

MIXED DISULFIDE CONJUGATES OF THIENOPYRIDINE COMPOUNDS AND USES THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority to U.S. Provisional Patent Application No. 62/155,231, filed April 30, 2015, hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

This invention is in the field of medicinal chemistry. In particular, the invention relates to mixed disulfide conjugates of thienopyridine compounds, and their use as therapeutics for the treatment, amelioration, and prevention of cardiovascular diseases.

INTRODUCTION

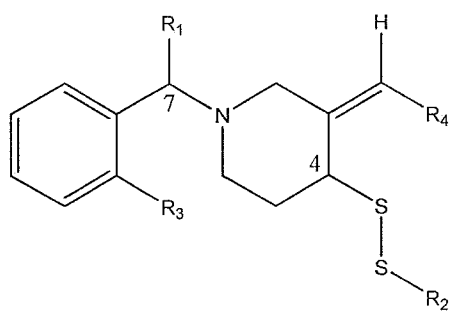
Thienopyridinyl compounds are widely used as antiplatelet agents to prevent heart attack and stroke. In this category, clopidogrel (Plavix), ticlopidine (Ticlid) and prasugrel (Effient) are three commonly used prodrugs. These agents require polymorphic cytochrome (P450) mediated oxidative bioactivation. Such oxidative bioactivation results in slow on-set of therapeutic effect and several adverse effects including neutropenia and thrombotic thrombocytopenic purpura.

Improved antiplatelet agents not requiring polymorphic cytochrome (P450) mediated oxidative bioactivation are needed.

SUMMARY

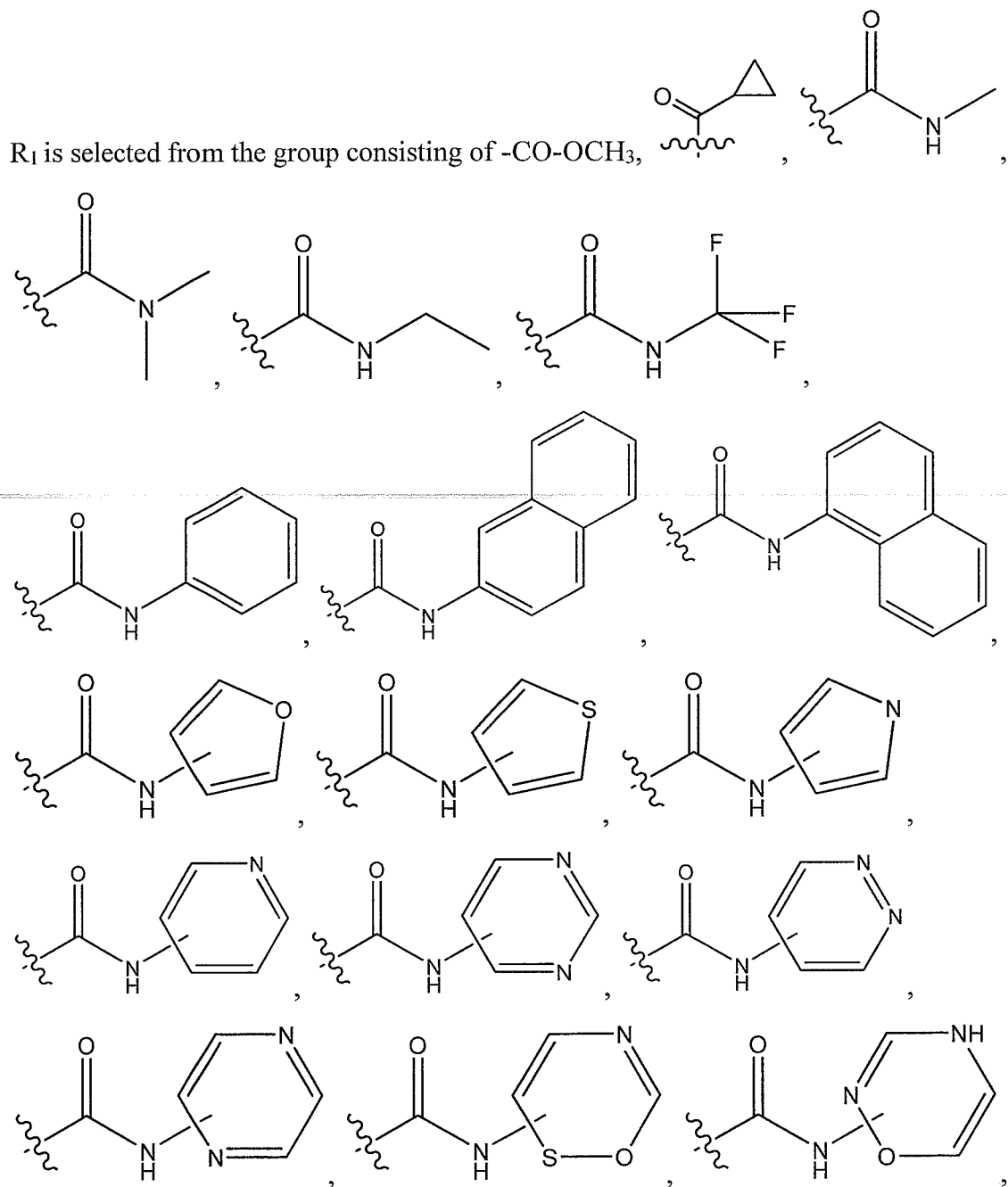
Clopidogrel (Plavix), ticlopidine (Ticlid) and prasugrel (Effient) belong to a class of thienopyridinyl compounds widely used as antiplatelet agents to prevent heart attack and stroke. However, several serious drawbacks have been associated with these drugs including lack of response, toxicity and excessive bleeding. These drawbacks are closely related to the fact that they are all prodrugs that require oxidative bioactivation by polymorphic cytochromes P450 enzymes (P450s).

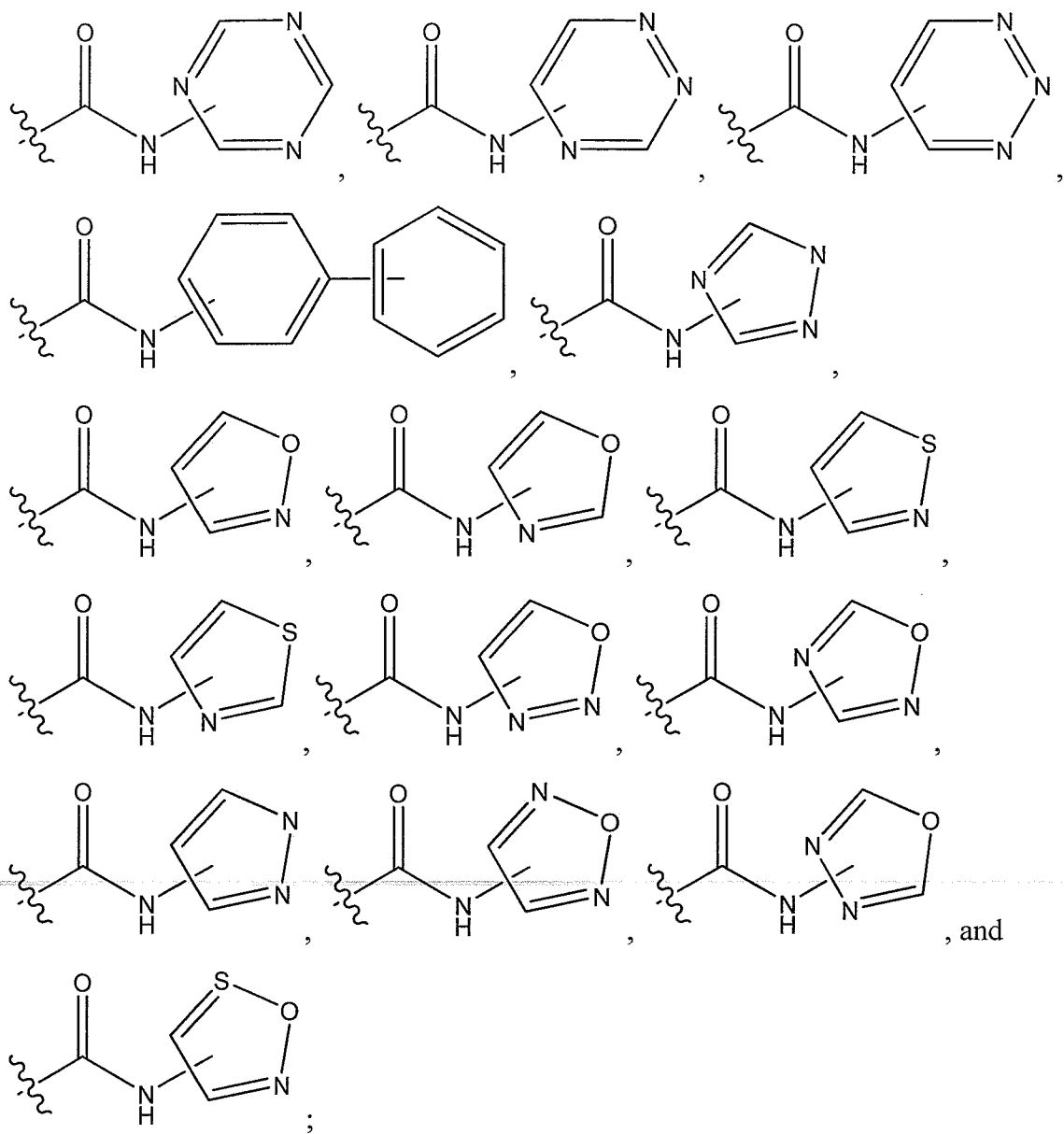
In one aspect, the present invention refers to a compound having Formula I:



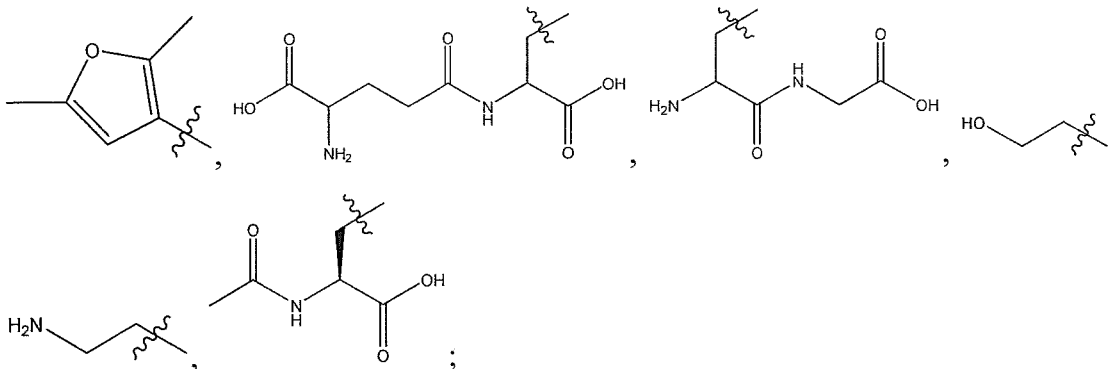
, or a pharmaceutically acceptable salt thereof;

wherein independently each of R₁, R₂, R₃ and R₄ are



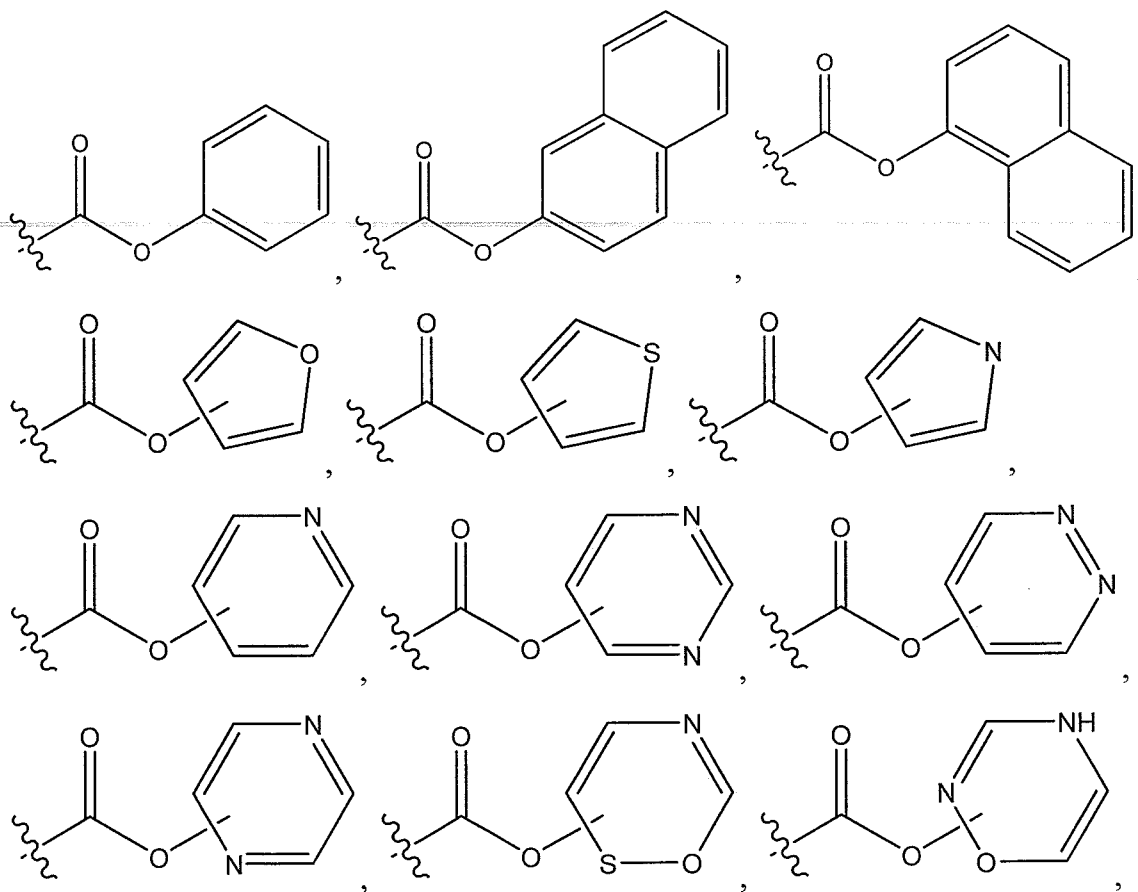


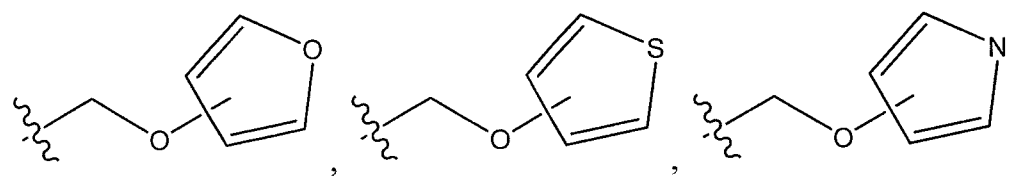
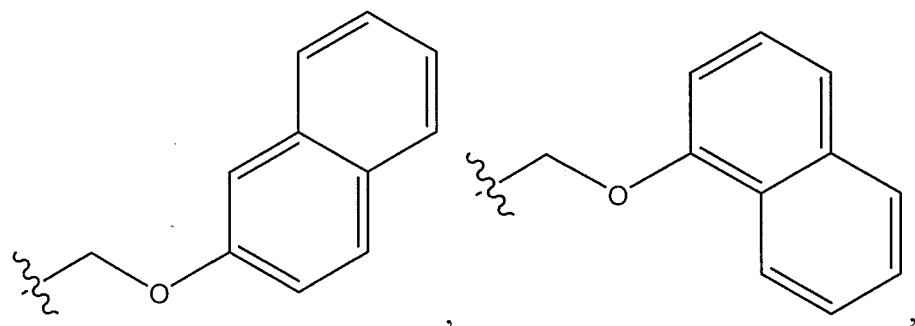
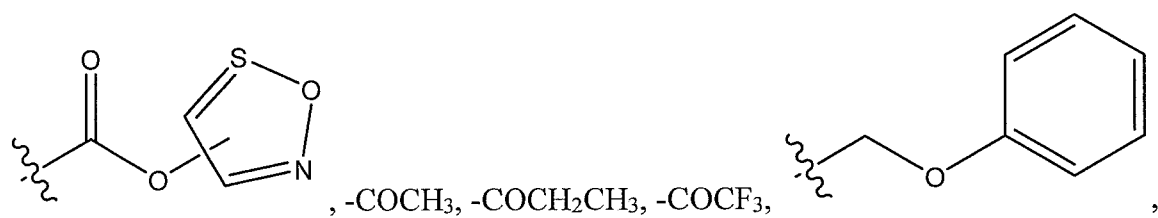
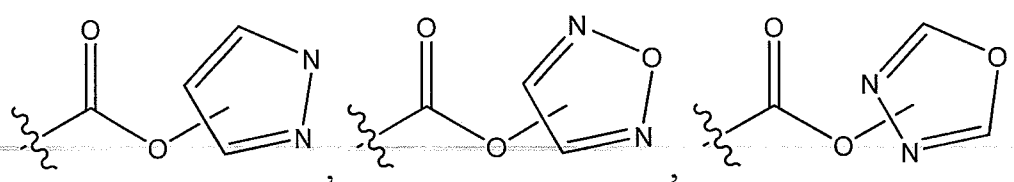
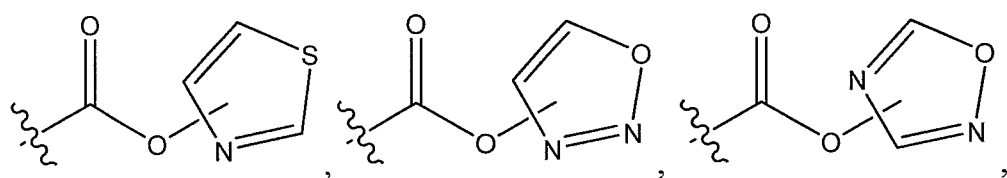
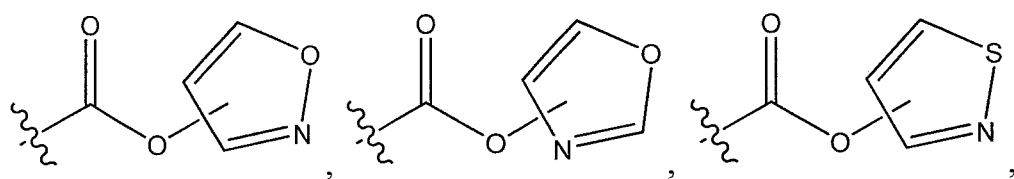
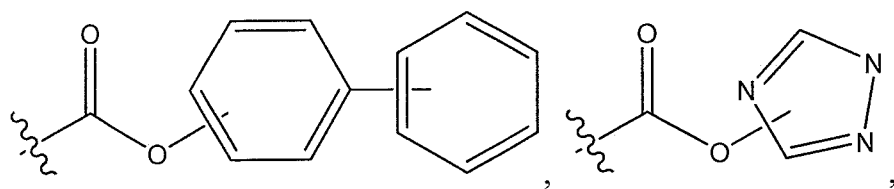
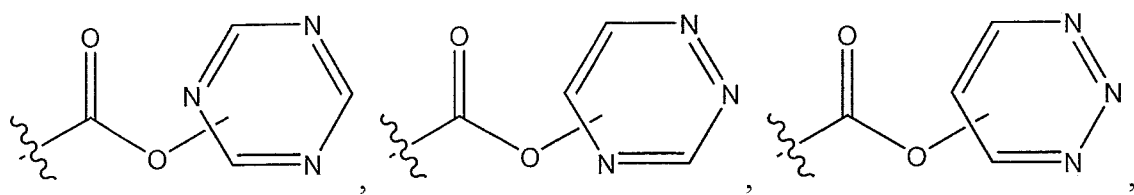
The image shows two chemical structures. The left structure is a 2-pyridyl ring with a cyano group (-C≡N) at the 4-position and a wavy line at the 2-position. The right structure is a 2-pyridyl ring with a nitro group (-NO₂) at the 4-position and a wavy line at the 2-position.

