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CA 2739321 A1 2010/04/08

(21) 2 739 321

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2009/10/01
(87) Date publication PCT/PCT Publication Date: 2010/04/08
(85) Entrée phase nationale/National Entry: 2011/03/31
(86) N° demande PCT/PCT Application No.: US 2009/005406
(87) N° publication PCT/PCT Publication No.: 2010/039236
(30) Priorité/Priority: 2008/10/01 (US61/194,829)

(51) Cl.Int./Int.Cl. *C07D 211/96* (2006.01), *A61K 31/435* (2006.01), *A61K 31/495* (2006.01), *C07D 401/04* (2006.01), *C07D 401/14* (2006.01), *C07D 417/04* (2006.01), *C07D 417/14* (2006.01), *A61P 29/00* (2006.01), *A61P 37/00* (2006.01)

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(54) Titre : COMPOSES POUR DES UTILISATIONS LIEES A UNE INFLAMMATION ET AU SYSTEME IMMUNITAIRE
(54) Title: COMPOUNDS FOR INFLAMMATION AND IMMUNE-RELATED USES

(57) Abrégé/Abstract:
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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 April 2010 (08.04.2010)

PCT

(10) International Publication Number
WO 2010/039236 A1

(51) International Patent Classification:
C07D 211/96 (2006.01) *A61K 31/435* (2006.01)
C07D 401/04 (2006.01) *A61K 31/495* (2006.01)
C07D 401/14 (2006.01) *A61P 29/00* (2006.01)
C07D 417/04 (2006.01) *A61P 37/00* (2006.01)
C07D 417/14 (2006.01)

(21) International Application Number:
PCT/US2009/005406

(22) International Filing Date:
1 October 2009 (01.10.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/194,829 1 October 2008 (01.10.2008) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

WO 2010/039236 A1

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COMPOUNDS FOR INFLAMMATION AND IMMUNE-RELATED USES

RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/194,829, filed October 1, 2008, the entire disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates to biologically active chemical compounds that may be used for immunosuppression or to treat or prevent inflammatory conditions and immune disorders.

BACKGROUND OF THE INVENTION

Inflammation is a mechanism that protects mammals from invading pathogens. However, while transient inflammation is necessary to protect a mammal from infection, uncontrolled inflammation causes tissue damage and is the underlying cause of many illnesses. Inflammation is typically initiated by binding of an antigen to T-cell antigen receptor. Antigen binding by a T-cell initiates calcium influx into the cell via calcium ion channels, such as Ca^{2+}-release-activated Ca^{2+} channels (CRAC). Calcium ion influx in turn initiates a signaling cascade that leads to activation of these cells and an inflammatory response characterized by cytokine production.

Interleukin 2 (IL-2) is a cytokine that is secreted by T cells in response to calcium ion influx into the cell. IL-2 modulates immunological effects on many cells of the immune system. For example, it is a potent T cell mitogen that is required for the T cell proliferation, promoting their progression from G1 to S phase of the cell cycle; it stimulates the growth of NK cells; and it acts as a growth factor to B cells and stimulates antibody synthesis.

IL-2, although useful in the immune response, can cause a variety of problems. IL-2 damages the blood-brain barrier and the endothelium of brain vessels. These effects may be the underlying causes of neuropsychiatric side effects observed under IL-2 therapy, *e.g.*, fatigue, disorientation and depression. It also alters the electrophysiological behavior of neurons.

Due to its effects on both T and B cells, IL-2 is a major central regulator of immune responses. It plays a role in inflammatory reactions, tumor surveillance, and hematopoiesis. It

also affects the production of other cytokines, inducing IL-1, TNFα and TNF-β secretion, as well as stimulating the synthesis of IFN-γ in peripheral leukocytes.

T cells that are unable to produce IL-2 become inactive (anergic). This renders them potentially inert to any antigenic stimulation they might receive in the future. As a result, agents which inhibit IL-2 production can be used for immunosuppression or to treat or prevent inflammation and immune disorders. This approach has been clinically validated with immunosuppressive drugs such as cyclosporin, FK506, and RS61443. Despite this proof of concept, agents that inhibit IL-2 production remain far from ideal. Among other problems, efficacy limitations and unwanted side effects (including dose-dependant nephrotoxicity and hypertension) hinder their use.

Over-production of proinflammatory cytokines other than IL-2 has also been implicated in many autoimmune diseases. For example, Interleukin 5 (IL-5), a cytokine that increases the production of eosinophils, is increased in asthma. Overproduction of IL-5 is associated with accumulation of eosinophils in the asthmatic bronchial mucosa, a hallmark of allergic inflammation. Thus, patients with asthma and other inflammatory disorders involving the accumulation of eosinophils would benefit from the development of new drugs that inhibit the production of IL-5.

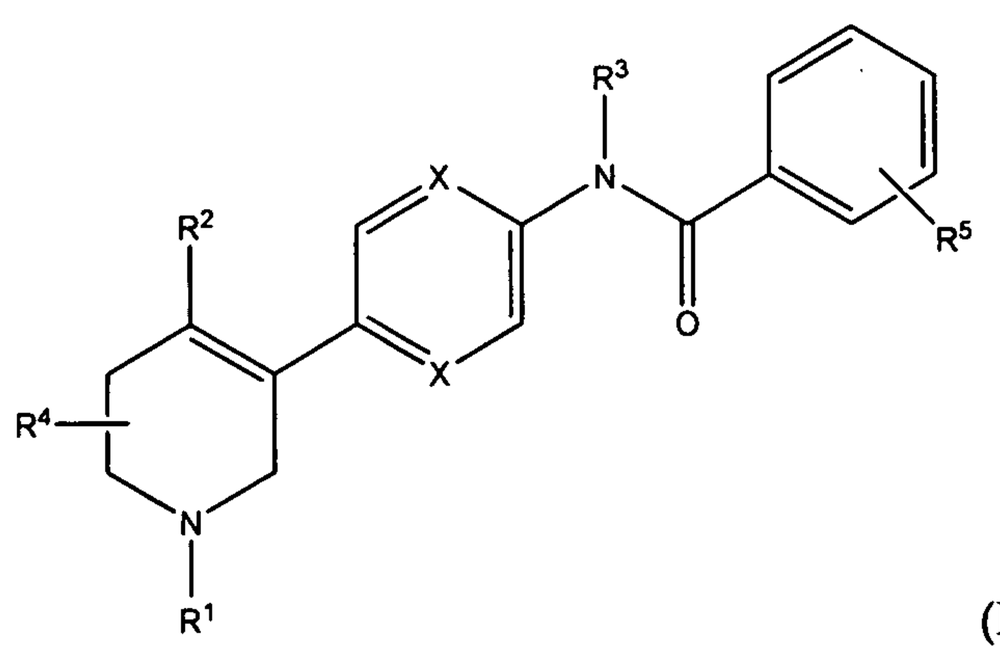
Interleukin 4 (IL-4) and interleukin 13 (IL-13) have been identified as mediators of the hypercontractility of smooth muscle found in inflammatory bowel disease and asthma. Thus, patients with asthma and inflammatory bowel disease would benefit from the development of new drugs that inhibit IL-4 and IL-13 production.

Granulocyte macrophage-colony stimulating factor (GM-CSF) is a regulator of maturation of granulocyte and macrophage lineage population and has been implicated as a key factor in inflammatory and autoimmune diseases. Anti-GM-CSF antibody blockade has been shown to ameliorate autoimmune disease. Thus, development of new drugs that inhibit the production of GM-CSF would be beneficial to patients with an inflammatory or autoimmune disease.

SUMMARY OF THE INVENTION

The present disclosure, in an aspect, addresses the continuing need for new drugs which overcome one or more of the shortcomings of drugs currently used for immunosuppression or in the treatment or prevention of inflammatory disorders, allergic disorders and autoimmune disorders. Desirable properties of such drugs include efficacy against diseases or disorders that are currently untreatable or poorly treatable, new mechanism of action, oral bioavailability and/or reduced side effects. Accordingly, compounds that inhibit the activity of CRAC ion channels and inhibit the production of IL-2, IL-4, IL-5, IL-13, GM-CSF, TNFα, and IFN-γ are disclosed herein. These compounds are particularly useful for immunosuppression and/or to treat or prevent inflammatory conditions and immune disorders. The particular genus of compounds described herein are particularly advantageous in that they are believed to combine inhibition of CRAC ion channels (*e.g.*, as measured by modulated I_{CRAC} current) and cytokines including IL-2, low incidence of off-target effects, and a favorable toxicity profile.

The invention features compounds of formula (I):



(I)

or a pharmaceutically acceptable salt thereof; wherein:

each of X_1 and X_2 is independently N, C or N^+O^-;

R^1 is heteroaryl or $S(O)_2N(R^6)_2$, wherein heteroaryl is optionally substituted with one to three halo, $(C_1\text{-}C_4)$alkyl, $(C_1\text{-}C_4)$alkenyl, $(C_1\text{-}C_4)$alkynyl, heteroaryl, COR^6, $COOR^6$, $CON(R^6)_2$, $N(R^6)_2$, $NR^6CON(R^6)_2$, $NR^6CSN(R^6)_2$, OR^6, SR^6, CN, NO_2, or N_3;

R^2 is $(C_1\text{-}C_6)$alkyl, $(C_1\text{-}C_6)$alkenyl, $(C_1\text{-}C_6)$alkynyl, heteroaryl, heteroaryl$(C_1\text{-}C_2)$alkyl, heteroaryl$(C_1\text{-}C_2)$alkenyl, heteroaryl$(C_1\text{-}C_2)$alkynyl, COR^6, $COOR^6$, $CON(R^6)_2$, CSR^6, $CSOR^6$,

$CSN(R^6)_2$, wherein each substituent represented by R^2 is independently and optionally substituted with one to three halo, $(C_1\text{-}C_4)$alkyl, $(C_1\text{-}C_4)$alkenyl, $(C_1\text{-}C_4)$alkynyl, COR^6, $COOR^6$, $CON(R^6)_2$, $N(R^6)_2$, $NR^6CON(R^6)_2$, $NR^6CSN(R^6)_2$, OR^6, SR^6, CN, NO_2, N_3, etc.

R^3 is H, halo, $(C_1\text{-}C_6)$alkyl, $(C_1\text{-}C_6)$alkenyl, $(C_1\text{-}C_6)$alkynyl, halo, COR^6, $COOR^6$, $CON(R^6)_2$, $N(R^6)_2$, $NR^6CON(R^6)_2$, $NR^6CSN(R^6)_2$, OR^6, SR^6, CN, NO_2, or N_3;

R^4 is H, $(C_1\text{-}C_6)$alkyl, $(C_1\text{-}C_6)$alkenyl, $(C_1\text{-}C_6)$alkynyl, heteroaryl, heteroaryl$(C_1\text{-}C_2)$alkyl, heteroaryl$(C_1\text{-}C_2)$alkenyl, heteroaryl$(C_1\text{-}C_2)$alkynyl, aryl, aryl$(C_1\text{-}C_2)$alkyl, aryl$(C_1\text{-}C_2)$alkenyl, aryl$(C_1\text{-}C_2)$alkynyl, OR^6, or $CON(R^6)_2$

each R^5 is independently halo, $(C_1\text{-}C_6)$alkyl, $(C_1\text{-}C_6)$alkenyl, $(C_1\text{-}C_6)$alkynyl, heteroaryl, heteroaryl$(C_1\text{-}C_2)$alkyl, heteroaryl$(C_1\text{-}C_2)$alkenyl, heteroaryl$(C_1\text{-}C_2)$alkynyl, cycloalkyl, heterocycloalkyl, aryl, aryl$(C_1\text{-}C_2)$alkyl, aryl$(C_1\text{-}C_2)$alkenyl, aryl$(C_1\text{-}C_2)$alkynyl, $(C_1\text{-}C_6)$haloalkyl, COR^6, $COOR^6$, $CON(R^6)_2$, $N(R^6)_2$, $NR^6CON(R^6)_2$, $NR^6CSN(R^6)_2$, OR^6, SR^6, CN, NO_2, or N_3;

each R^6 is independently H, $(C_1\text{-}C_6)$alkyl, $(C_2\text{-}C_6)$alkenyl, $(C_2\text{-}C_6)$alkynyl, heteroaryl, heteroaryl$(C_1\text{-}C_2)$alkyl, heteroaryl$(C_1\text{-}C_2)$alkenyl, heteroaryl$(C_1\text{-}C_2)$alkynyl, aryl, aryl$(C_1\text{-}C_2)$alkyl, aryl$(C_1\text{-}C_2)$alkenyl, or aryl$(C_1\text{-}C_2)$alkynyl; or two R^6 substituents attached to the same or adjacent atoms are taken together to form a heterocycloalkyl or heteroaryl;

Y is CH or N; and

n = 0-5.

In certain embodiments, R^1 may be pyridinyl, thiazolyl, or pyrazinyl, each of which may be substituted with $(C_1\text{-}C_6)$alkyl, halo, CN, or heteroaryl. In an alternative, R^1 is $S(O)_2N(R^6)_2$, wherein each R^6 is independently $(C_1\text{-}C_6)$alkyl.

In other embodiments, R^2 is $(C_1\text{-}C_6)$alkyl; R^3 and R^4 are H; and/or n is 2, and R^5 is halo. In yet further embodiments, X_1 and X_2 are C; X_1 is N, and X_2 is N; X_1 is C, and X_2 is N; or X_1 is N, and X_2 is C.

In other embodiments, Y is advantageously C.

Particular compounds and groups of exemplified herein have especially desirable properties as a whole that have been heretofore unavailable in compounds of differing or similar

class. These properties include one or more of the following: higher chemical stability which provides resistance to degradation of the compound; eliminating possible metabolism that results in genotoxic fragments that are undesirable in the intended methods of administration; a longer half life *in vivo*; improved metabolic stability; and reducing or eliminating CYP induction, which may result in time- or concentration-dependent loss of drug, all of which otherwise reduce drug efficacy.

Exemplary compounds are provided herein. In other aspects, pharmaceutical compositions including a pharmaceutically acceptable carrier and a compound of the invention are disclosed. The composition may further include one or more additional therapeutic agents, *e.g.*, immunosuppressive agents, anti-inflammatory agents and suitable mixtures thereof. Other additional therapeutic agents include steroids, non-steroidal anti-inflammatory agents, antihistamines, analgesics, and suitable mixtures thereof.

Compounds as disclosed herein, or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof, are particularly useful inhibiting immune cell (*e.g.*, T-cells and/or B-cells) activation (*e.g.*, activation in response to an antigen). In particular, these compounds or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof can inhibit the production of certain cytokines that regulate immune cell activation. For example, a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof can inhibit the production of IL-2, IL-4, IL-5, IL-13, GM-CSF, TNFα, IFN-γ or combinations thereof. Moreover, a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof can modulate the activity of one or more ion channel involved in activation of immune cells, such as CRAC ion channels.

A compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof is particularly useful for immunosuppression or for treating or preventing inflammatory conditions, allergic disorders, and immune disorders.

The invention also encompasses pharmaceutical compositions comprising a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof; and a pharmaceutically acceptable carrier or vehicle. These compositions may further comprise

additional agents. These compositions are useful for immunosuppression and treating or preventing inflammatory conditions, allergic disorders and immune disorders.

The invention further encompasses methods for treating or preventing inflammatory conditions, allergic disorders, and immune disorders, comprising administering to a subject in need thereof an effective amount of a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof, or a pharmaceutical composition comprising a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof. These methods may also comprise administering to the subject an additional agent separately or in a combination composition with the compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof.

The invention further encompasses methods for suppressing the immune system of a subject, comprising administering to a subject in need thereof an effective amount of a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof, or a pharmaceutical composition comprising a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof. These methods may also comprise administering to the subject an additional agent separately or in a combination composition with the compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof.

The invention further encompasses methods for inhibiting immune cell activation, including inhibiting proliferation of T cells and/or B cells, *in vivo* or *in vitro* comprising administering to the cell an effective amount of a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof or a pharmaceutical composition comprising a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof.

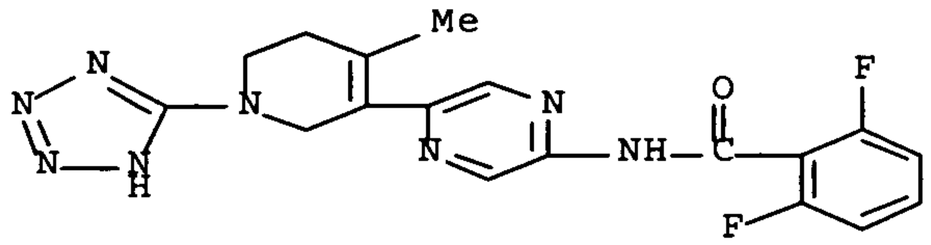
The invention further encompasses methods for inhibiting cytokine production in a cell, (*e.g.*, IL-2, IL-4, IL-5, IL-13, GM-CSF, TNFα, and/or IFN-γ production) *in vivo* or *in vitro* comprising administering to a cell an effective amount of a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof or a pharmaceutical

composition comprising a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof.

The invention further encompasses methods for modulating ion channel activity (*e.g.*, CRAC) *in vivo* or *in vitro* comprising administering an effective amount of a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof or a pharmaceutical composition comprising a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof.

All of the methods of this invention may be practiced with a compound of the invention alone, or in combination with other agents, such as other immunosuppressive agents, anti-inflammatory agents, agents for the treatment of allergic disorders or agents for the treatment of immune disorders.

In certain embodiments, the following compounds are explicitly excluded from formula (I):



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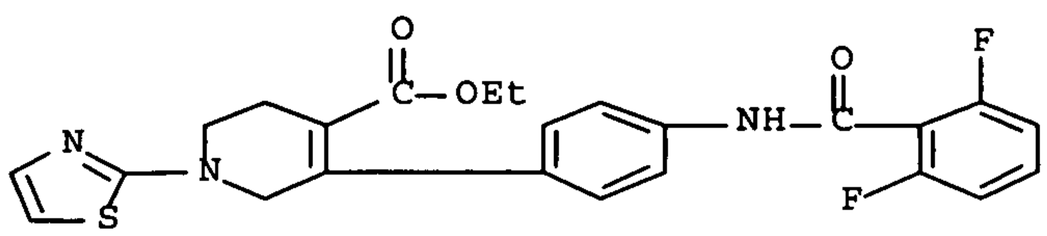

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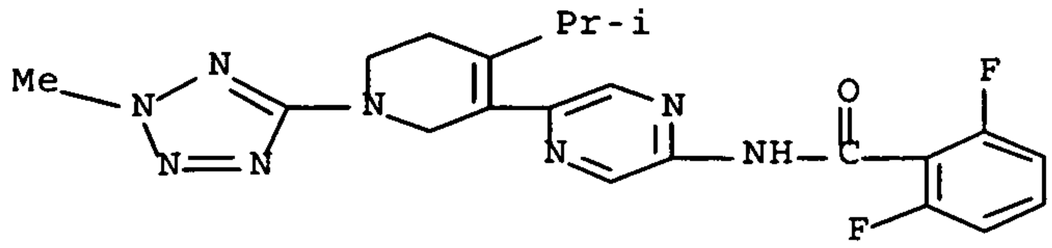

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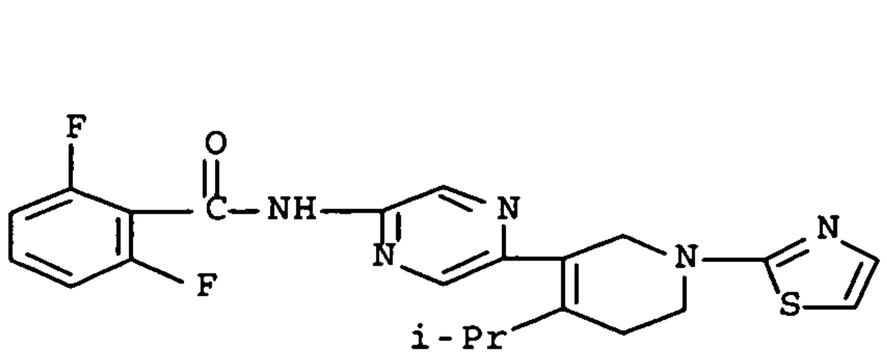

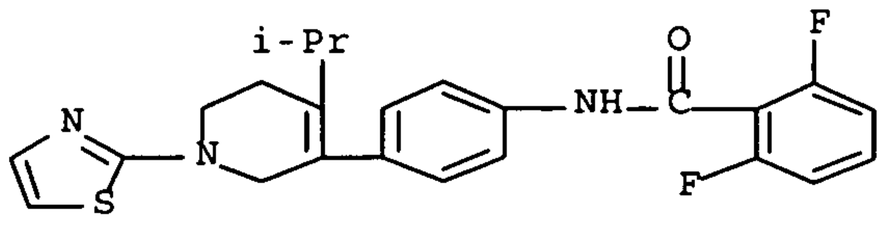

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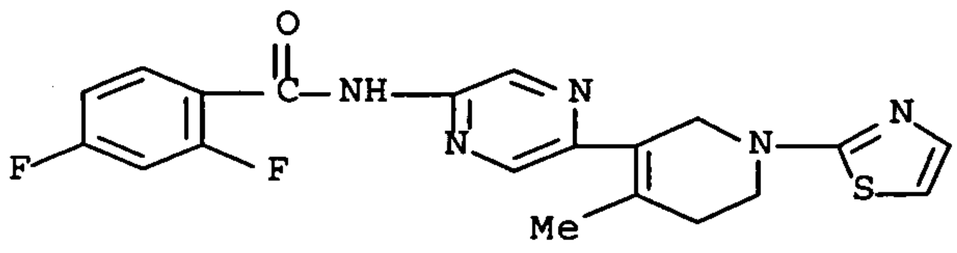

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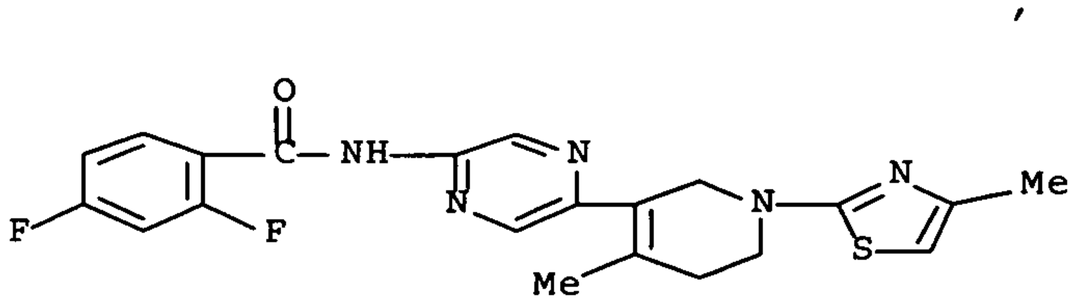

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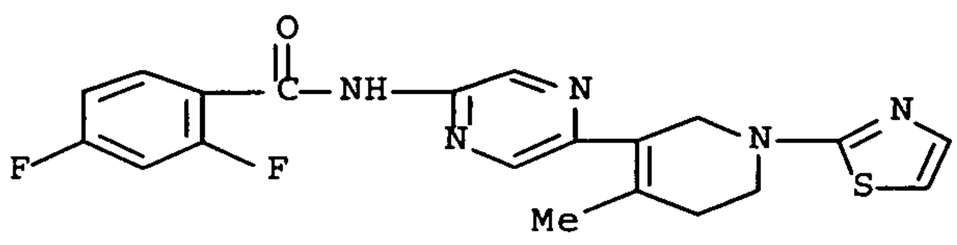

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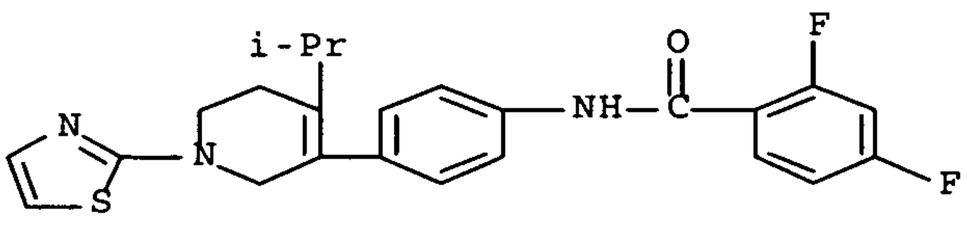

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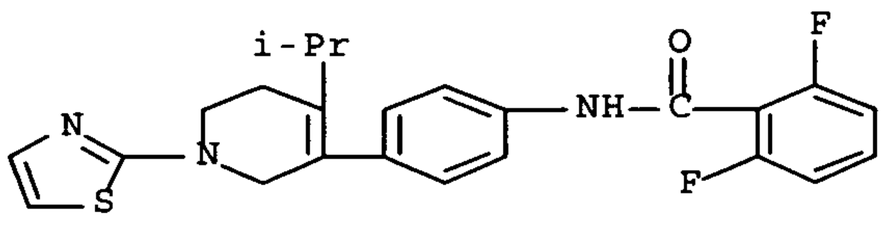

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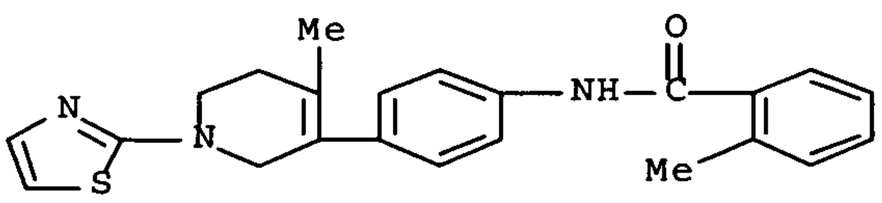

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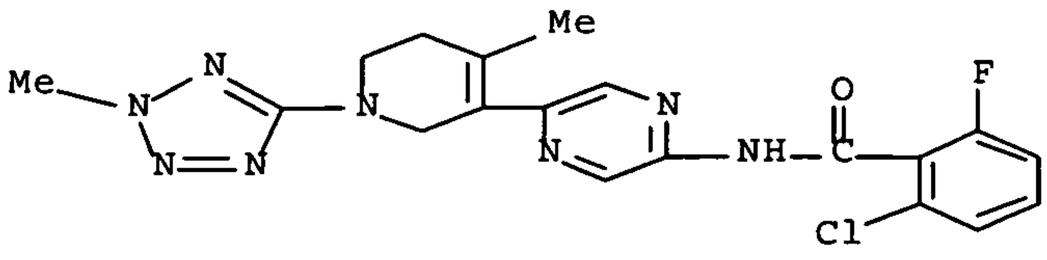

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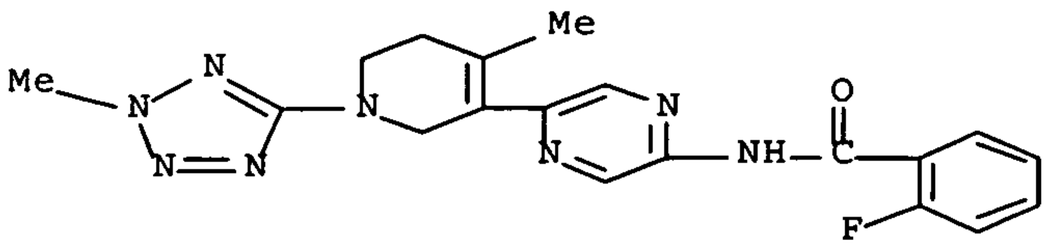

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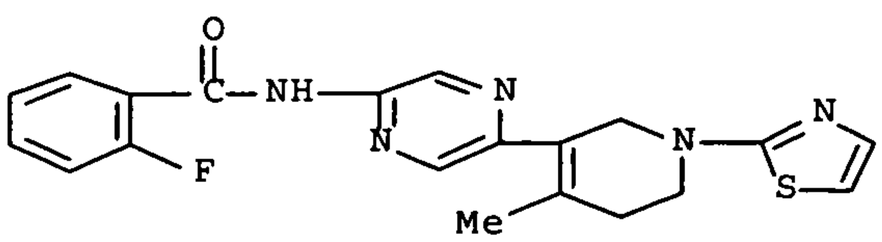

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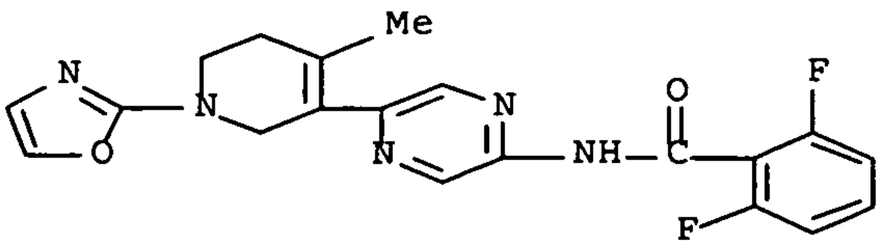

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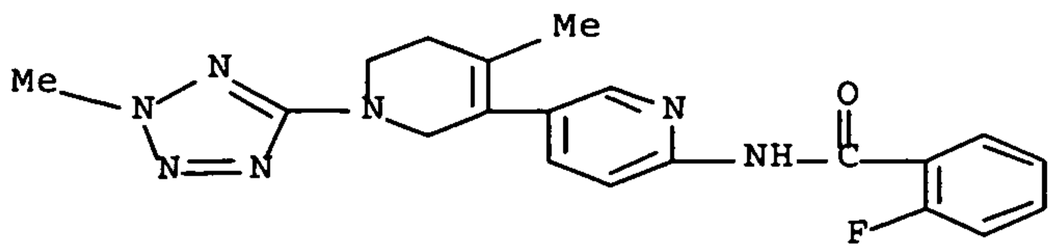

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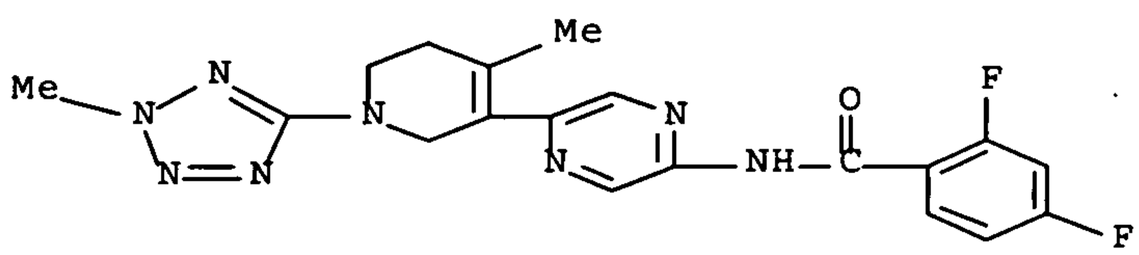

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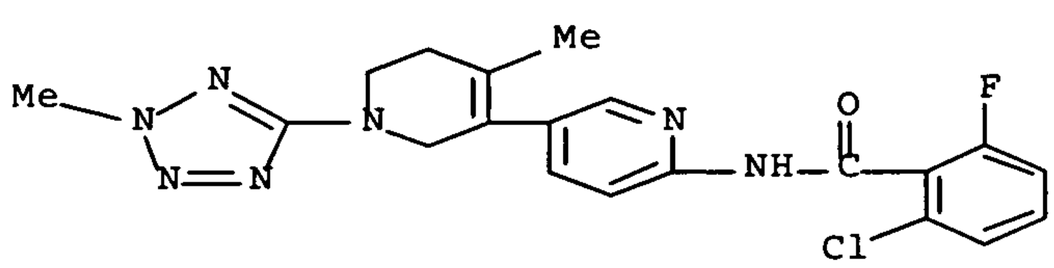

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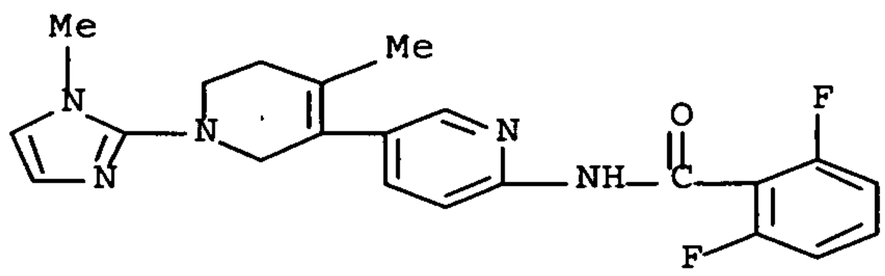

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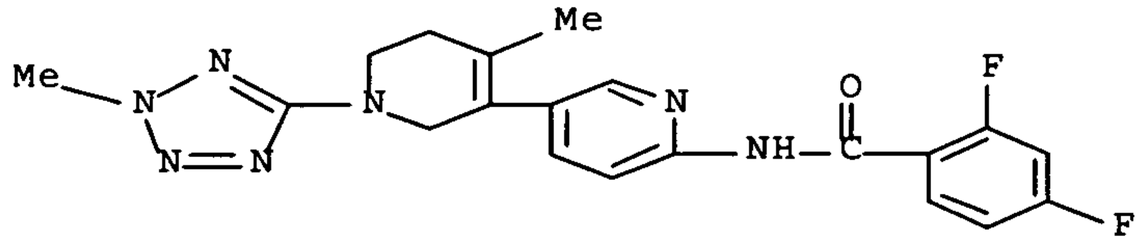

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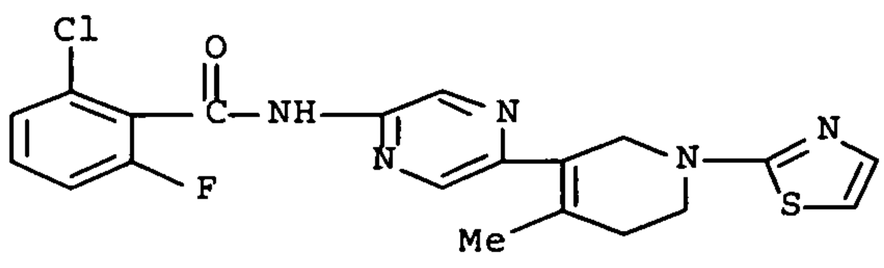

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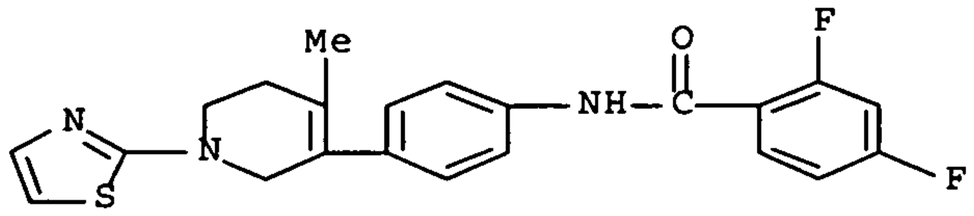

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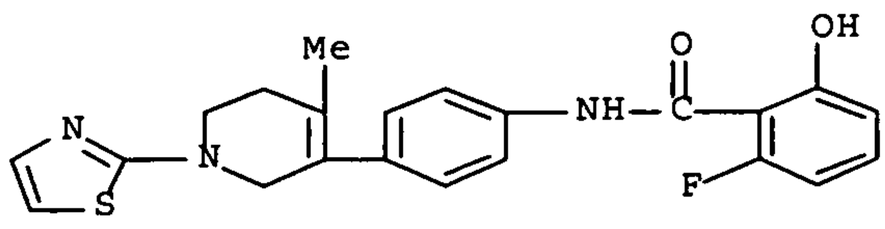

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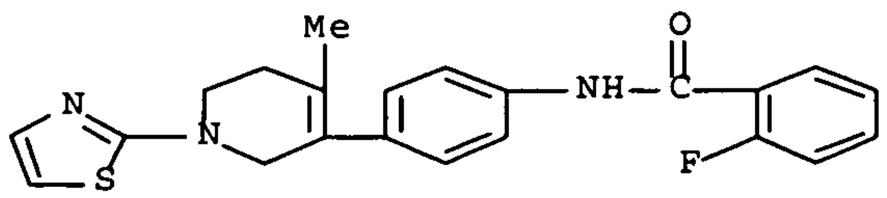

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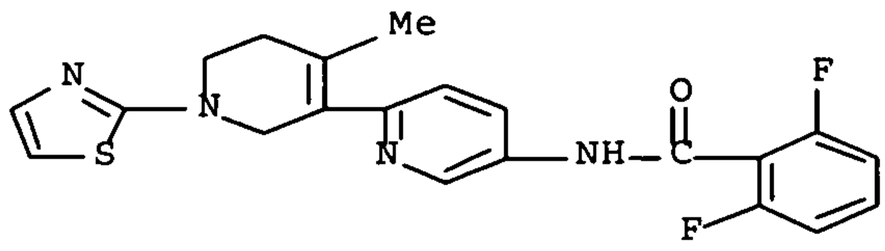

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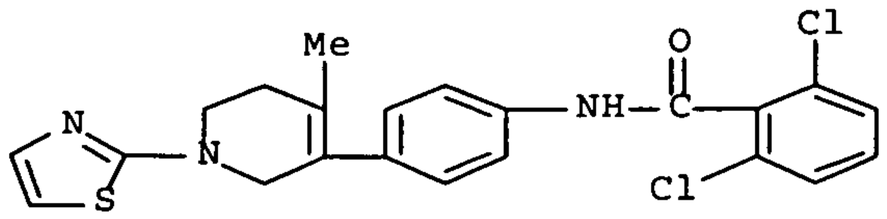

