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**Indole and indoline cyclopropyl amide derivatives as EP4 receptor antagonists**

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(54) Title: INDOLE AND INDOLINE CYCLOPROPYL AMIDE DERIVATIVES AS EP4 RECEPTOR ANTAGONISTS

(57) Abstract: The invention is directed to indole and indoline cyclopropyl amide derivatives as EP4 receptor antagonists useful for the treatment of EP4 mediated diseases or conditions, such as acute and chronic pain, osteoarthritis, rheumatoid arthritis and cancer. Pharmaceutical compositions and methods of use are also included.

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## TITLE OF THE INVENTION

## INDOLE AND INDOLINE CYCLOPROPYL AMIDE DERIVATIVES AS EP4 RECEPTOR ANTAGONISTS

## 5 BACKGROUND OF THE INVENTION

This invention relates to compounds and methods for treating prostaglandin E mediated diseases, and certain pharmaceutical compositions thereof. More particularly, the compounds of the invention are structurally different from NSAIDs and opiates, and are antagonists of the pain and inflammatory effects of E-type prostaglandins.

10 Three review articles describe the characterization and therapeutic relevance of the prostanoid receptors as well as the most commonly used selective agonists and antagonists: *Eicosanoids: From Biotechnology to Therapeutic Applications*, Folco, Samuelsson, Macclouf, and Velo eds, Plenum Press, New York, 1996, chap. 14, 137-154; *Journal of Lipid Mediators and Cell Signalling*, 1996, 14, 83-87; and *Prostaglandins and Other Lipid Mediators*, 2002, 69, 15 557-573.

Thus, selective prostaglandin ligands, agonists or antagonists, depending on which prostaglandin E receptor subtype is being considered, have anti-inflammatory, antipyretic and analgesic properties similar to a conventional non-steroidal anti-inflammatory drug, and in addition, have effects on vascular homeostasis, reproduction, gastrointestinal functions and bone metabolism. These compounds may have a diminished ability to induce some of the mechanism-based side effects of NSAIDs which are indiscriminate cyclooxygenase inhibitors. In particular, the compounds are believed to have a reduced potential for gastrointestinal toxicity, a reduced potential for renal side effects, a reduced effect on bleeding times and a lessened ability to induce asthma attacks in aspirin-sensitive asthmatic subjects.

25 In *The Journal of Clinical Investigation* (2002, 110, 651-658), studies suggest that chronic inflammation induced by collagen antibody injection in mice is mediated primarily through the EP4 subtype of PGE<sub>2</sub> receptors. Patent application publications WO 96/06822 (March 7, 1996), WO 96/11902 (April 25, 1996) and EP 752421-A1 (January 08, 1997) disclose compounds as being useful in the treatment of prostaglandin mediated diseases.

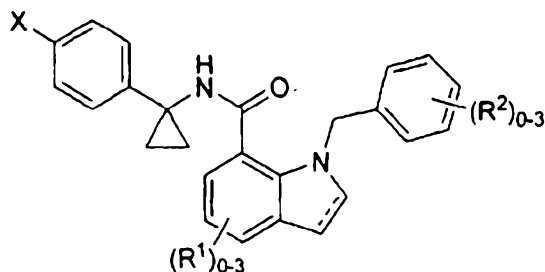
30 The present invention is directed to novel compounds that are antagonists of the EP4 subtype of PGE<sub>2</sub> receptors. The compounds would therefore be useful for the treatment of diseases or conditions mediated by the EP4 receptor, such as acute and chronic pain, osteoarthritis, rheumatoid arthritis and cancer.

## SUMMARY OF THE INVENTION

The invention is directed to indole and indoline cyclopropyl amide derivatives as EP4 receptor antagonists useful for the treatment of EP4 mediated diseases or conditions, such as acute and chronic pain, osteoarthritis, rheumatoid arthritis and cancer. Pharmaceutical compositions and methods of use are also included.

## DETAILED DESCRIPTION OF THE INVENTION

The invention encompasses a genus of compounds of Formula I



I

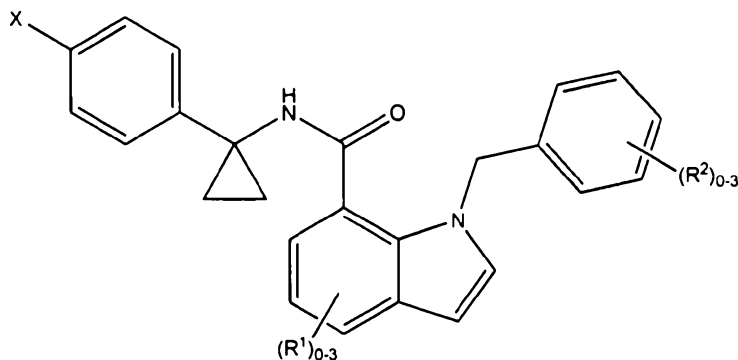
or a pharmaceutically acceptable salt thereof, wherein:

----- is an optional double bond;

X is -COOH or tetrazolyl; and

R<sup>1</sup> and R<sup>2</sup> are independently selected from the group consisting of: halo, C<sub>1</sub>-4alkyl, C<sub>1</sub>-4fluoroalkyl, C<sub>1</sub>-4alkoxy, C<sub>1</sub>-4fluoroalkoxy and acetyl.

According to a first aspect of the present invention, there is provided a compound of Formula I



I

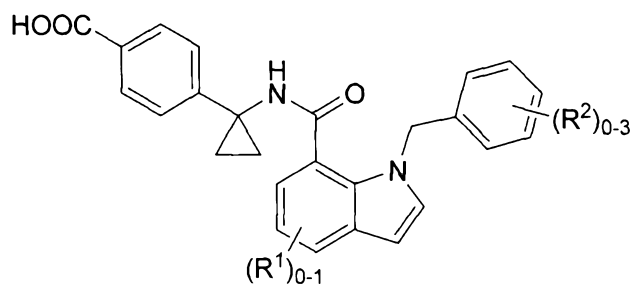
or a pharmaceutically acceptable salt thereof, wherein:

2a

X is -COOH or tetrazolyl;

R<sup>1</sup> and R<sup>2</sup> are independently selected from the group consisting of: halo, C<sub>1</sub>-4alkyl, C<sub>1</sub>-4fluoroalkyl, C<sub>1</sub>-4alkoxy, C<sub>1</sub>-4fluoroalkoxy and acetyl.

Within the genus, the invention encompasses a sub-genus of compounds of Formula Ia

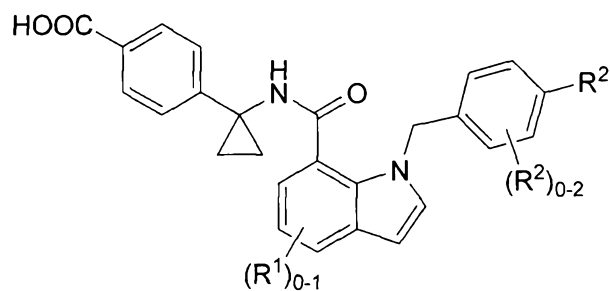


Ia

or a pharmaceutically acceptable salt thereof, wherein the variables  $R^1$  and  $R^2$  are as previously  
 5 defined.

Within this sub-genus, the invention encompasses a class of compounds of

Formula Ib

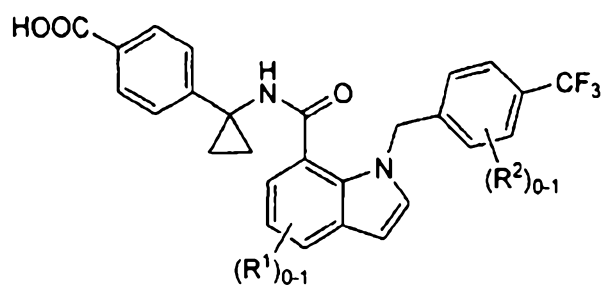


Ib

or a pharmaceutically acceptable salt thereof, wherein the variables  $R^1$  and  $R^2$  are as previously  
 15 defined.

Within the class, the invention encompasses a sub-class of compounds of Formula

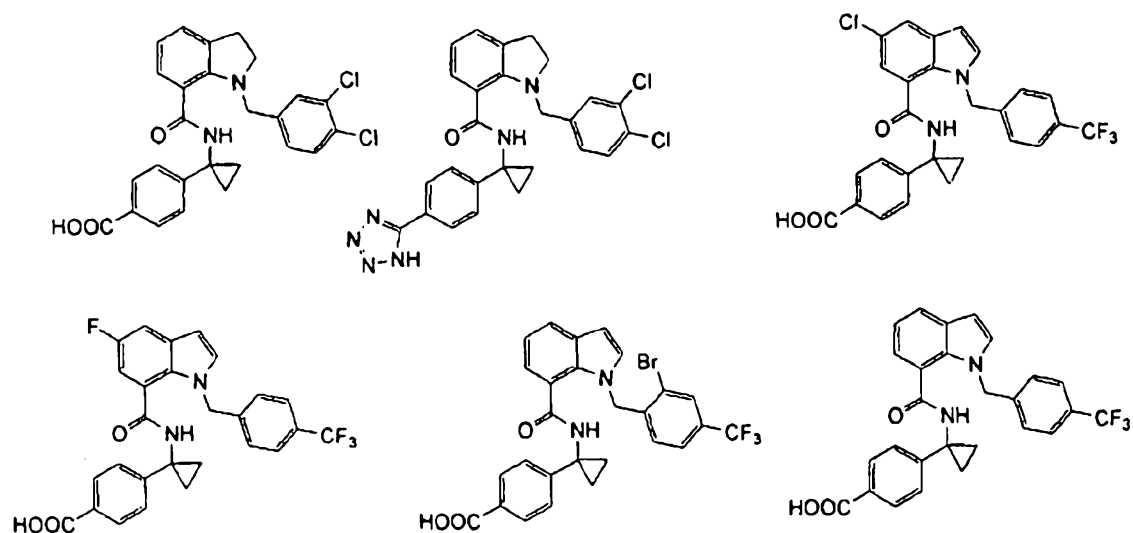
Ic



1c

or a pharmaceutically acceptable salt thereof, wherein the variables  $R^1$  and  $R^2$  are as previously defined.

Disclosed herein is a compound selected from the following:



or a pharmaceutically acceptable salt of any of the foregoing compounds. In an embodiment of the invention, the invention encompasses the diethylamine, sodium, potassium and L-lysine salt of any of the foregoing compounds.

The invention also encompasses a pharmaceutical composition comprising a compound of Formula I in admixture with one or more physiologically acceptable carriers or excipients.

The invention also encompasses a compound of Formula I or a pharmaceutically acceptable derivative thereof for use in human or veterinary medicine.

The invention also encompasses a method of treating a human or animal subject suffering from a condition which is mediated by the action of PGE2 at EP4 receptors, which method comprises administering to said subject an effective amount of a compound of Formula I.

The invention also encompasses the use of a compound of Formula I for the manufacture of a therapeutic agent for the treatment of a condition which is mediated by the action of PGE2 at EP4 receptors.

The invention also encompasses a method for treating acute or chronic pain, migraine, osteoarthritis, rheumatoid arthritis, juvenile rheumatoid arthritis, gout, bursitis, ankylosing spondylitis, primary dysmenorrhea, cancer or atherosclerosis in a patient in need thereof comprising administering to the patient a therapeutically effective amount of a compound of Formula I or a pharmaceutically acceptable salt thereof.

#### Abbreviations

The following abbreviations have the indicated meanings:

	DCM	=	dichloromethane
	DIPEA	=	N,N'-diisopropylethylamine
20	DMF	=	N,N-dimethylformamide
	DMSO	=	dimethyl sulfoxide
	HATU	=	o-(7-azabenzotriazole-1-yl)-N, N,N'-tetramethyluronium hexafluorophosphate
	RT	=	room temperature
25	TFA	=	trifluoroacetic acid
	THF	=	tetrahydrofuran
	TMEDA	=	N,N,N',N'-tetramethylethylenediamine

#### Definitions

"Alkyl", as well as other groups having the prefix "alk", such as alkoxy, alkanoyl, means carbon chains which may be linear or branched or combinations thereof. Examples of alkyl groups include methyl, ethyl, propyl, isopropyl, butyl, sec- and tert-butyl, pentyl, hexyl, heptyl, octyl, nonyl, and the like.