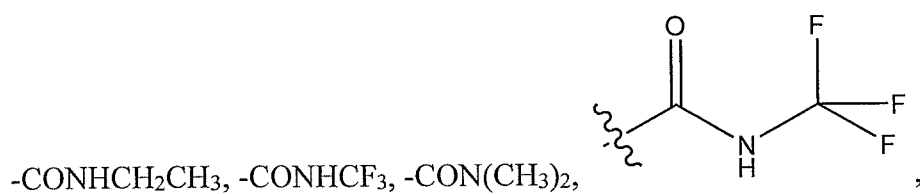
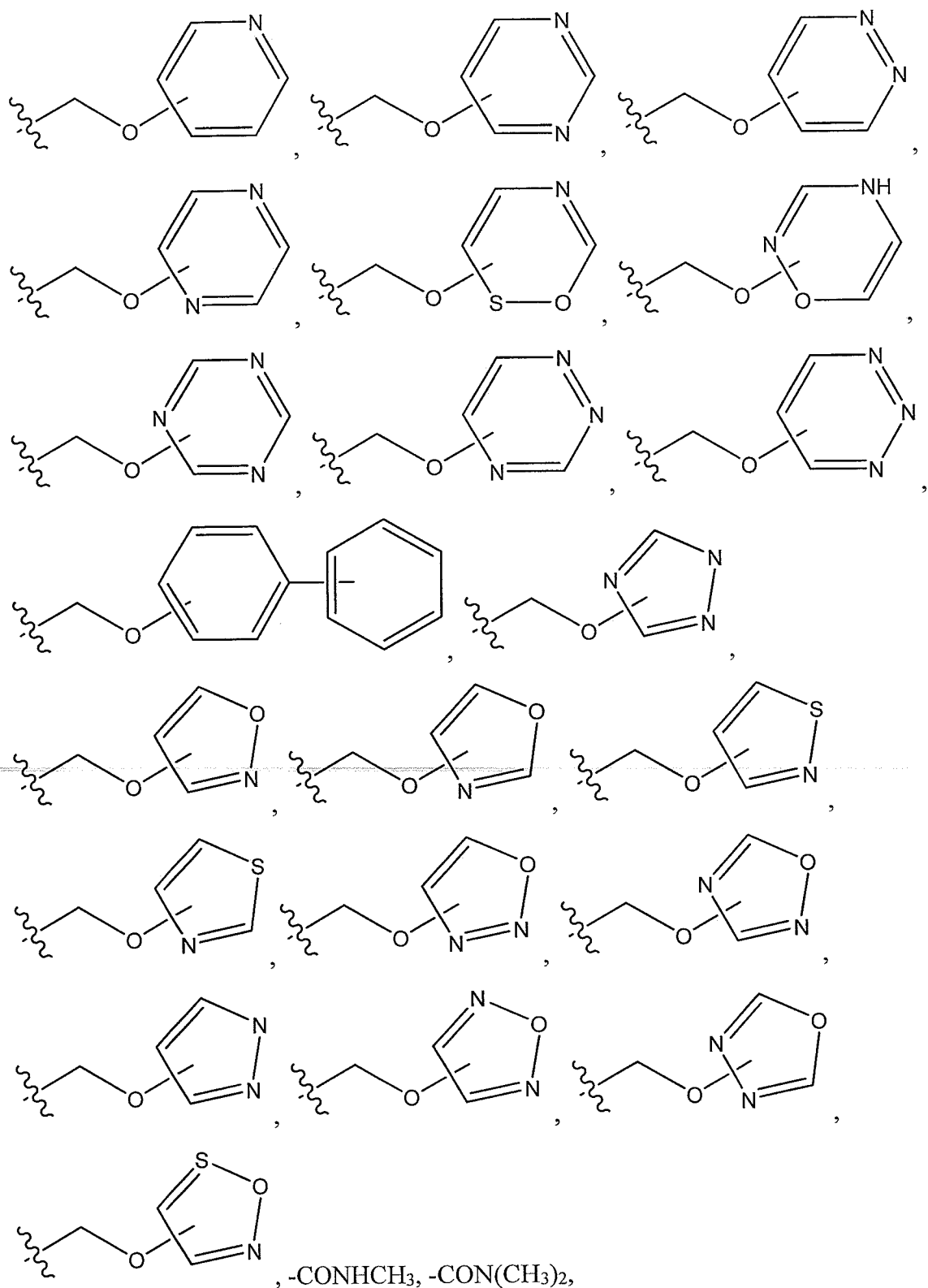


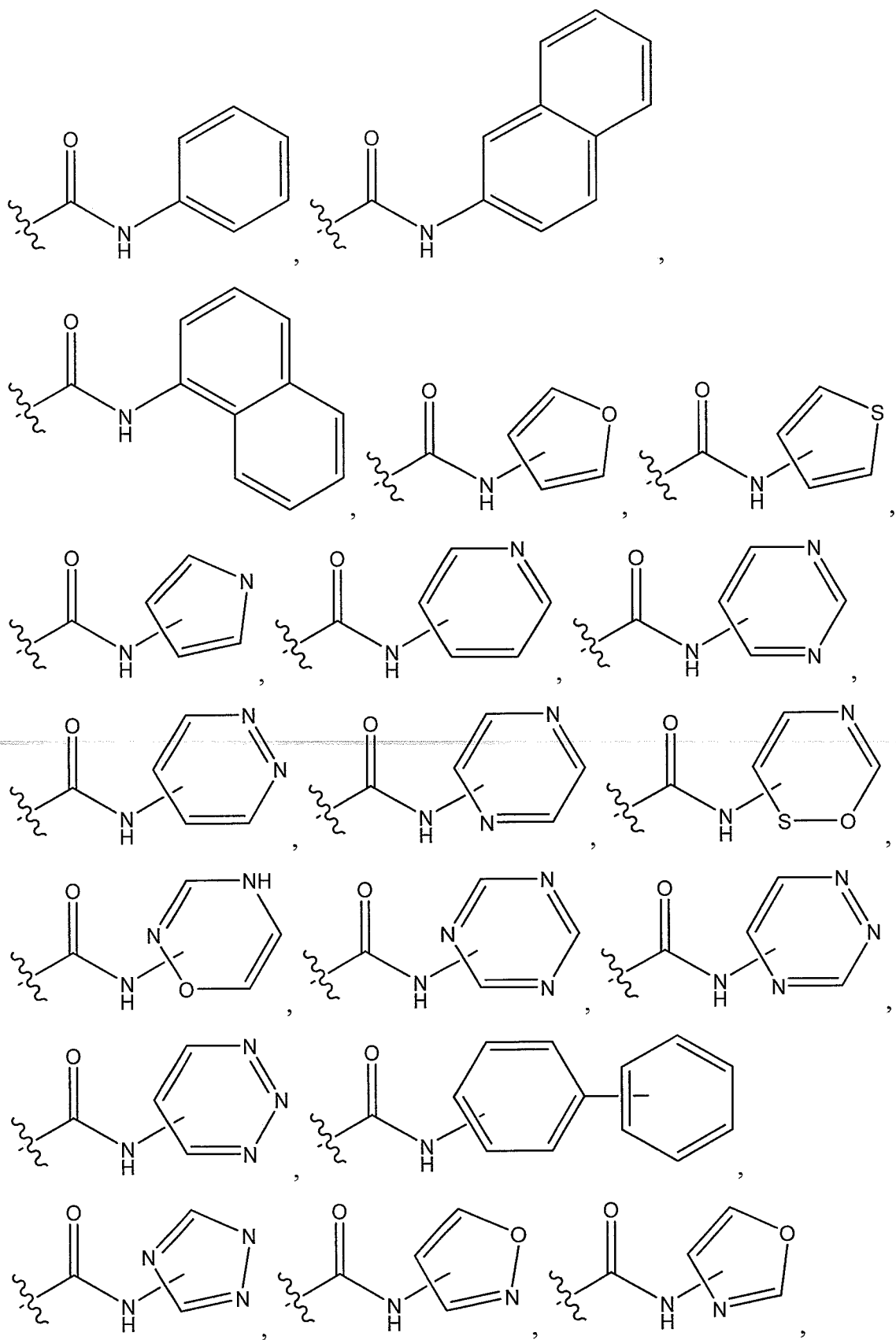
R₃ is selected from the group consisting of Cl, Br, I, F, CN, NO₂, CF₃, H, and OCH₃; and

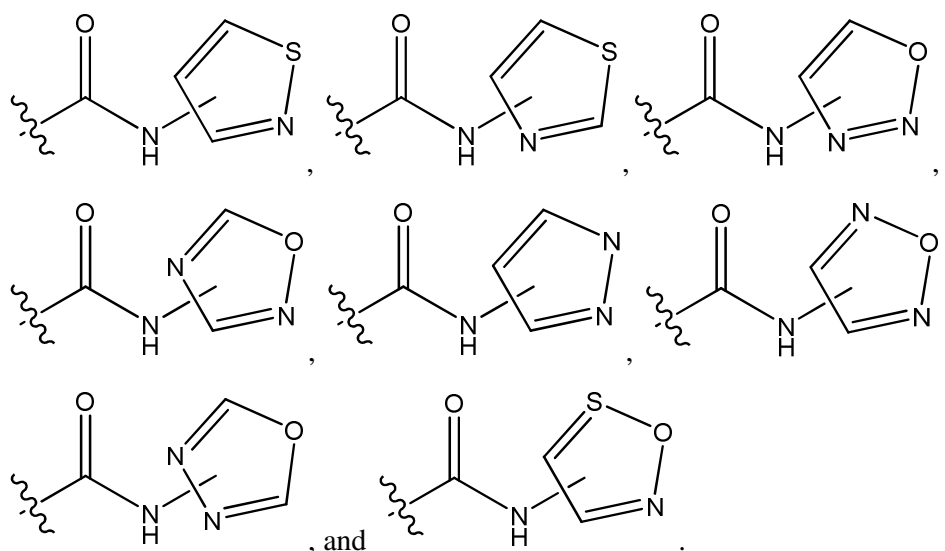
R₄ is selected from the group consisting of -COOCH₃, -COOCH₂CH₃, COOCF₃,











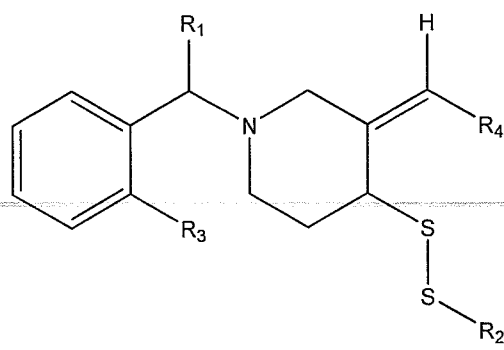
In another aspect, the present invention refers to pharmaceutical composition comprising an effective amount of the compound of the present invention, and a pharmaceutically acceptable carrier.

To overcome drawbacks associated with thienopyridine compounds (Clopidogrel (Plavix), ticlopidine (Ticlid) and prasugrel (Effient)), the present disclosure provides mixed disulfide conjugates of thienopyridine compounds. It is contemplated that such mixed disulfide conjugates of thienopyridine compounds of the present disclosure are capable of producing active thienopyridine metabolites (e.g., active thienopyridine metabolites capable of antiplatelet activity) in the presence of endogenous glutathione (GSH) without the need for bioactivation by P450s. This approach not only bypasses the oxidative bioactivation process by P450s, but circumvents many of the drawbacks associated with thienopyridinyl drugs. For example, it is contemplated that the mixed disulfide conjugates of thienopyridine compounds of the present disclosure improve dosing consistency because production of the active metabolite from the conjugates is predictable. In addition, it is contemplated that use of the mixed disulfide conjugates of thienopyridine compounds of the present disclosure as antiplatelet agents reduce the toxicity as toxic reactive metabolites will not be produced by the thiol-exchange reaction. In addition, the therapeutic onset time for the mixed disulfide

conjugates of thienopyridine compounds of the present disclosure is shortened, which greatly benefits patients who experience acute cardiovascular events. For example, the standard regimen for thienopyridines requires continuously dosing patients for 3-5 days as only a small percentage of ingested thienopyridines are converted to the active metabolite. In contrast, it is contemplated that the mixed disulfide conjugates of thienopyridine compounds of the present disclosure will release the active metabolites with high yields in less than 5 min. In addition, it is contemplated that the mixed disulfide conjugates of thienopyridine compounds of the present disclosure will have superior stability over the active metabolites and therefore can be used to quantitatively generate the active metabolites for basic and clinical research in vitro.

Accordingly, in certain examples, the present disclosure provides mixed disulfide conjugates of thienopyridine compounds capable of overcoming such drawbacks associated with thienopyridinyl compounds widely used as antiplatelet agents (e.g., Clopidogrel (Plavix), ticlopidine (Ticlid) and prasugrel (Effient)).

The present disclosure is not limited to particular mixed disulfide conjugates of thienopyridine compounds. In some examples, the mixed disulfide conjugates of thienopyridine compounds are described by Formula I:

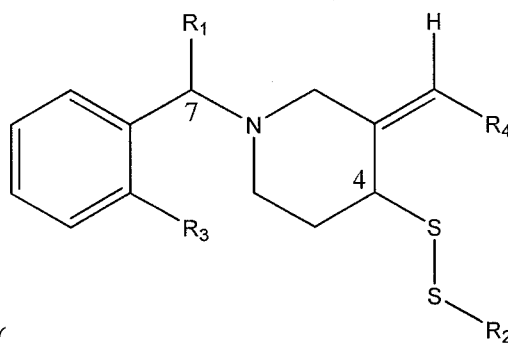


, including pharmaceutically acceptable salts, solvates, and/or prodrugs thereof, wherein R4 is selected from the group consisting of an ester moiety with an aliphatic and/or aromatic substituent, a ketone moiety with an aliphatic and/or aromatic substituent, and an amide moiety with an aliphatic and/or aromatic substituent.

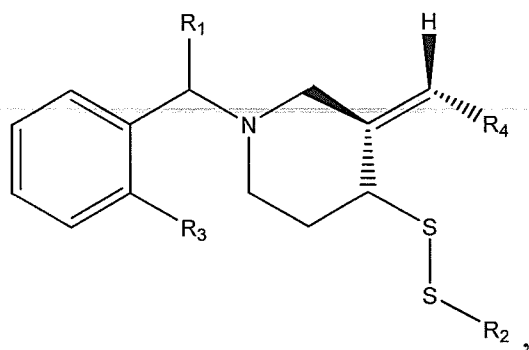
Formula I is not limited to a particular chemical moiety R1, R2, R3, and R4. In some examples, R1, R2, R3, and R4 each independently include any chemical moiety that renders the resulting compound capable of producing active thienopyridine metabolites upon interaction with endogenous glutathione (GSH) (e.g., active thienopyridine metabolites capable of antiplatelet activity). In some examples R1, R2, R3, and R4 each independently include any chemical moiety that renders the resulting compound capable of producing active thienopyridine metabolites in the presence of endogenous glutathione (GSH) without the need for bioactivation by P450s. In some examples, R1, R2, R3, and R4 each independently include any chemical moiety that renders the resulting compound capable of treating, ameliorating, or preventing cardiovascular disorders (e.g., coronary artery disease, peripheral vascular disease, and cerebrovascular disease) in a patient, such as those that are responsive to antiplatelet agents (such as clopidogrel, ticlopidine, and prasugrel). In some examples, R1,

R2, R3, and R4 each independently include any chemical moiety that renders the resulting compound capable of inhibiting platelet aggregation by, for example, altering the function of platelet membranes by blocking ADP receptors (e.g., thereby preventing a conformational change of glycoprotein IIb/IIIa which allows platelet binding to fibrinogen). In some examples, R1, R2, R3, and R4 each independently include any chemical moiety that renders the resulting compound capable of reducing aggregation ("clumping") of platelets by irreversibly binding to P2Y₁₂ receptors.

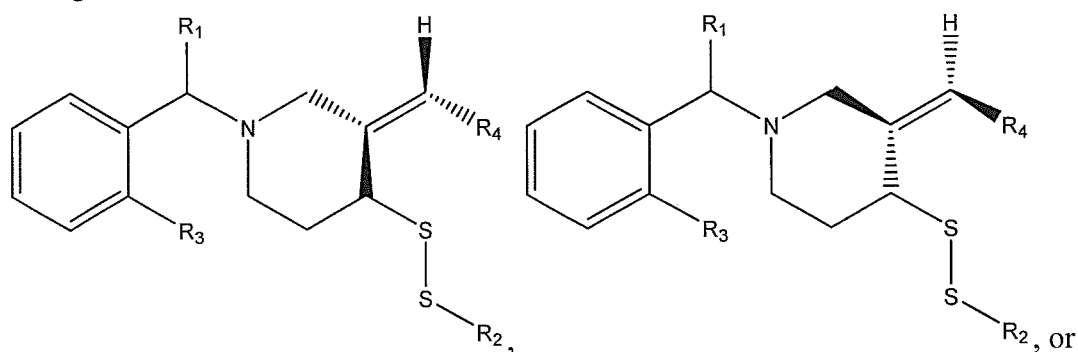
Such mixed disulfide conjugates are not limited to particular stereochemical

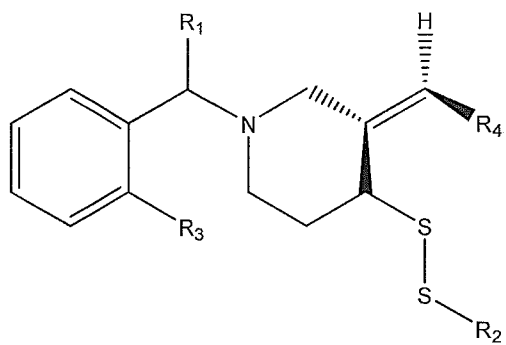


configurations within Formula I (configurations within Formula I (the double bond connected with the R4 substituent is either in a Z or cis configuration. For example, in some examples, Formula I is represented by any of the following stereochemical

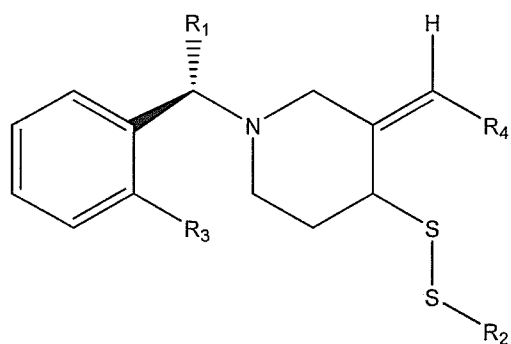


configurations:

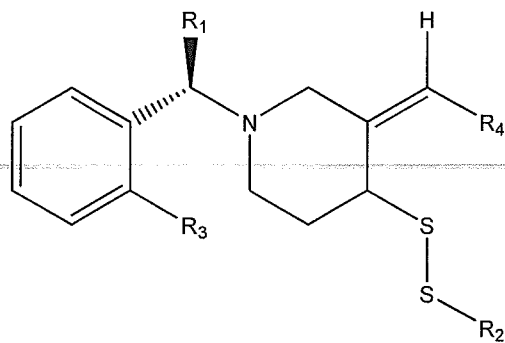




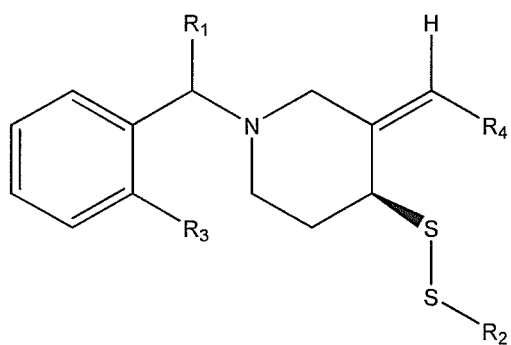
In some examples, the C7 carbon is either in a racemic, R or S configuration. For example, in some examples, Formula I is represented by



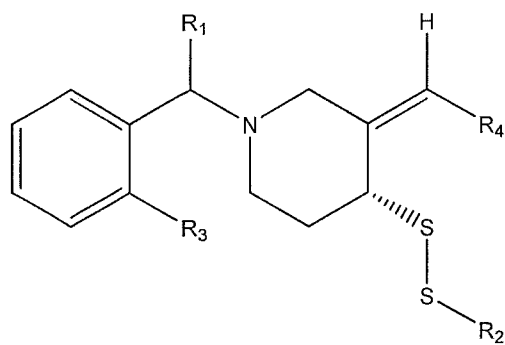
any of the following stereochemical configurations:



or
In some examples, the C7 carbon is either in a racemic, R or S configuration. For example, in some examples, Formula I is represented by

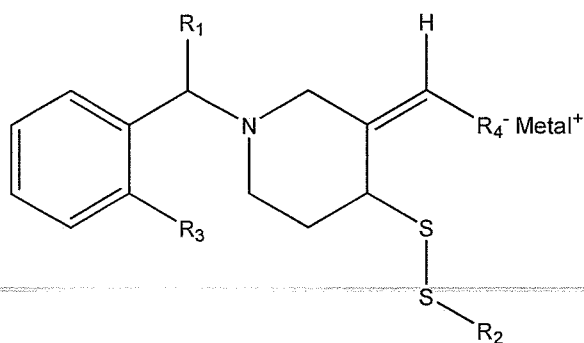


any of the following stereochemical configurations:

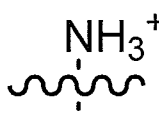


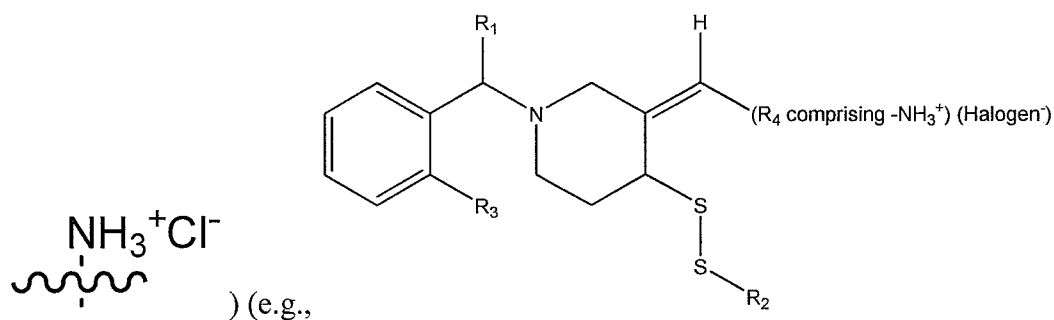
or
 within Formula I contains one or more stereochemical configurations for the double bond connected to R4 (e.g., Z or cis configuration), the C7 carbon (e.g., racemic, R or S configuration), and the C4 carbon (e.g., racemic, R or S configuration).

In some examples, the compound encompassed within Formula I is in a pharmaceutically acceptable salt form. For example, in some examples, the R4 substituent is engaged with an applicable metal to form a salt (e.g., Li, Na, K, etc) (e.g.,

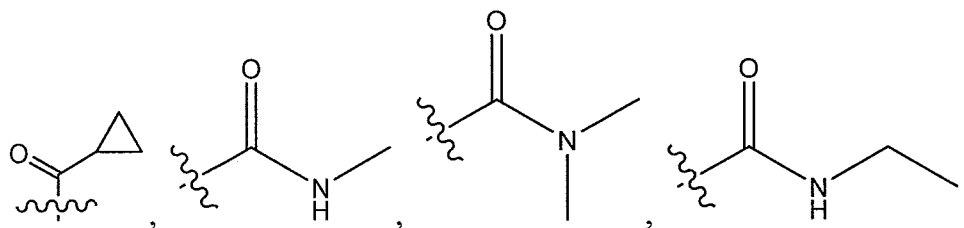


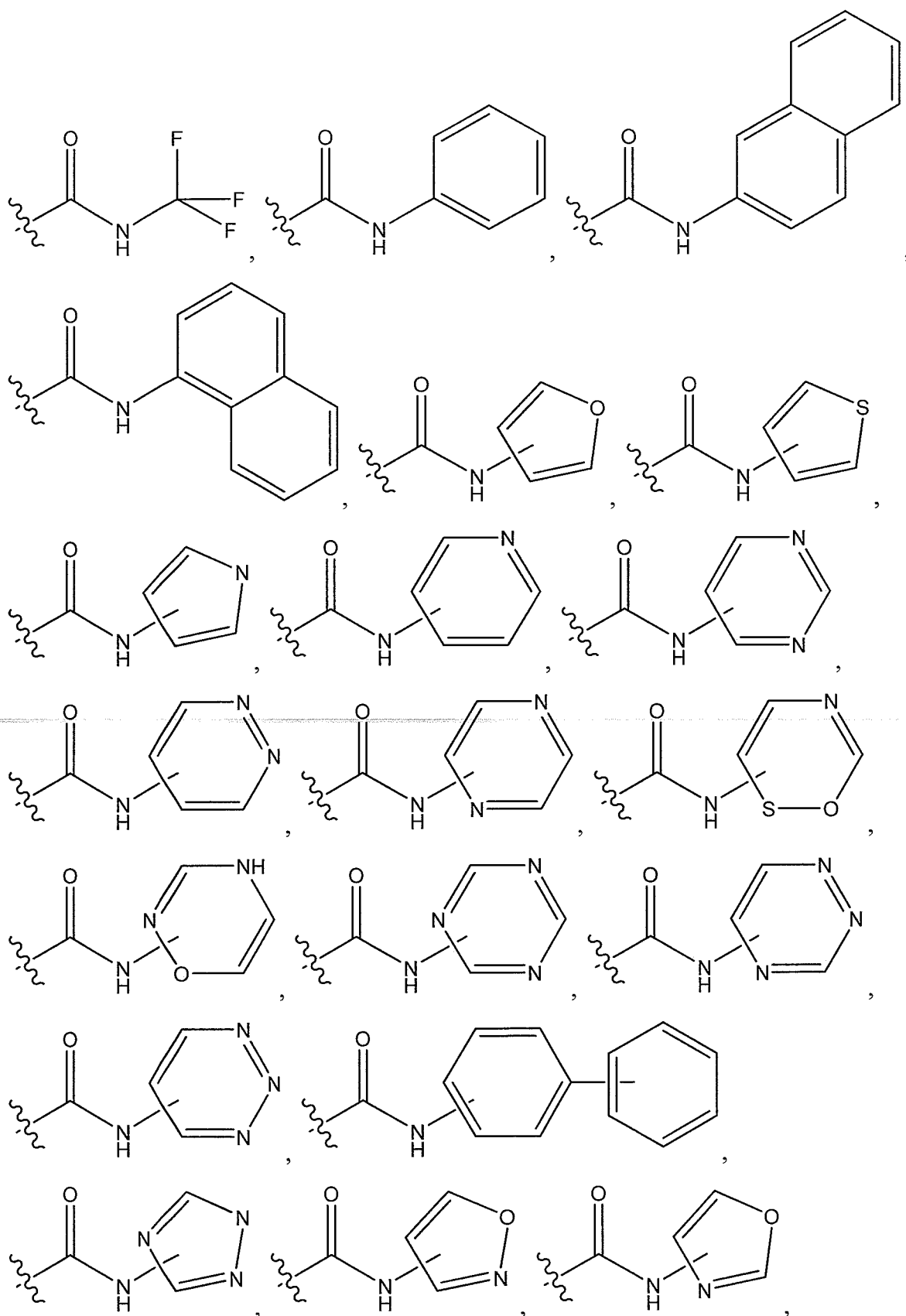
). For example, in some examples, the R4