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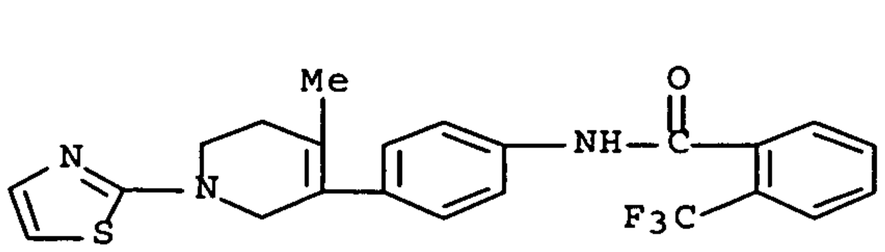

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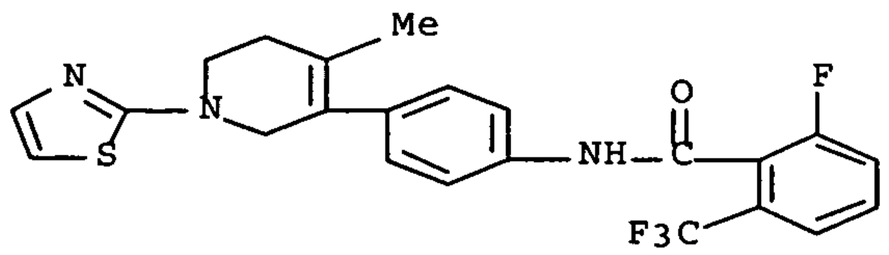

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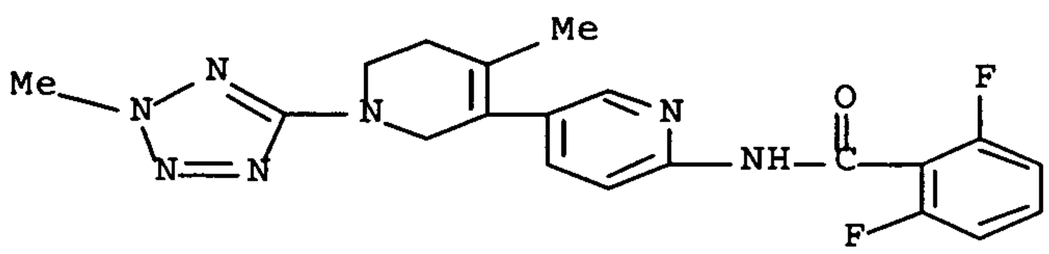

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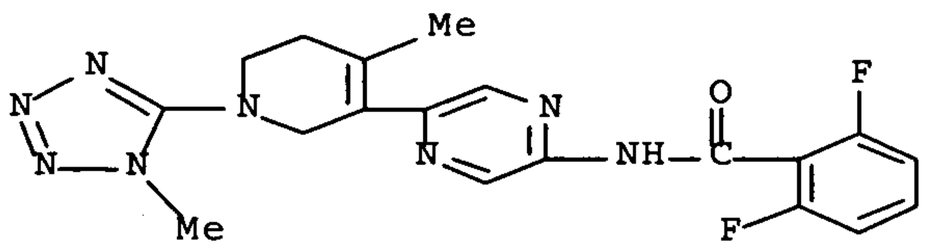

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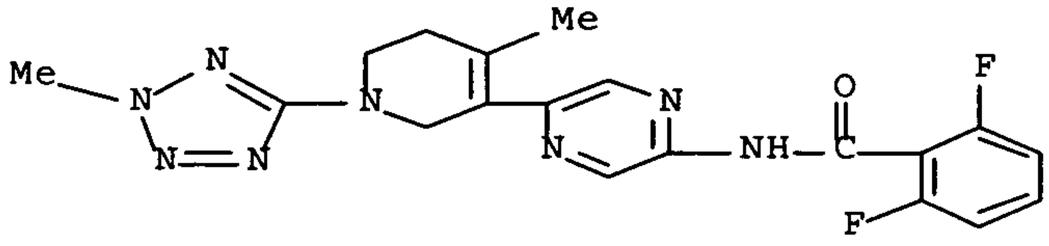

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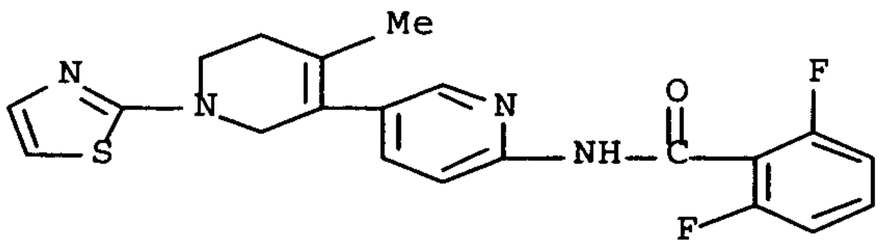

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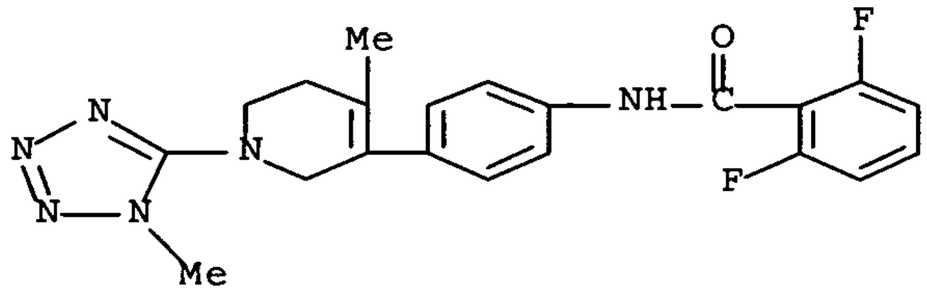

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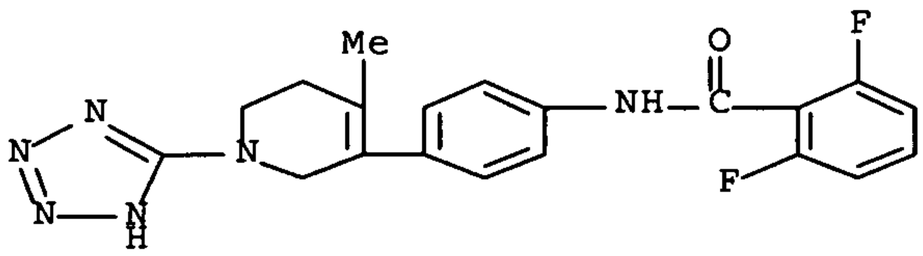

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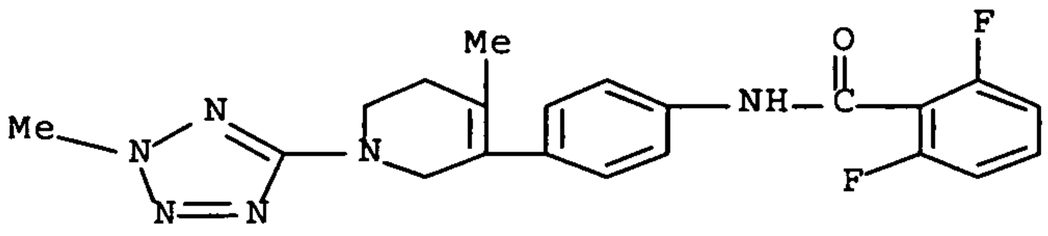

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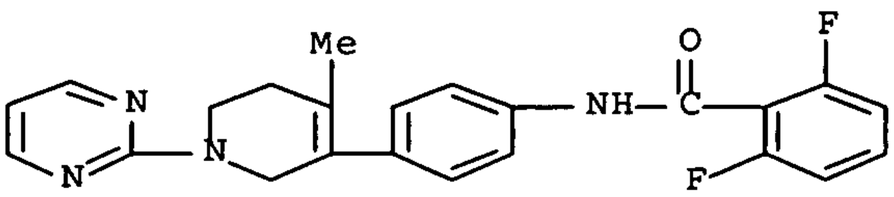

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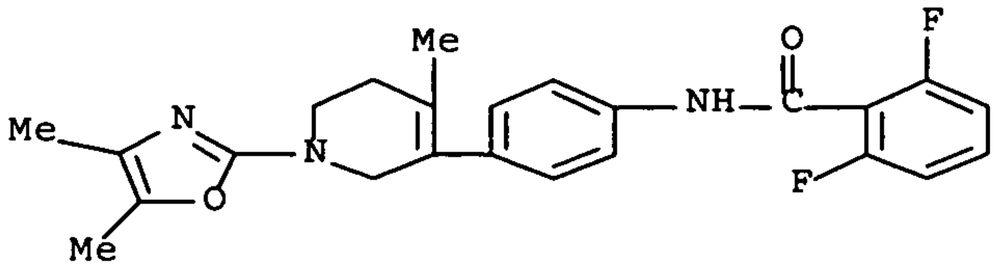

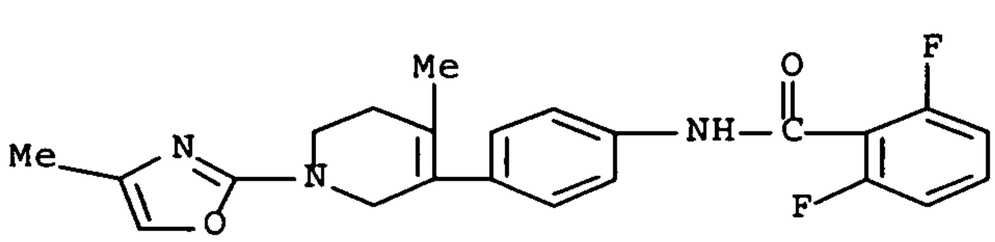

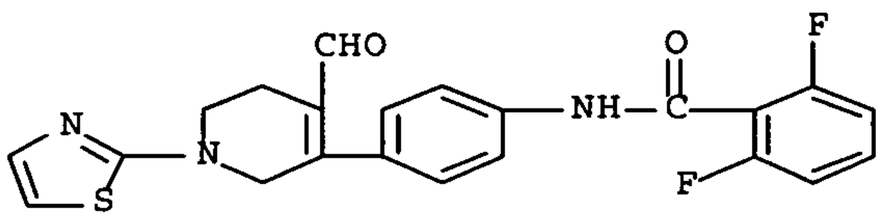

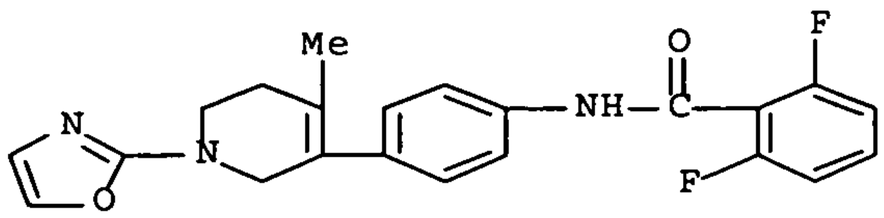

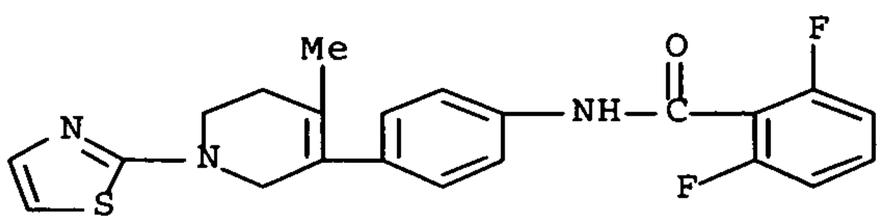

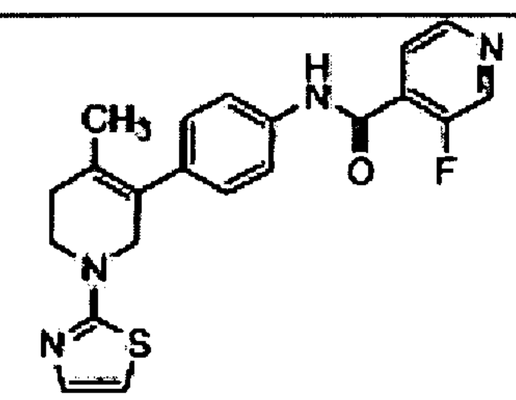

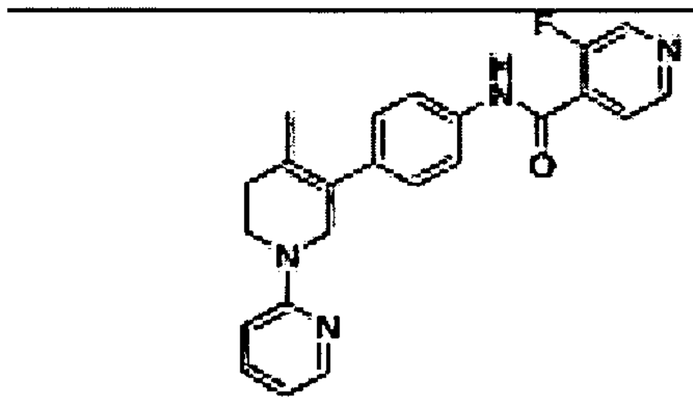

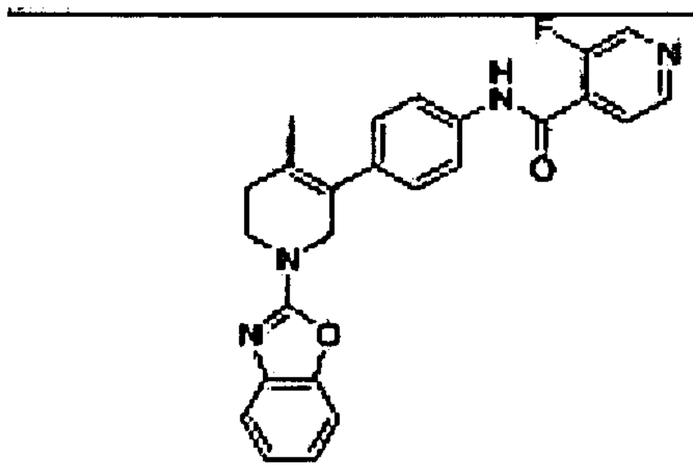

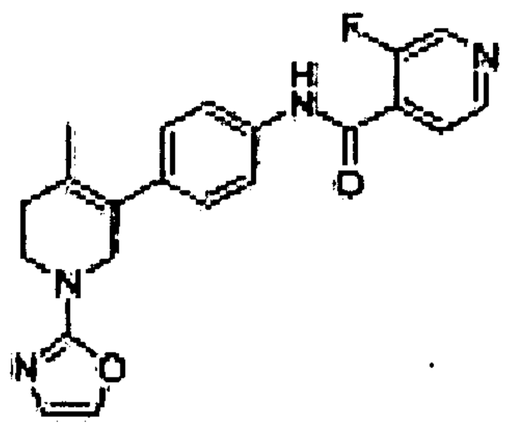

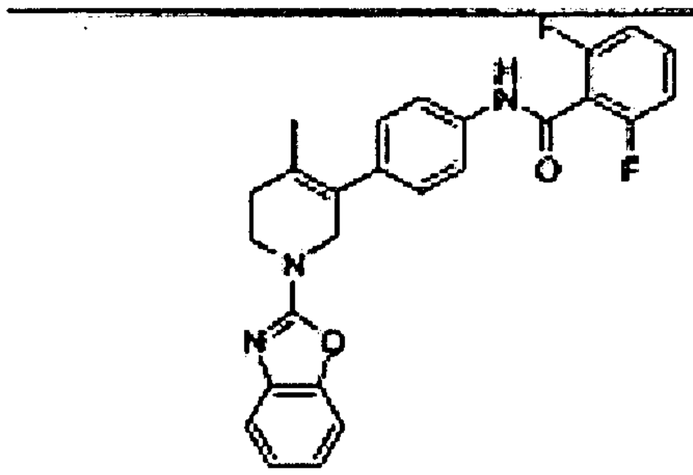

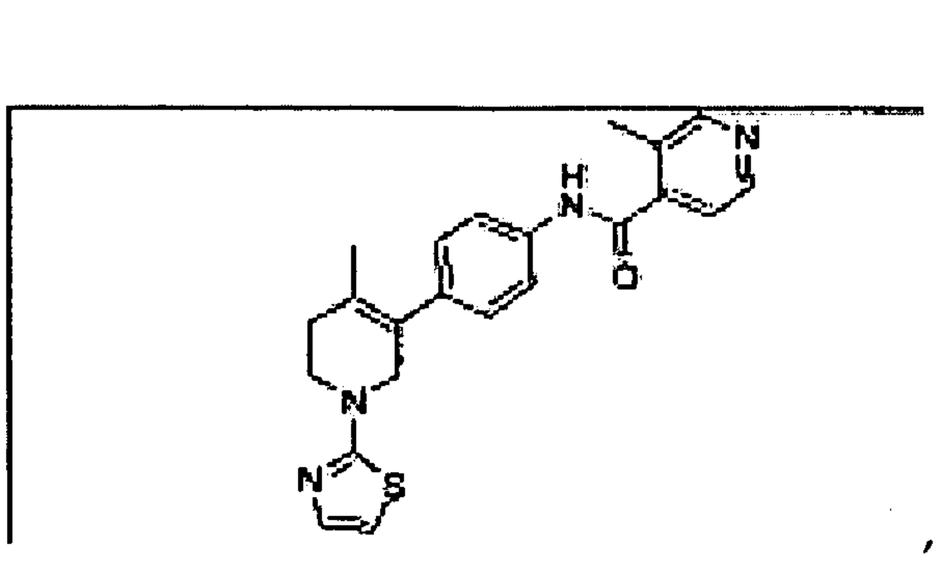

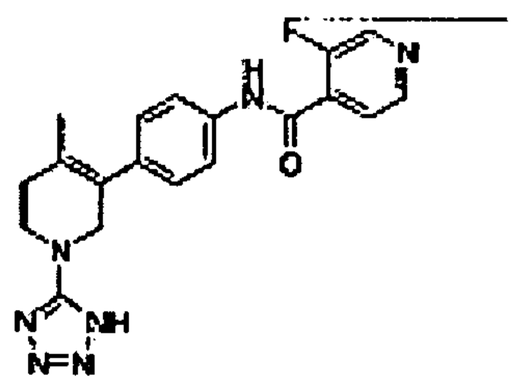

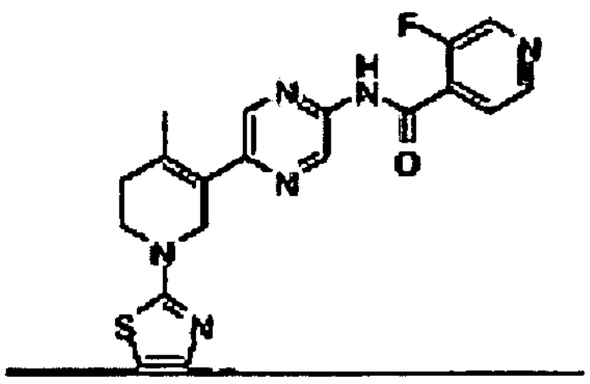

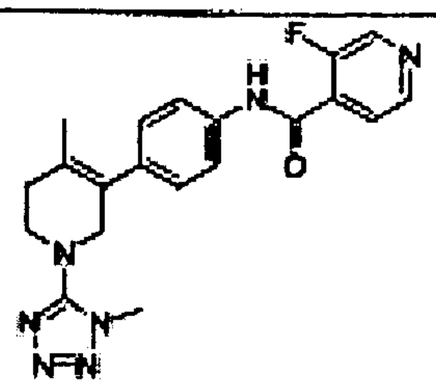

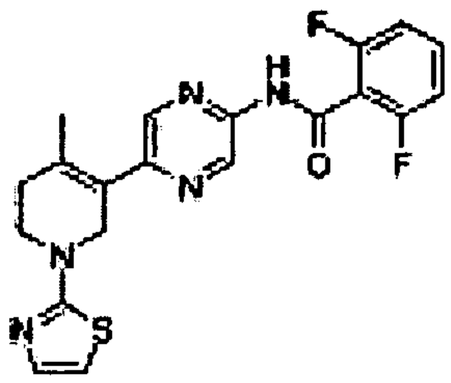

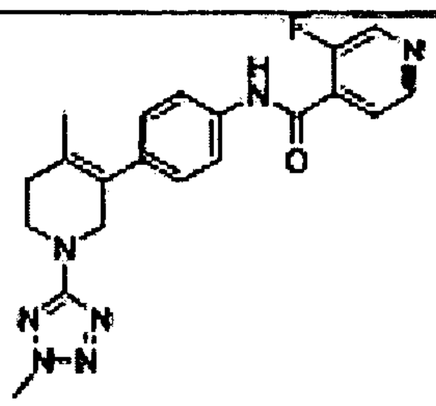

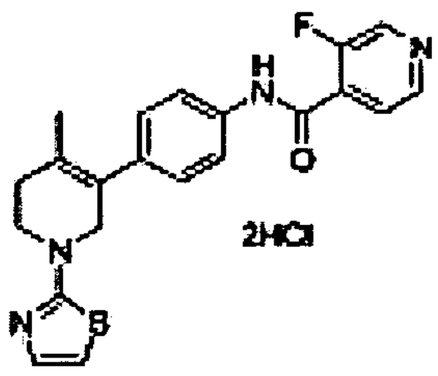
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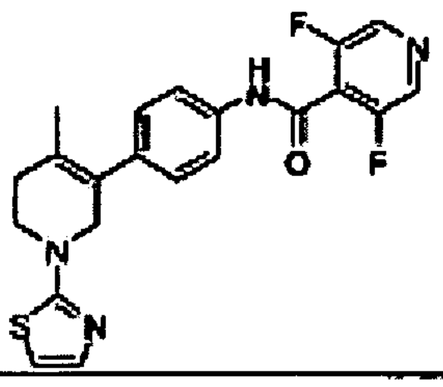

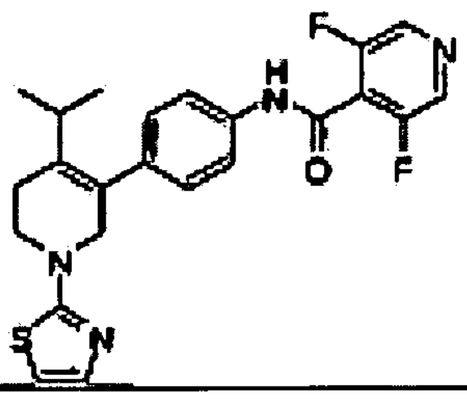

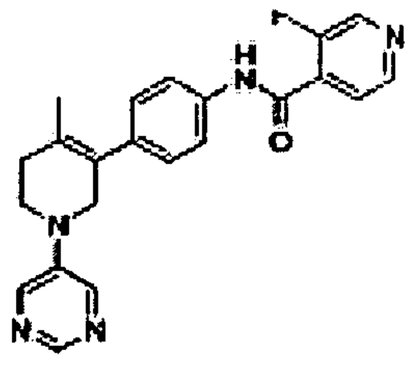

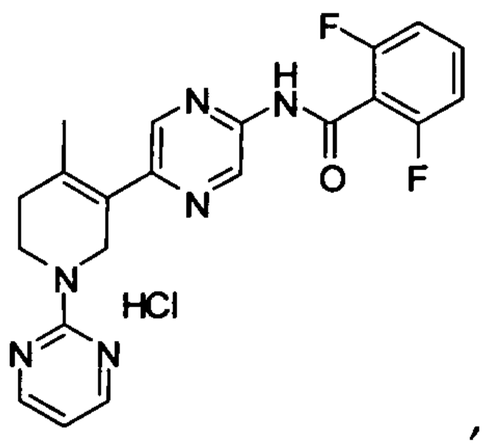
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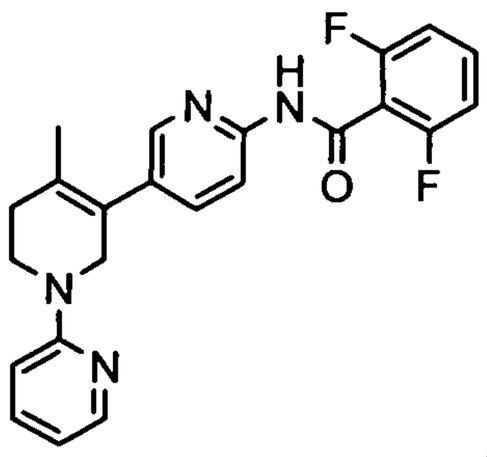

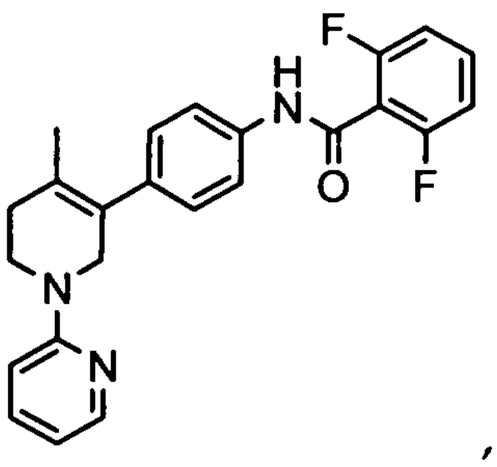

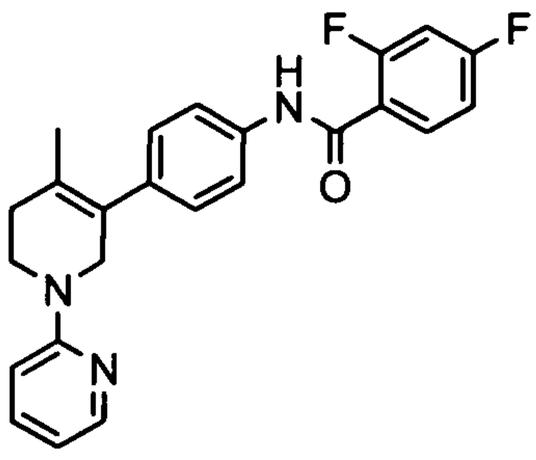

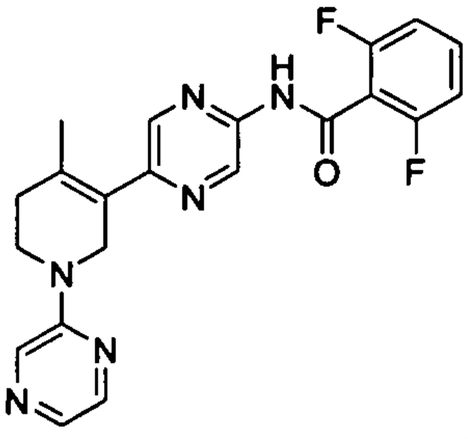

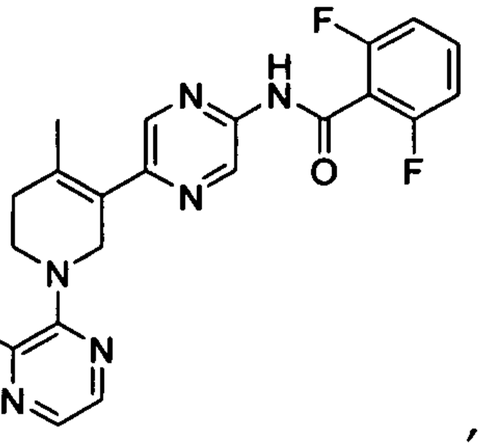

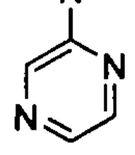

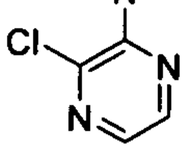
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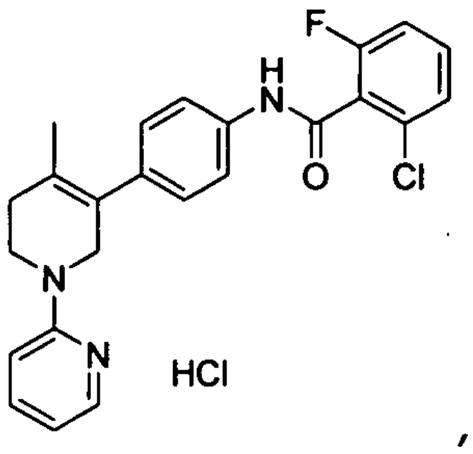
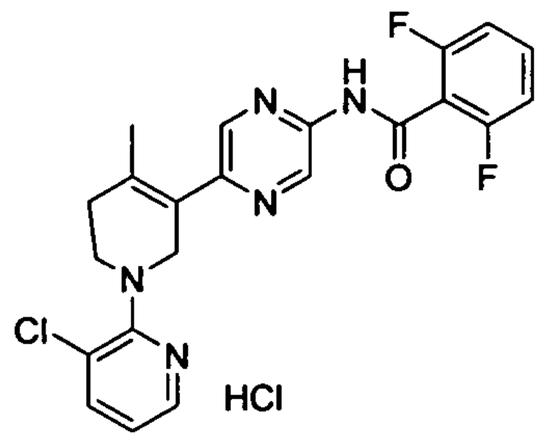
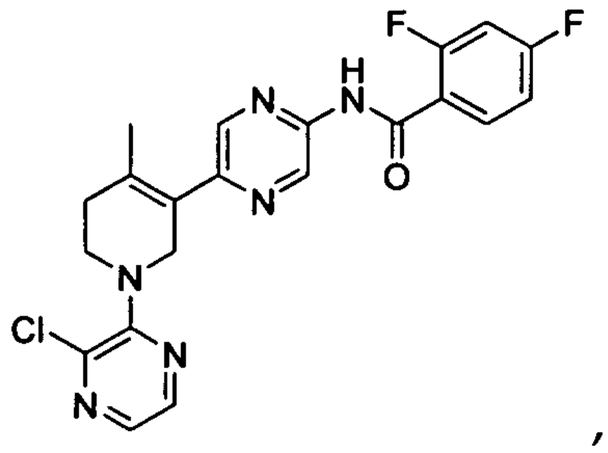
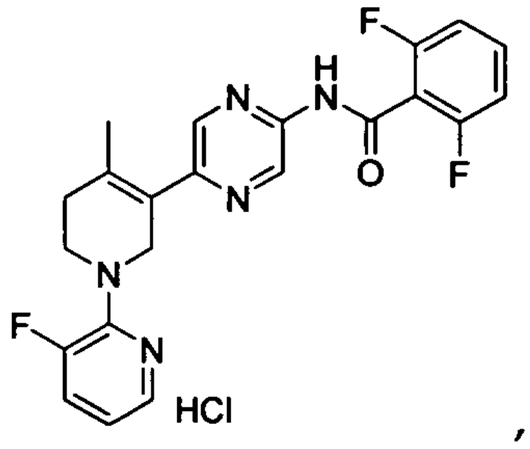
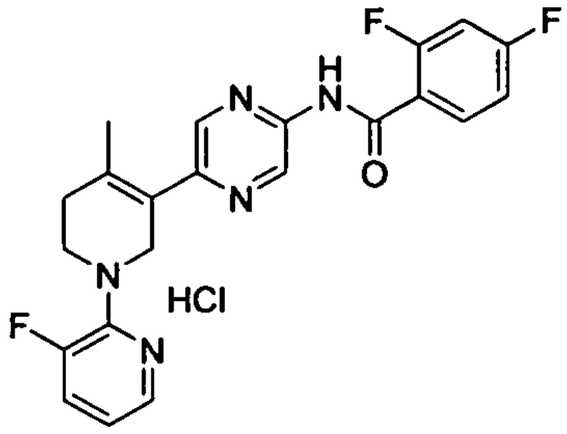
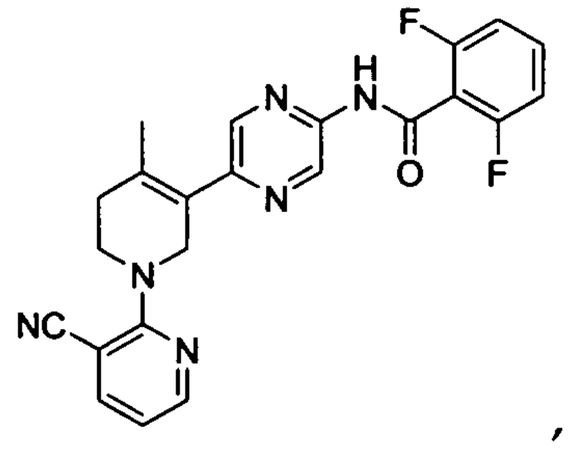
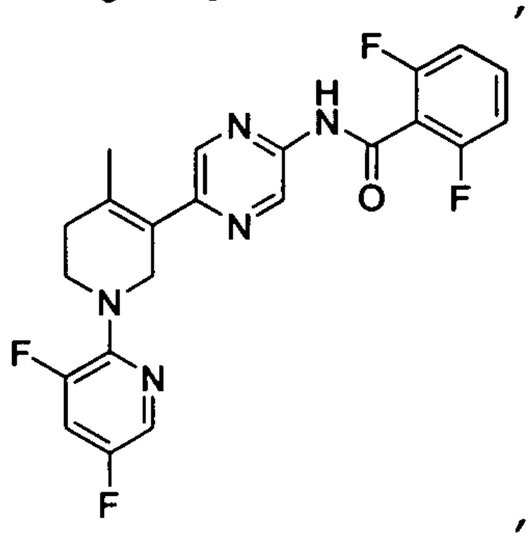
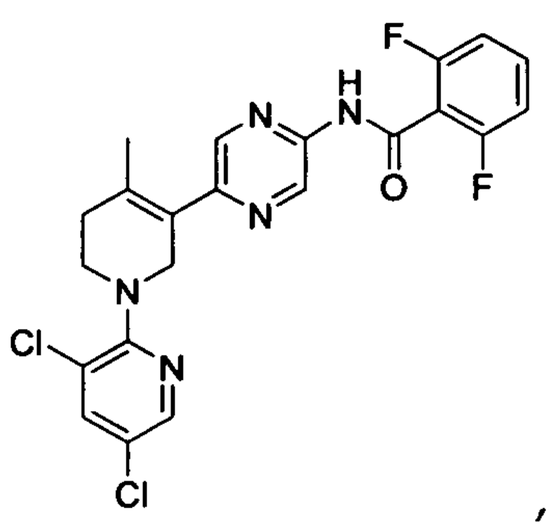
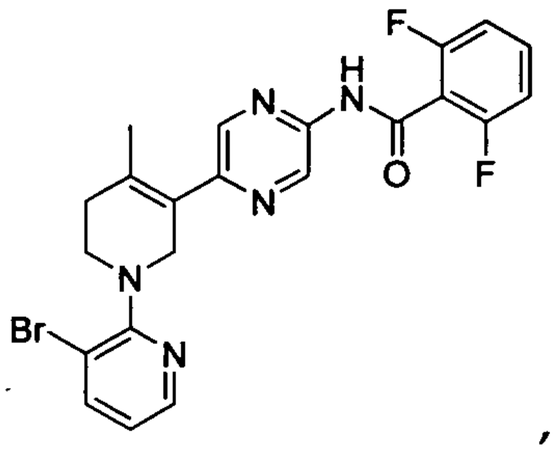
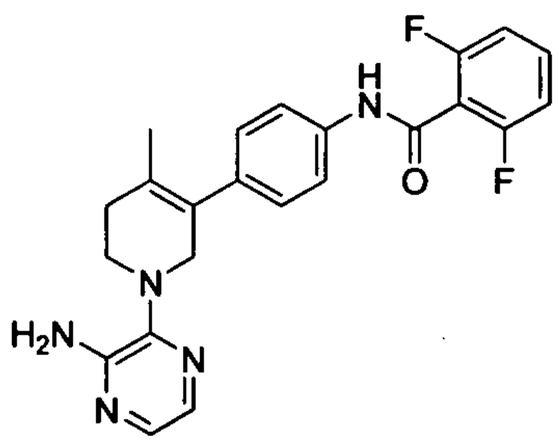
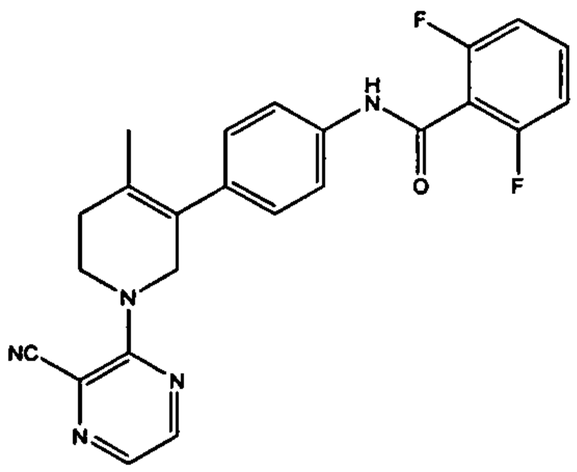
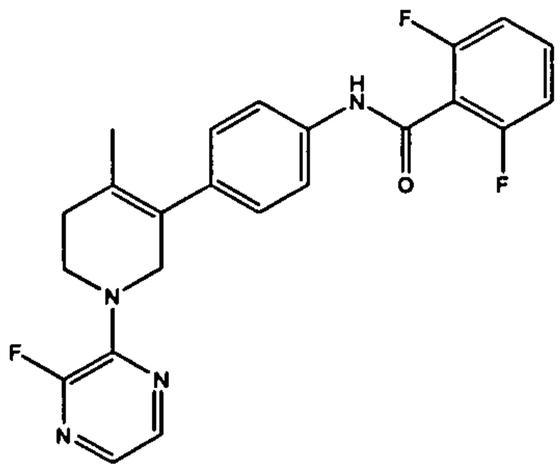
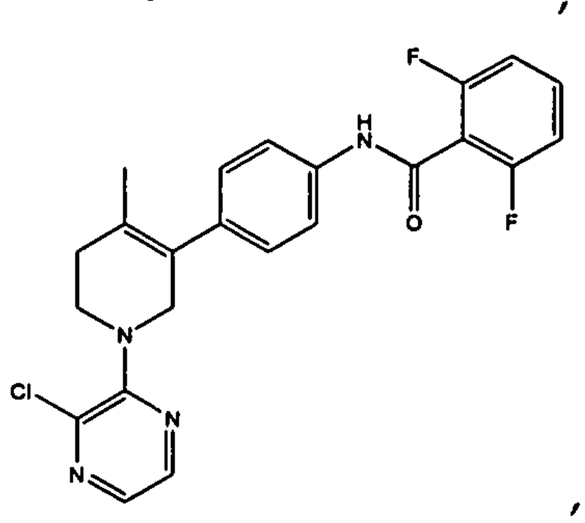
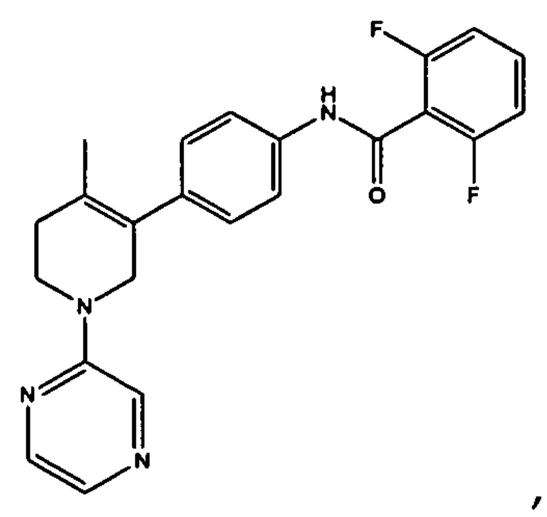
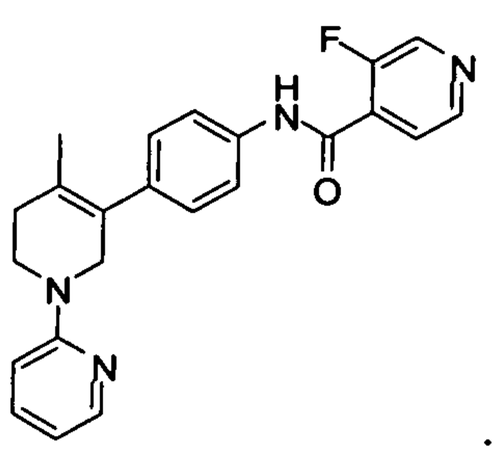
















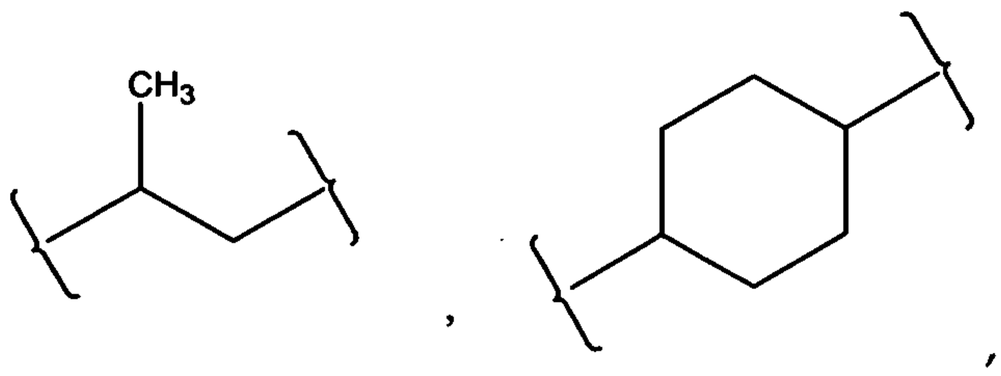
DETAILED DESCRIPTION OF THE INVENTION

As used herein, the term an "aromatic ring" or "aryl" means a monocyclic or polycyclic-aromatic ring or ring radical comprising carbon and hydrogen atoms. Examples of

suitable aryl groups include, but are not limited to, phenyl, tolyl, anthracenyl, fluorenyl, indenyl, azulenyl, and naphthyl, as well as benzo-fused carbocyclic moieties such as 5,6,7,8-tetrahydronaphthyl. An aryl group can be unsubstituted or substituted with one or more substituents (including without limitation alkyl (preferably, lower alkyl or alkyl substituted with one or more halo), hydroxy, alkoxy (preferably, lower alkoxy), alkylthio, cyano, halo, amino, and nitro. In certain embodiments, the aryl group is a monocyclic ring, wherein the ring comprises 6 carbon atoms.