"Fluoroalkyl" means alkyl as defined above wherein one or more hydrogen atoms have been replaced by fluoro atoms.

"Alkenyl" means carbon chains which contain at least one carbon-carbon double bond, and which may be linear or branched or combinations thereof. Examples of alkenyl include vinyl, allyl, isopropenyl, pentenyl, hexenyl, heptenyl, 1-propenyl, 2-butenyl, 2-methyl-2-butenyl, and the like.

"Alkynyl" means carbon chains which contain at least one carbon-carbon triple bond, and which may be linear or branched or combinations thereof. Examples of alkynyl include ethynyl, propargyl, 3-methyl-1-pentynyl, 2-heptynyl and the like.

"Cycloalkyl" means mono- or bicyclic saturated carbocyclic rings, each of which having from 3 to 10 carbon atoms. A "fused analog" of cycloalkyl means a monocyclic rings fused to an aryl or heteroaryl group in which the point of attachment is on the non-aromatic portion. Examples of cycloalkyl and fused analogs thereof include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, tetrahydronaphthyl, decahydronaphthyl, indanyl, and the like.

"Alkoxy" means alkoxy groups of a straight or branched having the indicated number of carbon atoms. C<sub>1-6</sub>alkoxy, for example, includes methoxy, ethoxy, propoxy, isopropoxy, and the like.

"Cycloalkoxy" means cycloalkyl as defined above bonded to an oxygen atom, such as cyclopropyloxy.

"Fluoroalkoxy" means alkoxy as defined above wherein one or more hydrogen atoms have been replaced by fluoro atoms.

"Aryl" means mono- or bicyclic aromatic rings containing only carbon atoms. A "fused analog" of aryl means an aryl group fused to a monocyclic cycloalkyl or monocyclic heterocyclyl group in which the point of attachment is on the aromatic portion. Examples of aryl and fused analogs thereof include phenyl, naphthyl, indanyl, indenyl, tetrahydronaphthyl, 2,3-dihydrobenzofuranyl, dihydrobenzopyranyl, 1,4-benzodioxanyl, and the like.

"Heteroaryl" means a mono- or bicyclic aromatic ring containing at least one heteroatom selected from N, O and S, with each ring containing 5 to 6 atoms. A "fused analog" of heteroaryl means a heteroaryl group fused to a monocyclic cycloalkyl or monocyclic heterocyclyl group in which the point of attachment is on the aromatic portion. Examples of heteroaryl include pyrrolyl, isoxazolyl, isothiazolyl, pyrazolyl, pyridyl, oxazolyl, oxadiazolyl, thiadiazolyl, thiazolyl, imidazolyl, triazolyl, tetrazolyl, furanyl, triazinyl, thienyl, pyrimidyl,

pyridazinyl, pyrazinyl, benzoxazolyl, benzothiazolyl, benzimidazolyl, benzofuranyl, benzothiophenyl, furo(2,3-b)pyridyl, quinolyl, indolyl, isoquinolyl, and the like.

"Heterocyclyl" means mono- or bicyclic saturated rings or partially unsaturated monocyclic rings that are not aromatic containing at least one heteroatom selected from N, S and O, each of said rings having from 3 to 10 atoms in which the point of attachment may be carbon or nitrogen. A "fused analog" of heterocyclyl means a monocyclic heterocycle fused to an aryl or heteroaryl group in which the point of attachment is on the non-aromatic portion. Examples of "heterocyclyl" and fused analogs thereof include pyrrolidinyl, piperidinyl, piperazinyl, imidazolidinyl, 2,3-dihydrofuro(2,3-b)pyridyl, benzoxazinyl, tetrahydrohydroquinolinyl, tetrahydroisoquinolinyl, dihydroindolyl, and the like. The term also includes partially unsaturated monocyclic rings that are not aromatic, such as 2- or 4-pyridones attached through the nitrogen or N-substituted-(1H,3H)-pyrimidine-2,4-diones (N-substituted uracils).

"Halogen" and "halo" includes fluorine, chlorine, bromine and iodine.

#### Optical Isomers - Diastereomers - Geometric Isomers - Tautomers

Compounds of Formula I contain one or more asymmetric centers and can thus occur as racemates and racemic mixtures, single enantiomers, diastereomeric mixtures and individual diastereomers. The present invention is meant to comprehend all such isomeric forms of the compounds of Formula I.

Some of the compounds described herein contain olefinic double bonds, and unless specified otherwise, are meant to include both E and Z geometric isomers.

Some of the compounds described herein may exist with different points of attachment of hydrogen, referred to as tautomers. Such an example may be a ketone and its enol form known as keto-enol tautomers. The individual tautomers as well as mixture thereof are encompassed with compounds of Formula I.

Compounds of the Formula I may be separated into diastereoisomeric pairs of enantiomers by, for example, fractional crystallization from a suitable solvent, for example MeOH or EtOAc or a mixture thereof. The pair of enantiomers thus obtained may be separated into individual stereoisomers by conventional means, for example by the use of an optically active amine as a resolving agent or on a chiral HPLC column.

Alternatively, any enantiomer of a compound of the general Formula I may be obtained by stereospecific synthesis using optically pure starting materials or reagents of known configuration.

### Salts

The term "pharmaceutically acceptable salts" refers to salts prepared from pharmaceutically acceptable non-toxic bases or acids including inorganic or organic bases and inorganic or organic acids. Salts derived from inorganic bases include aluminum, ammonium, calcium, copper, ferric, ferrous, lithium, magnesium, manganic salts, manganous, potassium, sodium, zinc, and the like. Particularly preferred are the ammonium, calcium, magnesium, potassium, and sodium salts. Salts derived from pharmaceutically acceptable organic non-toxic bases include salts of primary, secondary, and tertiary amines, substituted amines including naturally occurring substituted amines, cyclic amines, and basic ion exchange resins, such as arginine, betaine, caffeine, choline, N,N'-dibenzylethylenediamine, diethylamine, 2-diethyl-aminoethanol, 2-dimethylaminoethanol, ethanolamine, ethylenediamine, N-ethyl-morpholine, N-ethylpiperidine, glucamine, glucosamine, histidine, hydrabamine, isopropylamine, lysine, methyl-glucamine, morpholine, piperazine, piperidine, polyamine resins, procaine, purines, theobromine, triethylamine, trimethylamine, tripropylamine, tromethamine, and the like.

When the compound of the present invention is basic, salts may be prepared from pharmaceutically acceptable non-toxic acids, including inorganic and organic acids. Such acids include acetic, benzenesulfonic, benzoic, camphorsulfonic, citric, ethanesulfonic, fumaric, gluconic, glutamic, hydrobromic, hydrochloric, isethionic, lactic, maleic, malic, mandelic, methanesulfonic, mucic, nitric, pamoic, pantothenic, phosphoric, succinic, sulfuric, tartaric, p-toluenesulfonic acid, and the like. Particularly preferred are citric, hydrobromic, hydrochloric, maleic, phosphoric, sulfuric, and tartaric acids.

It will be understood that, as used herein, references to the compounds of Formula I are meant to also include the pharmaceutically acceptable salts.

### Utilities

The compounds of the invention are antagonists of the EP4 receptor and are therefore useful in treating EP4 receptor mediated diseases.

In view of their ability to bind to the EP4 receptor, the compounds of the invention are useful in the treatment of the disorders that follow. Thus, the compounds of the invention are useful as analgesics. For example they are useful in the treatment of chronic articular pain (e.g. rheumatoid arthritis, osteoarthritis, rheumatoid spondylitis, gouty arthritis and juvenile arthritis) including the property of disease modification and joint structure preservation;

musculoskeletal pain; lower back and neck pain; sprains and strains; neuropathic pain; sympathetically maintained pain; myositis; pain associated with cancer and fibromyalgia; pain associated with migraine; pain associated with influenza or other viral infections, such as the common cold; rheumatic fever; pain associated with functional bowel disorders such as non-ulcer dyspepsia, non-cardiac chest pain and irritable bowel syndrome; pain associated with myocardial ischemia; post operative pain; headache; toothache; and dysmenorrhea.

The compounds of the invention are useful in the treatment of neuropathic pain. Neuropathic pain syndromes can develop following neuronal injury and the resulting pain may persist for months or years, even after the original injury has healed. Neuronal injury may occur in the peripheral nerves, dorsal roots, spinal cord or certain regions in the brain. Neuropathic pain syndromes are traditionally classified according to the disease or event that precipitated them. Neuropathic pain syndromes include: diabetic neuropathy; sciatica; non-specific lower back pain; multiple sclerosis pain; fibromyalgia; HIV related neuropathy; post-herpetic neuralgia; trigeminal neuralgia; and pain resulting from physical trauma, amputation, cancer, toxins or chronic inflammatory conditions. These conditions are difficult to treat and although several drugs are known to have limited efficacy, complete pain control is rarely achieved. The symptoms of neuropathic pain are incredibly heterogeneous and are often described as spontaneous shooting and lancinating pain, or ongoing, burning pain. In addition, there is pain associated with normally non-painful sensations such as "pins and needles" (paraesthesias and dysesthesias), increased sensitivity to touch (hyperesthesias), painful sensation following innocuous stimulation (dynamic, static or thermal allodynia), increased sensitivity to noxious stimuli (thermal, cold, mechanical hyperalgesia), continuing pain sensation after removal of the stimulation (hyperpathia) or an absence of or deficit in selective sensory pathways (hypoalgesia).

The compounds of the invention are also useful in the treatment of inflammation, for example in the treatment of skin conditions (e.g. sunburn, burns, eczema, dermatitis, psoriasis); ophthalmic diseases such as glaucoma, retinitis, retinopathies, uveitis and of acute injury to the eye tissue (e.g. conjunctivitis); lung disorders (e.g. asthma, bronchitis, emphysema, allergic rhinitis, respiratory distress syndrome pigeon fancier's disease, farmer's lung, CORD); gastrointestinal tract disorders (e.g. aphthous ulcer, Crohn's disease, atopic gastritis, gastritis varialoforme, ulcerative colitis, coeliac disease, regional ileitis, irritable bowel syndrome, inflammatory bowel disease, gastrointestinal reflux disease); organ transplantation; other conditions with an inflammatory component such as vascular disease, migraine, periarteritis nodosa, thyroiditis, aplastic anaemia, Hodgkin's disease, scleroderma, myaesthesia gravis,

multiple sclerosis, sarcoidosis, nephrotic syndrome, Bechet's syndrome, polymyositis, gingivitis, myocardial ischemia, pyrexia, systemic lupus erythematosus, polymyositis, tendinitis, bursitis, and Sjogren's syndrome.

The compounds of the invention are also useful in the treatment of immunological diseases such as autoimmune diseases, immunological deficiency diseases or organ transplantation. The compounds of the invention are also effective in increasing the latency of HIV infection.

The compounds of the invention are also useful in the treatment of diseases of abnormal platelet function (e.g. occlusive vascular diseases).

The compounds of the invention are also useful for the preparation of a drug with diuretic action.

The compounds of the invention are also useful in the treatment of impotence or erectile dysfunction.

The compounds of the invention are also useful in the treatment of bone disease characterized by abnormal bone metabolism or resorption such as osteoporosis (especially postmenopausal osteoporosis), hyper-calcemia, hyperparathyroidism, Paget's bone diseases, osteolysis, hypercalcemia of malignancy with or without bone metastases, rheumatoid arthritis, periodontitis, osteoarthritis, ostealgia, osteopenia, cancer cachexia, calculosis, lithiasis (especially urolithiasis), solid carcinoma, gout and ankylosing spondylitis, tendinitis and bursitis. In a further aspect compounds of the invention may be useful in inhibiting bone resorption and/or promoting bone generation.