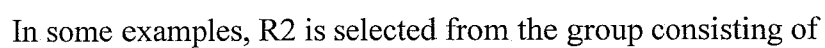
substituent has therein a Nitrogen moiety having a positive charge (e.g., ) which is engaged with a halogen (e.g., Cl⁻, Br⁻, I⁻, etc) thereby generating an ammonium salt (e.g.,



n some example, R1 is selected from the group consisting of H, -CO-OCH3,



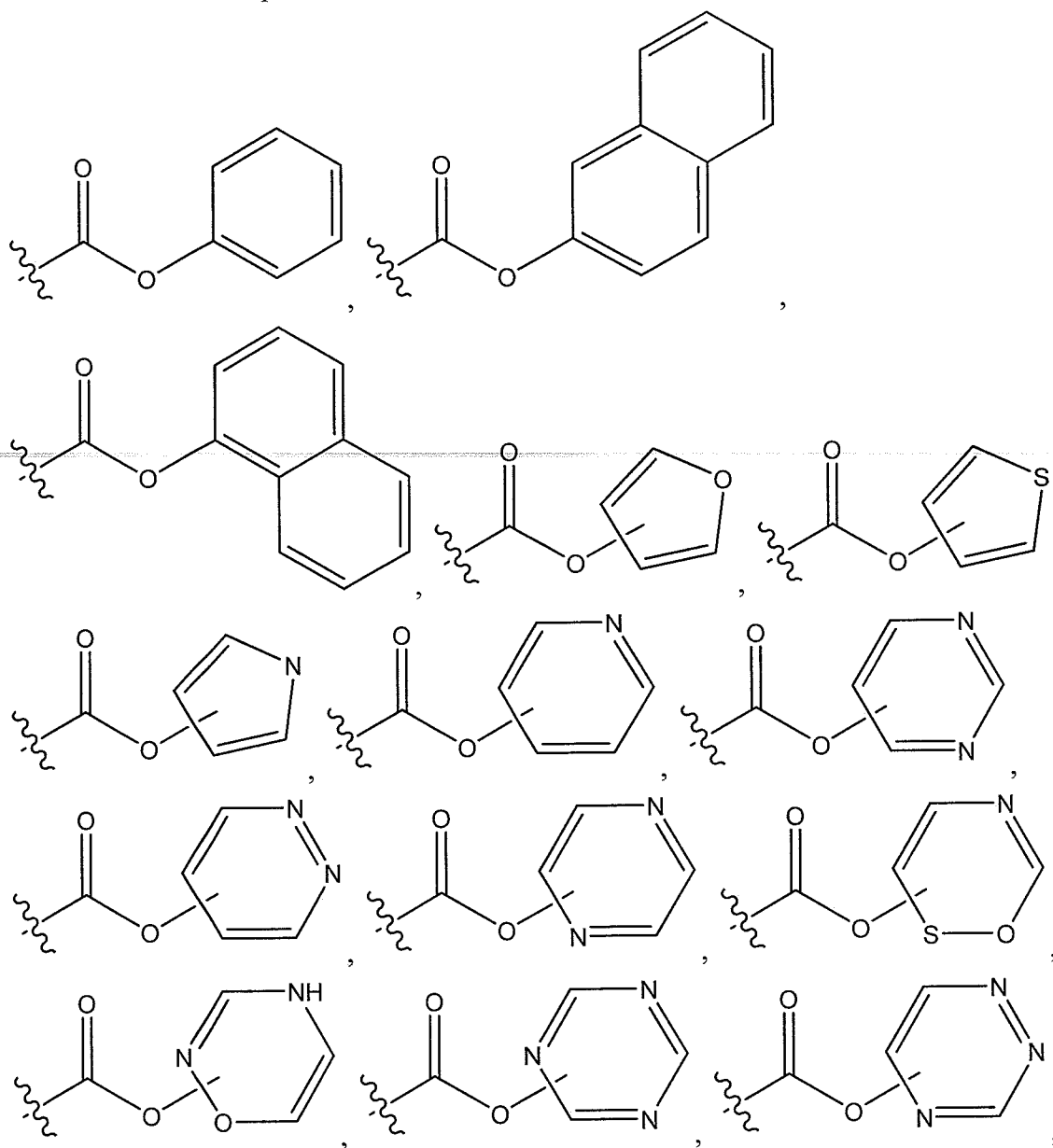


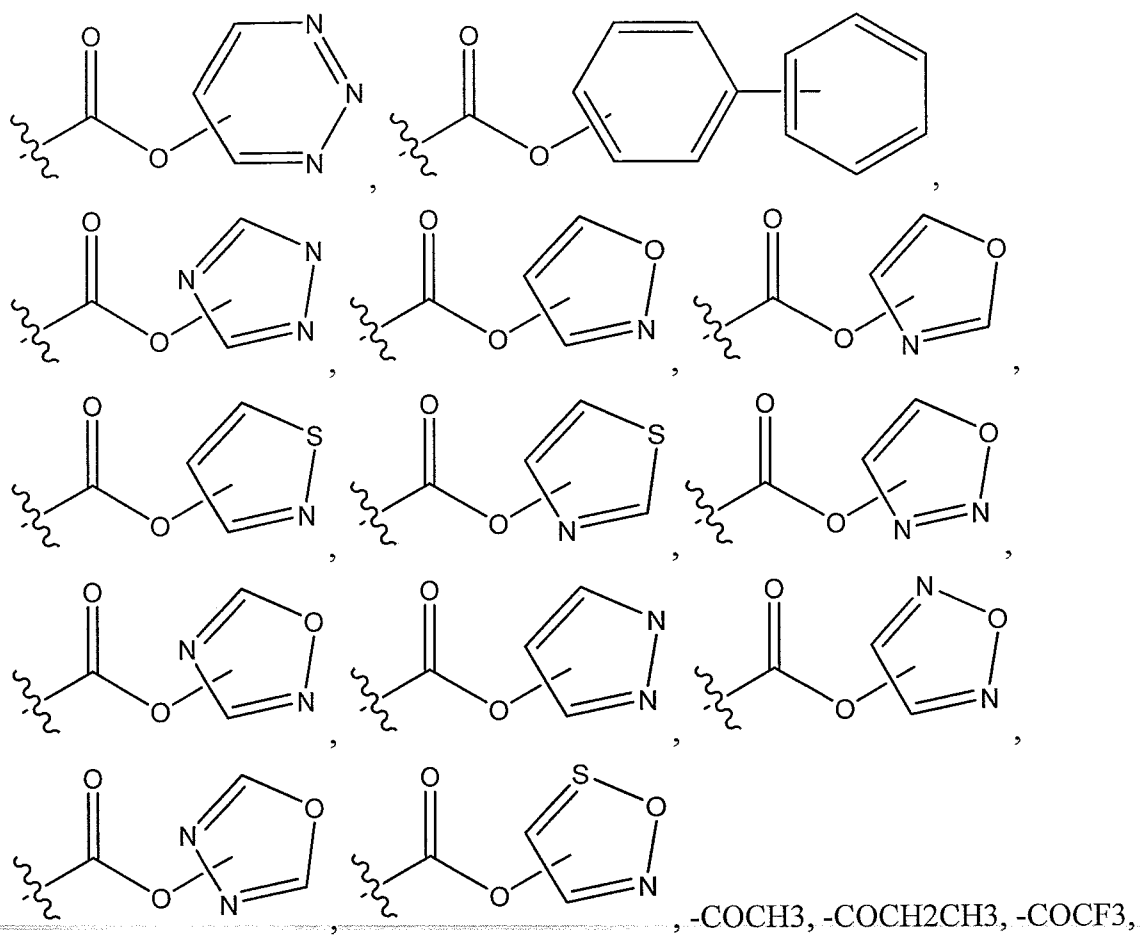


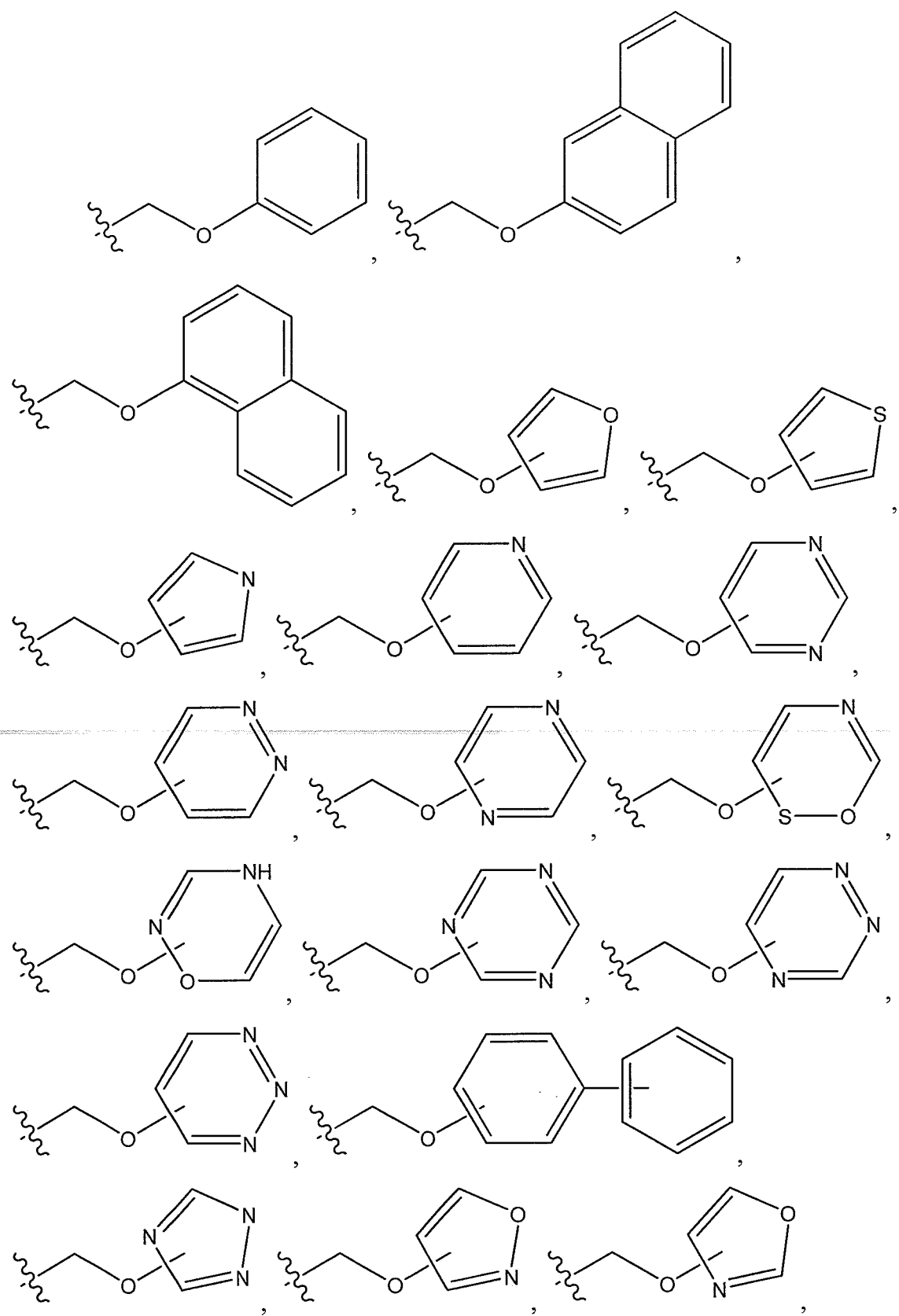
In some examples, R3 is an electron withdrawing group. In some examples, R3 is a halogen. In some examples, R3 is selected from Cl, Br, I, F, CN, NO₂, CF₃, H, OCH₃. In some examples, R3 is selected from a halogenated hydrocarbon group such as a trifluoromethyl group; a carboxyl group; an alkoxycarbonyl group such as a methoxycarbonyl group; an aryloxy carbonyl group such as a phenoxycarbonyl group; an acyl group such as an acetyl group; an acyloxy groups such as an acetoxy group; a cyano group; an aryl group; a 1-alkenyl group; a nitro group; a sulfo group; an alkanesulfonyl group; an alkanesulfinyl group; and an alkoxysulfonyl group.

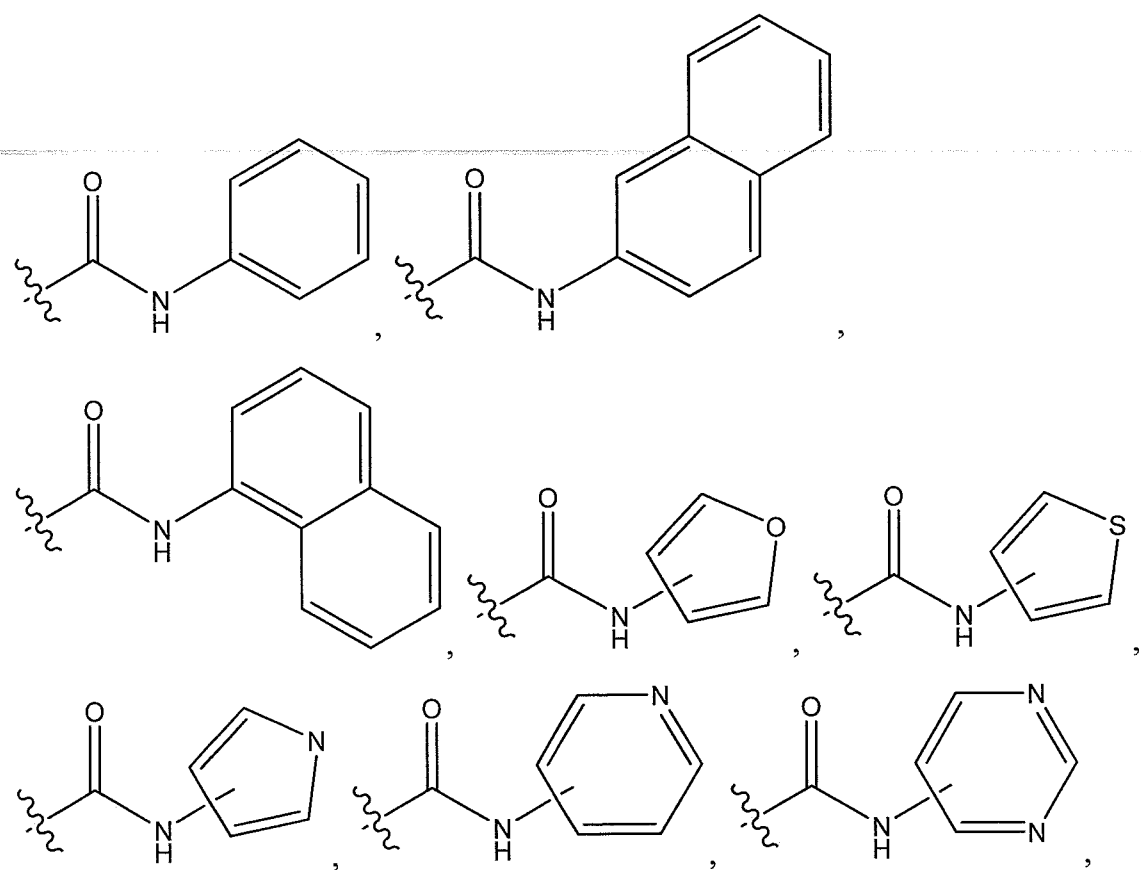
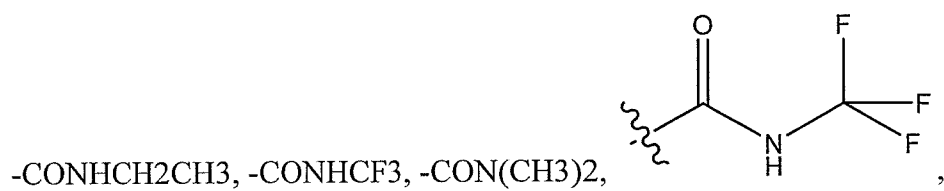
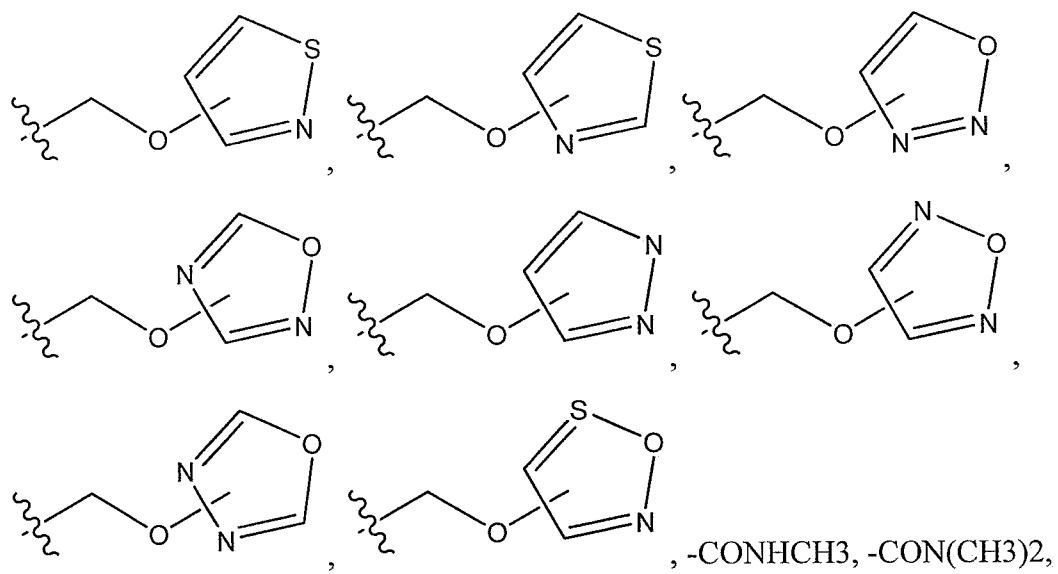
In some examples, R4 is any form of a salt.

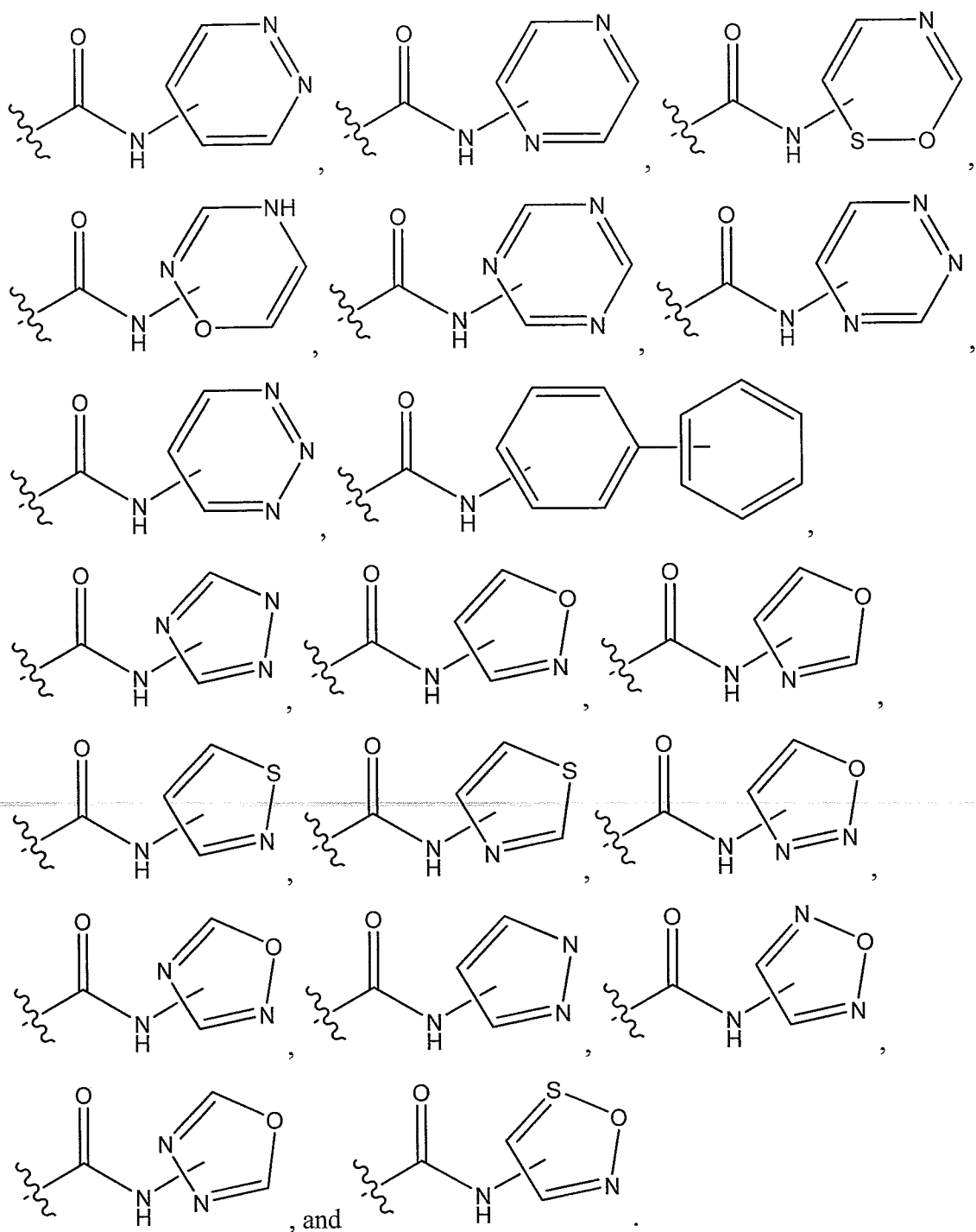
In some examples, R4 is selected from -COOCH₃, -COOCH₂CH₃, COOCF₃,











In some examples, the compounds encompassed within Formula I are stable in isolated form.

In some examples, the compounds are conjugated with a targeting moiety. For example, in some examples, the compounds are conjugated with an agent for targeting tumor cells. In some examples, the compounds are conjugated with antibodies that target tumor cells.

In certain examples, the present disclosure provides pharmaceutical compositions comprising a mixed disulfide conjugate of a thienopyridine compound and a pharmaceutically acceptable carrier.

In certain examples, the present disclosure provides pharmaceutical compositions comprising mixed disulfide conjugates of thienopyridine compounds configured for intravenous (IV) administration. In some examples, such pharmaceutical compositions comprising mixed disulfide conjugates of thienopyridine compounds configured for intravenous (IV) administration are used in the treatment, amelioration and prevention of atherothrombosis. In some examples, such pharmaceutical compositions comprising mixed disulfide conjugates of thienopyridine compounds configured for intravenous (IV) administration are used for rapid inhibition of platelet aggregation. In some examples, such pharmaceutical compositions comprising mixed disulfide conjugates of thienopyridine compounds configured for intravenous (IV) administration are used during percutaneous coronary intervention procedures (e.g., coronary angioplasty) for rapid inhibition of platelet aggregation.