As used herein, the term "alkyl" means a saturated straight chain or branched non-cyclic hydrocarbon typically having from 1 to 10 carbon atoms. Representative saturated straight chain alkyls include methyl, ethyl, n-propyl, n-butyl, n-pentyl, n-hexyl, n-heptyl, n-octyl, n-nonyl and n-decyl; while saturated branched alkyls include isopropyl, *sec*-butyl, isobutyl, *tert*-butyl, isopentyl, 2-methylbutyl, 3-methylbutyl, 2-methylpentyl, 3-methylpentyl, 4-methylpentyl, 2-methylhexyl, 3-methylhexyl, 4-methylhexyl, 5-methylhexyl, 2,3-dimethylbutyl, 2,3-dimethylpentyl, 2,4-dimethylpentyl, 2,3-dimethylhexyl, 2,4-dimethylhexyl, 2,5-dimethylhexyl, 2,2-dimethylpentyl, 2,2-dimethylhexyl, 3,3-dimtheylpentyl, 3,3-dimethylhexyl, 4,4-dimethylhexyl, 2-ethylpentyl, 3-ethylpentyl, 2-ethylhexyl, 3-ethylhexyl, 4-ethylhexyl, 2-methyl-2-ethylpentyl, 2-methyl-3-ethylpentyl, 2-methyl-4-ethylpentyl, 2-methyl-2-ethylhexyl, 2-methyl-3-ethylhexyl, 2-methyl-4-ethylhexyl, 2,2-diethylpentyl, 3,3-diethylhexyl, 2,2-diethylhexyl, 3,3-diethylhexyl and the like. Alkyl groups included in compounds of this invention may be optionally substituted with one or more substituents, such as amino, alkylamino, alkoxy, alkylthio, oxo, halo, acyl, nitro, hydroxyl, cyano, aryl, alkylaryl, aryloxy, arylthio, arylamino, carbocyclyl, carbocyclyloxy, carbocyclylthio, carbocyclylamino, heterocyclyl, heterocyclyloxy, heterocyclylamino, heterocyclylthio, and the like. In addition, any carbon in the alkyl segment may be substituted with oxygen (=O), sulfur (=S), or nitrogen (=NR^{23}, wherein R^{23} is –H, an alkyl, acetyl, or aralkyl). Lower alkyls are typically preferred for the compounds of this invention.

The term alkylene refers to an alkyl group that has two points of attachment to two moieties (*e.g.*, {-CH_2-}, -{CH_2CH_2-},



etc., wherein the brackets indicate the points of attachment). Alkylene groups may be substituted or unsubstituted, as with an alkyl group.

An aralkyl group refers to an aryl group that is attached to another moiety via an alkylene linker. Aralkyl groups can be substituted or unsubstituted, as with an aryl group and/or alkyl group.

The term "alkoxy," as used herein, refers to an alkyl group that is linked to another moiety though an oxygen atom. Alkoxy groups can be substituted or unsubstituted, as with an alkyl group.

The term "alkoxyalkoxy," as used herein, refers to an alkoxy group in which the alkyl portion is substituted with another alkoxy group.

The term "alkyl sulfanyl," as used herein, refers to an alkyl group that is linked to another moiety though a divalent sulfur atom. Alkyl sulfanyl groups can be substituted or unsubstituted, as with an alkyl group.

The term "alkylamino," as used herein, refers to an amino group in which one hydrogen atom attached to the nitrogen has been replaced by an alkyl group. The term "dialkylamino," as used herein, refers to an amino group in which two hydrogen atoms attached to the nitrogen have been replaced by alkyl groups, in which the alkyl groups can be the same or different. Alkylamino groups and dialkylamino groups can be substituted or unsubstituted, as with an alkyl group.

As used herein, the term "alkenyl" means a straight chain or branched, hydrocarbon radical typically having from 2 to 10 carbon atoms and having at least one carbon-carbon double bond. Representative straight chain and branched alkenyls include vinyl, allyl, 1-butenyl, 2-butenyl, isobutylenyl, 1-pentenyl, 2-pentenyl, 3-methyl-1-butenyl, 1-methyl-2-butenyl, 2,3-dimethyl-2-butenyl, 1-hexenyl, 2-hexenyl, 3-hexenyl, 1-heptenyl, 2-heptenyl, 3-heptenyl,

1-octenyl, 2-octenyl, 3-octenyl, 1-nonenyl, 2-nonenyl, 3-nonenyl, 1-decenyl, 2-decenyl, 3-decenyl and the like. Alkenyl groups can be substituted or unsubstituted, as with alkyl groups.

As used herein, the term "alkynyl" means a straight chain or branched, hydrocarbonon radical typically having from 2 to 10 carbon atoms and having at lease one carbon-carbon triple bond. Representative straight chain and branched alkynyls include acetylenyl, propynyl, 1-butynyl, 2-butynyl, 1-pentynyl, 2-pentynyl, 3-methyl-1-butynyl, 4-pentynyl,-1-hexynyl, 2-hexynyl, 5-hexynyl, 1-heptynyl, 2-heptynyl, 6-heptynyl, 1-octynyl, 2-octynyl, 7-octynyl, 1-nonynyl, 2-nonynyl, 8-nonynyl, 1-decynyl, 2-decynyl, 9-decynyl and the like. Alkynyl groups can be substituted or unsubstituted.

As used herein, the term "cycloalkyl" means a saturated, mono- or polycyclic alkyl radical typically having from 3 to 10 carbon atoms. Representative cycloalkyls include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, cyclooctyl, cyclononyl, cyclodecyl, adamantlyl, decahydronaphthyl, octahydropentalene, bicyclo[1,1,1]pentanyl, and the like. Cycloalkyl groups can be substituted or unsubstituted, as with alkyl groups.

As used herein, the term "cycloalkenyl" means a cyclic non-aromatic alkenyl radical having at least one carbon-carbon double bond in the cyclic system and typically having from 5 to 10 carbon atoms. Representative cycloalkenyls include cyclopentenyl, cyclopentadienyl, cyclohexenyl, cyclohexadienyl, cycloheptenyl, cycloheptadienyl, cycloheptatrienyl, cyclooctenyl, cyclooctadienyl, cyclooctatrienyl, cyclooctatetraenyl, cyclononenyl, cyclononadienyl, cyclodecenyl, cyclodecadienyl and the like. Cycloalkenyl groups can be substituted or unsubstituted, as with alkyl groups.

As used herein, the term "heterocycle" or "heterocyclyl" means a monocyclic or polycyclic heterocyclic ring (typically having 3- to 14-members) that is either a saturated ring or an unsaturated non-aromatic ring. A 3-membered heterocycle can contain up to 3 heteroatoms, and a 4- to 14-membered heterocycle can contain from 1 to about 8 heteroatoms. Each heteroatom is independently selected from nitrogen, which can be quaternized; oxygen; and sulfur, including sulfoxide and sulfone. The heterocycle may be attached via any heteroatom or carbon atom. Representative heterocycles include morpholinyl, thiomorpholinyl, pyrrolidinonyl, pyrrolidinyl, piperidinyl, piperazinyl, hydantoinyl, valerolactamyl, oxiranyl,

oxetanyl, tetrahydrofuranyl, tetrahydropyranyl, tetrahydropyrindinyl, tetrahydropyrimidinyl, tetrahydrothiophenyl, tetrahydrothiopyranyl, and the like. A heteroatom may be substituted with a protecting group known to those of ordinary skill in the art, for example, the hydrogen on a nitrogen may be substituted with a tert-butoxycarbonyl group. Furthermore, the heterocyclyl may be optionally substituted with one or more substituents (including without limitation a halogen atom, an alkyl radical, or aryl radical). Only stable isomers of such substituted heterocyclic groups are contemplated in this definition.

As used herein, the term "heteroaromatic" or "heteroaryl" means a monocyclic or polycyclic heteroaromatic ring (or radical thereof) comprising carbon atom ring members and one or more heteroatom ring members (such as, for example, oxygen, sulfur or nitrogen). Typically, the heteroaromatic ring has from 5 to about 14 ring members in which at least 1 ring member is a heteroatom selected from oxygen, sulfur, and nitrogen. In another embodiment, the heteroaromatic ring is a 5 or 6 membered ring and may contain from 1 to about 4 heteroatoms. In another embodiment, the heteroaromatic ring system has a 7 to 14 ring members and may contain from 1 to about 7 heteroatoms. Representative heteroaryls include pyridyl, furyl, thienyl, pyrrolyl, oxazolyl, imidazolyl, indolizinyl, thiazolyl, isoxazolyl, pyrazolyl, isothiazolyl, pyridazinyl, pyrimidinyl, pyrazinyl, triazinyl, triazolyl, pyridinyl, thiadiazolyl, pyrazinyl, quinolyl, isoquniolyl, indazolyl, benzoxazolyl, benzofuryl, benzothiazolyl, indolizinyl, imidazopyridinyl, isothiazolyl, tetrazolyl, benzimidazolyl, benzoxazolyl, benzothiazolyl, benzothiadiazolyl, benzoxadiazolyl, indolyl, tetrahydroindolyl, azaindolyl, imidazopyridyl, qunizaolinyl, purinyl, pyrrolo[2,3]pyrimidyl, pyrazolo[3,4]pyrimidyl, benzo(b)thienyl, and the like. These heteroaryl groups may be optionally substituted with one or more substituents.

A heteroaralkyl group refers to a heteroaryl group that is attached to another moiety via an alkylene linker. Heteroaralkyl groups can be substituted or unsubstituted.

As used herein, the term "halogen" or "halo" means -F, -Cl, -Br, or -I.

As used herein, the term "haloalkyl" means an alkyl group in which one or more –H is replaced with a halo group. Examples of haloalkyl groups include $-CF_3$, $-CHF_2$, $-CCl_3$, $-CH_2CH_2Br$, $-CH_2CH(CH_2CH_2Br)CH_3$, $-CHICH_3$, and the like.

As used herein, the term "haloalkoxy" means an alkoxy group in which one or more –H is replaced with a halo group. Examples of haloalkoxy groups include -OCF_3 and –$OCHF_2$.

As used herein, the term "linker" means a diradical having from 1-6 atoms connected together so as to form an uninterrupted array or series of atoms, and which covalently connects two other moieties. For example, a linker of the compounds described herein having a specified number of atoms in contiguous connectivity has at least that number of atoms connected together so as to form an uninterrupted chain, but may also include additional atoms that are not so connected (*e.g.*, branches or atoms contained within a ring system). The atoms of the linker may be connected by saturated or unsaturated covalent bonds. Linkers include, but are not limited to, alkylidene, alkenylidene, alkynylidene and cycloalkylidene (such as lower alkylidene, cycloalkylidene, alkylycloalkylidene and alkyl-substituted alkylidene) linkers wherein one or more (*e.g.*, between 1 and 3, (*e.g.*, 1 or 2)) carbon atoms may be optionally replaced with O, S, or N and wherein two or more (*e.g.*, 2-3 (*e.g.*, 2 or 3)) adjacent atoms may be optionally linked together to form a carbocyclic or heterocyclic moiety within the linker (which may be monocyclic, polycyclic and/or fused, and which may be saturated, unsaturated, or aromatic). Examples of specific linkers useful in the compounds of the invention include (without limitation) diradicals of alkyl, alkenyl, alynyl, alkoxy, alkoxyalkyl, alkylaminoalkyl, cycloalkyl, alkylcycloalkyl, and alkyl-substituted alkylcycloalkyl (wherein one or more carbon atoms in any of these linkers may be optionally replaced with O, S, or N).

As used herein, the terms "subject," "patient," and "animal", are used interchangeably and include, but are not limited to, a cow, monkey, horse, sheep, pig, chicken, turkey, quail, cat, dog, mouse, rat, rabbit, guinea pig, or human. The preferred subject, patient, or animal is a human.

As used herein, the term "lower" refers to a group having up to four carbon atoms. For example, a "lower alkyl" refers to an alkyl radical having from 1 to 4 carbon atoms, and a "lower alkenyl" or "lower alkynyl" refers to an alkenyl or alkynyl radical having from 2 to 4 carbon atoms, respectively. A lower alkoxy or a lower alkyl sulfanyl refers to an alkoxy or an alkyl sulfanyl having from 1 to 4 carbon atoms. Lower substituents are typically preferred.

Where a particular substituent, such as an alkyl substituent, occurs multiple times in a given structure or moiety, the identity of the substituent is independent in each case and may be the same as or different from other occurrences of that substituent in the structure or moiety. Furthermore, individual substituents in the specific embodiments and exemplary compounds of this invention are preferred in combination with other such substituents in the compounds of this invention, even if such individual substituents are not expressly noted as being preferred or not expressly shown in combination with other substituents.

The compounds of the invention are defined herein by their chemical structures and/or chemical names. Where a compound is referred to by both a chemical structure and a chemical name, and the chemical structure and chemical name conflict, the chemical structure is determinative of the compound's identity.

Suitable substituents for an alkyl, alkoxy, alkyl sulfanyl, alkylamino, dialkylamino, alkylene, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, heterocyclyl, aryl, aralkyl, heteroaryl, and heteroarylalkyl groups include any substituent that will form a stable compound of the invention. Examples of substituents for an alkyl, alkoxy, alkylsulfanyl, alkylamino, dialkylamino, alkylene, alkenyl, alkynyl, cycloalkyl, cycloalkenyl, heterocyclyl, aryl, aralkyl, heteroaryl, and heteroarylalkyl include an alkyl, alkoxy, alkyl sulfanyl, alkylamino, dialkylamino, an alkenyl, an alkynyl, an cycloalkyl, an cycloalkenyl, an heterocyclyl, an aryl, an heteroaryl, an aralkyl, an heteroaralkyl, a haloalkyl, $-C(O)NR_{13}R_{14}$, $-NR_{15}C(O)R_{16}$, halo, $-OR_{15}$, cyano, nitro, haloalkoxy, $-C(O)R_{15}$, $-NR_{13}R_{14}$, $-SR_{15}$, $-C(O)OR_{15}$, $-OC(O)R_{15}$, $-NR_{15}C(O)NR_{13}R_{14}$, $-OC(O)NR_{13}R_{14}$, $-NR_{15}C(O)OR_{16}$, $-S(O)_pR_{15}$, or $-S(O)_pNR_{13}R_{14}$, wherein R_{13} and R_{14}, for each occurrence are, independently, H, an optionally substituted alkyl, an optionally substituted alkenyl, an optionally substituted alkynyl, an optionally substituted cycloalkyl, an optionally substituted cycloalkenyl, an optionally substituted heterocyclyl, an optionally substituted aryl, an optionally substituted heteroaryl, an optionally substituted aralkyl, or an optionally substituted heteroaralkyl; or R_{13} and R_{14} taken together with the nitrogen to which they are attached form optionally substituted heterocyclyl or optionally substituted heteroaryl; and R_{15} and R_{16} for each occurrence are, independently, H, an optionally substituted alkyl, an optionally substituted alkenyl, an optionally substituted alkynyl, an optionally substituted

cycloalkyl, an optionally substituted cycloalkenyl, an optionally substituted heterocyclyl, an optionally substituted aryl, an optionally substituted heteroaryl, an optionally substituted aralkyl, or an optionally substituted heteroaralkyl.

In addition, alkyl, cycloalkyl, alkylene, heterocyclyl, and any saturated portion of a alkenyl, cycloalkenyl, alkynyl, aralkyl, or heteroaralkyl group, may also be substituted with =O, =S, or =N-R_{15}.

When a heterocyclyl, heteroaryl, or heteroaralkyl group contains a nitrogen atom, it may be substituted or unsubstituted. When a nitrogen atom in the aromatic ring of a heteroaryl group has a substituent the nitrogen may be a quaternary nitrogen.

Choices and combinations of substituents and variables envisioned by this invention are only those that result in the formation of stable compounds. The term "stable", as used herein, refers to compounds which possess stability sufficient to allow manufacture and which maintains the integrity of the compound for a sufficient period of time to be useful for the purposes detailed herein (*e.g.*, therapeutic or prophylactic administration to a subject). Typically, such compounds are stable at a temperature of 40°C or less, in the absence of excessive moisture, for at least one week. Such choices and combinations will be apparent to those of ordinary skill in the art and may be determined without undue experimentation.

Unless indicated otherwise, the compounds of the invention containing reactive functional groups (such as, without limitation, carboxy, hydroxy, and amino moieties) also include protected derivatives thereof. "Protected derivatives" are those compounds in which a reactive site or sites are blocked with one ore more protecting groups. Suitable protecting groups for carboxy moieties include benzyl, tert-butyl, and the like. Suitable protecting groups for amino and amido groups include acetyl, tert-butoxycarbonyl, benzyloxycarbonyl, and the like. Suitable protecting groups for hydroxy include benzyl and the like. Other suitable protecting groups are well known to those of ordinary skill in the art and include those found in T. W. Greene, Protecting Groups in Organic Synthesis, John Wiley & Sons, Inc. 1981, the entire teachings of which are incorporated herein by reference.

As used herein, the term "compound(s) of this invention" and similar terms refers to a compound of formula I or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof and also include protected derivatives thereof.

As used herein and unless otherwise indicated, the term "prodrug" means a derivative of a compound that can hydrolyze, oxidize, or otherwise react under biological conditions (*in vitro* or *in vivo*) to provide a compound of this invention. Prodrugs may only become active upon such reaction under biological conditions, but they may have activity in their unreacted forms. Examples of prodrugs contemplated in this invention include, but are not limited to, analogs or derivatives of compounds of the invention that comprise biohydrolyzable moieties such as biohydrolyzable amides, biohydrolyzable esters, biohydrolyzable carbamates, biohydrolyzable carbonates, biohydrolyzable ureides, and biohydrolyzable phosphate analogues. Other examples of prodrugs include derivatives of compounds of the invention that include -NO, $-NO_2$, -ONO, or $-ONO_2$ moieties. Prodrugs can typically be prepared using well-known methods, such as those described by BURGER'S MEDICINAL CHEMISTRY AND DRUG DISCOVERY (1995) 172-178, 949-982 (Manfred E. Wolff ed., 5th ed), the entire teachings of which are incorporated herein by reference.

As used herein and unless otherwise indicated, the terms "biohydrolyzable amide", "biohydrolyzable ester", "biohydrolyzable carbamate", "biohydrolyzable carbonate", "biohydrolyzable ureide" and "biohydrolyzable phosphate analogue" mean an amide, ester, carbamate, carbonate, ureide, or phosphate analogue, respectively, that either: 1) does not destroy the biological activity of the compound and confers upon that compound advantageous properties *in vivo*, such as uptake, duration of action, or onset of action; or 2) is itself biologically inactive but is converted *in vivo* to a biologically active compound. Examples of biohydrolyzable amides include, but are not limited to, lower alkyl amides, α-amino acid amides, alkoxyacyl amides, and alkylaminoalkylcarbonyl amides. Examples of biohydrolyzable esters include, but are not limited to, lower alkyl esters, alkoxyacyloxy esters, alkyl acylamino alkyl esters, and choline esters. Examples of biohydrolyzable carbamates include, but are not limited to, lower alkylamines, substituted ethylenediamines, amino acids, hydroxyalkylamines, heterocyclic and heteroaromatic amines, and polyether amines.

As used herein, the term "pharmaceutically acceptable salt," is a salt formed from an acid and a basic group of one of the compounds of the invention. Illustrative salts include, but are not limited, to sulfate, citrate, acetate, oxalate, chloride, bromide, iodide, nitrate, bisulfate, phosphate, acid phosphate, isonicotinate, lactate, salicylate, acid citrate, tartrate, oleate, tannate, pantothenate, bitartrate, ascorbate, succinate, maleate, gentisinate, fumarate, gluconate, glucaronate, saccharate, formate, benzoate, glutamate, methanesulfonate, ethanesulfonate, benzenesulfonate, *p*-toluenesulfonate, and pamoate (*i.e.*, 1,1'-methylene-bis-(2-hydroxy-3-naphthoate)) salts. The term "pharmaceutically acceptable salt" also refers to a salt prepared from a compound of the invention having an acidic functional group, such as a carboxylic acid functional group, and a pharmaceutically acceptable inorganic or organic base. Suitable bases include, but are not limited to, hydroxides of alkali metals such as sodium, potassium, and lithium; hydroxides of alkaline earth metal such as calcium and magnesium; hydroxides of other metals, such as aluminum and zinc; ammonia, and organic amines, such as unsubstituted or hydroxy-substituted mono-, di-, or trialkylamines; dicyclohexylamine; tributyl amine; pyridine; N-methyl,N-ethylamine; diethylamine; triethylamine; mono-, bis-, or tris-(2-hydroxy-lower alkyl amines), such as mono-, bis-, or tris-(2-hydroxyethyl)- amine, 2-hydroxy-tert-butylamine, or tris-(hydroxymethyl)methylamine, N, N,-di-lower alkyl-N-(hydroxy lower alkyl)-amines, such as N,N-dimethyl-N-(2-hydroxyethyl)- amine, or tri-(2-hydroxyethyl)amine; N-methyl-D-glucamine; and amino acids such as arginine, lysine, and the like. The term "pharmaceutically acceptable salt" also refers to a salt prepared from a compound of the invention having a basic functional group, such as an amino functional group, and a pharmaceutically acceptable inorganic or organic acid. Suitable acids include, but are not limited to, hydrogen sulfate, citric acid, acetic acid, oxalic acid, hydrochloric acid, hydrogen bromide, hydrogen iodide, nitric acid, phosphoric acid, isonicotinic acid, lactic acid, salicylic acid, tartaric acid, ascorbic acid, succinic acid, maleic acid, besylic acid, fumaric acid, gluconic acid, glucaronic acid, saccharic acid, formic acid, benzoic acid, glutamic acid, methanesulfonic acid, ethanesulfonic acid, benzenesulfonic acid, and *p*-toluenesulfonic acid.

When a disclosed compound is named or depicted by structure, it is to be understood that solvates (*e.g.*, hydrates) of the compound or its pharmaceutically acceptable salts are also included. "Solvates" refer to crystalline forms wherein solvent molecules are incorporated into the crystal lattice during crystallization. Solvate may include water or nonaqueous solvents such as ethanol, isopropanol, DMSO, acetic acid, ethanolamine, and EtOAc. Solvates, wherein water is the solvent molecule incorporated into the crystal lattice, are typically referred to as "hydrates". Hydrates include a stoichiometric or non-stoichiometric amount of water bound by non-covalent intermolecular forces.

When a disclosed compound is named or depicted by structure, it is to be understood that the compound, including solvates thereof, may exist in crystalline forms, non-crystalline forms or a mixture thereof. The compounds or solvates may also exhibit polymorphism (*i.e.*, the capacity to occur in different crystalline forms). These different crystalline forms are typically known as "polymorphs." It is to be understood that when named or depicted by structure, the disclosed compounds and solvates (*e.g.*, hydrates) also include all polymorphs thereof. As used herein, the term "polymorph" means solid crystalline forms of a compound of the present invention or complex thereof. Different polymorphs of the same compound can exhibit different physical, chemical and/or spectroscopic properties. Different physical properties include, but are not limited to stability (*e.g.*, to heat or light), compressibility and density (important in formulation and product manufacturing), and dissolution rates (which can affect bioavailability). Differences in stability can result from changes in chemical reactivity (*e.g.*, differential oxidation, such that a dosage form discolors more rapidly when comprised of one polymorph than when comprised of another polymorph) or mechanical characteristics (*e.g.*, tablets crumble on storage as a kinetically favored polymorph converts to thermodynamically more stable polymorph) or both (*e.g.*, tablets of one polymorph are more susceptible to breakdown at high humidity). Different physical properties of polymorphs can affect their processing. For example, one polymorph might be more likely to form solvates or might be more difficult to filter or wash free of impurities than another due to, for example, the shape or size distribution of particles of it. In addition, one polymorph may spontaneously convert to another polymorph under certain conditions.

When a disclosed compound is named or depicted by structure, it is to be understood that clathrates ("inclusion compounds") of the compound or its pharmaceutically acceptable salts, solvates or polymorphs are also included. As used herein, he term "clathrate" means a compound of the present invention or a salt thereof in the form of a crystal lattice that contains spaces (*e.g.*, channels) that have a guest molecule (*e.g.*, a solvent or water) trapped within.

As used herein, the term "asthma" means a pulmonary disease, disorder or condition characterized by reversible airway obstruction, airway inflammation, and increased airway responsiveness to a variety of stimuli.

"Immunosuppression" refers to impairment of any component of the immune system resulting in decreased immune function. This impairment may be measured by any conventional means including whole blood assays of lymphocyte function, detection of lymphocyte proliferation and assessment of the expression of T cell surface antigens. The antisheep red blood cell (SRBC) primary (IgM) antibody response assay (usually referred to as the plaque assay) is one specific method. This and other methods are described in Luster, M.I., Portier, C., Pait, D.G., White, K.L., Jr., Gennings, C., Munson, A.E., and Rosenthal, G.J. (1992). "Risk Assessment in Immunotoxicology I: Sensitivity and Predictability of Immune Tests." Fundam. Appl. Toxicol., 18, 200-210. Measuring the immune response to a T-cell dependent immunogen is another particularly useful assay (Dean, J.H., House, R.V., and Luster, M.I. (2001). "Immunotoxicology: Effects of, and Responses to, Drugs and Chemicals." In Principles and Methods of Toxicology: Fourth Edition (A.W. Hayes, Ed.), pp. 1415-1450, Taylor & Francis, Philadelphia, Pennsylvania).

The compounds of this invention can be used to treat subjects with immune disorders. As used herein, the term "immune disorder" and like terms means a disease, disorder or condition caused by the immune system of an animal, including autoimmune disorders. Immune disorders include those diseases, disorders or conditions that have an immune component and those that are substantially or entirely immune system-mediated. Autoimmune disorders are those wherein the animal's own immune system mistakenly attacks itself, thereby targeting the cells, tissues, and/or organs of the animal's own body. For example, the autoimmune reaction is directed against the nervous system in multiple sclerosis and the gut in

Crohn's disease. In other autoimmune disorders such as systemic lupus erythematosus (lupus), affected tissues and organs may vary among individuals with the same disease. One person with lupus may have affected skin and joints whereas another may have affected skin, kidney, and lungs. Ultimately, damage to certain tissues by the immune system may be permanent, as with destruction of insulin-producing cells of the pancreas in Type 1 diabetes mellitus. Specific autoimmune disorders that may be ameliorated using the compounds and methods of this invention include without limitation, autoimmune disorders of the nervous system (*e.g.*, multiple sclerosis, myasthenia gravis, autoimmune neuropathies such as Guillain-Barré, and autoimmune uveitis), autoimmune disorders of the blood (*e.g.*, autoimmune hemolytic anemia, pernicious anemia, and autoimmune thrombocytopenia), autoimmune disorders of the blood vessels (*e.g.*, temporal arteritis, anti-phospholipid syndrome, vasculitides such as Wegener's granulomatosis, and Behcet's disease), autoimmune disorders of the skin (*e.g.*, psoriasis, dermatitis herpetiformis, pemphigus vulgaris, and vitiligo), autoimmune disorders of the gastrointestinal system (*e.g.*, Crohn's disease, ulcerative colitis, primary biliary cirrhosis, and autoimmune hepatitis), autoimmune disorders of the endocrine glands (*e.g.*, Type 1 or immune-mediated diabetes mellitus, Grave's disease. Hashimoto's thyroiditis, autoimmune oophoritis and orchitis, and autoimmune disorder of the adrenal gland); and autoimmune disorders of multiple organs (including connective tissue and musculoskeletal system diseases) (*e.g.*, rheumatoid arthritis, systemic lupus erythematosus, scleroderma, polymyositis, dermatomyositis, spondyloarthropathies such as ankylosing spondylitis, and Sjogren's syndrome). In addition, other immune system mediated diseases, such as graft-versus-host disease and allergic disorders, are also included in the definition of immune disorders herein. Because a number of immune disorders are caused by inflammation, there is some overlap between disorders that are considered immune disorders and inflammatory disorders. For the purpose of this invention, in the case of such an overlapping disorder, it may be considered either an immune disorder or an inflammatory disorder. "Treatment of an immune disorder" herein refers to administering a compound or a composition of the invention to a subject, who has an immune disorder, a symptom of such a disease or a predisposition towards such a disease, with the purpose to cure, relieve, alter, affect, or prevent the autoimmune disorder, the symptom of it, or the predisposition towards it.

As used herein, the term "allergic disorder" means a disease, condition or disorder associated with an allergic response against normally innocuous substances. These substances may be found in the environment (such as indoor air pollutants and aeroallergens) or they may be non-environmental (such as those causing dermatological or food allergies). Allergens can enter the body through a number of routes, including by inhalation, ingestion, contact with the skin or injection (including by insect sting). Many allergic disorders are linked to atopy, a predisposition to generate the allergic antibody IgE. Because IgE is able to sensitize mast cells anywhere in the body, atopic individuals often express disease in more than one organ. For the purpose of this invention, allergic disorders include any hypersensitivity that occurs upon re-exposure to the sensitizing allergen, which in turn causes the release of inflammatory mediators. Allergic disorders include without limitation, allergic rhinitis (*e.g.*, hay fever), sinusitis, rhinosinusitis, chronic or recurrent otitis media, drug reactions, insect sting reactions, latex reactions, conjunctivitis, urticaria, anaphylaxis and anaphylactoid reactions, atopic dermatitis, asthma, and food allergies.

The compounds of this invention can be used to prevent or to treat subjects with inflammatory disorders. As used herein, an "inflammatory disorder" means a disease, disorder or condition characterized by inflammation of body tissue or having an inflammatory component. These include local inflammatory responses and systemic inflammation. Examples of such inflammatory disorders include: transplant rejection, including skin graft rejection; chronic inflammatory disorders of the joints, including arthritis, rheumatoid arthritis, osteoarthritis and bone diseases associated with increased bone resorption; inflammatory bowel diseases such as ileitis, ulcerative colitis, Barrett's syndrome, and Crohn's disease; inflammatory lung disorders such as asthma, adult respiratory distress syndrome, and chronic obstructive airway disease; inflammatory disorders of the eye including corneal dystrophy, trachoma, onchocerciasis, uveitis, sympathetic ophthalmitis and endophthalmitis; chronic inflammatory disorders of the gums, including gingivitis and periodontitis; tuberculosis; leprosy; inflammatory diseases of the kidney including uremic complications, glomerulonephritis and nephrosis; inflammatory disorders of the skin including sclerodermatitis, psoriasis and eczema; inflammatory diseases of the central nervous system, including chronic demyelinating diseases

of the nervous system, multiple sclerosis, AIDS-related neurodegeneration and Alzheimer's disease, infectious meningitis, encephalomyelitis, Parkinson's disease, Huntington's disease, amyotrophic lateral sclerosis and viral or autoimmune encephalitis; autoimmune disorders, immune-complex vasculitis, systemic lupus and erythematodes; systemic lupus erythematosus (SLE); and inflammatory diseases of the heart such as cardiomyopathy, ischemic heart disease hypercholesterolemia, atherosclerosis); as well as various other diseases with significant inflammatory components, including preeclampsia; chronic liver failure, brain and spinal cord trauma, cancer). There may also be a systemic inflammation of the body, exemplified by gram-positive or gram negative shock, hemorrhagic or anaphylactic shock, or shock induced by cancer chemotherapy in response to pro-inflammatory cytokines, *e.g.*, shock associated with pro-inflammatory cytokines. Such shock can be induced, *e.g.*, by a chemotherapeutic agent used in cancer chemotherapy. "Treatment of an inflammatory disorder" herein refers to administering a compound or a composition of the invention to a subject, who has an inflammatory disorder, a symptom of such a disorder or a predisposition towards such a disorder, with the purpose to cure, relieve, alter, affect, or prevent the inflammatory disorder, the symptom of it, or the predisposition towards it.