The compounds of the invention are also useful for attenuating the hemodynamic side effects of NSAIDs and COX-2 inhibitors.

The compounds of the invention are also useful in the treatment of cardiovascular diseases such as hypertension or myocardial ischemia; functional or organic venous insufficiency; varicose therapy; haemorrhoids; and shock states associated with a marked drop in arterial pressure (e.g. septic shock).

The compounds of the invention are also useful in the treatment of neurodegenerative diseases and neurodegeneration such as dementia, particularly degenerative dementia (including senile dementia, Alzheimer's disease, Pick's disease, Huntingdon's chorea, Parkinson's disease and Creutzfeldt-Jakob disease, ALS, motor neuron disease); vascular dementia (including multi-infarct dementia); as well as dementia associated with intracranial space occupying lesions; trauma; infections and related conditions (including HIV infection);

metabolism; toxins; anoxia and vitamin deficiency; and mild cognitive impairment associated with ageing, particularly Age Associated Memory Impairment.

The compounds of Formula I are also useful in the treatment of neuroprotection and in the treatment of neurodegeneration following stroke, cardiac arrest, pulmonary bypass, traumatic  
5 brain injury, spinal cord injury or the like.

The compounds of the invention are also useful in the treatment of tinnitus.

The compounds of the invention are also useful in preventing or reducing dependence on, or preventing or reducing tolerance or reverse tolerance to, a dependence - inducing agent. Examples of dependence inducing agents include opioids (e.g. morphine), CNS  
10 depressants (e.g. ethanol), psychostimulants (e.g. cocaine) and nicotine.

The compounds of the invention are also useful in the treatment of complications of Type 1 diabetes (e.g. diabetic microangiopathy, diabetic retinopathy, diabetic nephropathy, macular degeneration, glaucoma), nephrotic syndrome, aplastic anaemia, uveitis, Kawasaki disease and sarcoidosis.

15 The compounds of the invention are also useful in the treatment of kidney dysfunction (nephritis, particularly mesangial proliferative glomerulonephritis, nephritic syndrome), liver dysfunction (hepatitis, cirrhosis), gastrointestinal dysfunction (diarrhoea) and colon cancer.

The compounds of the invention are also useful for treating or preventing a  
20 neoplasia in a subject in need of such treatment or prevention. The term "treatment" includes partial or total inhibition of the neoplasia growth, spreading or metastasis, as well as partial or total destruction of the neoplastic cells. The term "prevention" includes either preventing the onset of clinically evident neoplasia altogether or preventing the onset of a preclinically evident stage of neoplasia in individuals at risk. Also intended to be encompassed by this definition is the  
25 prevention of initiation for malignant cells or to arrest or reverse the progression of premalignant cells to malignant cells. This includes prophylactic treatment of those at risk of developing the neoplasia. The term "subject" for purposes of treatment includes any human or mammal subject who has any one of the known neoplasias, and preferably is a human subject. For methods of prevention, the subject is any human or animal subject, and preferably is a human subject who is  
30 at risk for obtaining a neoplasia. The subject may be at risk due to exposure to carcinogenic agents, being genetically predisposed to have the neoplasia, and the like.

The term "neoplasia" includes both benign and cancerous tumors, growths and polyps. Thus, the compounds of the invention are useful for treating or preventing benign

tumors, growths and polyps including squamous cell papilloma, basal cell tumor, transitional cell papilloma, adenoma, gastrinoma, cholangiocellular adenoma, hepatocellular adenoma, renal tubular adenoma, oncocytoma, glomus tumor, melanocytic nevus, fibroma, myxoma, lipoma, leiomyoma, rhabdomyoma, benign teratoma, hemangioma, osteoma, chondroma and

5 meningeoma. The compounds of the invention are also useful for treating or preventing cancerous tumors, growths and polyps including squamous cell carcinoma, basal cell carcinoma, transitional cell carcinoma, adenocarcinoma, malignant gastrinoma, cholangiocellular carcinoma, hepatocellular carcinoma, renal cell carcinoma, malignant melanoma, fibrosarcoma, myxosarcoma, liposarcoma, leiomyosarcoma, rhabdomyosarcoma, malignant teratoma,

10 hemangiosarcoma, Kaposi sarcoma, lymphangiosarcoma, osteosarcoma, chondrosarcoma, malignant meningeoma, non-Hodgkin lymphoma, Hodgkin lymphoma and leukemia. For purposes of this specification, "neoplasia" includes brain cancer, bone cancer, epithelial cell-derived neoplasia (epithelial carcinoma), basal cell carcinoma, adenocarcinoma, gastrointestinal cancer such as lip cancer, mouth cancer, esophageal cancer, small bowel cancer and stomach

15 cancer, colon cancer, rectal cancer, liver cancer, bladder cancer, pancreas cancer, ovary cancer, cervical cancer, lung cancer, breast cancer and skin cancer, such as squamous cell and basal cell cancers, prostate cancer, renal cell carcinoma, and other known cancers that affect epithelial, mesenchymal or blood cells throughout the body. The compounds of the invention are useful for treating or preventing any of the aforementioned cancers. The compounds of the invention are

20 useful for treating or preventing benign and cancerous tumors, growths and polyps of the following cell types: squamous epithelium, basal cells, transitional epithelium, glandular epithelium, G cells, bile ducts epithelium, hepatocytes, tubules epithelium, melanocytes, fibrous connective tissue, cardiac skeleton, adipose tissue, smooth muscle, skeletal muscle, germ cells, blood vessels, lymphatic vessels, bone, cartilage, meninges, lymphoid cells and hematopoietic

25 cells. The compounds can be used to treat subjects having adenomatous polyps, including those with familial adenomatous polyposis (FAP). Additionally, the compounds can be used to prevent polyps from forming in patients at risk of FAP. Preferably, the compounds of the invention are useful for treating or preventing the following cancers: colorectal, esophagus stomach, breast, head and neck, skin, lung, liver, gall bladder, pancreas, bladder, endometrium cervix, prostate,

30 thyroid and brain.

It is to be understood that reference to treatment includes both treatment of established symptoms and prophylactic treatment, unless explicitly stated otherwise.

### Dose Ranges

The magnitude of prophylactic or therapeutic dose of a compound of Formula I will, of course, vary with the nature and severity of the condition to be treated, and with the particular compound of Formula I used and its route of administration. The dose will also vary according to the age, weight and response of the individual patient. In general, the daily dose range lie within the range of from about 0.001 mg to about 100 mg per kg body weight of a mammal, preferably 0.01 mg to about 50 mg per kg, and most preferably 0.1 to 10 mg per kg, in single or divided doses. On the other hand, it may be necessary to use dosages outside these limits in some cases.

For use where a composition for intravenous administration is employed, a suitable dosage range is from about 0.01 mg to about 25 mg (preferably from 0.1 mg to about 10 mg) of a compound of Formula I per kg of body weight per day.

In the case where an oral composition is employed, a suitable dosage range is, e.g. from about 0.01 mg to about 100 mg of a compound of Formulas I or I a per kg of body weight per day, preferably from about 0.1 mg to about 10 mg per kg.

For use where a composition for sublingual administration is employed, a suitable dosage range is from 0.01 mg to about 25 mg (preferably from 0.1 mg to about 5 mg) of a compound of Formula I per kg of body weight per day.

### Pharmaceutical Compositions

Another aspect of the present invention provides pharmaceutical compositions which comprises a compound of Formula I and a pharmaceutically acceptable carrier. The term "composition", as in pharmaceutical composition, is intended to encompass a product comprising the active ingredient(s), and the inert ingredient(s) (pharmaceutically acceptable excipients) that make up the carrier, as well as any product which results, directly or indirectly, from combination, complexation or aggregation of any two or more of the ingredients, or from dissociation of one or more of the ingredients, or from other types of reactions or interactions of one or more of the ingredients. Accordingly, the pharmaceutical compositions of the present invention encompass any composition made by admixing a compound of Formula I, additional active ingredient(s), and pharmaceutically acceptable excipients.

Any suitable route of administration may be employed for providing a mammal, especially a human with an effective dosage of a compound of the present invention. For example, oral, sublingual, rectal, topical, parenteral, ocular, pulmonary, nasal, and the like may



be employed. Dosage forms include tablets, troches, dispersions, suspensions, solutions, capsules, creams, ointments, aerosols, and the like.

The pharmaceutical compositions of the present invention comprise a compound of Formula I as an active ingredient or a pharmaceutically acceptable salt thereof, and may also  
5 contain a pharmaceutically acceptable carrier and optionally other therapeutic ingredients. The term "pharmaceutically acceptable salts" refers to salts prepared from pharmaceutically acceptable non-toxic bases or acids including inorganic bases or acids and organic bases or acids.

The compositions include compositions suitable for oral, sublingual, rectal, topical, parenteral (including subcutaneous, intramuscular, and intravenous), ocular  
10 (ophthalmic), pulmonary (aerosol inhalation), or nasal administration, although the most suitable route in any given case will depend on the nature and severity of the conditions being treated and on the nature of the active ingredient. They may be conveniently presented in unit dosage form and prepared by any of the methods well-known in the art of pharmacy.

For administration by inhalation, the compounds of the present invention are  
15 conveniently delivered in the form of an aerosol spray presentation from pressurized packs or nebulizers. The compounds may also be delivered as powders which may be formulated and the powder composition may be inhaled with the aid of an insufflation powder inhaler device. The preferred delivery systems for inhalation are metered dose inhalation (MDI) aerosol, which may be formulated as a suspension or solution of a compound of Formula I in suitable propellants,  
20 such as fluorocarbons or hydrocarbons and dry powder inhalation (DPI) aerosol, which may be formulated as a dry powder of a compound of Formula I with or without additional excipients.

Suitable topical formulations of a compound of formula I include transdermal devices, aerosols, creams, ointments, lotions, dusting powders, and the like.

In practical use, the compounds of Formula I can be combined as the active  
25 ingredient in intimate admixture with a pharmaceutical carrier according to conventional pharmaceutical compounding techniques. The carrier may take a wide variety of forms depending on the form of preparation desired for administration, e.g., oral or parenteral (including intravenous). In preparing the compositions for oral dosage form, any of the usual pharmaceutical media may be employed, such as, for example, water, glycols, oils, alcohols,  
30 flavoring agents, preservatives, coloring agents and the like in the case of oral liquid preparations, such as, for example, suspensions, elixirs and solutions; or carriers such as starches, sugars, microcrystalline cellulose, diluents, granulating agents, lubricants, binders, disintegrating agents and the like in the case of oral solid preparations such as, for example, powders, capsules

and tablets, with the solid oral preparations being preferred over the liquid preparations. Because of their ease of administration, tablets and capsules represent the most advantageous oral dosage unit form in which case solid pharmaceutical carriers are obviously employed. If desired, tablets may be coated by standard aqueous or nonaqueous techniques.

5 In addition to the common dosage forms set out above, the compounds of Formula I may also be administered by controlled release means and/or delivery devices such as those described in U.S. Patent Nos. 3,845,770; 3,916,899; 3,536,809; 3,598,123; 3,630,200 and 4,008,719.

10 Pharmaceutical compositions of the present invention suitable for oral administration may be presented as discrete units such as capsules, cachets or tablets each containing a predetermined amount of the active ingredient, as a powder or granules or as a solution or a suspension in an aqueous liquid, a non-aqueous liquid, an oil-in-water emulsion or a water-in-oil liquid emulsion. Such compositions may be prepared by any of the methods of pharmacy but all methods include the step of bringing into association the active ingredient with  
15 the carrier which constitutes one or more necessary ingredients. In general, the compositions are prepared by uniformly and intimately admixing the active ingredient with liquid carriers or finely divided solid carriers or both, and then, if necessary, shaping the product into the desired presentation. For example, a tablet may be prepared by compression or molding, optionally with one or more accessory ingredients. Compressed tablets may be prepared by compressing in a  
20 suitable machine, the active ingredient in a free-flowing form such as powder or granules, optionally mixed with a binder, lubricant, inert diluent, surface active or dispersing agent. Molded tablets may be made by molding in a suitable machine, a mixture of the powdered compound moistened with an inert liquid diluent. Desirably, each tablet contains from about 1 mg to about 500 mg of the active ingredient and each cachet or capsule contains from about 1 to  
25 about 500 mg of the active ingredient.