In certain examples, the present disclosure provides methods of treating, ameliorating, or preventing a cardiovascular disease comprising administering to a patient a therapeutically effective amount of a mixed disulfide conjugate of a thienopyridine compound. In some examples, the administration is intravenous administration. In some examples, the cardiovascular disease is selected from the group consisting of coronary artery disease, peripheral vascular disease, and cerebrovascular disease. In some examples, the compound reduces aggregation of platelets (e.g., through irreversible binding to P2Y₁₂ receptors) (e.g., through blocking ADP receptors). In some examples, the compound is capable of producing active thienopyridine metabolites in the presence of endogenous glutathione without the need for bioactivation by P450s. In some examples, the methods further comprise co-administration of at least one agent selected from the group consisting of a HMG-CoA reductase inhibitor, an ACE Inhibitor, a Calcium Channel Blocker, a Platelet Aggregation Inhibitor, a Polyunsaturated Fatty Acid, Fibrin Acid Derivative, a Bile Acid Sequestrant, an Antioxidant, and an Antianginal Agent.

In certain examples, the present disclosure provides methods of treating, ameliorating, or preventing aggregation of platelets onto blood vessels in a patient, comprising administering to the patient a therapeutically effective amount of a mixed disulfide conjugate of a thienopyridine compound. In some examples, the administration is intravenous

administration. In some examples, the patient has or is at risk for developing cardiovascular disease (e.g., coronary artery disease, peripheral vascular disease, and cerebrovascular disease). In some examples, the treating, ameliorating, or preventing the aggregation of the platelets occurs through irreversible binding to P2Y₁₂ receptors. In some examples, the treating, ameliorating, or preventing the aggregation of the platelets occurs through blocking ADP receptors. In some examples, the mixed disulfide conjugate of thienopyridine compound is capable of producing active thienopyridine metabolites in the presence of endogenous glutathione without the need for bioactivation by P450s.

DEFINITIONS

The term “thienopyridine compound” as used herein, refers to a class of ADP receptor/P2Y₁₂ inhibitors used for their anti-platelet activity. Examples include, but are not limited to, clopidogrel (Plavix), ticlopidine (Ticlid), and Prasugrel (Effient).

The term “mixed disulfide conjugate of a thienopyridine compound” as used herein, refers to a modified thienopyridine compound capable of producing active thienopyridine metabolites upon interaction with endogenous glutathione (GSH).

The term “prodrug” as used herein, refers to a pharmacologically inactive derivative of a parent “drug” molecule that requires biotransformation (*e.g.*, either spontaneous or enzymatic) within the target physiological system to release, or to convert (*e.g.*, enzymatically, physiologically, mechanically, electromagnetically) the prodrug into the active drug. Prodrugs are designed to overcome problems associated with stability, water solubility, toxicity, lack of specificity, or limited bioavailability. Exemplary prodrugs comprise an active drug molecule itself and a chemical masking group (*e.g.*, a group that reversibly suppresses the activity of the drug). Some prodrugs are variations or derivatives of compounds that have groups cleavable under metabolic conditions. Prodrugs can be readily prepared from the parent compounds using methods known in the art, such as those described in A Textbook of Drug Design and Development, Krogsgaard-Larsen and H. Bundgaard (eds.), Gordon & Breach, 1991, particularly Chapter 5: "Design and Applications of Prodrugs"; Design of Prodrugs, H. Bundgaard (ed.), Elsevier, 1985; Prodrugs: Topical and Ocular Drug Delivery, K. B. Sloan (ed.), Marcel Dekker, 1998; Methods in Enzymology, K. Widder et al. (eds.), Vol. 42, Academic Press, 1985, particularly pp. 309-396; Burger's Medicinal Chemistry and Drug Discovery, 5th Ed., M. Wolff (ed.), John Wiley & Sons, 1995, particularly Vol. 1 and pp. 172-178 and pp. 949-982; Pro-Drugs as Novel Delivery Systems,

T. Higuchi and V. Stella (eds.), Am. Chem. Soc., 1975; and Bioreversible Carriers in Drug Design, E. B. Roche (ed.), Elsevier, 1987.

Exemplary prodrugs become pharmaceutically active *in vivo* or *in vitro* when they undergo solvolysis under physiological conditions or undergo enzymatic degradation or other biochemical transformation (*e.g.*, phosphorylation, hydrogenation, dehydrogenation, glycosylation). Prodrugs often offer advantages of water solubility, tissue compatibility, or delayed release in the mammalian organism. (*See e.g.*, Bundgard, Design of Prodrugs, pp. 7-9, 21-24, Elsevier, Amsterdam (1985); and Silverman, The Organic Chemistry of Drug Design and Drug Action, pp. 352-401, Academic Press, San Diego, CA (1992)). Common prodrugs include acid derivatives such as esters prepared by reaction of parent acids with a suitable alcohol (*e.g.*, a lower alkanol) or esters prepared by reaction of parent alcohol with a suitable carboxylic acid, (*e.g.*, an amino acid), amides prepared by reaction of the parent acid compound with an amine, basic groups reacted to form an acylated base derivative (*e.g.*, a lower alkylamide), or phosphorus-containing derivatives, *e.g.*, phosphate, phosphonate, and phosphoramidate esters, including cyclic phosphate, phosphonate, and phosphoramidate (*see, e.g.*, US Patent Application Publication No. US 2007/0249564 A1).

The term "pharmaceutically acceptable salt" as used herein, refers to any salt (*e.g.*, obtained by reaction with an acid or a base) of a compound of the present disclosure that is physiologically tolerated in the target animal (*e.g.*, a mammal). Salts of the compounds of the present disclosure may be derived from inorganic or organic acids and bases. Examples of acids include, but are not limited to, hydrochloric, hydrobromic, sulfuric, nitric, perchloric, fumaric, maleic, phosphoric, glycolic, lactic, salicylic, succinic, toluene-p-sulfonic, tartaric, acetic, citric, methanesulfonic, ethanesulfonic, formic, benzoic, malonic, sulfonic, naphthalene-2-sulfonic, benzenesulfonic acid, and the like. Other acids, such as oxalic, while not in themselves pharmaceutically acceptable, may be employed in the preparation of salts useful as intermediates in obtaining the compounds of the disclosure and their pharmaceutically acceptable acid addition salts.

Examples of bases include, but are not limited to, alkali metal (*e.g.*, sodium) hydroxides, alkaline earth metal (*e.g.*, magnesium) hydroxides, ammonia, and compounds of formula NW_4^+ , wherein W is C_{1-4} alkyl, and the like.

Examples of salts include, but are not limited to: acetate, adipate, alginate, aspartate, benzoate, benzenesulfonate, bisulfate, butyrate, citrate, camphorate, camphorsulfonate, cyclopentanepropionate, digluconate, dodecylsulfate, ethanesulfonate, fumarate,

flucoheptanoate, glycerophosphate, hemisulfate, heptanoate, hexanoate, chloride, bromide, iodide, 2-hydroxyethanesulfonate, lactate, maleate, mesylate, methanesulfonate, 2-naphthalenesulfonate, nicotinate, oxalate, palmoate, pectinate, persulfate, phenylpropionate, picrate, pivalate, propionate, succinate, tartrate, thiocyanate, tosylate, undecanoate, and the like. Other examples of salts include anions of the compounds of the present disclosure compounded with a suitable cation such as Na^+ , NH_4^+ , and NW_4^+ (wherein W is a C_{1-4} alkyl group), and the like. For therapeutic use, salts of the compounds of the present disclosure are contemplated as being pharmaceutically acceptable. However, salts of acids and bases that are non-pharmaceutically acceptable may also find use, for example, in the preparation or purification of a pharmaceutically acceptable compound.

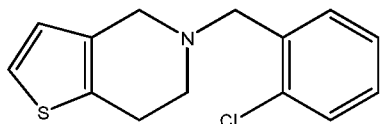
The term "solvate" as used herein, refers to the physical association of a compound of the disclosure with one or more solvent molecules, whether organic or inorganic. This physical association often includes hydrogen bonding. In certain instances, the solvate is capable of isolation, for example, when one or more solvate molecules are incorporated in the crystal lattice of the crystalline solid. "Solvate" encompasses both solution-phase and isolable solvates. Exemplary solvates include hydrates, ethanolates, and methanolates.

The term "therapeutically effective amount," as used herein, refers to that amount of the therapeutic agent sufficient to result in amelioration of one or more symptoms of a disorder, or prevent advancement of a disorder, or cause regression of the disorder. For example, with respect to the treatment and/or prevention of platelet aggregation onto a blood vessel, in one example, a therapeutically effective amount will refer to the amount of a therapeutic agent (e.g., a mixed disulfide conjugate of a thienopyridine compound) that decreases the reduces and/or prevents platelet aggregation by at least 5%, at least 10%, at least 15%, at least 20%, at least 25%, at least 30%, at least 35%, at least 40%, at least 45%, at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, or at least 100%.

The term "pharmaceutically acceptable carrier" or "pharmaceutically acceptable vehicle" encompasses any of the standard pharmaceutical carriers, solvents, surfactants, or vehicles. Suitable pharmaceutically acceptable vehicles include aqueous vehicles and nonaqueous vehicles. Standard pharmaceutical carriers and their formulations are described in Remington's Pharmaceutical Sciences, Mack Publishing Co., Easton, PA, 19th ed. 1995.

DETAILED DESCRIPTION OF THE INVENTION

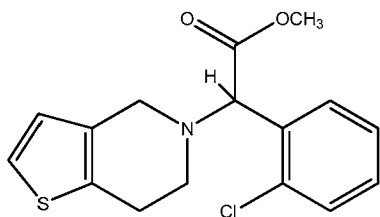
Thienopyridinyl antiplatelet agents include three clinically used drugs, clopidogrel (Plavix), ticlopidine (Ticlid), and prasugrel (Effient). Their chemical structures and IUPAC names for clopidogrel (Plavix), ticlopidine (Ticlid), and prasugrel (Effient) are as follows:



(ticlopidine; 5-(2-chlorobenzyl)-4,5,6,7-tetrahydrothieno[3,2-

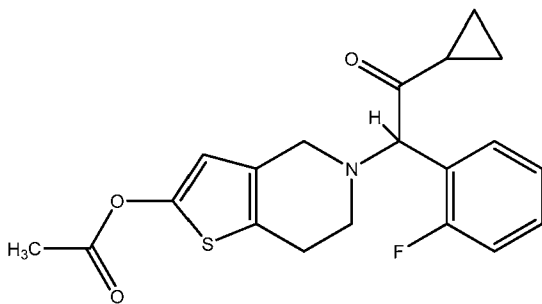
5

c]pyridine),



(clopidogrel; (+)-(S)-methyl 2-(2-chlorophenyl)-

2-(6,7-dihydrothieno[3,2-c]pyridine-5(4H)-yl)acetate), and



(prasugrel; (RS)-5-[2-cyclopropyl-1-(2-

fluorophenyl)-2-oxoethyl]-4,5,6,7-tetrahydrothieno[3,2-c]pyridine-2-yl acetate).

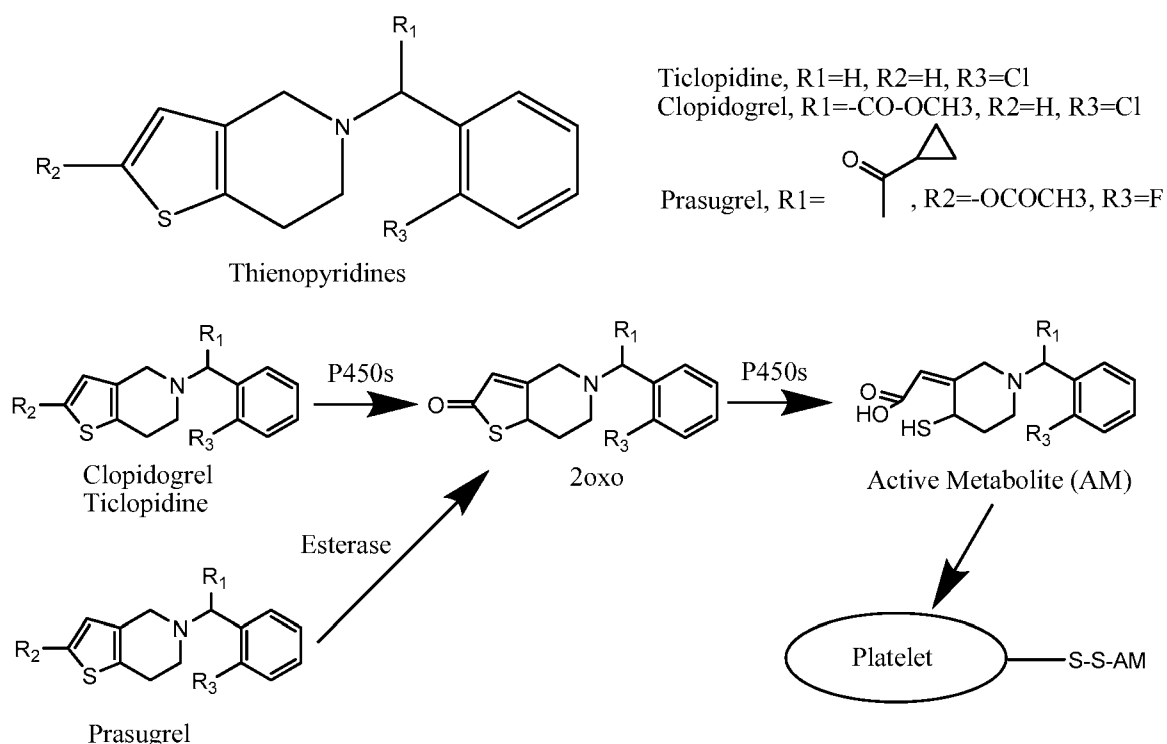
Thienopyridinyl antiplatelet agents are widely used to treat patients with acute cardiovascular syndromes and peripheral vascular diseases, particularly among those undergoing percutaneous coronary intervention (e.g., coronary angioplasty) to prevent heart attack and stroke. Nearly two million patients receive coronary and carotid stents every year in the United States and the annual sales for Plavix alone was worth \$6.5 billion in 2010.

In spite of widespread use, clopidogrel has shown significant inter-individual variability in its efficacy (see, e.g., Freedman JE and Hylek EM (2009) *New Engl J Med* 360(4):411-413; Gurbel PA and Tantry US (2007) *Thromb Res* 120(3):311-321; Sofi F, et al., (2011) *Pharmacogenomics J* 11(3):199-206). Nearly one-third of patients do not respond to clopidogrel therapy (see, e.g., Mason PJ, Jacobs AK and Freedman JE (2005) *J Am Coll Cardiol* 46(6):986-993). A large number of studies have been carried out attempting to identify genetic markers that correlate with the lack of response with the aim of overcoming this inter-individual variability. It has been shown that clopidogrel is less effective in patients who carry the mutant *CYP2C19*2* gene (see, e.g., Dick RJ, Dear AE and Byron KA (2011)

Heart Lung Circ 20(10):657-658; Shuldiner AR, et al., (2009) JAMA 302(8):849-857; Sofi F, et al., (2011) Pharmacogenomics J 11(3):199-206). However the *CYP2C19**2 mutant gene accounts for only 12% of the variations in response (see, e.g., Shuldiner AR, et al., (2009) JAMA 302(8):849-857). Other factors are likely involved, but have not been identified.

5 Indeed, though widely used as antiplatelet agents, there are drawbacks associated with thienopyridinyl antiplatelet agents. A major shortcoming for clopidogrel is a dosing inconsistency. For example, nearly one-third of patients do not respond to clopidogrel treatment. Ticlopidine can cause a series of adverse effects ranging from moderate symptoms of skin rashes and diarrhea to severe and sometimes fatal ones such as neutropenia and bone
10 marrow aplasia. In rare cases it causes severe idiosyncratic events of agranulocytosis. Excessive bleeding has been associated with the use of prasugrel, particularly in older patients.

 Such drawbacks associated with thienopyridinyl antiplatelet agents are closely related to the fact that these three drugs are all prodrugs that require oxidative bioactivation to the
15 active metabolite (AM) by polymorphic cytochromes P450 (P450s) as illustrated in Scheme 1. Because of this oxidative bioactivation process, the amount of the active metabolite produced by P450s varies with the genetic makeup of each patient's hepatic P450s. Furthermore, these drugs are extensively metabolized by P450s to produce multiple metabolites, some of which are highly reactive and potentially toxic. It has been reported that
20 the severe idiosyncratic events due to ticlopidine are associated with the production of reactive metabolites.

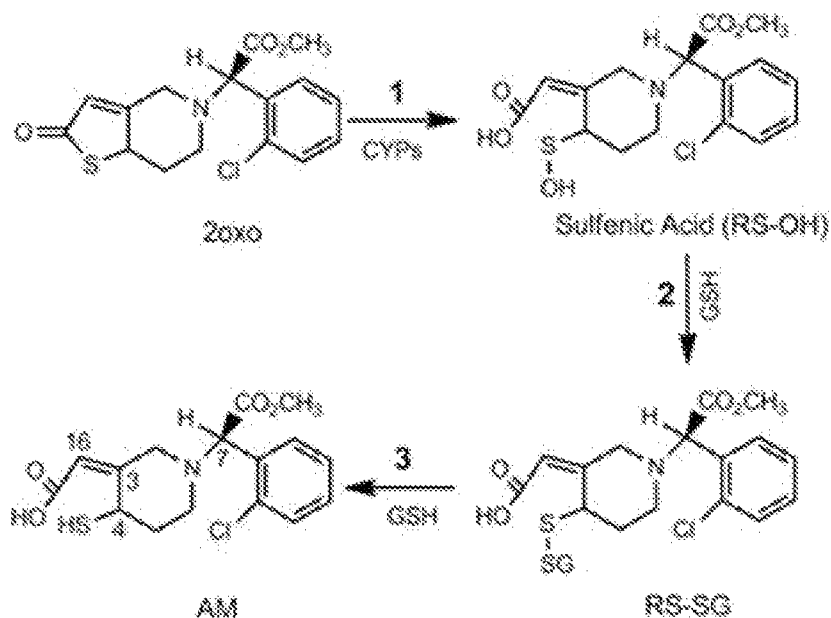


Scheme 1.

As noted, the variable response to clopidogrel therapy is closely related to the fact that clopidogrel is a prodrug that requires oxidative bioactivation by cytochromes P450 (P450s) to its pharmacologically active metabolite (AM) (see, e.g., Kazui M, et al., (2010) Drug Metab Dispos 38(1):92-99; Savi P, et al., (2000) Thromb Haemost 84(5):891-896). It is well documented that P450-mediated bioactivation involves two consecutive oxidative steps (see, e.g., Dansette PM, Thebault S, Bertho G and Mansuy D (2010) Chem Res Toxicol 23(7):1268-1274; Dansette PM, Rosi J, Bertho G and Mansuy D (2012) Chem Res Toxicol 25(2):348-356); clopidogrel is first monooxygenated to 2-oxoclopidogrel, which is in turn oxidized to the AM in the second step. Although it has been argued that esterase PON1 is responsible for converting 2-oxoclopidogrel to the AM (see, e.g., Bouman HJ, et al., (2011) Nat Med 17(1):110-116), increasing evidence supports the idea that 2-oxoclopidogrel is converted to the AM via a sulfenic acid intermediate (see, e.g., Dansette PM, Libraire J, Bertho G and Mansuy D (2009) Chem Res Toxicol 22(2):369-373; Dansette PM, Rosi J, Bertho G and Mansuy D (2012) Chem Res Toxicol 25(2):348-356; Dansette PM, Rosi J, Debernardi J, Bertho G and Mansuy D (2012) Chem Res Toxicol 25(5):1058-1065; Dansette

PM, Thebault S, Bertho G and Mansuy D (2010) Chem Res Toxicol 23(7):1268-1274), as illustrated in Scheme 2.

Scheme 2

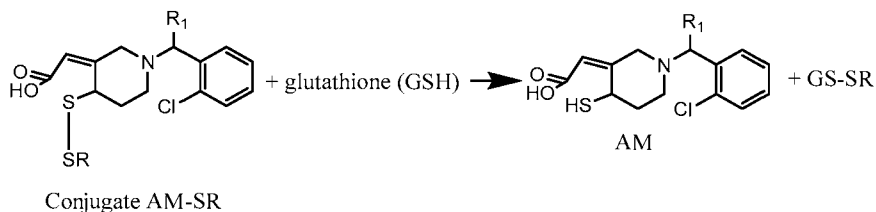


According to Scheme 2, 2-oxoclopidogrel is first oxidized to a sulfenic acid intermediate by P450s. The highly unstable sulfenic acid is then rapidly reduced by glutathione (GSH) to form a mixed disulfide conjugate (RS-SG) that is subsequently reduced by another GSH molecule to form the AM. This is consistent with the observation that GSH is required for the formation of the AM in human liver microsomes (HLMs) (see, e.g., Kazui M, et al., (2010) Drug Metab Dispos 38(1):92-99). It is widely accepted that the AM is responsible for inhibition of platelet aggregation through covalent modification of platelet P2Y₁₂ receptor (see, e.g., Ding Z, et al., (2003) Blood 101(10):3908-3914; Algaier I, et al., (2008) J Thromb Haemost 6(11):1908-1914). The anti-platelet activity of the mixed disulfide conjugate RS-SG remains untested.

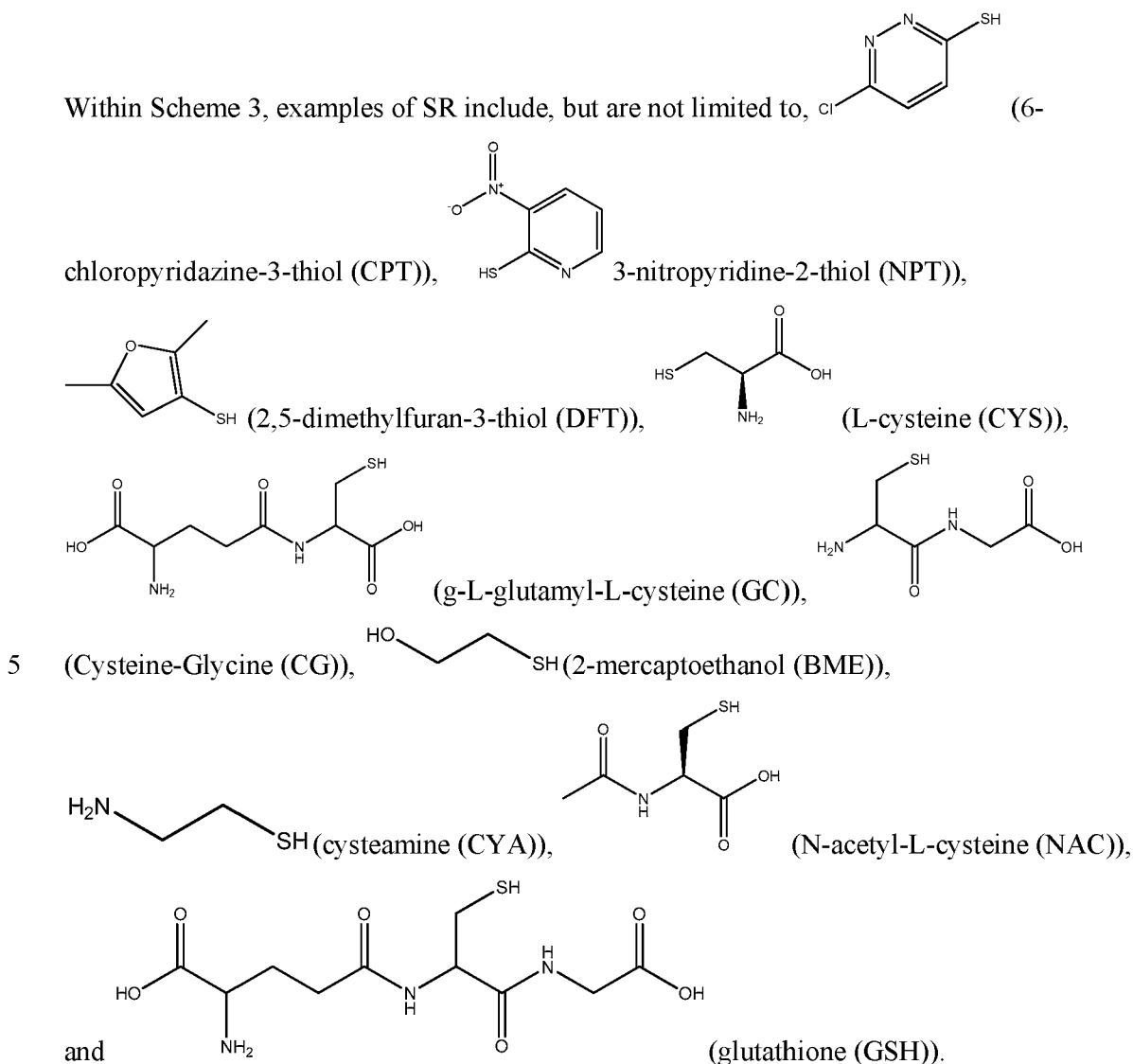
Metabolism of 2-oxoclopidogrel in the presence of N-acetyl-L-cysteine (NAC) and L-cysteine leads to the formation of both the AM and mixed disulfide conjugates (see, e.g., Zhang H, Lau WC and Hollenberg PF (2012) Mol Pharmacol 82:302-309). In addition, it was demonstrated that the mixed disulfide conjugates of NAC and L-cysteine exchange thiols with GSH and that the equilibrium between the AM, the AM conjugate and GSH is governed

by their redox potentials. The redox potential of the sulfenic acid intermediate is likely to be high because it is a reactive oxidant.