An "effective amount" is the quantity of compound in which a beneficial outcome is achieved when the compound is administered to a subject or alternatively, the quantity of compound that possess a desired activity *in vivo* or *in vitro*. In the case of inflammatory disorders and autoimmune disorders, a beneficial clinical outcome includes reduction in the extent or severity of the symptoms associated with the disease or disorder and/or an increase in the longevity and/or quality of life of the subject compared with the absence of the treatment. The precise amount of compound administered to a subject will depend on the type and severity of the disease or condition and on the characteristics of the subject, such as general health, age, sex, body weight and tolerance to drugs. It will also depend on the degree, severity and type of inflammatory disorder or autoimmune disorder or the degree of immunosuppression sought. The skilled artisan will be able to determine appropriate dosages depending on these and other factors. Effective amounts of the disclosed compounds typically range between about 1 mg/m^2

per day and about 10 grams/m^2 per day, and preferably between 10 mg/m^2 per day and about 1 gram/m^2.

The compounds of the invention may contain one or more chiral centers and/or double bonds and, therefore, exist as stereoisomers, such as double-bond isomers (*i.e.*, geometric isomers), enantiomers, or diastereomers. According to this invention, the chemical structures depicted herein, including the compounds of this invention, encompass all of the corresponding compounds' enantiomers and stereoisomers, that is, both the stereomerically pure form (*e.g.*, geometrically pure, enantiomerically pure, or diastereomerically pure) and enantiomeric, diastereomeric, and geometric isomeric mixtures. In some cases, one enantiomer, diastereomer, or geometric isomer will possess superior activity or an improved toxicity or kinetic profile compared to others. In those cases, such enantiomers, diastereomers, and geometric isomers of a compound of this invention are preferred.

The term "inhibit production of IL-2" and like terms means inhibiting IL-2 synthesis (*e.g.*, by inhibiting transcription (mRNA expression), or translation (protein expression)) and/or inhibiting IL-2 secretion in a cell that has the ability to produce and/or secrete IL-2 (*e.g.*, T lymphocyte). Likewise, the term "inhibiting production of IL-4, IL-5, IL-13, GM-CSF, TNFα or IFN-γ means inhibiting the synthesis (*e.g.*, by inhibiting transcription, or translation) and/or inhibiting the secretion in a cell that has the ability to produce and/or secrete these cytokines.

As used herein, a racemic mixture means about 50% of one enantiomer and about 50% of corresponding enantiomer relative to all chiral centers in the molecule. The invention encompasses all enantiomerically-pure, enantiomerically-enriched, diastereomerically pure, diastereomerically enriched, and racemic mixtures of the compounds of the invention.

Enantiomeric and diastereomeric mixtures can typically be resolved into their component enantiomers or stereoisomers by well known methods, such as chiral-phase gas chromatography, chiral-phase high performance liquid chromatography, crystallizing the compound as a chiral salt complex, or crystallizing the compound in a chiral solvent. Enantiomers and diastereomers can also be obtained from diastereomerically- or enantiomerically-pure intermediates, reagents, and catalysts by well-known asymmetric synthetic methods.

When administered to a patient, *e.g.*, to a non-human animal for veterinary use or for improvement of livestock, or to a human for clinical use, the compounds of the invention are typically administered in isolated form or as the isolated form in a pharmaceutical composition. As used herein, "isolated" means that the compounds of the invention are separated from other components of either (a) a natural source, such as a plant or cell, preferably bacterial culture, or (b) a synthetic organic chemical reaction mixture. Preferably, via conventional techniques, the compounds of the invention are purified. As used herein, "purified" means that when isolated, the isolate contains at least 95%, preferably at least 98%, of a single compound of the invention by weight of the isolate.

Only those choices and combinations of substituents that result in a stable structure are contemplated. Such choices and combinations will be apparent to those of ordinary skill in the art and may be determined without undue experimentation.

The invention can be understood more fully by reference to the following detailed description and illustrative examples, which are intended to exemplify non-limiting embodiments of the invention.

SPECIFIC EMBODIMENTS

The invention relates to compounds and pharmaceutical compositions that are particularly useful for immunosuppression or to treat or prevent inflammatory conditions, immune disorders, and allergic disorders.

The invention relates to compounds and pharmaceutical compositions that are particularly useful for immunosuppression or to treat or prevent inflammatory conditions, immune disorders, and allergic disorders. Embodiments of the invention include those compounds described hereinabove in the Summary, *e.g.*, those of formula (I).

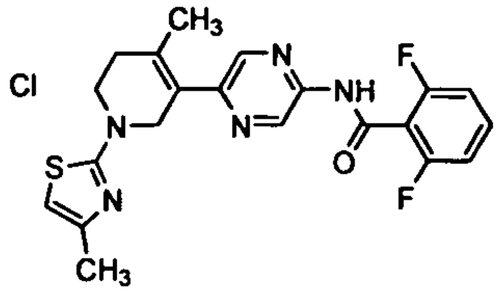
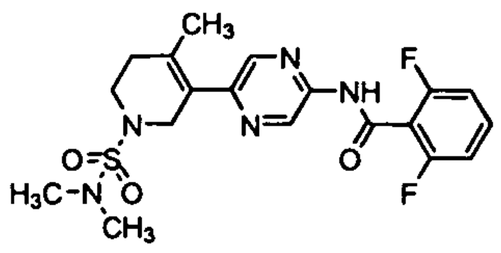
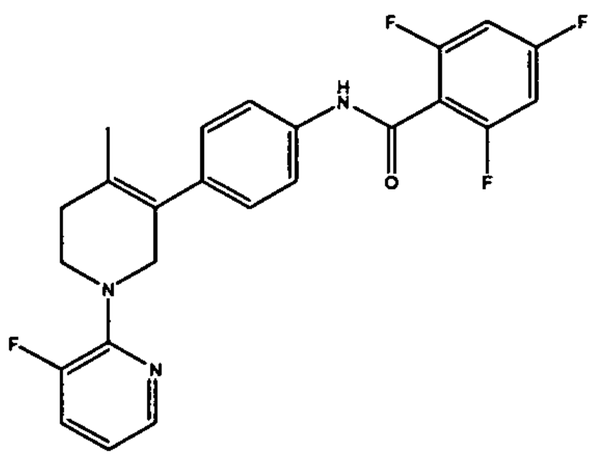
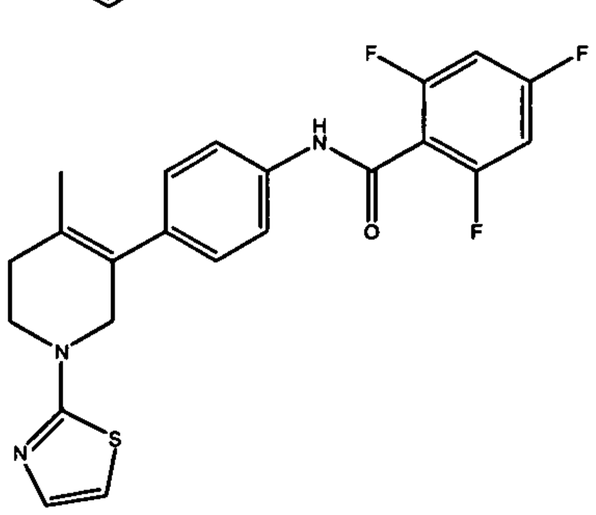
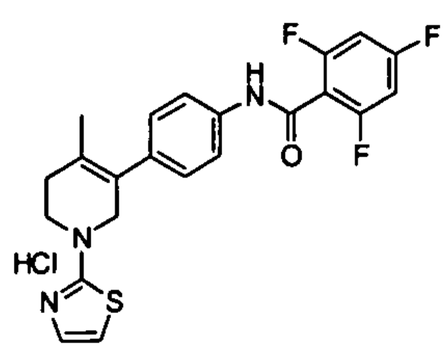
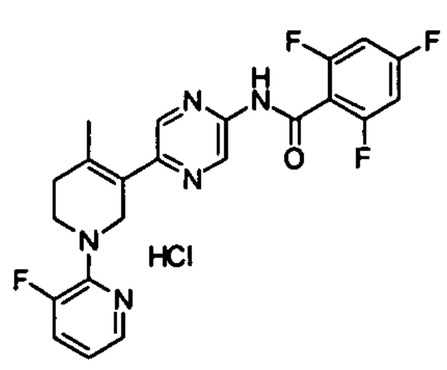
All of the features, specific embodiments and particular substituents disclosed herein may be combined in any combination. Each feature, embodiment or substituent disclosed in this specification may be replaced by an alternative feature, embodiment or substituent serving the same, equivalent, or similar purpose. In the case of chemical compounds, specific values for variables (*e.g.*, values shown in the exemplary compounds disclosed herein) in any chemical

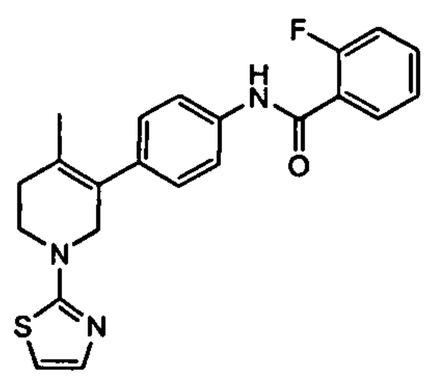
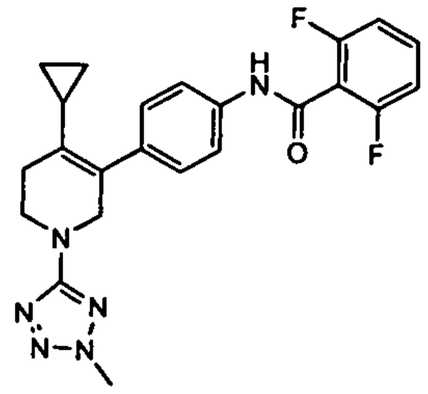
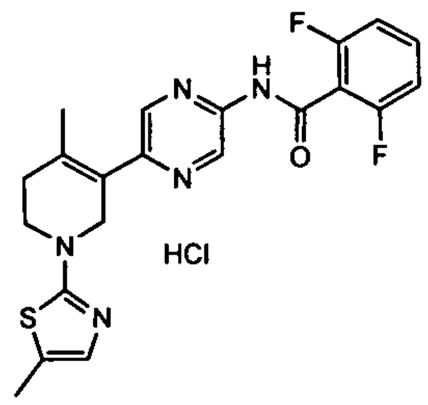
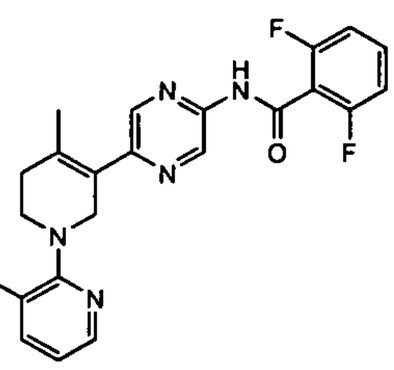
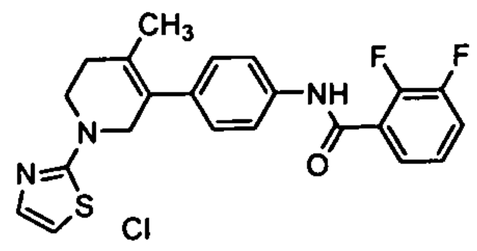
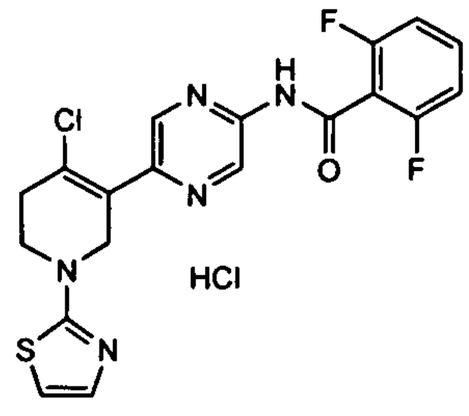
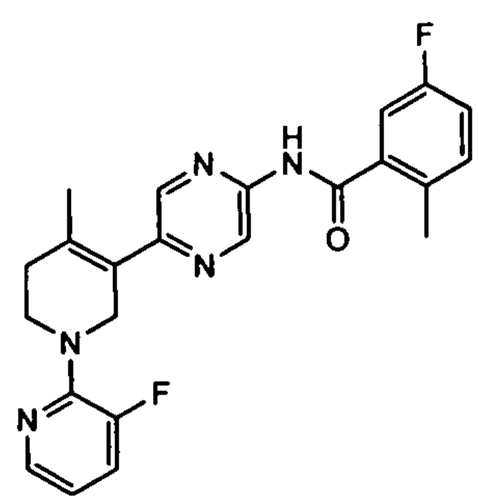
formula disclosed herein can be combined in any combination resulting in a stable structure. Furthermore, specific values (whether preferred or not) for substituents in one type of chemical structure may be combined with values for other substituents (whether preferred or not) in the same or different type of chemical structure. Thus, unless expressly stated otherwise, each feature, embodiment or substituent disclosed is only an example of a generic series of equivalent or similar features, embodiments or substituents.

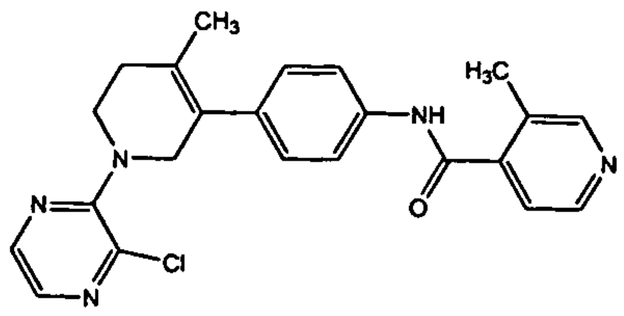
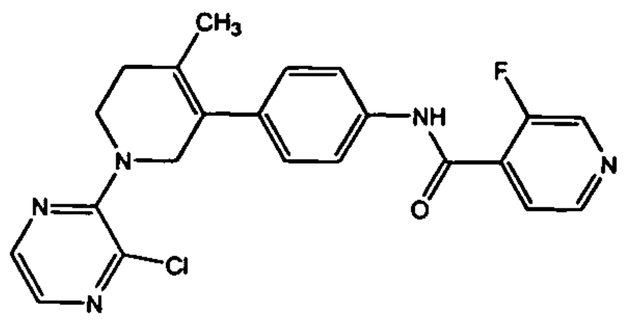
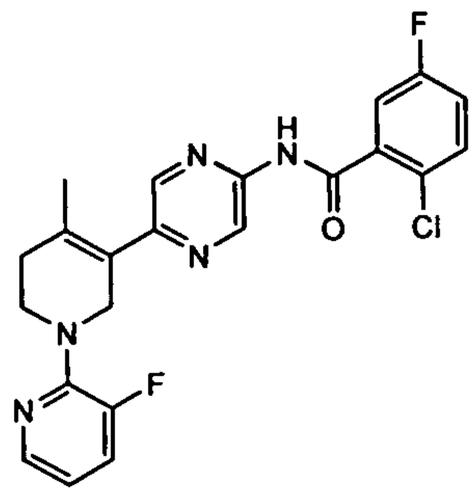
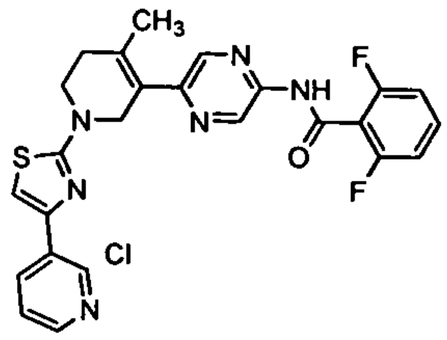
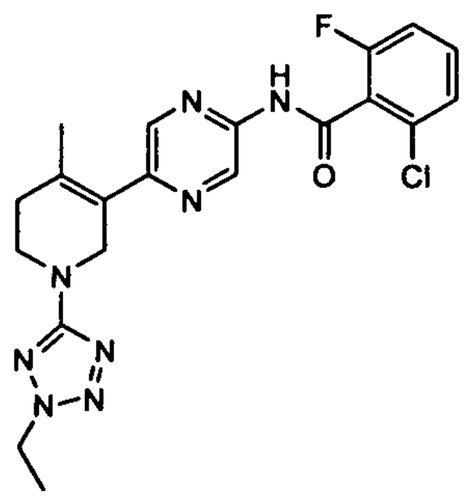
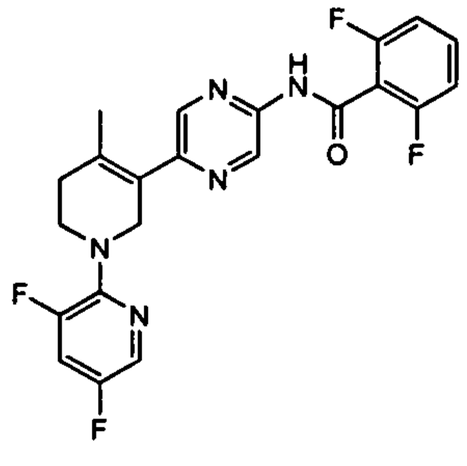
EXEMPLARY COMPOUNDS

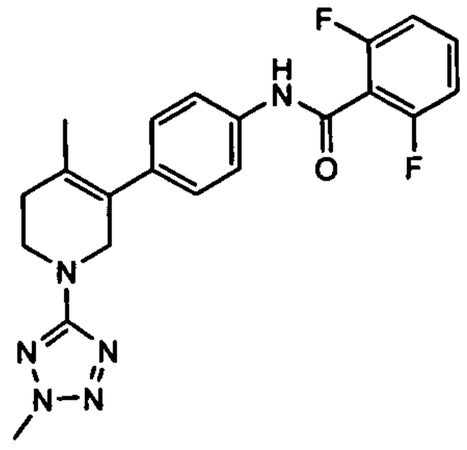
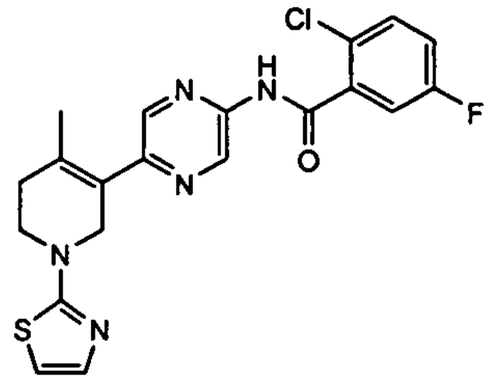
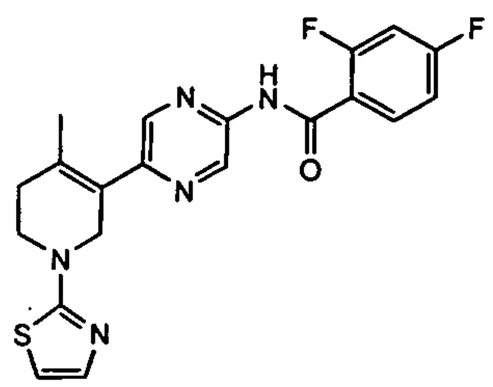
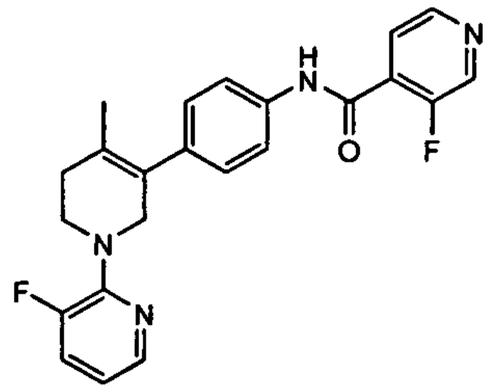
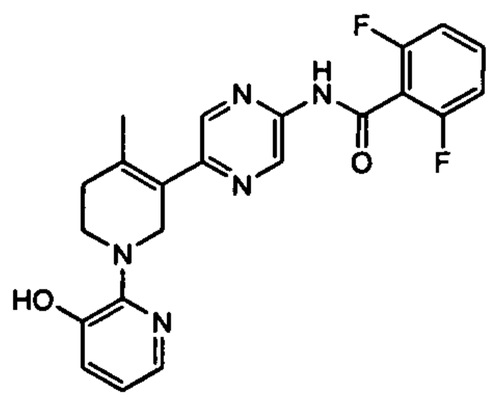
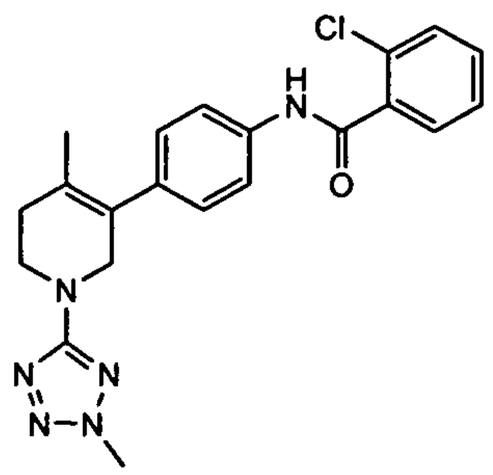
Exemplary compounds of the invention, that have been made in accordance with the descriptions in the examples below, are depicted in Table 1 below.

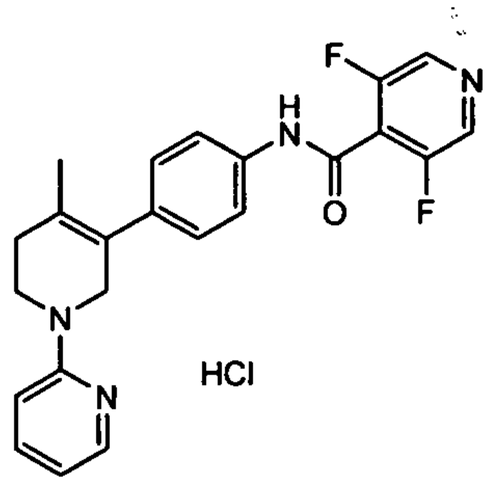
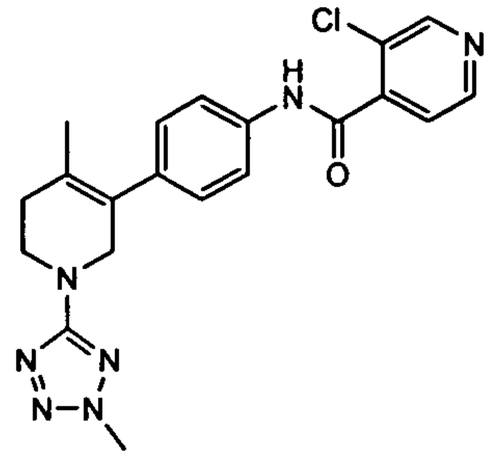
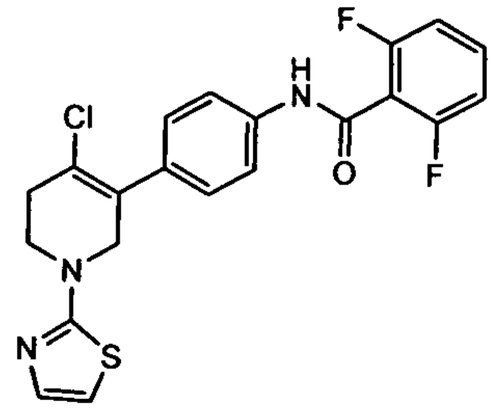
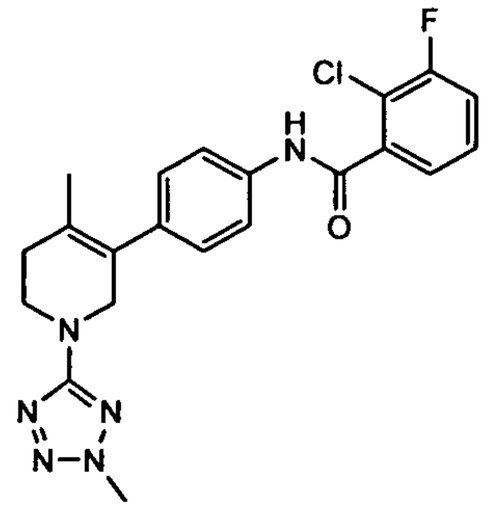
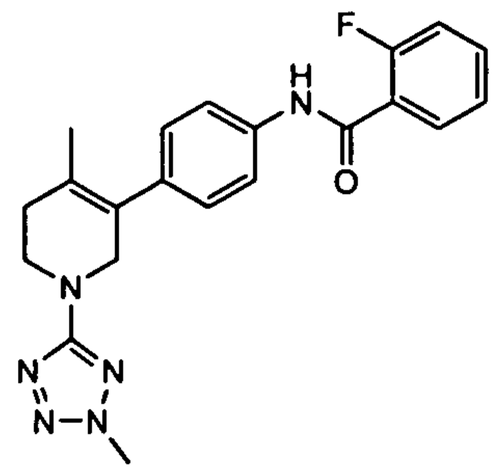
Table 1

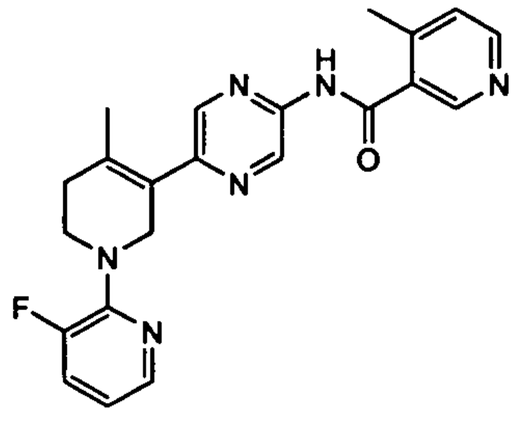
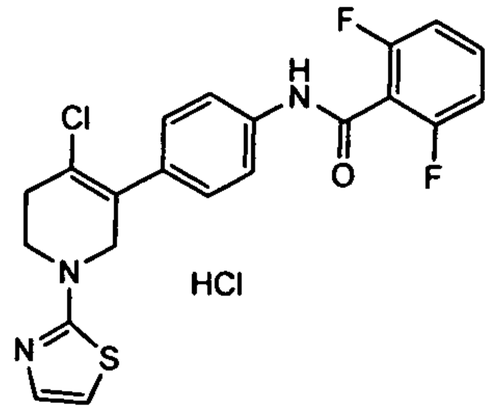
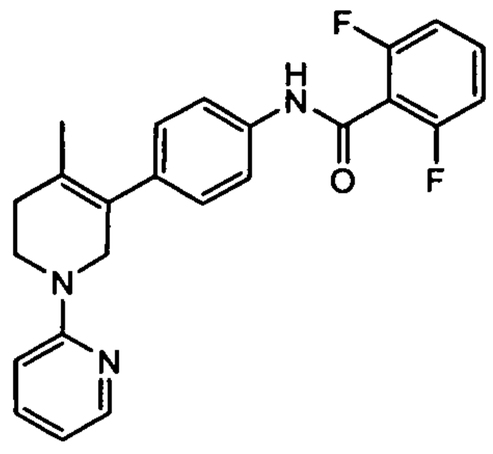
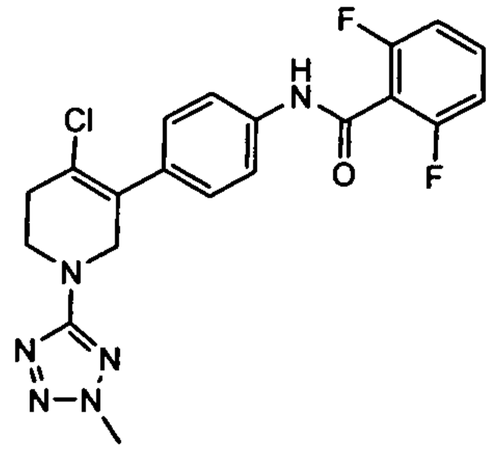
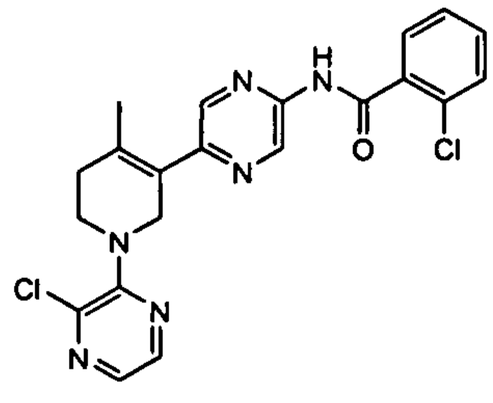
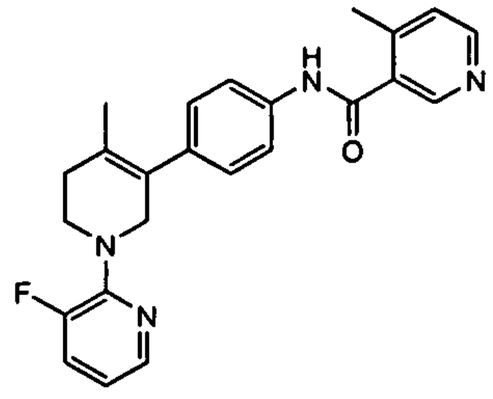
1		2,6-difluoro-N-(5-(4-methyl-1-(4-methylthiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide
2		N-(5-(1-(N,N-dimethylsulfamoyl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-2,6-difluorobenzamide
3		2,4,6-trifluoro-N-(4-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide
4		2,4,6-trifluoro-N-(4-(4-methyl-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide
5		2,4,6-trifluoro-N-(4-(4-methyl-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide hydrochloride
6		2,4,6-trifluoro-N-(5-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide hydrochloride

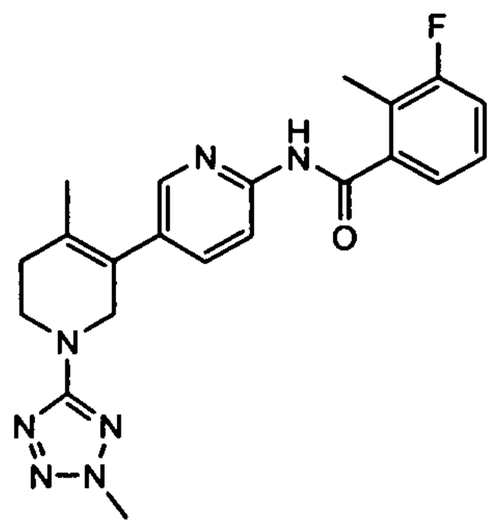
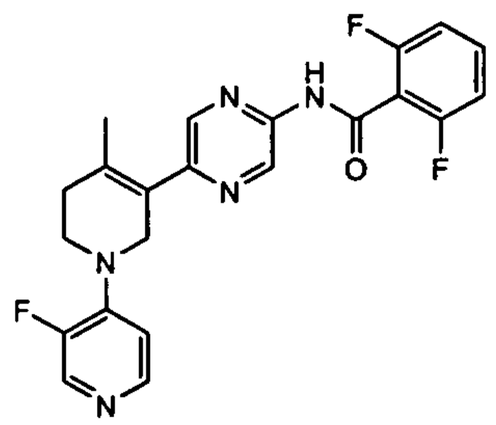
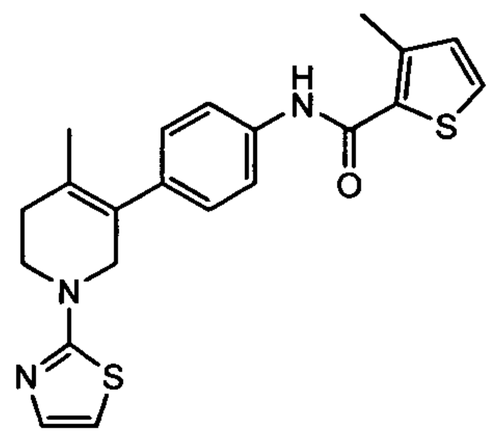
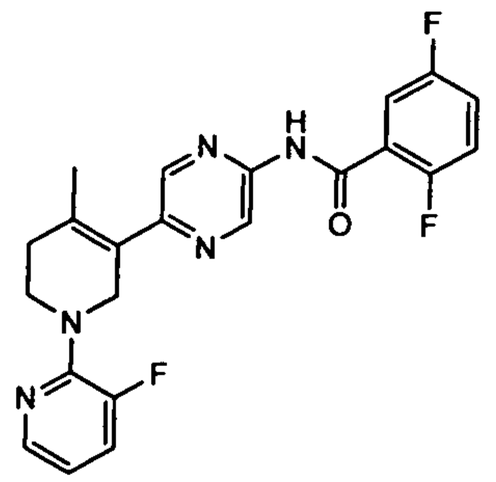
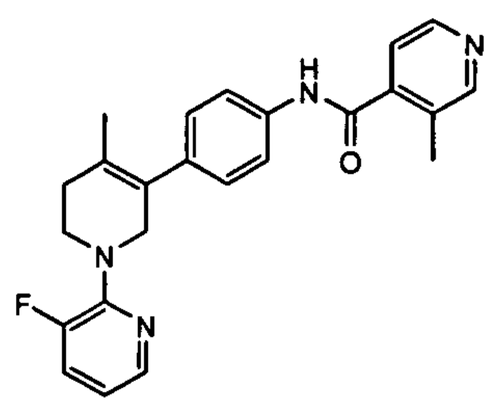
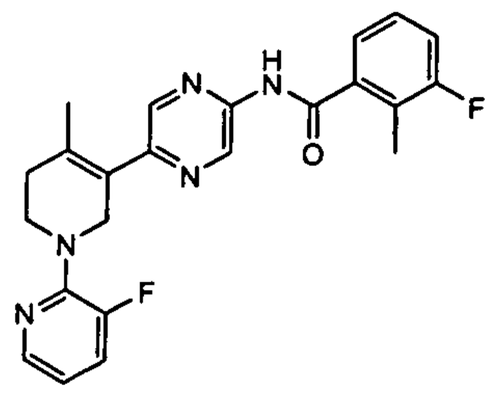
7		2-fluoro-N-(4-(4-methyl-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide
8		N-(4-(4-cyclopropyl-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-2,6-difluorobenzamide
9		2,6-difluoro-N-(5-(4-methyl-1-(5-methylthiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide hydrochloride
10		N-(5-(1-(3-cyanopyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-2,6-difluorobenzamide
11		2,3-difluoro-N-(4-(4-methyl-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide
12		N-(5-(4-chloro-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-2,6-difluorobenzamide hydrochloride
13		5-fluoro-N-(5-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-2-methylbenzamide

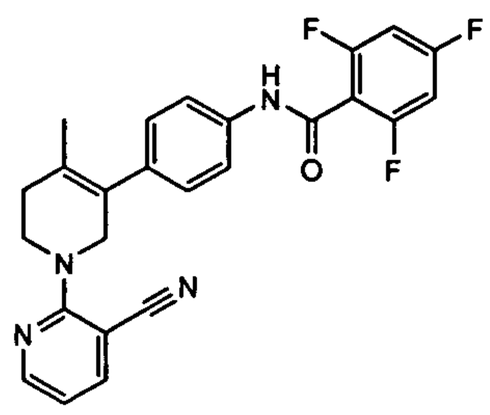
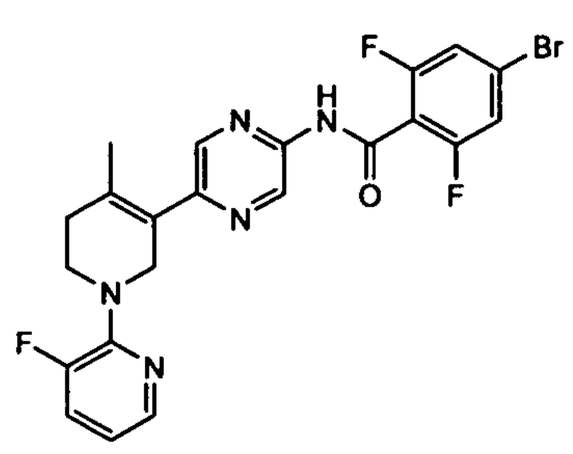
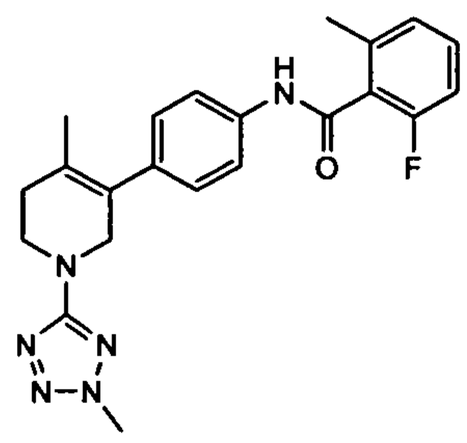
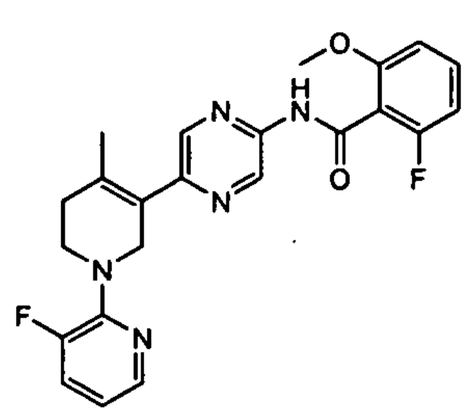
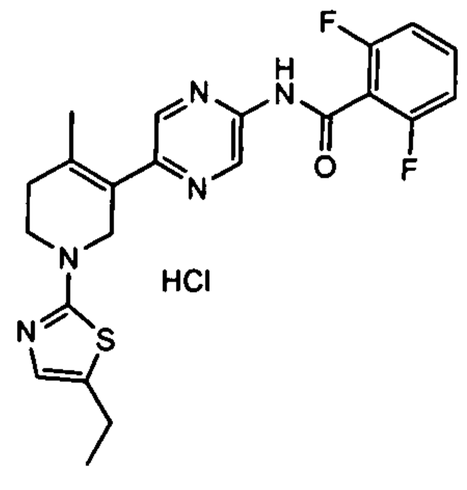
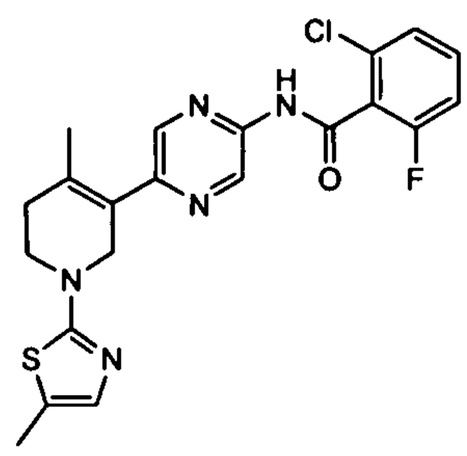
14		N-(4-(1-(3-chloropyrazin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-3-methylisonicotinamide
15		N-(4-(1-(3-chloropyrazin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-3-fluoroisonicotinamide
16		2-chloro-5-fluoro-N-(5-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide
17		2,6-difluoro-N-(5-(4-methyl-1-(4-(pyridin-3-yl)thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide
18		2-chloro-N-(5-(1-(2-ethyl-2H-tetrazol-5-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-6-fluorobenzamide
19		N-(5-(1-(3,5-difluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-2,6-difluorobenzamide