### Combination Therapy

Compounds of Formula I may be used in combination with other drugs that are used in the treatment/prevention/suppression or amelioration of the diseases or conditions for which compounds of Formula I are useful. Such other drugs may be administered, by a route and in an amount commonly used therefor, contemporaneously or sequentially with a compound of Formula I. When a compound of Formula I is used contemporaneously with one or more other drugs, a pharmaceutical composition containing such other drugs in addition to the compound of Formula I is preferred. Accordingly, the pharmaceutical compositions of the present invention include those that also contain one or more other active ingredients, in addition to a compound of Formula I. Examples of other active ingredients that may be combined with a compound of Formula I, either administered separately or in the same pharmaceutical compositions, include, but are not limited to: COX-2 inhibitors, such as celecoxib, rofecoxib, etoricoxib, valdecoxib or parecoxib; 5-lipoxygenase inhibitors; NSAIDs, such as diclofenac, indomethacin, nabumetone or ibuprofen; leukotriene receptor antagonists; DMARDs such as methotrexate; adenosine A1 receptor agonists; sodium channel blockers, such as lamotrigine; NMDA receptor modulators, such as glycine receptor antagonists; gabapentin and related compounds; tricyclic antidepressants such as amitriptyline; neurone stabilising antiepileptic drugs; mono-aminergic uptake inhibitors such as venlafaxine; opioid analgesics; local anaesthetics; 5HT agonists, such as triptans, for example sumatriptan, naratriptan, zolmitriptan, eletriptan, frovatriptan, almotriptan or rizatriptan; EP1 receptor ligands; EP2 receptor ligands; EP3 receptor ligands; EP1 antagonists; EP2 antagonists and EP3 antagonists. When the compounds are used in combination with other therapeutic agents, the compounds may be administered either sequentially or simultaneously by any convenient route.

The invention thus provides, in a further aspect, a combination comprising a compound of Formula I or a pharmaceutically acceptable derivative thereof together with a further therapeutic agent or agents.

The combinations referred to above may conveniently be presented for use in the form of a pharmaceutical formulation and thus pharmaceutical formulations comprising a combination as defined above together with a pharmaceutically acceptable carrier or excipient comprise a further aspect of the invention. The individual components of such combinations may be administered either sequentially or simultaneously in separate or combined pharmaceutical formulations.

The weight ratio of the compound of the Formula I to the second active ingredient may be varied and will depend upon the effective dose of each ingredient. Generally, an effective dose of each will be used. Thus, for example, when a compound of Formula I is combined with an NSAID the weight ratio of the compound of Formula I to the NSAID will generally range from about 1000:1 to about 1:1000, preferably about 200:1 to about 1:200. Combinations of a compound of Formula I and other active ingredients will generally also be within the aforementioned range, but in each case, an effective dose of each active ingredient should be used.

5 ) Assays For Determining Biological Activity

The compounds of Formula I can be tested using the following assays to determine their prostanoid antagonist or agonist activity *in vitro* and *in vivo* and their selectivity. The prostaglandin receptor activities demonstrated are DP, EP<sub>1</sub>, EP<sub>2</sub>, EP<sub>3</sub>, EP<sub>4</sub>, FP, IP and TP.

5 ) Stable expression of prostanoid receptors in the human embryonic kidney (HEK) 293(ebna) cell line

Prostanoid receptor cDNAs corresponding to full length coding sequences are subcloned into the appropriate sites of mammalian expression vectors and transfected into HEK 293(ebna) cells. HEK 293(ebna) cells expressing the individual cDNAs are grown under selection and individual colonies are isolated after 2-3 weeks of growth using the cloning ring method and subsequently expanded into clonal cell lines.

Prostanoid receptor binding assays

Transfected HEK 293(ebna) cells are maintained in culture, harvested and membranes are prepared by differential centrifugation, following lysis of the cells in the presence of protease inhibitors, for use in receptor binding assays. Prostanoid receptor binding assays (for DP<sub>1</sub>, DP<sub>2</sub> (CRTH2), EP<sub>1</sub>, EP<sub>2</sub>, EP<sub>3</sub>-III, EP<sub>4</sub>, FP, IP, and TP) are performed in 10 mM MES/KOH (pH 6.0) (EPs, FP and TP) or 10 mM HEPES/KOH (pH 7.4) (DPs and IP), containing 1 mM EDTA, 2.5-30 mM divalent cation and the appropriate radioligand. Synthetic compounds are added in dimethylsulfoxide which is kept constant at 1 % (v/v) in all incubations. The reaction is initiated by addition of membrane protein. Non-specific binding is determined in the presence of 10  $\mu$ M of the corresponding non-radioactive prostanoid. Incubations are conducted for 60-120 min at room temperature or 30 °C and terminated by rapid filtration.

Specific binding is calculated by subtracting non specific binding from total binding. The residual specific binding at each ligand concentration is calculated and expressed as a function of ligand concentration in order to construct sigmoidal concentration-response curves. The binding affinity of the compounds is determined by calculating the equilibrium inhibition constant ( $K_i$ ) from the equation  $K_i = \text{InPt} / (1 + [\text{radioligand}] / K_d)$  where  $K_d$  is the equilibrium dissociation constant for the radioligand:receptor interaction and InPt is the inflection point of the dose-response curves.

Examples 1 to 6 were tested in the above binding assay for the EP4 receptor and demonstrated  $\text{IC}_{50}$ s of less than 500 nM.

#### Prostanoid receptor agonist and antagonist assays

Whole cell second messenger assays measuring stimulation of intracellular cAMP accumulation in HEK-293(ebna)-hEP4 cells are performed to determine whether receptor ligands are agonists or antagonists. Cells are harvested and resuspended in HBSS containing 25 mM HEPES, pH 7.4. Incubations contain 0.5 mM IBMX (phosphodiesterase inhibitor, available from Biomol). Samples are incubated at 37°C for 10 min, the reaction is terminated and cAMP levels are then measured. Ligands are added in dimethylsulfoxide which is kept constant at 1 % (v/v; agonists) or 2% (v/v; antagonists) in all incubations. For agonists, second messenger responses are expressed as a function of ligand concentration and both  $\text{EC}_{50}$  values and the maximum response as compared to a  $\text{PGE}_2$  standard are calculated. For antagonists, the ability of a ligand to inhibit an agonist response is determined by carrying out dose-response curves in the presence of  $\text{PGE}_2$  agonist at a concentration corresponding to its  $\text{EC}_{70}$ .  $\text{IC}_{50}$  values are calculated as the concentration of ligand required to inhibit 50% of the  $\text{PGE}_2$ -induced activity.

In the EP4 receptor antagonist assay, the compounds of Examples 1 to 6 showed an  $\text{EC}_{50} \leq 500$  nM.

#### Rat Paw Edema Assay

The method is the same as described in Chan *et al* (J. Pharmacol. Exp. Ther. 274: 1531-1537, 1995).

#### Acute Inflammatory Hyperalgesia Induced by Carrageenan in Rats

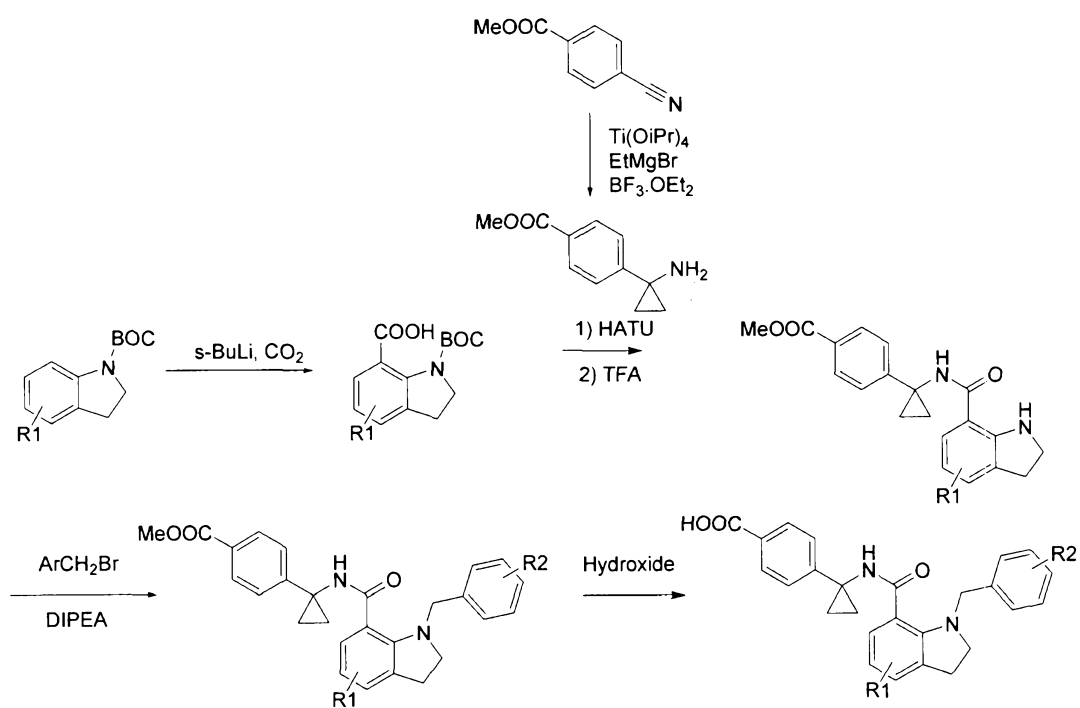
The method is the same as described in Boyce *et al* (Neuropharmacology 33: 1609-1611, 1994).

### Adjuvant-Induced Arthritis in Rats

Female Lewis rats (body weight ~146-170 g) are weighed, ear marked, and assigned to groups (a negative control group in which arthritis was not induced, a vehicle control group, a positive control group administered indomethacin at a total daily dose of 1 mg/kg and four groups administered with a test compound at total daily doses of 0.001-10.0 mg/kg) such that the body weights were equivalent within each group. Six groups of 10 rats each are injected into a hind paw with 0.5 mg of *Mycobacterium butyricum* in 0.1 mL of light mineral oil (adjuvant), and a negative control group of 10 rats was not injected with adjuvant. Body weights, contralateral paw volumes (determined by mercury displacement plethysmography) and lateral radiographs (obtained under Ketamine and Xylazine anesthesia) are determined before (day -1) and 17 to 21 days following adjuvant injection, and primary paw volumes are determined before (day -1) and on days 4 and 17 to 21 following adjuvant injection. The rats are anesthetized with an intramuscular injection of 0.03 - 0.1 mL of a combination of Ketamine (87 mg/kg) and Xylazine (13 mg/kg) for radiographs and injection of adjuvant. The radiographs are made of both hind paws on day 0 and day 17-21 using the Faxitron (45 kVp, 30 seconds) and Kodak X-OMAT TL film, and are developed in an automatic processor. Radiographs are evaluated for changes in the soft and hard tissues by an investigator who was blinded to experimental treatment. The following radiographic changes are graded numerically according to severity: increased soft issue volume (0-4), narrowing or widening of joint spaces (0-5) subchondral erosion (0-3), periosteal reaction (0-4), osteolysis (0-4) subluxation (0-3), and degenerative joint changes (0-3). Specific criteria are used to establish the numerical grade of severity for each radiographic change. The maximum possible score per foot was 26. A test compound at total daily doses of 0.1, 0.3, 1, and 3 mg/kg/day, indomethacin at a total daily dose of 1 mg/kg/day, or vehicle (0.5% methocel in sterile water) are administered per os b.i.d. beginning post injection of adjuvant and continuing for 17 to 21 days. The compounds are prepared weekly, refrigerated in the dark until used, and vortex mixed immediately prior to administration.