To overcome drawbacks associated with thienopyridine compounds, mixed disulfide conjugates of thienopyridine compounds were developed. It is contemplated that the mixed disulfide conjugates of thienopyridine compounds of the present invention are capable of producing active metabolites in the presence of endogenous glutathione (GSH) without the need for bioactivation by P450s, as illustrated in Scheme 3. It is contemplated that this approach will not only bypasses the oxidative bioactivation process by P450s, but will circumvent many of the drawbacks of the thienopyridinyl drugs. For example, it is contemplated that the mixed disulfide conjugates of thienopyridine compounds of the present invention will improve dosing consistency because production of the active metabolite from the conjugates is predictable. In addition, it is contemplated that use of the mixed disulfide conjugates of thienopyridine compounds of the present invention as antiplatelet agents will reduce the toxicity because toxic reactive metabolites are not produced by the thiol-exchange reaction. In addition, it is contemplated that the therapeutic onset time for the mixed disulfide conjugates of thienopyridine compounds of the present invention will be shortened, which greatly benefits patients who experience acute cardiovascular events. The standard regimen for thienopyridines requires continuously dosing patients for 3-5 days because only a small percentage of ingested thienopyridines are converted to the active metabolite. In contrast, it is contemplated that the mixed disulfide conjugates of thienopyridine compounds of the present invention can release the active metabolites with high yields in less than 30 min. In addition, it is contemplated that the mixed disulfide conjugates of thienopyridine compounds of the present invention will have superior stability over the active metabolites and therefore they can be used to quantitatively generate the active metabolites for basic and clinical research in vitro.



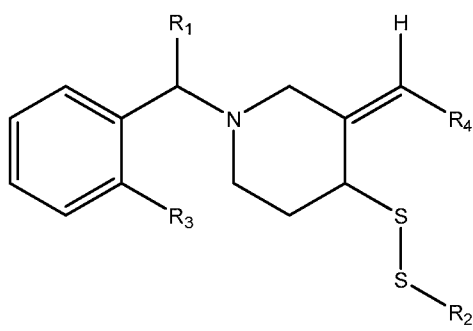
Scheme 3.



Accordingly, the present invention relates to mixed disulfide conjugates of thienopyridine compounds which are capable of producing active thienopyridine metabolites in the presence of endogenous glutathione (GSH) without the need for bioactivation by P450s. The invention further relates to methods of treating, ameliorating, or preventing cardiovascular disorders in a patient, such as those that are responsive to antiplatelet agents (such as clopidogrel, ticlopidine, and prasugrel) comprising administering to a patient a mixed disulfide conjugate of a thienopyridine compound of the invention. Such disorders include, but are not limited to, coronary artery disease, peripheral vascular disease, and cerebrovascular disease. In some embodiments, the mixed disulfide conjugates of thienopyridine compounds are used to inhibit platelet aggregation by, for example, altering the function of platelet membranes by blocking ADP receptors (e.g., thereby preventing a

conformational change of glycoprotein IIb/IIIa which allows platelet binding to fibrinogen). In some embodiments, the mixed disulfide conjugates of thienopyridine compounds reduce aggregation ("clumping") of platelets by irreversibly binding to P2Y₁₂ receptors. In some
5 embodiments, the mixed disulfide conjugates of thienopyridine compounds are used within pharmaceutical compositions configured for intravenous (IV) administration (e.g., in medical situations requiring IV administration of antiplatelet agents (e.g., coronary angioplasty)).

The present invention is not limited to particular mixed disulfide conjugates of thienopyridine compounds. In some embodiments, the mixed disulfide conjugates of thienopyridine compounds are described by Formula I:

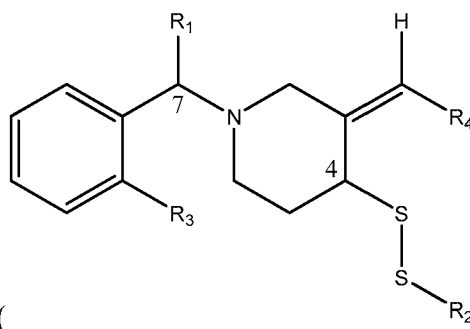


10 R₂, including pharmaceutically acceptable salts, solvates, and/or prodrugs thereof, wherein R₄ is selected from the group consisting of an ester moiety with an aliphatic and/or aromatic substituent, a ketone moiety with an aliphatic and/or aromatic substituent, and an amide moiety with an aliphatic and/or aromatic substituent..

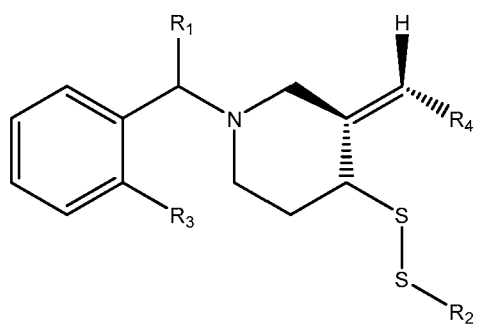
Formula I is not limited to a particular chemical moiety R₁, R₂, R₃, and R₄. In some
15 embodiments, R₁, R₂, R₃, and R₄ each independently include any chemical moiety that renders the resulting compound capable of producing active thienopyridine metabolites upon interaction with endogenous glutathione (GSH) (e.g., active thienopyridine metabolites capable of antiplatelet activity). In some embodiments R₁, R₂, R₃, and R₄ each
20 independently include any chemical moiety that renders the resulting compound capable of producing active thienopyridine metabolites in the presence of endogenous glutathione (GSH) without the need for bioactivation by P450s. In some embodiments, R₁, R₂, R₃, and R₄ each
25 independently include any chemical moiety that renders the resulting compound capable of treating, ameliorating, or preventing cardiovascular disorders (e.g., coronary artery disease, peripheral vascular disease, and cerebrovascular disease) in a patient, such as those that are responsive to antiplatelet agents (such as clopidogrel, ticlopidine, and prasugrel). In some
embodiments, R₁, R₂, R₃, and R₄ each independently include any chemical moiety that renders the resulting compound capable of inhibiting platelet aggregation by, for example,

- altering the function of platelet membranes by blocking ADP receptors (e.g., thereby preventing a conformational change of glycoprotein IIb/IIIa which allows platelet binding to fibrinogen). In some embodiments, R₁, R₂, R₃, and R₄ each independently include any chemical moiety that renders the resulting compound capable of reducing aggregation
- 5 ("clumping") of platelets by irreversibly binding to P₂Y₁₂ receptors.

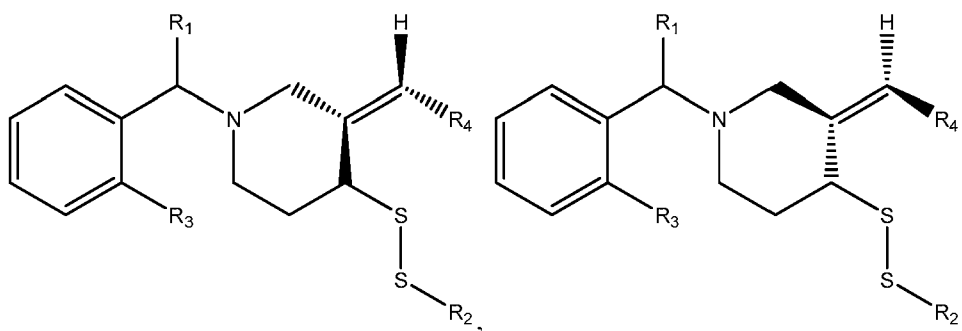
Such mixed disulfide conjugates are not limited to particular stereochemical

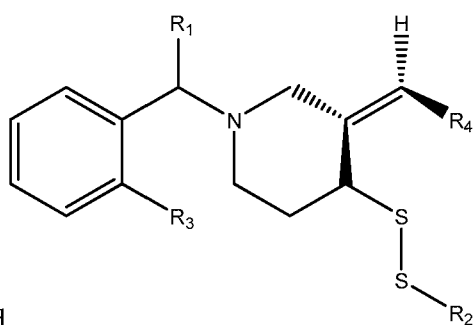


configurations within Formula I (embodiments, the double bond connected with the R₄ substituent is either in a Z or cis configuration. For example, in some embodiments, Formula I is represented by any of the

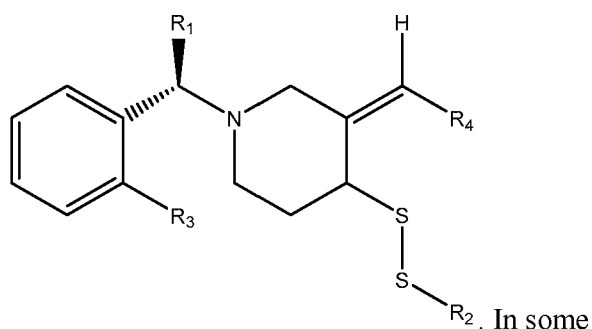
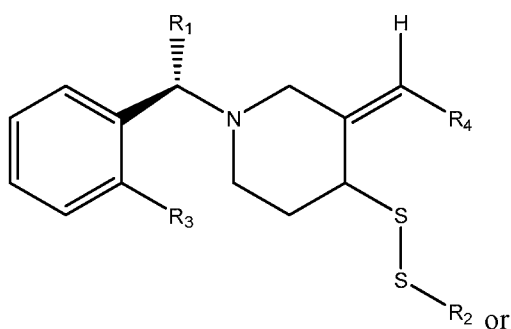


- 10 following stereochemical configurations:

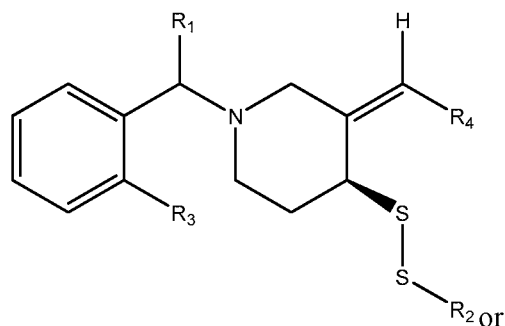




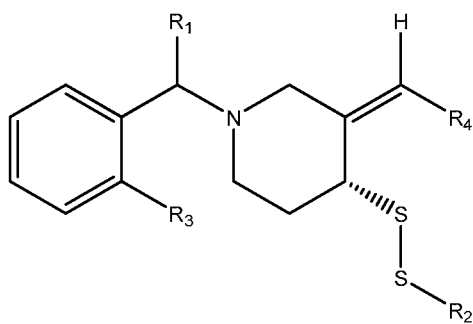
and
 racemic, R or S configuration. For example, in some embodiments, Formula I is represented by any of the following stereochemical configurations:



5 In some embodiments, the C7 carbon is either in a racemic, R or S configuration. For example, in some embodiments, Formula I is represented by any of the following stereochemical

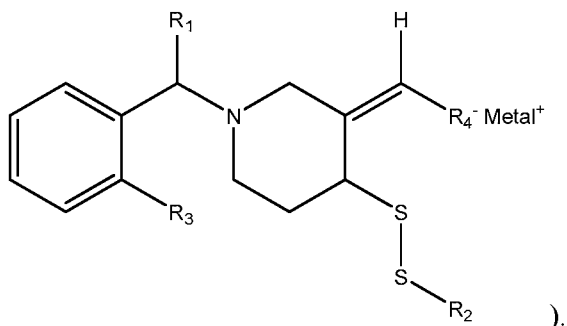


configurations:

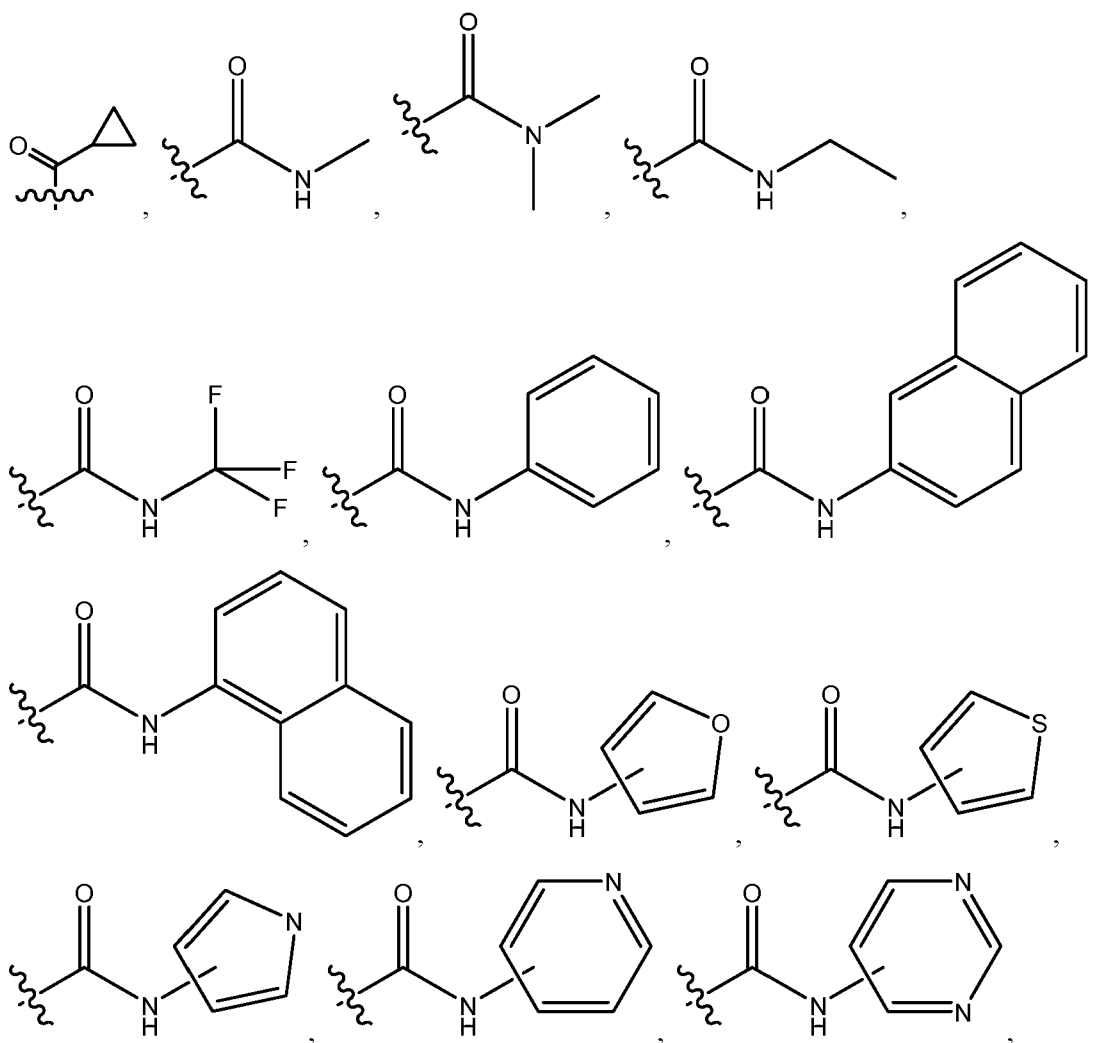


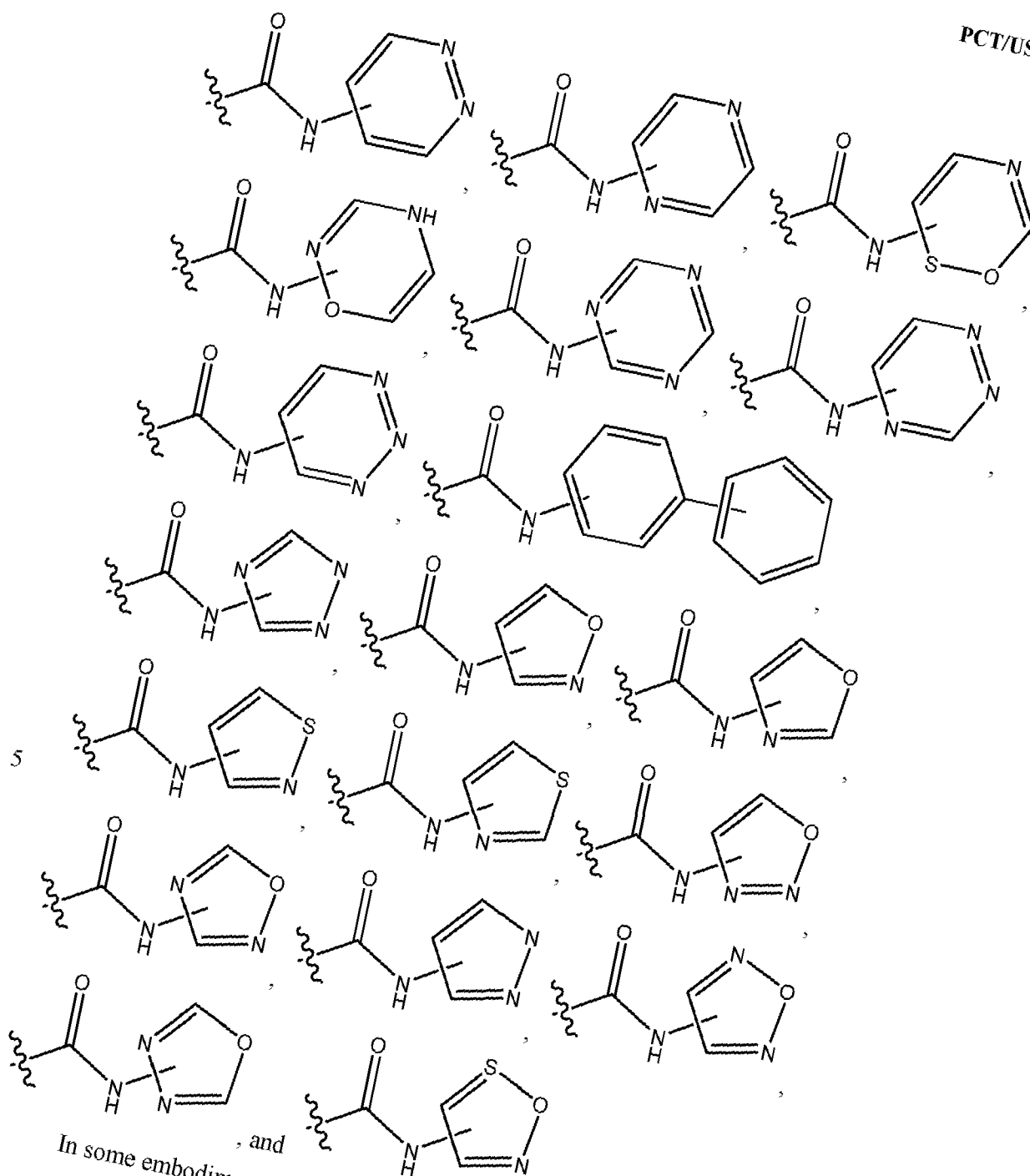
within Formula I contains one or more stereochemical configurations for the double bond
 10 connected to R4 (e.g., Z or cis configuration), the C7 carbon (e.g., racemic, R or S
 configuration), and the C4 carbon (e.g., racemic, R or S configuration).