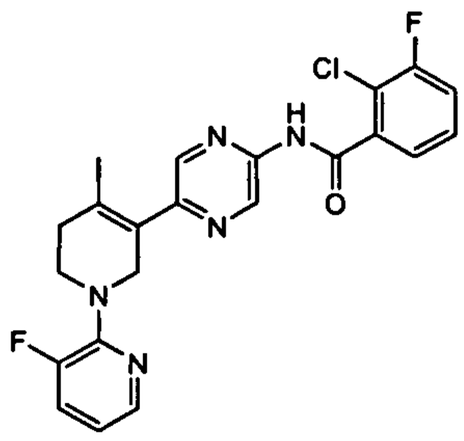
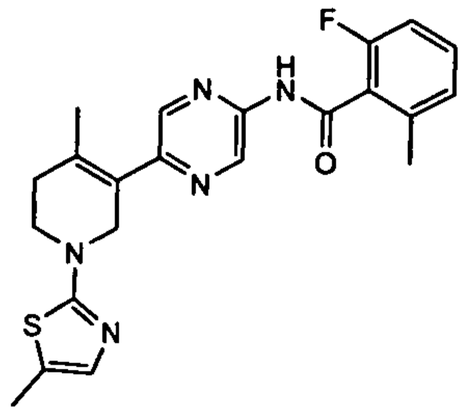
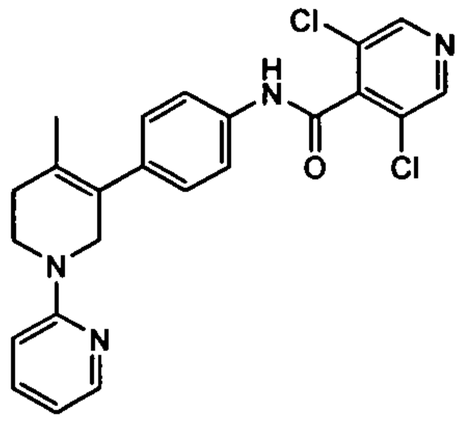
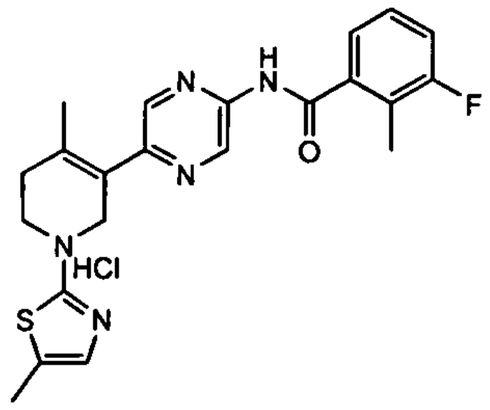
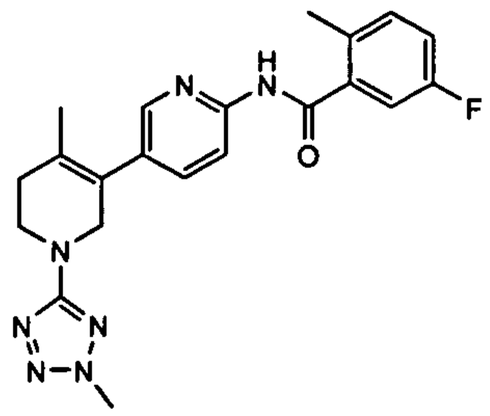
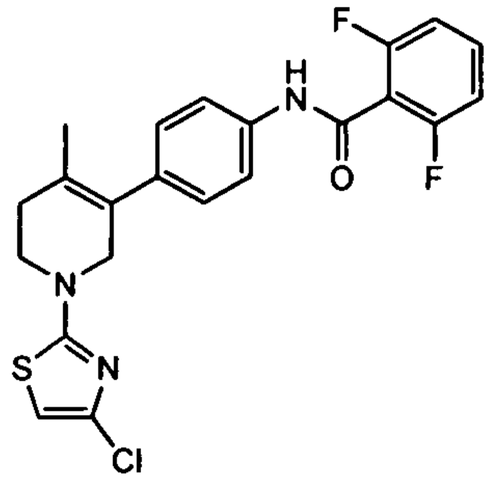
20		2,6-difluoro-N-(4-(4-methyl-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide
21		2-chloro-5-fluoro-N-(5-(4-methyl-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide
22		2,4-difluoro-N-(5-(4-methyl-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide
23		3-fluoro-N-(4-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)isonicotinamide
24		2,6-difluoro-N-(5-(1-(3-hydroxypyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide
25		2-chloro-N-(4-(4-methyl-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide

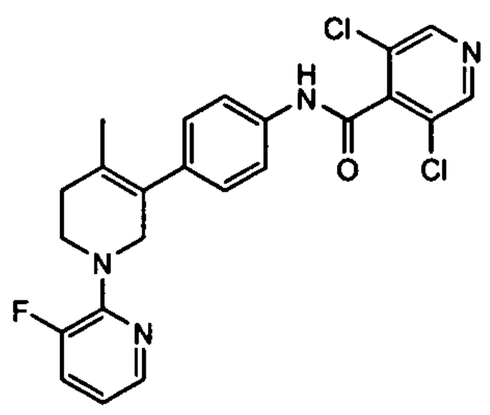
26		3,5-difluoro-N-(4-(4-methyl-1-(pyridin-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)isonicotinamide hydrochloride
27		3-chloro-N-(4-(4-methyl-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)isonicotinamide
28		N-(4-(4-chloro-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-2,6-difluorobenzamide
29		2-chloro-3-fluoro-N-(4-(4-methyl-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide
30		2-fluoro-N-(4-(4-methyl-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide

31		N-(5-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-4-methylnicotinamide
32		N-(4-(4-chloro-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-2,6-difluorobenzamide hydrochloride
33		2,6-difluoro-N-(4-(4-methyl-1-(pyridin-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide
34		N-(4-(4-chloro-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-2,6-difluorobenzamide
35		2-chloro-N-(5-(1-(3-chloropyrazin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide
36		N-(4-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-4-methylnicotinamide

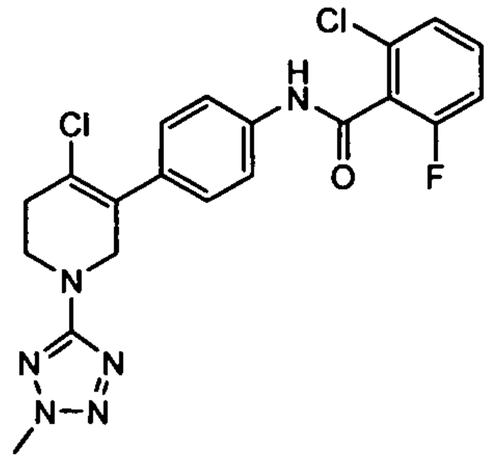
37		3-fluoro-2-methyl-N-(5-(4-methyl-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyridin-2-yl)benzamide
38		2,6-difluoro-N-(5-(1-(3-fluoropyridin-4-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide
39		3-methyl-N-(4-(4-methyl-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)thiophene-2-carboxamide
40		2,5-difluoro-N-(5-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide
41		N-(4-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-3-methylisonicotinamide
42		3-fluoro-N-(5-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-2-methylbenzamide

43		N-(4-(1-(3-cyanopyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-2,4,6-trifluorobenzamide
44		4-bromo-2,6-difluoro-N-(5-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide
45		2-fluoro-6-methyl-N-(4-(4-methyl-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide
46		2-fluoro-N-(5-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-6-methoxybenzamide
47		N-(5-(1-(5-ethylthiazol-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-2,6-difluorobenzamide hydrochloride
48		2-chloro-6-fluoro-N-(5-(4-methyl-1-(5-methylthiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide

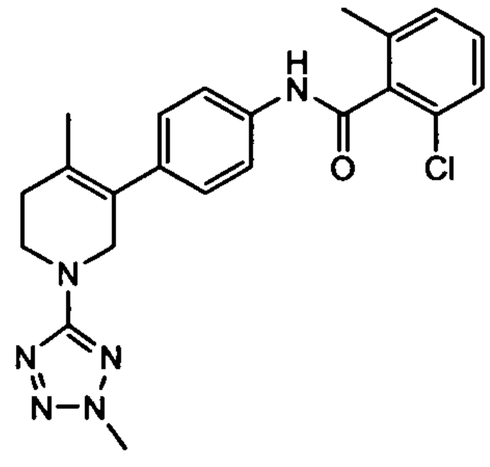
49		2-chloro-3-fluoro-N-(5-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide
50		2-fluoro-6-methyl-N-(5-(4-methyl-1-(5-methylthiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide
51		3,5-dichloro-N-(4-(4-methyl-1-(pyridin-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)isonicotinamide
52		3-fluoro-2-methyl-N-(5-(4-methyl-1-(5-methylthiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide hydrochloride
53		5-fluoro-2-methyl-N-(5-(4-methyl-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyridin-2-yl)benzamide
54		N-(4-(1-(4-chlorothiazol-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-2,6-difluorobenzamide

55 

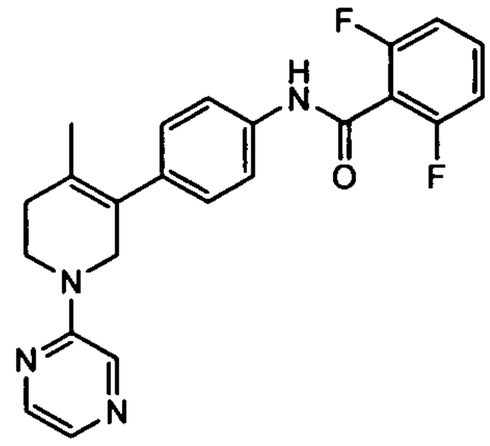
3,5-dichloro-N-(4-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)isonicotinamide

56 

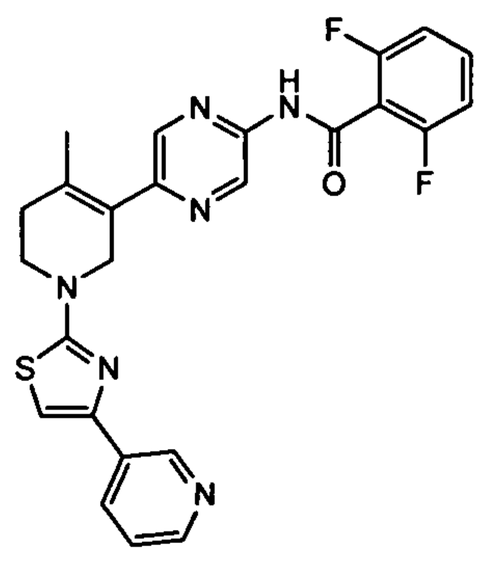
2-chloro-N-(4-(4-chloro-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-6-fluorobenzamide

57 

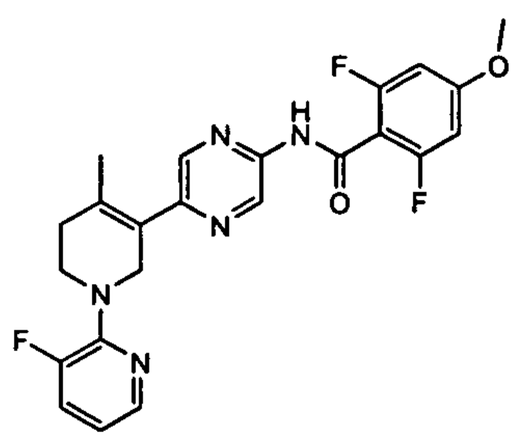
2-chloro-6-methyl-N-(4-(4-methyl-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide

58 

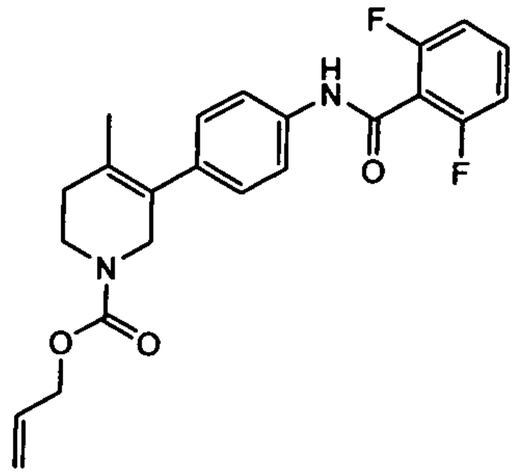
2,6-difluoro-N-(4-(4-methyl-1-(pyrazin-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide

59 

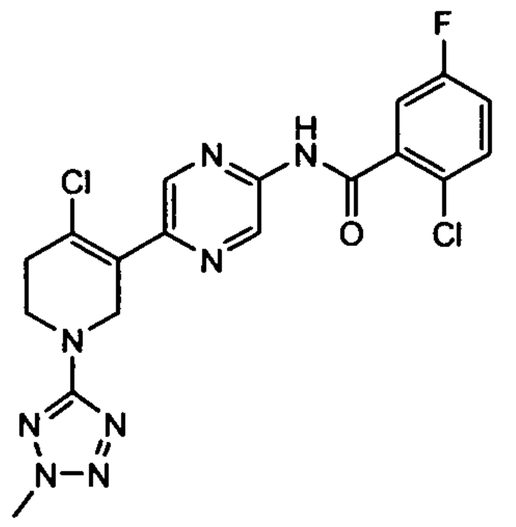
2,6-difluoro-N-(5-(4-methyl-1-(4-(pyridin-3-yl)thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide

60 

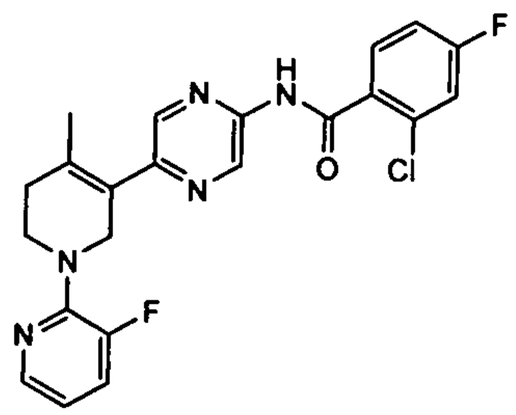
2,6-difluoro-N-(5-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-4-methoxybenzamide

61 

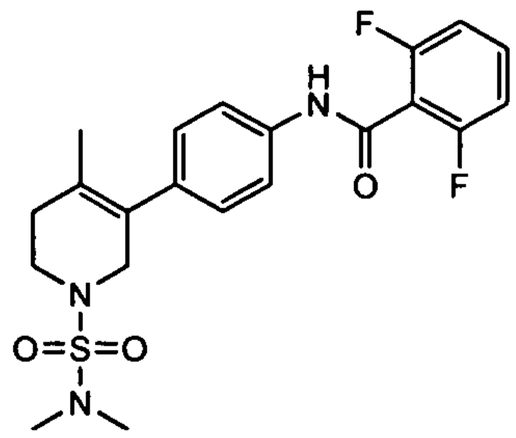
allyl 3-(4-(2,6-difluorobenzamido)phenyl)-4-methyl-5,6-dihydropyridine-1(2H)-carboxylate

62 

2-chloro-N-(5-(4-chloro-1-(2-methyl-2H-tetrazol-5-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-5-fluorobenzamide

63 

2-chloro-4-fluoro-N-(5-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide

64 

N-(4-(1-(N,N-dimethylsulfamoyl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-2,6-difluorobenzamide

MECHANISM OF ACTION

Activation of T-lymphocytes in response to an antigen is dependent on calcium ion oscillations. Calcium ion oscillations in T-lymphocytes are triggered through stimulation of the T-cell antigen receptor, and involve calcium ion influx through the stored-operated

Ca^{2+}-release-activated Ca^{2+} (CRAC) channel. Although a detailed electrophysiological profile of the channel exists, the molecular structure of the CRAC ion channel had not been identified till the recent identification of the pore-forming unit, named Orai1/CRACM1 (Vig, *Science* (2006), *312*:1220-3, Feske, *Nature* (2006), *441*:179-85). Thus, inhibition of CRAC ion channels can be measured by measuring inhibition of the I_{CRAC} current. Calcium ion oscillations in T-cells have been implicated in the activation of several transcription factors (*e.g.*, NFAT, Oct/Oap and NFκB) which are critical for T-cell activation (Lewis, *Biochemical Society Transactions* (2003), *31*:925-929, the entire teachings of which are incorporated herein by reference). Without wishing to be bound by any theory, it is believed that because the compounds of the invention inhibit the activity of CRAC ion channels, they inhibit immune cell activation.

METHODS OF TREATMENT AND PREVENTION

A effective amount of a compound of the invention or a pharmaceutically acceptable salt, solvate, clathrate, and prodrug thereof, or a pharmaceutical composition comprising a compound of the invention, or a pharmaceutically acceptable salt, solvate, clathrate, and prodrug thereof, is administered to a patient in need of immunosuppression or in need of treatment or prevention of an inflammatory condition, an immune disorder, or an allergic disorder. Such patients may be treatment naïve or may experience partial or no response to conventional therapies.

Responsiveness of a particular inflammatory condition, immune disorder, or allergic disorder in a subject can be measured directly (*e.g.*, measuring blood levels of inflammatory cytokines (such as IL-2, IL-4, IL-5, IL-13, GM-CSF, TNFα, IFN-γ and the like) after administration of a compound of this invention), or can be inferred based on an understanding of disease etiology and progression. The compounds of the invention, or pharmaceutically acceptable salts, solvates, clathrates, and prodrugs thereof can be assayed *in vitro* or *in vivo*, for the desired therapeutic or prophylactic activity, prior to use in humans. For example, known animal models of inflammatory conditions, immune disorders, or allergic disorders can be used to demonstrate the safety and efficacy of compounds of this invention.

PHARMACEUTICAL COMPOSITIONS AND DOSAGE FORMS

Pharmaceutical compositions and dosage forms of the invention comprise one or more active ingredients in relative amounts and formulated in such a way that a given pharmaceutical composition or dosage form can be used for immunosuppression or to treat or prevent inflammatory conditions, immune disorders, and allergic disorders. Preferred pharmaceutical compositions and dosage forms comprise a compound of the invention, or a pharmaceutically acceptable prodrug, salt, solvate, or clathrate thereof, optionally in combination with one or more additional active agents.

Single unit dosage forms of the invention are suitable for oral, mucosal (*e.g.*, nasal, sublingual, vaginal, buccal, or rectal), parenteral (*e.g.*, subcutaneous, intravenous, bolus injection, intramuscular, or intraarterial), or transdermal administration to a patient. Examples of dosage forms include, but are not limited to: tablets; caplets; capsules, such as soft elastic gelatin capsules; cachets; troches; lozenges; dispersions; suppositories; ointments; cataplasms (poultices); pastes; powders; dressings; creams; plasters; solutions; patches; aerosols (*e.g.*, nasal sprays or inhalers); gels; liquid dosage forms suitable for oral or mucosal administration to a patient, including suspensions (*e.g.*, aqueous or non-aqueous liquid suspensions, oil-in-water emulsions, or a water-in-oil liquid emulsions), solutions, and elixirs; liquid dosage forms suitable for parenteral administration to a patient; and sterile solids (*e.g.*, crystalline or amorphous solids) that can be reconstituted to provide liquid dosage forms suitable for parenteral administration to a patient.

The composition, shape, and type of dosage forms of the invention will typically vary depending on their use. For example, a dosage form suitable for mucosal administration may contain a smaller amount of active ingredient(s) than an oral dosage form used to treat the same indication. This aspect of the invention will be readily apparent to those skilled in the art. *See, e.g.*, Remington's Pharmaceutical Sciences (1990) 18th ed., Mack Publishing, Easton PA.

Typical pharmaceutical compositions and dosage forms comprise one or more excipients. Suitable excipients are well known to those skilled in the art of pharmacy, and non-limiting examples of suitable excipients are provided herein. Whether a particular excipient is suitable for incorporation into a pharmaceutical composition or dosage form depends on a variety of factors well known in the art including, but not limited to, the way in which the dosage form will

be administered to a patient. For example, oral dosage forms such as tablets may contain excipients not suited for use in parenteral dosage forms.

The suitability of a particular excipient may also depend on the specific active ingredients in the dosage form. For example, the decomposition of some active ingredients can be accelerated by some excipients such as lactose, or when exposed to water. Active ingredients that comprise primary or secondary amines (*e.g.*, N-desmethylvenlafaxine and N,N-didesmethylvenlafaxine) are particularly susceptible to such accelerated decomposition. Consequently, this invention encompasses pharmaceutical compositions and dosage forms that contain little, if any, lactose. As used herein, the term "lactose-free" means that the amount of lactose present, if any, is insufficient to substantially increase the degradation rate of an active ingredient. Lactose-free compositions of the invention can comprise excipients that are well known in the art and are listed, for example, in the U.S. Pharmacopeia (USP) SP (XXI)/NF (XVI). In general, lactose-free compositions comprise active ingredients, a binder/filler, and a lubricant in pharmaceutically compatible and pharmaceutically acceptable amounts. Preferred lactose-free dosage forms comprise active ingredients, microcrystalline cellulose, pre-gelatinized starch, and magnesium stearate.

This invention further encompasses anhydrous pharmaceutical compositions and dosage forms comprising active ingredients, since water can facilitate the degradation of some compounds. For example, the addition of water (*e.g.*, 5%) is widely accepted in the pharmaceutical arts as a means of simulating long-term storage in order to determine characteristics such as shelf-life or the stability of formulations over time. *See, e.g.*, Jens T. Carstensen (1995) Drug Stability: Principles & Practice, 2d. Ed., Marcel Dekker, NY, NY, 379-80. In effect, water and heat accelerate the decomposition of some compounds. Thus, the effect of water on a formulation can be of great significance since moisture and/or humidity are commonly encountered during manufacture, handling, packaging, storage, shipment, and use of formulations.

Anhydrous pharmaceutical compositions and dosage forms of the invention can be prepared using anhydrous or low moisture containing ingredients and low moisture or low humidity conditions. Pharmaceutical compositions and dosage forms that comprise lactose and

at least one active ingredient including a primary or secondary amine are preferably anhydrous if substantial contact with moisture and/or humidity during manufacturing, packaging, and/or storage is expected.

An anhydrous pharmaceutical composition should be prepared and stored such that its anhydrous nature is maintained. Accordingly, anhydrous compositions are preferably packaged using materials known to prevent exposure to water such that they can be included in suitable formulary kits. Examples of suitable packaging include, but are not limited to, hermetically sealed foils, plastics, unit dose containers (*e.g.*, vials), blister packs, and strip packs.

The invention further encompasses pharmaceutical compositions and dosage forms that comprise one or more compounds that reduce the rate by which an active ingredient will decompose. Such compounds, which are referred to herein as "stabilizer" include, but are not limited to, antioxidants such as ascorbic acid, pH buffers, or salt buffers.

Like the amounts and types of excipients, the amounts and specific types of active ingredients in a dosage form may differ depending on factors such as, but not limited to, the route by which it is to be administered to patients. However, typical dosage forms of the invention include a compound of the invention, or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof in an amount of from about 1 mg to about 1000 mg, preferably in an amount of from about 50 mg to about 500 mg, and most preferably in an amount of from about 75 mg to about 350 mg. The typical total daily dosage of a compound of the invention, or a pharmaceutically acceptable salt, solvate, clathrate, or prodrug thereof can range from about 1 mg to about 5000 mg per day, preferably in an amount from about 50 mg to about 1500 mg per day, more preferably from about 75 mg to about 1000 mg per day. It is within the skill of the art to determine the appropriate dose and dosage form for a given patient.

ORAL DOSAGE FORMS

Pharmaceutical compositions of the invention that are suitable for oral administration can be presented as discrete dosage forms, such as, but are not limited to, tablets (*e.g.*, chewable tablets), caplets, capsules, and liquids (*e.g.*, flavored syrups). Such dosage forms contain predetermined amounts of active ingredients, and may be prepared by methods of pharmacy

well known to those skilled in the art. *See generally,* Remington's Pharmaceutical Sciences (1990) 18th ed., Mack Publishing, Easton PA.

Typical oral dosage forms of the invention are prepared by combining the active ingredient(s) in an admixture with at least one excipient according to conventional pharmaceutical compounding techniques. Excipients can take a wide variety of forms depending on the form of preparation desired for administration. For example, excipients suitable for use in oral liquid or aerosol dosage forms include, but are not limited to, water, glycols, oils, alcohols, flavoring agents, preservatives, and coloring agents. Examples of excipients suitable for use in solid oral dosage forms (*e.g.*, powders, tablets, capsules, and caplets) include, but are not limited to, starches, sugars, micro-crystalline cellulose, diluents, granulating agents, lubricants, binders, and disintegrating agents.

Because of their ease of administration, tablets and capsules represent the most advantageous oral dosage unit forms, in which case solid excipients are employed. If desired, tablets can be coated by standard aqueous or nonaqueous techniques. Such dosage forms can be prepared by any of the methods of pharmacy. In general, pharmaceutical compositions and dosage forms are prepared by uniformly and intimately admixing the active ingredients with liquid carriers, finely divided solid carriers, or both, and then shaping the product into the desired presentation if necessary.

For example, a tablet can be prepared by compression or molding. Compressed tablets can be prepared by compressing in a suitable machine the active ingredients in a free-flowing form such as powder or granules, optionally mixed with an excipient. Molded tablets can be made by molding in a suitable machine a mixture of the powdered compound moistened with an inert liquid diluent.

Examples of excipients that can be used in oral dosage forms of the invention include, but are not limited to, binders, fillers, disintegrants, and lubricants. Binders suitable for use in pharmaceutical compositions and dosage forms include, but are not limited to, corn starch, potato starch, or other starches, gelatin, natural and synthetic gums such as acacia, sodium alginate, alginic acid, other alginates, powdered tragacanth, guar gum, cellulose and its derivatives (*e.g.*, ethyl cellulose, cellulose acetate, carboxymethyl cellulose calcium, sodium

carboxymethyl cellulose), polyvinyl pyrrolidone, methyl cellulose, pre-gelatinized starch, hydroxypropyl methyl cellulose, (*e.g.*, Nos. 2208, 2906, 2910), microcrystalline cellulose, and mixtures thereof.

Suitable forms of microcrystalline cellulose include, but are not limited to, the materials sold as AVICEL-PH-101, AVICEL-PH-103 AVICEL RC-581, AVICEL-PH-105 (available from FMC Corporation, American Viscose Division, Avicel Sales, Marcus Hook, PA), and mixtures thereof. One specific binder is a mixture of microcrystalline cellulose and sodium carboxymethyl cellulose sold as AVICEL RC-581. Suitable anhydrous or low moisture excipients or additives include AVICEL-PH-103J and Starch 1500 LM.

Examples of fillers suitable for use in the pharmaceutical compositions and dosage forms disclosed herein include, but are not limited to, talc, calcium carbonate (*e.g.*, granules or powder), microcrystalline cellulose, powdered cellulose, dextrates, kaolin, mannitol, silicic acid, sorbitol, starch, pre-gelatinized starch, and mixtures thereof. The binder or filler in pharmaceutical compositions of the invention is typically present in from about 50 to about 99 weight percent of the pharmaceutical composition or dosage form.

Disintegrants are used in the compositions of the invention to provide tablets that disintegrate when exposed to an aqueous environment. Tablets that contain too much disintegrant may disintegrate in storage, while those that contain too little may not disintegrate at a desired rate or under the desired conditions. Thus, a sufficient amount of disintegrant that is neither too much nor too little to detrimentally alter the release of the active ingredients should be used to form solid oral dosage forms of the invention. The amount of disintegrant used varies based upon the type of formulation, and is readily discernible to those of ordinary skill in the art. Typical pharmaceutical compositions comprise from about 0.5 to about 15 weight percent of disintegrant, preferably from about 1 to about 5 weight percent of disintegrant.

Disintegrants that can be used in pharmaceutical compositions and dosage forms of the invention include, but are not limited to, agar-agar, alginic acid, calcium carbonate, microcrystalline cellulose, croscarmellose sodium, crospovidone, polacrilin potassium, sodium starch glycolate, potato or tapioca starch, other starches, pre-gelatinized starch, other starches, clays, other algins, other celluloses, gums, and mixtures thereof.

Lubricants that can be used in pharmaceutical compositions and dosage forms of the invention include, but are not limited to, calcium stearate, magnesium stearate, mineral oil, light mineral oil, glycerin, sorbitol, mannitol, polyethylene glycol, other glycols, stearic acid, sodium lauryl sulfate, talc, hydrogenated vegetable oil (*e.g.*, peanut oil, cottonseed oil, sunflower oil, sesame oil, olive oil, corn oil, and soybean oil), zinc stearate, ethyl oleate, ethyl laureate, agar, and mixtures thereof. Additional lubricants include, for example, a syloid silica gel (AEROSIL 200, manufactured by W.R. Grace Co. of Baltimore, MD), a coagulated aerosol of synthetic silica (marketed by Degussa Co. of Plano, TX), CAB-O-SIL (a pyrogenic silicon dioxide product sold by Cabot Co. of Boston, MA), and mixtures thereof. If used at all, lubricants are typically used in an amount of less than about 1 weight percent of the pharmaceutical compositions or dosage forms into which they are incorporated.

CONTROLLED RELEASE DOSAGE FORMS

Active ingredients of the invention can be administered by controlled release means or by delivery devices that are well known to those of ordinary skill in the art. Examples include, but are not limited to, those described in U.S. Patent Nos.: 3,845,770; 3,916,899; 3,536,809; 3,598,123; and 4,008,719, 5,674,533, 5,059,595, 5,591,767, 5,120,548, 5,073,543, 5,639,476, 5,354,556, and 5,733,566, each of which is incorporated herein by reference. Such dosage forms can be used to provide slow or controlled-release of one or more active ingredients using, for example, hydroxypropylmethyl cellulose, other polymer matrices, gels, permeable membranes, osmotic systems, multilayer coatings, microparticles, liposomes, microspheres, or a combination thereof to provide the desired release profile in varying proportions. Suitable controlled-release formulations known to those of ordinary skill in the art, including those described herein, can be readily selected for use with the active ingredients of the invention. The invention thus encompasses single unit dosage forms suitable for oral administration such as, but not limited to, tablets, capsules, gelcaps, and caplets that are adapted for controlled-release.

All controlled-release pharmaceutical products have a common goal of improving drug therapy over that achieved by their non-controlled counterparts. Ideally, the use of an optimally designed controlled-release preparation in medical treatment is characterized by a minimum of drug substance being employed to cure or control the condition in a minimum amount of time.

Advantages of controlled-release formulations include extended activity of the drug, reduced dosage frequency, and increased patient compliance. In addition, controlled-release formulations can be used to affect the time of onset of action or other characteristics, such as blood levels of the drug, and can thus affect the occurrence of side (*e.g.*, adverse) effects.

Most controlled-release formulations are designed to initially release an amount of drug (active ingredient) that promptly produces the desired therapeutic effect, and gradually and continually release of other amounts of drug to maintain this level of therapeutic or prophylactic effect over an extended period of time. In order to maintain this constant level of drug in the body, the drug must be released from the dosage form at a rate that will replace the amount of drug being metabolized and excreted from the body. Controlled-release of an active ingredient can be stimulated by various conditions including, but not limited to, pH, temperature, enzymes, water, or other physiological conditions or compounds.

A particular extended release formulation of this invention comprises a therapeutically or prophylactically effective amount of a compound of the invention, or a pharmaceutically acceptable salt, solvate, hydrate, clathrate, or prodrug thereof, in spheroids which further comprise microcrystalline cellulose and, optionally, hydroxypropylmethyl-cellulose coated with a mixture of ethyl cellulose and hydroxypropylmethylcellulose. Such extended release formulations can be prepared according to U.S. Patent No. 6,274,171, the entire teachings of which are incorporated herein by reference.

A specific controlled-release formulation of this invention comprises from about 6% to about 40% a compound of the invention by weight, about 50% to about 94% microcrystalline cellulose, NF, by weight, and optionally from about 0.25% to about 1% by weight of hydroxypropyl-methylcellulose, USP, wherein the spheroids are coated with a film coating composition comprised of ethyl cellulose and hydroxypropylmethylcellulose.

PARENTERAL DOSAGE FORMS

Parenteral dosage forms can be administered to patients by various routes including, but not limited to, subcutaneous, intravenous (including bolus injection), intramuscular, and intraarterial. Because their administration typically bypasses patients' natural defenses against

contaminants, parenteral dosage forms are preferably sterile or capable of being sterilized prior to administration to a patient. Examples of parenteral dosage forms include, but are not limited to, solutions ready for injection, dry products ready to be dissolved or suspended in a pharmaceutically acceptable vehicle for injection, suspensions ready for injection, and emulsions.

Suitable vehicles that can be used to provide parenteral dosage forms of the invention are well known to those skilled in the art. Examples include, but are not limited to: Water for Injection USP; aqueous vehicles such as, but not limited to, Sodium Chloride Injection, Ringer's Injection, Dextrose Injection, Dextrose and Sodium Chloride Injection, and Lactated Ringer's Injection; water-miscible vehicles such as, but not limited to, ethyl alcohol, polyethylene glycol, and polypropylene glycol; and non-aqueous vehicles such as, but not limited to, corn oil, cottonseed oil, peanut oil, sesame oil, ethyl oleate, isopropyl myristate, and benzyl benzoate.

Compounds that increase the solubility of one or more of the active ingredients disclosed herein can also be incorporated into the parenteral dosage forms of the invention.

TRANSDERMAL, TOPICAL, AND MUCOSAL DOSAGE FORMS

Transdermal, topical, and mucosal dosage forms of the invention include, but are not limited to, ophthalmic solutions, sprays, aerosols, creams, lotions, ointments, gels, solutions, emulsions, suspensions, or other forms known to one of skill in the art. *See, e.g.*, Remington's Pharmaceutical Sciences (1980 & 1990) 16th and 18th eds., Mack Publishing, Easton PA and Introduction to Pharmaceutical Dosage Forms (1985) 4th ed., Lea & Febiger, Philadelphia. Dosage forms suitable for treating mucosal tissues within the oral cavity can be formulated as mouthwashes or as oral gels. Further, transdermal dosage forms include "reservoir type" or "matrix type" patches, which can be applied to the skin and worn for a specific period of time to permit the penetration of a desired amount of active ingredients.

Suitable excipients (*e.g.*, carriers and diluents) and other materials that can be used to provide transdermal, topical, and mucosal dosage forms encompassed by this invention are well known to those skilled in the pharmaceutical arts, and depend on the particular tissue to which a given pharmaceutical composition or dosage form will be applied. With that fact in mind, typical excipients include, but are not limited to, water, acetone, ethanol, ethylene glycol,

propylene glycol, butane-1,3-diol, isopropyl myristate, isopropyl palmitate, mineral oil, and mixtures thereof to form lotions, tinctures, creams, emulsions, gels or ointments, which are non-toxic and pharmaceutically acceptable. Moisturizers or humectants can also be added to pharmaceutical compositions and dosage forms if desired. Examples of such additional ingredients are well known in the art. *See, e.g.*, Remington's Pharmaceutical Sciences (1980 & 1990) 16th and 18th eds., Mack Publishing, Easton PA.

