4,3-α]pyridine, or a pharmaceutically acceptable salt or solvate thereof, and the adrenergic β2 receptor agonist is formoterol, or a pharmaceutically acceptable salt or solvate thereof.

8. A combination as claimed in any preceding claim for use as a medicament.

9. A combination as claimed in any one of claims 1 to 7 for simultaneous, sequential or separate administration in the treatment of an obstructive airways or other inflammatory disease.

10. A pharmaceutical composition comprising a selective PDE4 inhibitor of the formula (I), as defined in claim 1, an adrenergic β2 receptor agonist and a pharmaceutically acceptable excipient, diluent or carrier, for administration by the inhaled route in the treatment of an obstructive airways or other inflammatory disease.

11. A pharmaceutical composition as defined in claim 10 wherein the selective PDE4 inhibitor of the formula (I) and the adrenergic β2 receptor agonist are as defined in any one of claims 2 to 7.

12. The use of a selective PDE4 inhibitor of the formula (I), as defined in claim 1, or an adrenergic β2 receptor agonist in the manufacture of a medicament for simultaneous, sequential or separate administration of both agents by the inhaled route in the treatment of an obstructive airways or other inflammatory disease.

13. The use of claim 12 wherein the selective PDE4 inhibitor of the formula (I) and the adrenergic β2 receptor agonist are as defined in any one of claims 2 to 7.

14. A method of treating of an obstructive airways or other inflammatory disease comprising administering simultaneously, sequentially or separately, by the inhaled route, to a mammal in need of such treatment, an effective amount of a selective PDE4 inhibitor of the formula (I), as defined in claim 1, and an adrenergic β2 receptor agonist.

15. A method as claimed in claim 14 wherein the selective PDE4 inhibitor of the formula (I) and the adrenergic β2 receptor agonist are as defined in any one of claims 2 to 7.

16. An inhalation device for simultaneous, sequential or separate administration of a selective PDE4 inhibitor of the formula (I), as defined in claim 1, and an adrenergic β2 receptor agonist in the treatment of an obstructive airways or other inflammatory disease.

17. An inhalation device as claimed in claim 16 wherein the selective PDE4 inhibitor of the formula (I) and the adrenergic β2 receptor agonist are as defined in any one of claims 2 to 7.