In some embodiments, the compound encompassed within Formula I is in a pharmaceutically acceptable salt form. For example, in some embodiments, the R₄ substituent is engaged with an applicable metal to form a salt (e.g., Li, Na, K, etc) (e.g.,

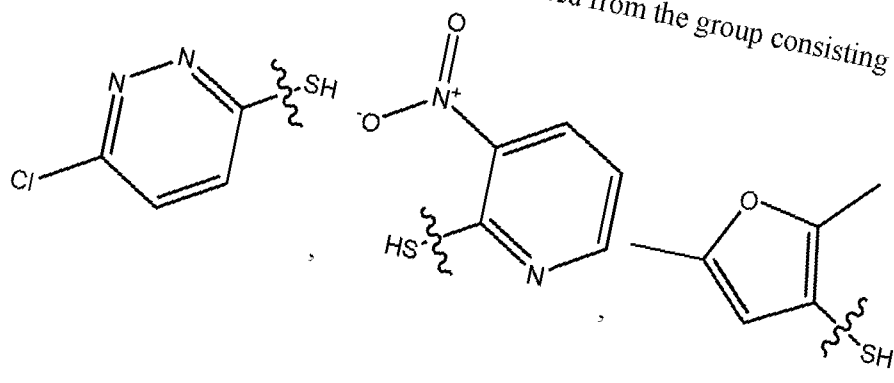


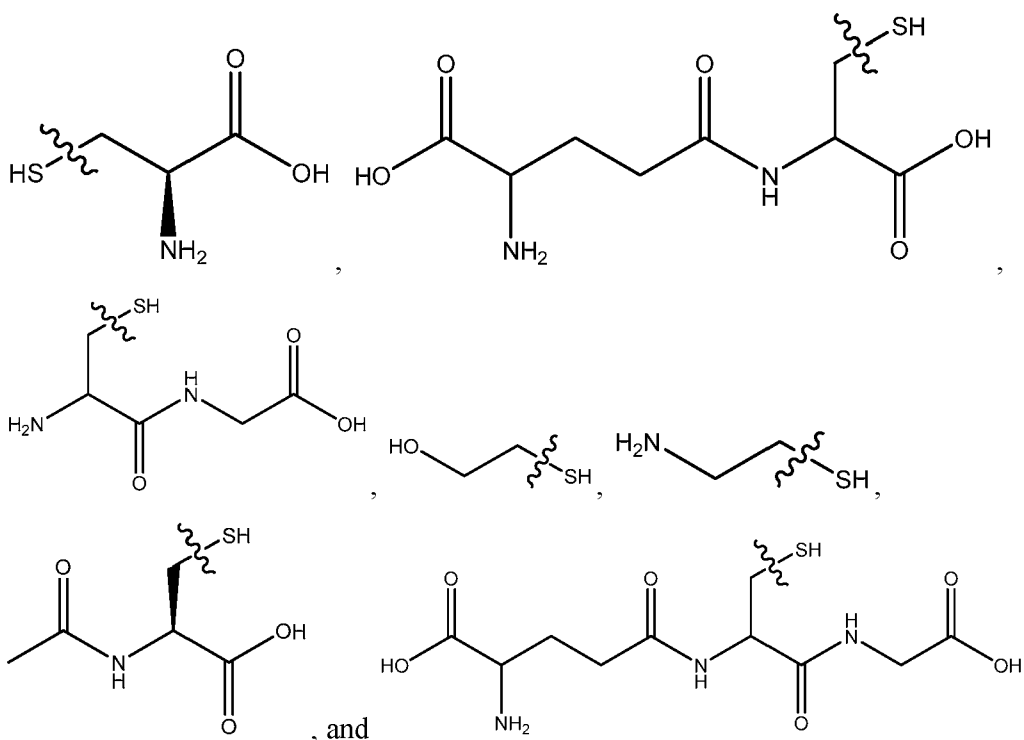
5 In some embodiment, R₁ is selected from the group consisting of H, -CO-OCH₃,





In some embodiments, R2 is selected from the group consisting of



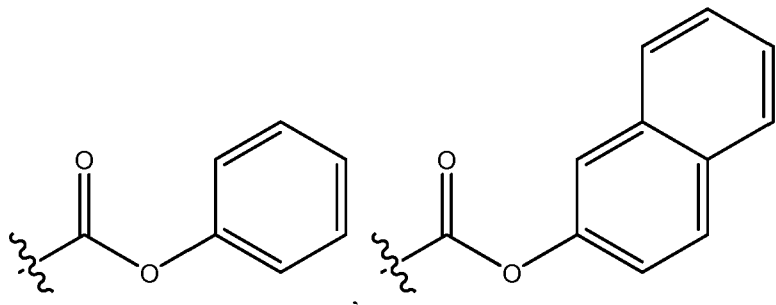


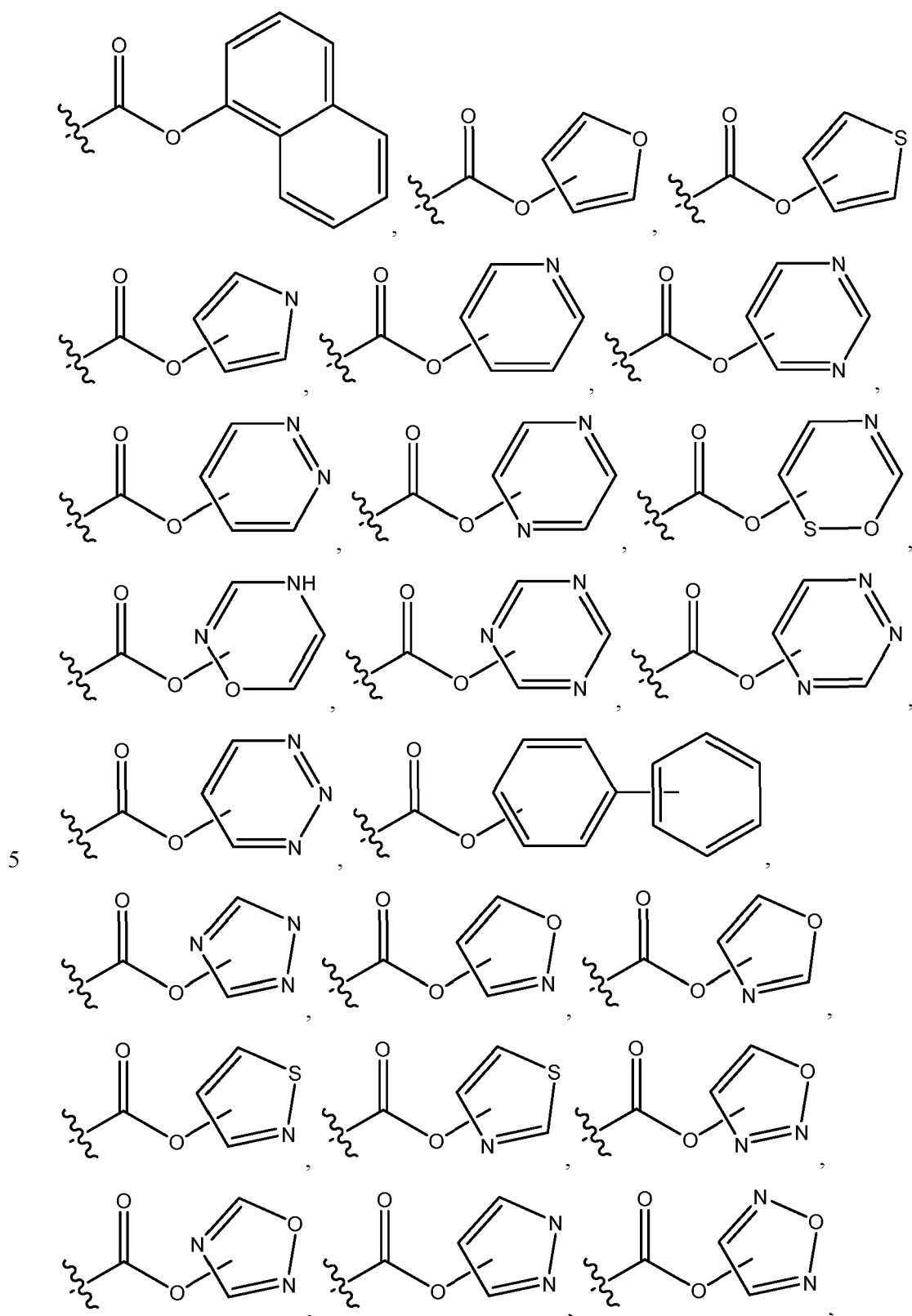
In some embodiments, R3 is an electron withdrawing group. In some embodiments,

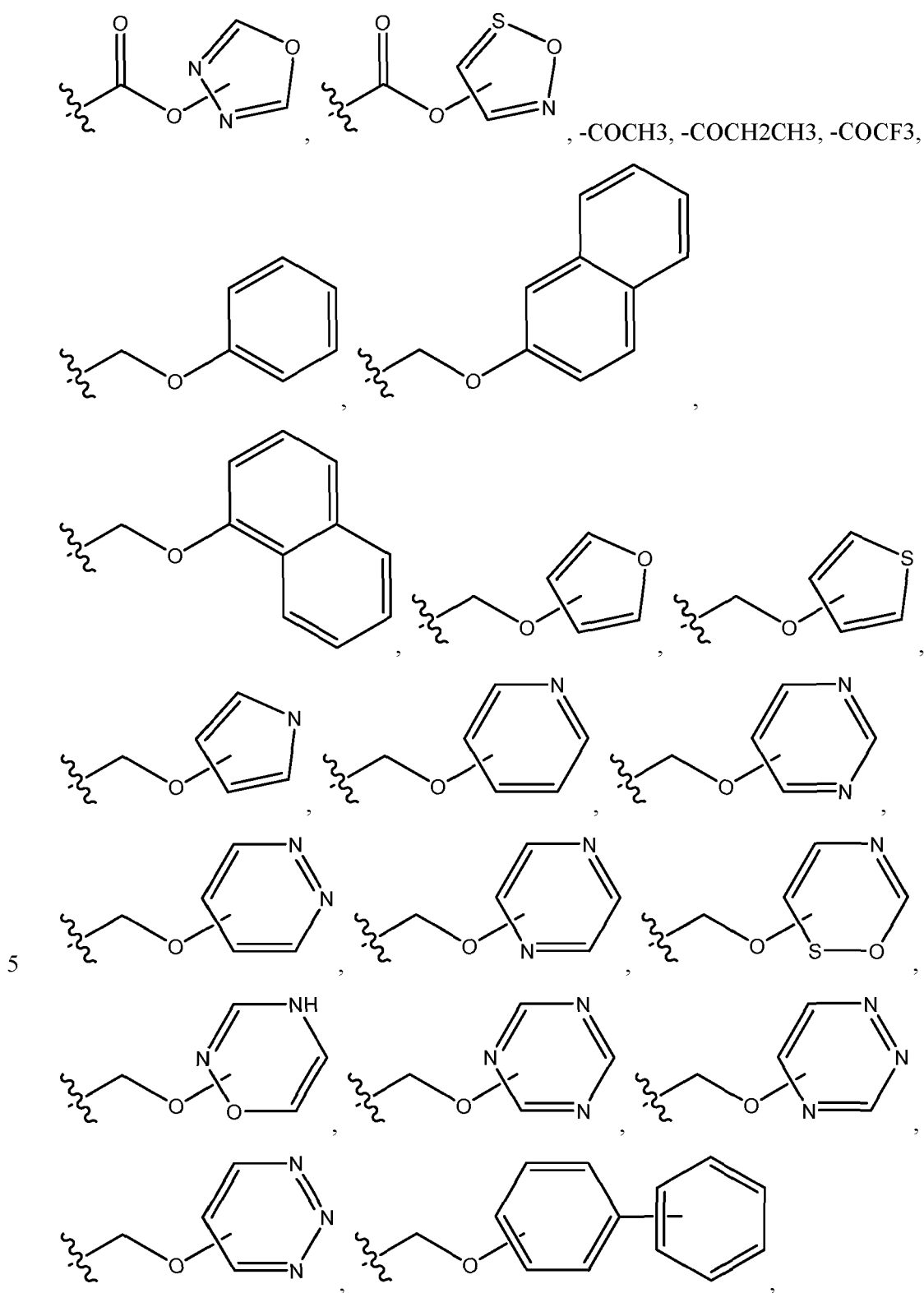
- 5 R3 is a halogen. In some embodiments, R3 is selected from Cl, Br, I, F, CN, NO₂, CF₃, H, OCH₃. In some embodiments, R3 is selected from a halogenated hydrocarbon group such as a trifluoromethyl group; a carboxyl group; an alkoxycarbonyl group such as a methoxycarbonyl group; an aryloxy carbonyl group such as a phenoxycarbonyl group; an acyl group such as an acetyl group; an acyloxy groups such as an acetoxyl group; a cyano group; an aryl group; a 1-
- 10 alkenyl group; a nitro group; a sulfo group; an alkanesulfonyl group; an alkanesulfinyl group; and an alkoxysulfonyl group.

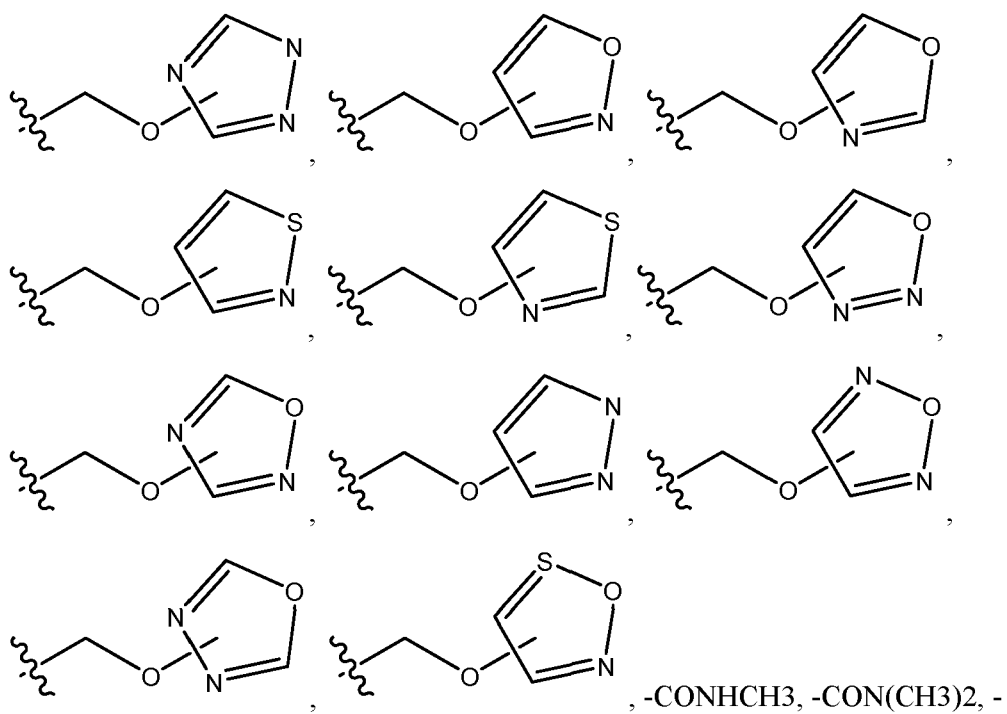
In some embodiments, R4 is any form of a salt.

In some embodiments, R4 is selected from -COOCH₃, -COOCH₂CH₃, COOCF₃,

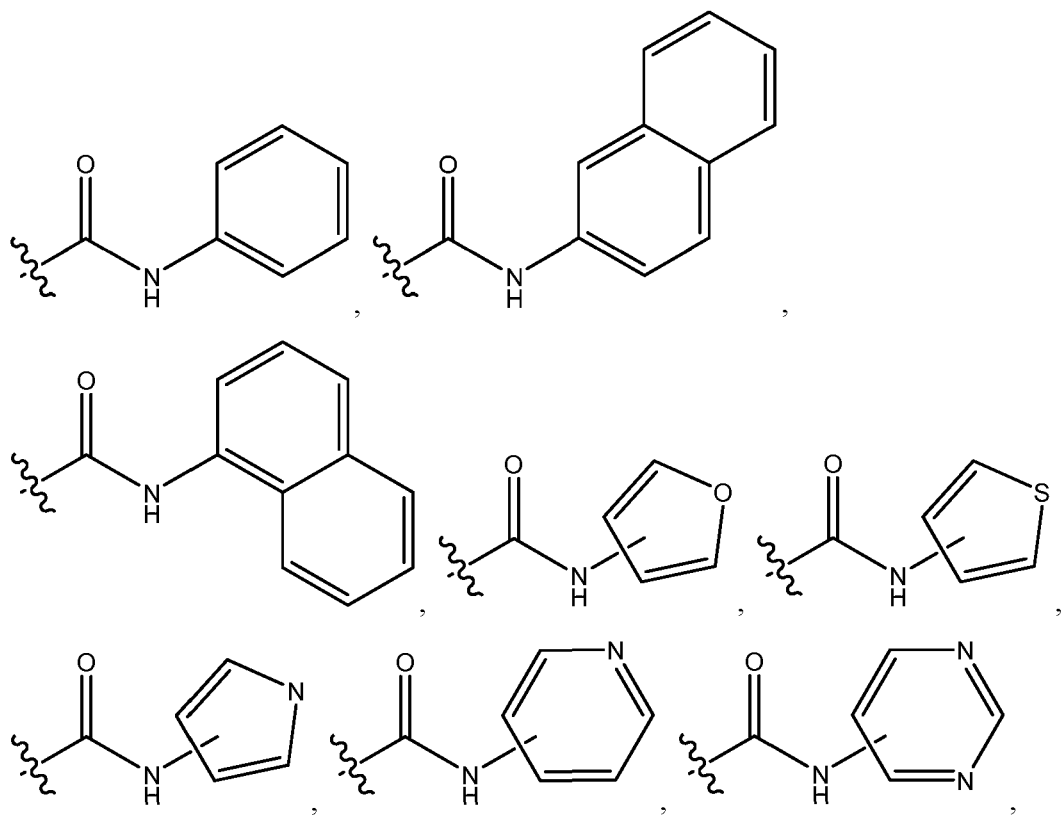
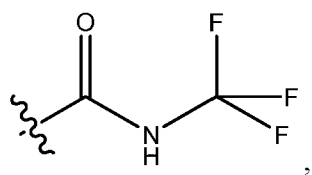


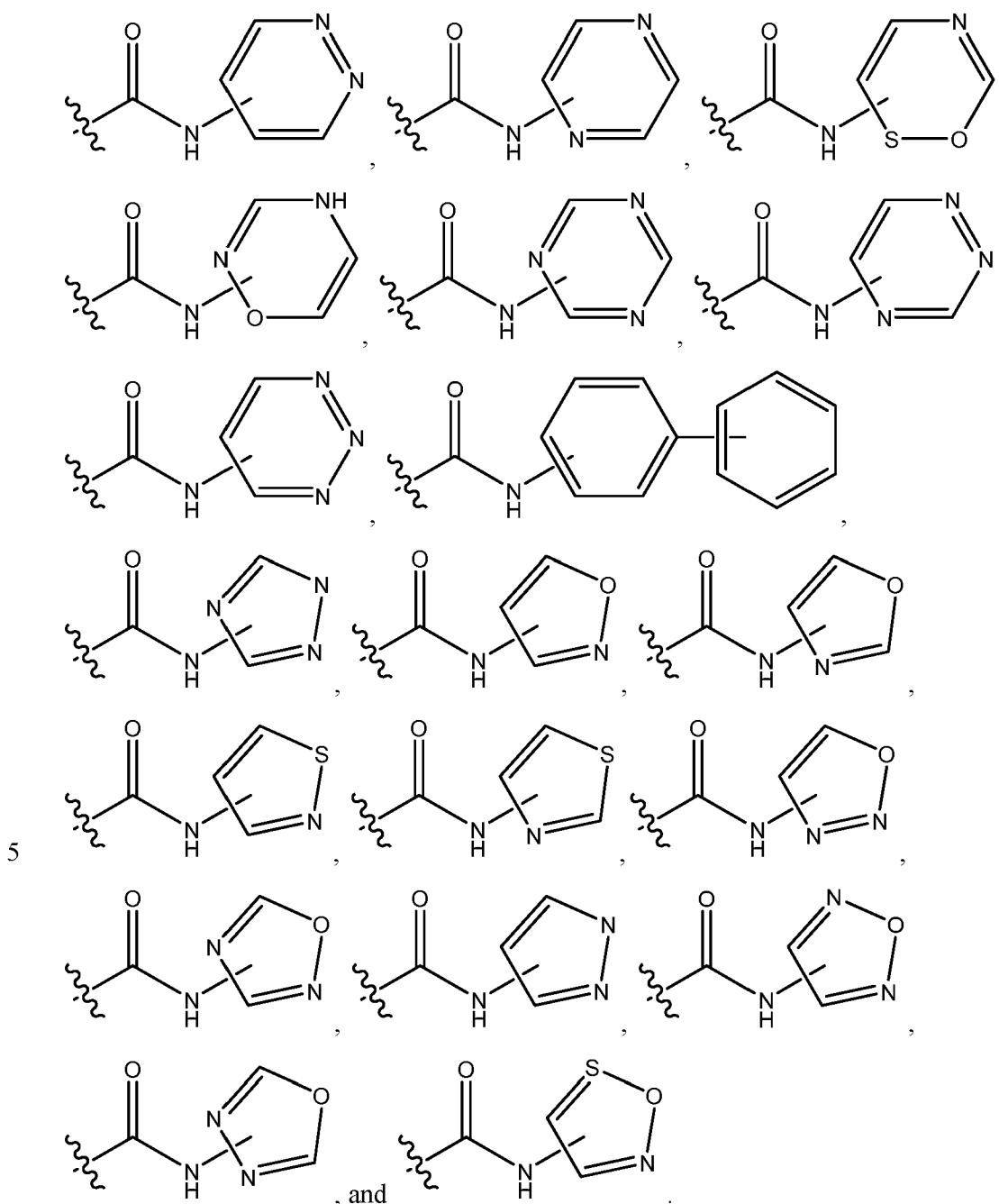






5 CONHCH₂CH₃, -CONHCF₃, -CON(CH₃)₂,





In some embodiments, the compounds are conjugated with a targeting moiety. For example, in some embodiments, the compounds are conjugated with an agent for targeting tumor cells. In some embodiments, the compounds are conjugated with antibodies that target tumor cells.

In some embodiments, the mixed disulfide conjugates of thienopyridine compounds are used to treat, ameliorate, or prevent cardiovascular disorders in an animal (*e.g.*, a mammalian patient including, but not limited to, humans and veterinary animals), such as

those that are responsive to antiplatelet agents (such as clopidogrel, ticlopidine, and prasugrel) comprising administering to a patient a mixed disulfide conjugate of thienopyridine compound of the invention. Such disorders include, but are not limited to, coronary artery disease, peripheral vascular disease, atherothrombosis, and cerebrovascular disease. Indeed, in some embodiments, the mixed disulfide conjugates of thienopyridine compounds are used to decrease platelet aggregation and/or inhibit thrombus formation. In this regard, such diseases and pathologies are amenable to treatment or prophylaxis using the present methods and mixed disulfide conjugates of thienopyridine compounds.

In some embodiments, the mixed disulfide conjugates of thienopyridine compounds are used in the prevention of vascular ischemic events in patients with symptomatic atherosclerosis. In some embodiments, the mixed disulfide conjugates of thienopyridine compounds are used to treat or prevent acute coronary syndrome without ST-segment elevation. In some embodiments, the mixed disulfide conjugates of thienopyridine compounds are used for the prevention of thrombosis after placement of intracoronary stent. In some embodiments, the mixed disulfide conjugates of thienopyridine compounds are used to inhibit platelet aggregation by, for example, altering the function of platelet membranes by blocking ADP receptors (e.g., thereby preventing a conformational change of glycoprotein IIb/IIIa which allows platelet binding to fibrinogen). In some embodiments, the mixed disulfide conjugates of thienopyridine compounds reduce aggregation ("clumping") of platelets by irreversibly binding to P2Y₁₂ receptors. In some embodiments, the mixed disulfide conjugates of thienopyridine compounds are used to prolong bleeding time. In some embodiments, the mixed disulfide conjugates of thienopyridine compounds are used to decrease incidence of stroke in high-risk patients.

In some embodiments, the present invention provides pharmaceutical compositions comprising mixed disulfide conjugates of thienopyridine compounds configured for intravenous (IV) administration. In some embodiments, such pharmaceutical compositions comprising mixed disulfide conjugates of thienopyridine compounds configured for intravenous (IV) administration are used in the treatment, amelioration and prevention of atherothrombosis. In some embodiments, such pharmaceutical compositions comprising mixed disulfide conjugates of thienopyridine compounds configured for intravenous (IV) administration are used for rapid inhibition of platelet aggregation. In some embodiments, such pharmaceutical compositions comprising mixed disulfide conjugates of thienopyridine compounds configured for intravenous (IV) administration are used during percutaneous

coronary intervention procedures (e.g., coronary angioplasty) for rapid inhibition of platelet aggregation. Indeed, anti-platelet therapy is at the cornerstone of prevention and treatment of atherothrombosis. Platelet activation by agonists such as plaque rupture and sheer pressure stress from stents plays an important role in the development of atherothrombosis. Under
5 certain clinical situations where patients suffer acute cardiovascular syndromes or undergo percutaneous cardiovascular intervention, rapid and complete inhibition of platelet aggregation is needed to prevent cardiovascular deaths and ischemic complications. Such medical scenarios require intravenous administration of anti-platelet agents that possess short onset time. However, this is still an unmet medical need since the anti-platelet agents
10 currently being used either have slow onset time or cannot be administrated intravenously (see, e.g., Silvain, J., and Montalescot, G., (2012) *Circ. Cardiovasc. Interv.* 5:328-331). The mixed disulfide conjugates of thienopyridine compounds of the present invention fulfill this unmet medical need as such compounds can be administrated both orally and intravenously and possess short onset time.