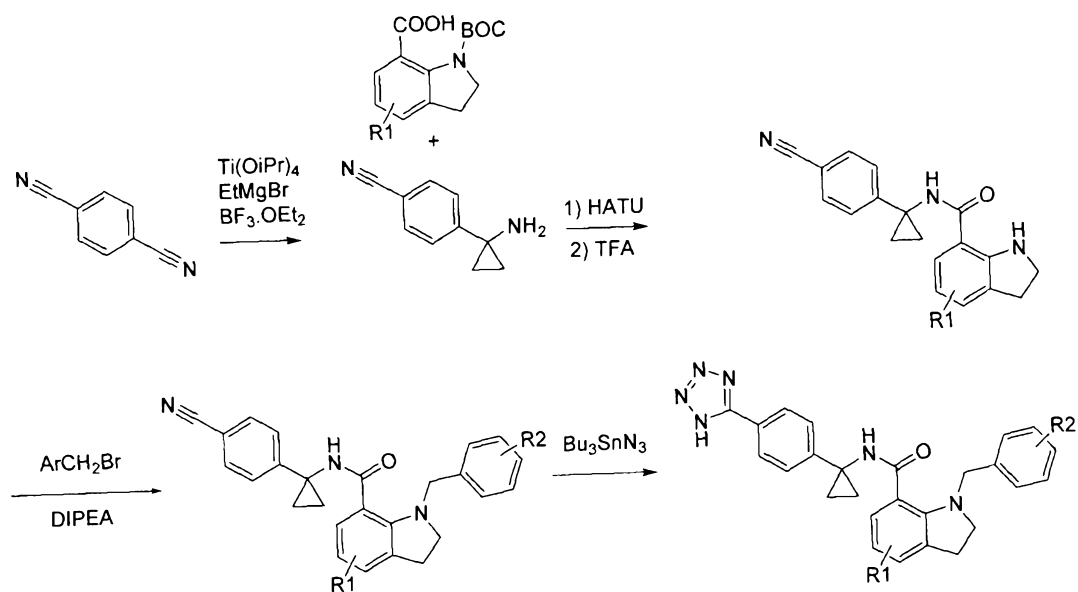
Method of Synthesis

SCHEME 1



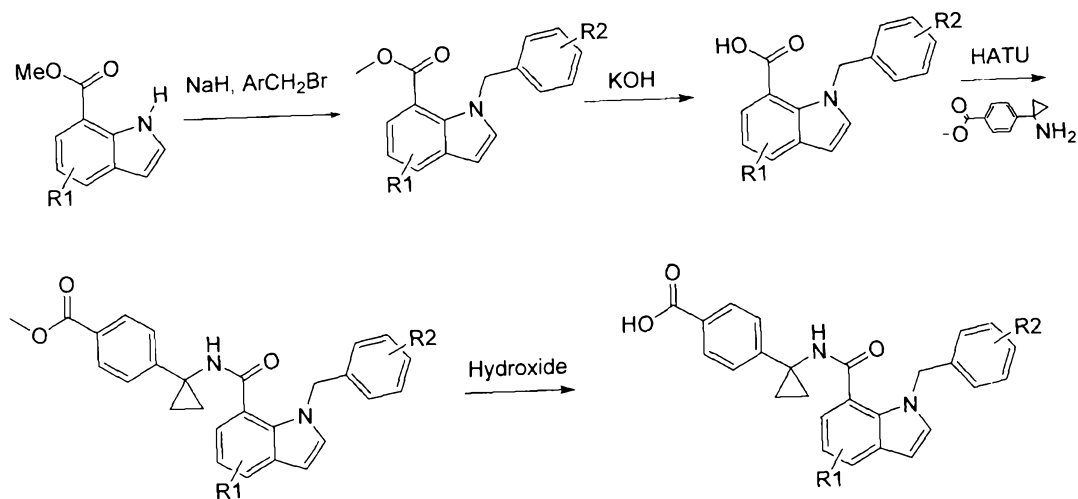
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## SCHEME 2



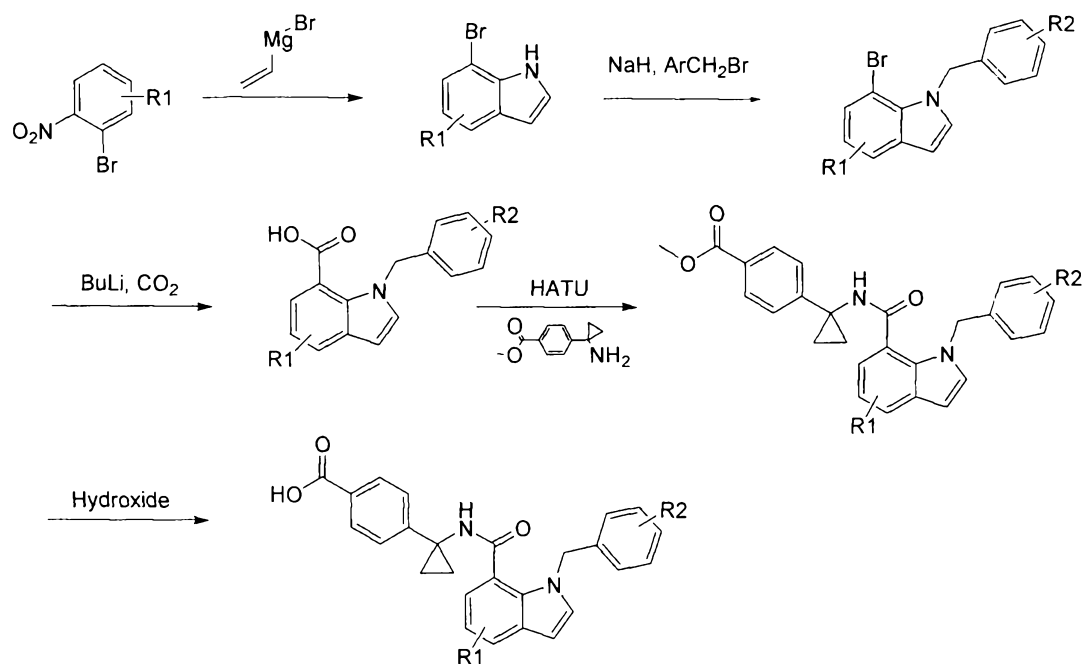
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## SCHEME 3





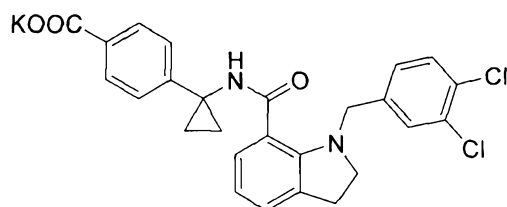
## SCHEME 4



5

## EXAMPLE 1

Potassium 4-[1-({[1-(3,4-dichlorobenzyl)-2,3-dihydro-1H-indol-7-yl]carbonyl}amino)cyclopropyl]benzoate



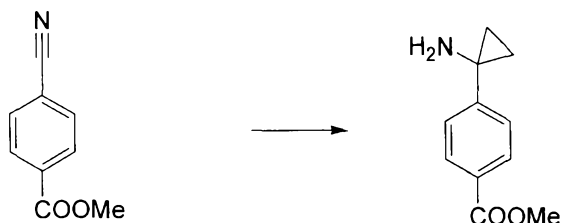
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Step 1: 1-(*tert*-butoxycarbonyl)indoline-7-carboxylic acid



5 *Tert*-butyl indoline-1-carboxylate (25 g, 114 mmol) and TMEDA (22.9 ml, 151 mmol) were added to 567 ml of ether. The solution was cooled to  $-78^{\circ}\text{C}$  and *s*-BuLi in *c*-hexane (1.2 eq, 1.4M) was added dropwise. The mixture was stirred at this temperature for 1 h.  $\text{CO}_2$  gas was bubbled in the mixture for 5 min and the bath was removed. After 10 min of stirring, the mixture was quenched with 1N HCl, warmed to RT and extracted 3x with EtOAc. The combined organic layers were washed with brine and dried over  $\text{MgSO}_4$ . The solvents were removed and the solid was triturated with 1:1 ether/hexanes.  $^1\text{H}$  NMR (500 MHz,  $\text{DMSO-d}_6$ ):  $\delta$  12.5 (bs, 1H), 7.35 (m, 2H), 7.05 (t, 1H), 4.00 (t, 2H), 3.00 (t, 2H), 1.45 (s, 9H)

Step 2: Methyl 4-(1-aminocyclopropyl)benzoate



5 Methyl 4-cyanobenzoate (2.6 kg, 16.1 mol) was dissolved in 40 L of toluene at  $-25^{\circ}\text{C}$  and  $\text{Ti}(\text{O}i\text{-Pr})_4$  (4.73 L, 16.1mol) was added over 5 min, followed by  $\text{EtMgBr}$  (10.5 L of a 3.07M solution in THF, 32.3 mol) over 2 hr. After aging for 30 min,  $\text{BF}_3\cdot\text{OEt}_2$  (4.1 L, 32 mol) was added over 40 min and the mixture was aged for another 40 min. The reaction was quenched by the addition of 40 L of 3N HCl. The layers were separated and the aqueous layer was washed with 13 L toluene. The aqueous layer was then extracted with 2-MeTHF (2x26L and 2x13L).

20 The combined 2-MeTHF layers were washed with 3N NaOH and the pH of the NaOH layer adjusted to 9 before separation of the layers. The organic layer was washed with 13 L of brine. Yield = 43%.  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.00 (d, 2H), 7.35 (d, 2H), 3.95 (s, 3H), 1.25 (t, 2H), 1.10 (t, 2H).

25

Step 3: Methyl 4-{1-[(2,3-dihydro-1*H*-indol-7-ylcarbonyl)amino]cyclopropyl}benzoate



5                    1-(*tert*-butoxycarbonyl)indoline-7-carboxylic acid (300 mg, 1.14 mmol), HATU (475 mg, 21.2 mmol) and methyl 4-(1-aminocyclopropyl)benzoate (262 mg, 1.37 mmol) were added to acetonitrile (7.6 ml). The solution was cooled in an ice bath and DIPEA (695  $\mu$ l, 3.99 mmol) was added. After 2 hr at RT, the mixture was poured into a solution of  $\text{NaHCO}_3$  (1/2sat.) and washed 3 times with EtOAc. The combined organic layers were washed with brine and dried  
0                    with  $\text{Na}_2\text{SO}_4$ . The solvent was removed and the crude mixture purified by flash chromatography on silica gel. The Boc group was removed with 1:1 TFA/DCM using the standard procedure.

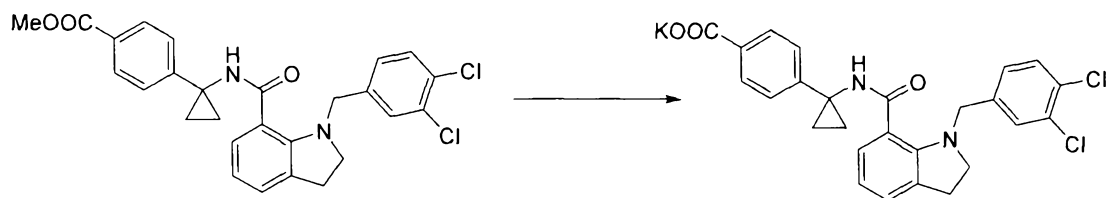
Step 4: Methyl 4-[1-({1-(3,4-dichlorobenzyl)-2,3-dihydro-1*H*-indol-7-yl}carbonyl)amino]cyclopropyl]benzoate



15

Methyl 4-{1-[(2,3-dihydro-1*H*-indol-7-ylcarbonyl)amino]cyclopropyl}benzoate (110 mg, 0.327 mmol) was dissolved in acetonitrile (1.3 ml). 3,4-dichlorobenzyl chloride (136  $\mu$ l, 0.981 mmol), DIPEA (171  $\mu$ l, 0.981 mmol) and a crystal of TBAI were added. The mixture stirred at 70°C for  
20                    2 h. The solvent was removed. Purification on silica gel.