Depending on the specific tissue to be treated, additional components may be used prior to, in conjunction with, or subsequent to treatment with active ingredients of the invention. For example, penetration enhancers can be used to assist in delivering the active ingredients to the tissue. Suitable penetration enhancers include, but are not limited to: acetone; various alcohols such as ethanol, oleyl, and tetrahydrofuryl; alkyl sulfoxides such as dimethyl sulfoxide; dimethyl acetamide; dimethyl formamide; polyethylene glycol; pyrrolidones such as polyvinylpyrrolidone; Kollidon grades (Povidone, Polyvidone); urea; and various water-soluble or insoluble sugar esters such as Tween 80 (polysorbate 80) and Span 60 (sorbitan monostearate).

The pH of a pharmaceutical composition or dosage form, or of the tissue to which the pharmaceutical composition or dosage form is applied, may also be adjusted to improve delivery of one or more active ingredients. Similarly, the polarity of a solvent carrier, its ionic strength, or tonicity can be adjusted to improve delivery. Compounds such as stearates can also be added to pharmaceutical compositions or dosage forms to advantageously alter the hydrophilicity or lipophilicity of one or more active ingredients so as to improve delivery. In this regard, stearates can serve as a lipid vehicle for the formulation, as an emulsifying agent or surfactant, and as a delivery-enhancing or penetration-enhancing agent. Different salts, hydrates or solvates of the active ingredients can be used to further adjust the properties of the resulting composition.

COMBINATION THERAPY

The methods for immunosuppression or for treating or preventing inflammatory conditions and immune disorders in a patient in need thereof can further comprise administering to the patient being administered a compound of this invention, an effective amount of one or more other active agents. Such active agents may include those used

conventionally for immunosuppression or for inflammatory conditions or immune disorders. These other active agents may also be those that provide other benefits when administered in combination with the compounds of this invention. For example, other therapeutic agents may include, without limitation, steroids, non-steroidal anti-inflammatory agents, antihistamines, analgesics, immunosuppressive agents and suitable mixtures thereof. In such combination therapy treatment, both the compounds of this invention and the other drug agent(s) are administered to a subject (*e.g.*, humans, male or female) by conventional methods. The agents may be administered in a single dosage form or in separate dosage forms. Effective amounts of the other therapeutic agents and dosage forms are well known to those skilled in the art. It is well within the skilled artisan's purview to determine the other therapeutic agent's optimal effective-amount range.

In one embodiment of the invention where another therapeutic agent is administered to a subject, the effective amount of the compound of this invention is less than its effective amount when the other therapeutic agent is not administered. In another embodiment, the effective amount of the conventional agent is less than its effective amount when the compound of this invention is not administered. In this way, undesired side effects associated with high doses of either agent may be minimized. Other potential advantages (including without limitation improved dosing regimens and/or reduced drug cost) will be apparent to those of skill in the art.

In one embodiment relating to autoimmune and inflammatory conditions, the other therapeutic agent may be a steroid or a non-steroidal anti-inflammatory agent. Particularly useful non-steroidal anti-inflammatory agents, include, but are not limited to, aspirin, ibuprofen, diclofenac, naproxen, benoxaprofen, flurbiprofen, fenoprofen, flubufen, ketoprofen, indoprofen, piroprofen, carprofen, oxaprozin, pramoprofen, muroprofen, trioxaprofen, suprofen, aminoprofen, tiaprofenic acid, fluprofen, bucloxic acid, indomethacin, sulindac, tolmetin, zomepirac, tiopinac, zidometacin, acemetacin, fentiazac, clidanac, oxpinac, mefenamic acid, meclofenamic acid, flufenamic acid, niflumic acid, tolfenamic acid, diflurisal, flufenisal, piroxicam, sudoxicam, isoxicam; salicylic acid derivatives, including aspirin, sodium salicylate, choline magnesium trisalicylate, salsalate, diflunisal, salicylsalicylic acid, sulfasalazine, and olsalazin; para-aminophenol derivatives including acetaminophen and phenacetin; indole and

indene acetic acids, including indomethacin, sulindac, and etodolac; heteroaryl acetic acids, including tolmetin, diclofenac, and ketorolac; anthranilic acids (fenamates), including mefenamic acid, and meclofenamic acid; enolic acids, including oxicams (piroxicam, tenoxicam), and pyrazolidinediones (phenylbutazone, oxyphenthartazone); and alkanones, including nabumetone and pharmaceutically acceptable salts thereof and mixtures thereof. For a more detailed description of the NSAIDs, *see Paul A. Insel, Analgesic-Antipyretic and Antiinflammatory Agents and Drugs Employed in the Treatment of Gout, in Goodman & Gilman's The Pharmacological Basis of Therapeutics* 617-57 (Perry B. Molinhoff and Raymond W. Ruddon eds., 9th ed 1996) and Glen R. Hanson, *Analgesic, Antipyretic and Anti-Inflammatory Drugs in Remington: The Science and Practice of Pharmacy Vol II* 1196-1221 (A.R. Gennaro ed. 19th ed. 1995) which are hereby incorporated by reference in their entireties.

Of particular relevance to allergic disorders, the other therapeutic agent may be an antihistamine. Useful antihistamines include, but are not limited to, loratadine, cetirizine, fexofenadine, desloratadine, diphenhydramine, chlorpheniramine, chlorcyclizine, pyrilamine, promethazine, terfenadine, doxepin, carbinoxamine, clemastine, tripelennamine, brompheniramine, hydroxyzine, cyclizine, meclizine, cyproheptadine, phenindamine, acrivastine, azelastine, levocabastine, and mixtures thereof. For a more detailed description of antihistamines, *see* Goodman & Gilman's The Pharmacological Basis of Therapeutics (2001) 651-57, 10th ed).

Immunosuppressive agents include glucocorticoids, corticosteroids (such as Prednisone or Solumedrol), T cell blockers (such as cyclosporin A and FK506), purine analogs (such as azathioprine (Imuran)), pyrimidine analogs (such as cytosine arabinoside), alkylating agents (such as nitrogen mustard, phenylalanine mustard, busulfan, and cyclophosphamide), folic acid antagonists (such as aminopterin and methotrexate), antibiotics (such as rapamycin, actinomycin D, mitomycin C, puramycin, and chloramphenicol), human IgG, antilymphocyte globulin (ALG), and antibodies (such as anti-CD3 (OKT3), anti-CD4 (OKT4), anti-CD5, anti-CD7, anti-IL-2 receptor, anti-alpha/beta TCR, anti-ICAM-1, anti-CD20 (Rituxan), anti-IL-12 and antibodies to immunotoxins).

The foregoing and other useful combination therapies will be understood and appreciated by those of skill in the art. Potential advantages of such combination therapies include a different efficacy profile, the ability to use less of each of the individual active ingredients to minimize toxic side effects, synergistic improvements in efficacy, improved ease of administration or use and/or reduced overall expense of compound preparation or formulation.

OTHER EMBODIMENTS

The compounds of this invention may be used as research tools (for example, as a positive control for evaluating other potential CRAC inhibitors, or IL-2, IL-4, IL-5, IL-13, GM-CSF, TNFα, and/or IFN-γ inhibitors). These and other uses and embodiments of the compounds and compositions of this invention will be apparent to those of ordinary skill in the art.

The invention is further defined by reference to the following examples describing in detail the preparation of compounds of the invention. It will be apparent to those skilled in the art that many modifications, both to materials and methods, may be practiced without departing from the purpose and interest of this invention. The following examples are set forth to assist in understanding the invention and should not be construed as specifically limiting the invention described and claimed herein. Such variations of the invention, including the substitution of all equivalents now known or later developed, which would be within the purview of those skilled in the art, and changes in formulation or minor changes in experimental design, are to be considered to fall within the scope of the invention incorporated herein.

EXAMPLES

EXPERIMENTAL RATIONALE

Without wishing to be bound by theory, it is believed that the compounds of this invention inhibit CRAC ion channels, thereby inhibiting production of IL-2 and other key cytokines involved with inflammatory and immune responses. The examples that follow demonstrate these properties.

Materials and General Methods

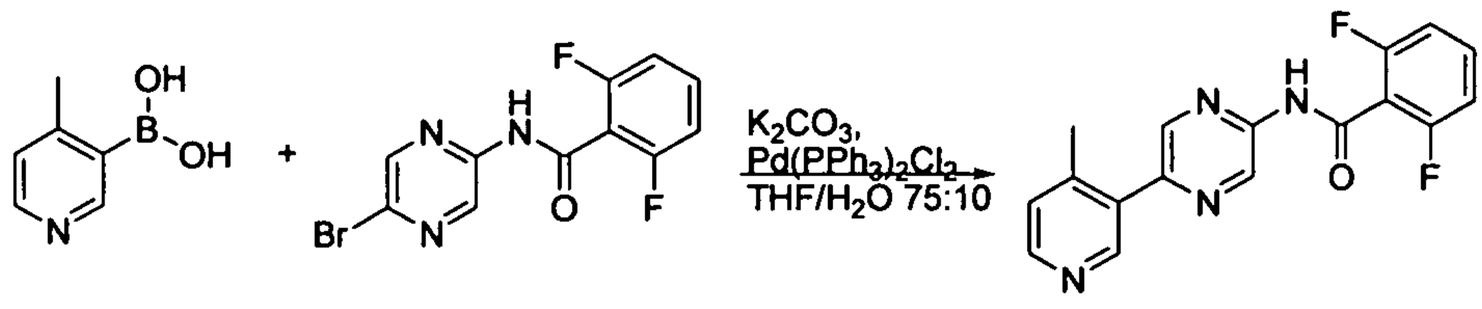
Reagents and solvents used below can be obtained from commercial sources such as Aldrich Chemical Co. (Milwaukee, Wisconsin, USA). ^{1}H-NMR and ^{13}C-NMR spectra were recorded on a Varian 300MHz NMR spectrometer. Significant peaks are tabulated in the order: δ (ppm): chemical shift, multiplicity (s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br s, broad singlet),coupling constant(s) in Hertz (Hz) and number of protons.

Manual patch clamp experiments are conducted in the tight-seal whole-cell configuration at room temperature (21-25°C). Patch pipettes are fashioned from borosilicate glass capillary tubes and have resistances between 2-4 MΩ after filling with standard intracellular solution. High resolution current recordings are acquired with a computer-based patch clamp amplifier system (EPC-10, HEKA, Lambrecht, Germany). All voltages are corrected for a liquid junction potential of 10 mV between external and internal solutions with glutamate as the intracellular anion. Currents are filtered at 2.9 kHz and digitized at 10 μs intervals. Capacitive currents and series resistance are determined and corrected before each voltage ramp using the automatic capacitance compensation of the EPC-10.

Automated patch clamp experiments are conducted with the QPatch 16 (Sophion Bioscience, Ballerup, Denmark) at room temperature (21-25°C). Immediately following the establishment of giga-seal whole-cell configuration, the cells membrane potential is clamped at 0 mV. Voltage ramps of 50 ms duration spanning the voltage range of -100 to +100 mV are then stimulated at a rate of 0.33 Hz. Currents are filtered at 2.9 kHz and digitized at 200 μs intervals. Capacitive currents and series resistance are determined and corrected before each voltage ramp using the automatic capacitance compensation.

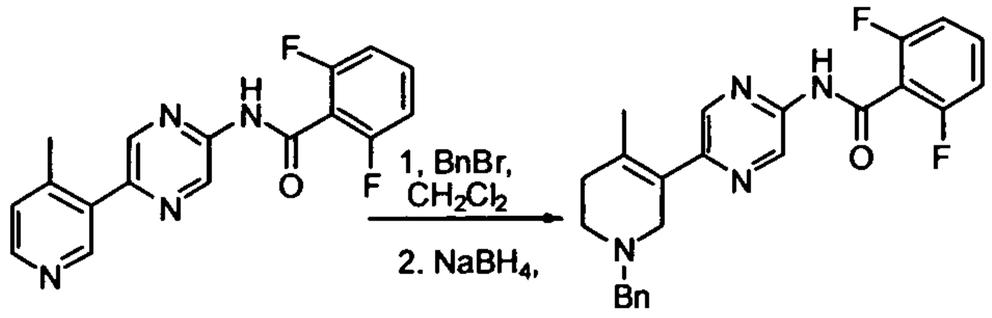
EXAMPLE 1: SYNTHESIS OF REPRESENTATIVE EXEMPLARY COMPOUNDS OF THIS INVENTION

General Suzuki Coupling of Pyridyl boronic acids:



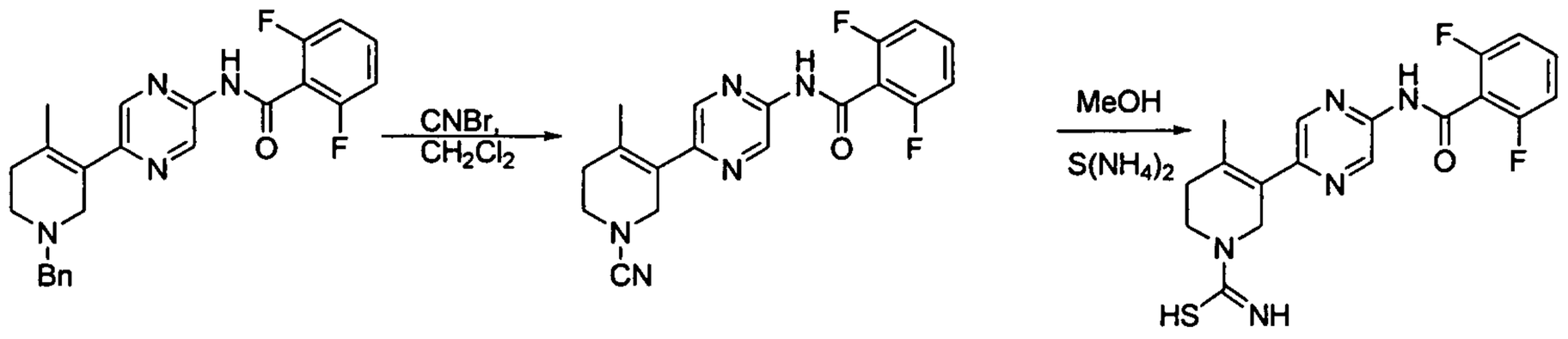
A solution of the N-(5-bromopyrazin-2-yl)-2,6-difluorobenzamide (20g, 63.7mmol) , 4-methylpyridin-3-ylboronic acid (8.27g, 60.6mmol) and palladium(3.19g, 4.5mmol) were dissolved in 368ml of THF and warmed to about 50°C. 73ml of DI water with potassium carbonate dissolved in it was added to the reaction mixture, and the reaction was heated to reflux in an oil bath. The reaction was refluxed for 6 hrs, and the solution turned dark reddish/brown. The reaction was cooled, and the THF was evaporated off. Ethyl acetate and water were added and stirred vigorously. 16.16g (82%) of product crashed out of solution and was filtered. The product is soluble in methylene chloride methanol mix. Slight impurity was carried on to next step.

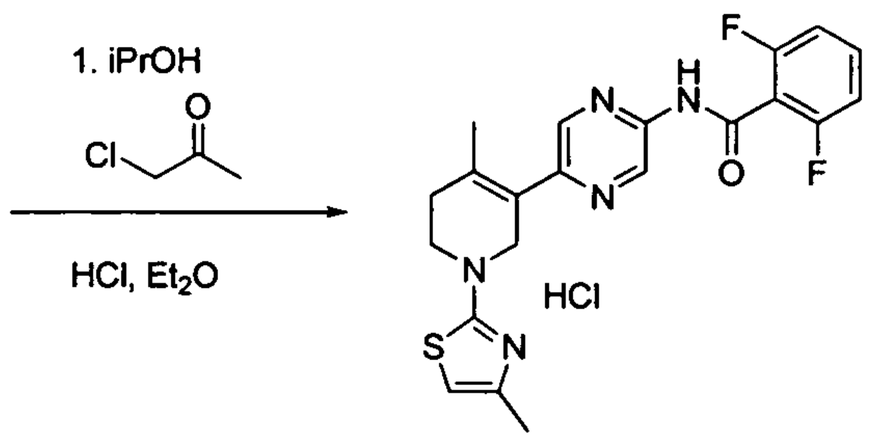
General Procedure for Tetrahydropyridine synthesis:



2,6-difluoro-N-(5-(4-methylpyridin-3-yl)pyrazin-2-yl)benzamide (16.1g, 49.38mmol) was dissolved in methylene chloride(0.15M) and benzyl bromide(11.75ml, 98.8mmol). The reaction was stirred overnight. 90% of the solvent was removed, and ethyl acetate was added while vigorously stirring. The solid was filtered and washed several times with ethyl acetate to remove benzyl bromide. The 1-benzyl-3-(5-(2,6-difluorobenzamido)pyrazin-2-yl)-4-methylpyridinium bromide was then dissolved in isopropanol/methylene chloride and sodium borohydride(7.5g, 19.7mmol). The reaction was stirred for 36 hours. After work-up with water and methylene chloride, the residue was purified by column chromatography. Isolated 4.9g of pure tetrahydropyridine.

Thiazole Synthesis from tertiary benzylamine:





The N-(5-(1-benzyl-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-2,6-difluorobenzamide(4.9g) was dissolved in dichloromethane and cooled to 0°C in an ice bath. Cyanogen bromide (1.6g, 12mmol) was added and stirred for 20 min, quenched with sodium bicarbonate solution, and purified by column chromatography with ethyl acetate/hexane elute. Isolated 3.3g (80% yield) of pure cyanamide.

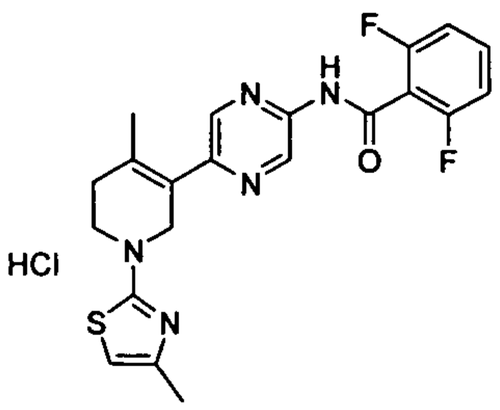
The N-(5-(1-cyano-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-2,6-difluorobenzamide was stirred in methanol(50ml), and ammonium sulfide(5.06g, 37.2mmol) was added. The reaction was stirred at room temperature for 24 hours. The reaction solution was concentrated to around 50% and then cooled and filtered. 3.6g (100% yield) of thiourea was isolated.

The thiourea (600mg, 1.54mmol) was added to a microwave vial followed by 10ml of isopropanol. Chloroacetone (600mg, 6.48mmol) was added, and the vial was capped. It was then heated to a temperature of 80°C for 30 minutes and cooled. The reaction was quenched with sodium bicarbonate solution and extracted with dichloromethane. After the solvent was evaporated, the residue was loaded on a silica gel column and eluted with ethyl acetate/hexane. The solvent was then evaporated, and isopropanol 10ml was added. To this slurry was added HCl in ether. The solid went into solution while stirring and then slowly crystallized out of

solution while stirring. The solid was filtered and dried on high vacuum. 510mg of pure product was isolated. 72% yield.

Example 1

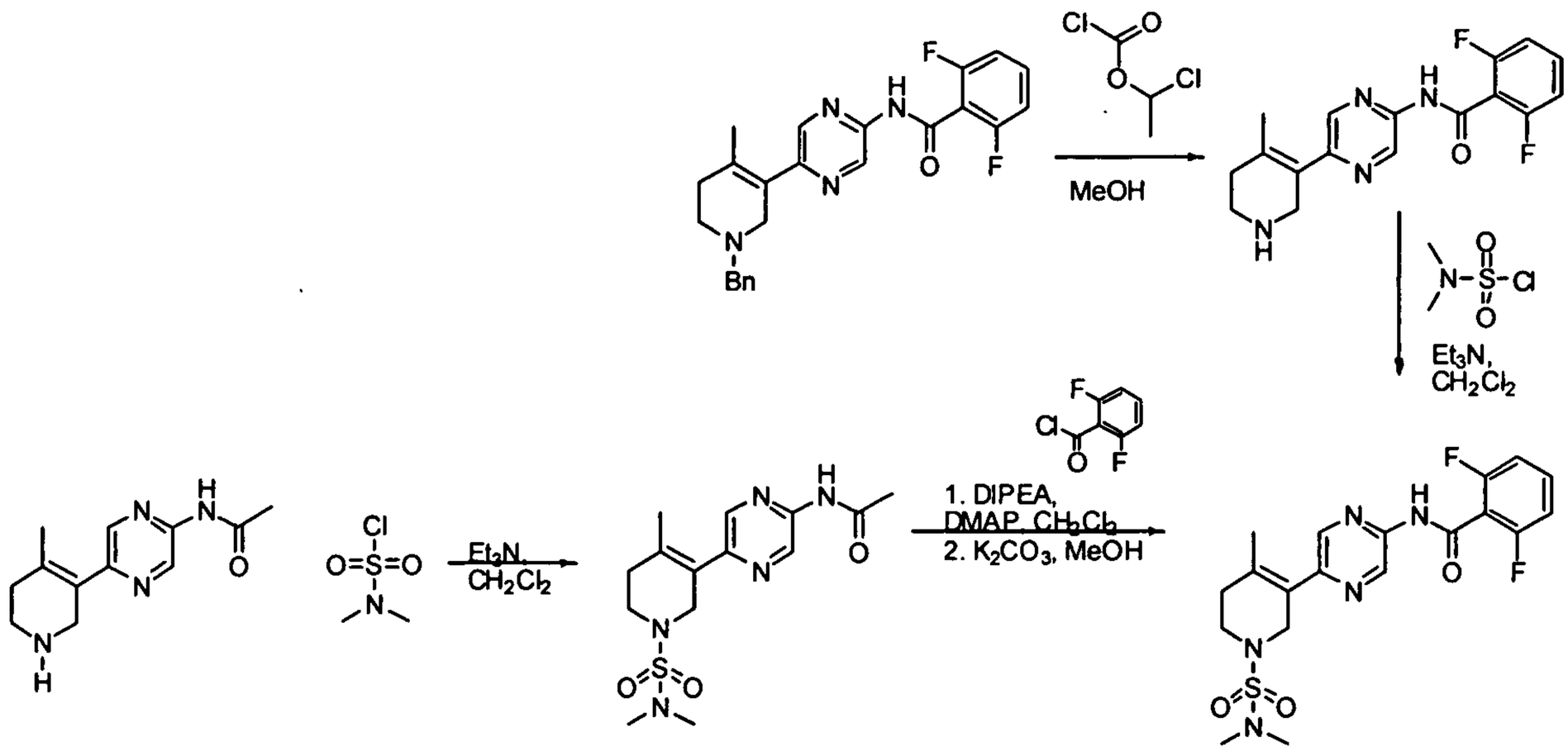
2,6-difluoro-N-(5-(4-methyl-1-(4-methylthiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide hydrochloride



^{1}H NMR (300 MHz, DMSO d6) 11.75 (s, 1H), 9.44 (s, 1H), 8.53 (s, 1H), 7.58-7.66 (m, 1H), 7.26 (t, J=6.0Hz, 2H), 6.66 (s, 1H), 4.40 (s, 2H), 3.80-3.82 (m, 2H), 2.47-2.49 (m, 2H), 2.25 (s, 3H), 1.89 (s, 2H)ppm . ESMS calcd. ($C_{21}H_{20}ClF_2N_5OS$) 463.1; found: 428.2 (M-Cl).

Example 2

N-(5-(1-(N,N-dimethylsulfamoyl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-2,6-difluorobenzamide



Procedure:

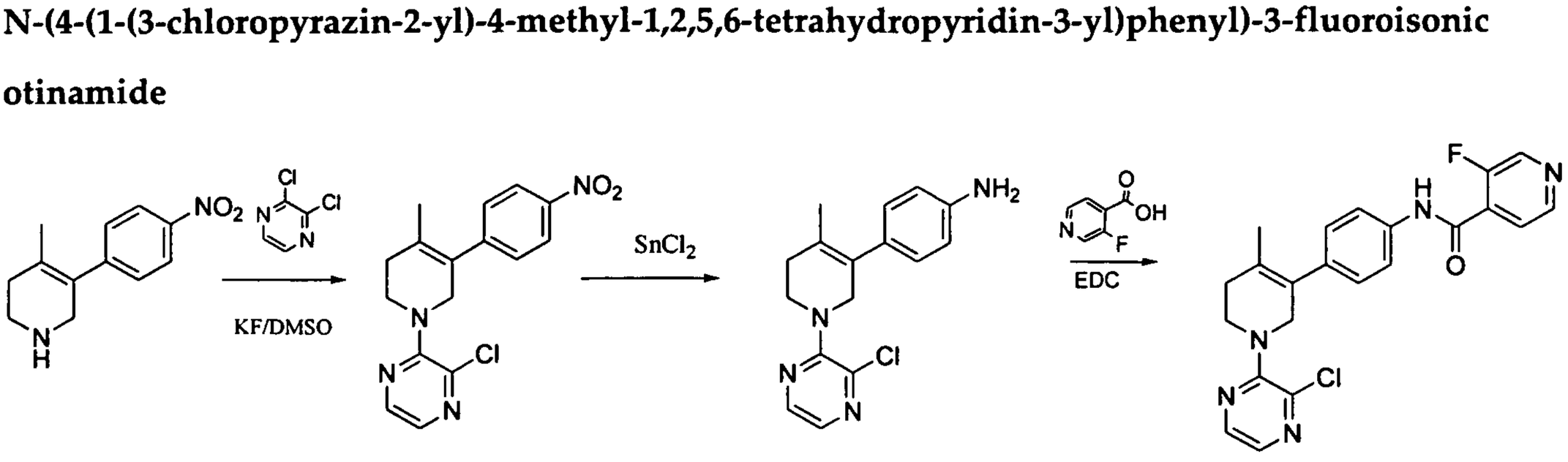
N-(5-(1-benzyl-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-2,6-difluorobenza mide was made as previously described in the general procedure for tetrahydropyridine synthesis. To a solution of this benzyl amine (1.25g, 2.97mmol) in methylene chloride was added 1-chloroethyl chloroformate (1.2ml) at room temperature. The reaction was stirred for 2 hours followed by the addition of methanol (10ml). The reaction was rotovaped until the majority of the methylene chloride was removed, and then more methanol was added and refluxed for 1 hour. The methanol was then evaporated, and ethyl acetate was added and stirred vigorously. The mixture was filtered leaving the pure product (718mg, 73%) as a white solid.

2,6-difluoro-N-(5-(4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)benzamide (100mg,0.305mmol) was stirred at room temperature for 3 hours with dimethylsulfamoyl chloride(65.5ul, 0.609mmol) and triethylamine (694ul, 1.5mmol). The reaction was quenched with saturated sodium bicarbonate solution, and the methylene chloride layer was separated and loaded onto a flash column. It was purified by methylene chloride/ethyl acetate eluent. 60mg (45% yield) of
N-(5-(1-(N,N-dimethylsulfamoyl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyrazin-2-yl)-2,6-difl uorobenzamide was isolated pure .

^{1}H NMR (300 MHz, $CDCl_3$) 9.66(s, 1H), 8.37 (s, 1H), 8.21 (d, J=1.2Hz, 1H), 7.46-7.53 (m, 1H), 7.05 (t, *J*=6.3Hz, 2H), 4.07-4.08 (m, 2H), 2.86 (s, 6H), 2.35-2.38 (m, 2H), 1.82 (s, 3H), 3.97 (t, *J*=4.2Hz, 2H), 2.49-2.50 (m, 2H), 1.82 (s, 3H), ppm ESMS calcd. ($C_{23}H_{18}F_2N_6O$) 432.2; found: 433.2 (M+H) ESMS calcd. ($C_{19}H_{21}F_2N_5O_3S$) 437.1; found: 438.2 (M+H)

Example 3

N-(4-(1-(3-chloropyrazin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-3-fluoroisonic otinamide



To 4-methyl-5-(4-nitrophenyl)-1,2,3,6-tetrahydropyridine (218 mg), DMSO (4ml) solution was added 60 mg of KF and 148 mg 2,3-dichloropyrazine, and the mixture was stirred and heated at 120°C for 1 hr. The reaction was quenched with water. The product was extracted with EtOAc, and the organic layer was washed with water. After removal of the solvent, the residue was subjected to silica gel column chromatography (Hexanes/EtOAc) to give 250 mg of 2-chloro-3-(4-methyl-3-(4-nitrophenyl)-5,6-dihydropyridin-1(2H)-yl)pyrazine.

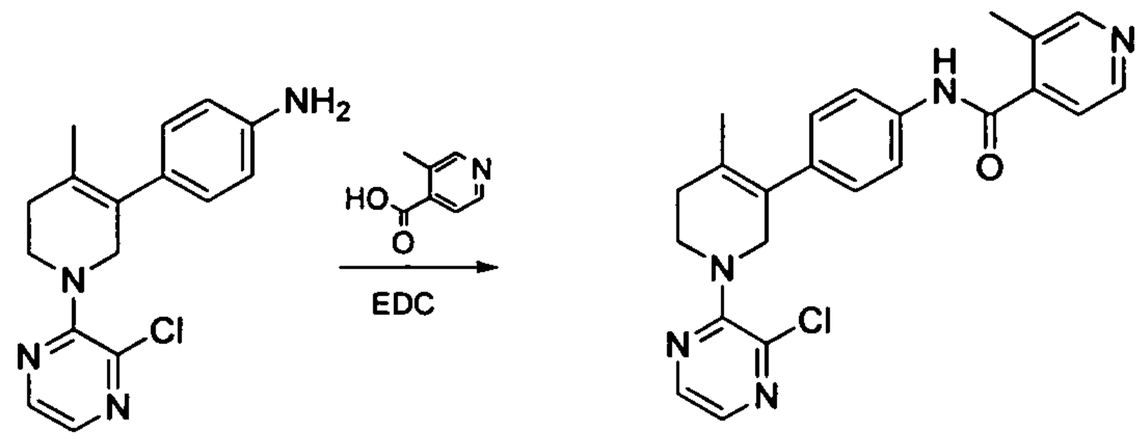
330 mg of 2-chloro-3-(4-methyl-3-(4-nitrophenyl)-5,6-dihydropyridin-1(2H)-yl)pyrazine was dissolved in 20 ml EtOH/DCM (1:1); to the solution was added 300 mg $SnCl_2$; and the mixture was refluxed at 120°C for 2 hr. The reaction solution was filtered with a silica gel funnel. The crude product was purified by silica gel column chromatography to give 280 mg of 4-(1-(3-chloropyrazin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)aniline.

150 mg of 4-(1-(3-chloropyrazin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)aniline, 71 mg 3-fluoroisonicotinic acid, and 110 mg EDC were dissolved in DMF and stirred at room temperature for 1 hr. The reaction was quenched with water and extracted with EtOAc, and the organic layer was washed with water. After removal of the solvent, the residue was subjected to silica gel column chromatography (Hexanes/EtOAc) to give 195 mg of N-(4-(1-(3-chloropyrazin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-3-fluoroisonicotinamide.

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.67 (d, *J*=1.8Hz, 1H), 8.65 (d, *J*= 3.6Hz, 1H), 8.38 (d, *J*=10.2Hz, 1H), 8.08 (d, *J*=1.8Hz, 1H), 8.05 (dd, *J*=3.6, 4.5Hz, 1H), 7.84 (d, *J*=1.8Hz, 1H), 7.65 (d, *J*=6.3Hz, 2H), 7.28-7.26 (m, 2H), 4.10 (d, *J*=1.5Hz, 2H), 3.72 (t, *J*=4.2, 2H), 2.43-2.39 (m, 2H), 1.69 (s, 3H)ppm. ESMS calcd. ($C_{22}H_{19}ClFN_5O$) 423.13; found: 423.2 (M+H).

Example 4

N-(4-(1-(3-chloropyrazin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-3-methylisonicotinamide

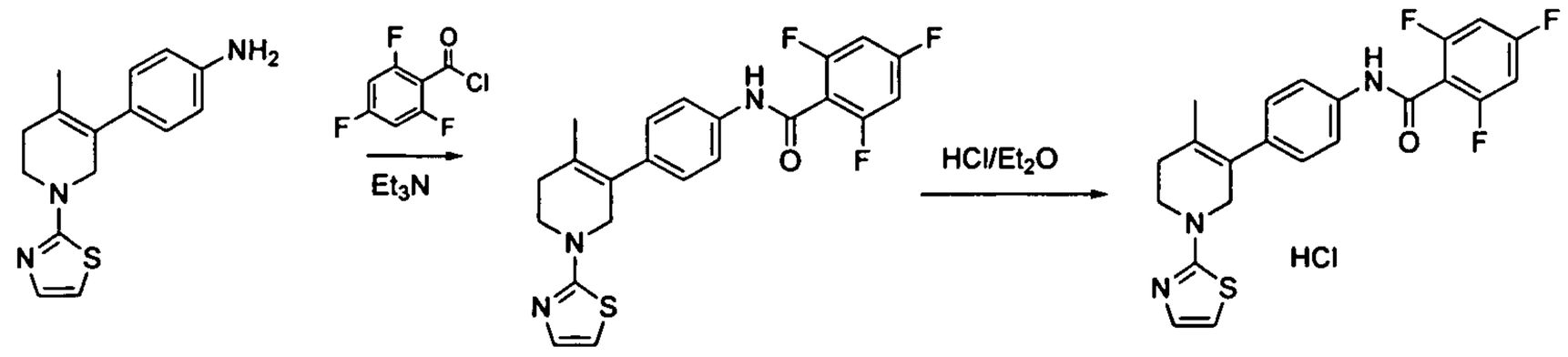


Procedure:

The coupling procedure is the same used as in the synthesis of N-(4-(1-(3-chloropyrazin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)phenyl)-3-fluoroisonicotinamide.

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.57-8.59 (m, 2H), 8.08 (d, J=1.8Hz, 1H), 7.85 (d, J=2.1Hz, 1H), 7.61 (d, J=6.3Hz, 2H), 7.5 (s, 1H), 7.37 (d, J=3.6Hz, 1H), 7.27-7.26 (m, 2H), 4.10-4.09 (m, 2H), 3.72 (t, J=4.2Hz, 2H), 2.51 (s, 3H), 2.42-2.38 (m, 2H), 1.69 (s, 3H)pp.ESMS calcd. ($C_{23}H_{22}ClN_5O$) 419.2; found: 420.1 (M + H).

Example 5

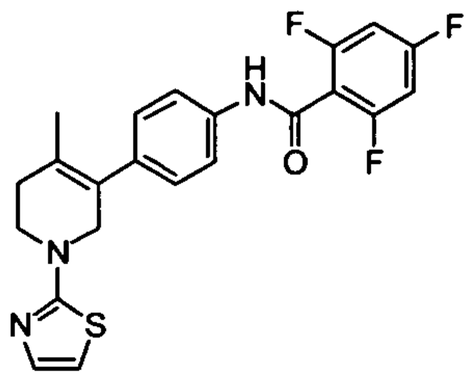


Procedure:

4-(4-methyl-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)aniline (510mg, 1.88mmol) was dissolved in methylene chloride (5ml) along with triethylamine (786ul, 5.64mmol). The 2,4,6-trifluorobenzoyl chloride (475.3mg) was slowly added at room temperature keeping the reaction close to room temperature. The reaction was quenched with sodium bicarbonate solution and diluted with methylene chloride. It was purified by column chromatography using methylene chloride methanol. The solid was tritiated in acetone to yield pure 2,4,6-trifluoro-N-(4-(4-methyl-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benzamide.

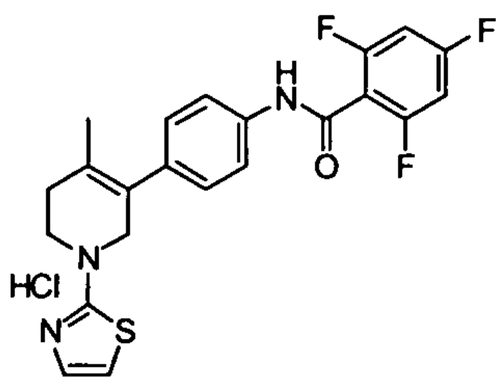
This solid was added to ethanol and vigorously stirred while excess hydrogen chloride was added in an ether solution. The solution turned to a slight yellow clear solution then fell out of solution as a white solid (600mg, 74.4% yield.)

2,4,6-trifluoro-N-(4-(4-methyl-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benz amide:



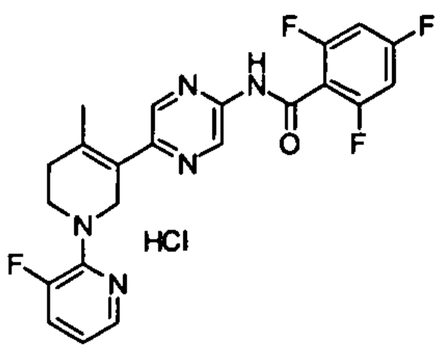
^{1}H NMR (400 MHz, CDCl3) δ 7.67 (s, 1H), 7.62 (d, *J* = 8.5, 1H), 7.24 (d, *J* = 8.5, 1H), 7.21 (d, *J* = 3.6, 1H), 6.78 (t, *J* = 8.2, 2H), 6.55 (d, *J* = 3.6, 0H), 4.09 – 4.04 (m, 1H), 3.74 (t, *J* = 5.8, 1H), 2.36 (t, *J* = 5.5, 2H), 1.67 (s, 3H).ppm ESMS calcd. ($C_{22}H_{18}F_3N_3OS$) 429.1; found: 430.1 (M + H).