15 Some embodiments of the present invention provide methods for administering an effective amount of a mixed disulfide conjugate of a thienopyridine compound of the invention and at least one additional therapeutic agent (including, but not limited to, a therapeutic agent known to treat, ameliorate, or prevent cardiovascular disorders), and/or therapeutic technique (e.g., a surgical intervention). A number of therapeutic agents known to
20 treat, ameliorate, or prevent cardiovascular disorders are contemplated for use in the methods of the present invention. Indeed, the present invention contemplates, but is not limited to, administration of numerous therapeutic agents known to treat, ameliorate, or prevent cardiovascular disorders. Examples include, but are not limited to, HMG-CoA reductase inhibitors (e.g., Atorvastatin (Lipitor), Pravastatin (Pravachol), Simvastatin (Zocor),
25 Rosuvastatin (Crestor), Pitavastatin (Livalo), Lovastatin (Mevacor, Altacor), Fluvastatin (Lescol)), ACE Inhibitors (e.g., Ramipril (Altace), Quinapril (Accupril), Captopril (Capoten), Enalapril (Vasotec), Lisinopril (Zestril)), Calcium Channel Blockers (e.g., Amlodipine (Norvasc), Nifedipine (Procardia), Verapamil (Calan), Felodipine (Plendil), Diltiazem (Cardizem)), Platelet Aggregation Inhibitors (other than Ticlopidine, Clopidogrel, and
30 Prasugrel) (e.g., Abciximab (ReoPro), Aspirin, Warfarin (Coumadin), Heparin), Polyunsaturated Fatty Acids (e.g., Omega-3 polyunsaturated fatty acid (Fish Oil)), Fibrin Acid Derivatives (e.g., Fenofibrate (Tricor), Gemfibrozil (Lopid)), Bile Acid Sequestrants (e.g., Colestipol (Colestid), Cholestyramine (Questran)), Antioxidants (e.g., Vitamin E),

Nicotinic Acid Derivatives (e.g., Niacin (Niaspan), Thrombolytic agents (e.g., Alteplase (Activase)), and Antianginal Agents (e.g., Ranolazine (Ranexa)).

In some embodiments of the present invention, a mixed disulfide conjugate of thienopyridine compound of the invention and one or more additional therapeutic agent is administered to an patient under one or more of the following conditions: at different
5 periodicities, at different durations, at different concentrations, by different administration routes, *etc.* In some embodiments, the mixed disulfide conjugate of thienopyridine compound is administered prior to the additional therapeutic agent, *e.g.*, 0.5, 1, 2, 3, 4, 5, 10, 12, or 18 hours, 1, 2, 3, 4, 5, or 6 days, or 1, 2, 3, or 4 weeks prior to the administration of the
10 additional therapeutic agent. In some embodiments, the mixed disulfide conjugate of thienopyridine compound is administered after the additional therapeutic agent, *e.g.*, 0.5, 1, 2, 3, 4, 5, 10, 12, or 18 hours, 1, 2, 3, 4, 5, or 6 days, or 1, 2, 3, or 4 weeks after the administration of the additional therapeutic agent. In some embodiments, the mixed disulfide conjugate of thienopyridine compound compound and the additional therapeutic agent are
15 administered concurrently but on different schedules, *e.g.*, the mixed disulfide conjugate of thienopyridine compound is administered daily while the additional therapeutic agent is administered once a week, once every two weeks, once every three weeks, or once every four weeks. In other embodiments, the mixed disulfide conjugate of thienopyridine compound is administered once a week while the additional therapeutic agent is administered daily, once a
20 week, once every two weeks, once every three weeks, or once every four weeks.

Compositions within the scope of this invention include all compositions wherein the mixed disulfide conjugates of thienopyridine compounds of the present invention are contained in an amount which is effective to achieve its intended purpose. While individual needs vary, determination of optimal ranges of effective amounts of each component is within
25 the skill of the art. Typically, the compounds may be administered to mammals, *e.g.* humans, orally at a dose of 0.0025 to 50 mg/kg, or an equivalent amount of the pharmaceutically acceptable salt thereof, per day of the body weight of the mammal being treated for disorders responsive to induction of apoptosis. In one embodiment, about 0.01 to about 25 mg/kg is orally administered to treat, ameliorate, or prevent such disorders. For intramuscular
30 injection, the dose is generally about one-half of the oral dose. For example, a suitable intramuscular dose would be about 0.0025 to about 25 mg/kg, or from about 0.01 to about 5 mg/kg.

The unit oral dose may comprise from about 0.01 to about 1000 mg, for example, about 0.1 to about 100 mg of the mixed disulfide conjugate of thienopyridine compound. The unit dose may be administered one or more times daily as one or more tablets or capsules each containing from about 0.1 to about 10 mg, conveniently about 0.25 to 50 mg of the compound or its solvates.

In a topical formulation, the compound may be present at a concentration of about 0.01 to 100 mg per gram of carrier. In one embodiment, the mixed disulfide conjugate of thienopyridine compound is present at a concentration of about 0.07-1.0 mg/ml, for example, about 0.1-0.5 mg/ml, and in one embodiment, about 0.4 mg/ml.

In addition to administering the mixed disulfide conjugate of thienopyridine compound as a raw chemical, the compounds of the invention may be administered as part of a pharmaceutical preparation containing suitable pharmaceutically acceptable carriers comprising excipients and auxiliaries which facilitate processing of the compounds into preparations which can be used pharmaceutically. The preparations, particularly those preparations which can be administered orally or topically and which can be used for one type of administration, such as tablets, dragees, slow release lozenges and capsules, mouth rinses and mouth washes, gels, liquid suspensions, hair rinses, hair gels, shampoos and also preparations which can be administered rectally, such as suppositories, as well as suitable solutions for administration by intravenous infusion, injection, topically or orally, contain from about 0.01 to 99 percent, in one embodiment from about 0.25 to 75 percent of active compound(s), together with the excipient.

The pharmaceutical compositions of the invention may be administered to any patient which may experience the beneficial effects of the mixed disulfide conjugates of thienopyridine compounds of the invention. Foremost among such patients are mammals, *e.g.*, humans, although the invention is not intended to be so limited. Other patients include veterinary animals (cows, sheep, pigs, horses, dogs, cats and the like).

The compounds and pharmaceutical compositions thereof may be administered by any means that achieve their intended purpose. For example, administration may be by parenteral, subcutaneous, intravenous, intramuscular, intraperitoneal, transdermal, buccal, intrathecal, intracranial, intranasal or topical routes. Alternatively, or concurrently, administration may be by the oral route. The dosage administered will be dependent upon the age, health, and weight of the recipient, kind of concurrent treatment, if any, frequency of treatment, and the nature of the effect desired.

The pharmaceutical preparations of the present invention are manufactured in a manner which is itself known, for example, by means of conventional mixing, granulating, dragee-making, dissolving, or lyophilizing processes. Thus, pharmaceutical preparations for oral use can be obtained by combining the active compounds with solid excipients, optionally
5 grinding the resulting mixture and processing the mixture of granules, after adding suitable auxiliaries, if desired or necessary, to obtain tablets or dragee cores.

Suitable excipients are, in particular, fillers such as saccharides, for example lactose or sucrose, mannitol or sorbitol, cellulose preparations and/or calcium phosphates, for example tricalcium phosphate or calcium hydrogen phosphate, as well as binders such as starch paste,
10 using, for example, maize starch, wheat starch, rice starch, potato starch, gelatin, tragacanth, methyl cellulose, hydroxypropylmethylcellulose, sodium carboxymethylcellulose, and/or polyvinyl pyrrolidone. If desired, disintegrating agents may be added such as the above-mentioned starches and also carboxymethyl-starch, cross-linked polyvinyl pyrrolidone, agar, or alginic acid or a salt thereof, such as sodium alginate. Auxiliaries are, above all, flow-
15 regulating agents and lubricants, for example, silica, talc, stearic acid or salts thereof, such as magnesium stearate or calcium stearate, and/or polyethylene glycol. Dragee cores are provided with suitable coatings which, if desired, are resistant to gastric juices. For this purpose, concentrated saccharide solutions may be used, which may optionally contain gum arabic, talc, polyvinyl pyrrolidone, polyethylene glycol and/or titanium dioxide, lacquer
20 solutions and suitable organic solvents or solvent mixtures. In order to produce coatings resistant to gastric juices, solutions of suitable cellulose preparations such as acetylcellulose phthalate or hydroxypropylmethyl-cellulose phthalate, are used. Dye stuffs or pigments may be added to the tablets or dragee coatings, for example, for identification or in order to characterize combinations of active compound doses.

25 Other pharmaceutical preparations which can be used orally include push-fit capsules made of gelatin, as well as soft, sealed capsules made of gelatin and a plasticizer such as glycerol or sorbitol. The push-fit capsules can contain the active compounds in the form of granules which may be mixed with fillers such as lactose, binders such as starches, and/or lubricants such as talc or magnesium stearate and, optionally, stabilizers. In soft capsules, the
30 active compounds are in one embodiment dissolved or suspended in suitable liquids, such as fatty oils, or liquid paraffin. In addition, stabilizers may be added.

Possible pharmaceutical preparations which can be used rectally include, for example, suppositories, which consist of a combination of one or more of the active compounds with a

suppository base. Suitable suppository bases are, for example, natural or synthetic triglycerides, or paraffin hydrocarbons. In addition, it is also possible to use gelatin rectal capsules which consist of a combination of the active compounds with a base. Possible base materials include, for example, liquid triglycerides, polyethylene glycols, or paraffin hydrocarbons.

Suitable formulations for parenteral administration include aqueous solutions of the active compounds in water-soluble form, for example, water-soluble salts and alkaline solutions. In addition, suspensions of the active compounds as appropriate oily injection suspensions may be administered. Suitable lipophilic solvents or vehicles include fatty oils, for example, sesame oil, or synthetic fatty acid esters, for example, ethyl oleate or triglycerides or polyethylene glycol-400. Aqueous injection suspensions may contain substances which increase the viscosity of the suspension include, for example, sodium carboxymethyl cellulose, sorbitol, and/or dextran. Optionally, the suspension may also contain stabilizers.

The topical compositions of this invention are formulated in one embodiment as oils, creams, lotions, ointments and the like by choice of appropriate carriers. Suitable carriers include vegetable or mineral oils, white petrolatum (white soft paraffin), branched chain fats or oils, animal fats and high molecular weight alcohol (greater than C₁₂). The carriers may be those in which the active ingredient is soluble. Emulsifiers, stabilizers, humectants and antioxidants may also be included as well as agents imparting color or fragrance, if desired. Additionally, transdermal penetration enhancers can be employed in these topical formulations. Examples of such enhancers can be found in U.S. Pat. Nos. 3,989,816 and 4,444,762.

Ointments may be formulated by mixing a solution of the active ingredient in a vegetable oil such as almond oil with warm soft paraffin and allowing the mixture to cool. A typical example of such an ointment is one which includes about 30% almond oil and about 70% white soft paraffin by weight. Lotions may be conveniently prepared by dissolving the active ingredient, in a suitable high molecular weight alcohol such as propylene glycol or polyethylene glycol.

One of ordinary skill in the art will readily recognize that the foregoing represents merely a detailed description of certain preferred embodiments of the present invention. Various modifications and alterations of the compositions and methods described above can

readily be achieved using expertise available in the art and are within the scope of the invention.

Having now fully described the invention, it will be understood by those of skill in the art that the same can be performed within a wide and equivalent range of conditions, formulations, and other parameters without affecting the scope of the invention or any
5 embodiment thereof. All patents, patent applications and publications cited herein are fully incorporated by reference herein in their entirety.

INCORPORATION BY REFERENCE

10 The entire disclosure of each of the patent documents and scientific articles referred to herein is incorporated by reference for all purposes.

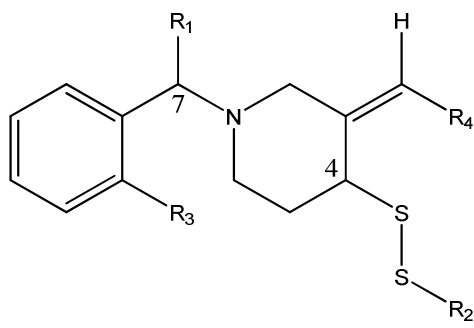
EQUIVALENTS

The invention may be embodied in other specific forms without departing from the
15 spirit or essential characteristics thereof. The foregoing embodiments are therefore to be considered in all respects illustrative rather than limiting the invention described herein. Scope of the invention is thus indicated by the appended claims rather than by the foregoing description, and all changes that come within the meaning and range of equivalency of the claims are intended to be embraced therein.

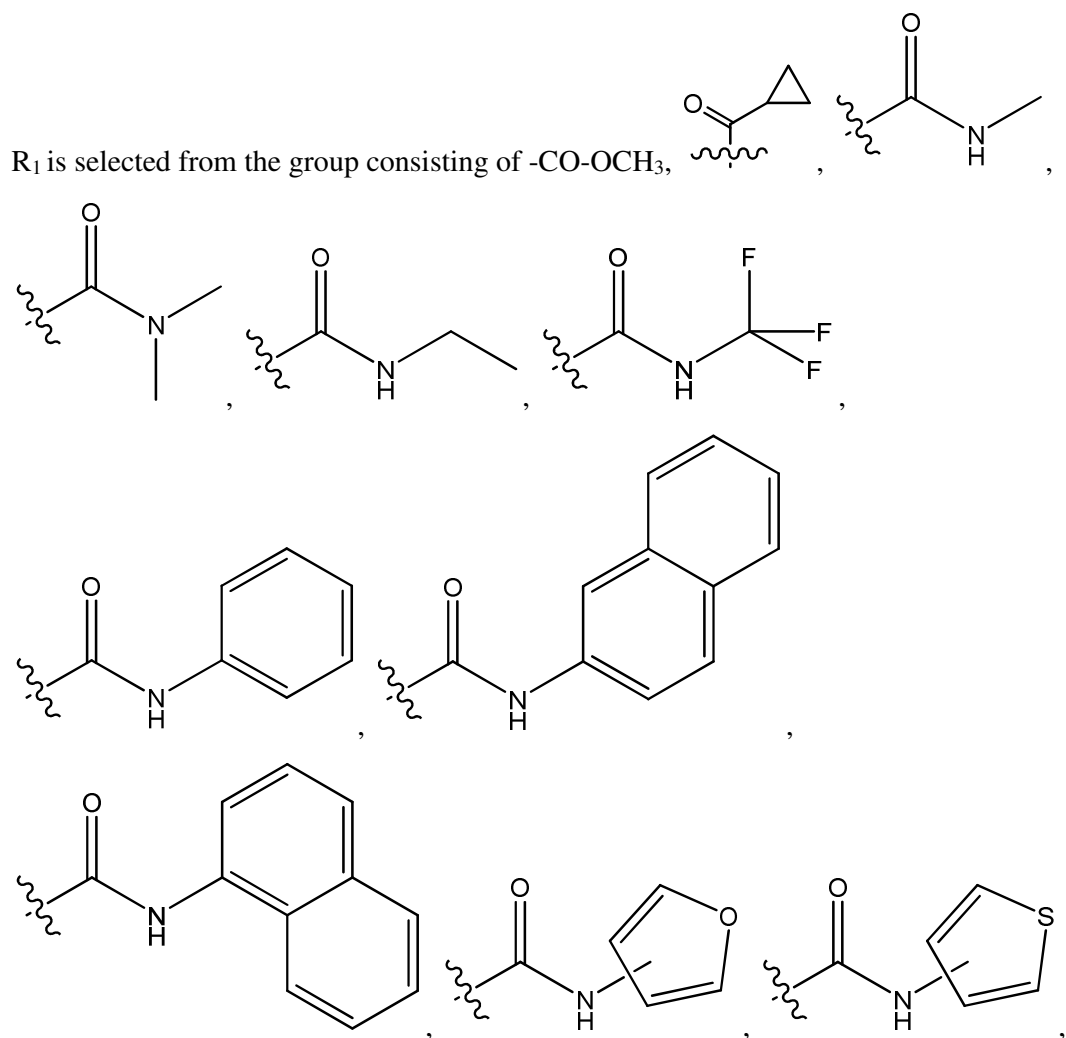
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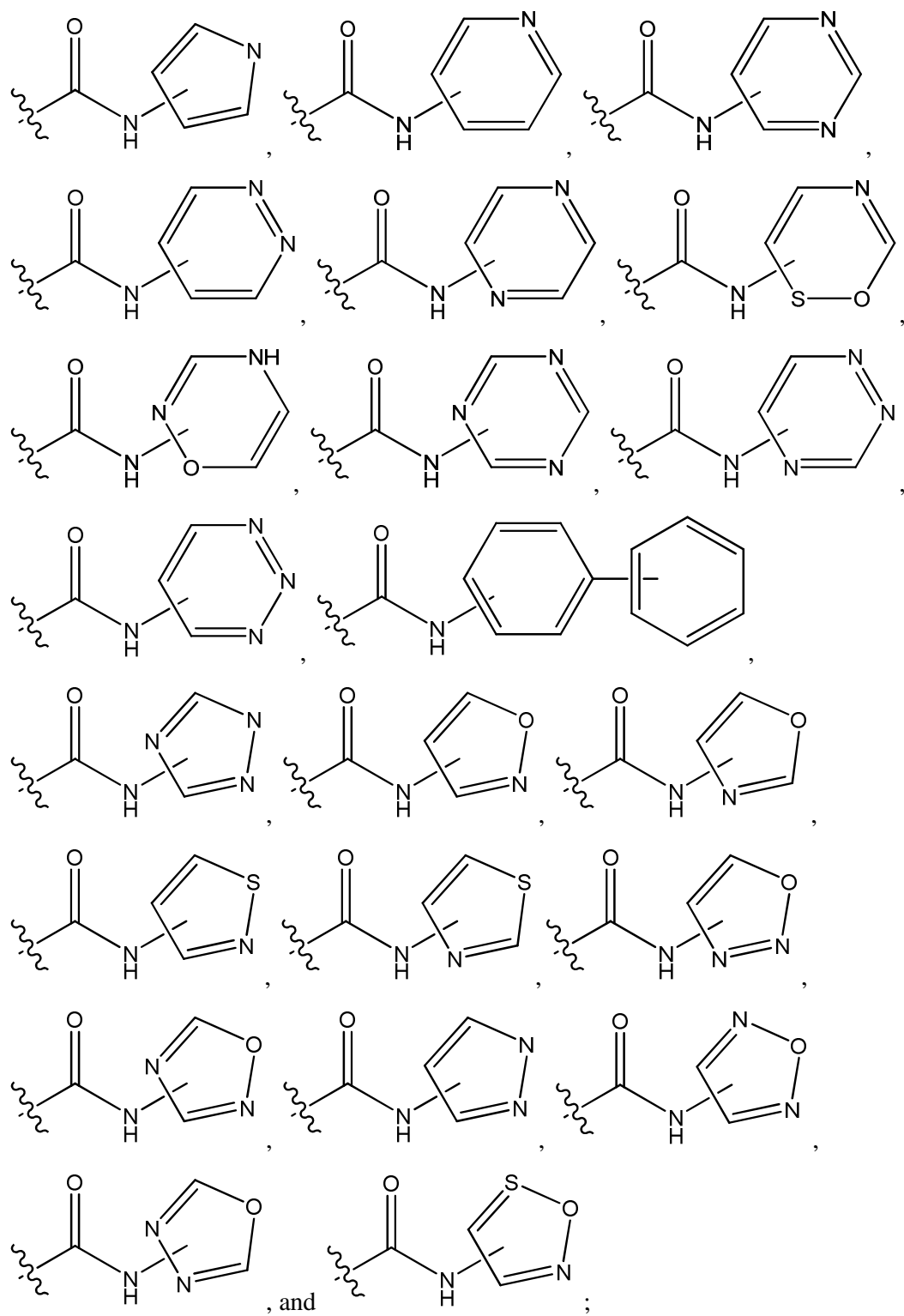
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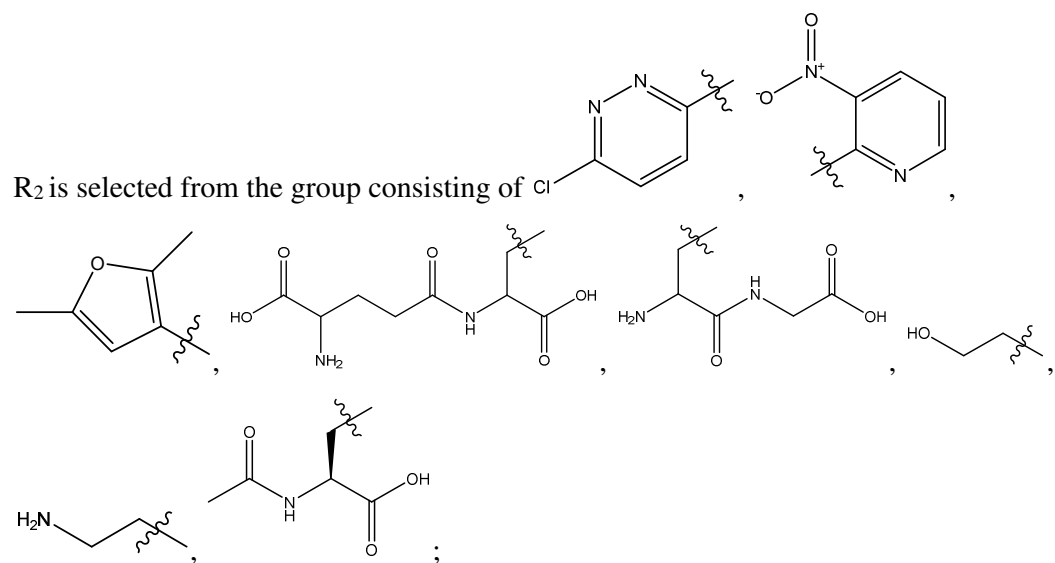
1. A compound having Formula I:



, or a pharmaceutically acceptable salt thereof;
wherein independently each of R₁, R₂, R₃ and R₄ are