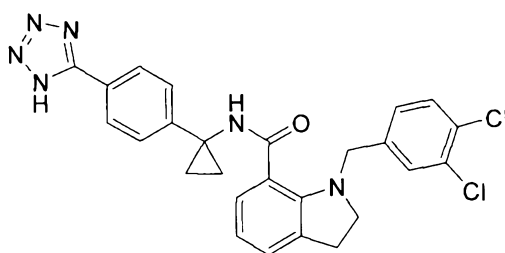
Step 5: Potassium 4-[1-({1-(3,4-dichlorobenzyl)-2,3-dihydro-1*H*-indol-7-yl}carbonyl)amino]cyclopropyl]benzoate



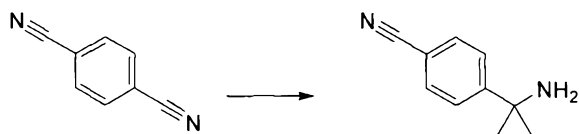
Methyl 4-([1-(3,4-dichlorobenzyl)-2,3-dihydro-1H-indol-7-yl]carbonyl)amino)cyclopropyl]benzoate (57 mg, 0.12 mmol) was dissolved in EtOH (0.54 ml). 2M KOH (0.075 ml, 0.13 mmol) was added and the mixture stirred at 80°C for 2 h. The mixture was cooled and the solvents removed. <sup>1</sup>H NMR (500 MHz, DMSO-d<sub>6</sub>): δ 9.05 (s, 1H), 7.65 (d, 2H), 7.55 (m, 2H), 7.25 (d, 1H), 7.15 (t, 2H), 7.00 (d, 2H), 6.65 (t, 1H), 4.30 (s, 2H), 3.25 (2H), 2.95 (t, 2H), 1.10 (2H), 0.95 (m, 2H). MS +ESI (480.8).

## EXAMPLE 2

1-(3,4-dichlorobenzyl)-N-{1-[4-(1H-tetrazol-5-yl)phenyl]cyclopropyl}indoline-7-carboxamide

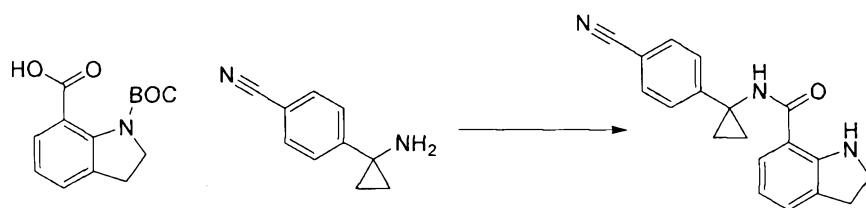


Step 1: 4-(1-aminocyclopropyl)benzonitrile



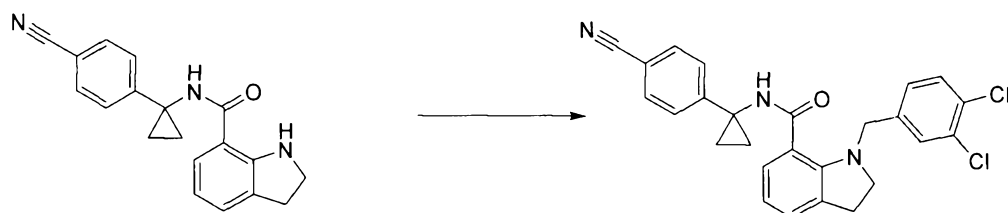
Terephthalonitrile (500 mg, 3.90 mmol) was dissolved in 10ml of DCM.  $\text{Ti}(\text{O}i\text{Pr})_4$  (1.1 ml, 3.9 mmol) was added to the solution, followed by a 3M solution of ethylmagnesium bromide in THF (2.3 ml, 7.0 mmol). The mixture was aged for 45 min at RT and  $\text{BF}_3 \cdot \text{Et}_2\text{O}$  (890  $\mu\text{l}$ , 7.0 mmol) was added. The mixture was then aged for an additional 2 h at RT. The reaction was quenched with  $\text{NH}_4\text{Cl}$  and 3N HCl. The layers were separated and the aqueous layer was washed with ether. The aqueous layer was then basicified using 10N NaOH (pH 9-10). EtOAc was added and the biphasic mixture was filtered. The layers were cut and the aqueous layer extracted with EtOAc. The combined organic layers were dried with  $\text{MgSO}_4$ , filtered and concentrated. Yield= 15%.

Step 2: *N*-[1-(4-cyanophenyl)cyclopropyl]indoline-7-carboxamide



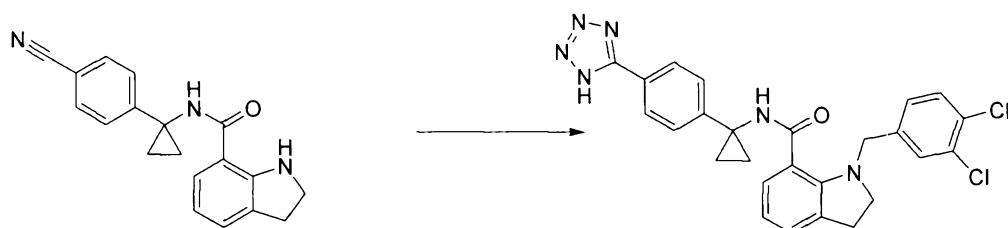
Procedure analogous to the one described in Example 1 Step 3.

Step 3: *N*-[1-(4-cyanophenyl)cyclopropyl]-1-(3,4-dichlorobenzyl)indoline-7-carboxamide



Procedure analogous to the one described in Example 1 step 4. <sup>1</sup>H NMR (500 MHz, DMSO-d<sub>6</sub>): δ 9.20 (s, 1H), 7.65 (d, 2H), 7.55 (m, 2H), 7.25 (m, 3H), 7.15 (m, 2H), 6.70 (t, 1H), 4.25 (s, 2H), 3.30 (t, 2H), 3.00 (t, 2H), 1.25 (m, 2H), 1.05 (m, 2H).

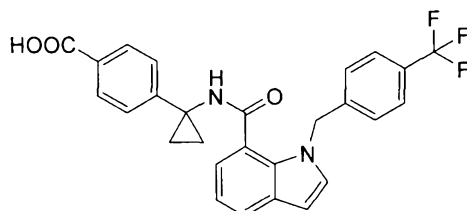
Step 4: 1-(3,4-dichlorobenzyl)-N-{1-[4-(1H-tetrazol-5-yl)phenyl]cyclopropyl}indoline-7-carboxamide



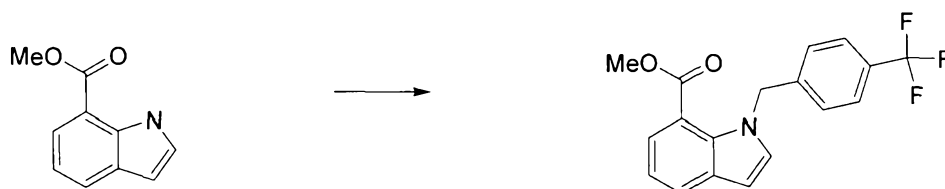
*N*-[1-(4-cyanophenyl)cyclopropyl]-1-(3,4-dichlorobenzyl)indoline-7-carboxamide (125 mg, 0.27 mmol) and azidotributyltin (222 µl, 0.81 mmol) were refluxed in 1 ml of toluene overnight. 350 µl of AcOH was added and the resulting solid was filtered and washed with toluene. <sup>1</sup>H NMR (500 MHz, DMSO-d<sub>6</sub>): δ 9.20 (s, 1H), 7.90 (d, 2H), 7.50 (m, 2H), 7.35 (d, 2H), 7.25 (d, 1H), 7.15 (m, 2H), 6.70 (t, 1H), 4.25 (s, 2H), 3.25 (2H), 2.95 (t, 2H), 1.20 (2H), 1.05 (m, 2H). MS -ESI (503.0).

## EXAMPLE 3

4-{1-[(1-[4-(trifluoromethyl)benzyl]-1*H*-indol-7-yl}carbonyl)amino]cyclopropyl}benzoic acid

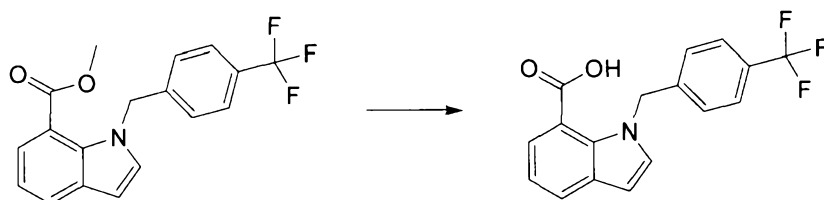


Step 1: Methyl 1-[4-(trifluoromethyl)benzyl]-1*H*-indole-7-carboxylate



Methyl 1*H*-indole-7-carboxylate (47.8 g, 273 mmol) and 1-(bromomethyl)-4-(trifluoromethyl)benzene (81 g, 341 mmol) were dissolved in DMF (1.3 L) at 0°C. 60% w/w NaH (12 g, 300 mmol) was added portion wise. The ice bath was removed and the mixture stirred at 0°C for 3 hours, then overnight at RT. The reaction mixture was quenched with 3 L of NH<sub>4</sub>Cl(sat.) and the aqueous layer was extracted 3 times with 1 L of ether. The organic layers were combined, washed with water and brine. The compound was purified by flash chromatography on silica gel. <sup>1</sup>H NMR (500 MHz, DMSO-*d*<sub>6</sub>): δ 8.90 (d, 1H), 7.70 (s, 1H), 7.60 (d, 2H), 7.40 (d, 1H), 7.10 (t, 1H), 7.00 (d, 2H), 6.70 (d, 1H), 5.70 (s, 2H).

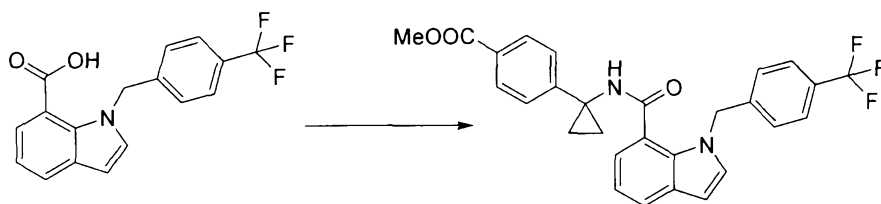
Step 2: 1-[4-(trifluoromethyl)benzyl]-1*H*-indole-7-carboxylic acid



Methyl 1-[4-(trifluoromethyl)benzyl]-1H-indole-7-carboxylate (11.7 g, 35.1 mmol) was dissolved in 350 ml of 1:1 THF/MeOH and 175 ml of 2N KOH (10 eq, 351 mmol).

The mixture was stirred at RT for 18 hr. Then the solvents were evaporated under reduced pressure. 2N HCl was added (pH=3) and the aqueous phase was extracted 3x with DCM. The combined organic layers were washed with water and brine, dried over MgSO<sub>4</sub>, filtered and then concentrated under reduced pressure. <sup>1</sup>H NMR (500 MHz, DMSO-d<sub>6</sub>): δ 12.85 (bs, 1H), 7.80 (d, 1H), 7.60 (m, 3H), 7.50 (m, 1H), 7.10 (t, 1H), 7.00 (d, 2H), 6.70 (d, 1H), 5.80 (s, 2H).