2,4,6-trifluoro-N-(4-(4-methyl-1-(thiazol-2-yl)-1,2,5,6-tetrahydropyridin-3-yl)phenyl)benz amide hydrochloride:



^{1}H NMR (400 MHz, DMSO) δ 10.93 (s, 1H), 7.72 (d, *J* = 8.5, 2H), 7.42 (d, *J* = 2.9, 1H), 7.40 (dd, *J* = 7.4, 8.3, 2H), 7.31 (d, *J* = 8.4, 2H), 7.06 (d, *J* = 4.1, 1H), 4.21 (s, 2H), 3.77 (t, *J* = 5.7, 2H), 2.39 (s, 2H), 1.69 (s, 3H)ppm ESMS calcd. ($C_{22}H_{19}ClF_3N_3OS$) 465.09; found: 430.1 (M - Cl).

2,4,6-trifluoro-N-(5-(1-(3-fluoropyridin-2-yl)-4-methyl-1,2,5,6-tetrahydropyridin-3-yl)pyr azin-2-yl)benzamide hydrochloride:



^{1}H NMR (400 MHz, DMSO) δ 11.75 (s, 0H), 9.41 (s, 1H), 8.49 (s, 1H), 8.01 (d, *J* = 5.1, 1H), 7.82 – 7.61 (m, 1H), 7.40 (t, *J* = 8.7, 2H), 7.02 – 6.90 (m, 1H), 4.39 (s, 2H), 3.74 (s, 2H), 2.43 (s, 2H), 1.85 (s, 3H) ppm. ESMS calcd. ($C_{22}H_{18}ClF_4N_5O$) 479.1; found: 444.2 (M - Cl).

Other compounds appearing in the table below were synthesized in a similar manner.

EXAMPLE 2: INHIBITION OF IL-2 PRODUCTION

Jurkat cells were placed in a 96 well plate (0.5 million cells per well in 1% FBS medium), and then a test compound of this invention was added at different concentrations. After 10 minutes, the cells were activated with PHA (final concentration 2.5 μg/mL) and incubated for 20 hours at 37°C under 5% CO_2. The final volume was 200 μL. Following incubation, the cells were centrifuged, and the supernatants collected and stored at -70°C prior to assaying for IL-2 production. A commercial ELISA kit (IL-2 Eli-pair, Diaclone Research, Besancon, France) was used to detect production of IL-2, from which dose response curves were obtained. The IC_{50} value was calculated as the concentration at which 50% of maximum IL-2 production after stimulation was inhibited versus a non-stimulation control.

Inhibition of other cytokines, such as IL-4, IL-5, IL-13, GM-CSF, TNFα, and IFN-γ, can be tested in a similar manner using a commercially available ELISA kit for each cytokine.

EXAMPLE 3: MANUAL PATCH CLAMP STUDIES OF INHIBITION OF I_{CRAC} CURRENT IN RBL CELLS, JURKAT CELLS, CRACM1/STIM1-CHOK1, AND PRIMARY T CELLS

In general, a whole cell patch clamp method is used to examine the effects of a compound of the invention on a channel(s) that mediates I_{CRAC}. In such experiments, a baseline I_{CRAC} measurement is established within the first 70 voltage ramps, or 140 seconds, for a patched cell. Then the cells are perfused with the compound to be tested and the effect of the compound on I_{CRAC} is measured for at least an additional 440 to 500 seconds. A compound that modulates I_{CRAC} (*e.g.*, inhibits) is a compound that is useful in the invention for modulating CRAC ion channel activity.

1) RBL and Jurkat cells

Cells

Rat basophilic leukemia cells (RBL-2H3) are grown in DMEM media supplemented with 10% fetal bovine serum in an atmosphere of 95% air/5% CO_2. Cells are seeded on glass coverslips 1-3 days before use.

Jurkat T cells are grown in RPMI media supplemented with 10% fetal bovine serum in an atmosphere of 95% air/5% CO_2. Cells are harvested by centrifugation and transferred to a recording chamber just prior to each experiment.

Recording Conditions

Membrane currents of individual cells are recorded using the manual patch clamp technique in the whole-cell configuration.

Intracellular pipette solution

The intracellular pipette solution contains Cs-Glutamate 100mM; CsCl 20mM; NaCl 8mM; $MgCl_2$ 3mM; D-*myo*-Inositol 1,4,5-trisphosphate (InsP3) 0.02mM; CsBAPTA 10mM; HEPES 10mM; pH=7.2 adjusted with CsOH. The solution is kept on ice and shielded from light before the experiments are preformed.

Extracellular solution

The extracellular solution contains NaCl 140 mM; KCl 5.4mM; CsCl 10mM; $CaCl_2$ 10mM; $MgCl_2$ 1 mM; HEPES 10mM; Glucose 5.5mM; at pH=7.4 adjusted with NaOH.

Compound treatment

Each compound is diluted from a 10 mM stock in series using DMSO. The final DMSO concentration is always kept at 0.1 %.

Experimental procedure

I_{CRAC} currents are measured using 50 msec voltage ramps between -100 mV to +100 mV. The voltage ramps are stimulated every 2 seconds for the first 70 sweeps, then every 5 seconds for the remainder of the experiment. The membrane potential is held at 0 mV between the test

ramps. In a typical experiment, the peak inward currents will develop within 50-100 seconds. Once the I_{CRAC} current is stabilized, the cells are perfused with a test compound in the extracellular solution for at least an additional 500 seconds.

Data analysis

Off-line analysis with the Heka PatchMaster software is used to separate the I_{CRAC} membrane current from the cells basal background currents. In a typical recording, InsP3 stimulated I_{CRAC} currents begin to develop in 6 to 12 seconds after whole cell is established. Therefore, the first 1-4 voltage ramps represent the basal membrane currents in the absence of I_{CRAC} and the average value is subtracted from all subsequent traces. The current value at -80 mV for each ramp trace is then measured and plotted against time. The resulting current versus time data is exported into a Microsoft Excel spreadsheet. The % I_{CRAC} inhibition in each cell is calculated by comparing the amount of current just prior to the compound perfusion to the amount of current after the cells has been perfused with the compound for 440-500 seconds. The IC_{50} value and Hill coefficient for each compound is estimated by fitting all the individual data points to a single-site Hill equation.

2) <u>Cho-K1 Cells Over-expressing Stim1 and either CracM1, CracM2 or CracM3</u>

Cells

TREx™-CHO cells were transfected with human Stim1 (recombinant DNA in pCDNA4/TO/*myc*-His™ A with a *myc* epitope tag in the N-terminal) and either CracM1, CracM2 or CracM3 (recombinant DNA in pCDNA 3.1 with a HA epitope tag in the N-terminal). Stably expressing cells were selected by growing the transfected cells in antibiotics for two to three weeks. Individual cell clones were isolated via serial dilution. Full length human Stim1, CracM1, CracM2 and CracM3 cDNA, TREx™-CHO cells, pCDNA4/TO/*myc*-His™ A and pCDNA 3.1 were purchased from Invitrogen (Carlsbad, CA). All cells clones are grown in Ham's F-12 media supplemented with 10% fetal bovine serum, penicillin 100U/ml, streptomycin 100 μg/ml, Zeocin™ (200μg/ml), Geneticin (500μg/ml) and blasticidin (10μg/ml) in an atmosphere of 95% air/5% CO_2. Stim1 expression was induced with doxycycline (1μg/ml) for

16-20 hrs. Cells were removed from the tissue culture plates with a solution of 0.25% trypsin/0.02% EDTA and transferred to a recording chamber just prior to each experiment.

Intracellular Pipette Solution

The intracellular pipette solution contains Cs-Glutamate 90mM; NaCl 8mM; $MgCl_2$ 3 mM; CsCl 20mM; CsBAPTA 20mM; HEPES 10mM; InsP3 0.02mM; pH=7.2 adjusted with CsOH. The solution is kept on ice and shielded from light before the experiments are preformed.

Extracellular Solution

The extracellular solution contains NaCl 120mM; KCl 5.4mM; CsCl 10mM; $CaCl_2$ 2mM; $MgCl_2$ 1 mM; HEPES 10mM; Glucose 5.5mM; ; at pH=7.4 adjusted with NaOH.

Patch-clamp recordings and data analysis

Experimental procedures and data analysis are identical to the above procedures for Rbl-2H3 cells and Jurkat cells.

3) **Primary T Cells**

Preparation of Primary T Cells

Primary T cells are obtained from human whole blood samples by adding 100µL of RosetteSep® human T cell enrichment cocktail to 2 mL of whole blood. The mixture is incubated for 20 minutes at room temperature, then diluted with an equal volume of PBS containing 2% FBS. The mixture is layered on top of RosetteSep® DM-L density medium and then centrifuged for 20 minutes at 1200 g at room temperature. The enriched T cells are recovered from the plasma/density medium interface, then washed with PBS containing 2% FBS twice, and used in patch clamp experiments following the procedure described for RBL cells.

TEST COMPOUNDS

	IL-2 inhibition Jurkat/PHA/1%FBS	I_{CRAC} current inhibition CRACM1/STIM1-CHOK1
	IC_{50} (nM)	%Inhibition at 500nM
1	mod	high
2	low	high

7	13	--
8	14	--
9	15	--
10	18	--
11	high	high
12	19	--
13	30	--
14	high	mod
15	high	mod
16	30	--
17	mod	
18	32	--
19	36	--
20	52	--
21	55	--
22	10	--
23	14	--
24	14	--
25	17	--
26	18	--
27	19	--
28	19	--
29	20	--
30	21	--
31	21	--
32	21	--
33	22	--
34	22	--
35	23	--
36	24	--
37	24	--
38	26	--
39	27	--
40	27	--
41	28	--
42	28	--
43	31	--
44	31	--
45	33	--
46	35	--
47	35	--
48	36	--

49	36	--
50	37	--
51	37	--
52	40	--
53	40	--
54	40	--
55	41	--
56	41	--
57	41	--
58	44	--
59	44	--
60	46	--
61	46	--
62	49	--
63	49	--
64	49	--

Low activity: $IC_{50} > 100$
Moderate activity: $50 < IC_{50} < 100$
High activity: $IC_{50} < 50$

High activity: $70 < \% < 100$
Moderate activity: $50 < \% < 70$
Low activity: $\% < 50$

EXAMPLE 4: AUTOMATED PATCH CLAMP STUDIES OF INHIBITION OF I_{CRAC}

1) Rbl-2H3 Cells.

Cells

RBL-2H3 are grown in DMEM media supplemented with 10% fetal bovine serum, penicillin 100U/ml and streptomycin 100 µg/ml in an atmosphere of 95% air/5% CO_2. Cells are grown to confluence in 175 cm^2 tissue culture flask. On the experimental day, cells harvested with 0.25% trypsin/0.02% EDTA and resuspended in extracelllular solution at density of $5x10^6$ cells/ml

Intracellular Solution

The intracellular solution contains Cs-Glutamate 90mM; NaCl 8mM; $MgCl_2$ 3 mM; CsCl 20mM; CsBAPTA 20mM; HEPES 10mM; InsP3 0.02mM; pH=7.2 adjusted with CsOH.

Extracellular Solution

The extracellular solution contains NMDGCl 120mM; KCl 5.4mM; CsCl 10mM; $CaCl_2$ 10mM; $MgCl_2$ 1 mM; HEPES 10mM; Glucose 5.5mM; ; at pH=7.4 adjusted with HCl.

Experimental Procedure

I_{CRAC} currents are measured using 50 msec voltage ramps between -100 mV to +100 mV. The voltage ramps are stimulated every 3 seconds for at least 570 seconds. The maximum I_{CRAC} current is allowed to develop for at least 135 seconds. Compounds diluted in extracellular solutions are then applied twice, 30 seconds apart. After incubating the cells with compound for 435 seconds, a reference solution is applied at the end of the experiment. The reference solution is a Ca^{2+} free extracellular solution.

Data Analysis

Off-line analysis with the Qpatch software is used to plot the current value at -80 mV for each ramp trace against time. The resulting current versus time data is then exported into a Microsoft Excel spreadsheet. The I_{CRAC} membrane currents are separated from the cells basal background currents by either subtracting out the average membrane current values during the first 1-3 traces, or the average membrane current values obtained with the reference solution at the end of the experiment. The % I_{CRAC} inhibition in each cell is calculated by comparing the amount of current just prior to the first compound addition to the amount of current after the cells has been perfused with the compound for at least 400 seconds.

2) <u>Cho-K1 Cells Over-expressing Stim1 and either CracM1, CracM2 or CracM3.</u>

Cells

The production of TREx™-CHO cells stably expressing recombinant human Stim1 and either CracM1, CracM2 or CracM3 cells is described above. Cells are grown to confluence in 175 cm^2 tissue culture flask. On the experimental day, cells harvested with 0.25% trypsin/0.02% EDTA and resuspended in extracellular solution at density of 5-15x10^6 cells/ml

Intracellular Solution

The intracellular solution contains Cs-Glutamate 90mM; NaCl 8mM; $MgCl_2$ 3 mM; CsCl 20mM; CsBAPTA 20mM; HEPES 10mM; InsP3 0.02mM; pH=7.2 adjusted with CsOH.

Extracellular Solution

The extracellular solution contains NMDGCl 120mM; KCl 5.4mM; CsCl 10mM; $CaCl_2$ 1mM; $MgCl_2$ 1 mM; HEPES 10mM; Glucose 5.5mM; ; at pH=7.4 adjusted with NaOH.

Experimental Procedure and Data Analysis

Experimental procedures and data analysis are identical to the above procedures for Rbl-2H3 cells.

EXAMPLE 5: INHIBITION OF MULTIPLE CYTOKINES IN PRIMARY HUMAN PBMCs

Human peripheral blood mononuclear cells (PBMCs) were prepared from heparinized human blood by separation over a Ficoll density gradient.

PBMCs are stimulated with phytohemagglutinin (PHA) in the presence of varying concentrations of compounds of the invention or cyclosporine A (CsA), a known inhibitor of cytokine production. Cytokine production is measured using commercially available human ELISA assay kits (from Cell Science, Inc.) following the manufacturers instructions.

Alternatively, PBMCs with 10% FCS at 1-2 x 10^6/ml are stimulated with pre-coated with anti-CD3 (clone UCHT1) and anti-CD28 (clone ANC28.1/5D10) at 5 μg/ml each, with or without compound or DMSO (maximun concentration: 0.1%). Cell cultures are incubated at 37 °C, 5% CO_2. Samples of the culture supernatant are collected after 48-72 hrs. incubation for measurement of multiple cytokines. Cytokines present in the supernatants are quantified using BioRad BioPlex assays according to the manufacturer's instructions.

The compounds of the invention are expected to be potent inhibitors of IL-2, IL-4, IL-5, IL-13, GM-CSF, IFN-γ and TNF-α in primary human PBM cells. In addition, compounds of the invention are not expected to inhibit the anti-inflammatory cytokine, IL-10.

EXAMPLE 6: INHIBITION OF DEGRANULATION IN RBL CELLS

Procedure:

The day before the assay is performed, RBL cells, that have been grown to confluence in a 96 well plate, are incubated at 37°C for at least 2 hours. The medium is replaced in each well with 100 µL of fresh medium containing 2µLg/mL of anti-DNP IgE.

On the following day, the cells are washed once with PRS (2.6 mM glucose and 0.1% BSA) and 160µL of PRS is added to each well. A test compound is added to a well in a 20µL solution at 10X of the desired concentration and incubated for 20 to 40 minutes at 37°C. 20µL of 10X mouse anti-IgE (10 µL/mL) is added. Maximum degranulation occurs between 15 to 40 minutes after addition of anti-IgE.

Compounds of the invention are expected to inhibit degranulation.

EXAMPLE 7: INHIBITION OF CHEMOTAXIS IN T CELLS

T-cell isolation:

Twenty ml aliquots of heparinized whole blood (2 pig, 1 human) are subjected to density gradient centrifugation on Ficoll Hypaque. The buffy coat layers representing peripheral blood mononuclear cells (PBMCs) containing lymphocytes and monocytes are washed once, resuspended in 12 ml of incomplete RPMI 1640 and then placed in gelatin-coated T75 culture flasks for 1 hr at 37°C. The non-adherent cells, representing peripheral blood lymphocytes (PBLs) depleted of monocytes, are resuspended in complete RPMI media and placed in loosely packed activated nylon wool columns that have been equilibrated with warm media. After 1 hr at 37°C, the non-adherent T cell populations are eluted by washing of the columns with additional media. The T cell preparations are centrifuged, resuspended in 5 ml of incomplete RPMI, and counted using a hemocytometer.

Cell migration assay:

Aliquots of each T cell preparation are labeled with Calcien AM (TefLabs) and suspended at a concentration of 2.4 x10^6/ml in HEPES-buffered Hank's Balanced Salt Solution containing 1.83 mM $CaCl_2$ and 0.8 mM $MgCl_2$, pH 7.4 (HHBSS). An equal volume of HHBSS containing 0, 20 nM, 200 nM or 2000 nM of compound 1 or 20 nM EDTA is then added and the cells incubated for 30 min at 37 °C. Fifty µl aliquots of the cell suspensions (60,000 cells) are placed on the membrane (pore size 5 µm) of a Neuroprobe ChemoTx 96 well chemotaxis unit that have been affixed over wells containing 10 ng/ml MIP-1α in HHBSS. The T cells are allowed to migrate for

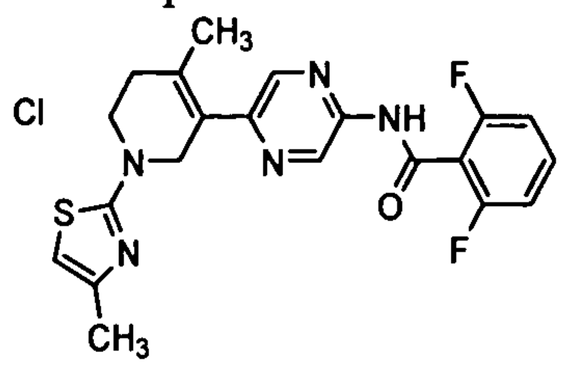
2 hr at 37 °C, after which the apical surface of the membrane is wiped clean of cells. The chemotaxis units are then placed in a CytoFluor 4000 (PerSeptive BioSystems) and the fluorescence of each well measured (excitation and emission wavelengths of 450 and 530 nm, respectively). The number of migrating cells in each well is determined from a standard curve generated from measuring the fluorescence of serial two-fold dilutions of the labeled cells placed in the lower wells of the chemotaxis unit prior to affixing the membrane.

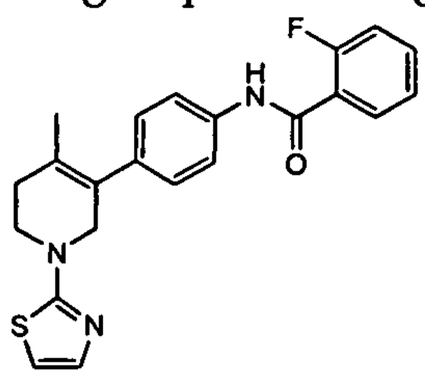
Compounds of the invention are expected to inhibit chemotactic response of T cells.

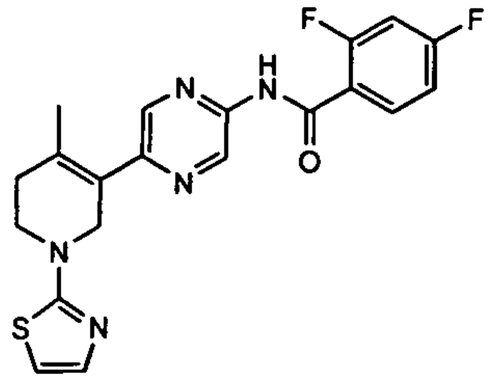
All publications, patent applications, patents, and other documents cited herein are incorporated by reference in their entirety. In case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting in any way.

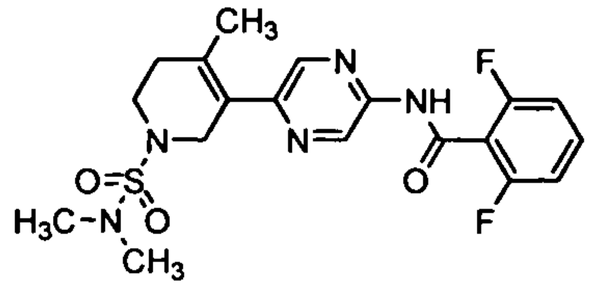
What is claimed is:

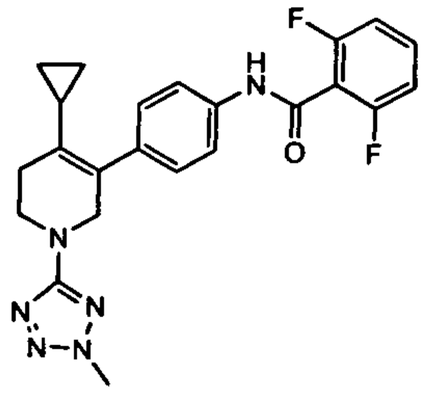
1. A compound selected from the group consisting of:

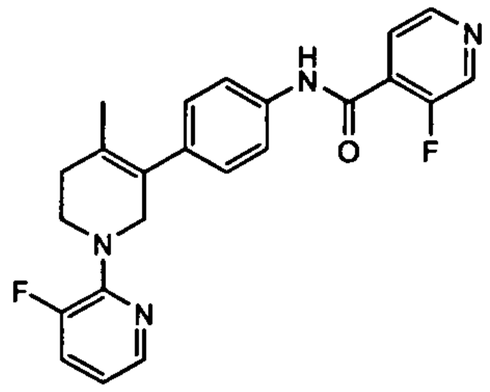


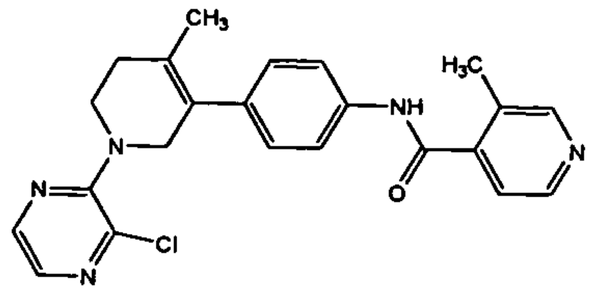


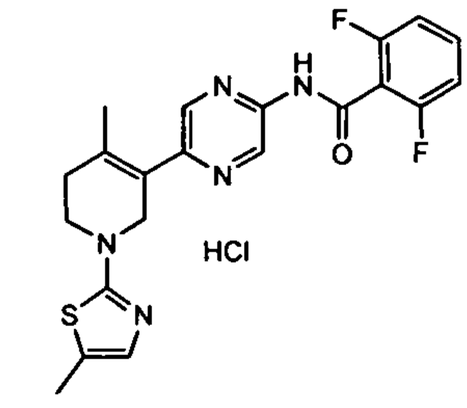


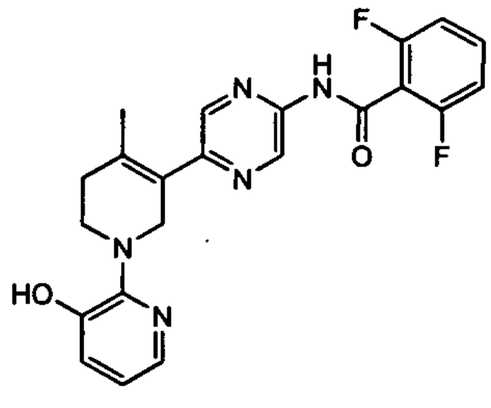


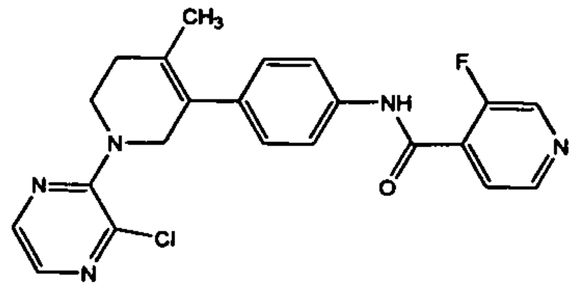


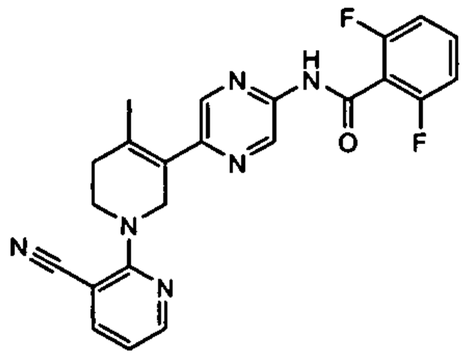


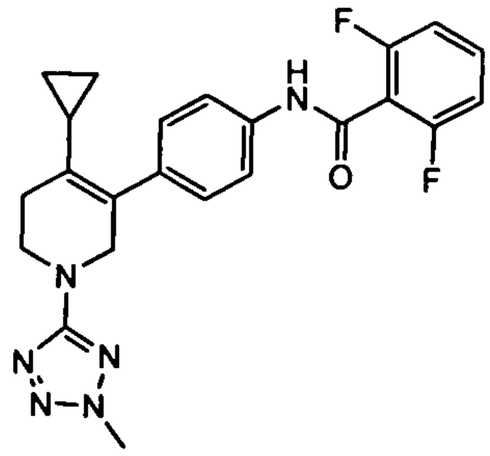


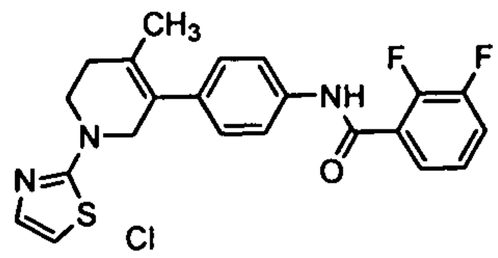


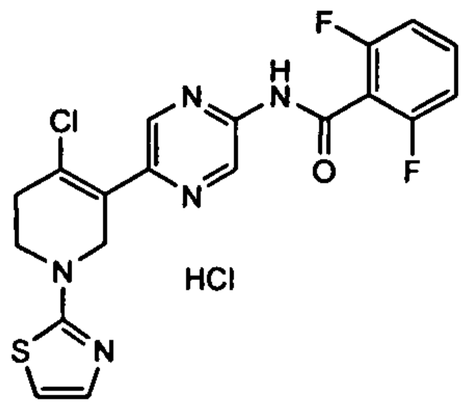


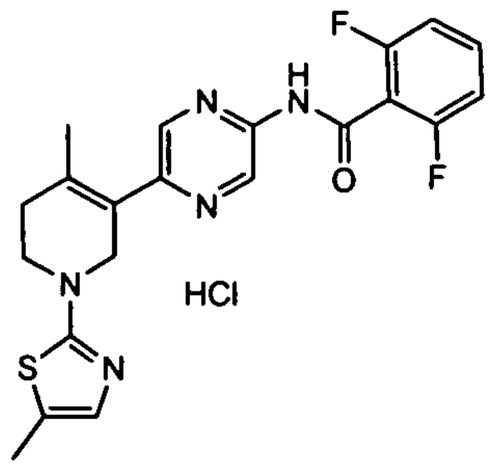


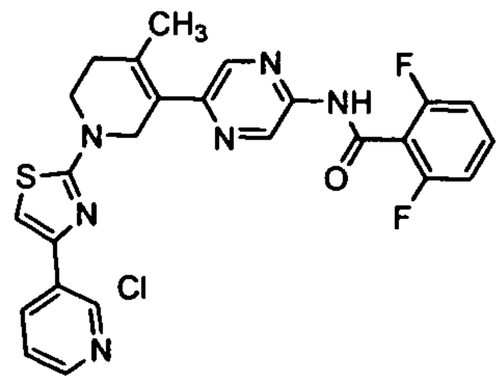


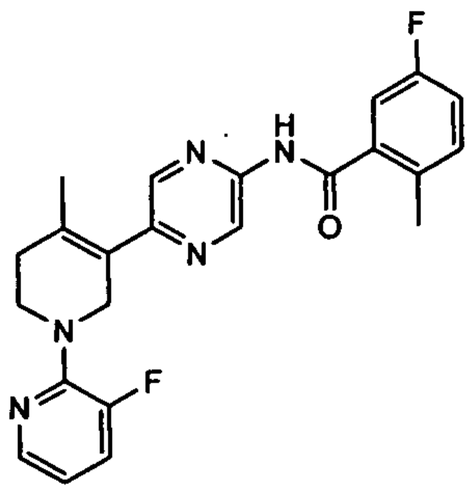


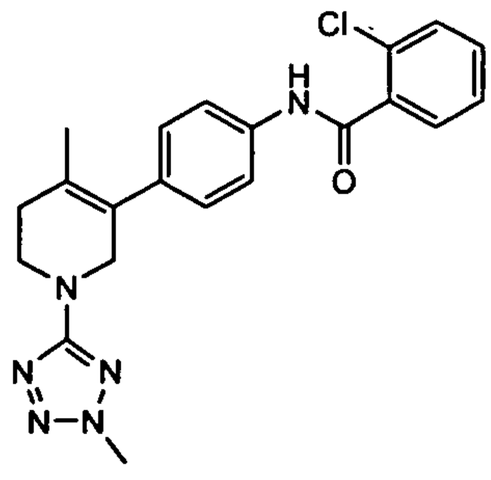


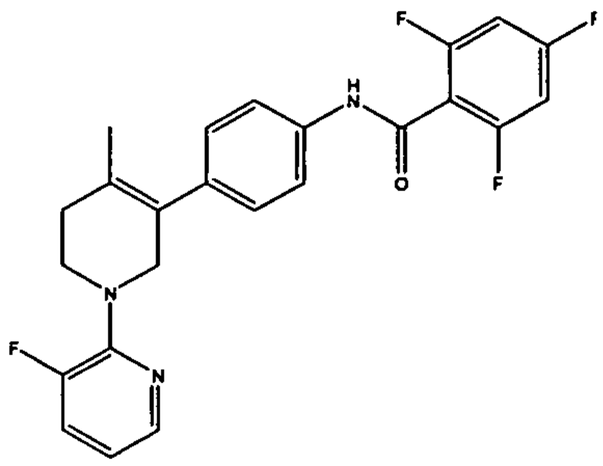


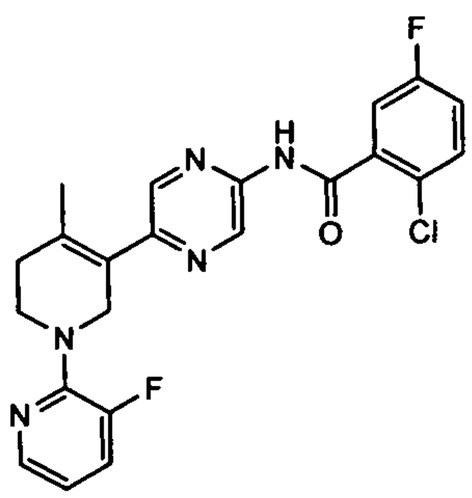


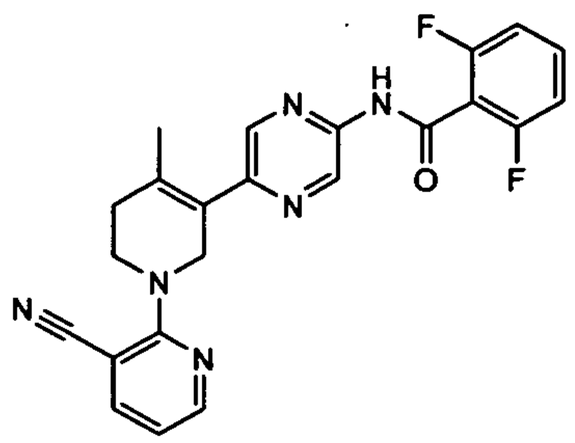


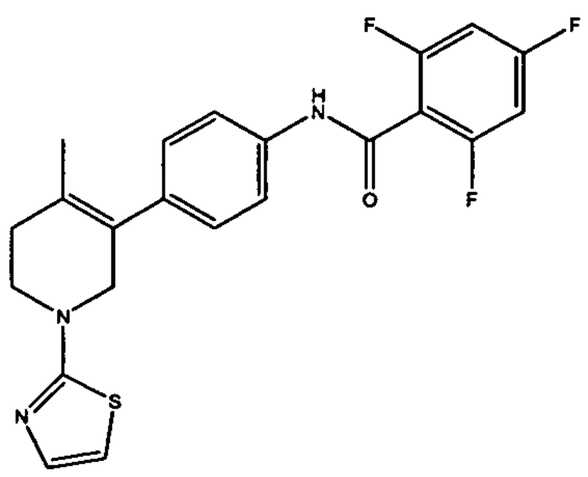


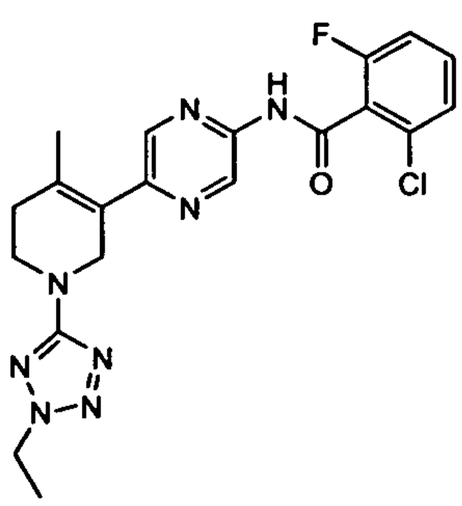


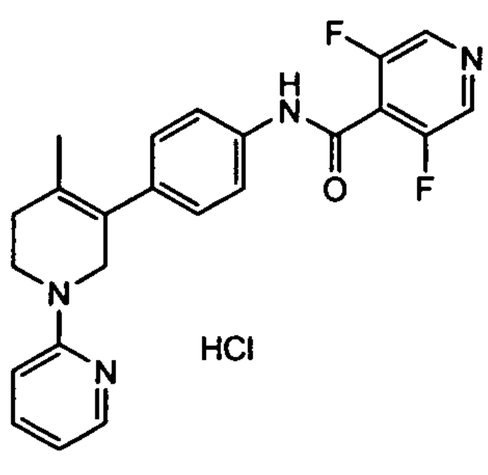








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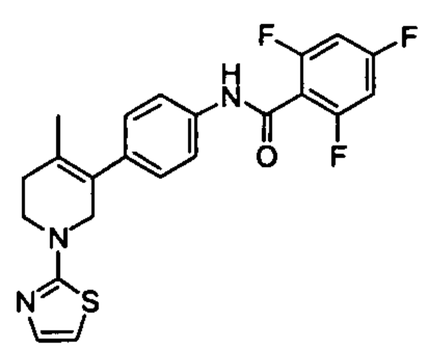

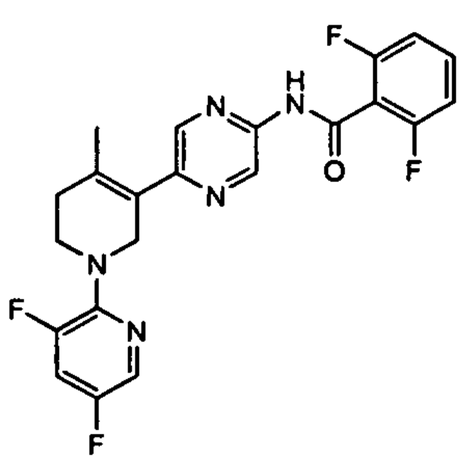

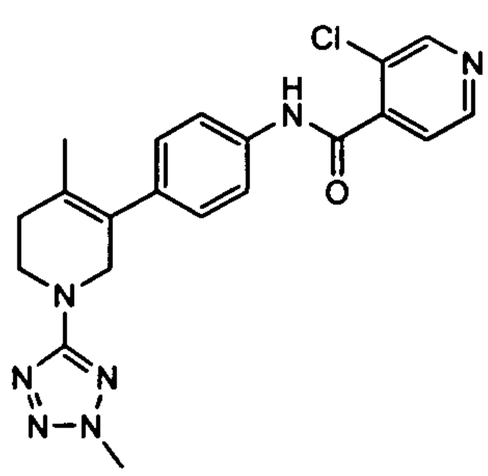

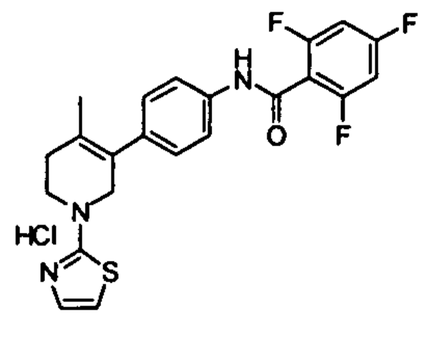
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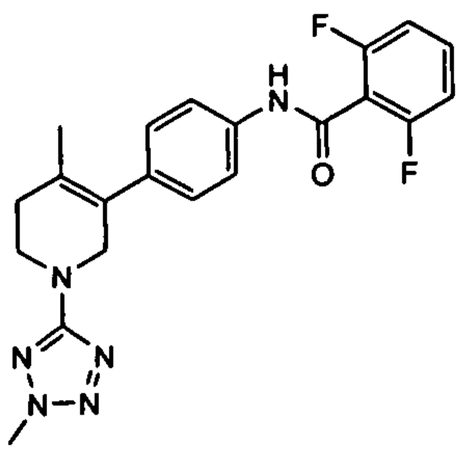