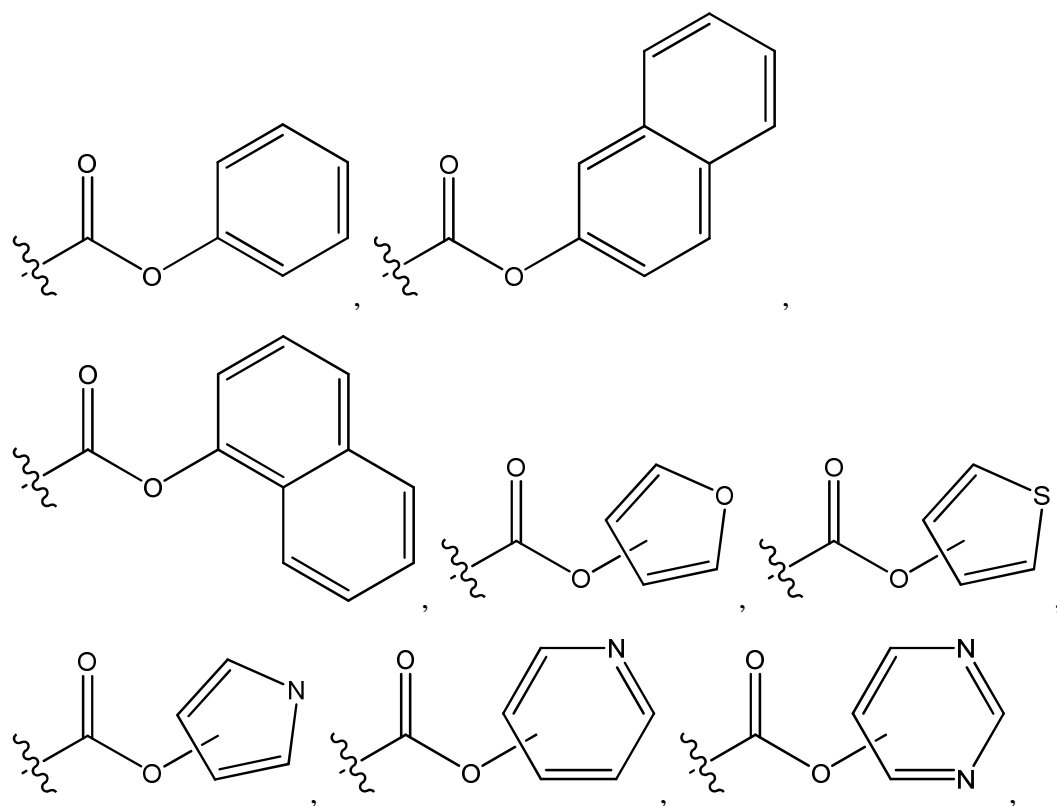


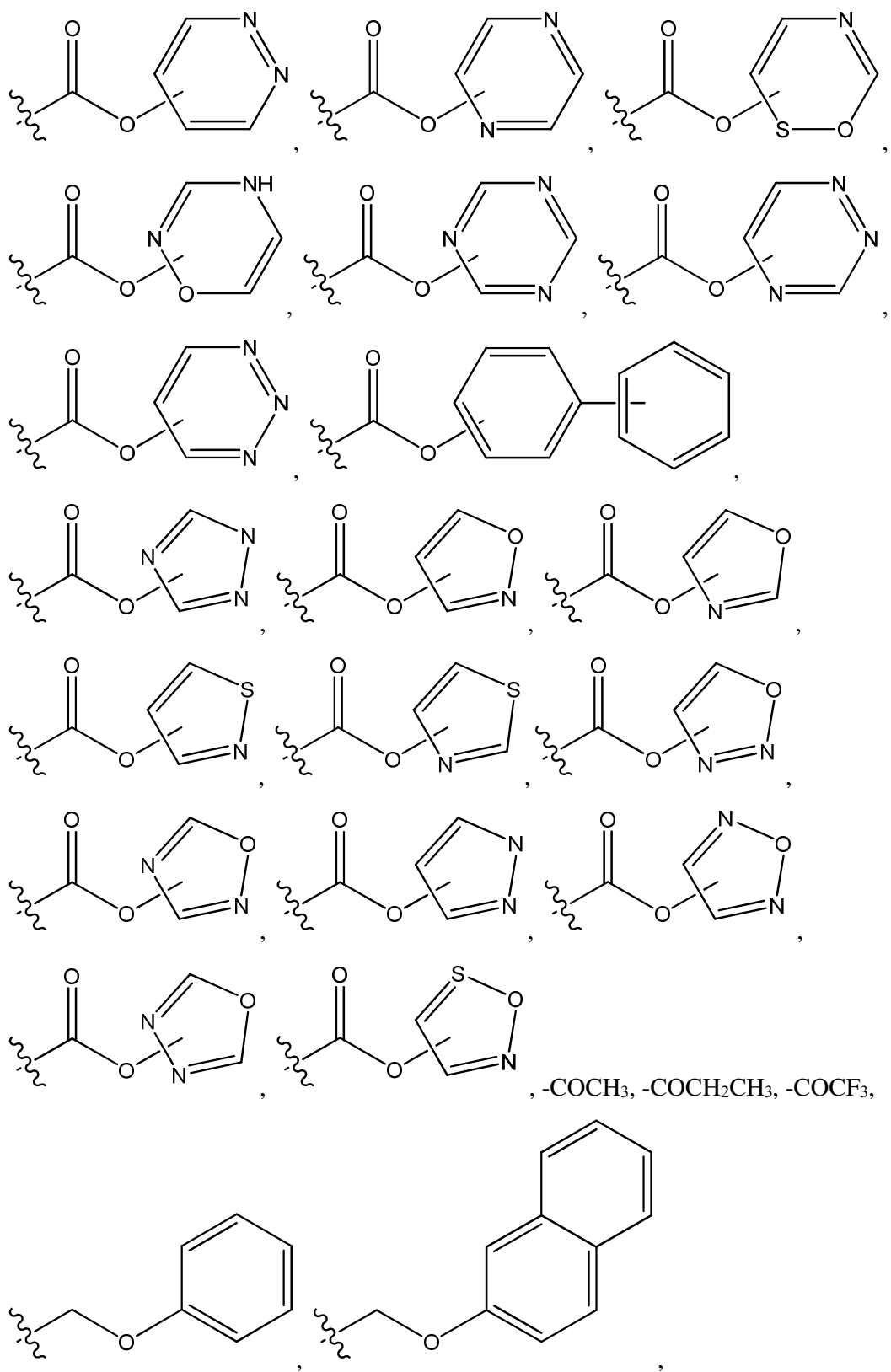


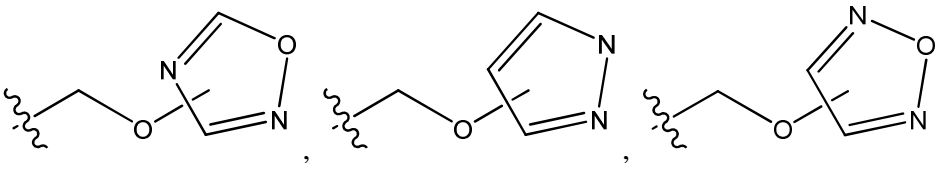
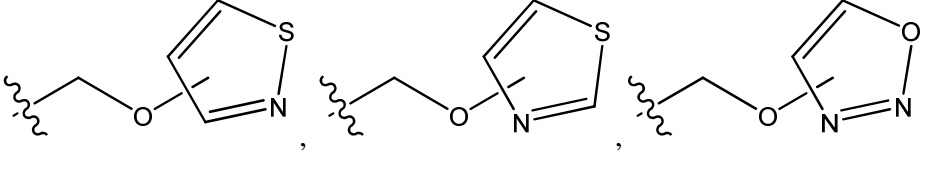
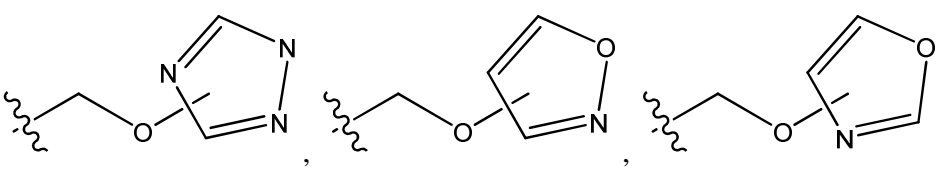
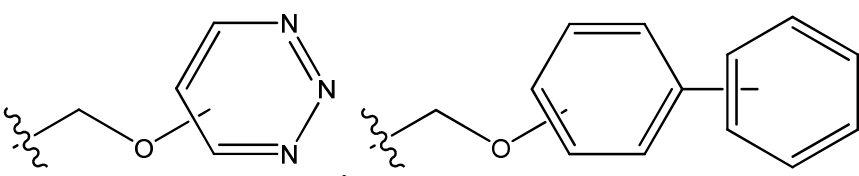
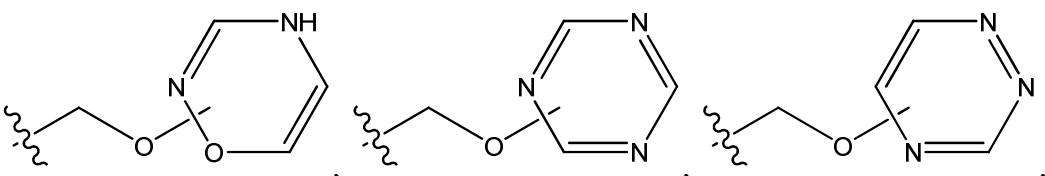
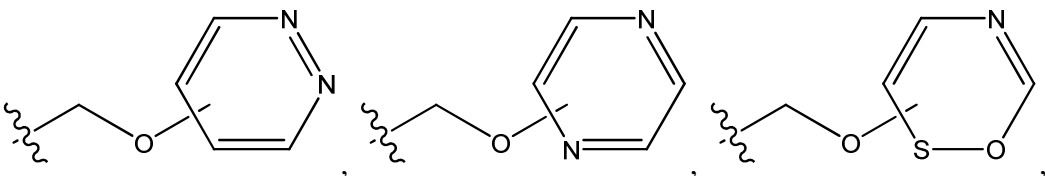
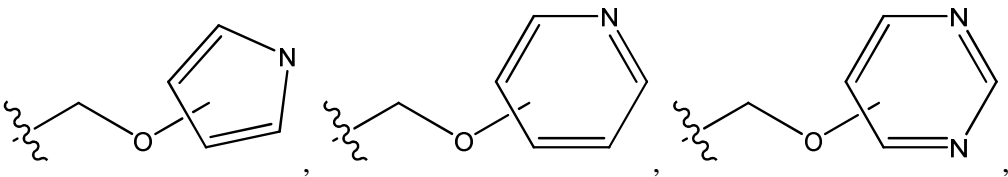
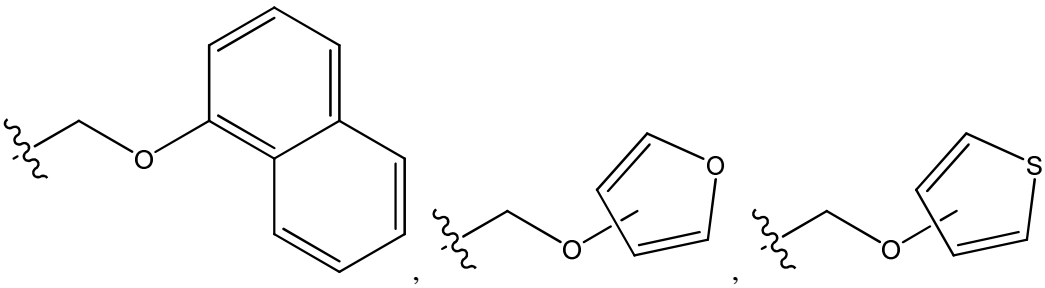


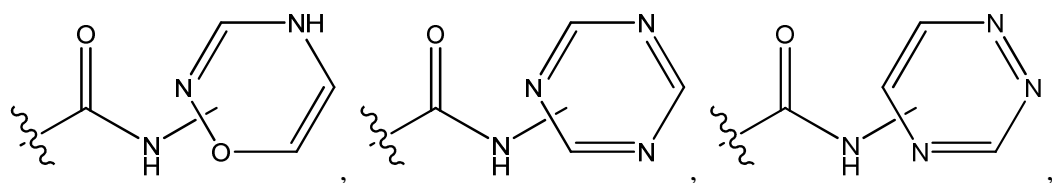
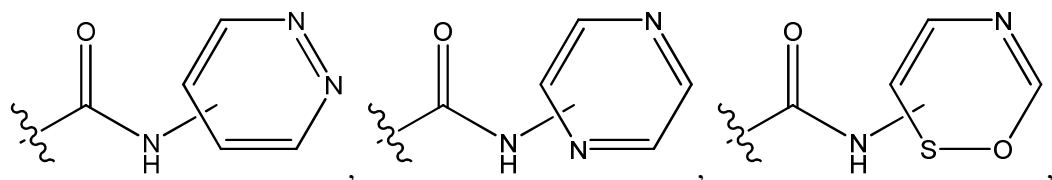
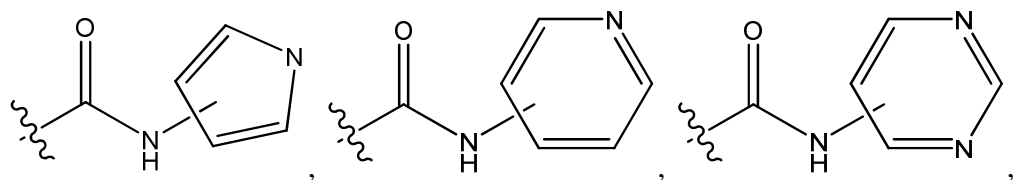
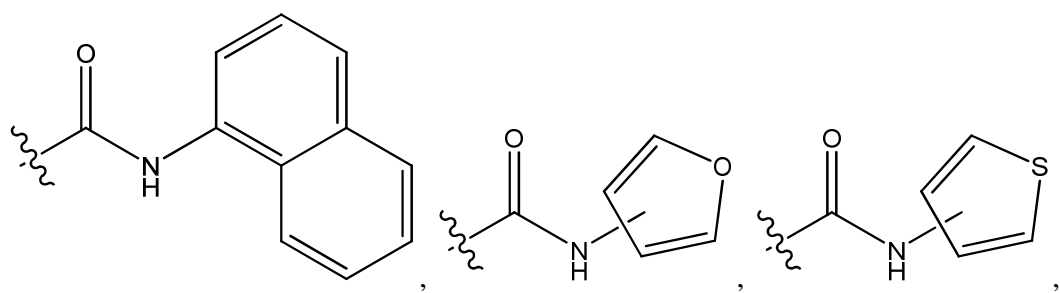
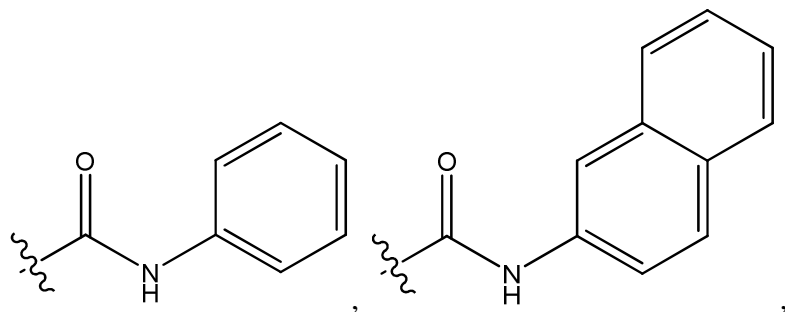
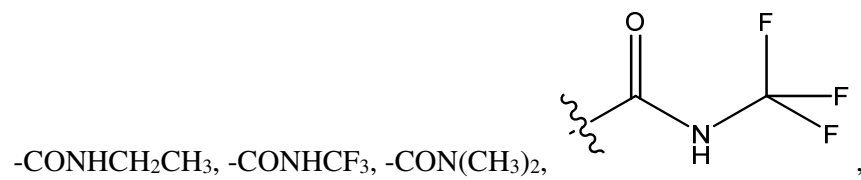
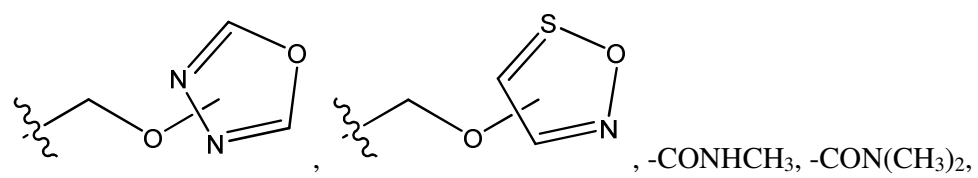
R_3 is selected from the group consisting of Cl, Br, I, F, CN, NO₂, CF₃, H, and OCH₃; and

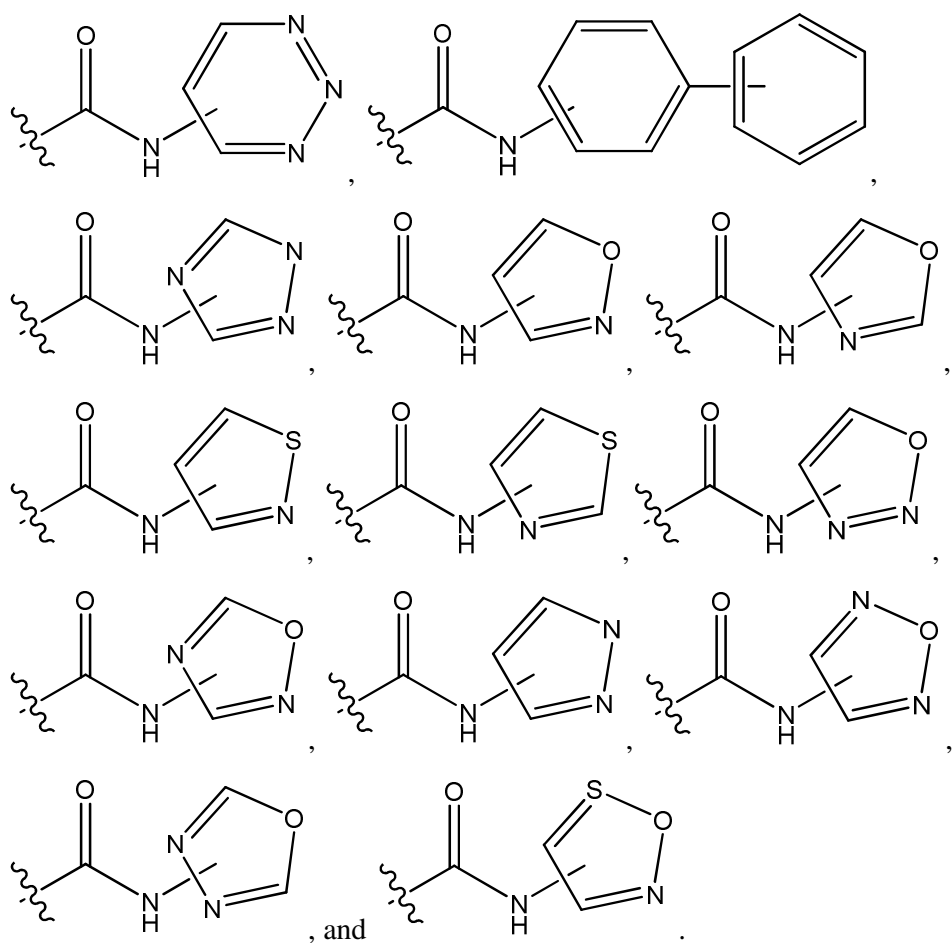
R_4 is selected from the group consisting of -COOCH₃, -COOCH₂CH₃, COOCF₃,



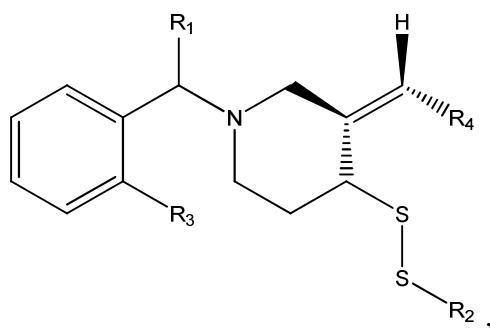




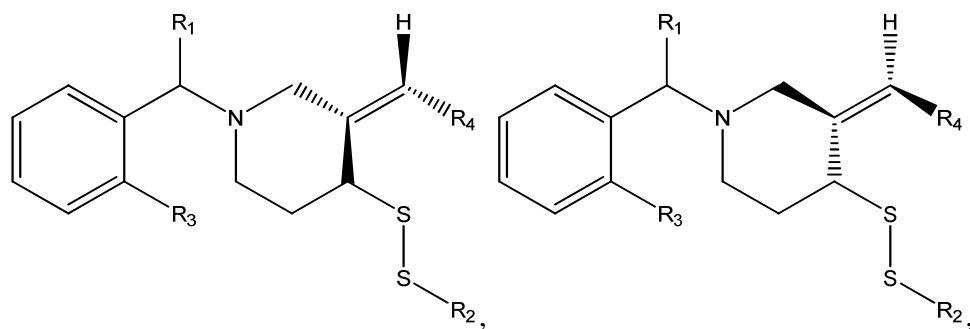


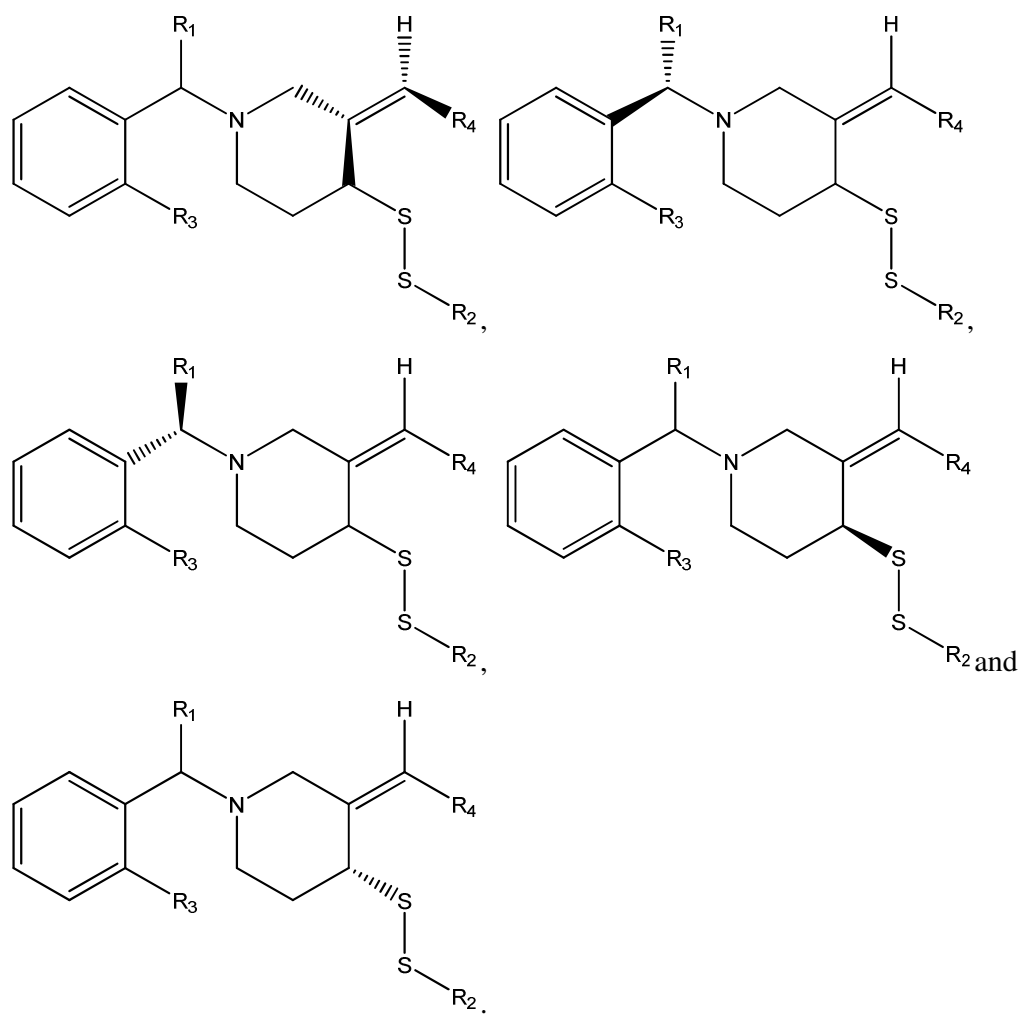


2. The compound of claim 1, wherein stereochemical configuration for Formula I is



selected from the group consisting of:





3. The compound of claim 1, wherein the R_4 substituent is engaged with an applicable metal to form a salt, wherein the applicable metal is selected from Na^+ , K^+ , and Li^+ , or wherein the R_4 substituent is engaged with an applicable halogen to form an ammonium salt.
4. A pharmaceutical composition comprising an effective amount of the compound of claim 1, and a pharmaceutically acceptable carrier.
5. The pharmaceutical composition of claim 4, wherein said pharmaceutical composition is configured for intravenous administration.

6. The pharmaceutical composition of claim 5, wherein said pharmaceutical composition is to be intravenously administered to a patient during a percutaneous coronary intervention procedure.

7. The pharmaceutical composition of claim 6, wherein said percutaneous coronary intervention procedure is coronary angioplasty.