Step 3: Methyl 4-{1-[(1-[4-(trifluoromethyl)benzyl]-1H-indol-7-yl)carbonyl]amino}cyclopropyl}benzoate

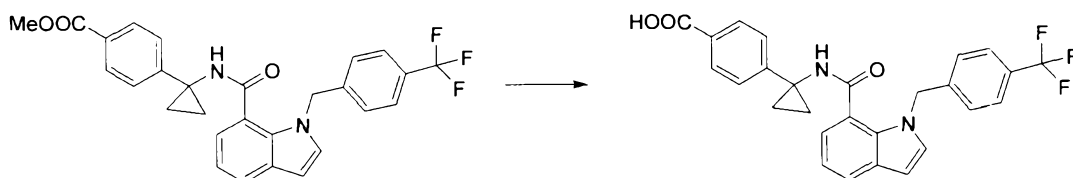


Methyl 1-[4-(trifluoromethyl)benzyl]-1H-indole-7-carboxylate (30.8 g, 97 mmol), HATU (38.6 g, 101 mmol) and methyl 4-(1-aminocyclopropyl)benzoate (24.9 g, 130 mmol) were added to DMF (483 ml). The solution was cooled in an ice bath and DIPEA (50.6 ml, 290 mmol) was added. The mixture was aged overnight at RT and 500 ml of EtOAc was added. The mixture was then poured into 2 L of NaHCO<sub>3</sub> (1/2sat.). The layers were cut and the aqueous layer was washed 2 more times with DCM. The combined organic layers were washed with brine and dried with Na<sub>2</sub>SO<sub>4</sub>. The solvent was removed and the crude mixture purified by flash chromatography on silica gel. <sup>1</sup>H NMR (500 MHz, DMSO-d<sub>6</sub>): δ 9.18 (s, 1H), 7.75 (m, 3H),



7.60 (d, 2H), 7.45 (d, 1H), 7.40 (d, 1H), 7.20 (d, 2H), 7.15 (t, 1H), 6.90 (d, 2H), 6.65 (d, 1H), 5.70 (s, 2H), 3.85 (s, 3H), 1.20 (m, 2H), 0.95 (m, 2H).

- 5 Step 4: 4-{1-[(1-[4-(trifluoromethyl)benzyl]-1*H*-indol-7-yl)carbonyl]amino}cyclopropyl}benzoic acid



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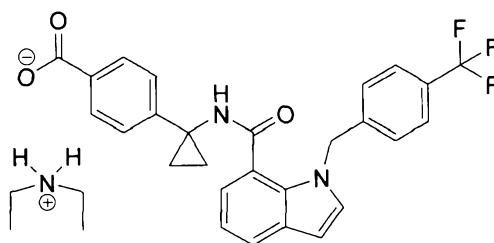
- Methyl 4-{1-[(1-[4-(trifluoromethyl)benzyl]-1*H*-indol-7-yl)carbonyl]amino}cyclopropyl}benzoate (27 g, 55 mmol) was dissolved in 549 ml of THF 549 ml of MeOH and 249 ml of a 2M solution of KOH. The mixture was heated at 50°C for 2 h. After cooling to RT, 200 ml of water was added and the organic solvents removed. The solution  
 5 was acidified to pH 1-1.5 with 3N HCl and the resulting solid was filtered and washed with water. <sup>1</sup>H NMR (500 MHz, DMSO-d<sub>6</sub>): δ 12.80 (bs, 1H), 9.15 (s, 1H), 7.80 (d, 3H), 7.60 (d, 2H), 7.50 (d, 1H), 7.40 (d, 1H), 7.25-7.11 (m, 3H), 6.90 (d, 2H), 6.65 (d, 1H), 5.70 (s, 2H), 1.15 (m, 2H), 0.90 (m, 2H). MS -ESI (477.4).

20

Example 3 was also synthesized as the diethylamine, sodium, potassium and L-lysine salts. The procedure for making the diethylamine salt of Example 3 is outlined in Example 3A below. The other salts can be readily made by one having ordinary skill in the art.

## EXAMPLE 3A

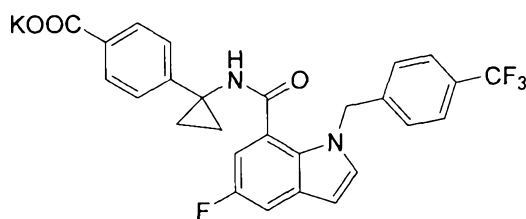
N-ethylethanaminium 4-{1-[(1-[4-(trifluoromethyl)benzyl]-1H-indol-7-yl)carbonyl]amino}cyclopropyl}benzoate

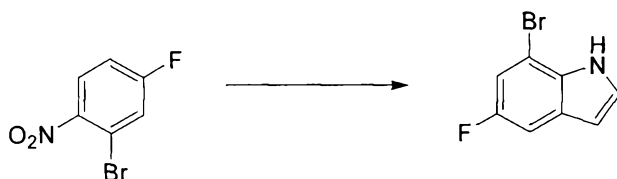


4-{1-[(1-[4-(trifluoromethyl)benzyl]-1H-indol-7-yl)carbonyl]amino}cyclopropyl}benzoic acid (13 g, 27.2 mmol) was dissolved in 146 ml ethanol. Diethylamine (3.4 ml, 33 mmol) was added and the mixture was stirred 30 min (formation of precipitate observed). 260 ml of methyl *tert*-butylether was added and the mixture aged one hour. The solid was collected by filtration, washed with methyl *tert*-butylether and dried under vacuum at 85°C for 24 h. <sup>1</sup>H NMR δ Acetone-d<sub>6</sub>: 8.30 (1H, s), 7.90 (2H, d), 7.80 (1H, d), 7.55 (2H, d), 7.45-7.35 (4H, m), 7.15 (1H, d), 7.00 (2H, d), 6.70 (1 H, d), 5.80 (2 H, s), 2.60 (4H, q), 1.25-1.20 (2 H, m), 1.10-1.05 (8H, m).

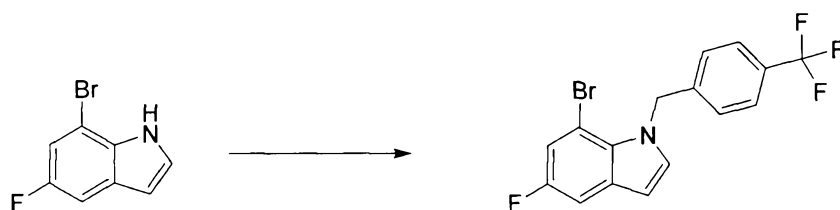
## EXAMPLE 4

Potassium 4-{1-[(5-fluoro-1-[4-(trifluoromethyl)benzyl]-1H-indol-7-yl)carbonyl]amino}cyclopropyl}benzoate

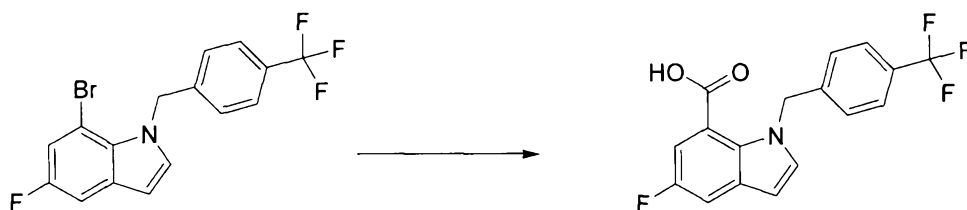


Step 1: 7-bromo-5-fluoro-1*H*-indole

2-bromo-4-fluoro-1-nitrobenzene (3.5 g, 15.9 mmol) was dissolved in anhydrous THF (160 ml) under N<sub>2</sub>. The reaction was cooled to -45°C and vinyl magnesium bromide (3 eq, 1M) was added, the mixture was stirred for 30 min at this temperature. The reaction was quenched with NH<sub>4</sub>Cl (sat.) and 1N HCl. The aqueous layer was then extracted 3x with ether. The combined organic layers were washed with water and brine, dried over MgSO<sub>4</sub>, filtered and then concentrated under reduced pressure. The product was purified by flash chromatography on silica gel. <sup>1</sup>H NMR (500 MHz, DMSO-d<sub>6</sub>): δ 11.45 (bs, 1H), 7.50 (t, 1H), 7.40 (dd, 1H), 7.25 (dd, 1H), 6.50 (dd, 1H).

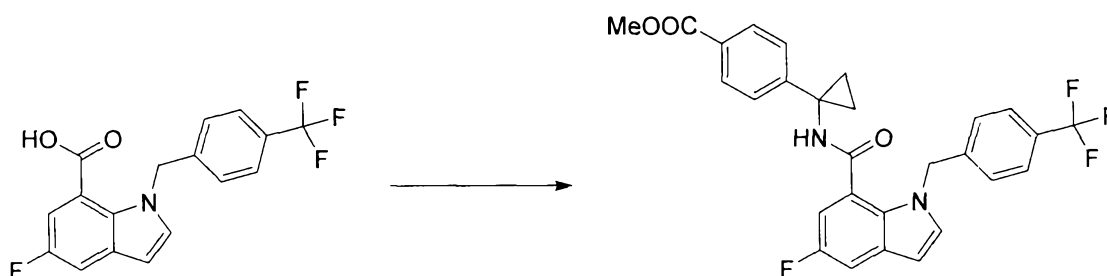
Step 2: 7-bromo-5-fluoro-1-[4-(trifluoromethyl)benzyl]-1*H*-indole

7-bromo-5-fluoro-1*H*-indole (900mg, 4.20mmol) and 1-(bromomethyl)-4-(trifluoromethyl)benzene (1.6g, 6.7mmol) were dissolved in DMF (20 ml). The mixture was cooled to -10 °C and NaH (185 mg, 4.6 mmol) was added portion wise over 5 min. The mixture was stirred for 1 hour at this temperature. Quenched with NH<sub>4</sub>Cl (1/2 sat.) and 1N HCl. The mixture was diluted with water and the aqueous phase was extracted 3x with ether. The combined organic layers were washed with 3x water, 1x brine and dried over MgSO<sub>4</sub>. The product was purified by flash chromatography on silica gel. <sup>1</sup>H NMR (500 MHz, DMSO-d<sub>6</sub>): δ 7.70 (m, 3H), 7.45 (dd, 1H), 7.25 (dd, 1H), 7.10 (d, 2H), 6.65 (d, 1H), 5.90 (s, 2H).

Step 3: 5-fluoro-1-[4-(trifluoromethyl)benzyl]-1*H*-indole-7-carboxylic acid

5                    7-bromo-5-fluoro-1-[4-(trifluoromethyl)benzyl]-1*H*-indole (1.3 g, 3.5 mmol) was dissolved in THF (18mL), the solution was degassed then cooled to -100°C under nitrogen. *n*-BuLi (1.15 eq, 2.5M) was added dropwise and the reaction was stirred for 5 min at this temperature. CO<sub>2</sub> gas was bubbled in the mixture for 5 in and the bath was removed. After 10 min of stirring, the mixture was quenched with 1N HCl, warmed to RT and extracted 3x with  
 10 EtOAc. The combined organic layers were washed with water and brine, dried over MgSO<sub>4</sub>, filtered and then concentrated under reduced pressure. The product was purified by flash chromatography on silica gel. <sup>1</sup>H NMR (500 MHz, DMSO-*d*<sub>6</sub>): δ 13.2 (bs, 1H), 7.73 (d, 1H), 7.65 (m, 3H), 7.30 (dd, 1H), 7.00 (d, 2H), 6.70 (d, 1H), 5.75 (m, 2H).