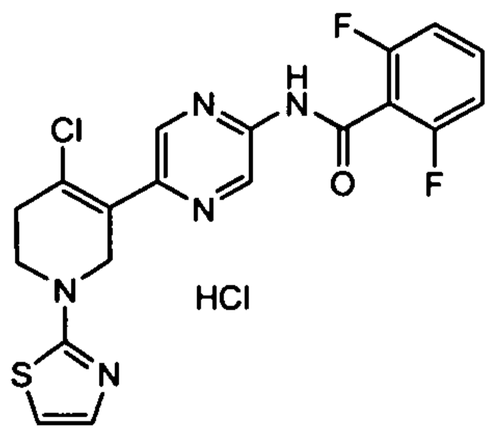
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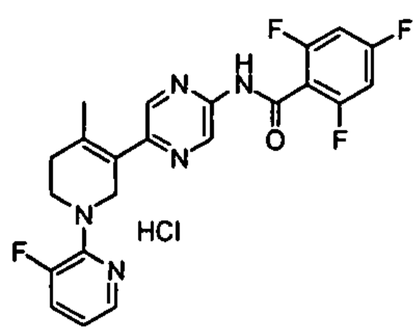
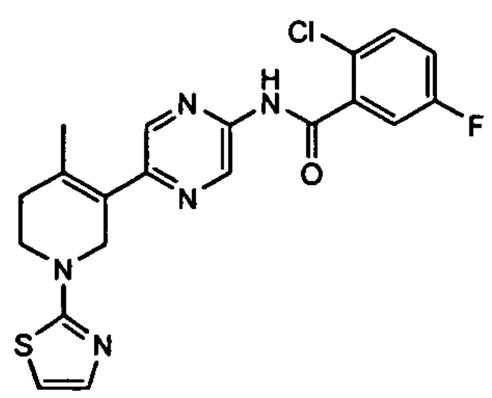
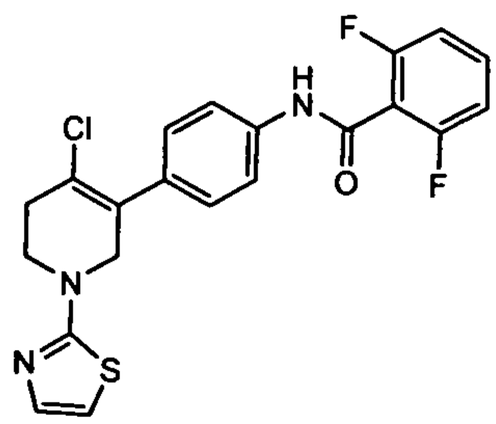
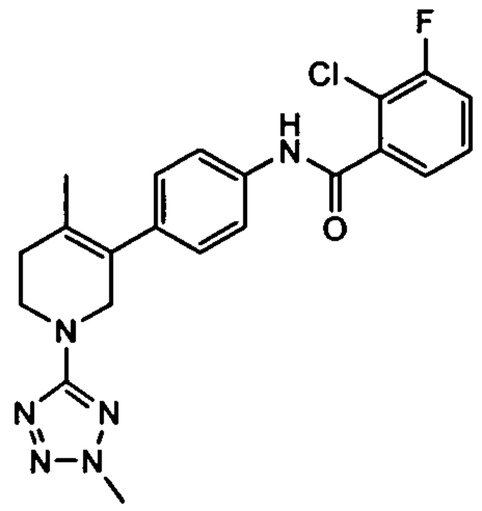
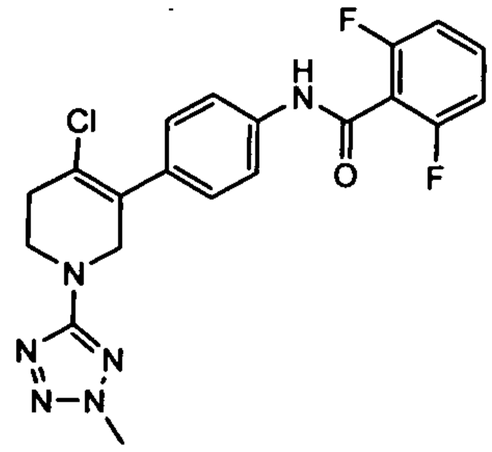
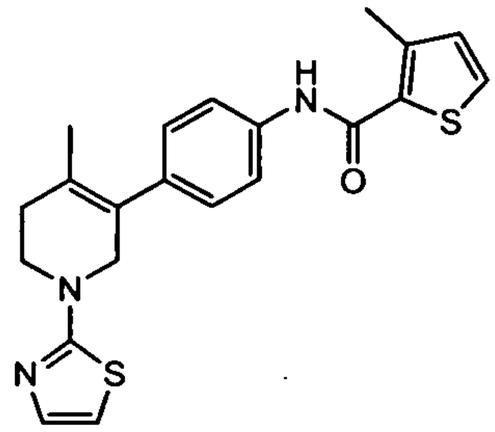
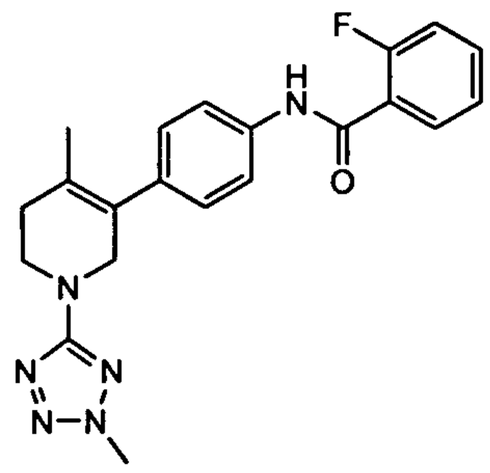
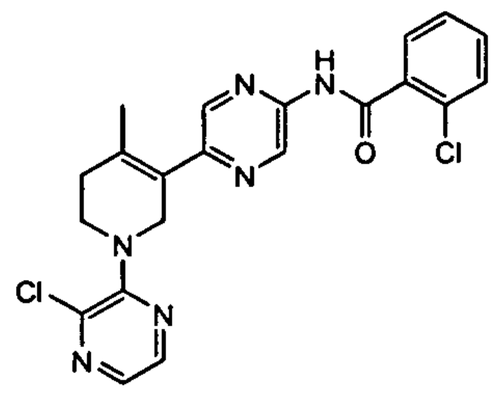
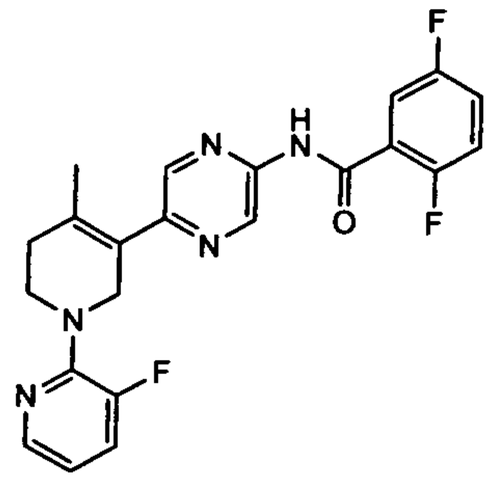
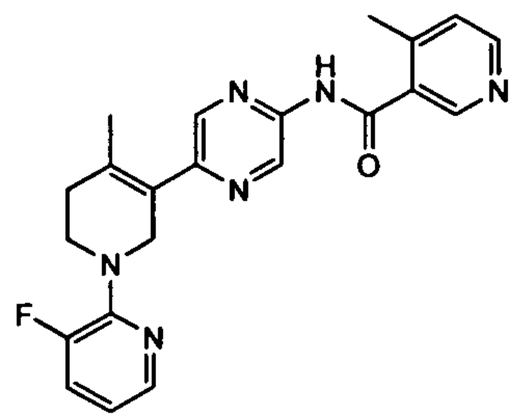
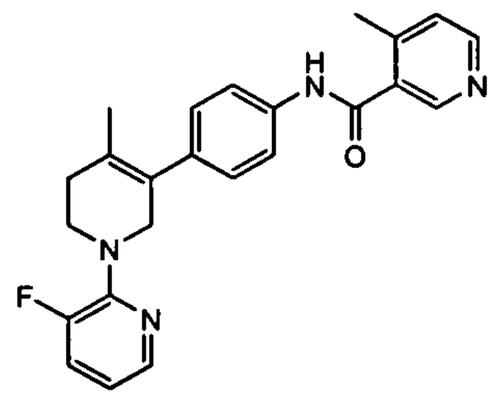
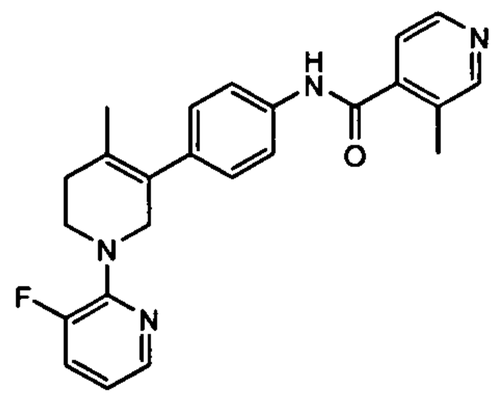
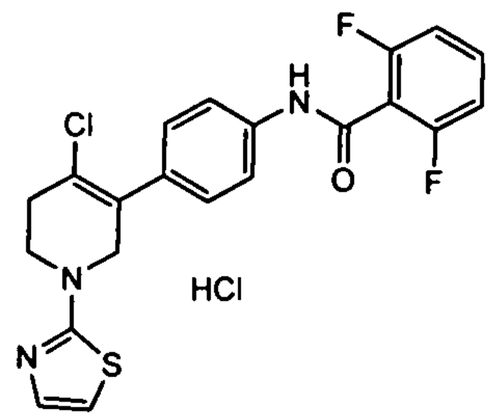
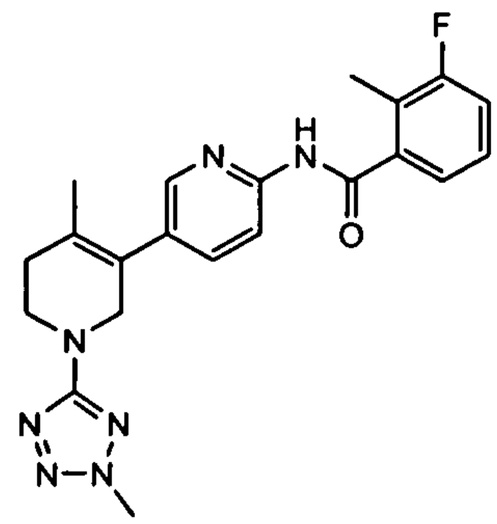
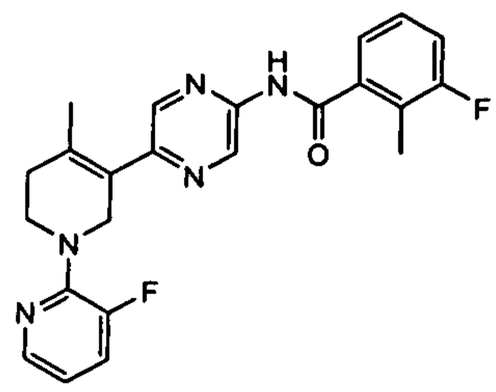

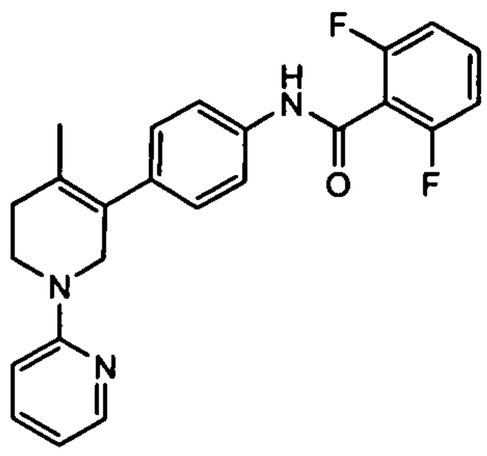

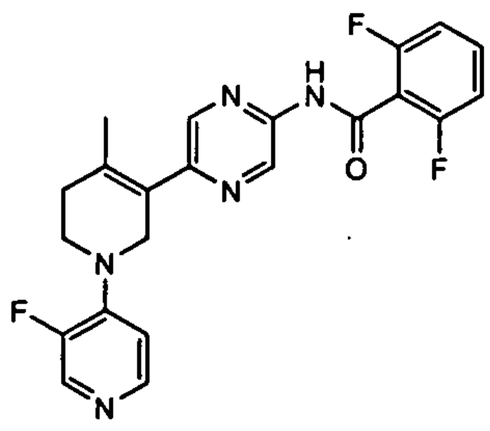

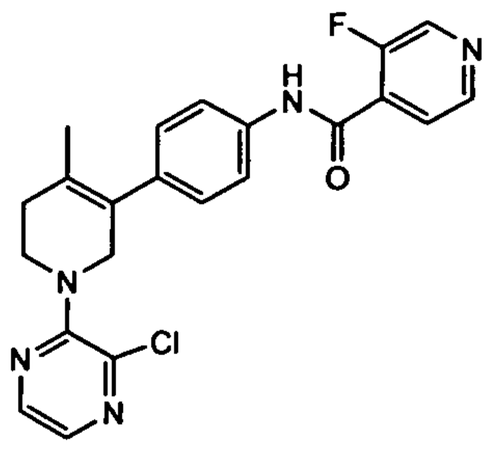

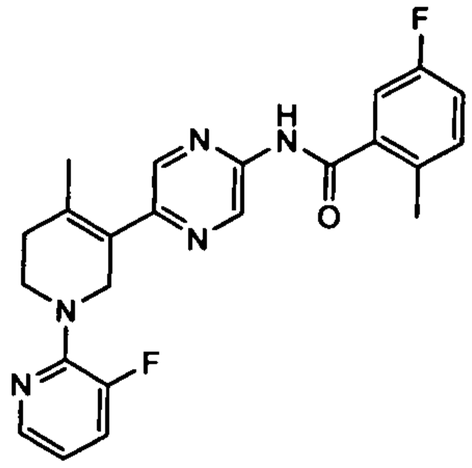

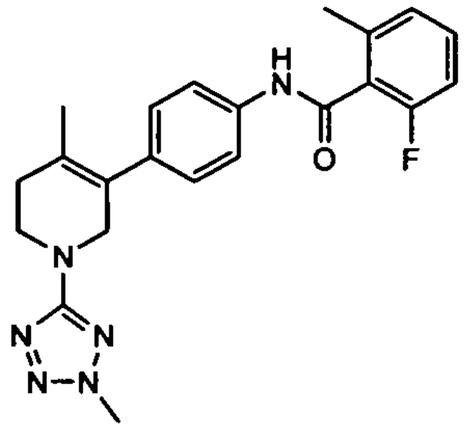

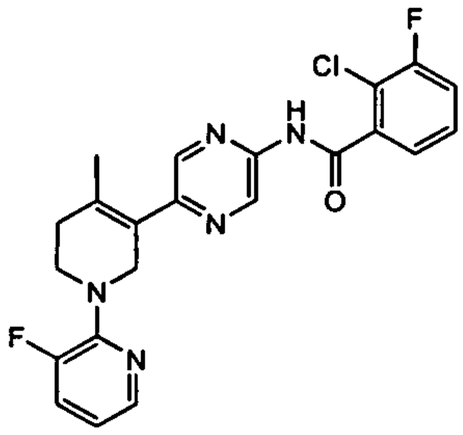

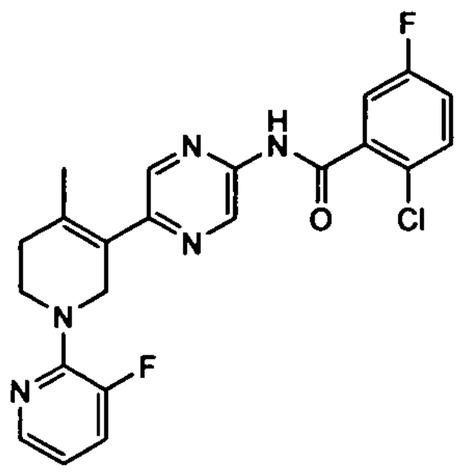

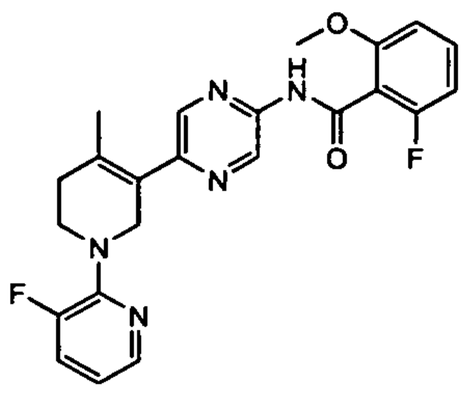

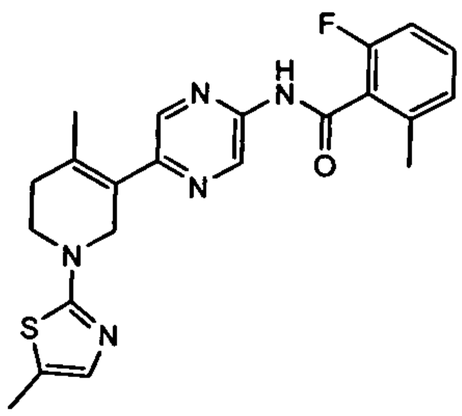

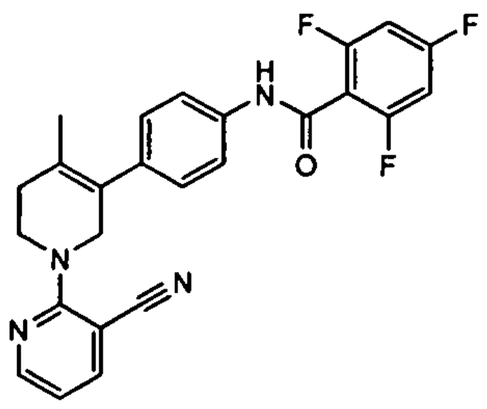

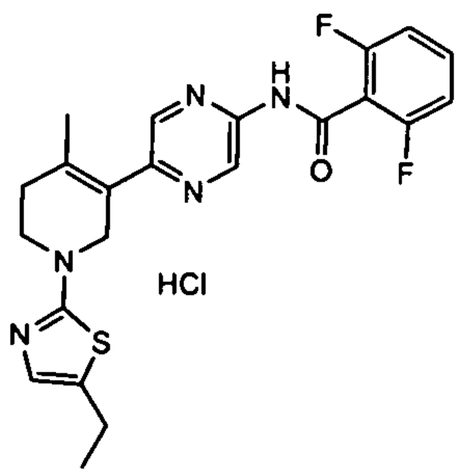
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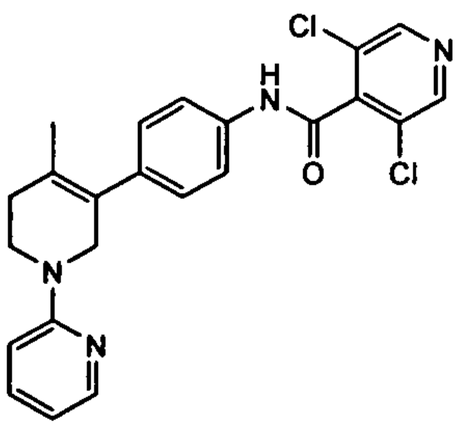

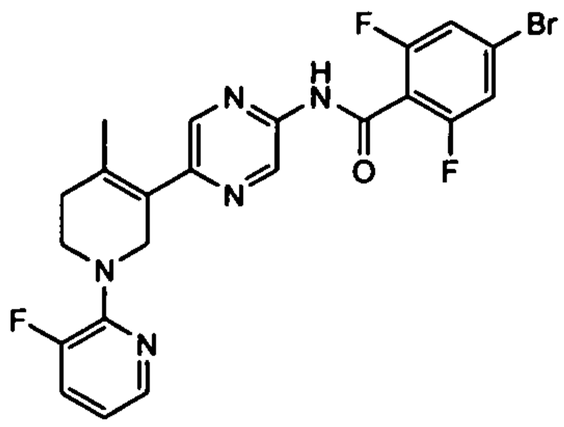

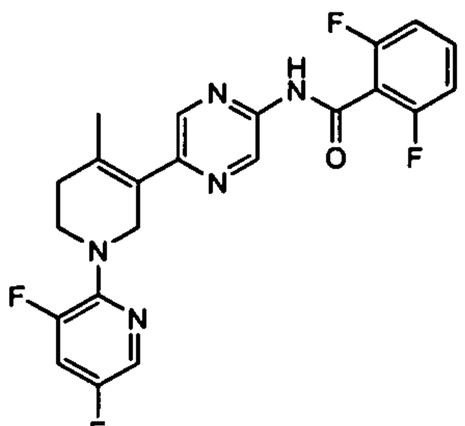

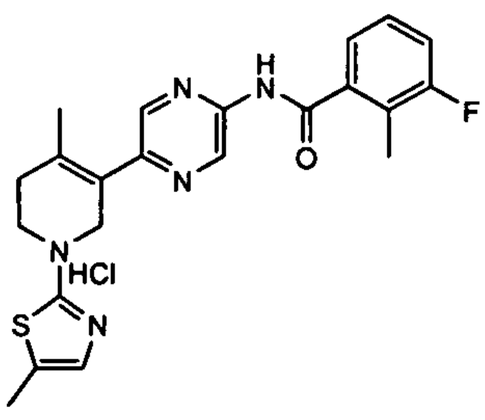
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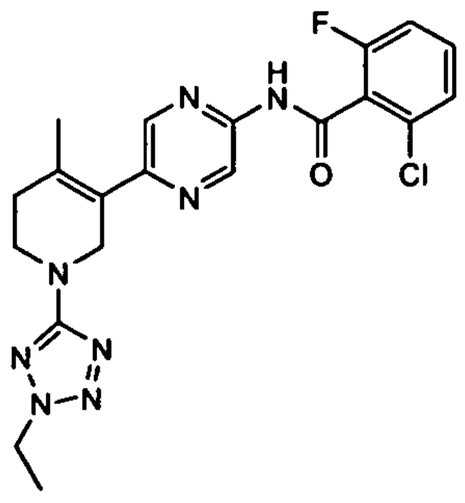

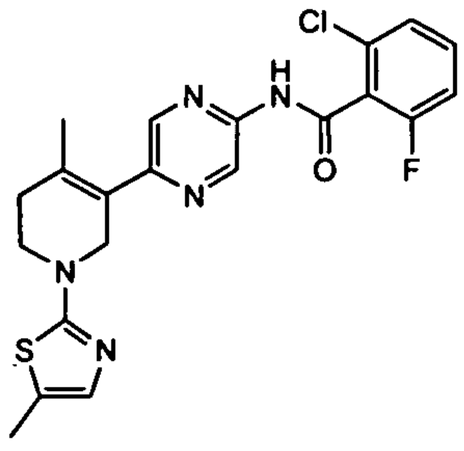

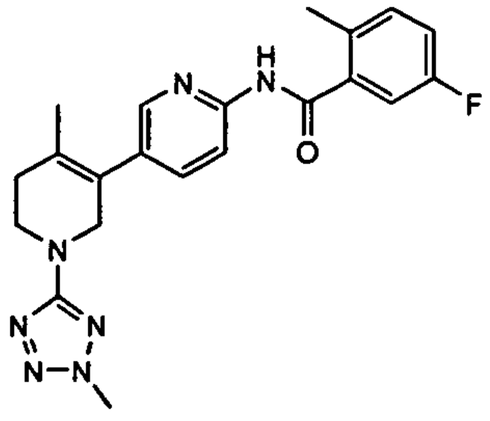

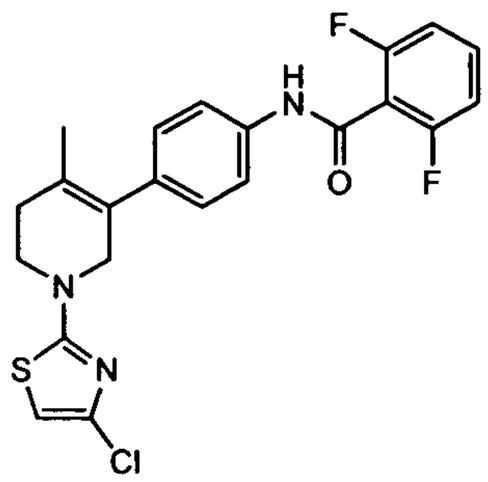

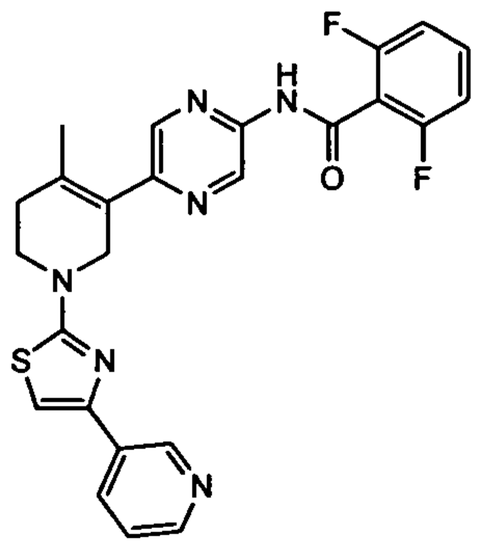

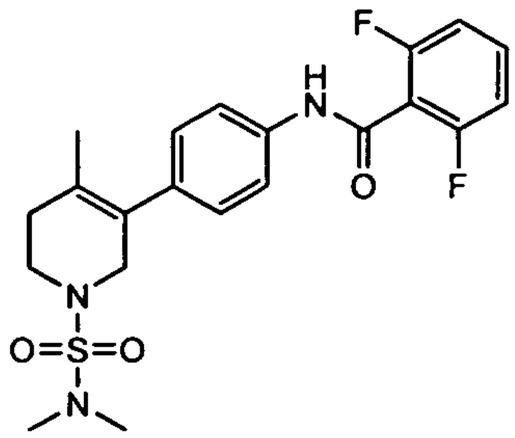

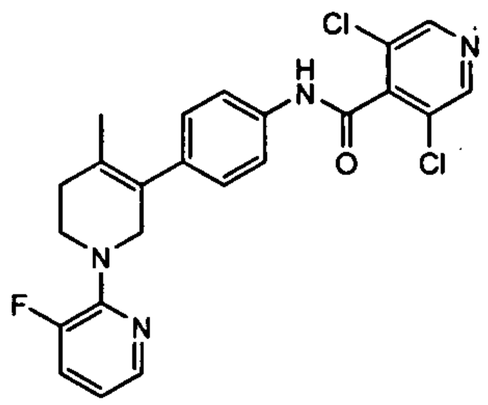

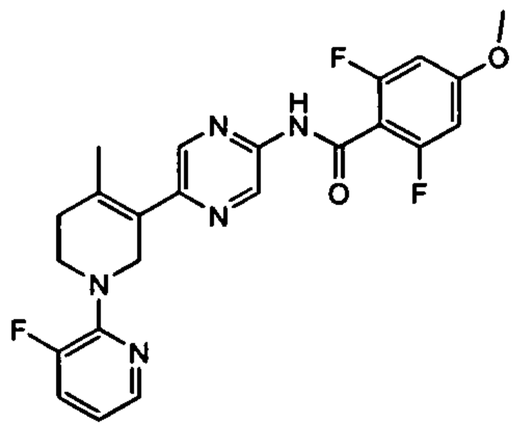

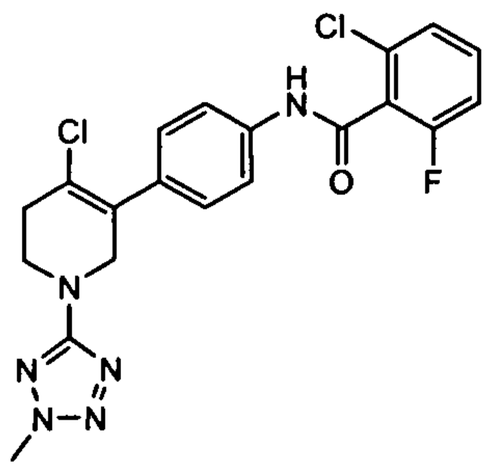

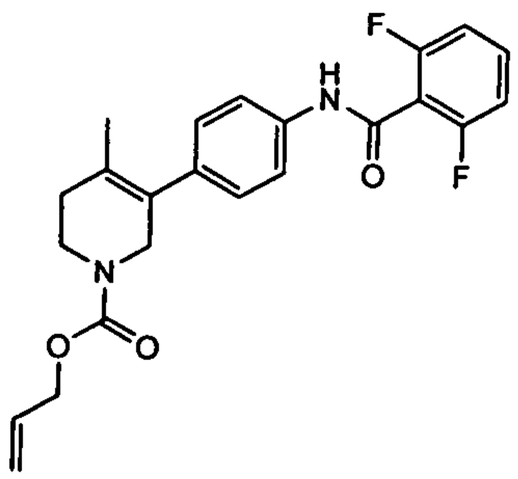

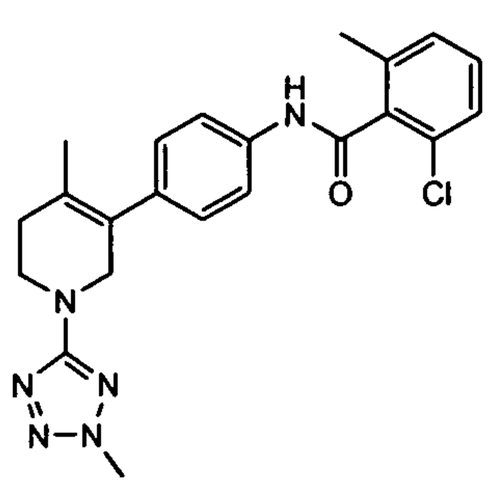

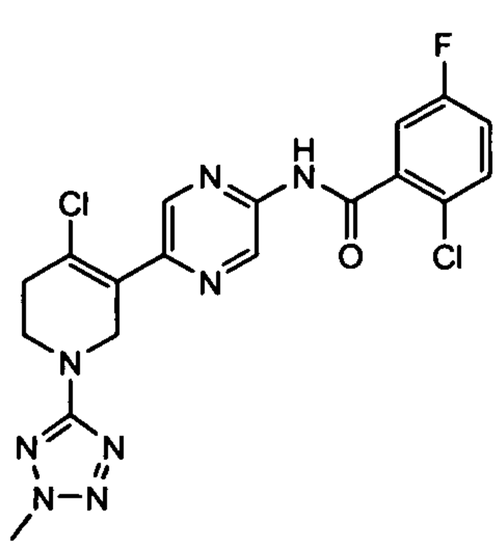

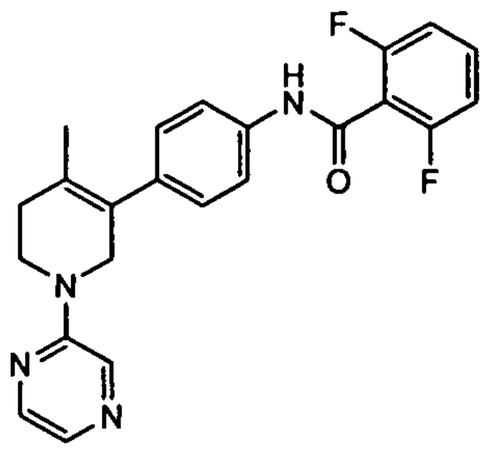

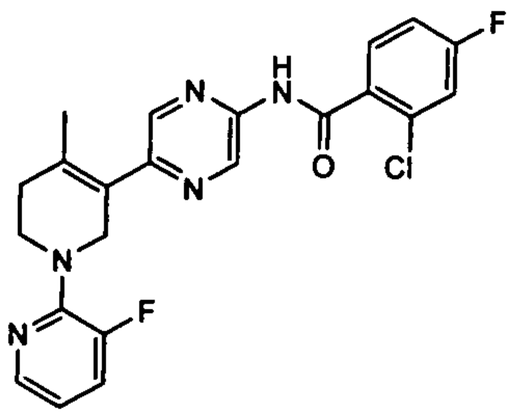

or a pharmaceutically acceptable salt thereof.

2. A pharmaceutical composition, comprising a pharmaceutically acceptable carrier and a compound of claim 1.

3. The pharmaceutical composition of claim 2, further comprising one or more additional therapeutic agents selected from the group consisting of immunosuppressive agents, anti-inflammatory agents, steroids, non-steroidal anti-inflammatory agents, antihistamines, analgesics, and suitable mixtures thereof.

4. A method of inhibiting immune cell activation comprising administering to an immune cell a compound of claim 1.

5. A method of inhibiting cytokine production in a cell, comprising administering to the cell a compound of claim 1.

6. The method of claim 5, wherein the cytokine is selected from the group consisting of IL-2, IL-4, IL-5, IL-13, GM-CSF, IFN-γ, TNFα, and combinations thereof.

7. A method of modulating an ion channel in a cell, wherein the ion channel is involved in immune cell activation, comprising administering to the cell a compound of claim 1.

8. The method of claim 7, wherein the ion channel is a Ca^{2+}-release-activated Ca^{2+} channel (CRAC).

9. A method of inhibiting T-cell and/or B-cell proliferation in response to an antigen, comprising administering to a T-cell and/or B-cell cell a compound of claim 1.

10. A method for treating or preventing an immune disorder in a subject in need thereof, comprising administering to the subject an effective amount of a compound of claim 1.

11. The method of claim 10, wherein the disorder is selected from the group consisting of multiple sclerosis, myasthenia gravis, Guillain-Barré, autoimmune uveitis, autoimmune hemolytic anemia, pernicious anemia, autoimmune thrombocytopenia, temporal arteritis, anti-phospholipid syndrome, vasculitides such as Wegener's granulomatosis, Behcet's disease, psoriasis, dermatitis herpetiformis, pemphigus vulgaris, vitiligo, Crohn's disease, ulcerative colitis, primary biliary cirrhosis, autoimmune hepatitis, Type 1 or immune-mediated diabetes mellitus, Grave's disease. Hashimoto's thyroiditis, autoimmune oophoritis and orchitis, autoimmune disorder of the adrenal gland, rheumatoid arthritis, systemic lupus erythematosus, scleroderma, polymyositis, dermatomyositis, ankylosing spondylitis, and Sjogren's syndrome.

12. A method for treating or preventing an inflammatory condition in a subject in need thereof, comprising administering to the subject an effective amount of a compound of claim 1.

13. The method of claim 12, wherein the disorder is selected from transplant rejection, skin graft rejection, arthritis, rheumatoid arthritis, osteoarthritis and bone diseases associated with increased bone resorption; inflammatory bowel disease, ileitis, ulcerative colitis, Barrett's syndrome, Crohn's disease; asthma, adult respiratory distress syndrome, chronic obstructive airway disease; corneal dystrophy, trachoma, onchocerciasis, uveitis, sympathetic ophthalmitis, endophthalmitis; gingivitis, periodontitis; tuberculosis; leprosy; uremic complications, glomerulonephritis, nephrosis;

sclerodermatitis, psoriasis, eczema; chronic demyelinating diseases of the nervous system, multiple sclerosis, AIDS-related neurodegeneration, Alzheimer's disease, infectious meningitis, encephalomyelitis, Parkinson's disease, Huntington's disease, amyotrophic lateral sclerosis viral or autoimmune encephalitis; autoimmune disorders, immune-complex vasculitis, systemic lupus and erythematodes; systemic lupus erythematosus (SLE); cardiomyopathy, ischemic heart disease hypercholesterolemia, atherosclerosis, preeclampsia; chronic liver failure, brain and spinal cord trauma, and cancer.

14. A method for suppressing the immune system of a subject in need thereof, comprising administering to the subject an effective amount of a compound of claim 1.

15. A method for treating or preventing an allergic disorder in a subject in need thereof, comprising administering to the subject an effective amount of a compound of claim 1.

16. The method of claim 15, wherein the disorder is allergic rhinitis, sinusitis, rhinosinusitis, chronic otitis media, recurrent otitis media, drug reactions, insect sting reactions, latex reactions, conjunctivitis, urticaria, anaphylaxis reactions, anaphylactoid reactions, atopic dermatitis, asthma, or food allergies.