15    Step 4: Methyl 4-{1-[(5-fluoro-1-[4-(trifluoromethyl)benzyl]-1*H*-indol-7-yl)carbonyl]amino}cyclopropyl}benzoate

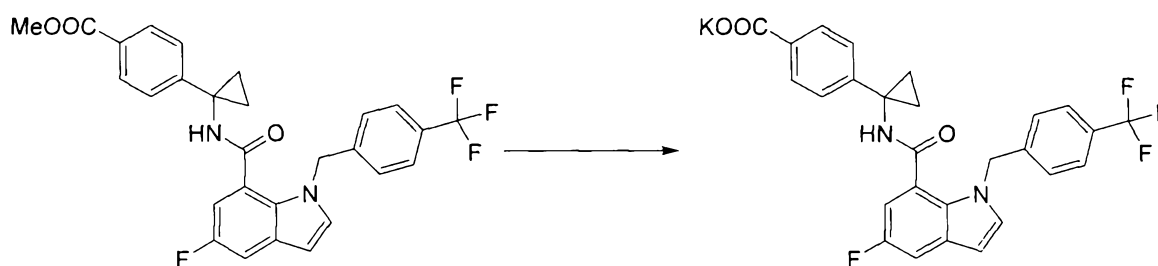


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5-fluoro-1-[4-(trifluoromethyl)benzyl]-1*H*-indole-7-carboxylic acid (218 mg, 0.65 mmol), HATU (283 mg, 0.74 mmol) and 1-[4-(methoxycarbonyl)phenyl] cyclopropanaminium methane sulfonate (374 mg, 1.3 mmol) were dissolved in DMF (4ml), then was added Hunig's base (0.34 ml, 2.0 mmol). The reaction mixture was aged at RT overnight. The mixture was

transferred to a separating funnel with EtOAc and NaHCO<sub>3</sub> (1/2 sat.). The organic layer was washed with 4x brine (1/2 sat.), dried over MgSO<sub>4</sub>, filtered and the solvent evaporated under reduced pressure. The product was purified by flash chromatography on silica gel. <sup>1</sup>H NMR (500 MHz, DMSO-d<sub>6</sub>): δ 9.25 (s, 1H), 7.75 (d, 2H), 7.55 (m, 4H), 7.20 (m, 3H), 6.90 (d, 2H), 6.65 (d, 1H), 5.65 (s, 2H), 3.85 (d, 3H), 1.20 (m, 2H), 0.95 (m, 2H).

Step 5: Potassium 4-{1-[(5-fluoro-1-[4-(trifluoromethyl)benzyl]-1*H*-indol-7-yl)carbonyl)amino]cyclopropyl}benzoate

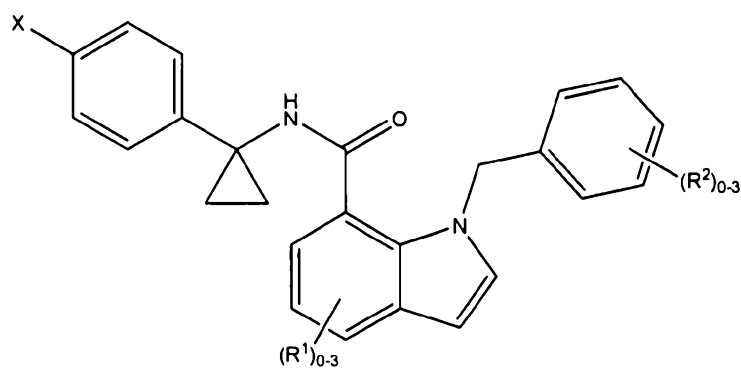


Methyl 4-{1-[(5-fluoro-1-[4-(trifluoromethyl)benzyl]-1*H*-indol-7-yl)carbonyl)amino]cyclopropyl}benzoate (67 mg, 0.13 mmol) was dissolved in 1 ml THF/MeOH (1:1) and 0.5 ml 2N KOH. Then reaction mixture was stirred at RT for 18 h. The mixture was cooled and the solvents were evaporated under reduced pressure. 2N HCl was added (until pH=3) and the aqueous phase was extracted 3x with DCM. The combined organic layers were washed with water and brine, then dried over MgSO<sub>4</sub>, filtered and concentrated under reduced pressure. The residue was dissolved in 1 ml methanol and 1 eq of KOH (0.065 ml of 2N KOH) was added, the methanol was then evaporated under reduced pressure. The resulting solid was solubilised in water and the solution was lyophilized. <sup>1</sup>H NMR (500 MHz, DMSO-d<sub>6</sub>): δ 9.15 (s, 1H), 7.70 (d, 2H), 7.55 (m, 4H), 7.15 (m, 1H), 7.05 (d, 2H), 6.90 (d, 2H), 6.65 (d, 1H), 5.65 (s, 2H), 1.70 (s, 2H), 1.05 (s, 2H), 0.80 (s, 2H).

Example	Structure	Name	m/z
1		Potassium 4-[1-({1-(3,4-dichlorobenzyl)-2,3-dihydro-1H-indol-7-yl}carbonyl)amino)cyclopropyl]benzoate	480.8 (M+1)
2		1-(3,4-dichlorobenzyl)-N-{1-[4-(1H-tetrazol-5-yl)phenyl]cyclopropyl}indoline-7-carboxamide	503.0 (M-1)
3		4-{1-[(1-[4-(trifluoromethyl)benzyl]-1H-indol-7-yl}carbonyl)amino]cyclopropyl}benzoic acid	477.4 (M-1)
4		Potassium 4-{1-[(1-[4-(trifluoromethyl)benzyl]-1H-indol-7-yl}carbonyl)amino]cyclopropyl}benzoate	495.2 (M-1)
5		Potassium 4-{1-[(1-[4-(trifluoromethyl)benzyl]-1H-indol-7-yl}carbonyl)amino]cyclopropyl}benzoate	510.6 (M-1)
6		Potassium 4-{1-[(1-[2-bromo-4-(trifluoromethyl)benzyl]-1H-indol-7-yl}carbonyl)amino]cyclopropyl}benzoate	556.8 (M-1)

## CLAIMS

1. A compound of Formula I



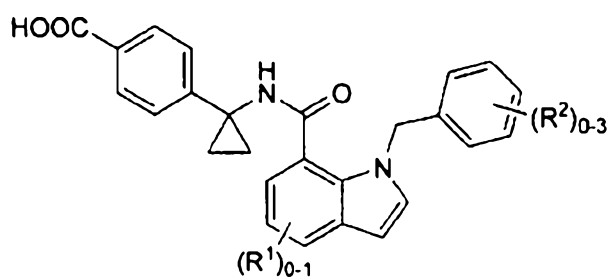
I

or a pharmaceutically acceptable salt thereof, wherein:

X is -COOH or tetrazolyl;

R<sup>1</sup> and R<sup>2</sup> are independently selected from the group consisting of: halo, C<sub>1-4</sub>alkyl, C<sub>1-4</sub>fluoroalkyl, C<sub>1-4</sub>alkoxy, C<sub>1-4</sub>fluoroalkoxy and acetyl.

2. The compound according to claim 1 of Formula Ia

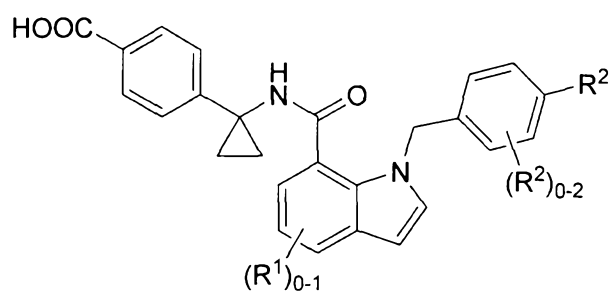


Ia

or a pharmaceutically acceptable salt thereof, wherein the variables  $R^1$  and  $R^2$  are as previously defined.

5

3. The compound according to Claim 2 of Formula Ib

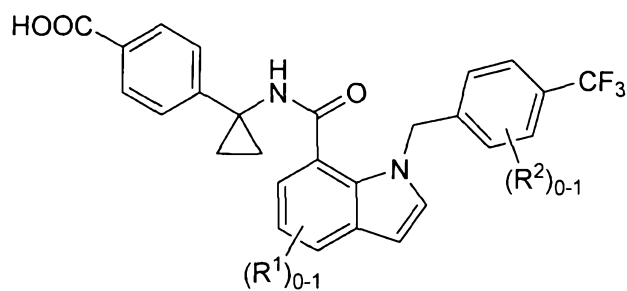


Ib

or a pharmaceutically acceptable salt thereof, wherein the variables  $R^1$  and  $R^2$  are as previously defined.

15

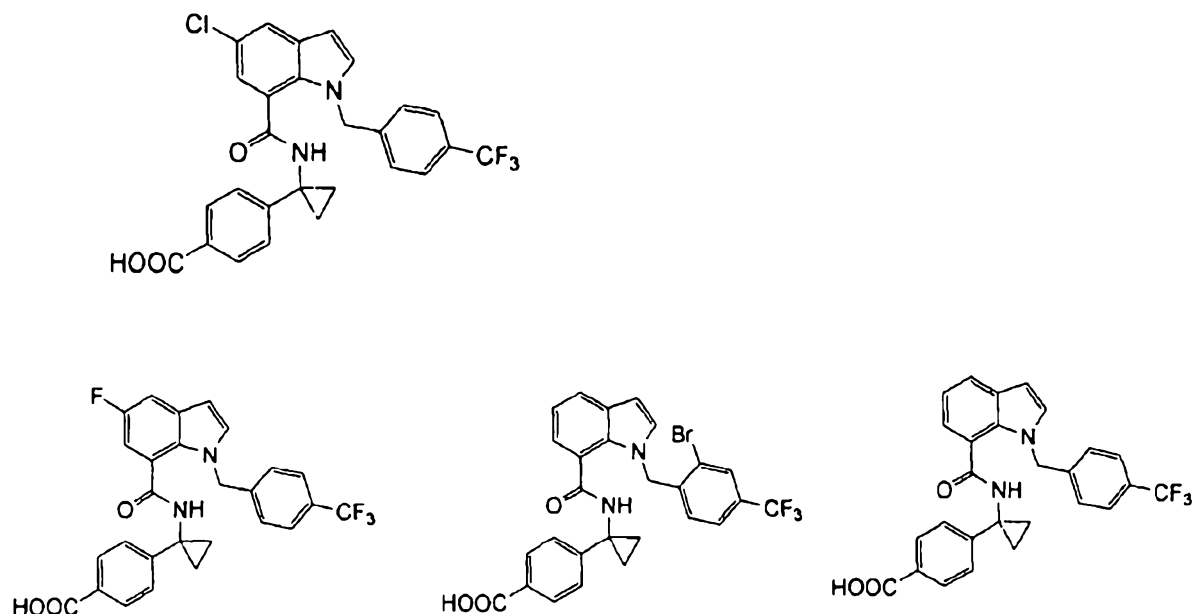
4. The compound according to Claim 3 of Formula Ic





or a pharmaceutically acceptable salt thereof, wherein the variables  $R^1$  and  $R^2$  are as previously defined.

5. The compound according to claim 1 selected from the following:



or a pharmaceutically acceptable salt of any of the foregoing compounds.

6. The diethylamine, sodium, potassium and L-lysine salt of a compound according to claim 5.
7. A pharmaceutical composition comprising a compound according to any one of claims 1 to 5 or a pharmaceutically acceptable salt thereof in admixture with one or more physiologically acceptable carriers or excipients.
8. A compound according to claim 1 or a pharmaceutically acceptable derivative thereof for use in human or veterinary medicine.
9. A method of treating a human or animal subject suffering from a condition which is mediated by the action of PGE<sub>2</sub> at EP<sub>4</sub> receptors, which method comprises administering to said subject an effective amount of a compound according to any one of claims 1 to 5 or a

pharmaceutically acceptable salt thereof, or an effective amount of a composition according to claim 7.

10. The use of a compound according to any one of claims 1 to 5 or a pharmaceutically acceptable salt thereof for the manufacture of a therapeutic agent for the treatment of a condition which is mediated by the action of PGE2 at EP4 receptors.

11. A method for treating acute or chronic pain, migraine, osteoarthritis, rheumatoid arthritis, juvenile rheumatoid arthritis, gout, bursitis, ankylosing spondylitis, primary dysmenorrhea, cancer or atherosclerosis in a patient in need thereof comprising administering to the patient a therapeutically effective amount of a compound according to any one of claims 1 to 5 or a pharmaceutically acceptable salt thereof or an effective amount of a composition according to claim 7.

12. A compound according to claim 1 and substantially as hereinbefore described with reference to any one of Examples 3 to 6.

**Merck Frosst Canada Ltd.**

**Patent Attorneys for the Applicant/Nominated Person**

**SPRUSON & FERGUSON**